A Survey of Literature on Oil Spill Effects on Marine Organisms on the West Coast of British Columbia, Canada With a Focus on Bitumen Related Products

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A SURVEY OF LITERATURE ON OIL SPILL EFFECTS ON MARINE ORGANISMS ON THE WEST COAST OF BRITISH COLUMBIA CANADA WITH A FOCUS ON BITUMEN RELATED PRODUCTS

by

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ABSTRACT

Herunter, H.E., Nomura, M., Jackson, J.S., and Macdonald, J.S. 2017. A survey of literature on oil spill effects on marine organisms on the west coast of British Columbia, Canada with a focus on bitumen related products. Can. Tech. Rep. Fish. Aquat. Sci. 3219: iii + 435 p.

A literature review, focusing on oil sand products (e.g., diluted bitumen), diluents, spill-treating agents, and crude oil toxicology and ecological studies, relevant to the northeast Pacific was compiled as part of the Government of Canada's World Class Tanker Safety program. Of the 763 references identified, 14 involved diluted bitumen and other heavy crude oils, indicating the need for further research of these products in the marine environment. Diluent research suggests relatively fast evaporation and dispersion times for this component, however high toxicities may pose a threat to marine biota. Historical studies indicate older dispersant formulations had potential ecological implications, therefore newer formulations, which have not been studied in detail, require full assessment. Consistent utilization of toxicology standards remains elusive, hindering species sensitivity analyses. Exxon Valdez literature demonstrates highly variable impacts from a single oil type and the need for baseline data, recovery status, and suitable ecological end-point determination.

RÉSUMÉ

Herunter, H.E., Nomura, M., Jackson, J.S. et MacDonald, J.S. 2017. Examen de la documentation sur les effets des déversements de pétrole, particulièrement les produits du bitume, sur les organismes marins sur la côte ouest de la Colombie-Britannique, au Canada. Rapp. tech. can. sci. halieut. aquat. 3219: iii + 435 p.

Une analyse documentaire, mettant l'accent sur la toxicologie et les études écologiques des produits des sables bitumineux (p. ex., bitume dilué), des diluants, des agents de traitement des déversements et du pétrole brut dans le nord-est du Pacifique, a été préparée dans le cadre du Programme de sécurité de classe mondiale pour les navires-citernes. Seulement 14 des 763 références analysées portaient sur le bitume dilué ou d'autres pétroles bruts, ce qui indique la nécessité d'une recherche plus poussée au sujet des effets de ces produits sur le milieu marin. La recherche sur les diluants semble indiquer que les périodes d'évaporation et de dispersion de ces composantes sont relativement courtes; par contre leurs hauts niveaux de toxicité pourraient représenter une menace pour le biote marin. Les études historiques indiquent que les anciennes formulations d'agents dispersants avaient des répercussions écologiques potentielles; il est donc nécessaire d'évaluer pleinement les nouvelles formulations pour déterminer leurs répercussions possibles. Le non-respect des normes de toxicologie est encore fréquent, ce qui nuit aux analyses de sensibilité des espèces. Selon la documentation d'Exxon Valdez, les répercussions pour un type de pétrole donné peuvent varier grandement; il est donc important de recueillir des données de base et des renseignements sur l'état du rétablissement et de déterminer les paramètres écologiques pertinents.

1.0 INTRODUCTION

Recent interest in ocean tanker transport of bitumen products from Vancouver and Kitimat to markets abroad initiated development of the World Class Tanker Safety program by the Government of Canada (Houston et al. 2013). Phase 1 of the program included collection of background data and information to assist first responders in the event of a spill in the marine environment. A component of this phase was to provide a detailed literature search on bitumen products, other petroleum products associated with tanker traffic (such as fuels), and spill-treating agents (such as dispersants and surface-washing agents) and their effects on marine biota in British Columbia (BC).

Bitumen is viscous and must be diluted before transport via pipeline and ocean tanker. Diluted bitumen (dilbit) is bitumen that has been thinned with 20-30% diluent, depending on the season and product. The diluent commonly used in Alberta (AB) is natural gas condensate, produced by the extraction and liquefaction of natural gas and comes from a variety of worldwide sources, including BC and AB (crudemonitor.ca). Other thinning agents include synthetic crude oil, which, when mixed with bitumen at a 1:1 ratio, produces “synbit”. A mixture of diluent, synthetic crude, and bitumen, at a variety of ratios, produces “dilsynbit”. Synthetic crude is bitumen that has been cracked to reduce carbon chain length, thereby reducing viscosity (Tsaprailis 2014). During a spill event, these products initially float and exposure to surface dwelling organisms and intertidal biota can occur. However, two mechanisms, weathering and adhesion of suspended or shore sediments, act to increase the density of spilled products. As their densities approach those of ambient waters, especially in high energy environments, sinking and subsequent exposure to subtidal biota may occur (Environment Canada et al. 2013).

The proposed Enbridge Northern Gateway pipeline is a “two-way” system whereby diluent would be delivered to Kitimat by ocean tanker and pumped to Alberta to be mixed with bitumen. The resulting dilbit is to be pumped back to the coast for shipment by tanker (Enbridge 2015). The proposed Trans Mountain Expansion Project (Kinder Morgan) plans to increase the volume of product pumped from AB to Vancouver by twinning the existing pipeline. Synthetic crude oil, synbit, and dilsynbit may also be transported to the BC coast by the pipelines (Trans Mountain 2016). During a marine spill event, biota in the marine environment may become exposed to tanker cargo (diluent and/or bitumen products), fuel (e.g., bunker C and other fuels), and chemical formulations used as spill-treating agents (e.g., dispersants and surface-washing agents).

The dispersant Corexit®EC9500A and the surface-washing agent Corexit®EC9580 have been widely used in the USA, especially during the 2010 Deepwater Horizon spill event (Lee et al. 2015). In 2016, the Canadian Minister of the Environment, approved both Corexit® products for use in the event of an oil spill from an offshore facility (pursuant to Section 14.2, *Regulations Establishing a List of Spill-treating Agents, Canada Oil and Gas Operations Act*, R.S.C., 1985, c.O-7). They are currently the only spill-treating agents allowed for use in Canada. Dispersants are blends of surfactants, light petroleum distillates, and proprietary substances used to emulsify and accelerate the weathering of spilled oil in aquatic environments by breaking up a slick and redistributing oil droplets in the water column. This helps to prevent slicks from directly impacting the shore (grounding) and increases the oil-water surface area to enhance biodegradation (Lee et al. 2015). Surface-washing agents aid in the remobilization of oil from hard surfaces such as shorelines and man-made structures. After treatment with a surface-washing agent, oiled shorelines can be flushed mechanically or by tidal action and the remobilized oil recovered by skimmers or absorbents. However, there is evidence that the aqueous component of oil/water/spill-treating agent mixtures may be toxic to marine organisms (Laramore et al. 2014, Schein et al. 2015).

Because petrogenic products are complex mixtures of chemicals, many toxicity experiments tend to focus on one or two constituents to elucidate the mechanism of toxicity (Kennedy 2014). As such, studies in the literature have investigated a variety of exposures ranging from whole product (e.g., oil or dispersant only, de Hoop et al. 2011), to mixtures of products (e.g., oil and dispersant, Radniecki et al. 2013) to specific constituents (e.g., polycyclic aromatic hydrocarbons - PAHs, Logan 2007). In addition to the complexity of whole oil versus constituent studies, both laboratory and field studies are reported in the literature. Laboratory studies can control for experimental variables that may influence toxicity, but do not generally represent realistic environmental exposure conditions (Fodrie et al. 2014). In contrast, most field studies are launched after a spill event has occurred, and there is limited control over experimental variables such as exposure concentrations, sample size, endpoints, and physical parameters (Peterson et al. 2001).

Measures of toxicity can range from acute lethality to sub-lethal effects. Sub-lethal effects can be exhibited through growth impairment, immunological responses, genotoxicity, reproductive inhibition, developmental abnormalities, or behavioural dysfunction (Kennedy 2014). Routes of exposure can be at the cellular diffusion level, through ingestion, inhalation, and dermal contact (Dupuis and Ucan-Marin 2015, Lee et al. 2015). Or exposure routes can be at the mechanical level causing direct asphyxiation, thermal control and buoyancy loss (Lee et al. 2015), or impairment of feeding appendages (e.g., in Dungeness crabs, Wright 1994). Spill response efforts (e.g., beach cleaning) may also have negative effects on biota (Lees et al. 1996).

Proposals for the transportation of oil and gas on the BC coast are not new, and shipping of petroleum products already exists in BC marine waterways. A report was presented in 1985 by Fisheries and Oceans Canada, as supplemental information for proposed oil and gas exploration, which discusses petroleum toxicity and exposure consequences on local marine biota (Birtwell and McAllister 2002). Although no offshore oil and gas production currently exists on the BC coast, approximately 110 million m^3 per year of petroleum is moved in and adjacent to coastal BC. Of this total volume, 42 million m^3 is ship fuel, 38 million m^3 is oil cargo (primarily Alaska North Slope crude), and most of the remaining 30 million m^3 are more refined products such as gasoline and diesel (Nuka Research and Planning Group 2013). Current oil tanker traffic through Vancouver Harbour is 7.1 million m^3 per year (Port of Vancouver 2016).

This review encompasses literature pertaining to the sensitivities of marine organisms to different petroleum types, including bitumen products, and concentrates on species found in the northeast Pacific Ocean. Toxicology experiments, ecological studies, physical aspects of petroleum products, and literature searches are included. The intent is to identify current toxicological data gaps and deficiencies and provide a baseline state of knowledge with regards to the coast of BC. The articles have been incorporated into tabular form which enables users to perform searches for specific parameters (e.g., author, oil type, species, location); electronic versions of the data will be posted at http://open.canada.ca/data/en/dataset/34d8a906-2a6b-43ed-8e0e-9b15e3e50a32. Potential applications of the database include the identification of sensitive or vulnerable species, assistance in the development of spill response protocols, and assistance in the derivation of marine water quality benchmarks. In the first section of the review, we focus on literature relevant to oil sand related products such as dilbit, other heavy crude oils (synbit, dilsynbit, and synthetic crude), and diluents. Subsequent sections on spill treating agents (dispersants and surface-washing agents), toxicology, and ecological case studies pertain to crude and fuel oils, as the majority of studies that currently exist on the environmental impacts of petroleum products are based on those products.

2.0 MATERIALS AND METHODS

A series of searches were performed using Web of Science, WAVES (the Fisheries and Oceans Canada library catalogue), ASFA (Aquatic Sciences and Fisheries Abstracts), ProQuest Aquatic Science Collection, ARLIS (Alaska Resources Library & Information Services), Google Scholar, the Simon Fraser University Library online catalogue and the University of British Columbia Library online catalogue. In the first series of searches, whole petrogenic contaminants and components (including dilbit, synbit, dilsynbit, orimulsion, bitumen, oil sands, tar sands, diluent, condensate, crude oil, heavy fuel oil, bunker c, diesel, dispersant, surfactant, corexit, PAH, BTEX, benzene, toluene, ethyl benzene, xylene) were used as keywords in search strings with the wildcard query "toxic*" to probe the primary literature for relevant toxicological data. A second search was run using relevant (coastal, northeast Pacific) aquatic organisms as keywords in search strings with whole petrogenic contaminants.

After a few search returns it became apparent that the 1989 Exxon Valdes oil spill (41,000 m^3 of Prudhoe Bay Crude) in Prince William Sound, AK has driven much of the oil spill related research on this coast. It remains one of the major events in the area and continues to be an impetus for oil spill based research. For inclusivity, a third search series used "Valdez" to locate literature pertaining to the Exxon Valdez oil spill.

Finally, three commonly cited northeast Pacific oil pollution research references were used in a citation search:

1) Johnson, D.K. and Rustin, L.R. 2013. Oil in the Environment: Legacies and Lessons from the Exxon Valdez Oil Spill.

2) Exxon Valdez Oil Spill Trustee Council. 2014. Exxon Valdez Oil Spill Final and Annual Reports.

3) Rice, S.D., Spies, R.B., Wolfe, D.A., and Wright, B.A. (eds). 1996. Proceedings of the Exxon Valdez Oil Spill Symposium.

The majority of searches included primary literature only; however, the WAVES database provided access to internal DFO Technical reports and some grey literature. Results from all searches were screened for relevancy based on proximity to the northeast Pacific, species similarity to local biota, and petroleum type.

References were incorporated into a Microsoft Excel® spreadsheet and assigned a reference number linked to its online source (when available). The Excel® spreadsheet contains several descriptor fields such as petroleum product type, component analyzed, location, event, and species, which provide enhanced searching using Excel's filter function. Complete spreadsheet field definitions are provided in Table 1. Excel® and .csv versions of the spreadsheet can be found here:
http://open.canada.ca/data/en/dataset/34d8a906-2a6b-43ed-8e0e-9b15e3e50a32
Tabular versions of the data are included in two appendices of this report. Appendix 1 includes reference information, species names, and relevant product and spill information. Abstracts and hyperlinks, when available, have been included for each reference in Appendix 2 and are cross referenced to Appendix 1 using the RefID code. The searches and data base include petrogenic literature from 1970 to 2015 pertaining to marine mammals, fishes, invertebrates, marine plants, and algae.

3.0 RESULTS

The literature search yielded 763 references either directly or indirectly associated with the biological effects of petrogenic contaminants and/or associated cleaning efforts on marine life relevant to the northeast Pacific. Summaries of the Main Product, Study Type, and Oil Sand Product fields are provided in Figures 1-3. The majority of references (591) pertain to crude oil, fuel oils account for 115, dispersants 107, background data 27, and studies involving oil sand products total 62. Many references include more than one research aspect so these numbers total more than 763.

Six of the 62 oil sand related studies contain information about crude bitumen, 35 deal with process water either directly or in tailings ponds, 5 pertain to Orimulsion (an oil sands product from Venezuela), 9 reference diluents, and 14 contain information regarding diluted bitumen and related products (Figure 3). Of those 14, 6 are literature searches and summaries, 3 deal with the physical aspects of dilbit, 1 is a hypothetical modeling exercise, 2 are lab based toxicology studies, and 2 pertain to a dilsynbit spill in Vancouver Harbour. One hundred and seven studies contain a component related to dispersants or surface-washing agents and of those, 70 contained information regarding Corexit® products.

With respect to study type, 324 references include ecological studies, 379 contain toxicity information, most in a lab setting, while some studies (71) had both ecological and toxicological information. Of the toxicity studies, 195 involve marine species or genera local to the northeast Pacific. Of these 195 studies, 30 involve dose-response data for whole contaminants such as crude oil, fuel oil, and dispersants. When specifically counting reports involving species local to the northeast Pacific, only 23 studies include dose-response data. Of these, 15 describe "whole oil" effects, while 8 deal with constituents of oil (Table 2).

Despite a focus on marine species of the northeast Pacific, numerous reports included in our database involve non-local species, as certain aspects of these reports (e.g., the genera studied and products similar to dilbit) were considered useful resources for future potential applications of the database. These applications include, but are not limited to, the construction of species sensitivity distributions using surrogate indicator species where data do not exist for local taxa, the design of future toxicity tests based on previously described methods, or the identification of specific data gaps and/or new toxicology-based research opportunities.

The greatest number of reports and studies on the ecological effects of an oil spill are about fish (133), followed by invertebrates (105), mammals (83), vascular plants (10), and algae (25, Figure 4). Commercially important species such as pink salmon (*Oncorhynchus gorbuscha*) and pacific herring (*Clupea pallasi*), iconic species such as orcas (*Orcinus orca*) and sea otters (*Enhydra lutris*), and ubiquitous and already well-studied organisms such as mussels (*Mytilus* spp.) are best represented. The majority of these papers originate from the Exxon Valdez Oil Spill (EVOS).

4.0 DISCUSSION

4.1 NORTHEAST PACIFIC OIL SPILL HISTORY

The West coast of Canada has experienced relatively few major marine oil spills. The largest spill was the 1988 Nestucca fuel barge spill (875 m^3 of Bunker C originating in Grays Harbour, Washington). This is the most significant spill to date in BC, affecting 116 Km of shoreline and resulting in fisheries closures and extensive shoreline cleaning operations (Davis 1989). The 2007 Burrard Inlet dilsynbit spill (234 m^3, of which 90 m^3 entered the marine environment) is the only recorded incident involving a Canadian bitumen product entering the marine environment. It was caused by an upland construction crew accidentally severing a pipeline, and the resultant spill entered Burrard Inlet via the storm water drainage system (Stantec 2012). The only other recorded major bitumen product spill affecting aquatic environments is a pipeline failure in Michigan where 3,600 m^3 of dilbit entered the Kalamazoo River (Silliman 2014). For comparison, the largest oil spill in Canadian history was the 1970 Arrow (11,000 m^3 Bunker C) of which an estimated 2,000 m^3 affected the Nova Scotia shoreline (Thomas 1973). The Exxon Valdez spill (41,000 m^3 crude oil) in Alaska remains one of the most catastrophic maritime spills in the eastern Pacific (Exxon Valdez Oil Spill Trustee Council 2014, Table 3).

The following is a synopsis of literature pertinent to marine life in the northeast Pacific and includes reference to oil sand related products (heavy crude oils and diluents), dispersants and surface-washing agents, toxicological and ecological studies and documents contained in our data base.

4.2 OIL SAND RELATED PRODUCTS

4.2.1 *Dilbit and other heavy crude oils*

Most of the aquatic toxicology data (35 documents; Figure 3) associated with the Alberta oil sands involve fresh water organisms exposed to tailings pond or process water, but not diluted bitumen itself. Process water is formed when bitumen is washed from oil sands: the bitumen is extracted and the process water, after treatment, is discharged into tailings ponds, which poses environmental concerns but is kept at the bitumen extraction site and does not directly affect the marine environment. Despite the potential ecological risks associated with the transport of dilbit or related products in marine environments, summaries and studies describing dilbit effects were limited to 14 documents including modelling, physical, ecological, toxicological, and summary information.

One of the major concerns with regards to marine spills involving dilbit (and similar products) involves determining the conditions which influence its buoyancy or potential to sink in the marine environment. A modelling study produced for the Enbridge Technical Data Report series (Belore 2010) suggests that after 120 hours of weathering, the dilbit modelled would not sink but may become emulsified in surface waters. In laboratory settings, certain blends of dilbit were found to initially float but sank after weathering (King et al. 2014) or exposure to suspended sediments (Environment Canada et al. 2013). Tsaprailis (2014) summarizes the current knowledge regarding transport of dilbit, terrestrial spill behavior, and aquatic spills. He acknowledges that there is limited information regarding marine spills and that weathering and exposure to sediments are important determinants of dilbit density. Yang et al. (2011) provide chemical analyses and comparisons of bitumen, dilbit, dilsynbit, and crude blend oils.

Studies on the toxicity of dilbit to marine organisms are very limited. However, a study by Madison et al. (2015) reports the lethal and sublethal effects of dilbit and dilbit-dispersant mixtures on the test fish medaka (*Oryzias latipes*). The water soluble fraction of dilbit was not acutely lethal to medaka but sublethal effects and embryological deformities were noted. Stubblefield et al. (1989) provide dilbit ingestion and inhalation effects on mice and rats as a preliminary investigation for oil sand worker safety. They found relatively low toxicity but noted some sublethal lung and liver effects. This study may provide some insight or foundation for future studies involving marine mammals as inhalation and ingestion are identified hydrocarbon exposure routes for seals and whales (Matkin et al. 2008).

There are two reports concerning a spill of dilsynbit (Albian Heavy Synthetic) into Burrard Inlet on July 24, 2007. Due to a pipeline rupture, dilsynbit entered the marine environment via subtidal storm water outfalls. The product floated to the surface, and due to a slack tide and lack of rainfall (which decreased storm water system flow), was not widely dispersed but did affect the shoreline area (Stantec 2012). The shoreline has since met recovery end-points with the exception of mussels, which continue to have high PAH levels (although PAH sources are not certain). Shang et al. (2012) detail shoreline cleaning techniques used during the response activities which are described below in Section 4.3 dispersants and surface-washing agents.

Six of the 14 dilbit related documents are literature searches or summaries. Environment Canada et al. (2013) summarize historic dilbit information and provide new data with regards to dilbit and dispersant physical behavior and fate. Lee et al. (2015) review the state of knowledge with respect to crude oil, including bitumen products and their release into aqueous environments, and discuss spill preparedness, spill response, and environmental remediation strategies in marine and freshwater systems. Dupuis and Ucan-Marin (2015) provide a comprehensive summary on the chemical and physical properties of petroleum oils including bitumen products, as well as relevant toxicological concepts and data which address the potential for adverse effects associated with marine spills. Power (2013) provides a summary of crude oil toxicities to a variety of anadromous fishes with a focus on Eulachon in the Kitimat area and possible scenarios during a dilbit spill. Silliman (2014) gives an overview of and preparedness guidelines for the Burrard Inlet and Kalamazoo River pipeline spills. Dew et al. (2015) synthesize fate, effects, and toxicity of dilbit in freshwater systems, suggesting that its impacts are similar to a lighter crude oil but benthic contamination due to sinking increases environmental risk. Although not included in our data base due to the 2016 publishing date (our cut-off was 2015), a recent book is noteworthy - Spills of Diluted Bitumen from Pipelines: A Comparative Study of Environmental Fate, Effects, and Response (National Academies of Sciences, Engineering, and Medicine), which deals with terrestrial impacts of bitumen products.

Orimulsion is a Venezuelan oil sands product consisting of approximately 70% bitumen, 30% water, a small amount of emulsion stabilizer and nonionic surfactant (Cekirge et al. 1997). As this is a form of bitumen product, studies using species similar to those found in Canada were included in the database. Following an 88-day exposure using artificially weathered oils, Suderman and Thistle (2004) reported no significant differences in toxicity between Orimulsion and a heavy fuel oil (Fuel Oil #6) to phytoplankton. One study observed increased mortality and developmental abnormalities in fish embryos exposed to concentrations of Orimulsion as low as 0.001% (Atlantic herring, *Clupea harengus*) and 0.032% mummichog (*Fundulus heteroclitus*, a coastal Atlantic killifish often used in toxicology studies). This same study reported that Orimulsion was 300 times more toxic to mummichog than Fuel Oil #6 (Boudreau et al. 2009). Svecevicius et al. (2003) found Orimulsion to be "moderately toxic" to rainbow trout embryos, larvae, and adults. In contrast, Williams et al. (2003) observed no increased adverse effects in Atlantic herring embryos except at the highest concentration tested (reported as 1000 mg/L Orimulsion). The limited and inconsistent data on Orimulsion toxicity indicate the need of further research and standardized toxicity testing to accurately characterize a range of marine species sensitivities to bitumen products.

4.2.2 *Diluents*

Natural gas condensate (NGC) diluents primarily contain low molecular weight (LMW) hydrocarbons, such as alkanes with 5 to 7 carbon atoms (averaging 21%) and significant amounts of mono-aromatic hydrocarbons such as benzene, toluene, ethyl-benzene, and xylene (BTEX), ranging from about 2 to 7% (crudemonitor.ca). They also contain EPA priority PAHs and naphthalenes which, together with LMW alkanes, significantly altered the chemical fingerprints of dilbit compared to bitumen (Yang et al. 2011). Dupuis and Ucan-Marin (2015), Yang et al. (2011), Lee et al. (2015), and the website crudemonitor.ca provide excellent background on sources, physical aspects, and use of diluents.

Belore (2010) modeled a condensate spill in Douglas channel and determined that, because of its LMW, 100% evaporation and dispersion would occur after 12 hours during summer conditions. Acute toxicity from the water soluble PAH and BTEX fractions, however, may be a concern (Neff et al. 2000) as they may remain in the water column, at significant concentrations, for up to one week in certain conditions. Working on Scotian shelf condensates, Lucas and Freedman (1989) found an immediate herbicidal effect on vascular plants but full recovery after two growing seasons. Mahon et al. (1987) found toxicities of the same Scotian shelf condensates on mummichog were similar to crude and fuel oils. Neff et al. (2000) found very high toxicities associated with dissolved fractions of Australian condensate to both fish and invertebrates. Villanueva et al. (2008 and 2011) found NGC lethality to corals varied by species and that for some, exposure to dissolved fractions for three hours had negative impacts on reproduction and they postulate that this could have population level effects. Even with relatively fast evaporation and dispersion times, diluent spills pose a threat to marine environments and require further toxicological investigation, especially as it pertains to the colder waters of the north Pacific.

4.3 DISPERSANTS AND SURFACE-WASHING AGENTS

Although other products are used globally, Corexit® dispersants have almost exclusively been used in North American oil spill response, therefore our focus is on Corexit® products. Seventy of the 107 database references dealing with dispersants pertain to Corexit® products; of these, over 85% are toxicological in nature and 16 refer directly to the 2010 Deepwater Horizon oil spill (DWH - 780,000 m^3 of crude oil) in the Gulf of Mexico. The DWH response was the largest use of Corexit® dispersants to date with over 3,200 m^3 injected at the well head, and an additional 4,200 m^3 sprayed on the ocean surface (Lee et al. 2015). Originally, Corexit® 9527 was used but this was changed to Corexit®EC9500A as it was determined that a solvent in the 9527 formulation (2-butoxyethanol) was considered too toxic for worker safety and environmental concerns.

One of the actions of a dispersant, with sufficient concomitant wave energy, is to break up an oil slick and diffuse it into the water column, thereby increasing the oil-water surface area and potential dissolution of hydrocarbons into the water column. This increase of dissolved hydrocarbons may have the resultant effect of more bioavailability (Laramore et al. 2014) and therefore increased toxicity (Schein et al. 2009). Studies involving dispersants generally compare the water accommodated fraction (WAF) to the chemically enhanced water accommodated fraction (CEWAF). WAF is water that has been exposed to the oil product of interest and contains the dissolved and/or suspended and/or emulsified fraction. CEWAF refers to water that has been exposed to an oil product treated with a dispersant. Preliminary studies into the effectiveness of dispersants on treating dilbit slicks had variable results between two dilbit blends and found the oil droplet size distributions formed were distinctly different from those formed by dispersant-crude oil mixtures (Environment Canada et al. 2013). Therefore extrapolations from crude oil – dispersant studies to the effects of bitumen-dispersant mixtures must be treated with caution.

WAF-CEWAF comparison studies attempt to elucidate whether treating an oil slick with a dispersant is beneficial and are complicated by several factors such as oil and dispersant type, test species, life stage, water temperature, and UV exposure. For example, Singer et al. (1998) found that topsmelt (*Atherinops affinis*) were more sensitive to WAF while mysids (*Holmesimysis costata*) were more sensitive to CEWAF of the same products. CEWAF was found to be more toxic than WAF for oyster larvae (Laramore et al. 2014), juvenile cod (Lyons et al. 2011), amphipods and molluscs (Gulec et al. 1997). While, Long and Holdway (2002) and Fuller et al. (2004) found CEWAF toxicity equivalent to or less than WAF for several species. And Lin et al. (2009) found CEWAF 20 times less toxic than WAF for Chinook salmon (*Oncorhynchus tshawytscha*) smolts. McIntosh et al. (2010) found the age of Atlantic herring embryos was negatively correlated with CEWAF sensitivity (older embryos were less sensitive) and dispersed oil dramatically impaired fertilization success. In a recent study, the only dilbit-CEWAF study we found, Madison et al. (2015) discovered that CEWAF had about 100 times the PAH concentration as WAF but generally had less mRNA activation than WAF in medaka test fish embryos. However, blue sac disease was more prevalent in their CEWAF treatment. Physical parameters such as temperature and sunlight exposure can play significant roles regarding the toxicity of CEWAF. Perkins et al. (2003 and 2005) found that cooler Alaskan waters accommodated greater concentrations of volatile organics (6-9 carbon atoms, including BTEX) than warmer waters, while Barron et al. (2003) found that oil and dispersant mixtures were more toxic to herring after exposure to sunlight light.

In anticipation of BC offshore oil gas exploration in the mid 1980's, several enclosed mesocosm toxicological experiments were performed using crude oil and dispersants (Parsons et al. 1984). In these studies, Harrison et al. (1986) found a major shift in the plankton community structure with bacteria and zooflagellates increasing in abundance in the oil plus Corexit® 9527 treatment, while shoreline studies determined that Corexit® 9527 and crude oil mixtures were more toxic to littleneck clam larva (*Protothaca stamineais*) than dispersant or oil alone (Hartwick et al. 1982). These historical BC studies indicate that the use of older Corexit® formulations had potential ecological implications. The impacts of newer formulations need to be determined.

Documentation of the surface-washing agent Corexit®EC9580 was limited to 4 references. The surface-washing agent was used on selected shorelines, particularly marshes, of Gulf Coast states affected by the DWH spill. Pezeshki et al. (1998 and 2001) found that marsh plants treated with oil and the washing agent had some physiological impairment but recovered to control conditions after 12 weeks, and that washing agent use may be necessary only when sensitive species are oiled. While, Hulathduwa and Brown (2006) found that the washing agent may be beneficial if used to clean oyster beds only when high levels of oil deposition occur.

During the Burrard Inlet dilsynbit spill response the beach cleaning efficacy of Corexit®EC9580 was compared to flushing and power washing techniques (Shang et al. 2012). Water samples indicated that after washing agent application and subsequent flushing, substantially more hydrocarbons were mobilized than by pressure washing or flushing alone. Moreover, the water flushed from the beach was not toxic as indicated by Microtox® and echinoid fertilization assays. This is a unique and beneficial in situ study, however suffers from lack of a balanced experimental design and replication.

4.4 TOXICOLOGY STUDIES

Bitumen products are a complex mixture of thousands of chemicals known to range in toxicity to aquatic organisms, including polycyclic and monocyclic aromatic hydrocarbons (PAH and MAH), naphthenic acids, and various non-hydrocarbon compounds (Tsaprailis 2014, Yang et al. 2011). Due to additive, synergistic, or antagonistic interactions between chemical components of complex mixtures, it is difficult to accurately predict the toxic effects of dilbit based on data for single toxicants (e.g., individual PAHs) or by comparison to other petroleum mixtures that vary in chemical composition (e.g., crude oil or bunker C). Research directly investigating bitumen product toxicity on marine organisms is therefore crucial in identifying and protecting sensitive species and habitats in the event of a dilbit spill in BC coastal waters.

A summary of the toxicological data for northeast Pacific species included in our database is provided in Table 2. Despite sufficient evidence that crude oil and its chemical components cause numerous adverse effects to marine life, including immunological, genetic, developmental, behavioural, and reproductive impairments, there remain significant challenges in characterizing the relative sensitivities of species to whole petrogenic contaminants (Kennedy 2014, Dupuis and Ucan-Marin 2015). These challenges are related to sources of variability in toxicity tests, such as numerous physical, chemical, and biological parameters that are seldom consistent from one study to the next. For example, physicochemical parameters that may impact the toxicity of oil to aquatic organisms include, but are not limited to, water temperature, salinity, UV radiation, as well as the chemical composition (e.g., percent composition of PAHs) of the specific oil being tested (Korn et al. 1979, Barron et al. 2005, Ramachandran et al. 2006). Furthermore, biological sources of variability in toxicity tests include the life stage, sex, behaviour, and health of the organisms under investigation. While an individual experiment can control for many of these variables, rating species sensitivities to oil (or any other substance) only makes sense if the exposure conditions reported in the literature are similar enough to draw meaningful comparisons across studies.

In addition to the above sources of variability in toxicity testing, the literature is rife with other obstacles for characterizing the relative sensitivities of marine species to oil, such as (1) a lack of comparable toxicological endpoints (e.g., acutely lethal endpoints versus various sublethal effects) among studies, (2) inconsistencies in exposure durations (e.g., acute vs. sub-chronic vs. chronic), (3) species differences in exposure pathways (e.g., oral ingestion, respiratory, and dermal absorption), and (4) limited consistency in the preparation of oil test solutions and water chemistry analyses between studies.

In our review of the available data, most oil studies involving toxicological data for species local to the northeast Pacific include measured exposures based on water chemistry analyses, but little consistency exists in the specific analyses performed. For example, many studies report oil exposure concentrations in units of total petroleum hydrocarbons (TPH), while others report total polycyclic aromatic hydrocarbons (TPAH), total hydrocarbons (THC), total aromatic hydrocarbons (TAH), or some combination thereof. Furthermore, some studies have reported nominal oil exposures as the percent WAF from a dilution series, with no chemical analyses performed (Table 2). These inconsistencies raise challenges when attempting to synthesize toxicity data from multiple studies, as experimental exposures ought to be designed and reported in a manner that is amenable to large-scale analyses aimed at predicting the effects of spilled oils on marine ecosystems.

The importance of adhering to standardized protocols for oil and dispersant toxicity testing (which are also applicable to dilbit) is well recognized and described in the literature (Coelho et al. 2013). A suite of standardized testing and reporting protocols have been developed by the Chemical Response to Oil Spills Ecological Effects Research Forum (CROSERF), which address the inconsistencies often associated with assessing the toxicity of oils, as well as characterizing the effects of chemical dispersants (Aurand and Coelho 2005). However, consistent utilization of these standards and protocols remains elusive.

4.5 ECOLOGICAL STUDIES

4.5.1 *EVOS Ecological Studies*

Although little data exists on the effects of bitumen products on marine organisms, there are many reports describing the effects of conventional crude oils on various life stages of northeast Pacific marine species. This large body of data is due, in large part, to the various research initiatives spawned from the Exxon Valdez oil spill (EVOS). One of the complicating factors of ecological field studies on oil spill effects, is the lack of pre-spill (temporal control) data; often non-oiled nearby sites are used for reference conditions which may or may not provide suitable spatial control conditions. The following summaries are EVOS studies unless otherwise indicated.

4.5.2 *Macroalgae*

Intertidal macroalgae such as rockweed (*Fucus gardneri*) were reported to be affected by the EVOS (Duncan and Hooten 1996) and even more so by cleaning activity (De Vogelaere and Foster 1994, Driskell et al. 2001, Stekoll and Deysher 1996, van Tamelen et al. 1997). Subtidal species such as kelp (*Laminaria* spp., *Nereocystis luetkeana*) may also have been affected, but in a study conducted one year after the EVOS, total density and biomass appeared similar between oiled and non-oiled sites (Dean et al. 1998). Kelp is often studied in conjunction with sea otter predation of sea urchins, as historically, reduction in urchin numbers has led to an increase in kelp biomass. However, after the EVOS Dean et al. (2000) found that the loss of half the sea otter population at some sites did not affect sea urchin or kelp densities. An older review of oil spill effects on algae summarize that intertidal macrophytes are generally restored to pre-spill community structure conditions 1 to 2 years after an event (O’Brien and Dixon 1976).

4.5.3 *Invertebrates*

Mussels (*Mytilus* spp.) form biogenic mats, and are well-established as a contaminant-monitoring species in NOAA’s Mussel Watch Program (Kimbrough et al. 2008). They are a ubiquitous intertidal filter-feeding genus, and being sessile in their adult form, are ideal organisms to test for contaminants in any particular location. We have collected over 40 ecological studies that include mussels, and of these, 37 describe the ecological effects of oil and of cleaning efforts on mussels or communities including mussels. Oil spills do have acute and chronic effects on mussel health (Babcock et al. 1998, Clark et al. 1978, Hwang et al. 2014, Stekoll et al. 1996), and the problem persists as oil that has seeped beneath the mussel beds may linger for years (Babcock et al. 1998, Boehm et al. 1995, Carls et al. 2001, Carls and Harris 2004, Day 2006, Harris et al. 1996, Roberts et al. 1999). Studies on the effects of post-spill cleaning using hot, pressurized water report more damage than the spill itself (Lees et al. 1996) and follow up studies indicate no differences in residual oil or lagging recovery of biota when compared to oiled, non-cleaned sites (Babcock et al. 1998, Carls et al. 2004, Driskell et al. 1996, Houghton et al. 1996).

Similar studies on littleneck clams (*Protothaca staminea*), which live buried in sandy beaches, suggest that the clams accumulate more PAHs than mussels (Shigenaka et al. 1999), and recover more slowly from oiling and cleanup activity (Fukuyama et al. 2000 and 2014, Houghton et al. 1995, Lees and Driskell 2007), although one EVOS study by Trowbridge et al. (2001) found little conclusive evidence of an oiling effect on clams at various sites in Prince William Sound.

Several studies on Dungeness crab (*Cancer magister*) caught post-EVOS in 1989 indicate trace contamination in a few samples; however, they were deemed safe for human consumption by the U.S. Food and Drug Administration (Freese and O'Clair 1995, O'Clair et al. 1990). The 1988 Nestucca bunker C spill, resulted in a prolonged closure of the crab fishery on the west coast of Vancouver Island (Davis 1989 and Wright 1994) but no in-depth studies were produced.

Studies on other invertebrates such as amphipods, barnacles, sea stars, urchins and anemones are in the database; many are included in reports that discuss community effects (Clark et al. 1978, Cretney et al. 1978, Jewett and Dean 1997, Houghton et al. 1996, Lees et al. 1996). Results vary across studies, and this is probably due to the variation among oil exposure, sites, habitats, and community structure.

4.5.4 *Fish*

There are 133 ecological studies on fish in our database, and almost half of them discuss salmonids. By far the majority of these are on pink salmon (*Oncorhynchus gorbuscha*), as their eggs were incubating in intertidal gravel beds when the EVOS occurred (Brannon et al. 1995, Bue et al. 1998, Wertheimer et al. 1999). There is an ongoing debate over whether the spill affected the embryos in terms of growth and survival (Brannon et al. 2012, Carls et al. 2004, Heintz et al. 1999, Marty et al. 1997), subsequent alevin outmigration (Geiger et al. 1996, Heintz et al. 2000, Sturdevant et al. 1996, Willette 1996), and whether there was lingering oil that could have affected following generations (Brannon et al. 1995, Craig et al. 2002, Cronin and Bickham 1998, Maki et al. 1995). Sockeye salmon (*O. nerka*) experienced a population decline that some believe was due to density dependent effects caused by a commercial harvest ban at the time of the spill where subsequent increases in juvenile populations in nursery lakes may have had a negative impact on smolt production (Ruggerone and Rogers 1998 and 2003, Schmidt et al. 1996, Tarbox et al. 1995).

A survey of recreationally caught fish in 1989 found no visible signs of contamination in any of the salmon, halibut and rockfish examined (Roth et al. 1990), although bile assays on rockfish, pink salmon and pollock caught in 1989 did find metabolites of aromatic compounds (Hoffman and Hansen 1994, Krahn et al. 1992, Marty et al. 2003, Varanasi et al. 1990).

Pacific herring (*Clupea pallasi*) were about to spawn in Prince William Sound when the EVOS occurred (Brown and Baker 1998). Spawning proceeded, and comparison of eggs and larvae from oiled and un-oiled sites indicated lethal and sublethal effects (Hose et al. 1996, Johnson et al. 1997, Marty et al. 1997, 2000, McGurk and Brown 1996, Norcross et al. 1995). Oil effects were not seen in eggs and larvae in subsequent years (Hose et al. 1996, Johnson et al. 1997), but adult herring returns in 1993, which would have been mostly of the 1989 brood class, were low and oil effects are implicated, both directly and indirectly (Kocan et al. 1996, Marty et al. 1999, Thorne and Thomas 2008 and 2014).

Some non-EVOS petrogenic studies such as Brannon et al. (1986) found that oil exposure did not affect homing instincts for adult Chinook salmon (*O. tshawytscha*), and Barbee et al. (2008) report that juvenile coho (*O. kisutch*) being held over PAH-contaminated sediment in a lake show genotoxic responses. Incardona et al. (2012) reported on the toxic effects and mortality of herring embryos and larvae following a bunker C spill near San Francisco, and West et al. (2014) reported on background PAH levels in five herring spawning grounds in Puget Sound, WA.

4.5.5 *Marine Mammals*

Of the 83 marine mammal studies collected, over 60% discuss sea otters (*Enhydra lutris*) as they are an iconic species that appeared to be most affected by the EVOS due to their nearshore habitat use and lack of blubber (Costa and Kooyman 1982, Loughlin et al. 1996). Actual numbers affected are under debate (Eberhardt and Garrott 1997, Garrott et al. 1993, Garshelis 1997, Garshelis and Estes 1997), but clearly there was an acute effect to some degree (Ballachey and Kloecker 1997a-c, Bodkin and Weltz 1990, Lipscomb et al. 1993 and 1996). There is also continuing debate over whether populations have recovered (Agler et al. 1994, Bodkin et al. 2002 and 2011, Garshelis and Johnson 2013, Holland-Bartels 1996, Monnett and Rotterman 1995, Monson et al. 2000), and whether exposure to subsurface oil residues continue (Bodkin et al. 2012, Boehm et al. 2011, Doroff and Bodkin 1994, Harwell et al. 2010, Harwell and Gentile 2014, Neff et al. 2011).

There are many studies on river otters (*Lontra canadensis*), as they forage along the intertidal zone and fecal samples are easily collected and analyzed (Ben-David et al. 2002, Bowyer et al. 1995, 2003, Duffy et al. 1993, 1994a, and 1994b). Harbour seal (*Phoca vitrulina*) populations had been declining since 1984, but an estimated 300 seals were thought to have died in the spill (Frost and Lowry 1994, Frost et al. 1999) while others contend that declines could be due to other factors such as emigration (Hoover-Miller et al. 2001). Humpback whales (*Megaptera novaeangliae*) and orcas (*Orcinus orca*) were monitored using aerial and boat surveys, and two papers that discuss humpback whales report no mortalities and no observations of whales swimming in oil (Dahlheim and von Ziegesar 1993, Loughlin et al. 1996). Two orca pods, one resident and one transient, are reported as having lost members in 1989 and 1990, likely due to the EVOS but there was no conclusive evidence as no carcasses were recovered (Dahlheim 1994, Dahlheim and Matkin 1993, 1994, Fraker 2013, Matkin et al. 1994, 2008).

5.0 SUMMARY AND RECOMMENDATIONS

Oil sand products include various mixtures of bitumen, synthetic crude, and diluent; thus the products are chemically and physically highly variable. In fact, Environment Canada et al. (2013) show that two Albertan dilbit products have different physical behaviours when placed in seawater. There is a need to determine the range of bitumen product physical responses in the marine environment—for example, does a particular product sink initially, or after weathering, or not at all? What are the toxicological implications over time as the product weathers? And correspondingly, appropriate spill response methodologies to handle these various outcomes require development. The fact that 6 of 14 dilbit related documents found in our literature search are summaries or reviews indicates a requirement for research on all aspects of these products, particularly in toxicology, ecological effects, and spill response.

Evidence in the literature suggests a variety of marine life toxicological responses to dispersed oil, while surface-washing agents have few studies regarding their impacts. Results are complicated by several factors such as oil and dispersant type, test species, life stage, water temperature, UV exposure, and variation in laboratory methods. The size distribution of oil droplets formed by dispersants varies from crude oil to bitumen products, and therefore, caution must be applied when extrapolating from crude oil-dispersant studies to the effects of bitumen-dispersant mixtures. There is evidence that older dispersant formulations had potential "bottom-up" ecological implications by affecting plankton community structure. The impacts of newer formulations need to be assessed from this perspective.

Although standardized testing and reporting protocols have been developed by the CROSERF, consistent utilization of these standards and protocols remains elusive. Furthermore, standards and protocols should take into account local species and local physical conditions.

There is a need for baseline ("pre-spill") ecological data which should consider suitable recovery end-points. The Exxon Valdez Oil Spill demonstrates highly variable impacts from a single oil type. Even with a well studied event such as EVOS, albeit with limited baseline data, controversies continue with impact assessment, recovery status, and suitable end-points.

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7.0 GLOSSARY OF TERMS AND ACRONYMS

Bitumen - extra-heavy oil that generally occurs in sands, in its natural state it is too viscous to pump.

BTEX- benzene, toluene, ethyl benzene, xylene. BTEX are forms of MAHs.

CEWAF - chemically enhanced water accommodated fraction - refers to water used in bioassays and toxicology experiments that has been exposed to an oil product treated with a dispersant. See WAF.

Dilbit - “diluted bitumen” is bitumen that has been thinned with 20-30% diluent. Diluting bitumen is necessary to make it less viscous and therefore easier to pump, for example in pipelines.

Dilsynbit - A mixture of diluent, synthetic crude, and bitumen.

Diluent - a thinning agent used to enable pumping of bitumen through pipelines. Common diluents used in Alberta are natural gas condensate and synthetic crude oil.

Dispersant - a product used to emulsify and accelerate the weathering of spilled oil in aquatic environments by breaking up a slick and redistributing oil droplets in the water column.

DWH - Deepwater Horizon oil spill in the Gulf of Mexico (2010).

EPA - US Environmental Protection Agency.

EVOS - Exxon Valdes oil spill in Prince William Sound, Alaska (1989).

LMW - Low molecular weight.

MAH - monocyclic aromatic hydrocarbons - organic compounds having a single aromatic ring. BTEX are forms of MAHs.

NGC - natural gas condensate - is produced by the extraction and liquefaction of natural gas, mainly composed of propane, butane, and pentane. NGC is used as a diluent to thin bitumen.

NOAA - US National Oceanic and Atmospheric Administration.

Oil sands - deposits of sand and bitumen, the largest deposits are found in Venezuela, USA, Russia and Canada.

Orimulsion - a Venezuelan oil sands product consisting of approximately 70% bitumen, 30% water, a small amount of emulsion stabilizer and nonionic surfactant.

PAH - polycyclic aromatic hydrocarbons - organic compounds composed of two or more benzene rings.

STA - spill-treating agents - substances such as dispersants and surface-washing agents used during a spill response.

Surface-washing agents - a product used to clean oil from hard surfaces such as shorelines and man-made structures.

Synbit - a 1:1 mixture of bitumen and synthetic crude oil.

Synthetic crude - bitumen that has been cracked to reduce carbon chain length, thereby reducing viscosity.

TAH - total aromatic hydrocarbons.

THC - total hydrocarbons.

TPAH - total polycyclic aromatic hydrocarbons.

TPH - total petroleum hydrocarbons.

WAF - water accommodated fraction- refers to water used in bioassays and toxicology experiments that has been exposed to the oil product of interest and contains the dissolved and/or suspended and/or emulsified fraction. See CEWAF.

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Table 1. Literature search spreadsheet abbreviations used for MainProduct, SpecificProduct, ComponentsAnalyzed, Event, Location, StudyType, and ExposureMedia fields.

MainProduct		SpecificProduct		SpecificProduct continued		ComponentAnalyzed		Event		Location		StudyType		ExposureMedia	
		Crude Oil		**Dispersant or Surface-washing agent**											
BG	Background	ALA	Alamin crude	AGM	Agma OSD	ALH	Aliphatic HC (includes alkanes)	AEG	Aegean Sea, NW Spain, 1992	AB	Alberta	LIT	Literature search, biliography, or review	AIR	Air bourne
CO	Crude Oil	ALB	Alberta crude	BIO	Biosolve	BTX	Benzene, Toluene, Ethylbenzene, Xylene (BTEX)	AMC	Amoco Cadiz, NW France,1992	AFR	Africa	TOX	Toxicology experiment, generally in the lab	EST	Estuarine
DS	Dispersant or Surface-washing agent	AMC	Arabian medium crude	COR	Corexit (Nalco)	CWF	Chemically enhanced water accomodated fraction	ANG	Antonio Gramsci, Finland, 1987	AK	Alaska	ECO	Ecological study, generally in the field	FW	Freshwater
FO	Fuel Oil	AMR	Arroyo minero river	CSG	Crystal simple green	MET	Metals	ARR	Arrow, Nova Scotia, 1970	ANT	Antarctic	MOD	Modelling	ING	Ingestion
OR	Oil Sand Related	ANG	Angolan crude	CYT	CytoSol	NAC	Naphthenic acid	BIP	Transmountain pipeline, Burrard Inlet, BC, 2007	AOS	Alberta - oil sands	PHY	Physical (habitat) assessment	SED	Sediment
		ANS	Alaska north slope (includes Pruhdoe Bay)	DAS	Dasic NS	NGC	Natural gas condensate	BOU	Bouchard barge, Buzzards Bay, Massachusetts, 1974	ARC	Arctic			SW	Seawater
		ARC	Arctic crude	DP1	DP-105	PAH	Polycyclic aromatic hydrocarbons	BRA	Braer, Scotland, 1993	ARG	Arabian Gulf			TER	Terrestrial
		ARL	Arabian light crude	HCN	HiClean	PRD	Produced water (from drilling operations)	COB	Cosco Busan, San Francisco, 2007	ASIA	Asia				
		ASC	Assam crude	HYT	Hytron #3A	SED	Sediment	CRB	Coral Bulker, Portugal, 2000	AUS	Australia				
		BAL	Baltic Sea crude	MAX	Maxiclean	TPH	Total petroleum hydrocarbons	DIA	Diamond Grace, Yokohama, 1997	BC	British Columbia				
		BAL	Brut arabian light	NEO	NEOS AB3000	UVT	UV Toxicity (phototoxicity)	DUB	Dubai Star, San Francisco, 2009	CA	California				
		BHC	Bombay high crude	NOK	Nokomis 3	WAF	Water accomodated fraction	DWH	Deepwater Horizon Spill, Gulf of Mexico, 2010	CAN	Canada				
		BNT	Brent crude	OSR	Finasol OSR	WHL	Whole product	ENB	Enbridge Northern Gateway	EUR	Europe				
		BPC	Brazilian petrobas crude	PAR	Pars1, Pars2			ERK	Erika, SW France, 1999	FIN	Finland				
		BRC	Barents Sea crude	SEG	Sea Green 805			EVOS	Exxon Valdez, Alaska, 1989	FRA	France				
		BRZ	Brazilian light crude	SGN	Slickgone			GWOS	Gulf War, Arabian Gulf, 1991	GAL	Galapagos				
		BSC	Bass Straight crude	SLK	Slik-A-Way			HEB	Hebei Spirit, Korea, 2007	GM	Gulf of Mexico				
		CHP	Champion crude	TFL	Total Fluides			IRI	Irini, stockholm archipelago, 1970	IND	India				
		CHU	Chukchi Sea crude	TTD	Taiho Tech D-1128			IST	Irish Stardust, BC, 1973	MA	Massachusetts				
		CLF	California crude	TWE	Tween			JES	Jessica, Galapagos, 2001	MES	Middle East				
		COK	Cook Inlet crude					KAL	Kalamazoo River pipeline, Michigan, 2010	MI	Michigan				
		EGT	Egyptian crude	**Fuel Oil**				MEG	General Meigs, WA, 1972	NL	Newfoundland				
		ESC	Escalante crude	BUC	BunkerC			MET	Metula oil spill, Strait of Magellan, Chile, 1974	NOR	Norway				
		FED	Federated crude	DSL	Diesel			NAK	Nakhodka, Sea of Japan, 1997	NS	Nova Scotia				
		FOR	Forcados light nigerian crude	HFO	Heavy fuel oil			NCP	North Cape, Rhode Island, 1996	NY	New York				
		FOR	Forties blend	IFO	Intermediate fuel oil			NES	Nestucca, BC, 1988	ON	Ontario				
		GRK	Girkaliai crude	LCO	Light cycle oil			PRES	Prestige, NW Spain, 2002	OR	Oregon				

Table 1 Cont'd.

HBN	Hibernia light crude	LFO	Light fuel oil	SEL	Selendang Ayu, AK, 2004	PGL	Portugal
IHC	Iranian heavy crude	LUB	lubricant oil	SEM	Sea Empress, UK, 1996	POL	Poland
KCO	Kuwait crude			STU	Stuttgart, Poland, 1943	SAM	South America
LAB	Laboratory reference	**Oil Sand Related**		WAB	Lake Wabamun train derailment, Alberta, 2005	SPN	Spain
LLC	Lybian light crude	BIT	Bitumen	WPR	World Prodigy, Rhode Island, 1989	SWE	Sweden
LLS	Light Louisiana sweet crude	DBT	Diluted Bitumen and related products			UK	Unitied Kingdom
LOC	Lufeng oceanic crude	DIL	Diluent			USA	United States
LTH	Lithuanian crude	ORI	Orimulsion			VAR	various
MAC	Macondo (Deepwater Horizon)	PRW	Process water (including tailings ponds)			WA	Washington
MAY	Maya crude						
MCK	McKee crude	**other codes**					
MCO	Malaysian crude	VAR	Various (generally > 3)				
MLC	Mesa light crude (Venezuela)	UKN	Unknown				
MSB	Mixed sour blend						
NCO	Nigerian crude						
NSC	North Sea crude (includes Gullfaks)						
NWC	Norman Wells crude						
NWG	Norwegian Sea crude						
PAT	Patagonia crude						
QIC	Qua Ibo crude (Nigeria)						
SCN	Scotian light						
SLC	South Louisiana crude						
STA	Statfjord A+B crude						
TCO	Texas crude						
TJP	Tia Juana Pesada crude						
TNA	Terra Nova						
TUN	Tunisian crude						

Table 2. Summary of dose-response data for marine species of British Columbia, Canada. The listed exposures (crude oil, diesel, fuel oil, and selected dispersant) refer to the water accommodated fraction (WAF). Exposures separated by semicolons were tested individually or in combination. Crude oils a – j: (a) Cook Inlet; (b) Alaska North Slope; (c) Lufeng; (d) North Sea; (e) Mocando Canyon; (f) Arabian Light; (g) Bass Strait; (h) South American Crude. Spill-treating agent (STA) a – c: (a) Corexit®EC9500A; (b) Nokomis 3®; (c) Corexit®EC9527. Fuel oils a, b: (a) recovered Prestige fuel oil, (b) standard intermediate Marine fuel oil (IFO 380). UV = ultraviolet light regime to test photo-enhanced toxicity of whole contaminant(s); NR = not reported; NC = not calculable; TAH = total aromatic hydrocarbons; TPAH = total polycyclic aromatic hydrocarbons; TPH = total petroleum hydrocarbons; HMWH = high molecular weight hydrocarbons (C12 - C28); THC = Total hydrocarbons. Where applicable, reported values summarize the range of results under multiple experimental conditions. Species with superscript "a" indicate the genera (but not the species) is local to BC waters; LC50 = the exposure concentration at which mortality is observed in 50% of test organism; EC50 = the exposure concentration at which a sublethal effect is observed in 50% of test organisms; "*" = LC50 and EC50 values were obtained through personal correspondence with author (February, 2015). In all other cases, specific dose-response values with associated error are published in the sources cited.

Taxa	Life stage	Whole contaminant exposure(s)	Exposure duration (days)	Water temperature (˚C)	Effect	End-point	Effect Concentration	Units	Measured component	Source
Fish										
Atherinops affinis	Larva	STA (b)	4	17.9 - 20.0	Mortality	LC_{50}	48.2 - 72.9	mg/L	WAF	Singer et al. (1994)
	Larva	Crude Oil (b); STA (c)	4	20	Mortality	LC_{50}	16.34 - 74.73	mg/L	THC	Singer et al. (1998)
Clupea pallasi	Adult	Crude Oil (a)	2, 10	NR	Mortality	LC_{50}	2.3	mg/L	TAH	Rice et al. (1986)
	Larvae	Crude Oil (a)	7 - 21	NR	Mortality	LC_{50}	0.36 - 1.8	mg/L	TAH	Rice et al. (1986)
	Larvae	Crude Oil (b); STA (a); UV	4, 8	NR	Mortality	LC_{50}	0.002 - 0.199*	mg/L	TPAH	Barron et al. (2003)
	Larvae	Crude Oil (a); STA (a); UV	4, 8	NR	Sub-lethal	EC_{50}	0.002 - 0.05*	mg/L	TPAH	Barron et al. (2003)
	Larvae	Crude Oil (b)	16	4.0 - 7.1	Mortality	LC_{50}	0.053	mg/L	WAF	Carls et al. (2000)
	Larvae	Crude Oil (b)	16	4.0 - 7.1	Sub-lethal	EC_{50}	0.00027 - 0.034	mg/L	WAF	Carls et al. (2000)
	Embryo	Crude Oil (a)	12	NR	Mortality	LC_{50}	1.5	mg/L	TAH	Rice et al. (1986)
	Embryo	Crude Oil (b)	18	8	Sub-lethal	EC_{50}	0.43	mg/L	HMWH	Kocan et al. (1996)
Clupea harengus[a]	Embryo	Crude Oil (b); Crude Oil (f)	<1 - 14	10	Mortality	LC_{50}	7.12 - NC (>35.65)	mg/L	TPH	Greer et al. (2012)
	Embryo	Crude Oil (b); Crude Oil (f)	<1 - 14	10	Sub-lethal	EC_{50}	NC (<1.41) - 60.48	mg/L	TPH	Greer et al. (2012)

Taxa	Life stage	Whole contaminant exposure(s)	Exposure duration (days)	Water temperature (˚C)	Effect	End-point	Effect Concentration	Units	Measured component	Source
Table 2 cont'd.										
	Embryo	Crude Oil (h); STA (a)	<1	8.8	Mortality	LC_{50}	20, 38	mg/L	TPAH	McIntosh et al. (2010)
	Embryo	Crude Oil (h); STA (a)	<1	8.8	Mortality	LC_{50}	75 - 146	mg/L	THC	McIntosh et al. (2010)
	Gametes	Crude Oil (h); STA (a)	<1 -1	8.8	Sub-lethal	EC_{50}	8.5 -21	mg/L	TPAH	McIntosh et al. (2010)
	Gametes	Crude Oil (h); STA (a)	<1 -1	8.8	Sub-lethal	EC_{50}	32 -79	mg/L	THC	McIntosh et al. (2010)
Myoxocephalus spp.[a]	Larva	Crude Oil (b); STA (a)	4	-1 - 5	Mortality	LC_{50}	0.05 - 0.16	mg/L	TPAH	Gardiner et al. (2013)
	Larva	Crude Oil (b); STA (a)	4	-1 - 5	Mortality	LC_{50}	0.05 - 0.16	mg/L	TPH	Gardiner et al. (2013)
	Larva	Crude Oil (b); STA (a)	4	-1 - 5	Mortality	LC_{10}	2 - 12	mg/L	TPH	Gardiner et al. (2013)
Oncorhynchus gorbuscha	Fry	Crude Oil (b)	4	8.6 - 9.7	Mortality	LC_{50}	1.0 - 2.8	mg/L	WAF	Birtwell et al. (1999)
	Fry	Crude Oil (a)	4	8	Mortality	LC_{50}	1.2	mg/L	WAF	Moles et al. (1983)
	Fry	Crude Oil (b)	4	NR	Mortality	LC_{50}	3.7	mg/L	TAH	Moles et al. (1979)
	Fry	Crude Oil (a)	4	4 - 12	Mortality	LC_{50}	0.0015 - 0.0018	mg/L	TAH	Korn et al. (1979)
	Fry	Crude Oil (b)	54	7.8	Mortality	LC_{50}	29	mg/g	THC/food	Carls et al. (1996)
	Fry	Crude Oil (b)	54	7.8	Sub-lethal	EC_{50}	~0.38	mg/g	THC/food	Carls et al. (1996)
Oncorhynchus kisutch	Fry	Crude Oil (b)	4	4	Mortality	LC_{50}	8.0	mg/L	TAH	Moles et al. (1979)
Oncorhynchus nerka	Smolt	Crude Oil (b)	4	6	Mortality	LC_{50}	1.05	mg/L	TAH	Moles et al. (1979)
Onchorhynchus tshawytscha	Smolt	Crude Oil (b); STA (a)	4	11.6 - 15.8	Mortality	LC_{50}	7.46 - 155.93	mg/L	THC	Lin et al. (2009)
Salvelinus malma	Smolt	Crude Oil (b)	4	8	Mortality	LC_{50}	1.38	mg/L	TAH	Moles et al. (1979)
Molluscs										
Crassostrea virginica[a]	Larva	Crude Oil (e); STA (a)	1 - 4	27	Mortality	LC_{50}	14.5 - NC (>1,200)	mg/L	WAF	Laramore et al. (2014)
	Larva	Crude Oil (e); STA (a)	1 - 4	27	Mortality	LC_{50}	0.32 - 5.56	mg/L	TPH	Laramore et al. (2014)

Taxa	Life stage	Whole contaminant exposure(s)	Exposure duration (days)	Water temperature (˚C)	Effect	End-point	Effect Concentration	Units	Measured component	Source
Table 2 cont'd.										
	Larva	Crude Oil (e); STA (a)	1 - 4	27	Mortality	LC_{50}	0.01 - 0.25	mg/L	TPAH	Laramore et al. (2014)
Mytilus galloprovincialis	Embryo	Fuel Oil (a); Fuel Oil (b); UV	2	4	Sub-lethal	EC_{50}	13 - NC (>100)	%	WAF	Saco-Alvarez et al. (2008)
	Embryo	Fuel Oil (a); Fuel Oil (b); UV	2	4	Sub-lethal	EC_{10}	6 - 83	%	WAF	Saco-Alvarez et al. (2008)
	Embryo	Fuel Oil (b)	1 - 80	18	Sub-lethal	EC_{50}	12 - 82	%	WAF	Bellas et al. (2013)
	Embryo	Fuel Oil (b)	1 - 80	18	Sub-lethal	EC_{10}	9 - 78	%	WAF	Bellas et al. (2013)
Haliotis rufescens [a]	Embryo	STA (a)	2	15.1	Sub-lethal	EC_{50}	13.6 - 19.7	mg/L	WAF	Singer et al. (1995)
	Embryo	STA (a)	4	13.4	Mortality	LC_{50}	158.0 - 245.4	mg/L	WAF	Singer et al. (1995)
	Larva	Crude Oil (b); STA (d)	2	14	Sub-lethal	EC_{50}	17.81 - 46.99	mg/L	THC	Singer et al. (1998)
Octopus pallidus[a]	Larva	Crude Oil (g); STA (d)	1,2	16.2 - 18.5	Mortality	LC_{50}	0.51 - 3.11	mg/L	WAF	Long et al. (2002)
Polinices conicus[a]	Adult	Crude Oil (g); STA (a)	0.5 - 1	17	Sub-lethal	EC_{50}	42.3 - 190,000	mg/L	WAF	Gulec et al. (1997)
Ruditapes philippinarum	Adult	Fuel Oil (b)	1 - 4	20	Mortality	LC_{50}	1.9 - 87.8	mg/L	TPH	Ara et al. (2004)
	Adult	Crude Oil (a)	3,4	14	Mortality	LC_{50}	6.58, 6.88	mg/L	WAF	Nunes et al. (1978)
Crustacea										
Eualus spp. [a]	Adult	Crude Oil (a)	4	4 - 12	Mortality	LC_{50}	0.0016 - 0.0017	mg/L	TPAH	Korn et al. (1979)
Allorchesteces compressa[a]	Adult	Crude Oil (g); STA (a)	4	17	Mortality	LC_{50}	3.48 - 311,000	mg/L	WAF	Gulec et al. (1997)
Chionoecetes bairdi	Larva	Crude Oil (b); STA (a)	4	7	Mortality	LC_{50}	0.41 - 5.54	mg/L	TPH	Perkins et al. (2003)
	Larva	Crude Oil (b); STA (a)	4	7	Mortality	LC_{50}	0.79 - 16.93	mg/L	THC	Perkins et al. (2003)

Taxa	Life stage	Whole contaminant exposure(s)	Exposure duration (days)	Water temperature (˚C)	Effect	End-point	Effect Concentration	Units	Measured component	Source
Table 2 cont'd.										
	Larva	Crude Oil (b); STA (a)	4	7	Sub-lethal	EC_{50}	2.22	mg/L	TPH	Perkins et al. (2005)
	Larva	Crude Oil (b); STA (a)	4	7	Sub-lethal	EC_{50}	10.72	mg/L	THC	Perkins et al. (2005)
Holmesimysis costata	Juvenile	Crude Oil (b); STA (c)	4	10	Mortality	LC_{50}	10.54 - 34.68	mg/L	THC	Singer et al. (1998)
Paracalanus parvus	Adult	Crude Oil (c)	1 - 3	22.5	Mortality	LC_{50}	1.31 - 3.86	mg/L	TPH	Jiang et al. (2012)
Oithona similis	Adult	Diesel fuel (a)	7	NR	Mortality	LC_{50}	0.176	mg/L	TPH	Payne et al. (2014)
Calanus finmarchius	Adult	Crude Oil (d)	4	10	Mortality	LC_{50}	0.309	mg/L	TPH	Miljeteig (2013)
Kelp										
Macrocystis pyrifera	Gameto-phyte	STA (b)	2	13.0 - 15.1	Sub-lethal	IC_{50}	73.0 - 79.4	mg/L	WAF	Singer et al. (1994)

Table 3. Aquatic bitumen product spills and major British Columbian, Canadian, and American marine oil spills.

Incident	Location of Slick Impact	Year	Primary Product	Volume (m^3)
Burrard Inlet	British Columbia	2007	Dilsynbit	234
Nestucca	British Columbia	1988	Bunker C	875
Kalamazoo	Michigan	2010	Dilbit	3,600
Arrow	Nova Scotia	1970	Bunker C	11,000
Valdez	Alaska	1989	Prudhoe Crude	41,000
Deepwater Horizon	Gulf of Mexico	2010	Macondo Crude	780,000

10.0 FIGURES

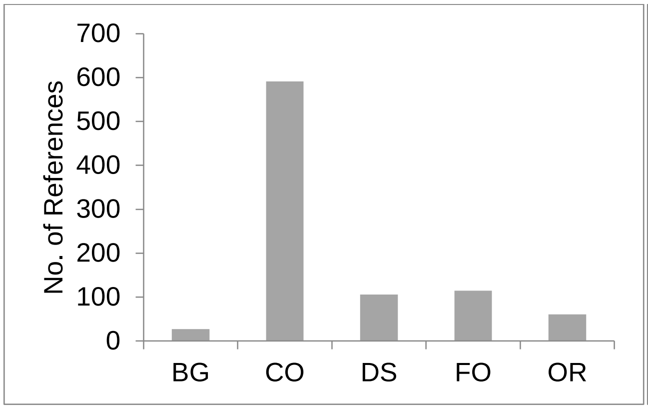

Figure 1. Number of references by petroleum product type. BG = background data, CO = crude oil, DS = Spill-treating agent, FO = fuel oil, OR = oil sands related

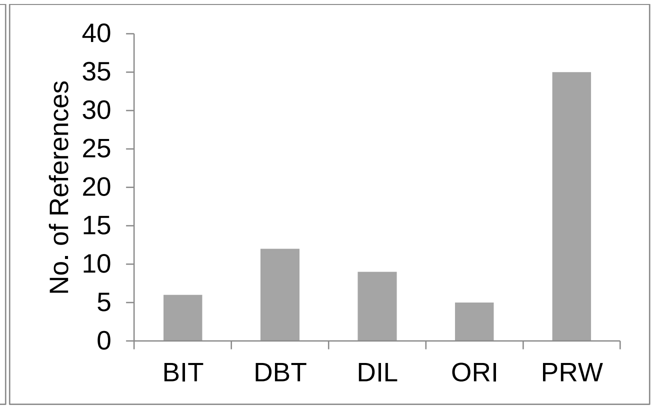

Figure 3. Type and number of references found in the "oil sands related" category (see Figure 1). BIT = bitumen, DBT = dilbit, synbit, or dilsynbit, DIL = diluent, ORI = Orimulsion, PRW = process water.

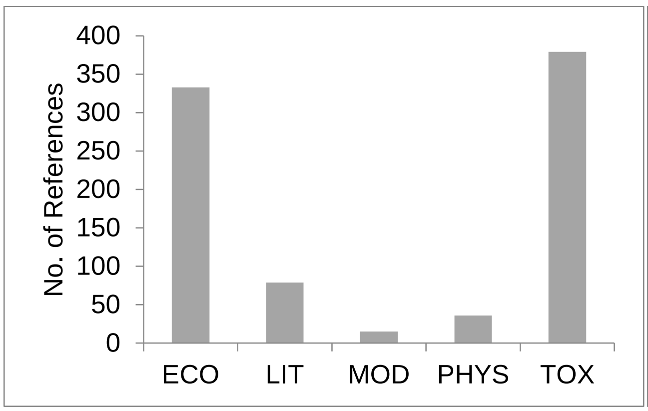

Figure 2. Number of references by study type. ECO = ecological, LIT = literature search, MOD = modelling, PHYS = physical, TOX = toxicological.

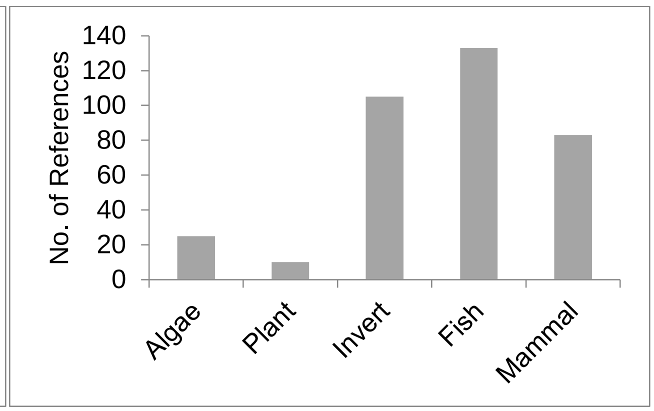

Figure 4. Number of ecological study references by taxonomic group.

11.0 APPENDIX 1
Oil Spill Bibliography Tabular Information

Appendix 1 includes reference information in tabular form. Species names and relevant product and spill information are presented. An index of abbreviations used for MainProduct, SpecificProduct, ComponentsAnalyzed, Event, Location, StudyType, and ExposureMedia fields is provided in Table 1. Abstracts and hyperlinks are included in Appendix 2 and cross referenced using the RefID number. Excel® and .csv versions which include information from Appendix 1 and 2 information can be found at the following URL:
http://open.canada.ca/data/en/dataset/34d8a906-2a6b-43ed-8e0e-9b15e3e50a32

RefID	Author(s)	Year	Title	Journal	Volume	Issue	Pages	Taxon	CommonName	Scientific Name	MainProduct	SpecificProduct	ComponentsAnalyzed	Event	Location	StudyType	ExposureMedia
1	Acosta-González, A., Martirani-von Abercron, S.-M., Rosselló-Móra, R., Wittich, R.-M., and Marqués, S.	2015	The effect of oil spills on the bacterial diversity and catabolic function in coastal sediments: a case study on the *Prestige* oil spill	Environmental Science and Pollution Research	22	20	15200-15214	MICROBIA	Bacteria (in sediment)		FO	HFO	ALH,PAH,WHL	PRES	SPN	ECO	SED,SW
2	Adams, J., Bornstein, J.M., Munno, K., Hollebone, B., King, T., Brown, R.S. and Hodson, P.V.	2014	Identification of compounds in heavy fuel oil that are chronically toxic to rainbow trout embryos by effects-driven chemical fractionation	Environmental Toxicology and Chemistry	33	4	825-835	FISH	Rainbow trout	*Oncorhynchus mykiss*	FO	HFO	PAH			TOX	FW
3	Adams, J., Sweezey, M. and Hodson, P.V.	2014	OIL AND OIL DISPERSANT DO NOT CAUSE SYNERGISTIC TOXICITY TO FISH EMBRYOS	Environmental Toxicology and Chemistry	33	1	107-114	FISH	Atlantic herring Rainbow trout	*Clupea harengus Oncorhynchus mykiss*	DS,FO	COR,HFO	CWF,WAF			TOX	FW
4	Adams, J.E.	2013	Identification of compounds in heavy fuel oil 7102 that are chronically toxic to rainbow trout (Oncorhynchus mykiss) embryos	Thesis, Queens University				FISH	Rainbow trout	*Oncorhynchus mykiss*	FO	HFO	PAH,WAF			TOX	FW
5	Adekunle, I.M., Ajijo, M.R., Adeofun, C.O. and Omoniyi, I.T.	2010	Response of Four Phytoplankton Species Found in Some Sectors of Nigerian Coastal Waters to Crude Oil in Controlled Ecosystem	International Journal of Environmental Research	4	1	65-74	ALGAE	Diatoms Dinoflagellates	*Coscnodiscus centralis Thalassionema frauenfeldii Odontella mobiliensis Ceratium trichoceros*	CO	NCO	WHL		AFR	TOX	SW
6	Adeyemo, O.K., Kroll, K.J., and Denslow, N.D.	2015	Developmental abnormalities and differential expression of genes induced in oil and dispersant exposed *Menidia beryllina* embryos	Aquatic Toxicology	168	2015	60-71	FISH	Inland silverside	*Menidia beryllina*	CO,DS	MAC,COR	BTX,CWF,PAH,WAF	DWH	GM	TOX	SW
7	Agamy, E.	2013	Sub chronic exposure to crude oil, dispersed oil and dispersant induces histopathological alterations in the gills of the juvenile rabbit fish (Siganus canaliculatus)	Ecotoxicology and Environmental Safety	92		180-190	FISH	Rabbit fish	*Siganus canaliculatus*	CO,DS	ARL,MAX	WAF	GWOS	ARG	TOX	SW
8	Agler, B.A., Seiser, P.E., Kendall, S.J. and Irons, D.B.	1994	Marine bird and sea otter population abundance of Prince William Sound, Alaska: trends following the T/V Exxon Valdez oil spill, 1989-93	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 93045		MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
9	Akbari, S., Law, A.T. and Shariff, M.	2004	Toxicity of water soluble fractions of crude oil to fish, Lutjanus argentimaculatus and shrimp, Penaeus monodon	Iranian Journal of Science and Technology	28	A1	169-175	CRUSTACEA FISH	Mangrove Red Snapper Black Tiger Shrimp	*Lutjanus argentimaculatus Penaeus monodon*	CO	MCO	WAF			TOX	SW
10	Ali, N.A., Ahmed, O.E. and Doheim, M.M.	2014	Evaluation of poly-aromatic hydrocarbons (PAHs) in the aquatic species of Suez Gulf water along El-Sokhna area to the Suez refineries	Environmental Monitoring and Assessment	186	2	1261-1269	CRUSTACEA FISH MOLLUSC	Brushtooth lizardfish Round sardinella Shrimp Common cuttlefish Pelagic crab Common squid Horse mackerel Keeled mullet Golden grey mullet Marbled spinefoot	*Saurida undosquamis Sardinella aurita Trachypenaeus curvirostris Sepia officinalis Portunus pelagicus Loligo sp Trachurus indicus Liza carinata Liza aurata Siganus rivulatus*	BG,CO	UKN	PAH		MES	ECO	SW
11	Almeda, R., Baca, S., Hyatt, C. and Buskey, E.J.	2014	Ingestion and sublethal effects of physically and chemically dispersed crude oil on marine planktonic copepods	Ecotoxicology	23	6	988-1003	CRUSTACEA	Copepods	*Acartia tonsa Temora turbinata Parvocalanus crassirostris*	CO,DS	LLS,COR	WHL			TOX	SW
12	Almeda, R., Bona, S., Foster, C.R. and Buskey, E.J.	2014	Dispersant Corexit 9500A and chemically dispersed crude oil decreases the growth rates of meroplanktonic barnacle nauplii (Amphibalanus improvisus) and tornaria larvae (Schizocardium sp.)	Marine Environmental Research	99		212-217	ANNELIDA CRUSTACEA	Barnacles Tornaria	*Amphibalanus improvisus Schizocardium sp*	CO,DS	LLS,COR	WHL	DWH	GM	TOX	SW
13	Almeda, R., Connelly, T.L. and Buskey, E.J.	2014	Novel insight into the role of heterotrophic dinoflagellates in the fate of crude oil in the sea	Scientific Reports	4	2014	7560	ZOOPLANKTON	Dinoflagellates	*Noctiluca scintillans and Gyrodinium spirale*	CO	LSC	WHL	DWH	GM	TOX	SW

RefID	Author(s)	Year	Title	Journal	Volume	Issue	Pages	Taxon	CommonName	Scientific Name	MainProduct	SpecificProduct	ComponentsAnalyzed	Event	Location	StudyType	ExposureMedia
14	Almeda, R., Hyatt, C. and Buskey, E.J.	2014	Toxicity of dispersant Corexit 9500A and crude oil to marine microzooplankton	Ecotoxicology and Environmental Safety	106		76-85	ZOOPLANKTON	Oligotrich ciliates Tintinnids Heterotrophic dinoflagellates	*Oligotrichia Choreotrichia Bacillariophyceae*	CO,DS	LLS,COR	WHL	DWH	GM	TOX	SW
15	Almeda, R., Wambaugh, Z., Chai, C., Wang, Z., Liu, Z. and Buskey, E.J.	2013	Effects of Crude Oil Exposure on Bioaccumulation of Polycyclic Aromatic Hydrocarbons and Survival of Adult and Larval Stages of Gelatinous Zooplankton	PloS One	8	10	e74476	ZOOPLANKTON	Moon jelly Purple striped jelly Warty comb jelly	*Aurelia aurita Chrysaora colorata Mnemiopsis leidyi*	CO,DS	LLS,COR	PAH	DWH	GM	TOX	SW
16	Almeda, R., Wambaugh, Z., Wang, Z., Hyatt, C., Liu, Z. and Buskey, E.J.	2013	Interactions between Zooplankton and Crude Oil: Toxic Effects and Bioaccumulation of Polycyclic Aromatic Hydrocarbons	PloS One	8	6	e67212	ZOOPLANKTON	Copepods Larvaceans Polychaete larvae Gastropod larvae Mysid larvae Cirripedia larvae	*Acartia tonsa Other copepoda Oikopleura dioica Mysidacea Polychaeta Gastropoda Cirripedia*	CO,DS	LLS,COR	PAH	DWH	GM	TOX	SW
17	Al-Yakoob, S., Saeed, T. and Al-Hashash, H.	1993	Polycyclic aromatic hydrocarbons in edible tissue of fish from the Gulf after the 1991 oil spill	Marine Pollution Bulletin	27		297-301	FISH	Groupers Sea bream Mackerel	*Epinephelus areolatus Lethrinus kallopterus Acanthopagrus spp Scomberomorus commerson*	CO	ARL	PAH	GWOS	ARG	ECO	SW
18	Ambrose, P.	1990	Bumper Salmon Catch After Oil Spill	Marine Pollution Bulletin	21	10	462-462	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW
19	Anderson, B.S., Arenella-Parkerson, D., Phillips, B.M., Tjeerdema, R.S. and Crane, D.	2009	Preliminary investigation of the effects of dispersed Prudhoe Bay Crude Oil on developing topsmelt embryos, Atherinops affinis	Environmental Pollution	157	3	1058-1061	FISH	Topsmelt	*Atherinops affinis*	CO,DS	ANS,COR	CWF,WAF			TOX	SW
20	Ansari, Z.A., Saldanha, M.C. and Rajkumar, R.	1997	Effects of petroleum hydrocarbons on the growth of a microalga, Isochrysis sp. (Chrysophyta)	Indian Journal of Marine Sciences	26		372-376	ALGAE	Microalgae	*Isochrysis sp.*	CO,FO	BHC,DSL	WHL		IND	TOX	SW
21	Antrim, L.D., Thom, R.M., Gardiner, W.W., Cullinan, V.I., Shreffler, D.K. and Bienert, R.W.	1995	Effects of petroleum products on bull kelp (Nereocystis luetkeana)	Marine Biology	122	1	23-31	ALGAE	Bull kelp	*Nereocystis luetkeana*	CO,FO	ANS,IFO,DSL	WHL			TOX	SW
22	Ara, K., Aoike, D., Hiromi, J. and Uchida, N.	2004	Acute toxicity of Bunker C refined oil to the Japanese littleneck clam Ruditapes philippinarum (Bivalvia : Veneridae)	Bulletin of Environmental Contamination and Toxicology	72	3	632-638	MOLLUSC	Japanese littleneck clam	*Ruditapes philippinarum (or Venerupis philippinarum)*	DS,FO	TTD,BUC	WHL		ASIA	TOX	SW
23	Arfsten, D.P., Schaeffer, D.J. and Mulveny, D.C.	1996	The effects of near ultraviolet radiation on the toxic effects of polycyclic aromatic hydrocarbons in animals and plants: A review	Ecotoxicology and Environmental Safety	33	1	1-24				BG	UKN	PAH,UVT			LIT	FW
24	Armstrong, D.A., Dinnel, P.A., Orensanz, J.M., Armstrong, J.L., McDonald, T.L., Cusimano, R.F., Nemeth, R.S., Landolt, M.L., Skalski, J.R., Lee, R.F. and Huggett, R.J.	1995	Status of selected bottomfish and crustacean species in Prince William Sound following the Exxon Valdez oil spill	Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters	1219		485-547	CRUSTACEA FISH MOLLUSC	Tanner crab Pandalid shrimps Flathead sole Scallop Clams	*Chionoecetes bairdi Pandalus spp Hippoglossoides elassodon Chlamys rubida Nuculana spp Yoldia spp Macoma spp*	CO	ANS	WHL	EVOS	AK	TOX	SW
25	Armstrong, S.A., Headley, J.V., Peru, K.M. and Germida, J.J.	2009	DIFFERENCES IN PHYTOTOXICITY AND DISSIPATION BETWEEN IONIZED AND NONIONIZED OIL SANDS NAPHTHENIC ACIDS IN WETLAND PLANTS	Environmental Toxicology and Chemistry	28	10	2167-2174	PLANT	Broadleaf cattail Common reed Hardstem bulrush Daphnia	*Typha latifolia Phragmites australis Scirpus acutus Daphnia magna*	OR	PRW	NAC			TOX	FW
26	Aunaas, T., Olsen, A. and Zachariassen, K.E.	1991	THE EFFECTS OF OIL AND OIL DISPERSANTS ON THE AMPHIPOD GAMMARUS-OCEANICUS FROM ARCTIC WATERS	Polar Research	10	2	619-630	CRUSTACEA	Copepods	*Gammarus oceanicus*	CO,DS	STA,OSR	WAF,WHL			TOX	SW

RefID	Author(s)	Year	Title	Journal	Volume	Issue	Pages	Taxon	CommonName	Scientific Name	MainProduct	SpecificProduct	ComponentsAnalyzed	Event	Location	StudyType	ExposureMedia
27	Babcock, M.M., Harris, .PM., Carls, M.G., Brodersen, C.C. and Rice, S.D.	1998	Mussel Bed Restoration and Monitoring, Exxon Valdez Oil Spill Restoration Final Project Report (Restoration Project 95090)	National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Auke Bay Laboratory, Juneau, Alaska			154 pp	MOLLUSC	Mussels	*Mytilus trossulus*	CO	ANS	WHL	EVOS	AK	ECO	SW
28	Babcock, M.M., Harris, P.M., Carls, M.G., Brodersen, C.C. and Rice, S.D.	1998	Mussel bed restoration and monitoring	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 95090	242 p	MOLLUSC	Mussels	*Mytilus trossulus*	CO	ANS	PAH,TPH	EVOS	AK	ECO	SW
29	Babcock, M.M., Irvine, G.V., Harris, .PM., Cusick, J.A. and Rice, S.D.	1996	Persistence of Oiling in Mussel Beds Three and Four Years after the Exxon Valdez Oil Spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		286-297	MOLLUSC	Mussels	*Mytilus trossulus*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
30	Bado-Nilles, A., Gagnaire, B., Thomas-Guyon, H., Le Floch, S. and Renault, T.	2008	Effects of 16 pure hydrocarbons and two oils on haemocyte and haemolymphatic parameters in the Pacific oyster, Crassostrea gigas (Thunberg)	Toxicology in Vitro	22	6	1610-1617	MOLLUSC	Pacific oyster	*Crassostrea gigas*	FO	HFO	PAH		EUR	TOX	SW
31	Bado-Nilles, A., Quentel, C., Mazurais, D., Zambonino-Infante, J.L., Auffret, M., Thomas-Guyon, H. and Le Floche, S.	2011	In vivo effects of the soluble fraction of light cycle oil on immune functions in the European sea bass, Dicentrarchus labrax (Linne)	Ecotoxicology and Environmental Safety	74	7	1896-1904	FISH	European sea bass	*Dicentrarchus labrax*	FO	LCO	PAH,WAF			TOX	SW
32	Bado-Nilles, A., Quentel, C., Thomas-Guyon, H. and Le Floch, S.	2009	Effects of two oils and 16 pure polycyclic aromatic hydrocarbons on plasmatic immune parameters in the European sea bass, Dicentrarchus labrax (Linne)	Toxicology in Vitro	23	2	235-241	FISH	European sea bass	*Dicentrarchus labrax*	FO	LFO	PAH		EUR	TOX	SW
33	Ball, A. and Truskewycz, A.	2013	Polyaromatic hydrocarbon exposure: an ecological impact ambiguity	Environmental Science and Pollution Research	20	7	4311-4326	MAMMAL	Humans and other organisms	*Homo sapiens*	BG,CO	UKN	PAH			LIT	FW,SW,TER
34	Ballachey, B.E.	1995	Biomarkers of damage to sea otters in Prince William Sound, Alaska following potential exposure to oil spilled from the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-1		MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
35	Ballachey, B.E. and Kloecker, K.A.	1997	Hydrocarbon residues in tissues of sea otters (Enhydra lutris) collected from Southeast Alaska	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-2	34 p	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	ALH,BTX,PAH	EVOS	AK	ECO	SW
36	Ballachey, B.E. and Kloecker, K.A.	1997	Hydrocarbons in hair, livers and intestines of sea otters (Enhydra lutris) found dead along the path of the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-3	54 p.	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	ALH,BTX,PAH	EVOS	AK	ECO	SW

RefID	Author(s)	Year	Title	Journal	Volume	Issue	Pages	Taxon	CommonName	Scientific Name	MainProduct	SpecificProduct	ComponentsAnalyzed	Event	Location	StudyType	ExposureMedia
37	Ballachey, B.E. and Kloecker, K.A.	1997	Hydrocarbon residues in tissues of sea otters (Enhydra lutris) collected following the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-16	59 p	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	ALH,BTX,PAH	EVOS	AK	ECO	SW
38	Ballachey, B.E., Bodkin, J.L. and Snyder, P.W.	2003	Lingering oil: bioavailability and effects of prey and predators	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 030585 Part II		MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	PAH	EVOS	AK	ECO	SW
39	Ballachey, B.E., Bodkin, .JL., Esler, D. and Rice, S.D.	2014	Lessons from the 1989 Exxon Valdez Oil Spill: A Biological Perspective	Impacts of Oil Spill Disasters on Marine Habitats and Fisheries in North America			181-198	BIRD FISH MAMMAL	Pink salmon Sea otter Harlequin duck	*Oncorhynchus gorbuscha Enhydra lutris Histrionicus histrionicus*	CO	ANS	WHL	EVOS	AK	LIT	SW
40	Ballachey, B.E., Bodkin, J.L. and Monson, D.H.	2013	Quantifying long-term risks to sea otters from the 1989 'Exxon Valdez' oil spill: Reply to Harwell & Gentile (2013)	Marine Ecology Progress Series	488		297-301	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	LIT	SW
41	Ballachey, B.E., Monson, D.H., Kloecker, K.S., Esslinger, G.G., Mohr, F.C., Lipscomb, T.P., Murray, M.J. and Howlin, S.	2014	Synthesis of Nearshore recovery following the 1989 Exxon Valdez oil spill: sea otter liver pathology and survival in Western Prince William Sound, 2001-2008	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 070808 and 070808A		MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
42	Barata, C., Calbet, A., Saiz, E., Ortiz, L. and Bayona, J.M.	2005	Predicting single and mixture toxicity of petrogenic polycyclic aromatic hydrocarbons to the copepod Oithona davisae	Environmental Toxicology and Chemistry	24	11	2992-2999	CRUSTACEA	Copepods	*Oithona davisae*	FO	HFO	PAH	PRES	SPN	TOX	SW
43	Barbee, G.C., Barich, J., Duncan, B., Bickham, J.W., Matson, C.W., Hintze, C.J., Autenrieth, R.L., Zhou, G.-D., McDonald, T.J., Cizmas, L., Norton, D. and Donnelly, K.C.	2008	In situ biomonitoring of PAH-contaminated sediments using juvenile coho salmon (Oncorhynchus kisutch)	Ecotoxicology and Environmental Safety	71	2	454-464	FISH	Coho salmon	*Oncorhynchus kisutch*	BG	UKN	PAH		USA NW	TOX	FW
44	Barber, W.E., McDonald, L.L., Erickson, W.P. and Vallarino, M.	1995	EFFECT OF THE EXXON-VALDEZ OIL-SPILL ON INTERTIDAL FISH - A FIELD-STUDY	Transactions of the American Fisheries Society	124	4	461-476	FISH	Cockscombs Pricklebacks Gunnels Sculpins Snailfish	*Anoplarchus purpurescens Ziphister spp Pholis laeta Oligocottus maculosus Liparis spp*	CO	ANS	WHL	EVOS	AK	ECO	SW
45	Barre, J.S., Bert, T.M. and Van Vleet, E.S.	1994	TOXICITY OF THE WATER-SOLUBLE FRACTION OF DIESEL FUEL TO POSTSETTLEMENT JUVENILE STONE CRABS (MENIPPE MERCENARIA)	Bulletin of Marine Science	55	1	240-246	CRUSTACEA	Stone crab	*Menippe mercenaria*	FO	DSL	WAF		USA SE	TOX	SW
46	Barron, M.G. and Holder, E.	2003	Are exposure and ecological risks of PAHs underestimated at petroleum contaminated sites?	Human and Ecological Risk Assessment	9	6	1533-1545	BIRD CRUSTACEA MAMMAL	Various benthic invertebrates Waterfowl Mink		CO	ANS	PAH	EVOS	AK	ECO	FW,SW
47	Barron, M.G., Carls, M.G., Short, J.W. and Rice, S.D.	2003	Photoenhanced toxicity of aqueous phase and chemically dispersed weathered Alaska North Slope crude oil to Pacific herring eggs and larvae	Environmental Toxicology and Chemistry	22	3	650-660	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	DS	ANS	PAH	EVOS	AK	TOX	SW
48	Barron, M.G., Carls, M.G., Short, J.W., Rice, S.D., Heintz, R.A., Rau, M. and Di Giulio, R.	2005	Assessment of the phototoxicity of weathered Alaska North Slope crude oil to juvenile pink salmon	Chemosphere	60	1	105-110	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	UVT,WHL	EVOS	AK	TOX	EST

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49	Barron, M.G., Podrabsky, T., Ogle, S. and Ricker, R.W.	1999	Are aromatic hydrocarbons the primary determinant of petroleum toxicity to aquatic organisms?	Aquatic Toxicology	46	3-4	253-268	CRUSTACEA	Mysid shrimp	*Mysidopsis bahia*	CO	CLF	PAH,WAF		CA	TOX	EST
50	Batterton, J.C., Winters, K. and Van Baalen, C.	1978	Sensitivity of three microalgae to crude oils and fuel oils	Marine Environmental Research	1	1	31-41	PHYTOPLANKTON	Blue green alga Green alga Diatom	*Agmenellum quadruplicatum Chlorella autotrophica Cylindrotheca sp.*	CO,FO	VAR	WAF,WHL			TOX	FW
51	Bechmann, R.K., Larsen, B.K., Taban, I.C., Hellgren, L.I., Moller, P. and Sanni, S.	2010	Chronic exposure of adults and embryos of Pandalus borealis to oil causes PAH accumulation, initiation of biomarker responses and an increase in larval mortality	Marine Pollution Bulletin	60	11	2087-2098	CRUSTACEA	Shrimp	*Pandalus borealis*	CO	NSC	PAH		EUR	TOX	SW
52	Beiras, R. and Saco-Alvarez, L.	2006	Toxicity of seawater and sand affected by the Prestige fuel-oil spill using bivalve and sea urchin embryogenesis bioassays	Water Air and Soil Pollution	177	42095	457-466	ECHINODERM MOLLUSC	Pacific oyster Clam Sea urchin	*Crassostrea gigas Venerupis sp Paracentrotus lividus*	FO	HFO	WAF,WHL	PRES	SPN	TOX	SW
53	Bejarano, A.C. and Barron, M.G.	2014	Development and Practical Application of Petroleum and Dispersant Interspecies Correlation Models for Aquatic Species	Environmental Science & Technology	48	8	4564-4572	CRUSTACEA FISH	Mysid shrimp Kelp forest mysid Inland silverside Topsmelt	*Americamysis bahia Holmesimysis costata Menidia beryllina Atherinops affinis*	CO,DS	VAR	VAR			MOD	FW,SW
54	Bejarano, A.C., Chandler, G.T., He, L., Cary, T.L. and Ferry, J.L.	2006	Risk assessment of the National Institute of Standards and Technology petroleum crude oil standard water accommodated fraction: Further application of a copepod-based, full life-cycle bioassay	Environmental Toxicology and Chemistry	25	7	1953-1960	CRUSTACEA	Copepods	*Amphiascus tenuiremis*	CO	LAB	UVT,WAF			TOX	SW
55	Bejarano, A.C., Levine, E. and Mearns, A.J.	2013	Effectiveness and potential ecological effects of offshore surface dispersant use during the Deepwater Horizon oil spill: a retrospective analysis of monitoring data	Environmental Monitoring and Assessment	185	12	10281-10295	PHYTOPLANKTON			CO,DS	MAC,COR	PAH,TPH	DWH	GM	ECO/TOX	SW
56	Bellas, J., Saco-Álvarez, L., Nieto, Ó., Bayona, J.M., Albaigés, J. and Beiras, R.	2013	Evaluation of artificially-weathered standard fuel oil toxicity by marine invertebrate embryogenesis bioassays	Chemosphere	90	3	1103-1108	ECHINODERM MOLLUSC	Purple Sea Urchin Mediterranean Mussel	*Paracentrotus lividus Mytilus galloprovincialis*	FO	IFO	UVT,WAF			TOX	SW
57	Belore, R.	2010	Technical Data Report-Properties and Fate of Hydrocarbons Associated with Hypothetical Spills in the Confined Channel Assessment Area	Enbridge Northern Gateway Project. SL Ross Environmental Research Ltd.	25		132 p				OR	DBT,DIL	VAR			MOD	SW
58	Ben-David, M., Blundell, G.M. and Blake, J.E.	2002	Post-release survival of river otters: Effects of exposure to crude oil and captivity	Journal of Wildlife Management	66	4	1208-1223	MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	ECO	SW
59	Ben-David, M., Bowyer, R.T. and Duffy, L.K.	1999	Responses of river otters to oil contamination: a controlled study of biological stress markers	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 99348		MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	TOX	SW
60	Ben-David, M., Duffy, L.K. and Bowyer, R.T.	2001	Biomarker responses in river otters experimentally exposed to oil contamination	Journal of Wildlife Diseases	37	3	489-508	MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	ECO	SW
61	Ben-David, M., Kondratyuk, T., Woodin, B.R., Snyder, P.W. and Stegeman, J.J.	2001	Induction of cytochrome P450 1A1 expression in captive river otters fed Prudhoe Bay crude oil: evaluation by immunohistochemistry and quantitative RT-PCR	Biomarkers	6	3	218-235	MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL		AK	TOX	SW
62	Bentivegna, C.S., Cooper, K.R., Olson, G., Pena, E.A., Milleman, D.R. and Portier, R.J.	2015	Chemical and histological comparisons between *Brevoortia* sp. (menhaden) collected in fall 2010 from Barataria Bay, LA and Delaware Bay, NJ following the DeepWater Horizon (DWH) oil spill	Marine Environmental Research	112	2015	21-34	FISH	Menhaden	*Brevoortia sp.*	CO	MAC	PAH	DWH	GM	ECO	SW
63	Bickham, J.W., Mazet, J.A., Blake, J., Smolen, M.J., Lou, Y.G. and Ballachey, B.E.	1998	Flow cytometric determination of genotoxic effects of exposure to petroleum in mink and sea otters	Ecotoxicology	7	4	191-199	MAMMAL	American mink Sea otter	*Neovison vison Enhydra lutris*	CO	ANS	WHL	EVOS	AK	TOX	ING

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64	Bidwell, J.R., Cherry, D.S. and Merski, A.T.	2003	Toxicity evaluation of a commercial bioremediation agent mixed with crude oil	Environmental Toxicology and Chemistry	22	1	84-91	FISH	Inland silverside minnow	*Menidia beryllina*	CO,DS	ANS,COR	PAH	EVOS	AK	TOX	FW
65	Bierkens, J. and Geerts, L.	2014	Environmental hazard and risk characterisation of petroleum substances: A guided "walking tour" of petroleum hydrocarbons	Environment International	66		182-193				CO,FO	VAR	VAR			LIT	VAR
66	Bilbao, E., Raingeard, D., de Cerio, O.D., Ortiz-Zarragoitia, M., Ruiz, P., Izagirre, U., Orbea, A., Marigomez, I., Cajaraville, M.P. and Cancio, I.	2010	Effects of exposure to Prestige-like heavy fuel oil and to perfluorooctane sulfonate on conventional biomarkers and target gene transcription in the thicklip grey mullet Chelon labrosus	Aquatic Toxicology	98	3	282-296	FISH	Thicklip grey mullet	*Chelon labrosus*	FO	HFO	PAH	PRES	SPN	TOX	SW
67	Binark, N., Güven, K.C., Gezgin, T. and Ünlü, S.	2000	Oil Pollution of Marine Algae	Bulletin of Environmental Contamination and Toxicology	64	6	866-872	ALGAE	Green algae Brown algae Red algae	*Ulva lactuca Enteromorpha linza Cystoseira barbata Ceramium rubrum Pterocladia capillacea etc*	BG,CO	VAR	VAR		EUR	ECO	SW
68	Birtwell, I.K. and McAllister, C.D.	2002	Hydrocarbons and their effects on aquatic organisms in relation to offshore oil and gas exploration and oil well blowout scenarios in British Columbia, 1985	Canadian Technical Report of Fisheries and Aquatic Sciences	2391		52 pp.	CRUSTACEA FISH MAMMAL MOLLUSC	Groundfish Herring Salmonids Zooplankton Crustaceans Bivalves Benthic communities Marine mammals	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO,FO	VAR	WHL		BC	LIT	SW
69	Birtwell, I.K., Fink, R., Brand, D., Alexander, R. and McAllister, C.D.	1999	Survival of pink salmon (Oncorhynchus gorbuscha) fry to adulthood following a 10-day exposure to the aromatic hydrocarbon water-soluble fraction of crude oil and release to the Pacific Ocean	Canadian Journal of Fisheries and Aquatic Sciences	56	11	2087-2098	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WAF		BC	ECO/TOX	SW
70	Blajeski, A., Duffy, .LK. and Bowyer, R.T.	1996	Differences in faecal profiles of porphyrins among river otters exposed to the Exxon Valdez oil spill	Biomarkers	1	4	262-266	MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	ECO	ING
71	Blum, D.J.W. and Speece, R.E.	1991	A DATABASE OF CHEMICAL TOXICITY TO ENVIRONMENTAL Bacteria AND ITS USE IN INTERSPECIES COMPARISONS AND CORRELATIONS	Research Journal of the Water Pollution Control Federation	63	3	198-207	FISH MICROBIA	Fathead minnow Bacteria	*Nitrosomonas sp. Photobacterium phosphoreum Pimephales promelas*	BG	VAR	VAR			TOX	FW
72	Bodkin, J.K., Mulcahy, D.M. and Lensink, C.J.	1996	Age-specific reproduction in female sea otters (Enhydra lutris) from Southcentral Alaska: analysis of reproductive tracts	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-4		MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
73	Bodkin, J.L. and Udevitz, M.S.	1995	An intersection model for estimating sea otter mortality from the Exxon Valdez oil spill along the Kenai Peninsula, Alaska	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-5		MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
74	Bodkin, J.L. and Weltz, F.	1990	EVALUATION OF SEA OTTER CAPTURE AFTER THE T-V EXXON VALDEZ OIL SPILL PRINCE WILLIAM SOUND ALASKA USA	U S Fish and Wildlife Service Biological Report	90	12	61-69	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW

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75	Bodkin, J.L., Ballachey, B.E. and Esslinger, G.G.	2011	Synthesis of nearshore recovery following the 1989 Exxon Valdez oil spill: trends in sea otter population abundance in Western Prince William Sound	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 070808, 070808A, 090808	23 p	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
76	Bodkin, J.L., Ballachey, B.E., Coletti, H.A., Esslinger, G.G., Kloecker, K.A., Rice, S.D., Reed, J.A. and Monson, D.H.	2012	Long-term effects of the 'Exxon Valdez' oil spill: sea otter foraging in the intertidal as a pathway of exposure to lingering oil	Marine Ecology Progress Series	447		273-287	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
77	Bodkin, J.L., Ballachey, B.E., Dean, T.A., Fukuyama, A.K., Jewett, S.C., McDonald, L., Monson, D.H., O'Clair, C.E. and VanBlaricom, G.R.	2002	Sea otter population status and the process of recovery from the 1989 'Exxon Valdez' oil spill	Marine Ecology Progress Series	241		237-253	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	LIT	SW
78	Boehm, P.D., Mankiewicz, P.J., Hartung, R., Neff, J.M., Page, D.S., Gilfillan, E.S., O'Reilly, J.E. and Parker, K.R.	1996	Characterization of mussel beds with residual oil and the risk to foraging wildlife 4 years after the Exxon Valdez oil spill	Environmental Toxicology and Chemistry	15	8	1289-1303	MOLLUSC	Foolish Mussel	*Mytilus trossulus*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
79	Boehm, P.D., Neff, J.M,. and Page, D.S.	2007	Assessment of polycyclic aromatic hydrocarbon exposure in the waters of Prince William Sound after the Exxon Valdez oil spill: 1989-2005	Marine Pollution Bulletin	54	3	339-356				CO	ANS	PAH	EVOS	AK	PHYS	SED,SW
80	Boehm, P.D., Neff, J.M. and Page, D.S.	2003	Exposure to hydrocarbons 10 years after the Exxon Valdez oil spill: evidence from cytochrome P4501A expression and biliary FACs in nearshore demersal fishes	Marine Environmental Research	55	5	459-461	FISH	Masked greenling Crescent gunnel	*Hexagrammos octogrammus Pholis laeta*	CO	ANS	WHL	EVOS	AK	ECO/TOX	SW
81	Boehm, P.D., Page, D.S., Brown, J.S., Neff, J.M. and Burns, W.A.	2004	Polycyclic aromatic hydrocarbon levels in mussels from Prince William Sound, Alaska, USA, document the return to baseline conditions	Environmental Toxicology and Chemistry	23	12	2916-2929	MOLLUSC	Foolish Mussel	*Mytilus trossulus*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
82	Boehm, P.D., Page, D.S., Brown, J.S., Neff, J.M., Bragg, J.R. and Atlas, R.M.	2008	Distribution and Weathering of Crude Oil Residues on Shorelines 18 Years After the Exxon Valdez Spill	Environmental Science & Technology	42	24	9210-9216				CO	ANS	PAH,WHL	EVOS	AK	ECO/PHYS	SED,SW
83	Boehm, P.D., Page, D.S., Gilfillan, E.S., Bence, A.E., Burns, W.A. and Mankiewicz, P.J.	1998	Study of the fates and effects of the Exxon Valdez oil spill on benthic sediments in two bays in Prince William Sound, Alaska. 1. Study design, chemistry, and source fingerprinting	Environmental Science & Technology	32	5	567-576				CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
84	Boehm, P.D., Page, D.S., Gilfillan, E.S., Stubblefield, W.A. and Harner, E.J.	1995	Shoreline Ecology Program for Prince William Sound, Alaska, Following the Exxon Valdez Oil Spill: Part II - Chemistry and Toxicology	Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters	1219		347-397	CRUSTACEA MOLLUSC	Mussels	*Mytilus sp.*	CO	ANS	PAH,WHL	EVOS	AK	ECO/TOX	SW
85	Boehm, P.D., Page, D.S., Neff, J.M. and Brown, J.S.	2011	Are sea otters being exposed to subsurface intertidal oil residues from the Exxon Valdez oil spill?	Marine Pollution Bulletin	62	3	581-589	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
86	Boehm, P.D., Page, D.S., Neff, J.M. and Johnson, C.B.	2007	Potential for sea otter exposure to remnants of buried oil from the exxon valdez oil spill	Environmental Science & Technology	41	19	6860-6867	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
87	Bookstaver, M., Bose, A. and Tripathi, A.	2015	Interaction of *Alcanivorax borkumensis* with a Surfactant Decorated Oil–Water Interface	Langmuir	31	21	5875-5881	MICROBIA	Hydrocarbon-degrading bacterium	*Alcanivorax borkumensis*	DS	VAR	WHL	DWH	GM	TOX	SW
88	Booth, A.M., Sutton, P.A., Lewis, C.A., Lewis, A.C., Scarlett, A., Chau, W., Widdows, J. and	2007	Unresolved complex mixtures of aromatic hydrocarbons: Thousands of overlooked persistent, bioaccumulative, and toxic contaminants in mussels	Environmental Science & Technology	41	2	457-464	MOLLUSC	Mussels	*Mytilus edulis*	BG	VAR	VAR		EUR	ECO/TOX	SW

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	Rowland, S.J.																
89	Bordbar, L., Emtyazjoo, M. and Farkhani, D.	2008	Comparison and influence of two newly produced Iranian oil dispersants (Pars1 Pars2) with the Gamlen OD4000 on rainbow trout	Journal of Environmental Science and Health	43	14	1598-1601	FISH	Rainbow trout	*Oncorhynchus mykiss*	DS	PAR	WHL			TOX	FW
90	Bornstein, J.M., Adams, J., Hollebone, B., King, T., Hodson, P.V. and Brown, R.S.	2014	Effects-driven chemical fractionation of heavy fuel oil to isolate compounds toxic to trout embryos	Environmental Toxicology and Chemistry	33	4	814-824	FISH	Rainbow trout	*Oncorhynchus mykiss*	FO	HFO	ALH,PAH		CAN	TOX	FW
91	Boudreau, M., Sweezey, M.J., Lee, K., Hodson, P.V. and Courtenay, S.C.	2009	TOXICITY OF ORIMULSION-400 (R) TO EARLY LIFE STAGES OF ATLANTIC HERRING (CLUPEA HARENGUS) AND MUMMICHOG (FUNDULUS HETEROCLITUS)	Environmental Toxicology and Chemistry	28	6	1206-1217	FISH	Atlantic Herring Mummichog	*Clupea harengus Fundulus heteroclitus*	FO,OR	HFO,ORI	PAH,WAF			TOX	SW
92	Bowman, D.T., Slater, G.F., Warren, L.A. and McCarry, B.E.	2014	Identification of individual thiophene-, indane-, tetralin-, cyclohexane-, and adamantane-type carboxylic acids in composite tailings pore water from Alberta oil sands	Rapid Communications in Mass Spectrometry	28	19	2075-2083				OR	PRW	NAC		AOS	PHYS	FW
93	Bowyer, R.T., Blundell, G.M., Ben-David, M., Jewett, S.C., Dean, T.A. and Duffy, L.K.	2003	Effects of the Exxon Valdez Oil Spill on River Otters: Injury and Recovery of a Sentinel Species	Wildlife Monographs		153	1-53	MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	ECO	SW
94	Bowyer, R.T., Testa, J.W. and Faro, J.B.	1995	HABITAT SELECTION AND HOME RANGES OF RIVER OTTERS IN A MARINE-ENVIRONMENT - EFFECTS OF THE EXXON-VALDEZ OIL-SPILL	Journal of Mammalogy	76	1	1-11	MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	ECO	SW
95	Bowyer, R.T., Testa, J.W., Faro, J.B., Schwartz, C.C,. and Browning, J.B.	1994	CHANGES IN DIETS OF RIVER OTTERS IN PRINCE WILLIAM SOUND, ALASKA - EFFECTS OF THE EXXON-VALDEZ OIL-SPILL	Canadian Journal of Zoology	72	6	970-976	MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	ECO	SW
96	Braddock, J.F. and Richter, Z.	1995	Microbiology of subtidal sediments: monitoring microbial populations	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 93047-2		MICROBIA	Various hydrocarbon-degrading microorganisms		CO	ANS	ALH,BTX,PAH	EVOS	AK	ECO	SED,SW
97	Braddock, J.F., Lindstrom, J.E., Yeager, T.R., Rasley, B.T. and Brown, E.J.	1996	Patterns of Microbial Activity in Oiled and Unoiled Sediments in Prince William Sound	Proceedings of the Exxon Valdez Oil Spill Symposium	18		94-108	MICROBIA	Various	Various	CO	ANS	WHL	EVOS	AK	ECO	SW
98	Braddock, J.F., Rasley, B.T., Yeager, T.R., Lindstrom, J.E. and Brown, E.J.	1992	Hydrocarbon mineralization potentials and microbial populations in marine sediments following the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Subtidal Study Number 1B		MICROBIA	Various hydrocarbon-degrading microorganisms		CO	ANS	ALH,PAH	EVOS	AK	ECO	SW
99	Brakstad, O.G., Throne-Holst, M., Netzer, R., Stoeckel, D.M. and Atlas, R.M.	2015	Microbial communities related to biodegradation of dispersed Macondo oil at low seawater temperature with Norwegian coastal seawater	Microbial Biotechnology	8	Thematic Issue: Fungal Biotechnology	989-998	MICROBIA	Oil-degrading bacterial community	Various	CO	MAC	WHL	DWH	NOR	TOX	SW
100	Brand, D.G., Fink, R., Bengeyfield, W., Birtwell, I.K. and McAllister, C.D.	2001	Salt water-acclimated pink salmon fry (Oncorhynchus gorbuscha) develop stress-related visceral lesions after 10-day exposure to sublethal concentrations of the water-soluble fraction of north slope crude oil	Toxicologic Pathology	29	5	574-584	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WAF	EVOS	AK	TOX	SW
101	Brannon, E.L. and Maki, A.W.	1996	The Exxon Valdez oil spill: Analysis of impacts on the Prince William Sound pink salmon	Reviews in Fisheries Science	4	4	289-337	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW

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102	Brannon, E.L., Collins, K., Cronin, M.A., Moulton, L.L., Maki, A.L. and Parker, K.R.	2012	Review of the Exxon Valdez Oil Spill Effects on Pink Salmon in Prince William Sound, Alaska	Reviews in Fisheries Science	20	1	20-60	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	EST
103	Brannon, E.L., Collins, K., Moulton, L., Parker, K.R.	2001	Review of studies on oil damage to Prince William Sound pink salmon	International Oil Spill Conference Proceedings	2001	1	569-575	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW
104	Brannon, E.L., Collins, K.C.M., Moulton, L.L. and Parker, K.R.	2001	Resolving allegations of oil damage to incubating pink salmon eggs in Prince William Sound	Canadian Journal of Fisheries and Aquatic Sciences	58	6	1070-1076	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	EST
105	Brannon, E.L., Collins, K.M., Brown, J.S., Neff, J.M., Parker, K.R. and Stubblefield, W.A.	2006	Toxicity of weathered Exxon Valdez crude oil to pink salmon embryos	Environmental Toxicology and Chemistry	25	4	962-972	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	TOX	FW
106	Brannon, E.L., Collins, K.M., Brown, J.S., Neff, J.M., Parker, K.R. and Stubblefield, W.A.	2008	Authors' reply to "Comment on "toxicity of weathered exxon valdez crude oil to pink salmon embryos""	Environmental Toxicology and Chemistry	27	7	1476-1478	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	TOX	FW
107	Brannon, E.L., Collins, K.M., Cronin, M.A., Moulton, L.L., Parker, K.R. and Wilson, W.	2007	Risk of weathered residual Exxon Valdez oil to pink salmon embryos in Prince William Sound	Environmental Toxicology and Chemistry	26	4	780-786	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	ECO	EST
108	Brannon, E.L., Cronin, M.A., Maki, A.W., Moulton, L.L. and Parker, K.R.	2013	Oiling Effects on Pink Salmon	Oil in the Environment: Legacies and Lessons of the Exxon Valdez Spill			263-291	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	LIT	SW
109	Brannon, E.L., Maki, A.W., Moulton, L.L. and Parker, K.R.	2006	Results from a sixteen year study on the effects of oiling from the Exxon Valdez on adult pink salmon returns	Marine Pollution Bulletin	52	8	892-899	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW
110	Brannon, E.L., Moulton, L.L., Gilbertson, L.G., Maki, A.W., snd Skalski, J.R.	1995	An assessment of oil-spill effects on pink salmon populations following the Exxon Valdez oil spill - Part 1: Early Life History	Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters	1219		548	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	ECO/TOX	FW,SED,SW
111	Brannon, E.L., Quinn, T.P., Whitman, R.P., Nevissi, A.E., Nakatani, R.E. and McAuliffe, C.D.	1986	HOMING OF ADULT CHINOOK SALMON AFTER BRIEF EXPOSURE TO WHOLE AND DISPERSED CRUDE-OIL	Transactions of the American Fisheries Society	115	6	823-827	FISH	Chinook salmon	*Oncorhynchus tshawytscha*	CO,DS	ANS,VAR	WHL		WA	ECO/TOX	FW
112	Brennan, K.	1998	Hydrocarbon injury assessment - Kodiak and Alaska Peninsula herring, Exxon Valdez Oil Spill State/Federal Natural Resource Damage Assessment Annual Report (Fish/Shellfish Study Number 12)	EVOS Trustee Council	Fish/Shellfish Study	FS12	87 pp.	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	ECO	SW
113	Brody, A.J., Ralls, K. and Siniff, D.B.	1996	Potential impact of oil spills on California sea otters: Implications of the Exxon Valdez spill in Alaska	Marine Mammal Science	12	1	38-53	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	MOD	SW
114	Brown, D.W., Burrows, D.G., Sloan, C.A., Pearce, R.W., Pierce, S.M., Bolton, J.L., Tilbury, K., Dana, K.L., Chan, S.L. and Varanasi, U.	1996	Survey of Alaskan subsistence invertebrate seafoods collected in 1989-1991 to determine exposure to oil spilled from the Exxon Valdez	Proceedings of the Exxon Valdez Oil Spill Symposium	18		844-855	MOLLUSC	Blue Mussel Butter Clam Pacific Littleneck Clam	*Mytilus sp. Saxidomus gigantea Protothaca staminea Chiton*	CO	ANS	PAH	EVOS	AK	ECO	SW

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115	Brown, E.D. and Baker, T.T.	1998	Injury to Prince William Sound herring following the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Fish/Shellfish Study Number 11	139 p.	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
116	Brown, E.D., Baker, T.T., Hose, J.E., Kocan, R.M., Marty, G.D., McGurk, M.D., Norcross, B.L. and Short, J.	1996	Injury to the Early Life History Stages of Pacific Herring in Prince William Sound after the Exxon Valdez Oil Spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		448-462	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	ECO	SW
117	Brown, E.D., Norcross, B.L. and Short, J.W.	1996	An introduction to studies on the effects of the Exxon Valdez oil spill on early life history stages of Pacific herring, Clupea pallasi, in Prince William Sound, Alaska	Canadian Journal of Fisheries and Aquatic Sciences	53	10	2337-2342	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	LIT	SW
118	Bue, B.G., Sharr, S. and Seeb, J.E.	1998	Evidence of Damage to Pink Salmon Populations Inhabiting Prince William Sound, Alaska, Two Generations after the Exxon Valdez Oil Spill	Transactions of the American Fisheries Society	127	1	35-43	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO/TOX	FW
119	Bue, B.G., Sharr, S., Moffitt, S.D. and Craig, A.K.	1996	Effects of the Exxon Valdez Oil Spill on Pink Salmon Embryos and Preemergent Fry	Proceedings of the Exxon Valdez Oil Spill Symposium	18		619-627	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	FW,SW
120	Burridge, T.R. and Shir, M.A.	1995	The comparative effects of oil dispersants and oil/dispersant conjugates on germination of the marine macroalga Phyllospora comosa (Fucales: Phaeophyta)	Marine Pollution Bulletin	31	42342	446-452	ALGAE	Crayweed	*Phyllospora comosa (Brown algae)*	CO,DS,FO	BSC,DSL,VAR	WAF,WHL			TOX	SW
121	Calbet, A., Saiz, E. and Barata, C.	2007	Lethal and sublethal effects of naphthalene and 1,2-dimethylnaphthalene on the marine copepod Paracartia grani	Marine Biology	151	1	195-204	CRUSTACEA	Copepods	*Paracartia (Acartia) grani*	FO	HFO	PAH,WAF			TOX	SW
122	Cameron, J.A. and Smith, R.L.	1980	ULTRASTRUCTURAL EFFECTS OF CRUDE-OIL ON EARLY LIFE STAGES OF PACIFIC HERRING	Transactions of the American Fisheries Society	109	2	224-228	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	TOX	SW
123	Cancio, I., Orbea, A., Volkl, A., Fahimi, H.D. and Cajaraville, M.P.	1998	Induction of peroxisomal oxidases in mussels: Comparison of effects of lubricant oil and benzo(a)pyrene with two typical peroxisome proliferators on peroxisome structure and function in Mytilus galloprovincialis	Toxicology and Applied Pharmacology	149	1	64-72	MOLLUSC	Mediterranean Mussel	*Mytilus galloprovincialis*	FO	LUB	PAH,WAF			TOX	SW
124	Carls, M.G.	2006	Nonparametric identification of petrogenic and pyrogenic hydrocarbons in aquatic ecosystems	Environmental Science & Technology	40	13	4233-4239	FISH	Fish Mussels	*Mytilus spp*	CO	ANS	PAH,WHL	EVOS	AK	MOD	SW
125	Carls, M.G. and Harris, P.M.	2004	Monitoring of oiled mussel beds in Prince William Sound and the Gulf of Alaska	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 00090	145 p	MOLLUSC	Mussels	*Mytilus sp.*	CO	ANS	WHL	EVOS	AK	ECO	SED,SW
126	Carls, M.G. and Meador, J.P.	2009	A Perspective on the Toxicity of Petrogenic PAHs to Developing Fish Embryos Related to Environmental Chemistry	Human and Ecological Risk Assessment	15	6	1084-1098	FISH	Pink salmon Pacific herring Zebrafish	*Oncorhynchus gorbuscha Clupea pallasii Danio rerio*	CO	ANS	PAH,WHL	EVOS	AK	LIT	SW
127	Carls, M.G. and Thedinga, J.F.	2010	Exposure of pink salmon embryos to dissolved polynuclear aromatic hydrocarbons delays development, prolonging vulnerability to mechanical damage	Marine Environmental Research	69	5	318-325	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	TOX	EST,FW
128	Carls, M.G., Babcock, M.M., Harris, P.M., Irvine, G.V., Cusick, J.A. and Rice, S.D.	2001	Persistence of oiling in mussel beds after the Exxon Valdez oil spill	Marine Environmental Research	51	2	167-190	MOLLUSC	Mussels	*Mytilus sp.*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW

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129	Carls, M.G., Harris, P.M. and Rice, S.D.	2004	Restoration of oiled mussel beds in Prince William Sound, Alaska	Marine Environmental Research	57	5	359-376	MOLLUSC	Foolish Mussel	*Mytilus trossulus*	CO	ANS	WHL	EVOS	AK	ECO	SW
130	Carls, M.G., Heintz, R.A. and Rice, S.D.	2003	Have wild pink salmon and their habitat recovered from persistent Exxon Valdez oil contamination?	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 00454		FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH	EVOS	AK	ECO	EST,SW
131	Carls, M.G., Holland, L., Larsen, M., Collier, T.K., Scholz, N.L. and Incardona, J.P.	2008	Fish embryos are damaged by dissolved PAHs, not oil particles	Aquatic Toxicology	88	2	121-127	FISH	Zebrafish	*Danio rerio*	CO	ANS	PAH,WHL	EVOS	AK	TOX	FW
132	Carls, M.G., Holland, L., Larsen, M., Lum, J.L., Mortensen, D.G., Wang, S.Y. and Wertheimer, A.C.	1996	Growth, Feeding, and Survival of Pink Salmon Fry Exposed to Food Contaminated with Crude Oil	Proceedings of the Exxon Valdez Oil Spill Symposium	18		608-618	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW
133	Carls, M.G., Hose, J.E., Thomas, R.E. and Rice, S.D.	2000	Exposure of Pacific herring to weathered crude oil: Assessing effects on ova	Environmental Toxicology and Chemistry	19	6	1649-1659	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,WHL	EVOS	AK	TOX	SW
134	Carls, M.G., Johnson, S.W., Thomas, R.E. and Rice, S.D.	1997	Health and reproductive implication of exposure of Pacific herring (Clupea pallasi) adults and eggs to weathered crude oil, and reproductive condition of herring stock in Prince William Sound six years after the Exxon Valdez oil spill	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 95074		FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,WHL	EVOS	AK	TOX	SW
135	Carls, M.G., Larsen, M.L. and Holland, L.G.	2015	Spilled Oils: Static Mixtures or Dynamic Weathering and Bioavailability?	PLoS ONE	10	9	e0134448	MOLLUSC	Mussels	*Mytilus trossulus*	FO	IFO	ALH,PAH	SEL	AK	ECO	SW
136	Carls, M.G., Marty, G.D. and Hose, J.E.	2001	Synthesis of the toxicological and epidemiological impacts of the Exxon Valdez oil spill on Pacific herring in Prince William Sound, Alaska	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 99328		FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,WHL	EVOS	AK	LIT	SW
137	Carls, M.G., Marty, G.D. and Hose, J.E.	2002	Synthesis of the toxicological impacts of the Exxon Valdez oil spill on Pacific herring (Clupea pallasi) in Prince William Sound, Alaska, USA	Canadian Journal of Fisheries and Aquatic Sciences	59	1	153-172	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH	EVOS	AK	ECO/TOX	SW
138	Carls, M.G., Marty, G.D., Meyers, T.R., Thomas, R.E. and Rice, S.D.	1998	Expression of viral hemorrhagic septicemia virus in prespawning Pacific herring (Clupea pallasi) exposed to weathered crude oil	Canadian Journal of Fisheries and Aquatic Sciences	55	10	2300-2309	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,WHL	EVOS	AK	TOX	SW
139	Carls, M.G., Rice, S.D. and Hose, J.E.	1999	Sensitivity of fish embryos to weathered crude oil: Part I. Low-level exposure during incubation causes malformations, genetic damage, and mortality in larval Pacific herring (Clupea pallasi)	Environmental Toxicology and Chemistry	18	3	481-493	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,WHL	EVOS	AK	TOX	SW
140	Carls, M.G., Rice, S.D. and Thomas, R.E.	1995	The impact of exposure of adult pre-spawn herring (Clupea harangues pallasi) on subsequent progeny, Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project 94166)	EVOS Trustee Council	Restoration Project	94166	130 pp.	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	ECO	SW
141	Carls, M.G., Rice, S.D., Marty, G.D. and Naydan, D.K.	2004	Pink salmon spawning habitat is recovering a decade after the Exxon Valdez oil spill	Transactions of the American Fisheries Society	133	4	834-844	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	ECO	EST
142	Carls, M.G., Thomas, R.E., Lilly, M.R. and Rice, S.D.	2003	Mechanism for transport of oil-contaminated groundwater into pink salmon redds	Marine Ecology Progress Series	248		245-255	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO/PHYS	EST,SED,SW
143	Carls, M.G., Wertheimer, A.C., Short, J.W., Smolowitz, R.M. and Stegeman, J.J.	1996	Contamination of juvenile pink and chum salmon by hydrocarbons in Prince William Sound after the Exxon Valdez oils spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		593-607	FISH	Pink salmon Chum salmon	*Oncorhynchus gorbuscha Oncorhynchus keta*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
144	Carrera-Martinez, D., Mateos-Sanz, A., Lopez-Rodas, V. and Costas, E.	2011	Adaptation of microalgae to a gradient of continuous petroleum contamination	Aquatic Toxicology	101	2	342-350	ALGAE	*Microalgae*	*Scenedesmus sp.*	CO	AMR,LAB	TPH		SAM	ECO/TOX	FW

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145	Caudle, K.L. and Maricle, B.R.	2014	Physiological relationship between oil tolerance and flooding tolerance in marsh plants	Environmental and Experimental Botany	107		7-14	PLANT	*Marsh grass*	*Phragmites australis Phalaris arundinacea Ammophila breviligulata Spartina alterniflora Spartina patens Panicum virgatume partina pectinata Schizachyrium littorale*	FO	LFO	WHL		USA SE	ECO	EST
146	Celewycz, A.G. and Wertheimer, A.C.	1996	Prey Availability to Juvenile Salmon after the Exxon Valdez Oil Spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		564-577	ZOOPLANKTON	epibenthos and zooplankton	*epibenthos and zooplankton*	CO	ANS	WHL	EVOS	AK	ECO	SW
147	Chakraborty, R., Borglin, S.E., Dubinsky, E.A., Andersen, G.L. and Hazen, T.C.	2012	Microbial response to the MC-252 oil and Corexit 9500 in the Gulf of Mexico	Frontiers in Microbiology	3	357	1-6	MICROBIA	Various	Various	CO,DS	LSC,COR	WHL	DWH	GM	ECO	SW
148	Chao, M., Shen, X., Lun, F., Shen, A. and Yuan, Q.	2012	Toxicity of Fuel Oil Water Accommodated Fractions on Two Marine Microalgae, Skeletonema costatum and Chlorela spp	Bulletin of Environmental Contamination and Toxicology	88	5	712-716	ALGAE	*Phytoplankton*	*Skeletonema costatum Chlorela spp*	FO	LFO,HFO	WAF		ASIA	TOX	SW
149	Chase, D.A. Edwards, D.S., Qin, G., Wages, M.R., Willming, M.M., Anderson, T.A. and Maul, J.D.	2013	Bioaccumulation of petroleum hydrocarbons in fiddler crabs (Uca minax) exposed to weathered MC-252 crude oil alone and in mixture with an oil dispersant	Science of the Total Environment	444		121-127	CRUSTACEA	Fiddler crab	*Uca minax*	CO,DS	LSC,COR	TPH,WAF	DWH	GM	TOX	SW
150	Cheney, M.A., Liu, J., Amei, A., Zhao, X., Joo, S.W. and Qian, S.	2009	A comparative study on the uptake of polycyclic aromatic hydrocarbons by Anodonta californiensis	Environmental Pollution	157	2	601-608	MOLLUSC	Freshwater mussel	*Anodonta californiensis*	DS	TWE	PAH		CA	TOX	FW
151	Claireaux, G., Desaunay, Y., Akcha, F., Auperin, B., Bocquene, G., Budzinski, F.N., Cravedi, J.P., Davoodi, F., Galois, R., Gilliers, C., Goanvec, C., Guerault, D., Imbert, N., Mazeas, O., Nonnotte, G., Nonnotte, L., Prunet, P., Sebert, P. and Vettier, A.	2004	Influence of oil exposure on the physiology and ecology of the common sole Solea solea: Experimental and field approaches	Aquatic Living Resources	17	3	335-351	FISH	Dover sole	*Solea solea*	CO	LFO	PAH	ERK	FRA	ECO/TOX	SW
152	Clark Jr, R.C., Patten, B.G. and DeNike, E.E.	1978	Observations of a Cold-Water Intertidal Community After 5 Years of a Low-Level, Persistent Oil Spill from the General M.C. Meigs	Journal of the Fisheries Research Board of Canada	35	5	754-765	ALGAE CNIDARIA CRUSTACEA MOLLUSC	Barnacles mussels sea anemones Various algae	*Balanus spp. Mytilus spp. Anthopleura spp. Hemigrapsus nudus Strongylocentrotus purpuratus Mitella polymerus Fucus gardneri Bossiella spp. Laminaria andersonii*	FO	HFO	WHL	MEG	WA	ECO	SW
153	Colavecchia, M.V., Backus, S.M., Hodson, P.V. and Parrott, J.L.	2004	Toxicity of oil sands to early life stages of fathead minnows (Pimephales promelas)	Environmental Toxicology and Chemistry	23	7	1709-1718	FISH	Fathead minnow	*Pimephales promelas*	OR	PRW	PAH		AOS	TOX	FW
154	Colavecchia, M.V., Hodson, P.V. and Parrott, J.L.	2007	The relationships among CYP1A induction, toxicity, and eye pathology in early life stages of fish exposed to oil sands	Journal of Toxicology and Environmental Health	70	18	1542-1555	FISH	Fathead minnow White sucker	*Pimephales promelas Catostomus commersoni*	OR	BIT	NAC,PAH		AOS	ECO/TOX	FW
155	Colavecchia, M.V., Hodson, P.V. and Parrott, J.L.	2006	CYP1A induction and blue sac disease in early life stages of white suckers (Catostomus commersoni) exposed to oil sands	Journal of Toxicology and Environmental Health	69	10	967-994	FISH	White sucker	*Catostomus commersoni*	OR	BIT	WHL		AOS	TOX	FW

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156	Collier, T.K., Anulacion, B.F., Arkoosh, M.R., Dietrich, J.P., Incardona, J.P., Johnson, L.L., Ylitalo, G.M. and Myers, M.S.	2014	Effects on Fish of Polycyclic Aromatic Hydrocarbons (PAHS) and Naphthenic Acid Exposures	Fish Physiology	33	Organic Chemical Toxicology of Fishes	195-255	FISH	Mummichog Winter flounder Brown bullhead catfish European flounder English sole	*Fundulus heteroclitus Pleuronectes americanus Ameirus nebulosus Platichthys flesus Parophrys vetulus*	OR	LAB,PRW	NAC,PAH			LIT	EST,FW,SW
157	Collier, T.K., Krone, C.A., Krahn, M.M., Stein, J.E., Chan, S.L. and Varanasi, U.	1996	Petroleum exposure and associated biochemical effects in subtidal fish after the Exxon Valdez oil spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		671-683	FISH	Dolly varden Yellowfin sole Walleye pollock Rock sole Flathead sole	*Salvelinus malma Limanda aspera Theragra chalcogramma Lepidopsetta bilineata Hippoglossoides elassodon*	CO	ANS	PAH	EVOS	AK	ECO	SW
158	Costa, D.P. and Kooyman, G.L.	1982	Oxygen consumption, thermoregulation, and the effect of fur oiling and washing on the sea otter, Enhydra lutris.	Canadian Journal of Zoology	60		2761-2767	MAMMAL	Sea Otter		CO	ANS	WHL		CA	TOX	SW
159	Couillard, C.M.	2002	A microscale test to measure petroleum oil toxicity to mummichog embryos	Environmental Toxicology	17	3	195-202	FISH	Mummichog	*Fundulus heteroclitus*	CO	ANS,MLC	WHL			TOX	SW
160	Couillard, C.M., Lee, K., Légaré, B. and King, T.L.	2005	Effect of dispersant on the composition of the water-accommodated fraction of crude oil and its toxicity to larval marine fish	Environmental Toxicology and Chemistry	24	6	1496-1504	FISH	Mummichog	*Fundulus heteroclitus*	CO,DS	MLC,COR	CWF,WAF			TOX	SW
161	Craig, A.K., Willette, T.M., Evans, D.G. and Bue, B.G.	2002	Injury to pink salmon embryos in Prince William Sound - field monitoring	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 98191A-1	105 p	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	EST
162	Cretney, W.J., Wong, C.S., Green, D.R. and Bawden, C.A.	1978	Long-Term Fate of a Heavy Fuel Oil in a Spill-Contaminated B.C. Coastal Bay	Journal of the Fisheries Research Board of Canada	35	5	521-527	ALGAE CRUSTACEA MOLLUSC PLANT	Marsh grasses Fucus amphipods molluscs etc	*Marsh grasses Fucus amphipods molluscs etc*	FO	HFO	WHL	IST	BC	ECO	SW
163	Croce, B. and Stagg, R.M.	1997	Exposure of Atlantic salmon parr (Salmo salar) to a combination of resin acids and a water soluble fraction of diesel fuel oil: A model to investigate the chemical causes of Pigmented Salmon Syndrome	Environmental Toxicology and Chemistry	16	9	1921-1929	FISH	Atlantic salmon	*Salmo salar*	FO	DSL	WAF			TOX	FW
164	Cronin, M.A. and Bickham, J.W.	1998	A population genetic analysis of the potential for a crude oil spill to induce heritable mutations and impact natural populations	Ecotoxicology	7	5	259-278	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	ECO	EST
165	Cronin, M.A. and Maki, A.W.	2004	Assessment of the genetic toxicological impacts of the Exxon Valdez oil spill on pink salmon (Oncorhynchus gorbuscha) may be confounded by the influence of hatchery fish	Ecotoxicology	13	6	495-501	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	EST
166	Cronin, M.A., Wickliffe, J.K., Dunina, Y. and Baker, R.J.	2002	K-ras oncogene DNA sequences in pink salmon in streams impacted by the Exxon Valdez oil spill: No evidence of oil-induced heritable mutations	Ecotoxicology	11	4	233-241	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	EST
167	Crowe, K.M., Newton, J.C., Kaltenboeck, B. and Johnson, C.	2014	OXIDATIVE STRESS RESPONSES OF GULF KILLIFISH EXPOSED TO HYDROCARBONS FROM THE DEEPWATER HORIZON OIL SPILL: POTENTIAL IMPLICATIONS FOR AQUATIC FOOD RESOURCES	Environmental Toxicology and Chemistry	33	2	370-374	FISH	Gulf killifish	*Fundulus grandis*	CO	MAC	PAH,WAF	DWH	GM	TOX	SW
168	Da Silva, A.Z., Zanette, J., Ferreira, J.F., Guzenski, J., Marques, M.R.F. and Bainy, A.C.D.	2005	Effects of salinity on biomarker responses in Crassostrea rhizophorae (Mollusca, Bivalvia) exposed to diesel oil	Ecotoxicology and Environmental Safety	62	3	376-382	MOLLUSC	Mangrove cup oyster	*Crassostrea rhizophorae*	FO	DSL	WHL			TOX	EST
169	Dahlheim, M.E.	1994	Assessment of injuries and recovery monitoring of Prince William Sound killer whales using photo-identification techniques	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 93042/94092	39 p	MAMMAL	Orca	*Orcinus orca*	CO	ANS	WHL	EVOS	AK	ECO	SW

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170	Dahlheim, M.E. and Matkin, C.O.	1993	Assessment of injuries to killer whales in Prince William Sound	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 2	29 p	MAMMAL	Orca	*Orcinus orca*	CO	ANS	WHL	EVOS	AK	ECO	SW
171	Dahlheim, M.E. and Matkin, C.O.	1994	Assessment of injuries to Prince William Sound killer whales	Marine mammals and the Exxon Valdez			163-171	MAMMAL	Orca	*Orcinus orca*	CO	ANS	WHL	EVOS	AK	ECO/TOX	SW
172	Dahlheim, M.E. and von Ziegesar, O.	1993	Effects of the Exxon Valdez oil spill on the abundance and distribution of humpback whales (Megaptera novaeangliae) in Prince William Sound	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 1	30 p	MAMMAL	Humpback whale	*Megaptera novaeangliae*	CO	ANS	WHL	EVOS	AK	ECO	SW
173	Danish, E.Y.	2010	Ecological impact from chemicals in the Arabian Gulf due to Gulf oil spill	Water and Environment Journal	24	1	65-73				CO	ARL,UKN	MET	GWOS	ARG	ECO	SW
174	Dauvin, J.C. and Ruellet, T.	2007	Polychaete/amphipod ratio revisited	Marine Pollution Bulletin	55	1-6	215-224	ANNELIDA CRUSTACEA	Amphipods Polychaetes	*Amphipoda Polychaeta*	CO	BNT	WHL	AMC	FRA	MOD	SW
175	Davis, H.K., Moffat, C.F. and Shepherd, N.J.	2002	Experimental Tainting of Marine Fish by Three Chemically Dispersed Petroleum Products, with Comparisons to the Braer Oil Spill	Spill Science & Technology Bulletin	7	5-6	257-278	FISH	Atlantic salmon Rainbow trout Blue mussel Brown crab	*Salmo salar Oncorhynchus mykiss Mytilus edulis Cancer pagurus*	CO,DS,FO	FOR,VAR,DSL	WHL	BRA	UK	TOX	SW
176	Davis, J.C.	1989	Nestucca oil spill : Department of Fisheries and Oceans report on spill response	DFO Report (WAVES Catalog #173303)			22 pp.	CRUSTACEA FISH MAMMAL	Pacific herring Sea otter Clams Pacific oyster Dungeoness crab Gooseneck barnacle	*Clupea pallasii Enhydra lutris Bivalvia Crassostrea gigas Cancer magister Pollicipes polymerus*	FO	BUC	WHL	NES	BC	ECO	SW
177	Davis, J.E. and Anderson, S.S.	1976	Effects of oil pollution on breeding Grey Seals	Marine Pollution Bulletin	7	6	115-118	MAMMAL	Grey seal	*Halichoerus grypus*	DS	VAR	WHL		EUR	ECO	SW
178	Day, B.	2006	Ecological effects to benthic infauna from lingering oil 15 years after the Exxon Valdez oil spill	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 040772	34 p	MOLLUSC	Mediterranean Mussel	*Mytilus galloprovincialis*	CO	ANS	PAH,WHL	EVOS	AK	ECO/TOX	SED,SW
179	de Hoop, L., Schipper, A.M., Leuven, R.S.E.W., Huijbregts, M.A.J., Olsen, G.H., Smit, M.G.D. and Hendriks, A.J.	2011	Sensitivity of Polar and Temperate Marine Organisms to Oil Components	Environmental Science & Technology	45	20	9017-9023	ANNELIDA CRUSTACEA FISH MOLLUSC	Cods Salmonids Minnows Flatfishes Sculpins Clams Snails Crabs Shrimps Urchins Sea stars Annelids	*See supplemental info*	BG,CO	VAR	WHL			LIT	SW
180	De Laender, F., Olsen, G.H., Frost, T., Grøsvik, B.E., Grung, M., Hansen, B.H., Hendriks, A J., Hjorth, M., Janssen, C.R., Klok, C., Nordtug, T., Smit, M., Carroll, J. and Camus, L.	2011	Ecotoxicological Mechanisms and Models in an Impact Analysis Tool for Oil Spills	Journal of Toxicology and Environmental Health	74	7-9	605-619	ALGAE CRUSTACEA FISH	Atlantic Cod	*Gadus morhua*	BG,CO	VAR	VAR			LIT	SW
181	de Soysa, T.Y., Ulrich, A., Friedrich, T., Pite, D., Compton, S.L., Ok, D., Bernardos, R.L., Downes, G.B., Hsieh, S., Stein, R., Lagdameo, M.C.,	2012	Macondo crude oil from the Deepwater Horizon oil spill disrupts specific developmental processes during zebrafish embryogenesis	BMC Biology	10	40		FISH	Zebrafish	*Danio rerio*	CO	MAC	WAF	DWH	GM	TOX	FW

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	Halvorsen, K., Kesich, L.R. and Barresi, M J.F.																
182	De Vogelaere, A.P. and Foster, M.S.	1994	DAMAGE AND RECOVERY IN INTERTIDAL FUCUS-GARDNERI ASSEMBLAGES FOLLOWING THE EXXON-VALDEZ OIL-SPILL	Marine Ecology Progress Series	106	3	263-271	ALGAE	Rockweed	*Fucus gardneri*	CO	ANS	WHL	EVOS	AK	ECO	SW
183	Dean, T.A., Bodkin, J.L., Jewett, S.C., Monson, D.H. and Jung, D.	2000	Changes in sea urchins and kelp following a reduction in sea otter density as a result of the Exxon Valdez oil spill	Marine Ecology Progress Series	199		281-291	ALGAE ECHINODERM MAMMAL	Kelps Green sea urchin Sea otter	*Agarum spp Laminaria spp Nereocystis luetkeana Strongylocentrotus droebachiensis Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
184	Dean, T.A., Jewett, S.C., Laur, D.R. and Smith, R.O.	1996	Injury to epibenthic invertebrates resulting from the Exxon Valdez oil spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		424-439	CRUSTACEA, ECHINODERM	Leather Star Helmut Crab Mottled Star Sunflower Sea Star	*Dermasterias imbricata Telmessus cheiragonus Evasterias troschelii Pycnopodia helianthoides*	CO	ANS	PAH,WHL	EVOS	AK	LIT	SW
185	Dean, T.A., Stekoll, M.S. and Smith, R.O.	1996	Kelps and oil: The effects of the Exxon Valdez oil spill on subtidal algae	Proceedings of the Exxon Valdez Oil Spill Symposium	18		412-423	ALGAE	Bull kelp Sieve kelp Sugar kelpq	*Nereocystis luetkeana Agarum cribrosum Laminaria saccharina Laminaria groenlandica*	CO	ANS	WHL	EVOS	AK	ECO	SW
186	Dean, T.A., Stekoll, M.S., Jewett, S.C., Smith, R.O. and Hose, J.E.	1998	Eelgrass (Zostera marina L.) in Prince William Sound, Alaska: Effects of the Exxon Valdez oil spill	Marine Pollution Bulletin	36	3	201-210	PLANT	Eel Grass	*Zostera marina*	CO	ANS	PAH	EVOS	AK	ECO	SW
187	Debenest, T., Turcotte, P., Gagné, F., Gagnon, C. and Blaise, C.	2012	Ecotoxicological impacts of effluents generated by oil sands bitumen extraction and oil sands lixiviation on Pseudokirchneriella subcapitata	Aquatic Toxicology	112-113		83-91	ALGAE	MICROALGAE	*Pseudokirchneriella subcapitata*	OR	PRW	MET		AOS	TOX	FW
188	Debruyn, A.M.H., Wernick, B.G., Stefura, C., McDonald, B.G., Rudolph, B.L., Patterson, L. and Chapmant, P.M.	2007	In situ experimental assessment of lake whitefish development following a freshwater oil spill	Environmental Science & Technology	41	20	6983-6989	FISH	Lake whitefish	*Coregonus clupeaformis*	FO	BUC	PAH	WAB	AB	ECO	FW
189	Deepthike, H.U., Tecon, R., Van Kooten, G., Van Der Meer, J.R., Harms, H., Wells, M. and Short, J.	2009	Unlike PAHs from Exxon Valdez Crude Oil, PAHs from Gulf of Alaska Coals are not Readily Bioavailable	Environmental Science & Technology	43	15	5864-5780				CO	ANS	PAH,WHL	EVOS	AK	ECO/PHYS	SED,SW
190	Deepthike, H.U., Tecon, R., Van Kooten, G., Van Der Meer, J.R., Harms, H., Wells, M. and Short, J.	2010	Response to Comment on "Unlike PAHs from Exxon Valdez Crude Oil, PAHs from Gulf of Alaska Coals are not Readily Bioavailable"	Environmental Science & Technology	44	6	2212-2213				CO	ANS	PAH,WHL	EVOS	AK	ECO/PHYS	SED,SW
191	Degange, A.R. and Lensink, C.J.	1990	DISTRIBUTION AGE AND SEX COMPOSITION OF SEA OTTER CARCASSES RECOVERED DURING THE RESPONSE TO THE T-V EXXON VALDEZ OIL SPILL	U S Fish and Wildlife Service Biological Report	90	12	124-129	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW

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192	DeGange, A.R., Douglas, D.C., Monson, D.H. and Robbins, C.M.	1995	Surveys of sea otters in the Gulf of Alaska in response to the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-7		MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
193	Degange, A.R., Monson, D.H., Irons, D.B., Robbins, C.M. and Douglas, D.C.	1990	DISTRIBUTION AND RELATIVE ABUNDANCE OF SEA OTTERS IN SOUTH-CENTRAL AND SOUTHWESTERN ALASKA USA BEFORE OR AT THE TIME OF THE T-V EXXON VALDEZ OIL SPILL	U S Fish and Wildlife Service Biological Report	90	12	18-25	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
194	Della Torre, C., Tornambè, A., Cappello, S., Mariottini, M., Perra, G., Giuliani, S., Amato, E., Falugi, C., Crisari, A., Yakimov, M.M. and Magaletti, E.	2012	Modulation of CYP1A and genotoxic effects in European seabass (Dicentrarchus labrax) exposed to weathered oil: A mesocosm study	Marine Environmental Research	76		48-55	FISH	European sea bass	*Dicentrarchus labrax*	CO	UKN	ALH,PAH		EUR	TOX	SW
195	Demes, K., Chang, S., Quayle, M., Withers, D., Raymond, J. and Stevens, D.	2013	Economic and Biophysical Impacts of Oil Tanker Spills Relevant to Vancouver, Canada A Literature Review	Report			153 pp.				BG,CO	UKN	UKN		BC	LIT	EST,FW,SW
196	Dew, W.A., Hontela, A., Rood, S.B. and Pyle, G.G.	2015	Biological effects and toxicity of diluted bitumen and its constituents in freshwater systems	Journal of Applied Toxicology	35	11	1219-1227	CRUSTACEA FISH INSECT	Flies Amphipods Smallmouth bass Golden redhorse Yellow perch Rainbow trout	*Chironomus dilutans Hyalella azteca Micropterus dolomieu Moxostoma erythrurum Perca flavescens Oncorhynchus mykiss*	OR	DBT	WHL	KAL	MI	LIT	FW
197	Djomo, J.E., Dauta, A., Ferrier, V., Narbonne, J.F., Monkiedje, A., Njine, T. and Garrigues, P.	2004	Toxic effects of some major polyaromatic hydrocarbons found in crude oil and aquatic sediments on Scenedesmus subspicatus	Water Research	38	7	1817-1821	ALGAE	MICROALGAE	*Microalga (Scenedesmus subspicatus)*	CO	UKN	PAH			TOX	FW
198	Donaldson, W. and Byersdorfer, S.	1998	Sea Urchin Injury: Assessment of impacts of oil on green sea urchins, *Strongylocentrotus droebachiensis*, in the Kodiak Island area, Exxon Valdez Oil Spill State/Federal Natural Resource Damage Assessment Annual Report (Fish/Shellfish Study Number 26)	EVOS Trustee Council	Fish/Shellfish Study	FS26	109 pp.	ECHINODERM	GREEN SEA URCHIN PURPLE SEA URCHIN	*Strongylocentrotus droebachiensis Strongylocentrotus purpuratus*	CO	ANS	WAF,WHL	EVOS	AK	ECO/TOX	SW
199	Donkin, P., Smith, E.L. and Rowland, S.J.	2003	Toxic effects of unresolved complex mixtures of aromatic hydrocarbons accumulated by mussels, Mytilus edulis, from contaminated field sites	Environmental Science & Technology	37	21	4825-4830	MOLLUSC	Mussels	*Mytilus edulis*	BG,CO	UKN	BTX,PAH		EUR	ECO/TOX	SW
200	Doroff, A.M. and A.R. DeGange.	1995	Experiments to determine drift patterns and rates of recovery of sea otter carcasses following the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-9		MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW

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201	Doroff, A.M. and Bodkin, J.L.	1996	Sea otter foraging behavior and hydrocarbon concentrations in prey following the Exxon Valdez oil spill in Prince William Sound, Alaska	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-8		MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	ALH,BTX,PAH	EVOS	AK	ECO	SW
202	Doroff, A.M. and Bodkin, J.L.	1994	Sea otter foraging behavior and hydrocarbon levels in prey	Marine mammals and the Exxon Valdez			193-208	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO/TOX	SW
203	Downs, C.A., Shigenaka, G., Fauth, J.E., Robinson, C.E. and Huang, A.	2002	Cellular physiological assessment of bivalves after chronic exposure to spilled Exxon Valdez crude oil using a novel molecular diagnostic biotechnology	Environmental Science & Technology	36	13	2987-2993	MOLLUSC	Softshell Clam Foolish Mussel	*Mya arenaria Mytilus trossulus*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
204	Driskell, W.B., Fukuyama, A.K., Houghton, J.P., Lees, D.C., Mearns, A.J. and Shigenaka, G.	1996	Recovery of Prince William Sound Intertidal Infauna From Exxon Valdez Oiling and Shoreline Treatments, 1989 Through 1992	Proceedings of the Exxon Valdez Oil Spill Symposium	18		362-378	ANNELIDA CRUSTACEA MOLLUSC	Benthic marine invertebrates	*Benthic marine invertebrates*	CO	ANS	WHL	EVOS	AK	ECO	SW
205	Driskell, W.B., Ruesink, J.L., Lees, D.C., Houghton, J.P. and Lindstrom, S.C.	2001	LONG-TERM SIGNAL OF DISTURBANCE: FUCUS GARDNERI AFTER THE EXXON VALDEZ OIL SPILL	Ecological Applications	11	3	815-827	ALGAE	Rockweed	*Fucus gardneri*	CO	ANS	WHL	EVOS	AK	ECO	SW
206	Duarte, H.O. and Droguett, E.L.	2015	Quantitative ecological risk assessment of accidental oil spills on ship routes nearby a marine national park in Brazil	Human and Ecological Risk Assessment: An International Journal	22	2	350-368	CNIDARIA	Coral (no common name)	*Siderastrea stellata*	CO	VAR	WHL		SAM	MOD	SW
207	Dubansky, B., Whitehead, A., Miller, J.T., Rice, C.D. and Galvez, F.	2013	Multitissue Molecular, Genomic, and Developmental Effects of the Deepwater Horizon Oil Spill on Resident Gulf Killifish (Fundulus grandis)	Environmental Science & Technology	47	10	5074-5082	FISH	Gulf killifish	*Fundulus grandis*	CO	MAC	WHL	DWH	GM	ECO/TOX	SED,SW
208	Duesterloh, S., Short, J.W. and Barron, M.G.	2002	Photoenhanced toxicity of weathered Alaska north slope crude oil to the calanoid copepods Calanus marshallae and Metridia okhotensis	Environmental Science & Technology	36	18	3953-3959	CRUSTACEA	Copepods	*Calanus marshallae Metridia okhotensis*	CO	ANS	PAH,UVT	EVOS	AK	ECO/TOX	SW
209	Duffy, L.K.	1999	APEX Project: Alaska Predator Ecosystem Experiment in Prince William Sound and the Gulf of Alaska, Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project 98163)	EVOS Trustee Council	Restoration Project	98163	462 pp.	BIRD FISH	Capelin Herring Sandlance Pollock Rockfish	*Mallotus villosus Clupea pallasii Ammodytes hexapterus Theragra chalcogramma Sebastes spp*	CO	ANS	WHL	EVOS	AK	ECO	SW
210	Duffy, L.K., Bowyer, R.T., Testa, J.W. and Faro, J.B.	1994	CHRONIC EFFECTS OF THE EXXON-VALDEZ OIL-SPILL ON BLOOD AND ENZYME CHEMISTRY OF RIVER OTTERS	Environmental Toxicology and Chemistry	13	4	643-647	MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	ECO	SW
211	Duffy, L.K., Bowyer, R.T., Testa, J.W. and Faro, J.B.	1993	DIFFERENCES IN BLOOD HAPTOGLOBIN AND LENGTH-MASS RELATIONSHIPS IN RIVER OTTERS (LUTRA-CANADENSIS) FROM OILED AND NONOILED AREAS OF PRINCE-WILLIAM-SOUND, ALASKA	Journal of Wildlife Diseases	29	2	353-359	MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	ECO	SW
212	Duffy, L.K., Bowyer, R.T., Testa, J.W. and Faro, J.B.	1994	EVIDENCE FOR RECOVERY OF BODY-MASS AND HAPTOGLOBIN VALUES OF RIVER OTTERS FOLLOWING THE EXXON-VALDEZ OIL-SPILL	Journal of Wildlife Diseases	30	3	421-425	MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	ECO	SW
213	Duffy, L.K., Hecker, M.K., Blundell, G.M. and Bowyer, R.T.	1999	An analysis of the fur of river otters in Prince William Sound, Alaska: oil related hydrocarbons 8 years after the Exxon Valdez oil spill	Polar Biology	21	1	56-58	MAMMAL	River otter	*Lontra canadensis*	CO	ANS	ALH,PAH	EVOS	AK	ECO	SW
214	Duncan, P.B. and Hooten, A.J.	1996	Influence of residual and applied oil on intertidal algal recruitment	Proceedings of the Exxon Valdez Oil Spill Symposium	18		238-248	ALGAE	Rockweed	*Fucus gardneri*	CO	ANS	WHL	EVOS	AK	ECO	SW

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215	Dupuis, A. and Ucan-Marin, F.	2015	A literature review on the aquatic toxicology of petroleum oil: An overview of oil properties and effects to aquatic biota	Fisheries and Oceans Canada, Canadian Science Advisory Secretariat research document			vi +52pp	COMMUNITY	Various	Various	CO,DS,OR	VAR,BIT,DBT,DIL	VAR			LIT	FW,SW
216	Durako, M..J, Kenworthy, W.J., Fatemy, S.M.R., Valavi, H. and Thayer, G.W.	1993	Assessment of the toxicity of Kuwait crude oil on the photosynthesis and respiration of seagrasses of the northern Gulf	Marine Pollution Bulletin	27		223-227	PLANT	Seagrass	*Halophila spp.*	CO	ARL,KCO	WHL	GWOS	ARG	TOX	SW
217	Durako, M.J., Kenworthy, W.J., Fatemy, S.M.R., Valavi, H. and Thayer, G.W.	1993	ASSESSMENT OF THE TOXICITY OF KUWAIT CRUDE-OIL ON THE PHOTOSYNTHESIS AND RESPIRATION OF SEAGRASSES OF THE NORTHERN GULF	Marine Pollution Bulletin	27		223-227	PLANT	Seagrass	*Halophila ovalis Halophila stipulacea Halodule uninervis*	CO	KCO	WHL			TOX	SW
218	Dussauze, M., Camus, L., Le Floch, S., Pichavant-Rafini, K., Geraudie, P., Coquille, N., Amerand, A., Lemaire, P. and Theron, M.	2014	Impact of dispersed fuel oil on cardiac mitochondrial function in polar cod Boreogadus saida	Environmental Science and Pollution Research	21	24	13779-13788	FISH	Polar cod	*Boreogadus saida*	CO,DS	ARL,COR,OSR	WHL			TOX	SW
219	Eberhardt, L.L. and Garrott, R.A.	1997	Sea otter mortality from the Exxon Valdez oil spill: Evaluation of an estimate from boat-based surveys - Response	Marine Mammal Science	13	2	351-354	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
220	Ebert, T.A. and Lees, D.C.	1996	Growth and Loss of Tagged Individuals of the Predatory Snail *Nucella lamellosa* in Areas within the Influence of the *Exxon Valdez* Oil Spill in Prince William Sound	Proceedings of the Exxon Valdez Oil Spill Symposium	18		349-361	MOLLUSC	Frilled Dogwinkle	*Nucella lamellosa*	CO	ANS	WHL	EVOS	AK	ECO	SW
221	Ekanem, A.P., Asuquo, F.E. and Ndick, E.J.	2011	Toxicity of Crude Oil to Fresh Water Shrimp, Macrobrachium macrobrachion and Macrobrachium vollenhovenii From Nigerian Coastal Water	Bulletin of Environmental Contamination and Toxicology	86	4	394-397	CRUSTACEA	Freshwater Shrimp	*Macrobrachium spp.*	CO	QIC	WAF		AFR	TOX	EST
222	Eldridge, M.B., Echeverria, T. and Whipple, J.A.	1977	ENERGETICS OF PACIFIC HERRING (CLUPEA-HARENGUS-PALLASI) EMBRYOS AND LARVAE EXPOSED TO LOW CONCENTRATIONS OF BENZENE, A MONOAROMATIC COMPONENT OF CRUDE-OIL	Transactions of the American Fisheries Society	106	5	452-461	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	LAB	BTX		CA	TOX	SW
223	El-Sheekh, M.M., El-Naggar, A.H., Osman, M.E.H. and Haieder, A.	2000	Comparative studies on the green algae Chlorella homosphaera and Chlorella vulgaris with respect to oil pollution in the river Nile	Water Air and Soil Pollution	124	42036	187-204	ALGAE	MICROALGAE	*Chlorella homosphaera C. vulgaris*	CO	ALA	TPH		AFR	ECO/TOX	FW
224	Elston, R.A. and Meyers, T.R.	2009	Effect of viral hemorrhagic septicemia virus on Pacific herring in Prince William Sound, Alaska, from 1989 to 2005	Diseases of Aquatic Organisms	83	3	223-246	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	LIT	SW
225	Environment Canada, Fisheries and Oceans Canada, and Natural Resources Canada	2013	Properties, Composition and Marine Spill Behaviour, Fate and Transport of Two Diluted Bitumen Products from the Canadian Oil Sands	Federal Government Technical Report	En84-96/2013E-PDF		87pp				OR,DS	DBT,COR	WHL		CAN	LIT/PHYS	SW
226	Estes, J.A.	1991	CATASTROPHES AND CONSERVATION - LESSONS FROM SEA OTTERS AND THE EXXON-VALDEZ	Science	254	5038	1596-1596	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	LIT	SW
227	Etkin, D.S., Joeckel, J., Hayward Walker, A., Scholz, D., Moore, C., Baker, C., Hatzenbuhler, D., Patton, R.G., Lyman, E. and Culpepper, D.	2015	Washington State 2014 Marine and Rail Oil Transportation Study	Report			570 pp				BG	VAR	VAR		WA	LIT	EST,FW,SW

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228	EVOS Trustee Council	2014	Exxon Valdez Oil Spill Final and Annual Reports	EVOS Trustee Council							CO	ANS	VAR	EVOS	AK	LIT	SW
229	Fadely, B.S., Castellini, J.M. and Castellini, M.A.	1997	Recovery of harbor seals from EVOS: condition and health status	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 97001		MAMMAL	Harbour seal	*Phoca vitulina*	CO	ANS	WHL	EVOS	AK	ECO	SW
230	Fadely, B.S., Castellini, M.A. and Castellini, J.M.	1996	Harbor seals and EVOS: blubber and lipids as indices of food limitation, Exxon Valdez Oil Spilll Restoration Project Annual Report (Restoration Project 95131)	EVOS Trustee Council	Restoration Project	95117-BAA	24 pp.	MAMMAL	Harbour seal	*Phoca vitulina*	CO	ANS	WHL	EVOS	AK	ECO	SW
231	Faro, J.B., Bowyer, R.T., Testa, J.W. and Duffy, L.K.	1994	River otter component of the oiled mussel-bed study	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Restoration Study Number 103-3		MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	ECO	SW
232	Faro, J.B., Bowyer, R.T., Testa, J.W. and Duffy, L.K.	1994	Assessment of injury to river otters in Prince William Sound, Alaska, following the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Terrestrial Mammal Study Number 3		MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	ECO	SW
233	Feder, H.M.	1995	Injury to deep benthos	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Subtidal Study 2B/Air Water 2		BENTHOS			CO	ANS	ALH,PAH	EVOS	AK	ECO	SW
234	Feder, H.M. and Blanchard, A.	1998	The deep benthos of Prince William Sound, Alaska, 16 months after the Exxon Valdez oil spill	Marine Pollution Bulletin	36	2	118-130	ANNELIDA CRUSTACEA MOLLUSC	Benthic marine invertebrates	*Benthic marine invertebrates*	CO	ANS	PAH,WHL	EVOS	AK	ECO/TOX	SW
235	Fernandez, N., Cesar, A., Salamanca, M.J. and Delvalls, T.A.	2006	Toxicological characterisation of the aqueous soluble phase of the Prestige fuel-oil using the sea-urchin embryo bioassay	Ecotoxicology	15	7	593-599	ECHINODERM	Paracentrotus lividus (sea urchin)	*Paracentrotus lividus (sea urchin)*	FO	HFO	PAH	PRES	SPN	TOX	SW
236	Ferrando, A., Gonzalez, E., Franco, M., Commendatore, M., Nievas, M., Militon, C., Stora, G., Gilbert, F., Esteves, J.L. and Cuny, P.	2015	Oil spill effects on macrofaunal communities and bioturbation of pristine marine sediments (Caleta Valdés, Patagonia, Argentina): experimental evidence of low resistance capacities of benthic systems without history of pollution	Environmental Science and Pollution Research	22	20	15294-15306	ANNELIDA CRUSTACEA	Macrobenthic invertebrates		CO	ESC	WHL		SAM	ECO/TOX	SW
237	Ferrante, P.	1990	FOOD PROCUREMENT AND FEEDING OF SEA OTTERS DURING THE T-V EXXON VALDEZ OIL SPILL	U S Fish and Wildlife Service Biological Report	90	12	321-322	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
238	Fleeger, J.W., Shirley, T.C., Carls, M.G., Todaro, M.A.	1996	Meiofaunal recolonization experiment with oiled sediments	Proceedings of the Exxon Valdez Oil Spill Symposium	18		271-285	CRUSTACEA	HARPACTICOIDS	*Halectinosoma sp. Mesochra pygmaea Paralaophonte perplexa Amphiascus minutus*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
239	Fodrie, F.J., Able, K.W., Galvez, F., Heck, K.L. Jr, Jensen, O.P., López-Duarte, P.C.,	2014	Integrating Organismal and Population Responses of Estuarine Fishes in Macondo Spill Research	BioScience	64	9	778-788	FISH	Gobies Drums Herrings	*Gobiidae Sciaenidae Clupeidae*	CO	MAC	WHL	DWH	GM	LIT	EST

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	Martin, C.W., Turner, R.E. and Whitehead, A.																
240	Fraker, M.A.	2013	Killer Whale (Orcinus orca) Deaths in Prince William Sound, Alaska, 1985-1990	Human and Ecological Risk Assessment	19	1	28-52	MAMMAL	Orca	*Orcinus orca*	CO	ANS	WHL	EVOS	AK	ECO	SW
241	Franco, M.A., Viñas, L., Soriano, J.A., de Armas, D., González, J.J., Beiras, R., Salas, N., Bayona, J.M. and Albaigés, J.	2006	Spatial distribution and ecotoxicity of petroleum hydrocarbons in sediments from the Galicia continental shelf (NW Spain) after the Prestige oil spill	Marine Pollution Bulletin	53	5-7	260-271	MOLLUSC	Pullet carpet shell Venerupis pullastra	*Pullet carpet shell Venerupis pullastra*	FO	HFO	PAH	PRES	SPN	PHYS	SED,SW
242	Frank, R.A., Fischer, K., Kavanagh, R., Burnison, B.K., Arsenault, G., Headley, J.V., Peru, K.M., Van der Kraak, G. and Solomon, K.R.	2009	Effect of Carboxylic Acid Content on the Acute Toxicity of Oil Sands Naphthenic Acids	Environmental Science & Technology	43	2	266-271	CRUSTACEA MICROBIA	MICROTOX® Daphnia	*Vibrio fischeri Daphnia magna*	OR	PRW	NAC		AOS	TOX	FW
243	Frank, R.A., Kavanagh, R., Kent Burnison, B., Arsenault, G., Headley, J.V., Peru, K.M., Van Der Kraak, G. and Solomon, K.R.	2008	Toxicity assessment of collected fractions from an extracted naphthenic acid mixture	Chemosphere	72	9	1309-1314	MICROBIA	MICROTOX®	*Vibrio fischeri*	OR	PRW	NAC		AOS	TOX	FW
244	Frantzen, M., Falk-Petersen, I.B., Nahrgang, J., Smith, T..J, Olsen, G.H., Hangstad, T.A. and Camus, L.	2012	Toxicity of crude oil and pyrene to the embryos of beach spawning capelin (Mallotus villosus)	Aquatic Toxicology	108	SI	42-52	FISH	Capelin	*Mallotus villosus*	CO	BRC	PAH,WHL		EUR	TOX	SW
245	Freese, J.L. and O'Clair, C.E.	1995	Injury to crabs outside Prince William Sound	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Fish/Shellfish Study Number 22	21 p	CRUSTACEA	Dungeness crab	*Metacarcinus magister*	CO	ANS	WHL	EVOS	AK	ECO	SW
246	Fried, S.M., Bue, B.G., Sharp, D. and Sharr, S.	1998	Injury to spawning areas and an evaluation of spawning escapement enumeration of pink salmon in Prince William Sound, Alaska	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Fish/Shellfish Study Number1, Restoration Study Number 9, Restoration Study Number 60B		FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW
247	Frost, K.J. and Lowry, L.F.	1994	Assessment of injury to harbor seals in Prince William Sound, Alaska, and adjacent areas following the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 5, Restoration Study Number 73	169 p	MAMMAL	Harbour seal	*Phoca vitulina*	CO	ANS	WHL	EVOS	AK	ECO	SW

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248	Frost, K.J., Lowry, L.F. and Ver Hoef, J.M.	1999	MONITORING THE TREND OF HARBOR SEALS IN PRINCE WILLIAM SOUND, ALASKA, AFTER THE EXXON VALDEZ OIL SPILL	Marine Mammal Science	15	2	494-506	MAMMAL	Harbour seal	*Phoca vitulina*	CO	ANS	WHL	EVOS	AK	ECO	SW
249	Fukuyama, A.K., Shigenaka, G. and Coats, D.A.	2014	Status of intertidal infaunal communities following the Exxon Valdez oil crossMark spill in Prince William Sound, Alaska	Marine Pollution Bulletin	84	1-2	56-69	MOLLUSC	Various	Various	CO	ANS	WHL	EVOS	AK	ECO	SED,SW
250	Fukuyama, AK, Shigenaka, G and Hoff, RZ	2000	Effects of residual Exxon Valdez oil on intertidal protothaca staminea: Mortality, growth, and bioaccumulation of hydrocarbons in transplanted clams	Marine Pollution Bulletin	40	11	1042-1050	MOLLUSC	Littleneck clam	*Protothaca staminea*	CO	ANS	WHL	EVOS	AK	ECO/TOX	SED,SW
251	Fuller, C., Bonner, J., Page, C., Ernest, A., McDonald, T. and McDonald, S.	2004	Comparative toxicity of oil, dispersant, and oil plus dispersant to several marine species	Environmental Toxicology and Chemistry	23	12	2941-2949	CRUSTACEA FISH MICROBIA	Sheepshead minnow Inland silverside Mysid shrimp Microtox®	*Cyprinodon variegatus Menidia beryllina Americamysis bahia Vibro fischeri*	CO,DS	AMC,COR	TPH,WHL			TOX	EST
252	Gagné, F., André, C., Turcotte, P., Gagnon, C., Sherry, J. and Talbot, A.	2013	A comparative toxicogenomic investigation of oil sand water and processed water in rainbow trout hepatocytes	Archives of Environmental Contamination and Toxicology	65	2	309-323	FISH	Rainbow trout hepatocytes	*Oncorhynchus mykiss*	OR	PRW	WHL		AOS	TOX	FW
253	Gagné, F., Douville, M., André, C., Debenest, T., Talbot, A., Sherry, J., Hewitt, L.M., Frank, R.A., McMaster, M.E., Parrott, J. and Bickerton, G.	2012	Differential changes in gene expression in rainbow trout hepatocytes exposed to extracts of oil sands process-affected water and the Athabasca River	Comparative Biochemistry and Physiology	155	4	551-559	FISH	Rainbow trout hepatocytes	*Oncorhynchus mykiss*	OR	PRW	WHL		AOS	ECO/TOX	FW
254	Gagnon, M.M. and Holdway, D.A.	1999	Metabolic enzyme activities in fish gills as biomarkers of exposure to petroleum hydrocarbons	Ecotoxicology and Environmental Safety	44	1	92-99	FISH	Atlantic salmon	*Salmo salar*	CO,DS	BSC,COR	WAF			TOX	SW
255	Gardiner, W.W., Word, J.Q., Word, J.D., Perkins, R.A., McFarlin, K.M., Hester, B W., Word, L.S. and Ray, C. M.	2013	The acute toxicity of chemically and physically dispersed crude oil to key arctic species under arctic conditions during the open water season	Environmental Toxicology and Chemistry	32	10	2284-2300	CRUSTACEA FISH	Calanoid copepod Arctic cod Sculpin	*Calanus glacialis Boreogadus saida Myxocephalus sp.*	CO,DS	ANS,COR	CWF,WAF		ARC	TOX	SW
256	Garrott, R.A., Eberhardt, L.L. and Burn, D.M.	1993	Mortality of sea otters in Prince William Sound following the Exxon Valdez oil spill	Marine Mammal Science	9	4	343-359	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
257	Garshelis, D.L.	1997	Sea otter mortality estimated from carcasses collected after the Exxon Valdez oil spill	Conservation Biology	11	4	905-916	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
258	Garshelis, D.L. and Estes, J.A.	1997	Sea otter mortality from the Exxon Valdez oil spill: Evaluation of an estimate from boat-based surveys	Marine Mammal Science	13	2	341-351	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
259	Garshelis, D.L. and Johnson, C.B.	2013	Prolonged recovery of sea otters from the Exxon Valdez oil spill? A re-examination of the evidence	Marine Pollution Bulletin	71	1-2	7-19	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
260	Garshelis, D.L. and Johnson, C.B.	2001	Sea otter population dynamics and the Exxon Valdez oil spill: disentangling the confounding effects	Journal of Applied Ecology	38	1	19-35	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	MOD	SW
261	Geffard, O., Budzinski, H. and LeMenach, K.	2004	Chemical and ecotoxicological characterization of the "Erika" petroleum: Bio-tests applied to petroleum water-accommodated fractions and natural contaminated samples	Aquatic Living Resources	17	3	289-296	ALGAE MOLLUSC	Mediterranean Mussel Pacific Oyster	*Mytilus galloprovincialis Crassostrea gigas Isochrysis galbana*	FO	HFO	PAH	ERK	FRA	ECO/TOX	SW
262	Geiger, H.J., Bue, B.G., Sharr, S., Wertheimer, A.C. and Willette, T.M.	1996	A Life history approach to estimating damage to Prince William Sound Pink Salmon caused by the Exxon Valdez oils spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		487-498	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	FW,SW
263	Geiger, J.G. and Buikema Jr, A.L.	1982	Hydrocarbons Depress Growth and Reproduction of Daphnia pulex (Cladocera)	Canadian Journal of Fisheries and Aquatic Sciences	39	6	830-836	CRUSTACEA	Daphnia	*Daphnia pulex*	FO	LFO	PAH			TOX	FW

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264	Gilbert, F., Stora, G. and Cuny, P.	2015	Functional response of an adapted subtidal macrobenthic community to an oil spill: macrobenthic structure and bioturbation activity over time throughout an 18-month field experiment	Environmental Science and Pollution Research	22	20	15285-15293	ANNELIDA CRUSTACEA ECHINODERM MOLLUSC	Macrobenthic invertebrates		CO	BAL	WHL		EUR	ECO/TOX	SW
265	Gilde, K. and Pinckney, J.L.	2012	Sublethal Effects of Crude Oil on the Community Structure of Estuarine Phytoplankton	Estuaries and Coasts	35	3	853-861	ALGAE	Phytoplankton		CO	MAC,TCO	WHL	DWH	GM	ECO	EST
266	Gilfillan, E.S., Page, D.S., Harner, E.J. and Boehm, P.D.	1995	Shoreline Ecology Program for Prince William Sound, Alaska, Following the Exxon Valdez Oil Spill: Part III - Biology	Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters	1219		398	COMMUNITY	Intertidal Community	Various	CO	ANS	WHL	EVOS	AK	ECO/TOX	SW
267	Gilfillan, E.S., Suchanek, T.H., Boehm, P.D., Harner, E.J., Page, D.S. and Sloan, N.A.	1995	Shoreline Impacts in the Gulf of Alaska Region Following the Exxon Valdez Spill	Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters	1219		444	MOLLUSC	Mussels	*Mytilus sp.*	CO	ANS	WHL	EVOS	AK	ECO/TOX	SW
268	Glegg, G.A. and Rowland, S.J.	1996	The Braer oil spill - Hydrocarbon concentrations in intertidal organisms	Marine Pollution Bulletin	32	6	486-492	MOLLUSC	Limpets Razor clams	*Patella vulgata Ensis spp.*	CO	NSC	BTX,PAH	BRA	UK	ECO	SW
269	Goff, K.L., Headley, J.V., Lawrence, J.R. and Wilson, K.E.	2013	Assessment of the effects of oil sands naphthenic acids on the growth and morphology of Chlamydomonas reinhardtii using microscopic and spectromicroscopic techniques	Science of the Total Environment	442		116-122	ALGAE	MICROALGAE	*Chlamydomonas reinhardtii*	OR	PRW	NAC			TOX	FW
270	Gohlke, J.M., Doke, D., Tipre, M., Leader, M. and Fitzgerald, T.	2011	A Review of Seafood Safety after the Deepwater Horizon Blowout	Environmental Health Perspectives	119	8	1062-1069	CRUSTACEA FISH MOLLUSC	Various commercially important finfish and shellfish		CO	MAC	PAH	DWH	GM	LIT	SW
271	Gómez Gesteira, J.L. and Dauvin, J.-C.	2000	Amphipods are Good Bioindicators of the Impact of Oil Spills on Soft-Bottom Macrobenthic Communities	Marine Pollution Bulletin	40	11	1017-1027	ANNELIDA CRUSTACEA	Amphipods Polychaetes	*Ampelisca spp. etc*	CO	ARL,BNT	WHL	AEG,AMC	FRA,SPN	ECO	SW
272	González-Doncel, M., González, L., Fernandez-Torija, C., Navas, J.M. and Tarazona, J.V.	2008	Toxic effects of an oil spill on fish early life stages may not be exclusively associated to PAHs: Studies with Prestige oil and medaka (Oryzias latipes)	Aquatic Toxicology	87	4	280-288	FISH	Golden medaka	*Oryzias latipes*	FO	HFO	PAH,WAF	PRES	SPN	TOX	FW
273	Greer, C.D., Hodson, P.V., Li, Z., King, T. and Lee, K.	2012	Toxicity of crude oil chemically dispersed in a wave tank to embryos of Atlantic herring (Clupea harengus)	Environmental Toxicology and Chemistry	31	6	1324-1333	FISH	Atlantic Herring	*Clupea harengus*	CO,DS	ANS,ARL,COR	WHL	EVOS	AK	TOX	SW
274	Gulec, I., Leonard, B. and Holdway, D.A.	1997	Oil and dispersed oil toxicity to amphipods and snails	Spill Science & Technology Bulletin	4	1	1-6	CRUSTACEA MOLLUSC	Amphipod (Allorchestes compressa) marine sand snail (Polinices conicus)	*Amphipod (Allorchestes compressa) marine sand snail (Polinices conicus)*	CO,DS	BSC,COR	CWF,WAF		AUS	TOX	SW
275	Gundlach, E.R., Domeracki, D.D. and Thebeau, L.C.	1982	Persistence of METULA oil in the strait of Magellan six and one-half years after the incident	Oil and Petrochemical Pollution	1	1	37-48				CO,FO	ARL,BUC	WHL	MET	SAM	ECO/PHYS	SW
276	Gundlach, E.R., Page, D.S., Neff, J.M. and Boehm, P.D.	2013	Shoreline Biota	Oil in the Environment: Legacies and Lessons of the Exxon Valdez Spill			241- 262	COMMUNITY	Intertidal Community	Various	CO	ANS	WHL	EVOS	AK	LIT	SW
277	Hagen, M.O., Garcia-Garcia, E., Oladiran, A., Karpman, M., Mitchell, S., El-Din, M.G., Martin, J.W, and Belosevic, M.	2012	The acute and sub-chronic exposures of goldfish to naphthenic acids induce different host defense responses	Aquatic Toxicology	109		143-149	FISH	Goldfish	*Carassius auratus*	OR	PRW	NAC		AOS	TOX	FW
278	Hall, A.J., Watkins, J. and Hiby, L.	1996	The impact of the 1993 Braer oil spill on grey seals in Shetland	Science of The Total Environment	186	1–2	119-125	MAMMAL	Grey seal	*Halichoerus grypus*	CO	NSC	WHL	BRA	UK	ECO	SW
279	Hamdan, L.J. and Fulmer, P.A.	2011	Effects of COREXIT (R) EC9500A on bacteria from a beach oiled by the Deepwater Horizon spill	Aquatic Microbial Ecology	63	2	101-109	MICROBIA	*Hydrocarbon-degrading bacteria*	*Acinetobacter Marinobacter*	CO,DS	LSC,COR	WHL	DWH	GM	ECO/TOX	SW

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280	Hampson, G.R. and Moul, E.T.	1978	No. 2 Fuel Oil Spill in Bourne, Massachusetts: Immediate Assessment of the Effects on Marine Invertebrates and a 3-Year Study of Growth and Recovery of a Salt Marsh	Journal of the Fisheries Research Board of Canada	35	5	731-744	ANNELIDA CRUSTACEA MOLLUSC	Polychaetes fiddler crab surf clam razor clam	*Nereis virens Uca pugnax Spisula solidissima Ensis directus*	FO	LFO	WHL	BOU	MA	ECO	SW
281	Han, J., Won, E.J., Hwang, D.S., Shin, K.H., Lee, Y.S., Leung, K.M.Y., Lee, S.J. and Lee, J.S.	2014	Crude oil exposure results in oxidative stress-mediated dysfunctional development and reproduction in the copepod Tigriopus japonicus and modulates expression of cytochrome P450 (CYP) genes	Aquatic Toxicology	152		308-317	CRUSTACEA	Copepods	*Tigriopus japonicus*	CO	IHC	WAF,WHL		ASIA	TOX	SW
282	Hannam, M.L., Bamber, S.D., Galloway, T.S., Moody, A.J. and Jones, M.B.	2010	Effects of the model PAH phenanthrene on immune function and oxidative stress in the haemolymph of the temperate scallop Pecten maximus	Chemosphere	78	7	779-784	MOLLUSC	Scallop	*Pecten maximus*	CO	LAB	PAH		EUR	TOX	SW
283	Hansen, B.H., Altin, D., Bonaunet, K. and Øverjordet, I.B.	2014	Acute Toxicity of Eight Oil Spill Response Chemicals to Temperate, Boreal, and Arctic Species	Journal of Toxicology and Environmental Health	77	9-11 (SI)	495-505	ALGAE CRUSTACEA	Algae (Skeletonema costatum) copepods (Acartia tonsa Calanus finmarchicus and Calanus glacialis) and benthic amphipod (Corophium volutator)	*Skeletonema costatum Acartia tonsa Calanus finmarchicus Calanus glacialis Corophium volutator*	DS	VAR	WHL		EUR	TOX	SW
284	Hansen, B.H., Altin, D., Olsen, A.J. and Nordtug, T.	2012	Acute toxicity of naturally and chemically dispersed oil on the filter-feeding copepod Calanus finmarchicus	Ecotoxicology and Environmental Safety	86		38-46	CRUSTACEA	Copepods	*Calanus finmarchicus*	CO,DS	NSC,DAS	WHL		EUR	TOX	SW
285	Hansen, B.H., Nordtug, T., Altin, D., Booth, A., Hessen, K.M. and Olsen, A J.	2009	Gene Expression of GST and CYP330A1 in Lipid-Rich and Lipid-Poor Female Calanus finmarchicus (Copepoda: Crustacea) Exposed to Dispersed Oil	Journal of Toxicology and Environmental Health	72	3-4	131-139	CRUSTACEA	Copepods	*Calanus finmarchicus*	CO	NSC	WAF,WHL		EUR	TOX	SW
286	Harding, L.E.; Englar, J.R.	1989	The Nestucca oil spill : fate and effects to May 31, 1989	Canada. Environmental Protection Service. Pacific and Yukon Region Regional program report (Vancouver, B.C.); 89-01	89-01		52 pp + app	COMMUNITY	Various	Various	FO	BUC	VAR	NES	BC	ECO	SW
287	Harris, P.M., Rice, S.D., Babcock, M.M. and Brodersen, C.C.	1996	Within-Bed Distribution of Exxon Valdez Crude Oil in Prince William Sound Blue Mussels and Underlying Sediments	Proceedings of the Exxon Valdez Oil Spill Symposium	18		298-308	MOLLUSC	Foolish Mussel	*Mytilus trossulus*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
288	Harris, R.K., Moeller, R.B., Lipscomb, T.P., Pletcher, J.M., Haebler, R.J., Tuomi, P.A., McCormick, C.R., Degange, A.R., Mulcahy, D. and Williams, T.D.	1990	IDENTIFICATION OF A HERPES-LIKE VIRUS IN SEA OTTERS DURING REHABILITATION AFTER THE T-V EXXON VALDEZ OIL SPILL	U S Fish and Wildlife Service Biological Report	90	12	366-368	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
289	Harrison, P.J., Cochlan, W.P., Acreman, J.C., Parsons, T.R., Thompson, P.A. and Dovey, H.M.	1986	The effects of crude oil and Corexit 9527 on marine phytoplankton in an experimental enclosure	Marine Environmental Research	18	2	93-109	PHYTOPLANKTON	PHYTOPLANKTON	Various	CO,DS	ANS,COR	WHL			ECO	SW
290	Hartwick, E.B., Wu, R.S.S., and Parker, D.B.	1982	Effects of a crude oil and an oil dispersant (Corexit 9527) on populations of the littleneck clam (protothaca staminea)	Marine Environmental Research	6	4	291-306	MOLLUSC	Littleneck Clam	*Protothaca staminea*	CO,DS	ALB,COR	WHL		BC	ECO	SW

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291	Harvey, H.R., Taylor, K.A., Pie, H.V. and Mitchelmore, C.L.	2014	Polycyclic aromatic and aliphatic hydrocarbons in Chukchi Sea biota and sediments and their toxicological response in the Arctic cod, Boreogadus saida	Deep-Sea Research Part II-Topical Studies in Oceanography	102		32-55	FISH MOLLUSC	Northern Whelk Arctic cod	*Neptunea heros Boreogadus saida*	CO	CHU	PAH		AK	ECO	SW
292	Harvey, J.T. and Dahlheim, M.E.	1994	Cetaceans in oil	Marine mammals and the Exxon Valdez			257-264	MAMMAL	Dall's porpoise Orca Harbour porpoise	*Phocoenoides dalli Orcinus orca Phocoena phocoena*	CO	ANS	WHL	EVOS	AK	TOX	SW
293	Harwell, M.A. and Gentile, J.H.	2014	Assessing Risks to Sea Otters and the Exxon Valdez Oil Spill: New Scenarios, Attributable Risk, and Recovery	Human and Ecological Risk Assessment	20	4	889-916	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
294	Harwell, M.A. and Gentile, J.H.	2013	Quantifying long-term risks to sea otters from the 1989 'Exxon Valdez' oil spill: Comment on Bodkin et al. (2012)	Marine Ecology Progress Series	488		291-296	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	PAH	EVOS	AK	LIT	SW
295	Harwell, M.A., Gentile, J.H. and Parker, K.R.	2013	Characterizing Ecological Risks, Significance, and Recovery	Oil in the Environment: Legacies and Lessons of the Exxon Valdez Spill			383-420	COMMUNITY	Various	Various	CO	ANS	WHL	EVOS	AK	LIT	SW
296	Harwell, M.A., Gentile, J.H. and Parker, K.R.	2012	Quantifying population-level risks using an individual-based model: Sea otters, Harlequin Ducks, and the Exxon Valdez oil spill	Integrated Environmental Assessment and Management	8	3	503-522	MAMMAL	Harlequin duck Sea otter	*Histrionicus histrionicus Enhydra lutris*	CO	ANS	PAH,WHL	EVOS	AK	MOD	SW
297	Harwell, M.A., Gentile, J.H., Johnson, C.B., Garshelis, D.L. and Parker, K.R.	2010	A Quantitative Ecological Risk Assessment of the Toxicological Risks from Exxon Valdez Subsurface Oil Residues to Sea Otters at Northern Knight Island, Prince William Sound, Alaska	Human and Ecological Risk Assessment	16	4	727-761	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
298	Hatlen, K., Sloan, C.A., Burrows, D.G., Collier, T.K., Scholz, N.L. and Incardona, J.P.	2010	Natural sunlight and residual fuel oils are an acutely lethal combination for fish embryos	Aquatic Toxicology	99	1	56-64	FISH	Zebrafish	*Danio rerio*	CO,FO	ANS	PAH,UVT			TOX	FW
299	Hayakawa, K., Nomura, M., Nakagawa, T., Oguri, S., Kawanishi, T., Toriba, A., Kizu, R., Sakaguchi, T. and Tamiya, E.	2006	Damage to and recovery of coastlines polluted with C-heavy oil spilled from the Nakhodka	Water Research	40	5	981-989	FISH	Greenling Globefish	*Hexagrammidae Tetraodontidae*	FO	BUC	PAH	NAK	ASIA	ECO	SW
300	Haynes, E., Rutecki, T., Murphy, M. and Urban, D.	1995	Impacts of the Exxon Valdez oil spill on bottomfish and shellfish in Prince William Sound	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final ReportAlaska.	Fish/Shellfish Study Number 18		FISH MOLLUSC	Halibut Flathead sole Walleye pollock Pacific cod Sablefish Pacific herring Sidestripe shrimp Tanner crab	*Hippoglossus stenolepis Hippoglossoides elassodon Theragra chalcogramma Gadus macrocephalus Anoplopoma fimbria Clupea harengus Pandalopsis dispar Chionoecetes bairdi*	CO	ANS	WHL	EVOS	AK	ECO	SW
301	Headley, J.V. and McMartin, D.W.	2004	A review of the occurrence and fate of naphthenic acids in aquatic environments	Journal of Environmental Science and Health	39	8	1989-2010				OR	PRW	NAC		AOS	LIT	FW
302	Heintz, R.A.	2001	Effects of oiled incubation substrate on pink salmon reproduction. Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project 01476)	EVOS Trustee Council	Restoration Project	01476	27 pp.	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW

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303	Heintz, R.A., Rice, S. and Bue, B.	1996	Field and laboratory evidence for reduced fitness in pink salmon that incubate in oiled gravel	Proceedings of the Contaminant Effects on Fish Symposium, International Congress of the Biology of Fishes			91-94	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO/TOX	EST,SW
304	Heintz, R.A., Rice, S.D., Carls, M.G. and Short, J.W.	2012	SENSITIVITY OF PINK SALMON (ONCORHYNCHUS GORBUSCHA) EMBRYOS TO WEATHERED CRUDE OIL	Environmental Toxicology and Chemistry	31	3	472-473	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH	EVOS	AK	ECO/TOX	FW
305	Heintz, R.A., Rice, S.D., Carls, M.G. and Short, J.W.	2012	SENSITIVITY OF PINK SALMON (ONCORHYNCHUS GORBUSCHA) EMBRYOS TO WEATHERED CRUDE OIL	Environmental Toxicology and Chemistry	31	3	475-476	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH	EVOS	AK	ECO/TOX	FW
306	Heintz, R.A., Rice, S.D., Wertheimer, A.C., Bradshaw, R.F., Thrower, F.P., Joyce, J.E. and Short, J.W.	2000	Delayed effects on growth and marine survival of pink salmon Oncorhynchus gorbuscha after exposure to crude oil during embryonic development	Marine Ecology Progress Series	208		205-216	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	ECO/TOX	FW
307	Heintz, R.A., Short, J.W. and Rice, S.D.	1999	Sensitivity of fish embryos to weathered crude oil: Part II. Increased mortality of pink salmon (Oncorhynchus gorbuscha) embryos incubating downstream from weathered Exxon Valdez crude oil	Environmental Toxicology and Chemistry	18	3	494-503	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	ECO/TOX	FW
308	Heintz, R.A., Short, J.W., Rice, S.D. and Carls, M.G.	2008	Comment on "toxicity of weathered exxon valdez crude oil to pink salmon embryos"	Environmental Toxicology and Chemistry	27	7	1475-1476	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	TOX	FW
309	Hemmer, M.J., Barron, M.G. and Greene, R.M.	2011	COMPARATIVE TOXICITY OF EIGHT OIL DISPERSANTS, LOUISIANA SWEET CRUDE OIL (LSC), AND CHEMICALLY DISPERSED LSC TO TWO AQUATIC TEST SPECIES	Environmental Toxicology and Chemistry	30	10	2244-2252	CRUSTACEA FISH	Mysid shrimp Inland Silverside	*Americamysis bahia Menidia beryllina*	CO,DS	LSC,VAR	WHL	DWH	GM	TOX	EST
310	Hepler, K.R., Hansen, P.A. and Bernard, D.R.	1994	Impact of oil spilled from the Exxon Valdez on survival and growth of Dolly Varden and cutthroat trout in Prince William Sound, Alaska	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Fish/Shellfish Study Number 5; Restoration Study Number 90		FISH	Dolly varden Cutthroat trout	*Salvelinus malma Oncorhynchus clarkii*	CO	ANS	WHL	EVOS	AK	ECO	SW
311	Hepler, K.R., Hansen, P.A. and Bernard, D.R.	1996	Impact of oil spilled from the Exxon Valdez on survival and growth of Dolly Varden and cutthroat trout in Prince William Sound	Proceedings of the Exxon Valdez Oil Spill Symposium	18		645-658	FISH	Dolly varden Cutthroat trout	*Salvelinus malma Oncorhynchus clarkii*	CO	ANS	WHL	EVOS	AK	ECO	SW
312	Hicken, C.E., Linbo, T.L., Baldwin, D.H., Willis, M.L., Myers, M.S., Holland, L., Larsen, M., Stekoll, M.S., Rice, S.D., Collier, T.K., Scholz, N.L. and Incardona, J.P.	2011	Sublethal exposure to crude oil during embryonic development alters cardiac morphology and reduces aerobic capacity in adult fish	Proceedings of the National Academy of Sciences of the United States of America	108	17	7086-7090	FISH	Zebrafish	*Danio rerio*	CO	ANS	PAH	EVOS	AK	TOX	FW
313	Highsmith, R.C., Rucker, T.L., Stekoll, M.S., Saupe, S.M., Lindeberg, M.R., Jenne, R.N. and Erickson, W.P.	1996	Impact of the Exxon Valdez Oil Spill on Intertidal Biota	Proceedings of the Exxon Valdez Oil Spill Symposium	18		212-237	ALGAE ANNELIDA CRUSTACEA MOLLUSC	Rock Weed Barnacles Mussels Sitka Periwinkle Checkered Periwinkle Limpets Oligochaetes	*Fucus gardneri Balanus spp Mytilus spp Littorina sitkana Littorina scutulata Lottia spp Oligochaeta*	CO	ANS	WHL	EVOS	AK	ECO	SW

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314	Highsmith, R.C., Stekoll, M.S., Barber, W.E., McDonald, L., Strickland, D. and Erickson, W.P.	1994	Comprehensive assessment of coastal habitat	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Coastal Habitat Study Number 1A		COMMUNITY	Intertidal Community	Various	CO	ANS	WHL	EVOS	AK	ECO	SW
315	Hilborn, R.	1996	Detecting population impacts from oil spills: A comparison of methodologies	Proceedings of the Exxon Valdez Oil Spill Symposium	18		639-644				CO	ANS	WHL	EVOS	AK	ECO	SW
316	Hilborn, R. and Eggers, D.	2000	A review of the hatchery programs for pink salmon in Prince William Sound and Kodiak Island, Alaska	Transactions of the American Fisheries Society	129	2	333-350	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	EST,FW
317	Hing, L.S., Ford, T., Finch, P., Crane, M. and Morritt, D.	2011	Laboratory stimulation of oil-spill effects on marine phytoplankton	Aquatic Toxicology	103	42036	32-37	ALGAE	PHYTOPLANKTON	*Phaeodactylum tricornutum Isochrysis galbana Chlorella salina*	FO	DSL	WHL			TOX	SW
318	Hjermann, D.Ø., Melsom, A., Dingsør, G.E., Durant, J.M., Eikeset, A.M., Røed, L.P., Ottersen, G., Storvik, G. and Stenseth, N.C.	2007	Fish and oil in the Lofoten-Barents Sea system: synoptic review of the effect of oil spills on fish populations	Marine Ecology Progress Series	339		283-299	FISH	Atlantic cod Capelin Atlantic herring	*Gadus morhua Mallotus villosus Clupea harengus*	CO	BRC	WHL		EUR	LIT	SW
319	Hoffmann, A. and Hansen, P.	1994	Injury to demersal rockfish and shallow reef habitats in Prince William Sound, 1989-1991	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Subtidal Study Number 6, Fish/Shellfish 17		FISH	Rockfishes	*Sebastes spp*	CO	ANS	WHL	EVOS	AK	ECO	SW
320	Hoffmann, A. and Hansen, P.	1994	Injury to Demersal Rockfish and Shallow Reef Habitats in Prince William Sound, 1989~1991, Subtidal Study Number 6 (Fish/Shellfish Study Number 17), Final Report	EVOS Trustee Council	Subtidal Study (Fish/Shellfish Study)	ST06 (FS17)	128 pp.	FISH	Rockfishes	*Sebastes spp*	CO	ANS	WHL	EVOS	AK	ECO	SW
321	Holdway, D.A.	2002	The acute and chronic effects of wastes associated with offshore oil and gas production on temperate and tropical marine ecological processes	Marine Pollution Bulletin	44	3	185-203				CO	VAR	PRD			LIT	SW
322	Holland-Bartels, L.	1996	Mechanisms of impact and potential recovery of nearshore vertebrate predators, Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project 95025)	EVOS Trustee Council	Restoration Project	95025	116 pp.	MAMMAL	Harlequin duck Sea otter	*Histrionicus histrionicus Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
323	Hom, T., Varanasi, U., Stein, J.E., Sloan, C.A., Tilbury, K.L. and Chan, S.L.	1996	Assessment of the Exposure of Subsistence Fish to Aromatic Compounds after the Exxon Valdez Oil Spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		856-866	FISH	Pink salmon Coho salmon Chinook salmon Pacific halibut Pacific cod	*Oncorhynchus gorbuscha Oncorhynchus kisutch Oncorhynchus tshawytscha Hippoglossus stenolepsis Gadus macrocephalus*	CO	ANS	PAH	EVOS	AK	ECO	SW
324	Hook, S.E. and Osborn, H.L.	2012	Comparison of toxicity and transcriptomic profiles in a diatom exposed to oil, dispersants, dispersed oil	Aquatic Toxicology	124		139-151	PHYTOPLANKTON	Diatoms	*Phaeodactylum tricornutum*	CO,DS	BSC,SGN	CWF,WAF		AUS	TOX	SW
325	Hook, S.E., Lampi, M.A., Febbo, E.J., Ward, J.A. and Parkerton, T.F.	2010	Temporal patterns in the transcriptomic response of rainbow trout, Oncorhynchus mykiss, to crude oil	Aquatic Toxicology	99	3	320-329	FISH	Rainbow trout	*Oncorhynchus mykiss*	CO	UKN	WAF,WHL			TOX	FW

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326	Hook, S.E., Lampi, M.A., Febbo, E.J., Ward, J.A. and Parkerton, T.F.	2010	HEPATIC GENE EXPRESSION IN RAINBOW TROUT (ONCORHYNCHUS MYKISS) EXPOSED TO DIFFERENT HYDROCARBON MIXTURES	Environmental Toxicology and Chemistry	29	9	2034-2043	FISH	Rainbow trout	*Oncorhynchus mykiss*	CO,FO	UKN,HFO,IFO,LFO	WAF			TOX	FW
327	Hook, S.E., Osborn, H.L., Spadaro, D.A. and Simpson, S.L.	2014	Assessing mechanisms of toxicant response in the amphipod Melita plumulosa through transcriptomic profiling	Aquatic Toxicology	146		247-257	CRUSTACEA	*Amphipod*	*Melita plumulosa*	CO,FO	UKN,DSL	BTX,PAH,TPH			TOX	FW,SED,SW
328	Hooten, A.J. and Highsmith, R.C.	1996	Impacts on Selected Intertidal Invertebrates in Herring Bay, Prince William Sound, after the Exxon Valdez Oil Spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		249-270	ECHINODERM MOLLUSC	Masked Limpet Sitka Periwinkle	*Littorina sitkana Tectura persona*	CO	ANS	WHL	EVOS	AK	ECO	SW
329	Hoover-Miller, A., Parker, K.R. and Burns, J.J.	2001	A reassessment of the impact of the Exxon Valdez oil spill on harbor seals (Phoca vitulina richardsi) in Prince William Sound, Alaska	Marine Mammal Science	17	1	111-135	MAMMAL	Harbour seal	*Phoca vitulina*	CO	ANS	WHL	EVOS	AK	ECO	SW
330	Horel, A., Mortazavi, B. and Sobecky, P.A.	2012	Responses of microbial community from northern Gulf of Mexico sandy sediments following exposure to deepwater horizon crude oil	Environmental Toxicology and Chemistry	31	5	1004-1011	MICROBIA	Various	Various	CO,FO	MAC,DSL	PAH,WHL	DWH	GM	ECO	SW
331	Hose, J.E. and Brown, E.D.	1998	Field applications of the piscine anaphase aberration test: lessons from the Exxon Valdez oil spill	Mutation Research-Fundamental and Molecular Mechanisms of Mutagenesis	399	2	167-178	FISH	Pacific herring	*Clupea pallasii*	CO	ANS	PAH,WHL	EVOS	AK	LIT	SW
332	Hose, J.E., McGurk, M.D., Marty, G.D., Hinton, D.E., Brown, E.D. and Baker, T.T.	1996	Sublethal effects of the (Exxon Valdez) oil spill on herring embryos and larvae: morphological, cytogenetic, and histopathological assessments, 1989 1991	Canadian Journal of Fisheries and Aquatic Sciences	53	10	2355-2365	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	ECO/TOX	SW
333	Houghton, J.P., Fukuyama, A.K., Lees, D.C., Hague, P.J. and Cumberland, H.L.	1992	Evaluation of the condition of Prince William Sound shorelines following the Exxon Valdez oil spill and subsequent shoreline treatment: Volume 2, 1991 Biological Monitoring Survey	NOAA Technical Memorandum			262 pp.	COMMUNITY	Various	Various	CO	ANS	WHL	EVOS	AK	ECO	SW
334	Houghton, J.P., Gilmour, R., Lees, D.C. and Driskell, W.B.	1995	Hard shelled clam recovery from Exxon Valdez oiling and shoreline treatment	International Oil Spill Conference Proceedings	1995	1	985-987	MOLLUSC	Native Littleneck Clam	*Protothaca staminea*	CO	ANS	WHL	EVOS	AK	ECO	SW
335	Houghton, J.P., Gilmour, R., Lees, D.C., Driskell, W.B., Lindstrom, S.C. and Mearns, A.	1997	PRINCE WILLIAM SOUND INTERTIDAL BIOTA SEVEN YEARS LATER: HAS IT RECOVERED?	International Oil Spill Conference Proceedings	1997	1	679-686	COMMUNITY	Various	Various	CO	ANS	WHL	EVOS	AK	ECO	SW
336	Houghton, J.P., Lees, D.C., Driskell, W.B. and Lindstrom, S.C.	1997	Evaluation of the condition of Prince William Sound shorelines following the Exxon Valdez oil spill and subsequent shoreline treatment: Volume 1, 1995 Biological Monitoring Survey	NOAA Technical Memorandum			134 pp.	COMMUNITY	Various	Various	CO	ANS	WHL	EVOS	AK	ECO	SW
337	Houghton, J.P., Lees, D.C., Driskell, W.B., Lindstrom, S.C. and Mearns, A.J.	1996	Recovery of Prince William Sound Intertidal Epibiota From Exxon Valdez Oiling and Shoreline Treatments, 1989 Through 1992	Proceedings of the Exxon Valdez Oil Spill Symposium	18		379-441	ALGAE CRUSTACEA MOLLUSC	Rock Weed Black Pine Barnacles Periwinkles Limpets Mussels Hairy Hermit Crab	*Fucus gardneri Rhodomela larix Balanus spp Littorina spp Lottia spp Mytilus spp Pagrus hirsutiusculus*	CO	ANS	WHL	EVOS	AK	ECO	SW
338	Huang, Y.J., Jiang, Z.B., Zeng, J.N., Chen, Q.Z., Zhao, Y.Q., Liao, Y.B., Shou, L. and Xu, X.Q.	2011	The chronic effects of oil pollution on marine phytoplankton in a subtropical bay, China	Environmental Monitoring and Assessment	176	42095	517-530	ALGAE	PHYTOPLANKTON	Various	CO	LOC	WAF		ASIA	TOX	SW
339	Huggett, R.J., Neff, J.M., Stegeman, J.J., Woodin, B., Parker, K.R. and Brown, J.S.	2006	Biomarkers of PAH exposure in an intertidal fish species from Prince William Sound, Alaska: 2004-2005	Environmental Science & Technology	40	20	6513-6517	FISH	High cockscomb	*Anoplarchus purpurescens*	CO	ANS	PAH,WHL	EVOS	AK	ECO/TOX	SW

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340	Hughes, J.B.	1999	Cytological-cytogenetic analyses of winter flounder embryos collected from the benthos at the barge North Cape oil spill	Marine Pollution Bulletin	38	1	30-35	FISH	Winter flounder	*Pseudopleuronectes americanus*	FO	DSL	WHL	NCP	NY	ECO/TOX	SW
341	Hulathduwa, Y.D. and Brown, K.M.	2006	Relative importance of hydrocarbon pollutants, salinity and tidal height in colonization of oyster reefs	Marine Environmental Research	62	4	301-314	CRUSTACEA FISH MOLLUSC	Gobies Shrimp Crab Snails	*Gobionellus spp Alpheus heterochaelis Panopeus simpsoni Nassarius acutus*	CO,DS	LLS,COR	WHL		GM	TOX	SW
342	Hwang, H.M., Stanton, B., Mcbride, T. and Anderson, M.J.	2014	POLYCYCLIC AROMATIC HYDROCARBON BODY RESIDUES AND LYSOSOMAL MEMBRANE DESTABILIZATION IN MUSSELS EXPOSED TO THE DUBAI STAR BUNKER FUEL OIL (INTERMEDIATE FUEL OIL 380) SPILL IN SAN FRANCISCO BAY	Environmental Toxicology and Chemistry	33	5	1117-1121	MOLLUSC	Mussels	*Mytilus sp.*	FO	IFO	PAH	DUB	CA	ECO	SW
343	Hylland, K.	2006	Polycyclic aromatic hydrocarbon (PAH) ecotoxicology in marine ecosystems	Journal of Toxicology and Environmental Health	69	1-2	109-123				BG,CO	VAR	PAH			LIT	SW
344	Incardona, J.P., Carls, M.G., Day, H.L., Sloan, C.A., Bolton, J.L., Collier, T.K. and Scholz, N.L.	2009	Cardiac Arrhythmia Is the Primary Response of Embryonic Pacific Herring (Clupea pallasi) Exposed to Crude Oil during Weathering	Environmental Science & Technology	43	1	201-207	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,WHL	EVOS	AK	TOX	SW
345	Incardona, J.P., Carls, M.G., Teraoka, H., Sloan, C.A., Collier, T.K. and Scholz, N.L.	2005	Aryl hydrocarbon receptor-independent toxicity of weathered crude oil during fish development	Environmental Health Perspectives	113	12	1755-1762	FISH	Zebrafish	*Danio rerio*	CO	LAB	PAH	EVOS	AK	TOX	FW
346	Incardona, J.P., Collier, T.K. and Scholz, N.L.	2004	Defects in cardiac function precede morphological abnormalities in fish embryos exposed to polycyclic aromatic hydrocarbons	Toxicology and Applied Pharmacology	196	2	191-205	FISH	Zebrafish	*Danio rerio*	CO	LAB	PAH	EVOS	AK	TOX	FW
347	Incardona, J.P., Gardner, L.D., Linbo, T.L., Brown, T.L., Esbaugh, A.J., Mager, E.M., Stieglitz, J.D., French, B.L., Labenia, J.S., Laetz, C A., Tagal, M., Sloan, C.A., Elizur, A., Benetti, D.D., Grosell, M., Block, B.A. and Scholz, N.L.	2014	Deepwater Horizon crude oil impacts the developing hearts of large predatory pelagic fish	Proceedings of the National Academy of Sciences of the United States of America	111	15	E1510-E1518	FISH	Yellowfin tuna Southern bluefin tuna Yellowtail jack	*Thunnus albacares Thunnus maccoyii Seriola lalandi*	CO	MAC	PAH	DWH	GM	TOX	SW
348	Incardona, J.P., Swarts, T.L., Edmunds, R.C., Linbo, T.L., Aquilina-Beck, A., Sloan, C.A., Gardner, L.D., Block, B.A. and Scholz, N.L.	2013	Exxon Valdez to Deepwater Horizon: Comparable toxicity of both crude oils to fish early life stages	Aquatic Toxicology	142		303-316	FISH	Zebrafish	*Danio rerio*	CO	ANS,MAC	WHL	EVOS,DWH	AK,GM	TOX	FW
349	Incardona, J.P., Vines, C.A., Anulacion, B.F., Baldwin, D.H., Day, H.L., French, B.L., Labenia, J.S., Linbo, T.L., Myers, M.S., Olson, O.P., Sloan, C.A., Sol, S., Griffin, F.J., Menard, K., Morgan, S G., West, J.E., Collier, T.K., Ylitalo, G.M., Cherr, G.N. and Scholz,	2012	Unexpectedly high mortality in Pacific herring embryos exposed to the 2007 Cosco Busan oil spill in San Francisco Bay	Proceedings of the National Academy of Sciences of the United States of America	109	2	E51-E58	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	FO	BUC	UVT	COB	CA	ECO/TOX	SW

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	N.L.																
350	Incardona, J.P., Vines, C.A., Linbo, T.L., Myers, M.S., Sloan, C.A., Anulacion, B.F., Boyd, D., Collier, T.K., Morgan, S., Cherr, G N. and Scholz, N.L.	2012	Potent Phototoxicity of Marine Bunker Oil to Translucent Herring Embryos after Prolonged Weathering	Plos One	7	2	E30116	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	FO	BUC	UVT	COB	CA	ECO/TOX	SW
351	Ingvarsdóttir, A., Bjørkblom, C., Ravagnan, E., Godal, B.F., Arnberg, M., Joachim, D.L. and Sanni, S.	2012	Effects of different concentrations of crude oil on first feeding larvae of Atlantic herring (Clupea harengus)	Journal of Marine Systems	93	SI	69-76	FISH	Atlantic Herring	*Clupea harengus*	CO	ARC	PAH		EUR	TOX	SW
352	Irie, K., Kawaguchi, M., Mizuno, K., Song, J.Y., Nakayama, K., Kitamura, S. and Murakami, Y.	2011	Effect of heavy oil on the development of the nervous system of floating and sinking teleost eggs	Marine Pollution Bulletin	63	5-12 SI	297-302	FISH	Grouper Convict grouper Thread-sail filefish Filefish Japanese flounder Pufferfish	*Epinephelus bruneus Epinephelus septemfasciatus Stephanolepis cirrhifer Thamnaconus modestus Paralichthys olivaceus Takifugu rubripes*	FO	HFO	WHL		ASIA	TOX	SW
353	Irvine, G.V., Mann, D.H. and Short, J.W.	1996	Geomorphic position, weathering, and possible biotic impacts of oil mousse persisting on a high energy coastline distant from the Exxon Valdez spill	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 94266-1					CO	ANS	PAH	EVOS	AK	PHYS	SED,SW
354	Irvine, G.V., Mann, D.H. and Short, J.W.	2002	Residual oiling of armored beaches and mussel beds in the Gulf of Alaska	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 00459		MOLLUSC	Mussels	*Mytilus sp.*	CO	ANS	TPH	EVOS	AK	PHYS	SED,SW
355	Irvine, G.V., Mann, D.H. and Short, J.W.	2007	Monitoring lingering oil from the Exxon Valdez Spill in Gulf of Alaska armored beaches and mussel beds sixteen years post-spill	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 040708		MOLLUSC	Mussels	*Mytilus sp.*	CO	ANS	TPH	EVOS	AK	PHYS	SED,SW
356	Irvine, G.V., Mann, D.H. and Short, J.W.	1999	Multi-year persistence of oil mousse on high energy beaches distant from the Exxon Valdez spill origin	Marine Pollution Bulletin	38	7	572-584				CO	ANS	PAH,WHL	EVOS	AK	PHYS	SED,SW
357	Jenssen, B.M.	1996	An overview of exposure to, and effects of, petroleum oil and organochlorine pollution in Grey seals (Halichoerus grypus)	Science of The Total Environment	186	1–2	109-118	MAMMAL	Baltic Grey Seal	*Halichoerus grypus*	CO	VAR	WHL		EUR	LIT	SW
358	Jewett, S.C. and Dean, T.A.	1997	Effects of the Exxon Valdez oil spill on eelgrass communities in Prince William Sound, Alaska, 1990-95	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 95106	291 p	CRUSTACEA FISH MOLLUSC PLANT	Cods Clams Snails Crabs Amphipods Sea stars Worms Eelgrass	*Gadidae Bivalvia Gastropoda Crustacea Echinodermata Zostera marina*	CO	ANS	PAH	EVOS	AK	ECO	SW
359	Jewett, S.C., Dean, T.A. and Laur, D.R.	1996	Effects of the Exxon Valdez Oil Spill on Benthic Invertebrates in an Oxygen-Deficient Embayment in Prince William Sound, Alaska	Proceedings of the Exxon Valdez Oil Spill Symposium	18		440-447	COMMUNITY	Various	Various	CO	ANS	WHL	EVOS	AK	ECO	SW

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360	Jewett, S.C., Dean, T.A., Smith, R.O. and Blanchard, A.	1999	'Exxon Valdez' oil spill: impacts and recovery in the soft-bottom benthic community in and adjacent to eelgrass beds	Marine Ecology Progress Series	185		59-83	COMMUNITY	Various	Various	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
361	Jewett, S.C., Dean, T.A., Smith, R.O., Stekoll, M., Haldorson, L.J., Laur, D.R. and McDonald, L.	1995	Effects of the Exxon Valdez oil spill on shallow subtidal communities in Prince William Sound, Alaska 1989-93	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 93047, Subtidal Study Number 2A		CRUSTACEA FISH MOLLUSC PLANT	Cods Clams Snails Crabs Amphipods Sea stars Worms Eelgrass	*Gadidae Bivalvia Gastropoda Crustacea Echinodermata Zostera marina*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
362	Jewett, S.C., Dean, T.A., Woodin, B.R., Hoberg, M.K. and Stegeman, J.J.	2002	Exposure to hydrocarbons 10 years after the Exxon Valdez oil spill: evidence from cytochrome P4501A expression and biliary FACs in nearshore demersal fishes	Marine Environmental Research	54	1	21-48	FISH	Masked greenling Crescent gunnel	*Hexagrammos octogrammus Pholis laeta*	CO	ANS	WAF,WHL	EVOS	AK	ECO/TOX	SW
363	Jewett, S.C., Hoberg, M.K., Dean, T.A., Woodin, B.R. and Stegeman, J.J.	2003	Exposure to hydrocarbons 10 years after the Exxon Valdez oil spill: evidence from cytochrome P4501A expression and biliary FACs in nearshore demersal fishes	Marine Environmental Research	55	5	463-468	FISH	Masked greenling Crescent gunnel	*Hexagrammos octogrammus Pholis laeta*	CO	ANS	WHL	EVOS	AK	ECO/TOX	SW
364	Jiang, X., Wang, G. and Lin, Q.	2008	Reduction of hydrocarbon contamination on viability of Acartia pacifica benthic resting eggs	Chinese Journal of Oceanology and Limnology	26	1	91-96	CRUSTACEA	Copepods	*Acartia pacifica*	FO	LFO	WHL		ASIA	TOX	SED,SW
365	Jiang, Z., Huang, Y., Chen, Q., Zeng, J. and Xu, X.	2012	Acute toxicity of crude oil water accommodated fraction on marine copepods: the relative importance of acclimatization temperature and body size	Marine environmental research	81		12-17	CRUSTACEA	Copepods	*Acartia pacifica Acartia spinicauda Calanopia thompsoni Calanus sinicus Centropages dorsispinatus Eucalanus subcrassus Euchaeta concinna Euchaeta marina Harpacticus uniremis Labidocera euchaeta Paracalanus aculeatus Paracalanus parvus Sinocalanus tenellus Tortanus spinicaudatus and Tortanus vermiculus*	CO	LOC	WAF		ASIA	TOX	SW
366	Johnson, D.K. and Rustin, L.R.	2013	Bibliography of Exxon Valdez Oil Spill Publications	Oil in the Environment: Legacies and Lessons of the Exxon Valdez Spill			436 pp.				CO	ANS	VAR	EVOS	AK	LIT	SW
367	Johnson, S.W., Carls, M.G., Stone, R.P., Brodersen, C.C. and Rice, S.D.	1997	Reproductive success of Pacific herring, Clupea pallasi, in Prince William Sound, Alaska, six years after the Exxon Valdez oil spill	Fishery Bulletin	95	4	748-761	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	ECO	SW
368	Jones, D., Scarlett, A.G., West, C.E. and Rowland, S.J.	2011	Toxicity of Individual Naphthenic Acids to Vibrio fischeri	Environmental Science & Technology	45	22	9776-9782	CRUSTACEA MICROBIA	MICROTOX® Daphnia	*Vibrio fischeri Daphnia magna*	CO,OR	LAB,PRW	NAC			TOX	FW
369	Jonker, M.T.O., Brils, J.M., Sinke, A.J.C., Murk, A.J. and Koelmans, A.A.	2006	Weathering and toxicity of marine sediments contaminated with oils and polycyclic aromatic hydrocarbons	Environmental Toxicology and Chemistry	25	5	1345-1353	MICROBIA	MICROTOX®	*Vibrio fischeri*	CO,FO	ARL	PAH,WHL		EUR	TOX	SED,SW
370	Jung, J.H., Yim, U.H., Han, G.M. and Shim, W.J.	2009	Biochemical changes in rockfish, Sebasres schlegeli, exposed to dispersed crude oil	Comparative Biochemistry and Physiology	150	2	218-223	FISH	Korean (black) rockfish	*Sebastes schlegeli*	CO,DS	AMC,COR,HCN	CWF,WAF		ASIA	TOX	SW

RefID	Author(s)	Year	Title	Journal	Volume	Issue	Pages	Taxon	CommonName	Scientific Name	MainProduct	SpecificProduct	ComponentsAnalyzed	Event	Location	StudyType	ExposureMedia
371	Karydis, M.	1981	THE TOXICITY OF CRUDE-OIL FOR THE MARINE ALGA SKELETONEMA-COSTATUM (GREVILLE) CLEVE IN RELATION TO NUTRIENT LIMITATION	Hydrobiologia	85	2	137-143	ALGAE	Diatoms	*Skeletonema costatum*	CO	TUN	WHL		EUR	TOX	SW
372	Kauss, P., Hutchinson, T.C., Soto, C., Hellebust, J. and Griffiths, M.	1973	The Toxicity of Crude Oil and its Components to Freshwater Algae	International Oil Spill Conference Proceedings	1973	1	703-714	ALGAE	Green algae (Chlorella vulgaris Chlamydomonas angulosa Cosmarium minutissimum Ankistrodesmus convolutus A. falcatus var. acicularis) yellow-green alga (Dinobryon sertularia)	*Green algae (Chlorella vulgaris Chlamydomonas angulosa Cosmarium minutissimum Ankistrodesmus convolutus A. falcatus var. acicularis) yellow-green alga (Dinobryon sertularia)*	CO	MSB	WHL		ON	ECO/TOX	FW
373	Kavanagh, R.J., Frank, R.A., Oakes, K.D., Servos, M.R., Young, R.F., Fedorak, P.M., MacKinnon, M.D., Solomon, K.R., Dixon, D.G. and Van Der Kraak, G.	2011	Fathead minnow (Pimephales promelas) reproduction is impaired in aged oil sands process-affected waters	Aquatic Toxicology	101	1	214-220	FISH	Fathead minnow	*Pimephales promelas*	OR	PRW	NAC		AOS	TOX	FW
374	Kawaguchi, M., Song, J.Y., Irie, K., Murakami, Y., Nakayama, K. and Kitamura, S.	2011	Disruption of Sema3A expression causes abnormal neural projection in heavy oil exposed Japanese flounder larvae	Marine Pollution Bulletin	63	5-12	356-361	FISH	Olive flounder	*Paralichthys olivaceus*	FO	BUC	WHL		ASIA	TOX	SW
375	Kawaguchi, M., Sugahara, Y., Watanabe, T., Irie, K., Ishida, M., Kurokawa, D., Kitamura, S., Takata, H., Handoh, I.C., Nakayama, K. and Murakami, Y.	2012	Nervous system disruption and concomitant behavioral abnormality in early hatched pufferfish larvae exposed to heavy oil	Environmental Science and Pollution Research	19	7	2488-2497	FISH	Japanese puffer	*Takifugu rubripes*	FO	BUC	WHL		ASIA	TOX	SW
376	Kazlauskienė, N. and Taujanskis, E.	2011	Effects of Crude Oil and Oil Cleaner Mixture on Rainbow Trout in Early Ontogenesis	Polish Journal of Environmental Studies	20	2	509-511	FISH	Rainbow trout	*Oncorhynchus mykiss*	CO,DS	LTH,CSG	WHL		EUR	TOX	FW
377	Kazlauskienė, N., Svecevičius, G., Petrauskienė, L. and Vosylienė, M.Z.	2010	Behavioural Responses of Medicinal Leech and Rainbow Trout Exposed to Crude Oil and Heavy Fuel Oil in Ontogenesis	Polish Journal of Environmental Studies	19	2	429-433	ANNELIDA FISH	Medicinal leech Rainbow trout	*Hirudo verbana Oncorhynchus mykiss*	CO,FO	GRK,HFO	WHL		EUR	TOX	FW
378	Kazlauskienė, N., Svecevicius, G., Vosylienė, M.Z., Marciulionienė, D. and Montvydienė, D.	2004	Comparative study on sensitivity of higher plants and fish to heavy fuel oil	Environmental Toxicology	19	4	449-451	FISH PLANT	Garden cress Great duckweed *Tradescantia* clone BNL 02 Rainbow trout	*Lepidium sativum Spirodela polyrrhiza Tradescantia sp Oncorhynchus mykiss*	FO	HFO	WHL		EUR	TOX	FW
379	Kennedy, C.J.	2014	Multiple Effects of Oil and Its Components in Fish	Impacts of Oil Spill Disasters on Marine Habitats and Fisheries in North America			3-34	FISH	Cods Salmonids Herrings	*Gadus spp Oncorhynchus spp Clupea spp*	CO	VAR	PAH			LIT	FW,SW
380	Kennedy, C.J. and Farrell, A.P.	2005	Ion homeostasis and interrenal stress responses in juvenile Pacific herring, Clupea pallasi, exposed to the water-soluble fraction of crude oil	Journal of Experimental Marine Biology and Ecology	323	1	43-56	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,WHL	EVOS	AK	TOX	SW
381	Kennedy, C.J. and Farrell, A.P.	2006	Effects of exposure to the water-soluble fraction of crude oil on the swimming performance and the metabolic and ionic recovery postexercise in pacific herring (Clupea pallasi)	Environmental Toxicology and Chemistry	25	10	2715-2724	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,WAF	EVOS	AK	TOX	SW
382	Kennedy, C.J. and Farrell, A.P.	2008	Immunological alterations in juvenile Pacific herring, Clupea pallasi, exposed to aqueous hydrocarbons derived from crude oil	Environmental Pollution	153	3	638-648	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,WHL	EVOS	AK	TOX	SW

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383	Khan, N., Warith, M.A. and Luk, G.	2007	A comparison of acute toxicity of biodiesel, biodiesel blends, and diesel on aquatic organisms	Journal of the Air & Waste Management Association	57	3	286-296	CRUSTACEA FISH	Daphnia Rainbow trout	*Daphnia magna Oncorhynchus mykiss*	FO	DSL	WHL			TOX	FW
384	Khan, R.A.	1990	PARASITISM IN MARINE FISH AFTER CHRONIC EXPOSURE TO PETROLEUM-HYDROCARBONS IN THE LABORATORY AND TO THE EXXON VALDEZ OIL-SPILL	Bulletin of Environmental Contamination and Toxicology	44	5	759-763	FISH	Atlantic cod Longhorn sculpin Tidepool sculpin	*Gadus morhua Myoxocephalus octodecemspinosus Oligocottus maculatus*	CO	ANS,HBN	WAF,WHL	EVOS	AK	ECO/TOX	SW
385	Khan, R.A.	1991	EFFECT OF OIL-CONTAMINATED SEDIMENT ON THE LONGHORN SCULPIN (MYOXOCEPHALUS-OCTODECEMSPINOSUS) FOLLOWING CHRONIC EXPOSURE	Bulletin of Environmental Contamination and Toxicology	47	1	63-69	FISH	Longhorn sculpin	*Myoxocephalus octodecemspinosus*	BG,CO	HBN	WHL		NL	TOX	SW
386	Khan, R.A. and Nag, K.	1993	ESTIMATION OF HEMOSIDEROSIS IN SEABIRDS AND FISH EXPOSED TO PETROLEUM	Bulletin of Environmental Contamination and Toxicology	50	1	125-131	FISH	Longhorn sculpin Yellowfin sole Quillback rockfish kelp greenling	*Myoxocephalus octodecemspinosus Limanda aspersa Sebastes maliger Hexagrammos decagrammus*	CO	ANS	WHL	EVOS	AK	ECO	SW
387	Khan, R.A. and Payne, J.F.	2005	Influence of a crude oil dispersant, corexit 9527, and dispersed oil on capelin (Mallotus villosus), Atlantic cod (Gadus morhua), longhorn sculpin (Myoxocephalus octodecemspinosus), and cunner (Tautogolabrus adspersus)	Bulletin of Environmental Contamination and Toxicology	75	1	50-56	FISH	Capelin Atlantic cod Longhorn sculpin Cunner	*Mallotus villosus Gadus morhua Myoxocephalus octodecemspinosus Tautogolabrus adspersus*	CO,DS	HBN,COR	WHL		NL	TOX	SW
388	Kim, H.N., Park, C., Chae, Y.S., Shim, W.J., Kim, M., Addison, R.F.,and Jung, J.H.	2013	Acute toxic responses of the rockfish (Sebastes schlegeli) to Iranian heavy crude oil: Feeding disrupts the biotransformation and innate immune systems	Fish & Shellfish Immunology	35	2	357-365	FISH	Korean (black) rockfish	*Sebastes schlegeli*	CO	IHC	WHL	HEB	ASIA	TOX	SW
389	King, T.L., Robinson, B., Boufadel, M. and Lee, K.	2014	Flume tank studies to elucidate the fate and behavior of diluted bitumen spilled at sea	Marine pollution bulletin	83	1	32-37				OR	DBT	WHL		AOS	PHYS	SW
390	Knag, A.C., Sebire, M., Mayer, I., Meier, S., Renner, P. and Katsiadaki, I.	2013	In vivo endocrine effects of naphthenic acids in fish	Chemosphere	93	10	2356-2364	FISH	Threespine stickleback	*Gasterosteus aculeatus*	CO	NSC	NAC,WAF		EUR	TOX	FW,SW
391	Ko, J.Y. and Day, J.W.	2004	A review of ecological impacts of oil and gas development on coastal ecosystems in the Mississippi Delta	Ocean & Coastal Management	47	11-12	597-623	COMMUNITY	Various	Various	CO,DS	VAR	WHL		GM	LIT	EST
392	Kocan, R.M., Hose, J.E., Brown, E.D. and Baker, T.T.	1996	Pacific herring (Clupea pallasi) embryo sensitivity to Prudhoe Bay petroleum hydrocarbons: Laboratory evaluation and in situ exposure at oiled and unoiled sites in Prince William Sound	Canadian Journal of Fisheries and Aquatic Sciences	53	10	2366-2375	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	TOX	SW
393	Kocan, R.M., Marty, G.D. and Kennedy, C.J.	1999	Investigations of disease factors affecting declines of Pacific herring populations in Prince William Sound	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 98162		FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	ECO	SW
394	Kocan, R.M., Marty, G.D., Okihiro, M.S., Brown, E.D. and Baker, T.T.	1996	Reproductive success and histopathology of individual Prince William Sound Pacific herring 3 years after the Exxon Valdez oil spill	Canadian Journal of Fisheries and Aquatic Sciences	53	10	2388-2393	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	ECO	SW
395	Korn, S., Moles, D.A. and Rice, S.D.	1979	Effects of Temperature on the Median Tolerance Limit of Pink Salmon and Shrimp Exposed to Toluene, Naphthalene, and Cook Inlet Crude Oil	Bulletin of Environmental Contamination and Toxicology	21	4-5	521-525	CRUSTACEA FISH	Pink salmon Eualid shrimp Pink shrimp	*Oncorhynchus gorbuscha Eualus spp Pandalus goniurus*	CO	COI	BTX,PAH,WAF		AK	TOX	SW
396	Kovalenko, K.E., Ciborowski, J.J.H., Daly, C., Dixon, D.G., Farwell, A.J., Foote, A.L., Frederick, K.R., Costa, J.M.G.,	2013	Food web structure in oil sands reclaimed wetlands	Ecological Applications	23	5	1048-1060	COMMUNITY	Various	Various	OR	BIT	WHL		AOS	ECO	FW

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	Kennedy, K., Liber, K., Roy, M.C., Slama, C.A. and Smits, J.E.G.																
397	Koyama, J. and Kakuno, A.	2004	Toxicity of heavy fuel oil, dispersant, and oil-dispersant mixtures to a marine fish, Pagrus major	Fisheries Science	70	4	587-594	FISH	Red Sea Bream	*Pagrus major*	DS,FO	NEO,SEG,HYT,HFO,BUC	WAF	DIA	ASIA	TOX	SW
398	Krahn, M.M., Burrows, D.G., Ylitalo, G.M., Brown, D.W., Wigren, C.A., Collier, T.K., Chan, S.L. and Varanasi, U.	1992	MASS-SPECTROMETRIC ANALYSIS FOR AROMATIC-COMPOUNDS IN BILE OF FISH SAMPLED AFTER THE EXXON-VALDEZ OIL-SPILL	Environmental Science & Technology	26	1	116-126	FISH	Pacific halibut Pink salmon Walleye pollock	*Hippoglossus stenolepsis Oncorhynchus gorbuscha Theragra chalcogramma*	CO	ANS	PAH	EVOS	AK	ECO/TOX	SW
399	Kuhl, A.J., Nyman, J.A., Kaller, M.D. and Green, C.C.	2013	DISPERSANT AND SALINITY EFFECTS ON WEATHERING AND ACUTE TOXICITY OF SOUTH LOUISIANA CRUDE OIL	Environmental Toxicology and Chemistry	32	11	2611-2620	FISH	Gulf killifish	*Fundulus grandis*	CO,DS	LSC,COR	PAH,WAF	DWH	GM	TOX	EST,SW
400	Lacaze, E., Devaux, A., Bruneau, A., Bony, S., Sherry, J. and Gagné, F.	2014	Genotoxic potential of several naphthenic acids and a synthetic oil sands process-affected water in rainbow trout (Oncorhynchus mykiss)	Aquatic Toxicology	152	0	291-299	FISH	Rainbow trout hepatocytes	*Oncorhynchus mykiss*	OR	PRW	NAC,PAH		AOS	TOX	FW
401	Landrum, P.F., Chapman, P.M., Neff, J. and Page, D.S.	2013	Influence of exposure and toxicokinetics on measures of aquatic toxicity for organic contaminants: A case study review	Integrated Environmental Assessment and Management	9	2	196-210	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	LIT	SW
402	Lane, S.M., Smith, C.R., Mitchell, J., Balmer, B.C., Barry, K.P., McDonald, T., Mori, C.S., Rosel, P.E., Rowles, T.K., Speakman, T.R., Townsend, F.I., Tumlin, M.C., Wells, R.S., Zolman, E.S. and Schwacke, L.H.	2015	Reproductive outcome and survival of common bottlenose dolphins sampled in Barataria Bay, Louisiana, USA, following the Deepwater Horizon oil spill	Proceedings of the Royal Society B	282	1818		MAMMAL	Bottlenose dolphin	*Tursiops truncatus*	CO	MAC	WHL	DWH	GM	ECO	SW
403	Laramore, S., Krebs, W. and Garr, A.	2014	Effects of macondo canyon 252 oil (naturally and chemically dispersed) on larval *Crassostrea virginica* (gmelin, 1791)	Journal of Shellfish Research	33	3	709-718	MOLLUSC	Atlantic Oyster	*Crassostrea virginica*	CO,DS	MAC,COR	CWF,TPH,WAF	DWH	GM	TOX	SW
404	Laramore, S., Shawl, A. and Krebs, W.	2012	Toxic effects of crude oil and the corexit 9500 dispersant on conch (Strombus gigas), oyster (Crassostrea virginica) and shrimp (Penaeus duorarum) larvae	Journal of Shellfish Research	31	1	309-309	MOLLUSC	Conch Atlantic Oyster Shrimp	*Strombus gigas Crassostrea virginica Penaeus duorarum*	CO,DS	UKN,COR	WHL			TOX	SW
405	Laur, D. and Haldorson, L.	1996	Coastal habitat studies: The effect of the Exxon Valdez oil spill on shallow subtidal fishes in Prince William Sound	Proceedings of the Exxon Valdez Oil Spill Symposium	18		659-670	FISH	Pacific cod Arctic shanny Sculpins Lingcod Greenlings Gunnels	*Gadus macrocephalus Stichaeus punctatus Cottidae Ophiodon elongatus Hexagrammos spp Pholis laeta Apodichthys flavidus*	CO	ANS	WHL	EVOS	AK	ECO	SW
406	Law, R.J., Kelly, C., Baker, K., Jones, J., McIntosh, A.D. and Moffat, C.F.	2002	Toxic equivalency factors for PAH and their applicability in shellfish pollution monitoring studies	Journal of Environmental Monitoring	4	3	383-388	FISH MOLLUSC	Fish and shellfish (not specified)		CO	VAR	PAH			LIT	SW
407	Leclair, L.A., MacDonald, G.Z., Phalen, L.J., Koellner, B., Hogan, N.S. and van den Heuvel, M.R.	2013	The immunological effects of oil sands surface waters and naphthenic acids on rainbow trout (Oncorhynchus mykiss)	Aquatic Toxicology	142		185-194	FISH	Rainbow trout	*Oncorhynchus mykiss*	OR	PRW	NAC		AOS	ECO/TOX	FW
408	Lee, K., Boufadel, M., Chen, B., Foght, J., Hodson, P., Swanson, S. and	2015	Expert Panel Report on the Behaviour and Environmental Impacts of Crude Oil Released into Aqueous Environments	Royal Society of Canada Report			461 pp	FISH	Various	Various	CO,OR	VAR,BIT,DBT,DIL	VAR			LIT	EST,FW,SW

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	Venosa, A.																
409	Lee, K., Prince, R.C., Greer, C.W., Doe, K.G., Wilson, J.E.H., Cobanli, S.E., Wohlgeschaffen, G.D., Alroumi, D., King, T. and Tremblay, G.H.	2003	Composition and Toxicity of Residual Bunker C Fuel Oil in Intertidal Sediments After 30 Years	Spill Science & Technology Bulletin	8	2	187-199	CRUSTACEA ECHINODERM FISH MICROBIA	Winter flounder Amphipod Echinoid fertilization test Grass shrimp embryo-larval toxicity (GSELTOX) test Microtox® solid phase test	*Pleuronectes americanus Eohaustorius estuarius Lytechinus pictus Palaemonetes pugio Vibrio fischeri*	FO	BUC	WHL	ARR	NS	ECO/TOX	SW
410	Lee, K.W., Shim, W.J., Yim, U.H. and Kang, J.H.	2013	Acute and chronic toxicity study of the water accommodated fraction (WAF), chemically enhanced WAF (CEWAF) of crude oil and dispersant in the rock pool copepod Tigriopus japonicus	Chemosphere	92	9	1161-1168	CRUSTACEA	Copepods	*Tigriopus japonicus*	CO,DS	IHC,COR,HCN	CWF,WAF	HEB	ASIA	TOX	SW
411	Lee, R.F. and Page, D.S.	1997	Petroleum hydrocarbons and their effects in subtidal regions after major oil spills	Marine Pollution Bulletin	34	11	928-940				CO,FO	VAR	WHL	VAR	VAR	LIT	SW
412	Lees, D.C. and Driskell, W.B.	2007	Assessment of bivalve recovery on treated mixed-soft beaches in Prince William Sound, Alaska	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 040574	120 p	MOLLUSC	Various	Various	CO	ANS	WHL	EVOS	AK	ECO	SW
413	Lees, D.C., Driskell, W.B. and Houghton, J.P.	1999	Response of Infaunal Bivalves to the Exxon Valdez Oil Spill andRelated Shoreline Treatment	International Oil Spill Conference Proceedings	1999	1	999-1002	MOLLUSC	Various	Various	CO	ANS	WHL	EVOS	AK	ECO	SW
414	Lees, D.C., Houghton, J.P. and Driskell, W.B.	1996	Short-Term Effects of Several Types of Shoreline Treatment on Rocky Intertidal Biota in Prince William Sound	Proceedings of the Exxon Valdez Oil Spill Symposium	18		329-348	ALGAE CNIDARIA CRUSTACEA MOLLUSC	Rock Weed Barnacles Mussels Green Sea Anemone Whelks Periwinkles Limpets Hairy Hermit Crab	*Fucus gardneri Balanus spp Mytilus spp Anthopleura xanthogrammica Buccinum spp Littorina spp Lottia spp Pagurus hirsutiusculus*	CO	ANS	WHL	EVOS	AK	ECO	SW
415	Lemiere, S., Cossu-Leguille, C., Bispo, A., Jourdain, M.J., Lanhers, M.C., Burnel, D. and Vasseur, P.	2005	DNA damage measured by the single-cell gel electrophoresis (comet) assay in mammals fed with mussels contaminated by the 'Erika' oil-spill	Mutation Research-Genetic Toxicology and Environmental Mutagenesis	581	1-2	11-21	MAMMAL MOLLUSC	MUSSELS Rats	*Mytilus spp Rattus norvegicus*	FO	HFO	PAH	ERK	FRA	ECO/TOX	SW
416	Lewis, C., Pook, C. and Galloway, T.	2008	Reproductive toxicity of the water accommodated fraction (WAF) of crude oil in the polychaetes Arenicola marina (L.) and Nereis virens (Sars)	Aquatic Toxicology	90	1	73-81	ANNELIDA	Polychaetes	*Arenicola marina Nereis virens*	CO	FOR	WAF		EUR	TOX	SW
417	Lewis, M. and Pryor, R.	2013	Toxicities of oils, dispersants and dispersed oils to algae and aquatic plants: Review and database value to resource sustainability	Environmental Pollution	180		345-367	ALGAE PLANT	Various	Various	CO,DS	VAR	VAR			LIT	SW
418	Lin, C.Y., Anderson, B.S., Phillips, B.M., Peng, A.C., Clark, S., Voorhees, J., Wu, H.D.I., Martin, M.J., McCall, J., Todd, C.R., Hsieh, F., Crane, D., Viant, M.R., Sowby, M.L. and Tjeerdema, R.S.	2009	Characterization of the metabolic actions of crude versus dispersed oil in salmon smolts via NMR-based metabolomics	Aquatic Toxicology	95	3	230-238	FISH	Chinook salmon	*Oncorhynchus tshawytscha*	CO,DS	ANS,COR	CWF,WAF		AK,BC,WA,OR,CA	TOX	SW
419	Lindstrom, J.E. and Braddock, J.F.	2002	Biodegradation of petroleum hydrocarbons at low temperature in the presence of the dispersant Corexit 9500	Marine Pollution Bulletin	44	8	739-747	MICROBIA	Various	Various	CO,DS	ANS,COR	ALH,CWF,PAH	EVOS	AK	TOX	SW

RefID	Author(s)	Year	Title	Journal	Volume	Issue	Pages	Taxon	CommonName	Scientific Name	MainProduct	SpecificProduct	ComponentsAnalyzed	Event	Location	StudyType	ExposureMedia
420	Lipscomb, T.P., Harris, R.K., Moeler,R.B., Pletcher, J.M., Haebler, R.J. and Ballachey, B.E.	1996	Histopathologic lesions associated with crude oil exposure in sea otters	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-10	20 p	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
421	Lipscomb, T.P., Harris, R.K., Moeller, R.B., Pletcher, J.M., Haebler, R.J. and Ballachey, B.E.	1993	HISTOPATHOLOGIC LESIONS IN SEA OTTERS EXPOSED TO CRUDE-OIL	Veterinary Pathology	30	1	42015	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
422	Lipscomb, T.P., Harris, R.K., Rebar, A.H., Ballachey, B.E. and Haebler, R.J.	1996	Pathological studies of sea otters	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-11		MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
423	Liu, B., Romaire, R.P., Delaune, R.D. and Lindau, C.W.	2006	Field investigation on the toxicity of Alaska North Slope crude oil (ANSC) and dispersed ANSC crude to Gulf killifish, Eastern oyster and white shrimp	Chemosphere	62	4	520-526	CRUSTACEA FISH MOLLUSC	Gulf killifish Eastern oyster White shrimp	*Fundulus grandis Crassostrea virginica Litopenaeus setiferus*	CO,DS	ANS,COR	WHL		GM	ECO/TOX	EST,SW
424	Lively, J.A.A. and Mckenzie, J.	2014	Toxicity of the Dispersant Corexit 9500 to Early Life Stages of Blue Crab, Callinectes sapidus	Bulletin of Environmental Contamination and Toxicology	93	6	649-653	CRUSTACEA	Blue crab	*Callinectes sapidus*	DS	COR	WHL	DWH	GM	TOX	SW
425	Lo, C.C., Brownlee, B.G. and Bunce, N.J.	2006	Mass spectrometric and toxicological assays of Athabasca oil sands naphthenic acids	Water Research	40	4	655-664	CRUSTACEA MICROBIA	MICROTOX® Daphnia	*Vibrio fischeri Daphnia magna*	OR	PRW	NAC		AOS	TOX	FW
426	Lockhart, W.L., Duncan, D A., Billeck, B.N., Danell, R.A. and Ryan, M J.	1996	Chronic toxicity of the 'water-soluble fraction' of Norman Wells crude oil to juvenile fish	Spill Science & Technology Bulletin	3	4	259-262	FISH	Rainbow trout	*Oncorhynchus mykiss*	CO,DS	NWC,COR	WAF			TOX	FW
427	Logan, D.T.	2007	Perspective on ecotoxicology of PAHs to fish	Human and Ecological Risk Assessment	13	2	302-316	FISH	Rainbow trout Pacific herring Pink salmon Eelpout Common carp Chinook salmon	*Oncorhynchus mykiss Clupea pallasii Oncorhynchus gorbuscha Zoarces viviparus Cyprinus carpio Oncorhynchus tshawytscha*	BG	VAR	PAH			LIT	FW,SW
428	Long, S.M. and Holdway, D.A.	2002	Acute toxicity of crude and dispersed oil to Octopus pallidus (Hoyle, 1885) hatchlings	Water Research	36	11	2769-2776	MOLLUSC	Pale octopus	*Octopus pallidus*	CO,DS	BSC,COR	CWF,WAF		AUS	TOX	SW
429	Loughlin, T.R.	1994	Tissue hydrocarbon levels and the number of cetaceans found dead after the spill	Marine mammals and the Exxon Valdez			359-370	MAMMAL	Grey whale Harbour porpoise Minke whale Fin whale	*Eschrichtus robustus Phocoena phocoena Balaenoptera acutorostrata Balaenoptera physalus*	CO	ANS	WHL	EVOS	AK	ECO/TOX	SW
430	Loughlin, T.R., Ballachey, B.E. and Wright, B.A.	1996	Overview of studies to determine injury caused by the Exxon Valdez oil spill to marine mammals	Proceedings of the Exxon Valdez Oil Spill Symposium	18		798-808	MAMMAL	Sea otter Harbour seal Orca Humpback whale Steller sea lion	*Enhydra lutris Phoca vitrulina Orcinus orca Megaptera novaeangliae Eumetopias jubatus*	CO	ANS	WHL	EVOS	AK	ECO	SW
431	Lowry, L.F.	1990	ALASKA'S ROLE IN MITIGATING THE EFFECTS OF THE T-V EXXON VALDEZ OIL SPILL ON SEA OTTERS	U S Fish and Wildlife Service Biological Report	90	12	29-31	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW

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432	Lucas, Z. and Freedman, B.	1989	The effects of experimental spills of natural gas condensate on three plant communities on Sable Island, Nova Scotia, Canada	Oil and Chemical Pollution	5	4	263-272	PLANT	Various	Various	OR	DIL	NGC		NS	ECO	Terrestrial
433	Luechmann, K.H., Dafre, A.L., Trevisan, R., Craft, J.A., Meng, X., Mattos, J.J., Zacchi, F.L., Dorrington, T.S., Schroeder, D.C. and Bainy, A.C.	2014	A light in the darkness: New biotransformation genes, antioxidant parameters and tissue-specific responses in oysters exposed to phenanthrene	Aquatic Toxicology	152		324-334	MOLLUSC	Oyster - Mangrove	*Crassostrea brasiliana*	BG,CO	LAB	PAH			TOX	SW
434	Luechmann, K.H., Mattos, J.J., Siebert, M.N., Dorrington, T.S., Toledo-Silva, G., Stoco, P.H., Grisard, E.C. and Bainy, A.C.	2012	Suppressive subtractive hybridization libraries prepared from the digestive gland of the oyster Crassostrea brasiliana exposed to a diesel fuel water-accommodated fraction	Environmental Toxicology and Chemistry	31	6	1249-1253	MOLLUSC	Oyster	*Crassostrea brasiliana*	FO	DSL	WAF			TOX	SW
435	Luechmann, K.H., Mattos, J.J., Siebert, M.N., Granucci, N., Dorrington, T.S., Bicego, M.C., Taniguchi, S., Sasaki, S.T., Daura-Jorge, F.G. and Bainy, A.C.	2011	Biochemical biomarkers and hydrocarbons concentrations in the mangrove oyster Crassostrea brasiliana following exposure to diesel fuel water-accommodated fraction	Aquatic Toxicology	105	42097	652-660	MOLLUSC	Oyster	*Crassostrea brasiliana*	FO	DSL	WAF			TOX	SW
436	Lyons, B.P., Pascoe, C.K. and McFadzen, I.R.B.	2002	Phototoxicity of pyrene and benzo a pyrene to embryo-larval stages of the pacific oyster Crassostrea gigas	Marine Environmental Research	54		627-631	MOLLUSC	PACIFIC OYSTER	*Crassostrea gigas*	BG	LAB	PAH,UVT			TOX	SW
437	Lyons, M.C., Wong, D.K.H., Mulder, I., Lee, K. and Burridge, L.E.	2011	The influence of water temperature on induced liver EROD activity in Atlantic cod (Gadus morhua) exposed to crude oil and oil dispersants	Ecotoxicology and Environmental Safety	74	4	904-910	FISH	Atlantic Cod	*Gadus morhua*	CO,DS	MLC,COR	CWF,WAF			TOX	SW
438	MacDonald, G.Z., Hogan, N.S., Koellner, B., Thorpe, K.L., Phalen, L.J., Wagner, B.D. and van den Heuvel, M.R.	2013	Immunotoxic effects of oil sands-derived naphthenic acids to rainbow trout	Aquatic Toxicology	126		95-103	FISH	Rainbow trout	*Oncorhynchus mykiss*	OR	LAB,PRW	NAC			TOX	FW
439	Macdonald, R.W., Morton, B. and Johannessen, S.C.	2003	A review of marine environmental contaminant issues in the North Pacific: The dangers and how to identify them	Environmental Reviews	11	2	103-139	COMMUNITY	Various	Various	CO	ANS	PAH	EVOS	AK	LIT	SW
440	MacFarlane, G.R., Reid, D J. and Esguerra, C.A.	2004	Sublethal behavioral effects of the water accommodated fractions of crude oil to gastropod molluscs	Bulletin of Environmental Contamination and Toxicology	72	5	1025-1031	MOLLUSC	Gastropod Molluscs (Australian)	*Gastropod Molluscs (Australian)*	CO	MCK	WAF		AUS	TOX	SW
441	Macías-Zamora, J.V., Meléndez-Sanchéz, A.L., Ramírez-Álvarez, N., Gutiérrez-Galindo, E.A. and Orozco-Borbón, M.V.	2014	On the effects of the dispersant Corexit 9500((c)) during the degradation process of n-alkanes and PAHs in marine sediments	Environmental Monitoring and Assessment	186	2	1051-1061				DS,FO	COR,HFO	ALH,PAH			PHYS	SED,SW
442	Macinnis-Ng, C.M.O. and Ralph, P.J.	2003	In situ impact of petrochemicals on the photosynthesis of the seagrass Zostera capricorni	Marine Pollution Bulletin	46	11	1395-1407	PLANT	Seagrass (Australian)	*Zostera capricomi*	CO,DS	CHP,VDC	WHL		AUS	TOX	SW
443	Madill, R.E.A., Brownlee, B.G., Josephy, P.D. and Bunce, N.J.	1999	Comparison of the Ames Salmonella assay and Mutatox genotoxicity assay for assessing the mutagenicity of polycyclic aromatic compounds in porewater from Athabasca oil sands mature fine tailings	Environmental Science & Technology	33	15	2510-2516	MICROBIA	Ames and Mutatox assays	*Ames and Mutatox assays*	OR	PRW	PAH			TOX	FW

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444	Madison, B.N., Hodson, P.V. and Langlois, V.S.	2015	Diluted bitumen causes deformities and molecular responses indicative of oxidative stress in Japanese medaka embryos	Aquatic Toxicology	165	2015	222-230	FISH	Medaka	*Oryzias latipes*	OR	DBT,DS,COR	CWF,PAH,WAF			TOX	FW
445	Mager, E.M., Esbaugh, A.J., Stieglitz, J.D., Hoenig, R., Bodinier, C., Incardona, J.P., Scholz, N.L., Benetti, D.D. and Grosell, M.	2014	Acute Embryonic or Juvenile Exposure to Deepwater Horizon Crude Oil Impairs the Swimming Performance of Mahi-Mahi (Coryphaena hippurus)	Environmental Science & Technology	48	12	7053-7061	FISH	Mahi-mahi	*Coryphaena hippurus*	CO	MAC	PAH,WAF	DWH	GM	TOX	SW
446	Mahon, S., Addison, R.F. and Willis, D.E.	1987	Effects of Scotian shelf natural gas condensate on the mummichog	Marine Pollution Bulletin	18	2	74-77	FISH	Mummichog	*Fundulus heteroclitus*	OR	DIL	NGC,WAF		NS	TOX	SW
447	Maki, A.W., Brannon, E.J., Gilbertson, L.G., Moulton, L.L. and Skalski, J.R.	1995	An assessment of oil-spill effects on pink salmon populations following the Exxon Valdez oil spill - Part II: Adults and escapement	Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters	1219		585-625	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
448	Mann, K.H. and Clark, R.B.	1978	SESSION III. Summary and Overview: Long-Term Effects of Oil Spills on Marine Intertidal Communities	Journal of the Fisheries Research Board of Canada	35	5	791-795	COMMUNITY	Various	Various	CO	VAR	VAR			LIT	SW
449	Manzetti, S.	2012	Ecotoxicity of polycyclic aromatic hydrocarbons, aromatic amines, and nitroarenes through molecular properties	Environmental Chemistry Letters	10	4	349-361				BG,CO	VAR	PAH			LIT	SW
450	Martin, J.D., Adams, J., Hollebone, B., King, T., Brown, R.S, and Hodson, P.V.	2014	Chronic toxicity of heavy fuel oils to fish embryos using multiple exposure scenarios	Environmental Toxicology and Chemistry	33	3	677-687	FISH	Rainbow trout	*Oncorhynchus mykiss*	CO,DS,FO	MLC,COR,HFO	CWF,WAF			TOX	FW
451	Martinez-Gómez, C., Vethaak, A.D., Hylland, K., Burgeot, T., Kohler, A., Lyons, B.P., Thain, J., Gubbins, M.J. and Davies, I.M.	2010	A guide to toxicity assessment and monitoring effects at lower levels of biological organization following marine oil spills in European waters	Archives of Environmental Contamination and Toxicology	20	1	113-117				CO,FO	VAR	VAR		EUR	LIT	SW
452	Martínez-Jerónimo, F., Villaseñor, R., Ríos, G. and Espinosa-Chavez, F.	2005	Toxicity of the crude oil water-soluble fraction and kaolin-adsorbed crude oil on Daphnia magna (Crustacea : Anomopoda)	Ices Journal of Marine Science	67	6	1105-1118	CRUSTACEA	Daphnia	*Daphnia magna*	CO	VAR	WAF,WHL			TOX	FW
453	Marty, G.D.	2008	Effects of the Exxon Valdez oil spill on Pacific herring in Prince William Sound, Alaska	Toxicology of Fishes			925-932	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	LIT	SW
454	Marty, G.D., Hoffmann, A., Okihiro, M.S., Hepler, K. and Hanes, D.	2003	Retrospective analysis: bile hydrocarbons and histopathology of demersal rockfish in Prince William Sound, Alaska, after the Exxon Valdez oil spill	Marine Environmental Research	56	5	569-584	FISH	Rockfishes	*Sebastes spp*	CO	ANS	WHL	EVOS	AK	ECO	SW
455	Marty, G.D., Hose, J.E., McGurk, M.D., Brown, E.D. and Hinton, D.E.	1997	Histopathology and cytogenetic evaluation of Pacific herring larvae exposed to petroleum hydrocarbons in the laboratory or in Prince William Sound, Alaska, after the Exxon Valdez oil spill	Canadian Journal of Fisheries and Aquatic Sciences	54	8	1846-1857	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	ECO/TOX	SW
456	Marty, G.D., Okihiro, M.S. and Hinton, D.E.	2000	Fish histopathology damage assessment after the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Technical Services Study Number 2	176 p	FISH	Dolly varden Pacific herring Rockfishes Pink salmon	*Salvelinus malma Clupea pallasii Sebastes spp Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW

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457	Marty, G.D., Okihiro, M.S., Brown, E.D., Hanes, D. and Hinton, D.E.	1999	Histopathology of adult pacific herring in Prince William Sound, Alaska, after the Exxon Valdez oil spill	Canadian Journal of Fisheries and Aquatic Sciences	56	3	419-426	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
458	Marty, G.D., Short, J.W., Dambach, D.M., Willits, N.H., Heintz, R.A., Rice, S.D., Stegeman, J.J. and Hinton, D.E.	1997	Ascites, premature emergence, increased gonadal cell apoptosis, and cytochrome P4501A induction in pink salmon larvae continuously exposed to oil-contaminated gravel during development	Canadian Journal of Zoology	75	6	989-1007	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	ECO/TOX	EST,SW
459	Matkin, C.O., Ellis, G.M., Dahlheim, M.E. and Zeh, J.	1994	Status of killer whales in Prince William Sound, 1985-1992	Marine mammals and the Exxon Valdez			141-162	MAMMAL	Orca	*Orcinus orca*	CO	ANS	WHL	EVOS	AK	ECO	SW
460	Matkin, C.O., Saulifis, E.L., Ellis, G.M., Olesiuk, P. and Rice, S.D.	2008	Ongoing population-level impacts on killer whales Orcinus orca following the 'Exxon Valdez' oil spill in Prince William Sound, Alaska	Marine Ecology Progress Series	356		269-281	MAMMAL	Orca	*Orcinus orca*	CO	ANS	WHL	EVOS	AK	ECO	SW
461	Mazet, J.A,, Gardner, I.A., Jessup, D.A. and Lowenstine, L.J.	2001	Effects of petroleum on mink applied as a model for reproductive success in sea otters	Journal of Wildlife Diseases	37	4	686-692	MAMMAL	American mink	*Neovison vison*	CO,FO	ANS,BUC	WHL			TOX	SW
462	McGurk, M.D. and Brown, E.D.	1996	Egg-larval mortality of Pacific herring in Prince William Sound, Alaska, after the Exxon Valdez oil spill	Canadian Journal of Fisheries and Aquatic Sciences	53	10	2343-2354	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	ECO	SW
463	McGurk, M.D., Warburton, H.D., Parker, T.B., Litke, M. and Marliave, J.B.	1993	Effects of the Exxon Valdez oil spill on survival of Pacific herring eggs and viability of their larvae	Canadian Technical Report of Fisheries and Aquatic Sciences	"Proceedings of the Nineteenth Annual Aquatic Toxicity Workshop: October 4-7, 1992, Edmonton, Alberta," Baddaloo, Ramamoorthy and Moore (Eds).	1942	255-257	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	ECO/TOX	SW
464	McIntosh, S., King, T., Wu, D. and Hodson, P.V.	2010	Toxicity of dispersed weathered crude oil to early life stages of Atlantic herring (Clupea harengus)	Environmental Toxicology and Chemistry	29	5	1160-1167	FISH	Atlantic Herring	*Clupea harengus*	CO,DS	MLC,COR	WHL			TOX	SW
465	McKenzie, N., Yue, S., Liu, X., Ramsay, B.A. and Ramsay, J.A.	2014	Biodegradation of naphthenic acids in oils sands process waters in an immobilized soil/sediment bioreactor	Chemosphere	109		164-172	MICROBIA	Various	Various	OR	PRW	NAC			TOX	FW
466	Meier, S., Morton, H.C., Nyhammer, G., Grøsvik, B.E., Makhotin, V., Geffen, A., Boitsov, S., Kvestad, K.A., Bohne-Kjersem, A., Goksøyr, A., Folkvord, A., Klungsøyr, J. and Svardal, A.	2010	Development of Atlantic cod (Gadus morhua) exposed to produced water during early life stages Effects on embryos, larvae, and juvenile fish	Marine Environmental Research	70	5	383-394	FISH	Atlantic Cod	*Gadus morhua*	CO	NSC,PNW	PAH			TOX	SW
467	Melbye, A.G., Brakstad, O.G., Hokstad, J.N., Gregersen, I.K., Hansen, B.H., Booth, A.M., Rowland, S.J. and Tollefsen, K.E.	2009	CHEMICAL AND TOXICOLOGICAL CHARACTERIZATION OF AN UNRESOLVED COMPLEX MIXTURE-RICH BIODEGRADED CRUDE OIL	Environmental Toxicology and Chemistry	28	9	1815-1824	FISH	Rainbow trout	*Oncorhynchus mykiss*	CO	NWG	PAH,WAF,WHL			TOX	FW

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468	Meudec, A., Poupart, N., Dussauze, J. and Deslandes, E.	2007	Relationship between heavy fuel oil phytotoxicity and polycyclic aromatic hydrocarbon contamination in Salicornia fragilis	Science of the Total Environment	381		146-156	PLANT	Pickleweed	*Salicornia fragilis*	FO	HFO	PAH,UVT		EUR	TOX	SW
469	Middaugh, D.P., Shelton, M.E., McKenney, C.L. Jr., Cherr, G., Chapman, P J. and Courtney, L.A.	1998	Preliminary observations on responses of embryonic and larval Pacific herring, Clupea pallasi, to neutral fraction biodegradation products of weathered Alaska North Slope oil	Aquatic Toxicology	86	2	166-175	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WAF		AK	TOX	SW
470	Milinkovitch, T., Godefroy, J., Theron, M. and Thomas-Guyon, H.	2011	Toxicity of dispersant application: Biomarkers responses in gills of juvenile golden grey mullet (Liza aurata)	Environmental Pollution	159	10	2921-2928	FISH	Golden Grey Mullet	*Liza aurata*	CO,DS	ARL,TFL	WAF,WHL			TOX	SW
471	Milinkovitch, T., Imbert, N., Sanchez, W., Le Floch, S. and Thomas-Guyon, H.	2013	Toxicological effects of crude oil and oil dispersant: Biomarkers in the heart of the juvenile golden grey mullet (Liza aurata)	Ecotoxicology and Environmental Safety	88		41647	FISH	Golden Grey Mullet	*Liza aurata*	CO,DS	ARL,TFL	WAF,WHL			TOX	SW
472	Milinkovitch, T., Kanan, R., Thomas-Guyon, H. and Le Floch, S.	2011	Effects of dispersed oil exposure on the bioaccumulation of polycyclic aromatic hydrocarbons and the mortality of juvenile Liza ramada	Science of the Total Environment	409	9	1643-1650	FISH	Thinlip Mullet	*Liza ramada*	CO,DS	ARL,TFL	PAH,WAF,WHL			TOX	SW
473	Milinkovitch, T., Thomas-Guyon, H., Lefrançois, C. and Imbert, N.	2013	Dispersant use as a response to oil spills: toxicological effects on fish cardiac performance	Fish Physiology and Biochemistry	39	2	257-262	FISH	Golden Grey Mullet	*Liza aurata*	CO,DS	ARL,TFL	WAF,WHL			TOX	SW
474	Militon, C., Jézéquel, R., Gilbert, F., Corsellis, Y., Sylvi, L., Cravo-Laureau, C., Duran, R. and Cuny, P.	2015	Dynamics of bacterial assemblages and removal of polycyclic aromatic hydrocarbons in oil-contaminated coastal marine sediments subjected to contrasted oxygen regimes	Environmental Science and Pollution Research	22	20	15260-15272	MICROBIA	Sediment microbial community		CO	ARL	PAH		EUR	ECO/TOX	SW
475	Miljeteig, C., Olsen, A.J., Nordtug, T., Altin, D. and Jenssen, B.M.	2013	Sublethal Exposure to Crude Oil Enhances Positive Phototaxis in the Calanoid Copepod Calanus finmarchicus	Environmental Science & Technology	47	24	14426-14433	CRUSTACEA	Copepods	*Calanus finmarchicus*	CO	NSC	WAF			TOX	SW
476	Mitchell, F.M. and Holdway, D.A.	2000	The acute and chronic toxicity of the dispersants Corexit 9527 and 9500, water accommodated fraction (WAF) of crude oil, and dispersant enhanced WAF (DEWAF) to Hydra viridissima (green hydra)	Water Research	34	1	343-348	CNIDARIA	Hydra	*Hydra viridissima*	CO,DS	BSC,COR	CWF,WAF			TOX	SW
477	Mohr, F.C., Lasley, B. and Bursian, S.	2008	Chronic oral exposure to bunker C fuel oil causes adrenal insufficiency in ranch mink (Mustela vison)	Archives of Environmental Contamination and Toxicology	54	2	337-347	MAMMAL	Ranch Mink	*Neovison vison*	FO	BUC	WHL			TOX	ING
478	Moles, A.	1980	SENSITIVITY OF PARASITIZED COHO SALMON FRY TO CRUDE-OIL, TOLUENE, AND NAPHTHALENE	Transactions of the American Fisheries Society	109	3	293-297	FISH	Coho salmon	*Oncorhynchus kisutch*	CO	ANS	BTX			TOX	FW
479	Moles, A. and Rice, S.D.	1983	EFFECTS OF CRUDE-OIL AND NAPHTHALENE ON GROWTH, CALORIC CONTENT, AND FAT-CONTENT OF PINK SALMON JUVENILES IN SEAWATER	Transactions of the American Fisheries Society	112	2	205-211	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	BTX			TOX	SW
480	Moles, A., Babcock, M.M. and Rice, S.D.	1987	EFFECTS OF OIL EXPOSURE ON PINK SALMON, ONCORHYNCHUS-GORBUSCHA, ALEVINS IN A SIMULATED INTERTIDAL ENVIRONMENT	Marine Environmental Research	21	1	49-58	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	COK	WAF,WHL		AK	TOX	FW,SW
481	Moles, A., Rice, S.D. and Korn, S.	1979	Sensitivity of Alaskan Freshwater and Anadromous Fishes to Prudhoe Bay Crude Oil and Benzene	Environment International	44		31-39	FISH	Sockeye Pink Dolly varden Chinook Coho Arctic grayling Arctic char Slimy sculpin Threespine stickleback	*Oncorhynchus nerka Salvelinus malma O. tshawytscha O. kisutch O.gorbuscha Thymallus arcticus S. alpinus Cottus cognatus Gasterosteus aculeatus*	CO	ANS	BTX		AK	ECO/TOX	FW,SW

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482	Monahan, T.P. and Maki, A.W.	1993	The Exxon Valdez 1989 wildlife rescue and rehabilitation program	International Oil Spill Conference Proceedings	1991	1	131-136	BIRD MAMMAL	Birds Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
483	Monnett, C. and Rotterman, L.M.	1995	Movements of weanling and adult female sea otters in Prince William Sound, Alaska after the T/V Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-12		MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
484	Monnett, C. and Rotterman, L.M.	1995	Mortality and reproduction of female sea otters in Prince William Sound, Alaska	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-13	19 p	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
485	Monson, D.H. and Ballachey, B.	1995	Age distributions of sea otters found dead in Prince William Sound, Alaska following the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-15		MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
486	Monson, D.H., Doak, D.F., Ballachey, B.E. and Bodkin, J.L.	2011	Could residual oil from the Exxon Valdez spill create a long-term population "sink" for sea otters in Alaska?	Ecological Applications	21	8	2917-2932	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	MOD	SW
487	Monson, D.H., Doak, D.F., Ballachey, B.E..,, Johnson, A and Bodkin, J.L.	2000	Long-term impacts of the Exxon Valdez oil spill on sea otters, assessed through age-dependent mortality patterns	Proceedings of the National Academy of Sciences of the United States of America	97	12	6562-6567	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
488	Moreira, C.B., Rodrigues, R.V., Romano, L.A., Gusmão, E.P., Seyffert, B.H., Sampaio, L. A. and Miranda-Filho, K.C.	2014	Genotoxicity and histological alterations in grey mullet Mugil liza exposed to petroleum water-soluble fraction (PWSF)	Environmental Science and Pollution Research	21	8	5565-5574	FISH	Grey Mullet	*Mugil liza*	CO	BRZ	WAF			TOX	SW
489	Moreira, S.M., Moreira-Santos, M., Ribeiro, R. and Guilhermino, L.	2004	The 'Coral bulker' fuel oil spill on the north coast of Portugal: Spatial and temporal biomarker responses in Mytilus galloprovincialis	Ecotoxicology	13	7	619-630	MOLLUSC	Mediterranean Mussel	*Mytilus galloprovincialis*	FO	HFO	WHL	CRB	PGL	ECO	SW
490	Mos, L., Cooper, G.A., Serben, K., Cameron, M. and Koop, B.F.	2008	Effects of diesel an survival growth, and gene expression in rainbow trout (Oncorhynchus mykiss) fry	Environmental Science & Technology	42	7	2656-2662	FISH	Rainbow trout	*Oncorhynchus mykiss*	FO	DSL	WHL			TOX	FW
491	Mulcahy, D.M. and Ballachey, B.E.	1994	Hydrocarbon residues in sea otter tissues	Marine mammals and the Exxon Valdez			313-330	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	TOX	SW
492	Munson, D.	1996	Shoreline assessment and oil removal in Prince William Sound, Alaska	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 94266b					CO	ANS	WHL	EVOS	AK	PHYS	SED,SW
493	Munson, D., Fay, G., Easton, D. and Ginter, J.	1998	Chenega Shoreline Restoration. Exxon Valdez Oil Spill Restoration Project Final Report (Restoration Project 97291)	EVOS Trustee Council	Restoration Project	97291	121 pp.	MOLLUSC	Mussels	*Mytilus sp.*	CO,DS	ANS,PES	WHL	EVOS	AK	ECO	SW

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494	Murakami, Y., Kitamura, S., Nakayama, K., Matsuoka, S. and Sakaguchi, H.	2008	Effects of heavy oil in the developing spotted halibut, Verasper variegatus	Marine Pollution Bulletin	57		524-528	FISH	Spotted Halibut	*Verasper variegatus*	FO	BUC	WHL		ASIA	TOX	SW
495	Murphy, M.L., Heintz, R.A., Short, J.W., Larsen, M.L. and Rice, S.D.	1998	Recovery of pink salmon spawning areas after the Exxon Valdez oil spill	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 97194		FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,TPH	EVOS	AK	PHYS	EST,SED
496	Murphy, M.L., Heintz, R.A., Short, J.W., Larsen, M.L. and Rice, S.D.	1999	Recovery of pink salmon spawning areas after the Exxon Valdez oil spill	Transactions of the American Fisheries Society	128	5	909-918	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,TPH	EVOS	AK	PHYS	EST,SED
497	Nakayama, K., Kitamura, S., Murakami, Y., Song, J.Y., Jung, S.J., Oh, M.J., Iwata, H. and Tanabe, S.	2008	Toxicogenomic analysis of immune system-related genes in Japanese flounder (Paralichthys olivaceus) exposed to heavy oil	Marine Pollution Bulletin	57	42167	445-452	FISH	Japanese flounder	*Paralichthys olivaceus*	FO	BUC	PAH			TOX	SW
498	National Research Council (NRC)	2013	An Ecosystem Services Approach to Assessing the Impacts of the Deepwater Horizon Oil Spill in the Gulf of Mexico	Book			247 pp	CRUSTACEAN FISH MAMMAL PLANT	Marsh grasses Mangroves Shrimp Bottlenose dolphin		CO	MAC	WHL	DWH	GM	LIT	SW
499	Nayar, S., Goh, B.P.L. and Chou, L.M.	2005	Environmental impacts of diesel fuel on bacteria and phytoplankton in a tropical estuary assessed using in situ mesocosms	Ecotoxicology	14	3	397-412	ALGAE MICROBIA	Phytoplankton Bacteria		FO	DSL	TPH		ASIA	ECO	EST,SED
500	Nayar, S., Goh, B.P.L. and Chou, L.M.	2004	The impact of petroleum hydrocarbons (diesel) on periphyton in an impacted tropical estuary based on in situ microcosms	Journal of Experimental Marine Biology and Ecology	302	2	213-232	ALGAE	Periphytic algal mass		FO	DSL	WHL		ASIA	ECO	SW
501	Neff, J.M. and Burns, W.A.	1996	Estimation of polycyclic aromatic hydrocarbon concentrations in the water column based on tissue residues in mussels and salmon: An equilibrium partitioning approach	Environmental Toxicology and Chemistry	15	12	2240-2253	FISH MOLLUSC	Mussel Pink Salmon	*Mytilus trossolus Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
502	Neff, J.M. and Stubblefield, W.A.	1995	Chemical and toxicological evaluation of water quality following the Exxon Valdez oil spill	Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters	1219		141-177	ALGAE CRUSTACEA FISH	Diatom Mysid shrimp Sheepshead minnow	*Skeletonema costatum Mysidopsis bahi Cyprinodon variegatus*	CO	ANS	ALH,PAH	EVOS	AK	TOX	SW
503	Neff, J.M., Bence, A.E., Parker, K.R., Page, D.S., Brown, J.S. and Boehm, P.D.	2006	Bioavailability of polycyclic aromatic hydrocarbons from buried shoreline oil residues thirteen years after the Exxon valdez oil spill: A multispecies assessment	Environmental Toxicology and Chemistry	25	4	947-961	ALGAE ANNELIDA CRUSTACEA FISH MOLLUSC	Sea lettuce Worms Blue mussels Whelks Hermit crabs Intertidal fish (High cockscomb)	*Ulva spp Oligochaeta Mytilus edulis Buccinum spp Pagurus spp Anoplarchus purpurescens*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
504	Neff, J.M., Ostazeski, S., Gardiner, W. and Stejskal, I.	2000	Effects of weathering on the toxicity of three offshore Australian crude oils and a diesel fuel to marine animals	Environmental Toxicology and Chemistry	19	7	1809-1821	CRUSTACEA ECHINODERM FISH	Mysid Urchin Clownfish Silverside	*Amphiprion clarkii Menidia beryllina Penaeus vannamei Americamysis bahia Arbacia punctulata Strongylocentrotus purpuratus Dendraster excentricus*	CO,FO,OR	VAR,DSL,DIL	BTX,PAH,WAF			TOX	SW
505	Neff, J.M., Owens, E.H., Stoker, S.W. and McCormick, D.M.	1995	Shoreline Oiling Conditions in Prince William Sound Following the Exxon Valdez Oil Spill	Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters	1219		312				CO	ANS	WHL	EVOS	AK	PHYS	SED,SW
506	Neff, J.M., Page, D.S. and Boehm, P.D.	2011	Exposure of sea otters and harlequin ducks in Prince William Sound, Alaska, USA, to shoreline oil residues 20 years after the Exxon Valdez oil spill.	Environmental Toxicology and Chemistry	30	3	659-672	MAMMAL	Sea Otter Harlequin duck	*Enhydra lutris Histrionicus histrionicus*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
507	Neff, J.M., Page, D.S., Landrum, P.F. and Chapman, P.M.	2013	The importance of both potency and mechanism in dose-response analysis: An example from exposure of Pacific herring (Clupea pallasi) embryos to low concentrations of weathered crude oil	Marine Pollution Bulletin	67		41835	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	UKN	PAH			TOX	SW

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508	Nelson, B.	2009	The Exxon Valdez Trustee Hydrocarbon Database	EVOS Trustee Council	Restoration Project	97290	11 pp.				CO	ANS	VAR	EVOS	AK	LIT	SW
509	Nelson, T.R., DeVries, D.R., Wright, R.A. and Gagnon, J.E.	2015	*Fundulus grandis* Otolith Microchemistry as a a Metric of Estuarine Discrimination and Oil Exposure	Estuaries and Coasts	38	6	2044-2058	FISH	Gulf killifish	*Fundulus grandis*	CO	MAC	MET	DWH	GM	ECO	EST,SW
510	Nero, V., Farwell, A., Lee, L.E.J., Van Meer, T., MacKinnon, M.D. and Dixon, D.G.	2006	The effects of salinity on naphthenic acid toxicity to yellow perch: Gill and liver histopathology	Ecotoxicology and Environmental Safety	65	2	252-264	FISH	Yellow perch	*Perca flavescens*	OR	PRW	NAC		AOS	TOX	FW
511	Nero, V., Farwell, A., Lister, A., Van der Kraak, G., Lee, L.E.J., Van Meer, T., MacKinnon, M.D. and Dixon, D.G.	2006	Gill and liver histopathological changes in yellow perch (Perca flavescens) and goldfish (Carassius auratus) exposed to oil sands process-affected water	Ecotoxicology and Environmental Safety	63	3	365-377	FISH	Yellow perch	*Perca flavescens*	OR	PRW	NAC,PAH		AOS	TOX	FW
512	Neto, A.G. and Costa, C.S.B.	2009	SURVIVAL AND GROWTH OF THE DOMINANT SALT MARSH GRASS SPARTINA ALTERNIFLORA IN AN OIL INDUSTRY SALINE WASTEWATER	International Journal of Phytoremediation	11	7	640-650	PLANT	Marsh grass	*Spartina alterniflora*	CO	PDW	WHL			TOX	SW
513	Neuparth, T., Capela, R., Pereira, S.P.P., Moreira, S.M., Santos, M.M. and Reis-Henriques, M.A.	2014	TOXICITY EFFECTS OF HAZARDOUS AND NOXIOUS SUBSTANCES (HNS) TO MARINE ORGANISMS: ACUTE AND CHRONIC TOXICITY OF p-XYLENE TO THE AMPHIPOD Gammarus locusta	Journal of Toxicology and Environmental Health	77	20	1210-1221	CRUSTACEA	Gammarid amphipod	*Gammarus locusta*	BG,CO	LAB	BTX			TOX	SW
514	Niu, H., Li, Z., Lee, K., Kepkay, P. and Mullin, J.	2010	A Method for Assessing Environmental Risks of Oil-Mineral-Aggregate to Benthic Organisms	Human and Ecological Risk Assessment	16	4	762-782				BG,CO	SLC	WHL			MOD	EST,SED
515	Norcross, B.L. and Frandsen, M.	1998	Injury to larval fish in Prince William Sound	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Fish/Shellfish Study Number 19		FISH	Walleye pollock Northern smoothtongue Pacific herring Capelin Rockfishes Flathead sole	*Theragra chalcogramma Leuroglossus schmidti Clupea pallasii Mallotus villosus Sebastes spp Hippoglossoides elassodon*	CO	ANS	WHL	EVOS	AK	ECO	SW
516	Norcross, B.L. and Frandsen, M.	1996	Distribution and abundance of larval fishes in Prince William Sound, Alaska, during 1989 after the Exxon Valdez oil spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		463-486	FISH	Walleye pollock Northern smoothtongue Pacific herring Capelin Rockfishes Flathead sole	*Theragra chalcogramma Leuroglossus schmidti Clupea pallasii Mallotus villosus Sebastes spp Hippoglossoides elassodon*	CO	ANS	WHL	EVOS	AK	ECO	SW
517	Norcross, B.L., Frandsen, M., Hose, J. and Biggs, E.	1995	Larval herring distribution, abundance and sublethal assessment in Prince William Sound, Alaska during 1989 following the Exxon Valdez oil spill	Canadian Technical Report of Fisheries and Aquatic Sciences	"Proceedings of the Seventh Pacific Coast Herring Workshop, January 27-28, 1994." Hay and McCarter (Eds)	2060	61-61	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	ECO	SW
518	Norcross, B.L., Hose, J.E., Frandsen, M. and Brown, E.D.	1996	Distribution, abundance, morphological condition, and cytogenetic abnormalities of larval herring in Prince William Sound, Alaska, following the Exxon Valdez oil spill	Canadian Journal of Fisheries and Aquatic Sciences	53	10	2376-2387	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	ECO	SW
519	Notini, M.	1978	Long-Term Effects of an Oil Spill on Fucus Macrofauna in a Small Baltic Bay	Journal of the Fisheries Research Board	35	5	745-753	CRUSTACEA FISH INSECT MOLLUSC	Bladder wrack Mussel Nerite Amphipods	*Fucus vesiculosus Mytilus edulis Theodoxus fluviatilis*	FO	HFO	WHL	IRI	SWE	ECO	SW

RefID	Author(s)	Year	Title	Journal	Volume	Issue	Pages	Taxon	CommonName	Scientific Name	MainProduct	SpecificProduct	ComponentsAnalyzed	Event	Location	StudyType	ExposureMedia
				of Canada					Isopods Chironomids	*Gammarus spp Idotea spp Iaera spp Chironomidae*							
520	Nunes, P. and Benville, P.E. Jr.	1978	ACUTE TOXICITY OF THE WATER-SOLUBLE FRACTION OF COOK INLET CRUDE-OIL TO THE MANILA CLAM	Marine Pollution Bulletin	9	12	324-331	MOLLUSC	Japanese littleneck clam	*Ruditapes philippinarum (or Venerupis philippinarum)*	CO	COK	WAF			TOX	SW
521	O'Clair, C.E., Short, J.W. and Rice, S.D.	1996	Petroleum hydrocarbon-induced injury to subtidal marine sediment resources	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Subtidal Study Number 1A		BENTHOS			CO	ANS	PAH	EVOS	AK	ECO/PHYS	SED,SW
522	O'Clair, C.E., Short, J.W. and Rice, S.D.	1996	Recovery of sediments in the lower intertidal and subtidal environment	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 93047-1					CO	ANS	PAH	EVOS	AK	PHYS	SED,SW
523	O'Brien, P.Y. and Dixon, P.S.	1976	The effects of oils and oil components on algae: A review	Book				ALGAE	Algae		CO	VAR	VAR			LIT	SW
524	O'brien, W.J.	1978	TOXICITY OF PRUDHOE BAY CRUDE-OIL TO ALASKAN ARCTIC ZOOPLANKTON	Arctic	31	3		ZOOPLANKTON	Fairy shrimp Daphnia Copepod	*Branchinecta paludosa Daphnia middendorffiana Heterocope septentrionalis*	CO	ANS	WHL		ARC	TOX	FW
525	O'Clair, C.E., Trowbridge, C. and Ackley, D.	1990	Injury to Prince William Sound crabs. Exxon Valdez Oil Spill StatelFederal Natural Resource Damage Assessment Annual Report (Fish/Shellfish Study Number 14)	EVOS Trustee Council	Fish/Shellfish Study	FS14	46 pp.	CRUSTACEA	Brown King Crab Dungeness Crab	*Lithodes aequispinus Cancer magister*	CO	ANS	WHL	EVOS	AK	ECO	SW
526	Olsen, A.J., Nordtug, T., Altin, D., Lervik, M. and Hansen, B.H.	2013	Effects of dispersed oil on reproduction in the cold water copepod Calanus finmarchicus (Gunnerus)	Environmental Toxicology and Chemistry	32	9	2045-2055	CRUSTACEA	Copepods	*Calanus finmarchicus*	CO	NSC	WHL			TOX	SW
527	Olsvik, P.A., Hansen, B.H., Nordtug, T., Moren, M., Holen, E. and Lie, K.K.	2011	Transcriptional evidence for low contribution of oil droplets to acute toxicity from dispersed oil in first feeding Atlantic cod (Gadus morhua) larvae	Comparative Biochemistry and Physiology	154	4	333-345	FISH	Atlantic Cod	*Gadus morhua*	CO	UKN	WAF,WHL			TOX	SW
528	Olsvik, P.A., Lie, K.K., Nordtug, T. and Hansen, B.H.	2012	Is chemically dispersed oil more toxic to Atlantic cod (Gadus morhua) larvae than mechanically dispersed oil? A transcriptional evaluation	BMC Genomics	13			FISH	Atlantic Cod	*Gadus morhua*	CO,DS	UKN,DAS	WHL			TOX	SW
529	Orbea, A., Garmendia, L., Marigómez, I. and Cajaraville, M.P.	2006	Effects of the 'Prestige' oil spill on cellular biomarkers in intertidal mussels: results of the first year of studies	Marine Ecology Progress Series	306		177-189	MOLLUSC	Mediterranean Mussel	*Mytilus galloprovincialis*	FO	HFO	WHL	PRES	SPN	ECO/TOX	SW
530	Oris, J.T. and Roberts, A.P.	2013	Cytochrome P450 1A (CYP1A) as a biomarker in oil spill assessments	Oil in the Environment: Legacies and Lessons of the Exxon Valdez Spill			201-219				CO	ANS	WHL	EVOS	AK	LIT	SW
531	Ormseth, O.A. and Ben-David, M.	2000	Ingestion of crude oil: effects on digesta retention times and nutrient uptake in captive river otters	Journal of Comparative Physiology	170	5-6	419-428	MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	MOD	ING
532	Otitoloju, A.A.	2005	Crude oil plus dispersant: always a boon or bane?	Ecotoxicology and Environmental Safety	60	2	198-202	CRUSTACEA	African River Prawn	*Macrobrachium vollenhovenii*	CO,DS	FOR,BIO	WHL			TOX	SW
533	Owens, E.H., Taylor, E. and Humphrey, B.	2008	The persistence and character of stranded oil on coarse-sediment beaches	Marine Pollution Bulletin	56	1	14-26				BG,CO	VAR	WHL			PHYS	SED,SW

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534	Ozhan, K. and Bargu, S.	2014	Can Crude Oil Toxicity on Phytoplankton Be Predicted Based on Toxicity Data on Benzo(a)Pyrene and Naphthalene?	Bulletin of Environmental Contamination and Toxicology	92	2	225-230	ALGAE	Diatoms Dinoflagellates	*Ditylum brightwellii Heterocapsa triquetra*	CO	LAB	PAH			TOX	SW
535	Özhan, K. and Bargu, S.	2014	Responses of sympatric Karenia brevis, Prorocentrum minimum, and Heterosigma akashiwo to the exposure of crude oil	Ecotoxicology	23	8	1387-1398	ALGAE	Diatoms Dinoflagellates	*Baccilariophyceae Dinoflagellata*	CO	MAC	PAH,WHL	DWH	GM	TOX	SW
536	Özhan, K., Miles, S.M., Gao, H. and Bargu, S.	2014	Relative Phytoplankton growth responses to physically and chemically dispersed South Louisiana sweet crude oil	Environmental Monitoring and Assessment	186	6	3941-3956	ALGAE	Diatoms Dinoflagellates	*Baccilariophyceae Dinoflagellata*	CO,DS	LLS,COR	PAH,TPH,WAF			TOX	SW
537	Ozhan, K., Parsons, M.L. and Bargu, S.	2014	How Were Phytoplankton Affected by the Deepwater Horizon Oil Spill?	Bioscience	64	9	829-836	ALGAE	PHYTOPLANKTON		CO	MAC	WHL	DWH	GM	LIT	SW
538	Page, D.S., Boehm, P.D. and Neff, J.M.	2010	Comment on "Unlike PAHs from Exxon Valdez Crude Oil, PAHs from Gulf of Alaska Coals are not Readily Bioavailable"	Environmental Science & Technology	44	6	2210-2211				CO	ANS	PAH,WHL	EVOS	AK	ECO/PHYS	SED,SW
539	Page, D.S., Boehm, P.D., Brown, J.S., Neff, J.M., Burns, W.A. and Bence, A.E.	2005	Mussels document loss of bioavailable polycyclic aromatic hydrocarbons and the return to baseline conditions for oiled shorelines in Prince William Sound, Alaska	Marine Environmental Research	60	4	422-436	MOLLUSC	Foolish Mussel	*Mytilus trossulus*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
540	Page, D.S., Boehm, P.D., Stubblefield, W.A., Parker, K.R., Gilfillan, E.S., Neff, J.M. and Maki, A.W.	2002	Hydrocarbon composition and toxicity of sediments following the Exxon valdez oil spill in Prince William Sound, Alaska, USA	Environmental Toxicology and Chemistry	21	7	1438-1450	MOLLUSC	Amphipod Mussels	*Amphipod Mytilus sp.*	CO	ANS	PAH	EVOS	AK	TOX	SW
541	Page, D.S., Chapman, P.M., Landrum, P.F., Neff, J. and Elston, R.	2012	A Perspective on the Toxicity of Low Concentrations of Petroleum-Derived Polycyclic Aromatic Hydrocarbons to Early Life Stages of Herring and Salmon	Human and Ecological Risk Assessment	18	2	229-260	FISH	Pink salmon Pacific herring	*Oncorhynchus gorbuscha Clupea pallasii*	CO	ANS	PAH,WAF			LIT	SW
542	Page, D.S., Gilfillan, E.S., Boehm, P.D. and Harner, E.J.	1995	Shoreline Ecology Program for Prince William Sound, Alaska, Following the Exxon Valdez Oil Spill: Part I - Study Design and Methods	Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters	1219		263	COMMUNITY	Intertidal Community	Various	CO	ANS	ALH,PAH,WHL	EVOS	AK	ECO/TOX	SW
543	Page, D.S., Gilfillan, E.S., Boehm, P.D., Stubblefield, W.A., Parker, K.R., Neff, J.M. and Maki, A.W.	2003	Comment on "hydrocarbon composition and toxicity of sediments following the Exxon valdez oil spill in Prince William Sound, Alaska, USA' - Reply	Environmental Toxicology and Chemistry	22	11	2540-2542	CRUSTACEA MOLLUSC	Amphipod Mussels	*Amphipod Mytilus sp.*	CO	ANS	PAH	EVOS	AK	TOX	SW
544	Page, D.S., Huggettt, R.J., Stegeman, J.J., Parker, K.R., Woodin, B., Brown, J.S. and Bence, A.E.	2004	Polycyclic aromatic hydrocarbon sources related to biomarker levels in fish from Prince William sound and the Gulf of Alaska	Environmental Science & Technology	38	19	4928-4936	FISH	Pacific halibut Rockfish	*Hippoglossus stenolepsis Sebastes spp*	CO	ANS	PAH	EVOS	AK	ECO/PHYS	SED,SW
545	Page, D.S., Neff, J.M., Landrum, P.F. and Chapman, P.M.	2012	SENSITIVITY OF PINK SALMON (ONCORHYNCHUS GORBUSCHA) EMBRYOS TO WEATHERED CRUDE OIL	Environmental Toxicology and Chemistry	31	3	469-471	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH	EVOS	AK	ECO/TOX	FW
546	Page, D.S., Neff, J.M., Landrum, P.F. and Chapman, P.M.	2012	SENSITIVITY OF PINK SALMON (ONCORHYNCHUS GORBUSCHA) EMBRYOS TO WEATHERED CRUDE OIL	Environmental Toxicology and Chemistry	31	3	473-475	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH	EVOS	AK	ECO/TOX	FW
547	Page, D.S., Neff, J.M., Landrum, P.F and Chapman, P.M.	2012	SENSITIVITY OF PINK SALMON (ONCORHYNCHUS GORBUSCHA) EMBRYOS TO WEATHERED CRUDE OIL	Environmental Toxicology and Chemistry	31	3		FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WAF			LIT	SW
548	Paine, M.D., Leggett, W.C., McRuer, J.K. and Frank, K.T.	1992	EFFECTS OF HIBERNIA CRUDE-OIL ON CAPELIN (MALLOTUS-VILLOSUS) EMBRYOS AND LARVAE	Marine Environmental Research	33	3		FISH	Capelin	*Mallotus villosus*	CO	HBN	WAF			TOX	SW
549	Paine, R.T., Ruesink, J.L., Sun, A., Soulanille, E.L., Wonham, M.J.,	1996	Trouble on oiled waters: lessons from the Exxon Valdez oil spill	Annual Review of Ecology and Systematics			197-235	COMMUNITY	Various	Various	CO	ANS	WHL	EVOS	AK	LIT	SW

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	Harley, C.D.G., Brumbaugh, D.R. and Secord, D.L.																
550	Parab, S.R., Pandit, R.A., Kadam, A.N.,and Indap, M.M.	2008	Effect of Bombay high crude oil and its water-soluble fraction on growth and metabolism of diatom Thalassiosira sp	Indian Journal of Geo-Marine Sciences	37	3	251-255	ALGAE	Diatoms	*Thalassiosira sp.*	CO	BHC	WAF			TOX	SW
551	Parker, K.R., Wiens, J.A., Day, R.H. and Murphy, S.H.	2013	Assessing Effects and Recovery from Environmental Accidents	Oil in the Environment: Legacies and Lessons of the Exxon Valdez Spill			220-240				CO	ANS	WHL	EVOS	AK	LIT	SW
552	Parsons, T.R., Harrison, P.J., Acreman, J.C., Dovey, H.M., Thompson, P.A., Lalli, C.M., Lee, K., Guanguo, L., and Xiaolin, C.	1984	An experimental marine ecosystem response to crude oil and Corexit 9527: Part 2—Biological effects	Marine Environmental Research	13	4	265-275	MICROBIA ZOOPLANKTON	Various	Various	CO,DS	ANS,COR			BC	ECO	SW
553	Pauka, L.M., Maceno, M., Rossi, S.C. and de Assis, H.C.S.	2011	Embryotoxicity and Biotransformation Responses in Zebrafish Exposed to Water-Soluble Fraction of Crude Oil	Bulletin of Environmental Contamination and Toxicology	86	4	389-393	FISH	Zebrafish	*Danio rerio*	CO	BPC	WAF			TOX	FW
554	Paul, J.H., Hollander, D., Coble, P., Daly, K.L., Murasko, S., English, D., Basso, J., Delaney, J., McDaniel, L. and Kovach, C.W.	2013	Toxicity and Mutagenicity of Gulf of Mexico Waters During and After the Deepwater Horizon Oil Spill	Environmental Science & Technology	47	17	9651-9659	ALGAE MICROBIA	Dinoflagellate Bacteria	*Pyrocistis lunula Escherichia coli*	CO	MAC	WHL	DWH	GM	ECO	SW
555	Payne, J.R., Driskell, W.B. and Short, J.W.	2003	PWSRCAC-EVOS Long-term environmental monitoring program: 2002-2003 LTEMP monitoring report, Exxon Valdez Oil Spill Gulf Ecosystem Monitoring and Research Project Final Report (GEM Project 030623)	EVOS Trustee Council	GEM Project	030623	110 pp.	MOLLUSC	Mussels	*Mytilus sp.*	CO	ANS	WHL	EVOS	AK	ECO	SW
556	Payne, J.R., Driskell, W.B., Short, J.W. and Larsen, M.L.	2008	Long term monitoring for oil in the Exxon Valdez spill region	Marine Pollution Bulletin	56	12	2067-2081	MOLLUSC	Foolish Mussel	*Mytilus trossulus*	CO	ANS	PAH	EVOS	AK	PHYS	SW
557	Payne, S.J., King, C.K., Zamora, L.M. and Virtue, P.	2014	Temporal changes in the sensitivity of coastal Antarctic zooplankton communities to diesel fuel: A comparison between single- and multi-species toxicity tests	Environmental Toxicology and Chemistry	33	4	882-890	CRUSTACEA	Copepods	*Oncaea curvata Oithona similis Stephos longipes*	FO	DSL	WHL		ANT	ECO/TOX	SW
558	Pearson, W.H., Bienert, R.W., Moksness, E. and Skalski, J.R.	1995	Potential effects of the Exxon Valdez oil spill on Pacific herring in Prince William Sound	Canadian Technical Report of Fisheries and Aquatic Sciences	"Proceedings of the Seventh Pacific Coast Herring Workshop, January 27-28, 1994." Hay and McCarter (Eds)	2060	63-68	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	LIT	SW
559	Pearson, W.H., Elston, R.A., Bienert, R.W., Drum, A.S. and Antrim, L.D.	1999	Why did the Prince William Sound, Alaska, Pacific herring (Clupea pallasi)fisheries collapse in 1993 and 1994? Review of hypotheses	Canadian Journal of Fisheries and Aquatic Sciences	56	4	711-737	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	LIT	SW
560	Pearson, W.H., Elston, R.A., Humphrey, K. and Deriso, R.B.	2013	Pacific Herring	Oil in the Environment: Legacies and Lessons of the Exxon Valdez			292-317	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	LIT	SW

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				Spill													
561	Pearson, W.H., Moksness, E. and Skalski, J.R.	1995	A field and laboratory assessment of oil spill effects on survival and reproduction of Pacific herring following the Exxon Valdez spill	Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters	1219		626-661	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,WHL	EVOS	AK	ECO/TOX	SW
562	Peckol, P., Levings, S.C. and Garrity, S.D.	1990	Kelp response following the World Prodigy oil spill	Marine Pollution Bulletin	21	10	473-476	ALGAE	Sugar Kelp	*Laminaria saccharina*	FO	LFO	WHL	WPR	NY	TOX	SW
563	Pelletier, M.C., Burgess, R.M., Ho, K.T., Kuhn, A., Mckinney, R.A. and Ryba, S.A.	1997	Phototoxicity of individual polycyclic aromatic hydrocarbons and petroleum to marine invertebrate larvae and juveniles	Environmental Toxicology and Chemistry	16	10	2190-2199	CRUSTACEA MOLLUSC	Mulinia lateralis Mysidopsis bahia (MYSIDA)	*Mulinia lateralis Mysidopsis bahia (MYSIDA)*	CO,FO	ANS,ARL,LFO,BUC	PAH,UVT			TOX	SW
564	Perez, P., Fernandez, E. and Beiras, R.	2010	Fuel toxicity on Isochrysis galbana and a coastal phytoplankton assemblage: Growth rate vs. variable fluorescence	Ecotoxicology and Environmental Safety	73	3	254-261	ALGAE	MICROALGAE	*Isochrysis galbana*	FO	HFO	WHL			TOX	SW
565	Perkins, R.A., Rhoton, S. and Behr-Andres, C.	2003	Toxicity of dispersed and undispersed, fresh and weathered oil to larvae of a cold-water species, Tanner, crab (C-bairdi), and standard warm-water test species	Cold Regions Science and Technology	36	1-3	129-140	CRUSTACEA	Tanner Crab	*Chionocetes bairdi*	CO,DS	ANS,COR	CWF,WAF,TPH			TOX	SW
566	Perkins, R.A., Rhoton, S. and Behr-Andres, C.	2005	Comparative marine toxicity testing: A cold-water species and standard warm-water test species exposed to crude oil and dispersant	Cold Regions Science and Technology	42	3	226-236	CRUSTACEA	Tanner Crab	*Chionocetes bairdi*	CO,DS	ANS,COR	CWF,WAF,TPH			TOX	SW
567	Peters, L.E., MacKinnon, M., Van Meer, T., van den Heuvel, M.R. and Dixon, D.G.	2007	Effects of oil sands process-affected waters and naphthenic acids on yellow perch (Perca flavescens) and Japanese medaka (Orizias latipes) embryonic development	Chemosphere	67	11	2177-2183	FISH	Yellow perch	*Perca flavescens*	OR	PRW	NAC,PAH		AOS	TOX	FW
568	Peterson, C.H.	2001	The “Exxon Valdez” oil spill in Alaska: acute, indirect and chronic effects on the ecosystem	Advances in Marine Biology	39		1-103	COMMUNITY	Various	Various	CO	ANS	WHL	EVOS	AK	LIT	SW
569	Peterson, C.H., McDonald, L.L., Green, R.H. and Erickson, W.P.	2001	Sampling design begets conclusions: the statistical basis for detection of injury to and recovery of shoreline communities after the 'Exxon Valdez' oil spill	Marine Ecology Progress Series	210		255-283	COMMUNITY	Intertidal Community	Various	CO	ANS	WHL	EVOS	AK	LIT	SW
570	Peterson, C.H., Rice, S.D., Short, J.W., Esler, D., Bodkin, J.L., Ballachey, B.E. and Irons, D.B.	2003	Long-term ecosystem response to the Exxon Valdez oil spill	Science	302		2082-2086	COMMUNITY	Various	Various	CO	ANS	WHL	EVOS	AK	LIT	SW
571	Pezeshki, S.R., Delaune, R.D. and Jugsujinda, A.	2001	The effects of crude oil and the effectiveness of cleaner application following oiling on US Gulf of Mexico coastal marsh plants	Environmental Pollution	112	3	483-489	PLANT	Marsh grass	*Sagittaria lancifolia Spartina patens*	CO,DS	SLC,COR	WHL		GM	ECO	EST
572	Pezeshki, S.R., Jugsujinda, A. and Delaune, R.D.	1998	Responses of selected US Gulf coast marsh macrophyte species to oiling and commercial cleaners	Water Air and Soil Pollution	107		185-195	PLANT	Marsh grass	*Sagittaria lancifolia Scirpus olneyi Typha latifolia*	CO,DS	SLC,AMC,COR	WHL		GM	ECO	EST
573	Pfeiffer, C.J., Sharova, L.V. and Gray, L.	2000	Functional and ultrastructural cell pathology induced by fuel oil in cultured dolphin renal cells	Ecotoxicology and Environmental Safety	47	2	210-217	MAMMAL	Atlantic spotted dolphin	*Stenella frontalis*	FO	LFO	WHL			TOX	SW
574	Phalen, L.J., Koellner, B., Leclair, L.A., Hogan, N.S. and van den Heuvel, M.R.	2014	The effects of benzo a pyrene on leucocyte distribution and antibody response in rainbow trout (Oncorhynchus mykiss)	Aquatic Toxicology	147		121-128	FISH	Rainbow trout	*Oncorhynchus mykiss*	BG	LAB	PAH			TOX	FW
575	Pham, P.H., Huang, Y.J., Chen, C. and Bols, N.C.	2014	Corexit 9500 Inactivates Two Enveloped Viruses of Aquatic Animals but Enhances the Infectivity of a Nonenveloped Fish Virus	Applied and Environmental Microbiology	80	3	1035-1041	MICROBIA	viruses	*Hemorrhagic septicemia virus Infectious pancreatic necrosis virus Chum salmon reovirus*	DS	COR	WHL			TOX	FW,SW

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576	Pilcher, W., Miles, S., Tang, S., Mayer, G. and Whitehead, A.	2014	Genomic and Genotoxic Responses to Controlled Weathered-Oil Exposures Confirm and Extend Field Studies on Impacts of the Deepwater Horizon Oil Spill on Native Killifish	Plos One	9	9		FISH	Mummichog	*Fundulus heteroclitus*	CO	SLC	WAF,WHL	DWH	GM	TOX	SW
577	Piñeiro, M.E.A., Yusty, M.A.L., González-Barros, S.T.C. and Lozano, J.S.	1996	Aliphatic hydrocarbon levels in turbot and salmon farmed close to the site of the Aegean Sea oil spill	Bulletin of Environmental Contamination and Toxicology	57	5	811-815	FISH	Turbot Atlantic salmon	*Scophthalmus maximus Salmo salar*	CO	BNT	ALH	AEG	SPN	TOX	SW
578	Pollino, C.A. and Holdway, D.A.	2002	Toxicity testing of crude oil and related compounds using early life stages of the crimson-spotted rainbowfish (Melanotaenia fluviatilis)	Ecotoxicology and Environmental Safety	52	3		FISH	Crimson-Spotted Rainbowfish	*Melanotaenia duboulayi*	CO,DS	UKN,COR	TPH,WAF			TOX	FW
579	Pollino, C.A., Georgiades, E. and Holdway, D.A.	2009	Physiological changes in reproductively active rainbowfish (Melanotaenia fluviatilis) following exposure to naphthalene	Ecotoxicology and Environmental Safety	72	4	1265-1270	FISH	Crimson-Spotted Rainbowfish	*Melanotaenia duboulayi*	CO	LAB	PAH			TOX	FW
580	Power, H.	2013	Risk of Enbridge Northern Gateway Pipeline Project to Eulachon (Thaleichthys pacificus)	Thesis, Queens University	Report for degree of Master of Environmental Studies		90 p.	FISH	Eulachon	*Thaleichthys pacificus*	OR	DBT	WHL		BC	LIT	FW,SW
581	Puttaswamy, N. and Liber, K.	2011	IDENTIFYING THE CAUSES OF OIL SANDS COKE LEACHATE TOXICITY TO AQUATIC Invertebrates	Environmental Toxicology and Chemistry	30	11	2576-2585	CRUSTACEA	Water Flea	*Ceriodaphnia dubia*	OR	PRW	WHL			TOX	FW
582	Quagraine, E.K., Peterson, H.G. and Headley, J.V.	2005	In situ bioremediation of naphthenic acids contaminated tailing pond waters in the Athabasca oil sands region-demonstrated field studies and plausible options: A review	Journal of Environmental Science and Health	40	3	685-722				OR	PRW	NAC		AOS	LIT	FW
583	Quesnel, D.M., Bhaskar, I.M., Gieg, L.M. and Chua, G.	2011	Naphthenic acid biodegradation by the unicellular alga Dunaliella tertiolecta	Chemosphere	84	4	504-511	ALGAE MICROBIA	Dunaliella tertiolecta Synechococcus leopoliensis	*Dunaliella tertiolecta Synechococcus leopoliensis*	OR	PRW	NAC			PHYS	FW,SW
584	Quinterno, P.J. and Carkin, B.A.	1991	Benthic foraminifers from Prince William Sound, Alaska -- One year after the Exxon Valdez Oil Spill	In: Carlson, PR (Ed.) "Sediment of Prince William Sound, beach to deep fjord floor, a year after the Exxon Valdez oil spill." U.S. Geological Survey Open-File Report 91-631, 101 p.				FORAMINIFERA	Various	Various	CO	ANS	WHL	EVOS	AK	ECO	SW
585	Radniecki, T.S., Schneider, M.C. and Semprini, L.	2013	The influence of Corexit 9500A and weathering on Alaska North Slope crude oil toxicity to the ammonia oxidizing bacterium, Nitrosomonas europaea	Marine Pollution Bulletin	68	1-2	64-70	MICROBIA	*Bacteria*	*Nitrosomonas europaea*	CO,DS	ANS,COR	CWF,WAF			TOX	SW
586	Raimondo, S., Jackson, C.R., Krzykwa, J., Hemmer, B.L., Awkerman, J.A. and Barron, M.G.	2014	Developmental toxicity of Louisiana crude oil-spiked sediment to zebrafish	Ecotoxicology and Environmental Safety	108		265-272	FISH	Zebrafish	*Danio rerio*	CO	MAC,SLC	PAH	DWH	GM	TOX	FW
587	Raingeard, D., Bilbao, E., Sáez-Morquecho, C., de Cerio, O.D., Orbea, A., Cancio, I. and Cajaraville, M.P.	2009	Cloning and transcription of nuclear receptors and other toxicologically relevant genes, and exposure biomarkers in European hake (Merluccius merluccius) after the Prestige oil spill	Marine Genomics	2	3-4	201-213	FISH	European Hake	*Merluccius merluccius*	FO	HFO	WHL	PRES	SPN	ECO	SW
588	Ramachandran, S.D., Hodson, P.V., Khan, C.W. and Lee, K.	2004	Oil dispersant increases PAH uptake by fish exposed to crude oil	Ecotoxicology and Environmental Safety	59	3	300-308	FISH	Rainbow trout	*Oncorhynchus mykiss*	CO,DS	MLC,TNA,SCN,COR	PAH,TPH,WAF			TOX	FW

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589	Ramachandran, S.D., Sweezey, M.J., Hodson, P.V., Boudreau, M., Courtenay, S.C., Lee, K., King, T. and Dixon, J.A.	2006	Influence of salinity and fish species on PAH uptake from dispersed crude oil	Marine Pollution Bulletin	52	10	1182-1189	FISH	Mummichog Rainbow trout	*Fundulus heteroclitus Oncorhynchus mykiss*	CO,DS	MLC,COR	CWF,PAH,WAF			TOX	FW,SW
590	Rebar, A.H., Ballachey, B.E., Bruden, D.K. and Kloecker, K.A.	1996	Hematology and clinical chemistry of sea otters captured in Prince William Sound, Alaska following the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-17		MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
591	Redman, A.D., McGrath, J.A., Stubblefield, W.A., Maki, A.W. and Di Toro, D.M.	2012	Quantifying the concentration of crude oil microdroplets in oil-water preparations	Environmental Toxicology and Chemistry	31	8	1814-1822				CO	ANS	ALH,BTX,PAH			PHYS	FW
592	Redman, A.D., Parkerton, T.F., Letinski, D.J., Manning, R.G., Adams, J.E. and Hodson, P.V.	2014	EVALUATING TOXICITY OF HEAVY FUEL OIL FRACTIONS USING COMPLEMENTARY MODELING AND BIOMIMETIC EXTRACTION METHODS	Environmental Toxicology and Chemistry	33	9	2094-2104	FISH	Rainbow trout	*Oncorhynchus mykiss*	FO	HFO	WAF			TOX	FW
593	Reynolds, J.H. and Braman, N.	2009	Using tolerance intervals to assess recovery of mussel beds impacted by the Exxon Valdez oil spill	Marine Pollution Bulletin	58	10	1496-1504	MOLLUSC	Foolish Mussel	*Mytilus trossulus*	CO	ANS	PAH	EVOS	AK	TOX	SW
594	Rial, D., Beiras, R., Vázquez, J.A. and Murado, M.A.	2010	Acute Toxicity of a Shoreline Cleaner, CytoSol, Mixed With Oil and Ecological Risk Assessment of its Use on the Galician Coast	Archives of Environmental Contamination and Toxicology	59	3	407-416	CRUSTACEA ECHINODERM MOLLUSC	sea urchin mussels mysid	*Paracentrotus lividus Mytilus galloprovincialis Siriella armata*	CO,DS	LLC,CYT	WAF,WHL	PRES	SPN	ECO/TOX	SW
595	Rial, D., Murado, M.A., Menduiña, A., Fuciños, P., González, P., Mirón, J. and Vázquez, J.A.	2013	Effects of spill-treating agents on growth kinetics of marine microalgae	Journal of Hazardous Materials	263		374-381	ALGAE	Diatoms	*Bacillariophyceae*	DS	AGM,CYT,OSR	WHL			TOX	SW
596	Rial, D., Radović, J.R., Bayona, J.M., Macrae, K., Thomas, K.V. and Beiras, R.	2013	Effects of simulated weathering on the toxicity of selected crude oils and their components to sea urchin embryos	Journal of Hazardous Materials	260		67-73	ECHINODERM	Sea urchin embryo	*Paracentrotus lividus*	CO,FO	ANG,HFO	UVT,WAF			TOX	SW
597	Rial, D., Vázquez, J.A. and Murado, M.A.	2014	Toxicity of spill-treating agents and oil to sea urchin embryos	Science of the Total Environment	472		302-308	ECHINODERM	Sea urchin embryo	*Paracentrotus lividus*	CO,DS	MAY,AGM,CYT,OSR	CWF,WAF			TOX	SW
598	Rial, D., Vázquez, J.A., Menduiña, A., García, A.M., González, M.P., Mirón, J., Murado, M.A.	2013	Toxicity of binary mixtures of oil fractions to sea urchin embryos	Journal of Hazardous Materials	263		431-440	ECHINODERM	Sea urchin embryo	*Paracentrotus lividus*	CO	MAY	ALH,BTX,PAH			TOX	SW
599	Rice, S.D. and Carls, M.G.	2007	Prince William Sound herring: an updated synthesis of population declines and lack of recovery	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 050794		FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,WHL	EVOS	AK	LIT	SW
600	Rice, S.D., Babcock, M.M., Brodersen, C.C., Carls, M.G., Gharrett, J.A., Kern, S., Moles, A. and Short, J.W.	1986	LETHAL AND SUBLETHAL EFFECTS OF THE WATER-SOLUBLE FRACTION OF COOK INLET CRUDE OIL ON PACIFIC HERRING (CLUPEA HARENGUS PALLASI) REPRODUCTION	NOAA Final Report: Outer Continental Shelf Environmental Assessment Program Research Unit 661				FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	COK	WAF			TOX	EST
601	Rice, S.D., Carls, M.G., Heintz, R.A. and Short, J.W.	2003	Comment on "hydrocarbon composition and toxicity of sediments following the Exxon valdez oil spill in Prince William Sound, Alaska, USA'	Environmental Toxicology and Chemistry	22	11	2539-2540	CRUSTACEA MOLLUSC	Amphipod Mussels	*Amphipod Mytilus sp.*	CO	ANS	PAH	EVOS	AK	TOX	SW

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602	Rice, S.D., Short, J.W., Carls, M.G., Moles, A. and Spies, R.B.	2006	The Exxon Valdez Oil Spill	Long-term ecological change in the northern Gulf of Alaska			419- 520	COMMUNITY	Various	Various	CO	ANS	WHL	EVOS	AK	LIT	SW
603	Rice, S.D., Thomas, R.E., Carls, M.G., Heintz, R.A., Wertheimer, A.C., Murphy, M.L., Short, J.W. and Moles, J.	2001	Impacts to Pink Salmon Following the Exxon Valdez Oil Spill: Persistence, Toxicity, Sensitivity, and Controversy	Reviews in Fisheries Science	9	3	165-211	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	EST,SW
604	Richmond, S.A., Lindstrom, J.E. and Braddock, J.F.	2001	Effects of chitin on microbial emulsification, mineralization potential, and toxicity of bunker C fuel oil	Marine Pollution Bulletin	42	9	773-779	MICROBIA	MICROTOX®	*Vibrio fischeri*	FO	BUC	WHL			PHYS	SED,SW
605	Rico-Martinez, R., Snell, T.W. and Shearer, T.L.	2013	Synergistic toxicity of Macondo crude oil and dispersant Corexit 9500A (R) to the Brachionus plicatilis species complex (Rotifera)	Environmental Pollution	173		41769	MICROBIA	Rotifer	*Brachionus plicatilis*	CO,DS	MAC,COR	WAF	DWH	GM	TOX	SW
606	Roberts, A.P., Oris, J.T. and Stubblefield, W.A.	2006	Gene expression in caged juvenile Coho Salmon (Oncorhynchys kisutch) exposed to the waters of Prince William Sound, Alaska	Marine Pollution Bulletin	52	11	1527-1532	FISH	Coho salmon	*Oncorhynchus kisutch*	CO	ANS	PAH,WHL	EVOS	AK	ECO/TOX	SW
607	Roberts, P.O., Henry, C.B. Jr, Shigenaka, G. and Fukuyama, A.	1999	Weathered Petroleum “Bioavailability” to Intertidal Bivalve Species After the T/V Exxon Valdez Incident	International Oil Spill Conference Proceedings	1999	1	1003-1005	MOLLUSC	Foolish Mussel Native Littleneck Clam	*Mytilus trossulus Protothaca staminea*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
608	Rodrigues, R.V., Miranda-Filho, K.C., Gusmão, E.P., Moreira, C.B., Romano, L.A. and Sampaio, L.A.	2010	Deleterious effects of water-soluble fraction of petroleum, diesel and gasoline on marine pejerrey Odontesthes argentinensis larvae	Science of the Total Environment	408	9	2054-2059	FISH	Pejerrey	*Odontesthes argentinensis*	CO,FO	BRZ,DSL	WAF			TOX	SW
609	Rogowska, J., Wolska, L. and Namieśnik, J.	2010	Impacts of pollution derived from ship wrecks on the marine environment on the basis of s/s "Stuttgart" (Polish coast, Europe)	Science of the Total Environment	408	23	5775-5783				FO	HFO	PAH	STU	POL	PHYS	SED,SW
610	Romero-Lopez, J., Lopez-Rodas, V. and Costas, E.	2012	Estimating the capability of microalgae to physiological acclimatization and genetic adaptation to petroleum and diesel oil contamination	Aquatic Toxicology	124		227-237	ALGAE	PHYTOPLANKTON	*Chlorophyta*	FO	LAB,DSL	WHL			TOX	FW,SW
611	Roth, K., Whitmore, C. and Hansen, P.	1990	Prince William Sound and Gulf of Alaska sport fishery harvest and effort, 1989, Exxon Valdez Oil Spill State/Federal Natural Resource Damage Assessment Report (Fish/Shellfish Study Number 6)	EVOS Trustee Council	Fish/Shellfish Study	FS06	125 pp.	FISH	Flatfishes Coho Pink Chinook Sockeye Chum Rockfishes Codfishes Dolly varden Octopus	*Pleuronectiformes Oncorhynchus kistuch O. gorbuscha O. tshawytscha O. nerka O. keta Sebastes spp Gadidae Salvelinus malma Octopus spp*	CO	ANS	WHL	EVOS	AK	ECO	SW
612	Rotterman, L.M. and Monnett, C.	1995	Mortality of sea otter weanlings in eastern and western Prince William Sound, Alaska, during the winter of 1990-91	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Marine Mammal Study Number 6-18		MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
613	Rotterman, L.M. and Monnett, C.	2002	Length-mass and total body length of adult female sea otters in Prince William Sound before and after the Exxon Valdez oil spill	Marine Mammal Science	18	4	977-993	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
614	Roubal, W.T., Stranahan, S.I. and Malins, D.C.	1978	ACCUMULATION OF LOW-MOLECULAR WEIGHT AROMATIC-HYDROCARBONS OF CRUDE-OIL BY COHO SALMON (ONCORHYNCHUS-KISUTCH) AND STARRY FLOUNDER (PLATICHTHYS-STELLATUS)	Archives of Environmental Contamination and Toxicology	7	2	237-244	FISH	Coho salmon Starry flounder	*Oncorhynchus kisutch Platichthys stellatus*	CO	ANS	PAH,WAF			TOX	SW

RefID	Author(s)	Year	Title	Journal	Volume	Issue	Pages	Taxon	CommonName	Scientific Name	MainProduct	SpecificProduct	ComponentsAnalyzed	Event	Location	StudyType	ExposureMedia
615	Rougée, L., Downs, C.A., Richmond,R.H. and Ostrander, G.K.	2006	Alteration of normal cellular profiles in the scleractinian coral (Pocillopora damicornis) following laboratory exposure to fuel oil	Environmental Toxicology and Chemistry	25	12	3181-3187	CNIDARIA	Hard coral	*Pocillopora damicornis*	FO	IFO	WAF			TOX	SW
616	Roy, N.K., Stabile, J., Seeb, J.E., Habicht, C. and Wirgin, I.	1999	High frequency of K-ras mutations in pink salmon embryos experimentally exposed to Exxon Valdez oil	Environmental Toxicology and Chemistry	18	7	1521-1528	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO/TOX	EST,SW
617	Ruggerone, G.T. and Rogers, D.E.	1998	Historical analysis of sockeye salmon growth among populations affected by the Exxon Valdez oil spill and large spawning escapements	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 96048-BAA	83 p	FISH	Sockeye salmon	*Oncorhynchus nerka*	CO	ANS	WHL	EVOS	AK	ECO	SW
618	Ruggerone, G.T. and Rogers, D.E.	2003	Multi-year effects of high densities of sockeye salmon spawners on juvenile salmon growth and survival: a case study from the Exxon Valdez oil spill	Fisheries Research	63	3	379-392	FISH	Sockeye salmon	*Oncorhynchus nerka*	CO	ANS	WHL	EVOS	AK	ECO	SW
619	Ruiz, P., Ortiz-Zarragoitia, M., Orbea, A., Theron, M., Le Floch, S. and Cajaraville, M.P.	2012	Responses of conventional and molecular biomarkers in turbot Scophthalmus maximus exposed to heavy fuel oil no. 6 and styrene	Aquatic Toxicology	116		116-128	FISH	Turbot	*Scophthalmus maximus*	FO	HFO	WAF	ERK,PRES	FRA,SPN	TOX	SW
620	Ryder, K., Temara, A. and Holdway, D.A.	2004	Avoidance of crude-oil contaminated sediment by the Australian seastar, Patiriella exigua (Echinodermata : Asteroidea)	Marine Pollution Bulletin	49	11-12	900-909	ECHINODERM	Australian sea star	*Patiriella exigua*	CO	BSC	WHL			TOX	SW
621	Saco-Álvarez, L., Bellas, J., Nieto, Ó., Bayona, J.M., Albaigés, J. and Beiras, R.	2008	Toxicity and phototoxicity of water-accommodated fraction obtained from Prestige fuel oil and marine fuel oil evaluated by marine bioassays	Science of the Total Environment	394		275-282	CRUSTACEA ECHINODERM FISH MOLLUSC	Sheepshead minnow Copepod sea urchin mussel	*Cyprinodon variegatus Acartia tonsa Paracentrotus lividus Mytilus galloprovincialis*	FO	HFO,IFO	UVT,WAF	PRES	SPN	TOX	SW
622	Saeed, T., Al-mutairi, M., Ali, L.N., Al-obaid, T. and Beg, M.U.	1998	The effect of temperature on the composition and relative toxicity of the water-soluble fraction of Kuwait crude oil (export) in the seawater	International Journal of Environmental Analytical Chemistry	72	4	275-287	MICROBIA	MICROTOX®	*Vibrio fischeri*	CO	KCO	BTX,WAF			TOX	SW
623	Salaberria, I., Brakstad, O.G., Olsen, A.J., Nordtug, T. and Hansen, B.H.	2014	Endocrine and AhR-CYP1A Pathway Responses to the Water-Soluble Fraction of Oil in Zebrafish (Danio rerio Hamilton)	Journal of Toxicology and Environmental Health	77	9-11	506-515	FISH	Zebrafish	*Danio rerio*	CO	NSC	WAF			TOX	FW
624	Salamanca, M.J., Jiménez-Tenorio, N., González de Canales, M.L. and Del Valls, T.A.	2008	Evaluation of the toxicity of an oil spill conducted through bioassays using the fish Solea senegalensis	Ciencias Marinas	34	3	339-348	FISH	Senegalese sole	*Solea senegalensis*	FO	HFO	WHL	PRES	SPN	TOX	SED,SW
625	Salazar, S.	2003	Impacts of the Jessica oil spill on sea lion (Zalophus wollebaeki) populations	Marine Pollution Bulletin	47	7–8	313-318	MAMMAL	Galápagos sea lion	*Zalophus wollebaeki*	FO	HFO,DSL	WHL	JES	GAL	ECO	SW
626	Sale, D.M., Gibeaut, J.C. and Short, J.W.	1995	Nearshore transport of hydrocarbons and sediments following the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Subtidal Study Number 3B					CO	ANS	PAH	EVOS	AK	PHYS	SED,SW
627	Samiullah, Y.	1985	Biological effects of marine oil pollution	Oil and Petrochemical Pollution	2	4	235-264	COMMUNITY	Various	Various	CO	VAR	VAR			LIT	SW
628	Sanders, S.M.	2005	Immunotoxicology of Pacific herring: Determination of reference ranges and their application to assessing exposure to the water-soluble fraction of crude oil	Aquatic Toxicology	152		324-334	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,WAF	EVOS	AK	TOX	EST
629	Sargian, P., Mas., S., Pelletier, É. and Demers, S.	2007	Multiple stressors on an Antarctic microplankton assemblage: water soluble crude oil and enhanced UVBR level at Ushuaia (Argentina)	Polar Biology	30	7	829-841	ALGAE	Phytoplankton		CO	PAT	UVT,WAF			TOX	SW

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630	Scarlett, A., Galloway, T.S. and Rowland, S.J.	2007	Chronic toxicity of unresolved complex mixtures (UCM) of hydrocarbons in marine sediments	Journal of Soils and Sediments	7	4	200-206	CRUSTACEA	Amphipod	*Corophium volutator*	CO	ANS,TJP,LUB	ALH,PAH			TOX	SED,SW
631	Schein, A., Scott, J.A., Mos, L. and Hodson, P.V.	2009	Oil dispersion increases the apparent bioavailability and toxicity of diesel to rainbow trout (Oncorhynchus mykiss)	Environmental Toxicology and Chemistry	28	3	595-602	FISH	Rainbow trout	*Oncorhynchus mykiss*	DS,FO	COR,DSL	CWF,WAF			TOX	FW
632	Schmidt, D.C., Tarbox, K.E., King, B.E., Brannian, L.K., Kyle, G.B. and Carlson, S.R.	1996	Kenai river sockeye salmon: An assessment of overescapements as a cause of the decline	Proceedings of the Exxon Valdez Oil Spill Symposium	18		628-638	FISH	Sockeye salmon	*Oncorhynchus nerka*	CO	ANS	WHL	EVOS	AK	ECO	SW
633	Schwacke, L.H., Smith, C.R., Townsend, F.I., Wells, R.S., Hart, L.B., Balmer, B.C., Collier, T.K., De Guise, S., Fry, M.M., Guillette, L.J., Jr., Lamb, S.V., Lane, S.M., Mcfee, W.E., Place, N.J., Tumlin, M.C., Ylitalo, G.M., Zolman, E.S. and Rowles, T.K.	2014	Health of Common Bottlenose Dolphins (Tursiops truncatus) in Barataria Bay, Louisiana, Following the Deepwater Horizon Oil Spill	Environmental Science & Technology	48	1	93-103	MAMMAL	Bottlenose Dolphin	*Tursiops truncatus*	CO,DS	MAC,COR	WHL	DWH	GM	ECO	SW
634	Schwartz, J.A., Aldridge, B.M., Lasley, B.L., Snyder, P.W., Stott, J.L. and Mohr, F.C.	2004	Chronic fuel oil toxicity in American mink (Mustela vison): systemic and hematological effects of ingestion of a low-concentration of bunker C fuel oil	Toxicology and Applied Pharmacology	200	2	146-158	MAMMAL	American mink	*Neovison vison*	FO	BUC	WHL			TOX	ING
635	Scott, A.C., MacKinnon, M.D. and Fedorak, P.M.	2005	Naphthenic acids in athabasca oil sands tailings waters are less biodegradable than commercial naphthenic acids	Environmental Science & Technology	39	21	8388-8394				OR	PRW	NAC		AOS	PHYS	FW
636	Scott, G.I., Fulton, M.H., DeLorenzo, M.E., Wirth, E.F., Key, P.B., Pennington, P.L., Kennedy, D.M., Porter, D., Chandler, G.T., Scott, C.H. and Ferry, J.L.	2013	The Environmental Sensitivity Index and Oil and Hazardous Materials Impact Assessments: Linking Prespill Contingency Planning and Ecological Risk Assessment	Journal of Coastal Research			100-113				BG,CO	UKN	UKN		USA	ECO	EST,FW,SW
637	See, M.G.	2001	Lessons learned: evaluating scientific sampling of effects from the Exxon Valdez oil spill	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 00530		FISH MAMMAL MOLLUSC	Blue mussels Pink salmon Pacific herring Sea otter	*Mytilus edulis Oncorhynchus gorbuscha Clupea pallasii Enhydra lutris*	CO	ANS	WHL	EVOS	AK	LIT	SW
638	Seeb, J.E. and Habicht, C.	1999	Laboratory examination of oil-related embryo mortalities that persist in pink salmon populations in Prince William Sound	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 97191A-2		FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	TOX	SW
639	Seeb, L.W., Habicht, C., Templin, W.D., Tarbox, K.E., Davis, R.Z., Brannian, L.K. and Seeb, J.E.	2000	Genetic diversity of sockeye salmon of Cook Inlet, Alaska, and its application to management of populations affected by the Exxon Valdez oil spill	Transactions of the American Fisheries Society	129	6	1223-1249	FISH	Sockeye salmon	*Oncorhynchus nerka*	CO	ANS	WHL	EVOS	AK	ECO	FW,SW
640	Sellin Jeffries, M.K., Claytor, C., Stubblefield, W., Pearson, W.H. and Oris, J.T.	2013	Quantitative Risk Model for Polycyclic Aromatic Hydrocarbon Photoinduced Toxicity in Pacific Herring Following the Exxon Valdez Oil Spill	Environmental Science & Technology	47	10	5450-5458	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	PAH,UVT	EVOS	AK	MOD	SW
641	Seuront, L.	2010	Zooplankton avoidance behaviour as a response to point sources of hydrocarbon-contaminated water	Marine and Freshwater Research	61	3	263-270	CRUSTACEA	Copepods	*Eurytemora affinis Temora longicomis*	FO	DSL	WAF			TOX	EST,SW

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642	Shafir, S., van Rijn, J. and Rinkevich, B.	2007	Short and long term toxicity of crude oil and oil dispersants to two representative coral species	Environmental Science & Technology	41	15	5571-5574	CNIDARIA	Hard Coral	*Stylophora pistillata Pocillopora damicornis*	CO,DS	EGT,VAR	CWF,WAF			TOX	SW
643	Shane, S.H.	1990	PROTECTING SEA OTTERS FROM OIL SPILLS RECOMMENDATIONS BASED ON THE ALASKA USA EXPERIENCE	U S Fish and Wildlife Service Biological Report	90	12	432-436	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
644	Shang, D., Buday, C., van Aggelen, G. and Colodey, A.	2012	Toxicity Evaluation of the Oil Surface Washing Agent Corexit® 9580 and its Shoreline Application in Burrard Inlet, British Columbia	In: Proceedings of the 35th Arctic and Marine Oilspill Program (AMOP) Technical Seminar	35	(31)	519-524	ECHINODERM FISH MICROBIA	Coho salmon Eccentric sand dollar Microtox®	*Oncorhynchus kisutch Dendraster excentricus Vibrio fischeri*	DS,OR	DBT,COR	WHL	BIP	BC	ECO/TOX	SW
645	Sharr, S., Bue, B.G., Moffitt, S.D., Craig, A. and Evans, D.G.	1994	Injury to salmon eggs and preemergent fry in Prince William Sound	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Fish/Shellfish Study Number 2		FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW
646	Sharr, S., Seeb, J.E., Bue, B.G., Craig, A. and Miller, G.D.	1994	Injury to salmon eggs and preemergent fry in Prince William Sound	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Restoration Study 60C		FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW
647	Shelton, M.E., Chapman, P.J., Foss, S.S. and Fisher, W.S.	1999	Degradation of weathered oil by mixed marine bacteria and the toxicity of accumulated water-soluble material to two marine crustacea	Archives of Environmental Contamination and Toxicology	36	1	13-20	CRUSTACEA	grass shrimp	*Palaemonetes pugio*	CO	ANS	WAF			TOX	SW
648	Shigenaka, G., Coats, D.A., Fukuyama, A.K. and Roberts, P.O.	1999	Effects and Trends in Littleneck Clams (Protothaca Staminea) Impacted by the Exxon Valdez Oil Spill	International Oil Spill Conference Proceedings	1999	1	349-356	MOLLUSC	Native Littleneck Clam	*Protothaca staminea*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
649	Short, J.W. and Babcock, M.M.	1996	Prespill and Postspill Concentrations of Hydrocarbons in Mussels and Sediments in Prince William Sound	Proceedings of the Exxon Valdez Oil Spill Symposium	18		149-166	MOLLUSC	Mussels	*Mytilus sp.*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
650	Short, J.W. and Harris, P.M.	1996	Petroleum Hydrocarbons in Caged Mussels Deployed in Prince William Sound after the Exxon Valdez Oil Spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		29-39	MOLLUSC	Foolish mussel	*Mytilus trossulus*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
651	Short, J.W., Rice, S.D., Heintz, R.A., Carls, M.G. and Moles, A.	2003	Long-term effects of crude oil on developing fish: Lessons from the Exxon Valdez oil spill	Energy Sources	25	6	509-517	FISH	Pink salmon Pacific herring	*Oncorhynchus gorbuscha Clupea pallasii*	CO	ANS	PAH,WHL	EVOS	AK	LIT	SW
652	Short, J.W., Springman, K.R., Lindeberg, M.R., Holland, L.G., Larsen, M.L., Sloan, C.A., Khan, C., Hodson, P.V. and Rice, S.D.	2008	Semipermeable membrane devices link site-specific contaminants to effects: PART II - A comparison of lingering Exxon Valdez oil with other potential sources of CYP1A inducers in Prince William Sound, Alaska	Marine Environmental Research	66	5	487-498	FISH	Rainbow trout	*Oncorhynchus mykiss*	CO	ANS	PAH,WHL	EVOS	AK	ECO/TOX	FW,SW
653	Shukla, P., Gopalani, M., Ramteke, D.S. and Wate, S.R.	2007	Influence of salinity on PAH uptake from water soluble fraction of crude oil in Tilapia mossambica	Bulletin of Environmental Contamination and Toxicology	79	6	601-605	FISH	Tilapia	*Oreochromis mossambicus*	CO	BHC	PAH			TOX	SW
654	Silliman, B.D.	2014	Guidelines to Prepare for Oil Sands Product Spills in Varied Aquatic Environments	International Oil Spill Conference Proceedings	2014	1	426-433				BG,OR	DBT	WHL	BIP,KAL	BC,MI	LIT	FW,SW

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655	Singer, M.M., George, S., Jacobson, S., Lee, I., Tjeerdema, R.S. and Sowby, M.L.	1994	COMPARATIVE EFFECTS OF OIL DISPERSANTS TO THE EARLY-LIFE STAGES OF TOPSMELT (ATHERINOPS-AFFINIS) AND KELP (MACROCYSTIS-PYRIFERA)	Environmental Toxicology and Chemistry	13	4	649-655	ALGAE FISH	Topsmelt Giant kelp	*Atherinops affinis Macrocystis pyrifera*	DS	NOK,SLK	WHL			TOX	SW
656	Singer, M.M., George, S., Jacobson, S., Lee, I., Weetman, L.L., Tjeerdema, R.S. and Sowby, M.L.	1995	ACUTE TOXICITY OF THE OIL DISPERSANT COREXIT-9554 TO MARINE ORGANISMS	Ecotoxicology and Environmental Safety	32	1	81-86	ALGAE CRUSTACEA FISH MOLLUSC	Topsmelt Forest kelp mysid Red abalone Giant kelp	*Atherinops affinis Holmesimysis costata Haliotis rufescens Macrocystis pyrifera*	DS	COR	WHL			TOX	SW
657	Singer, M.M., George, S., Jacobson, S., Lee, I., Weetman, L.L., Tjeerdema, R.S. and Sowby, M.L.	1996	Comparison of acute aquatic effects of the oil dispersant Corexit 9500 with those of other Corexit series dispersants	Ecotoxicology and Environmental Safety	35	2	183-189	CRUSTACEA MOLLUSC	Red abalone Mysid shrimp	*Haliotis rufescens Holmesimysis sculpta*	DS	COR	WHL			TOX	SW
658	Singer, M.M., George, S., Lee, I., Jacobson, S., Weetman, L.L., Blondina, G., Tjeerdema, R.S., Aurand, D. and Sowby, M.L.	1998	Effects of dispersant treatment on the acute aquatic toxicity of petroleum hydrocarbons	Archives of Environmental Contamination and Toxicology	34	2	177-187	CRUSTACEA FISH MOLLUSC	Red abalone Forest kelp mysid Topsmelt	*Haliotis rufescens Holmesimysis costata Atherinops affinis*	CO,DS	ANS,COR	WHL			TOX	SW
659	Singh, A.K. and Gaur, J.P.	1990	EFFECTS OF PETROLEUM OILS AND THEIR PARAFFINIC, ASPHALTIC, AND AROMATIC FRACTIONS ON PHOTOSYNTHESIS AND RESPIRATION OF MICROALGAE	Ecotoxicology and Environmental Safety	19	1	41867	ALGAE MICROBIA	Cyanobacteria Anabaena doliolum	*Cyanobacteria Anabaena doliolum*	CO	ASC	ALH,BTX,PAH			TOX	FW
660	Siron, R., Giusti, G., Berland, B., Morales-Loo, R. and Pelletier, E.	1991	WATER-SOLUBLE PETROLEUM COMPOUNDS - CHEMICAL ASPECTS AND EFFECTS ON THE GROWTH OF MICROALGAE	Science of the Total Environment	104	3	211-227	ALGAE	Diatoms Green Algae	*Bacillariophyceae Chlorophyta*	CO	ARL	WAF			TOX	SW
661	Siwik, P.L., Van Meer, T., MacKinnon, M.D. and Paszkowski, C.A.	2000	Growth of fathead minnows in oilsand-processed wastewater in laboratory and field	Environmental Toxicology and Chemistry	19	7	1837-1845	FISH	Fathead minnow	*Pimephales promelas*	OR	PRW	WHL		AOS	TOX	FW
662	Sloan, N.A.	1999	Oil impacts on cold water marine resources: a review relevant to Parks Canada's evolving marine mandate	Parks Canada Occasional Paper	11		67 pp	COMMUNITY	Various	Various	CO	VAR	WHL		CAN	LIT	SW
663	Smith, E.E., Carr, J.A., Wages, M., Wang, J.F., Murali, S. and Kendall, R.	2012	Response of larval frogs to Corexit 9500	Toxicological and Environmental Chemistry	94	6	1199-1210	AMPHIBIA	African clawed frog	*Xenopus laevis*	DS	COR	WHL			TOX	FW
664	Smith, R.L. and Cameron, J.A.	1979	EFFECT OF WATER-SOLUBLE FRACTION OF PRUDHOE BAY CRUDE-OIL ON EMBRYONIC-DEVELOPMENT OF PACIFIC HERRING	Transactions of the American Fisheries Society	108	1	70-75	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WAF			TOX	SW
665	Sogbanmu, T.O. and Otitoloju, A.A.	2014	Joint Action Toxicity and Biochemical effects of Binary Mixtures of Forcados Light Crude Oil and Three Dispersants against Clarias gariepinus	International Journal of Environmental Research	8	2	395-402	FISH	African sharptooth catfish	*Clarias gariepinus*	CO,DS	FLC,DST CCO OCT	CWF,WAF,WHL			TOX	FW
666	Sol, S.Y., Johnson, L.L., Horness, B.H. and Collier, T.K.	2000	Relationship between oil exposure and reproductive parameters in fish collected following the Exxon Valdez oil spill	Marine Pollution Bulletin	40	12	1139-1147	FISH	Dolly varden Yellowfin sole Walleye pollock	*Salvelinus malma Limanda aspera Theragra chalcogramma*	CO	ANS	WHL	EVOS	AK	ECO	SW
667	Solé, M., Buet, A., Ortiz, L., Maynou, F., Bayona, J.M. and Albaigés, J.	2007	Bioaccumulation and biochemical responses in mussels exposed to the water-accommodated fraction of the Prestige fuel oil	Scientia Marina	71	2	373-382	MOLLUSC	Mediterranean mussel	*Mytilus galloprovincialis*	FO	HFO	WAF	PRES	SPN	TOX	SW
668	Solé, M., Lima, D., Reis-Henriques, M.A. and Santos, M.M.	2008	Stress biomarkers in juvenile senegal sole, Solea senegalensis, exposed to the water-accommodated fraction of the "Prestige" fuel oil	Bulletin of Environmental Contamination and Toxicology	80	1	19-23	FISH	Senegalese sole	*Solea senegalensis*	FO	HFO	WAF	PRES	SPN	TOX	SW
669	Spies, R.B., Rice, S.D., Wolfe, D.A. and Wright, B.A.	1996	The effects of the Exxon Valdez oil spill on the Alaskan coastal environment	Proceedings of the Exxon Valdez Oil Spill Symposium	18		1 - 16	BIRD FISH MAMMAL MOLLUSC	Seabirds Salmonids Pacific herring Mammals		CO	ANS	WHL	EVOS	AK	ECO	SW

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670	Spraker, T.R.	1990	HAZARDS OF RELEASING REHABILITATED ANIMALS WITH EMPHASIS ON SEA OTTERS AND THE T-V EXXON VALDEZ OIL SPILL	U S Fish and Wildlife Service Biological Report	90	12	385-389	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	ECO	SW
671	Springman, K.R., Short, J.W., Lindeberg, M.R., Maselko, J.M., Khan, C., Hodson, P.V. and Rice, S.D.	2008	Semipermeable membrane devices link site-specific contaminants to effects: Part 1 – Induction of CYP1A in rainbow trout from contaminants in Prince William Sound, Alaska	Marine Environmental Research	66	5	477-486	FISH	Rainbow trout	*Oncorhynchus mykiss*	CO	ANS	WHL	EVOS	AK	ECO/TOX	FW,SW
672	Stagg, R.M., Robinson, C., McIntosh, A.M., Moffat, C.F. and Bruno, D.W.	1998	The effects of the 'Braer' oil spill, Shetland Isles, Scotland, on P4501A in farmed Atlantic salmon (Salmo salar) and the common dab (Limanda limanda)	Marine Environmental Research	46		301-306	FISH	Atlantic salmon Common dab	*Salmo salar Limanda limanda*	CO	NSC	WHL	BRA	UK	ECO	SW
673	Stagg, R.M., Rusin, J., McPhail, M.E., McIntosh, A.D., Moffat, C.F. and Craft, J.A.	2000	Effects of polycyclic aromatic hydrocarbons on expression of CYP1A in salmon (Salmo salar) following experimental exposure and after the Braer oil spill	Environmental Toxicology and Chemistry	19	11	2797-2805	FISH	Atlantic salmon	*Salmo salar*	CO	LAB	PAH	BRA	UK	TOX	SW
674	Stantec	2012	Summary of Clean up and Effects of the 2007 Spill of Oil from Trans Mountain Pipeline to Burrard Inlet	Stantec, 111 Dunsmuir St. #1100, Vancouver, BC V6B 6A3	Project No. 1231-10505		13 pp	CRUSTACEA MOLLUSC PLANT	Rockweed Red rock crab Dungeness crab Blue mussels	*Fucus gardneri Cancer productus Metacarcinus magister Mytilus edulis*	OR	DBT	PAH,WHL	BIP	BC	ECO	SW
675	Steadman, B.L., Farag, A.M. and Bergman, H.L.	1991	EXPOSURE-RELATED PATTERNS OF BIOCHEMICAL INDICATORS IN RAINBOW-TROUT EXPOSED TO NO-2 FUEL-OIL	Environmental Toxicology and Chemistry	10	3	365-374	FISH	Rainbow trout	*Oncorhynchus mykiss*	FO	LFO	WHL			TOX	FW
676	Steadman, B.L., Stubblefield, W.A., LaPoint, T.W., Bergman, H.L. and Kaiser, M.S.	1991	DECREASED SURVIVAL OF RAINBOW-TROUT EXPOSED TO NO-2 FUEL-OIL CAUSED BY SUBLETHAL PREEXPOSURE	Environmental Toxicology and Chemistry	10	3	355-363	FISH	Rainbow trout	*Oncorhynchus mykiss*	FO	LFO	WHL			TOX	SW
677	Stekoll, M.S. and Deysher, L.	1996	Recolonization and restoration of upper intertidal Fucus gardneri (Fucales, Phaeophyta) following the Exxon Valdez oil spill	Hydrobiologia	327		311-316	ALGAE	Rockweed	*Fucus gardneri*	CO	ANS	WHL	EVOS	AK	ECO	SW
678	Stekoll, M.S. and Deysher, L.	2000	Response of the Dominant Alga Fucus gardneri (Silva) (Phaeophyceae) to the Exxon Valdez Oil Spill and Clean-up	Marine Pollution Bulletin	40	11	1028-1041	ALGAE	Rockweed	*Fucus gardneri*	CO	ANS	WHL	EVOS	AK	ECO	SW
679	Stekoll, M.S., Deysher, L., Highsmith, R..C, Saupe, S.M., Guo, Z.Y., Erickson, W.P., McDonald, L. and Strickland, D.	1996	Coastal habitat injury assessment: Intertidal communities and the Exxon Valdez oil spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		177-192	ALGAE ANNELIDA CRUSTACEA MOLLUSC	Inventory of macroalgae and invertebrates Fucus used as indicator species	*Fucus gardneri*	CO	ANS	WHL	EVOS	AK	LIT	SW
680	Stubblefield, W.A., Hancock, G.A., Ford, W.H., Prince, H.H. and Ringer, R.K.	1995	Evaluation of the Toxic Properties of Naturally Weathered Exxon Valdez Crude Oil to Surrogate Wildlife Species	Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters	1219		665	BIRD MAMMAL	Mallard duck European ferret	*Anas platyrhynchos Mustela putorius*	CO	ANS	WHL	EVOS	AK	TOX	SW
681	Stubblefield, W.A., McKee, R.H., Kapp, R.W. and Hinz, J.P.	1989	An evaluation of the acute toxic properties of liquids derived from oil sands	Journal of Applied Toxicology	9	1	59-65	MAMMAL	Sprague-Dawley rat New Zealand white rabbit Swiss-Webster mouse	*Rattus norvegicus Oryctolagus cuniculus Mus musculus*	OR	DBT	WHL		AOS	TOX	ING
682	Sturdevant, M.V., Wertheimer, A.C. and Lum, J.L.	1996	Diets of juvenile pink and chum salmon in oiled and non-oiled nearshore habitats in Prince William Sound, 1989 and 1990	Proceedings of the Exxon Valdez Oil Spill Symposium	18		578-592	FISH	Pink salmon Chum salmon	*Oncorhynchus gorbuscha Oncorhynchus keta*	CO	ANS	WHL	EVOS	AK	ECO	SW
683	Suderman, K. and Thistle, D.	2004	The relative impacts of spills of two alternative fuels on the microalgae of a sandy site: a microcosm study	Marine Pollution Bulletin	49	5-6	473-478	ALGAE	Diatoms	*Bacillariophyceae*	FO,OR	BUC,ORI	WHL			TOX	SW
684	Sundberg, H., Ishaq, R., Tjärnlund, U., Åkerman, G., Grunder, K., Bandh, C., Broman, D. and Balk, L.	2006	Contribution of commonly analyzed polycyclic aromatic hydrocarbons (PAHs) to potential toxicity in early life stages of rainbow trout (Oncorhynchus mykiss)	Canadian Journal of Fisheries and Aquatic Sciences	63	6	1320-1333	FISH	Rainbow trout	*Oncorhynchus mykiss*	BG	UKN	PAH			TOX	FW,SED

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685	Svecevičius, G., Kazlauskienė, N. and Vosylienė, M.Z.	2003	Toxic effects of orimulsion on rainbow trout Oncorhynchus mykiss	Environmental Science and Pollution Research	10	5	281-283	FISH	Rainbow trout	*Oncorhynchus mykiss*	OR	ORI	WHL			TOX	FW
686	Swannell, R.P.J., Mitchell, D., Lethbridge, G., Jones, D., Heath, D., Hagley, M., Jones, M., Petch, S., Milne, R., Croxford, R. and Lee, K.	1999	A field demonstration of the efficacy of bioremediation to treat oiled shorelines following the Sea Empress incident	Environmental Technology	20	8	863-873	MICROBIA MOLLUSC	MICROTOX® Pacific oyster	*Vibrio fischeri Crassostrea gigas*	CO,FO	FBC,HFO	WHL	SEM	UK	TOX	SW
687	Swanton, C.O., Dalton, T.J., Barrett, B.M., Pengilly, D., Brennan, K.R. and Nelson, P.A.	1993	Effects of pink salmon (Oncorhynchus gorbuscha) escapement level of egg retention, preemergent fry, and adult returns to the Kodiak and Chignik management areas caused by the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Fish/Shellfish Study Number 7B and 8B		FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW
688	Swigert, J.P., Lee, C., Wong, D.C.L. and Podhasky, P.	2014	Aquatic hazard and biodegradability of light and middle atmospheric distillate petroleum streams	Chemosphere	108		41648	ALGAE CRUSTACEA FISH	Daphnia Rainbow trout Green algae	*Daphnia magna Oncorhynchus mykiss Pseudokirchnerella subcapitata*	FO	LFO	WHL			TOX	FW
689	Tarbox, K.E., Davis, R.Z., Brannian, L.K. and Fried, S.M.	1995	Kenai River sockeye salmon restoration, Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project 94255)	EVOS Trustee Council	Restoration Project	94255	58 pp.	FISH	Sockeye salmon	*Oncorhynchus nerka*	CO	ANS	WHL	EVOS	AK	ECO	SW
690	Taylor, C., Ben-David, M., Bowyer, R.T. and Duffy, L.K.	2001	Response of river otters to experimental exposure of weathered crude oil: Fecal porphyrin profiles	Environmental Science & Technology	35	4	747-752	MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	TOX	ING
691	Taylor, C., Duffy, L.K., Bowyer, R.T and Blundell, G.M.	2000	Profiles of fecal porphyrins in river otters following the Exxon Valdez oil spill	Marine Pollution Bulletin	40	12	1132-1138	MAMMAL	River otter	*Lontra canadensis*	CO	ANS	WHL	EVOS	AK	ECO	SW
692	Thomas, M.L.H.	1973	Effects of Bunker C Oil on Intertidal and Lagoonal Biota in Chedabucto Bay, Nova Scotia	Journal of the Fisheries Research Board of Canada	30	1	83-90	ALGAE MOLLUSC PLANT	Brown algae Eelgrass Barnacles Periwinkles Softshell clams	*Fucus spp Balanus balanoides Littorina littorea Zostera marina Mya arenaria*	FO	HFO	WHL	ARR	NS	ECO	SW
693	Thomas, M.L.H.	1978	Comparison of Oiled and Unoiled Intertidal Communities in Chedabucto Bay, Nova Scotia	Journal of the Fisheries Research Board of Canada	35	5	707-716	COMMUNITY	Brown algae Eelgrass Barnacles Periwinkles Softshell clams Smooth Cordgrass	*Fucus spp Balanus balanoides Littorina littorea Zostera marina Mya arenaria Spartina alterniflora*	FO	HFO	WHL	ARR	NS	ECO	SW
694	Thomas, R.E., Brodersen, C., Carls, M.G., Babcock, M. and Rice, S.D.	1999	Lack of physiological responses to hydrocarbon accumulation by Mytilus trossulus after 3-4 years chronic exposure to spilled Exxon Valdez crude oil in Prince William Sound	Comparative Biochemistry and Physiology	122	1	153-163	MOLLUSC	Mussels	*Mytilus trossulus*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
695	Thomas, R.E., Harris, P.M. and Rice, S.D.	1999	Survival in air of Mytilus trossulus following long-term exposure to spilled Exxon Valdez crude oil in Prince William sound	Comparative Biochemistry and Physiology	122	1	147-152	MOLLUSC	Mussels	*Mytilus trossulus*	CO	ANS	PAH,WHL	EVOS	AK	ECO/TOX	SW
696	Thomas, R.E., Lindeberg, M., Harris, P.M. and Rice, S.D.	2007	Induction of DNA strand breaks in the mussel (Mytilus trossulus) and clam (Protothaca staminea) following chronic field exposure to polycyclic aromatic hydrocarbons from the Exxon Valdez spill	Marine Pollution Bulletin	54	6	726-732	MOLLUSC	Mussels Littleneck clam	*Mytilus trossolus Protothaca staminea (Leukoma staminea)*	CO	ANS	PAH,WHL	EVOS	AK	ECO	SW
697	Thorne, R.E. and Thomas, G.L.	2014	The Exxon Valdez Oil Spill and the Collapse of the Prince William Sound Herring Stock: A reexamination of Critical Biomass Estimaties	Impacts of Oil Spill Disasters on Marine Habitats and Fisheries in North America			199- 208	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	ECO	SW
698	Thorne, R.E. and Thomas, G.L.	2008	Herring and the "Exxon Valdez" oil spill: an investigation into historical data conflicts	Ices Journal of Marine Science	65	1	44-50	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	CO	ANS	WHL	EVOS	AK	ECO	SW

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699	Trowbridge, C., Baker, T.T. and Johnson, J.D.	2001	Effects of hydrocarbons on bivalves following the Exxon Valdez oil spill	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Fish/Shellfish Study Number 13	149 p	MOLLUSC	Butter clam Littleneck clam Pacific razor clam	*Saxidomus giganteus Protothaca (Leukoma) staminea Siliqua patula*	CO	ANS	BTX,PAH	EVOS	AK	ECO	SW
700	Tsaprailis, H.	2014	Properties of Dilbit and Conventional Crude Oils	Alberta Innovates							CO,OR	VAR,DBT	VAR			PHYS	
701	Tsomides, H.J., Hughes, J.B., Thomas, J.M. and Ward, C.H.	1995	EFFECT OF SURFACTANT ADDITION ON PHENANTHRENE BIODEGRADATION IN SEDIMENTS	Environmental Toxicology and Chemistry	14	6	953-959	MICROBIA	Mixed microbial population (unspecified)		DS	VAR	PAH			PHYS	SED,SW
702	Turja, R., Guimarães, L., Nevala, A., Kankaanpää, H., Korpinen, S. and Lehtonen, K.K.	2014	Cumulative effects of exposure to cyanobacteria bloom extracts and benzo a pyrene on antioxidant defence biomarkers in Gammarus oceanicus (Crustacea: Amphipoda)	Toxicon	78		68-77	CRUSTACEA	Amphipod	*Gammarus oceanicus*	CO	LAB	PAH			TOX	SW
703	Upton, H.F.	2011	The Deepwater Horizon Oil Spill and the Gulf of Mexico Fishing Industry	Report			17 pp	CRUSTACEA FISH	Various fish and shellfish		CO	MAC	WHL	DWH	GM	LIT	EST,SW
704	Urho, L.	1990	IMPACT OF AN OIL-SPILL ON HERRING STOCK	Proceedings of the International Herring Symposium	9		569-582	FISH	Atlantic Herring	*Clupea harengus*	CO	BAL	WHL	ANG	FIN	ECO	SW
705	van den Heuvel, M.R., Hogan, N.S., Roloson, S.D. and Van Der Kraak, G.J.	2012	Reproductive development of yellow perch (Perca flavescens) exposed to oil sands-affected waters	Environmental Toxicology and Chemistry	31	3	654-662	FISH	Yellow perch	*Perca flavescens*	OR	PRW	WHL		AOS	TOX	FW
706	van den Heuvel, M.R., Power, M., Richards, J., MacKinnon, M. and Dixon, D.G.	2000	Disease and gill lesions in yellow perch (Perca flavescens) exposed to oil sands mining-associated waters	Ecotoxicology and Environmental Safety	46	3	334-341	FISH	Yellow perch	*Perca flavescens*	OR	PRW	WHL		AOS	TOX	FW
707	Van Scoy, A.R., Lin, C.Y., Anderson, B.S., Philips, B.M., Martin, M.J., McCall, J., Todd, C.R., Crane, D., Sowby, M.L., Viant, M.R. and Tjeerdema, R.S.	2010	Metabolic responses produced by crude versus dispersed oil in Chinook salmon pre-smolts via NMR-based metabolomics	Ecotoxicology and Environmental Safety	73	5	710-717	FISH	Chinook salmon	*Oncorhynchus tshawytscha*	CO,DS	ANS,COR	CWF,WAF			TOX	FW
708	van Tamelen, P.G. and Stekoll, M.S.	1996	Population response of the brown alga Fucus gardneri and other algae in Herring Bay, Prince William Sound, to the Exxon Valdez oil spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		193-211	ALGAE	Rockweed	*Fucus gardneri*	CO	ANS	WHL	EVOS	AK	ECO	SW
709	van Tamelen, P.G., Stekoll, M.S. and Deysher, L.	1997	Recovery processes of the brown alga Fucus gardneri following the 'Exxon Valdez' oil spill: settlement and recruitment	Marine Ecology Progress Series	160		265-277	ALGAE	Rockweed	*Fucus gardneri*	CO	ANS	WHL	EVOS	AK	ECO	SW
710	Varanasi, U., Chan, S.L., MacLeod, W.D., Stein, J.E., Brown, D.W., Burrows, D.G., Tilbury, K.L., Landahl, J.T., Wigren, C.A., Hom, T. and Pierce, S.M.	1990	Survey of subsistence fish and shellfish for exposure to oil spilled from the Exxon Valdez, First year: 1989	NOAA Technical Memorandum			178 pp	CRUSTACEA ECHINODERM FISH MOLLUSC	Salmonids Cods Rockfishes Flatfishes Clams Snails Urchins Crabs	*Oncorhynchus spp Gadus spp Sebastes spp Pleuronectiformes Bivalvia Gastropoda Echinacea Brachyura*	CO	ANS	PAH	EVOS	AK	ECO	SW

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711	Varanasi, U., Collier, T.K., Krone, C.A., Krahn, M.M., Johnson, L.L., Myers, M.S. and Chan, S.L.	1995	Assessment of oil spill impacts on fishery resources: measurement of hydrocarbons and their metabolites, and their effects, in important species	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Subtidal Study Number 7		FISH	Dolly varden Yellowfin sole Rock sole Pacific halibut Walleye pollock	*Salvelinus malma Limanda aspera Lepidopsetta bilineata Hippoglossus stenolepis Theragra chalcogramma*	CO	ANS	PAH	EVOS	AK	ECO	SW
712	Vieira, L.R. and Guilhermino, L.	2012	Multiple stress effects on marine planktonic organisms: Influence of temperature on the toxicity of polycyclic aromatic hydrocarbons to Tetraselmis chuii	Journal of Sea Research	72		94-98	ALGAE	Microalgae	*Tetraselmis chuii*	CO	LAB	PAH			MOD	SW
713	Vignier, V., Vandermeulen, J.H. and Fraser, A.J.	1992	GROWTH AND FOOD CONVERSION BY ATLANTIC SALMON PARR DURING 40 DAYS EXPOSURE TO CRUDE-OIL	Transactions of the American Fisheries Society	121	3	322-332	FISH	Atlantic salmon	*Salmo salar*	CO	HBN	WHL			TOX	FW
714	Vikebø, F.B., Rønningen, P., Lien, V.S., Meier, S., Reed, M., Ådlandsvik, B. and Kristiansen, T.	2014	Spatio-temporal overlap of oil spills and early life stages of fish	Ices Journal of Marine Science	71	4	970-981	FISH	Northeast arctic cod	*Gadus morhua*	CO	VAR	WHL			MOD	SW
715	Villanueva, R.D., Montaño, M.N.E. and Yap, H.T.	2008	Effects of natural gas condensate – water accommodated fraction on coral larvae	Marine Pollution Bulletin	56	8	1422-1428	CNIDARIA	Brooding coral larvae	*Seriatopora hystrix Seriatopora guttatus Stylophora pistilllata Pocillopora damicornis Pocillopora verrucosa*	OR	DIL	WAF			TOX	SW
716	Villanueva, R.D., Yap, H.T. and Montaño, M.N.E.	2011	Reproductive effects of the water-accommodated fraction of a natural gas condensate in the Indo-Pacific reef-building coral Pocillopora damicornis	Ecotoxicology and Environmental Safety	74	8	2268-2274	CNIDARIA	Brooding coral larvae	*Pocillopora damicornis*	OR	DIL	WAF			TOX	SW
717	Vosylienė, M.Z., Kazlauskienė, N. and Jokšas, K.	2005	Toxic effects of crude oil combined with oil cleaner simple green on yolk-sac larvae and adult rainbow trout Oncorhynchus mykiss	Environmental Science and Pollution Research	12	3	136-139	FISH	Rainbow trout	*Oncorhynchus mykiss*	CO,DS	LTH,CSG	WAF,WHL		EUR	TOX	FW
718	Vrabie, C.M., Jonker, M.T.O. and Murk, A.J.	2009	SPECIFIC IN VITRO TOXICITY OF CRUDE AND REFINED PETROLEUM PRODUCTS. 1. ARYL HYDROCARBON RECEPTOR-MEDIATED RESPONSES	Environmental Toxicology and Chemistry	28	9	1995-2003	MAMMAL	Rat	*Rattus norvegicus*	CO	VAR	PAH			TOX	FW
719	Waldichuk, M.	1990	SEA OTTERS AND OIL POLLUTION	Marine Pollution Bulletin	21	1	42292	MAMMAL	Sea otter	*Enhydra lutris*	CO	ANS	WHL	EVOS	AK	LIT	SW
720	Waldichuk, M.	1983	Pollution in the Strait of Georgia: a Review	Canadian Journal of Fisheries and Aquatic Sciences	40	7	1142-1167	FISH MOLLUSC	Pacific oyster Salmonids Starry flounder Herring Pacific cod English sole Pandalid shrimps Dungeness crab	*Crassostrea gigas Oncorhynchus spp Platichthys stellatus Gadus macrocephalus Parophrys vetulus Pandalus spp Cancer magister*	CO,FO	VAR	VAR		BC	LIT	SW
721	Wan, Y., Wang, B., Khim, J.S., Hong, S., Shim, W.J. and Hu, J.	2014	Naphthenic Acids in Coastal Sediments after the Hebei Spirit Oil Spill: A Potential Indicator for Oil Contamination	Environmental Science & Technology	48	7	4153-4162				CO	IHC,LAB	NAC,PAH	HEB	ASIA	PHYS	SED,SW
722	Wang, S.Y., Lum, J.L., Carls, M.G. and Rice, S.D.	1993	RELATIONSHIP BETWEEN GROWTH AND TOTAL NUCLEIC-ACIDS IN JUVENILE PINK SALMON, ONCORHYNCHUS-GORBUSCHA, FED CRUDE-OIL CONTAMINATED FOOD	Canadian Journal of Fisheries and Aquatic Sciences	50	5	996-1001	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL			TOX	SW
723	Wang, X. and Wang, W.X.	2006	Bioaccumulation and transfer of benzo(a)pyrene in a simplified marine food chain	Marine Ecology Progress Series	312		101-111	ALGAE CRUSTACEA FISH	Diatom Copepod Mangrove snapper	*Bacillariophyceae Copepoda Lutjanus griseus*	CO	LAB	PAH			MOD	SW

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724	Wang, X., Zhang, J., Shi, X., Zhu, C., An, Y., Jun, S., Li, R., Zhu, M. and Chen, S.	2002	Determination of toxicokinetic parameters for bioconcentration of water-soluble fraction of petroleum hydrocarbon associated with No. 0 diesel in Changjiang Estuary and Jiaozhou Bay: Model versus mesocosm experiments	Archives of Environmental Contamination and Toxicology	42	3	272-279	ALGAE	Microalgae	*Cylindrotheca closterium Chaetoceros spp Platymonas subcordiformis Chlorella vulgaris Gymnodinium spp*	FO	LFO	WAF,WHL		ASIA	TOX	SW
725	Wang, Z.D. and Fingas, M.	1996	Separation and characterization of petroleum hydrocarbons and surfactant in Orimulsion dispersion samples	Environmental Science & Technology	30	11	3351-3361				OR	ORI	ALH,BTX,PAH			PHYS	FW
726	Wells, P.G., Butler, J.N. and Hughes, J.S.	1995	Exxon Valdez oil spill: Fate and effects in Alaskan waters - Introduction, overview, issues	Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters	1219		3-38				CO	ANS	WHL	EVOS	AK	LIT	SW
727	Wertheimer, A.C. and Celewycz, A.G.	1996	Abundance and Growth of Juvenile Pink Salmon in Oiled and Non-oiled Locations of Western Prince William Sound after the Exxon Valdez Oil Spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		518-532	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW
728	Wertheimer, A.C., Bax, N.J., Celeqycz, A.G., Carls, M.G. and Landingham, J.H.	1996	Harpacticoid Copepod Abundance and Population Structure in Prince William Sound, One Year after the Exxon Valdez Oil Spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		551-563	CRUSTACEA	harpacticoid copepods	*Harpacticus spp*	CO	ANS	PAH,TPH	EVOS	AK	ECO	SW
729	Wertheimer, A.C., Celewycz, A.G., Carls, M.G. and Sturdevant, M.V.	1994	Impact of the oil spill on juvenile pink and chum salmon and their prey in critical nearshore habitats	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Fish/Shellfish Study Number 4, NMFS Component		FISH	Chum salmon Pink salmon	*Oncorhynchus keta Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW
730	Wertheimer, A.C., Celewycz, A.G., Carls, M.G. and Sturdevant, M.V.	1994	THE IMPACT OF THE EXXON-VALDEZ OIL SPILL ON JUVENILE PINK AND CHUM SALMON AND THEIR PREY IN NEARSHORE MARINE HABITATS	Proceedings of the 16th Northeast Pacific Pink and Chum Salmon Workshop		34366	179-180	FISH	Chum salmon Pink salmon	*Oncorhynchus keta Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW
731	Wertheimer, A.C., Heintz, R.A., Thedinga, J.F., Maselko, J.M. and Rice, S.D.	2000	Straying of adult pink salmon from their natal stream following embryonic exposure to weathered Exxon Valdez crude oil	Transactions of the American Fisheries Society	129	4	989-1004	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	TOX	SW
732	Wertheimer, A.C., Heintz, R.A., Thedinga, J.F., Maselko, J.M., Celewycz, A.G., Bradshaw, R.F. and Rice, S.D.	1999	Effects of oiled incubation substrate on survival and straying of wild pink salmon	EVOS Trustee Council	EVOS Restoration Project Final Report	Restoration Project 98076	143 p	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	PAH,WHL	EVOS	AK	ECO/TOX	FW,SW
733	West, J.E., O'Neill, S.M., Ylitalo, G.M., Incardona, J.P., Doty, D.C. and Dutch, M.E.	2014	An evaluation of background levels and sources of polycyclic aromatic hydrocarbons in naturally spawned embryos of Pacific herring (Clupea pallasii) from Puget Sound, Washington, USA	Science of the Total Environment	499		114-124	FISH	Pacific herring	*Clupea pallasii Oncorhynchus spp Crustacea Mollusca*	BG	UKN	PAH		WA	ECO	SW
734	Whitehead, A.	2013	Interactions between Oil-Spill Pollutants and Natural Stressors Can Compound Ecotoxicological Effects	Integrative and Comparative Biology	53	4	635-647	CRUSTACEA FISH	Gulf killifish Armoured catfish Rainbow trout Shrimps Crabs Pacific herring Common sole	*Fundulus heteroclitus Hoplosternum littorale Oncorhynchus mykiss Palaemon adspersus Sesarma catenata Clupea pallasii Solea solea*	CO	VAR	VAR	DWH	GM	LIT	SW

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735	Whitehead, A., Dubansky, B., Bodinier, C., Garcia, T.I., Miles, S., Pilley, C., Raghunathan, V., Roach, J.L., Walker, N., Walter, R.B., Rice, C.D. and Galvez, F.	2012	Genomic and physiological footprint of the Deepwater Horizon oil spill on resident marsh fishes	Proceedings of the National Academy of Sciences of the United States of America	109	50	20298-20302	FISH	Mummichog	*Fundulus heteroclitus*	CO	MAC	WHL	DWH	GM	ECO	SW
736	Wiedmer, M., Fink, M.J., Stegeman, J.J., Smolowitz, R., Marty, G.D. and Hinton, D.E.	1996	Cytochrome P-450 Induction and Histopathology in Preemergent Pink Salmon from Oiled Spawning Sites in Prince William Sound	Proceedings of the Exxon Valdez Oil Spill Symposium	18		509-517	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	FW,SW
737	Willette, M.	1996	Impacts of the Exxon Valdez oil spill on the migration, growth, and survival of juvenile pink salmon in Prince William Sound	Proceedings of the Exxon Valdez Oil Spill Symposium	18		533-550	FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW
738	Willette, T.M., Carpenter, G., Shields, P. and Carlson, S.R.	1994	Early marine salmon injury assessment in Prince William Sound	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Fish/Shellfish Study Number 4A		FISH	Pink salmon	*Oncorhynchus gorbuscha*	CO	ANS	WHL	EVOS	AK	ECO	SW
739	Williams, J., Roderick, C. and Alexander, R.	2003	Sublethal effects of Orimulsion-400((R)) on eggs and larvae of Atlantic herring (Clupea harengus L.)	Environmental Toxicology and Chemistry	22	12	3044-3048	FISH	Atlantic Herring	*Clupea harengus*	OR	ORI	WHL			TOX	SW
740	Williams, R., Gero, S., Bejder, L., Calambokidis, J., Kraus, S.D., Lusseau, D., Read, A.J. and Robbins, J.	2011	Underestimating the damage: interpreting cetacean carcass recoveries in the context of the Deepwater Horizon/BP incident	Conservation Letters	4	3	228-233	MAMMAL	Sperm whale Cuvier's beaked whale Striped dolphin Killer whale False killer whale Short-finned pilot whale Risso's dolphin	*Physeter macrocephalus Ziphius cavirostris Stenella coeruleoalba Orcinus orca Pseudorca crassidens Globicephala macroryhnchus Grampus griseus*	CO	MAC	WHL	DWH	GM	ECO	SW
741	Wise, C.F., Wise, J.T.F., Wise, S.S., Thompson, W.D., Wise, J.P., Jr. and Wise, J.P., Sr.	2014	Chemical dispersants used in the Gulf of Mexico oil crisis are cytotoxic and genotoxic to sperm whale skin cells	Aquatic Toxicology	152		335-340	MAMMAL	Sperm whale	*Physeter macrocephalus*	DS	COR	WHL	DWH	GM	TOX	SW
742	Wiseman, S.B., Anderson, J.C., Liber, K. and Giesy, J.P.	2013	Endocrine disruption and oxidative stress in larvae of Chironomus dilutus following short-term exposure to fresh or aged oil sands process-affected water	Aquatic Toxicology	142		414-421	INSECT	*Chironomus dilutus*	*Chironomus dilutus*	OR	PRW	WHL		AOS	TOX	FW
743	Wiseman, S.B., He, Y., Gamal-El Din, M., Martin, J.W., Jones, P.D., Hecker, M. and Giesy, J.P.	2013	Transcriptional responses of male fathead minnows exposed to oil sands process-affected water	Comparative Biochemistry and Physiology	157	2	227-235	FISH	Fathead minnow	*Pimephales promelas*	OR	PRW	WHL		AOS	TOX	FW
744	Wolf, D.A.	1996	Fate and toxicity of spilled oil from the Exxon Valdez	EVOS Trustee Council	EVOS State/Federal Natural Resource Damage Assessment Final Report	Subtidal Study Number 4		CRUSTACEA MICROBIA MOLLUSC	Benthic amphipod Pacific oyster Mussels Microtox®	*Ampelisca abdita Crassostrea gigas Mytilus sp Vibrio fischeri*	CO	ANS	WHL	EVOS	AK	TOX	SED,SW
745	Wolfe, D.A., Krahn, M.M., Casillas, E., Sol, S., Thompson, T.A., Lunz, J. and Scott, K.J.	1996	Toxicity of intertidal and subtidal sediments contaminated by the Exxon Valdez oil spill	Proceedings of the Exxon Valdez Oil Spill Symposium	18		121-139	CRUSTACEA MOLLUSC	Benthic amphipod Pacific oyster	*Ampelisca abdita Crassostrea gigas*	CO	ANS	TPH	EVOS	AK	TOX	SW

RefID	Author(s)	Year	Title	Journal	Volume	Issue	Pages	Taxon	CommonName	Scientific Name	MainProduct	SpecificProduct	ComponentsAnalyzed	Event	Location	StudyType	ExposureMedia
746	Wolfe, M.F., Schlosser, J.A., Schwartz, G.J.B., Singaram, S., Mielbrecht, E.E., Tjeerdema, R.S. and Sowby, M.L.	1998	Influence of dispersants on the bioavailability and trophic transfer of petroleum hydrocarbons to primary levels of a marine food chain	Aquatic Toxicology	42	3	211-227	ALGAE ZOOPLANKTON	Microalgae Rotifer	*Isochrysis galbana Brachionus plicatilis*	CO,DS	ANS,COR	CWF,WAF			TOX	SW
747	Wolfe, M.F., Schwartz, G.J.B., Singaram, S., Mielbrecht, E.E., Tjeerdema, R.S. and Sowby, M.L.	1998	Influence of dispersants on the bioavailability of naphthalene from the water-accommodated fraction crude oil to the golden-brown algae, Isochrysis galbana	Archives of Environmental Contamination and Toxicology	35	2	274-280	ALGAE	Microalgae	*Isochrysis galbana*	CO,DS	ANS,COR	CWF,WAF			TOX	SW
748	Wolfe, M.F., Schwartz, G.J.B., Singaram, S., Mielbrecht, E.E., Tjeerdema, R.S. and Sowby, M.L.	2001	Influence of dispersants on the bioavailability and trophic transfer of petroleum hydrocarbons to larval topsmelt (Atherinops affinis)	Aquatic Toxicology	52	1	49-60	FISH	Topsmelt	*Atherinops affinis*	CO,DS	ANS,COR	CWF,WAF			TOX	SW
749	Woodin, B.R. and Stegeman, J.J.	1993	Elevated P4501A protein in intertidal fish in Prince William Sound associated with the Exxon Valdez oil spill	Marine Environmental Research	35	1-2	203-204	FISH	High cockscomb Ribbon prickleback Black prickleback Crescent gunnel	*Anoplarchus purpurescens Phytichthys chirus Xiphister atropurpureus Pholis laeta*	CO	ANS	WHL	EVOS	AK	ECO/TOX	SW
750	Woodin, B.R., Smolowitz, R.M. and Stegeman, J.J.	1997	Induction of Cytochrome P4501A in the Intertidal Fish Anoplarchus purpurescens by Prudhoe Bay Crude Oil and Environmental Induction in Fish from Prince William Sound	Environmental Science & Technology	31	4	1198-1205	FISH	High cockscomb	*Anoplarchus purpurescens*	CO	ANS	WHL	EVOS	AK	ECO/TOX	SW
751	Wright, M.E.	1994	Nestucca project : inventory for Department of Fisheries and Oceans biological resource datasets	Canadian manuscript report of fisheries and aquatic sciences	2259		76 pp	COMMUNITY	Various	Various	FO	BUC	VAR	NES	BC	LIT	SW
752	Wu, D.M., Wang, Z., Hollebone, B., McIntosh, S., King, T. and Hodson, P.V.	2012	Comparative toxicity of four chemically dispersed and undispersed crude oils to rainbow trout embryos	Ecotoxicology	20	5	1124-1130	FISH	Rainbow trout	*Oncorhynchus mykiss*	CO,DS	ANS,MLC,SCN,FED,COR	CWF,PAH,WAF			TOX	FW
753	Yang, C., Wang, Z., Yang, Z., Hollebone, B., Brown, C.E., Landriault, M. and Fieldhouse, B.	2011	Chemical Fingerprints of Alberta Oil Sands and Related Petroleum Products	Environmental Forensics	12	2	173-188				OR	BIT,DIL,DBT	ALH,BTX,PAH		AOS	PHYS	
754	Young, R.F., Michel, L.M. and Fedorak, P.M.	2011	Distribution of naphthenic acids in tissues of laboratory-exposed fish and in wild fishes from near the Athabasca oil sands in Alberta, Canada	Ecotoxicology and Environmental Safety	74	4	889-896	FISH	Rainbow trout	*Oncorhynchus mykiss*	OR	LAB,PRW	NAC		AOS	TOX	FW
755	Young, R.F., Orr, E.A., Goss, G.G. and Fedorak, P.M.	2007	Detection of naphthenic acids in fish exposed to commercial naphthenic acids and oil sands process-affected water	Chemosphere	68	3	518-527	FISH	Rainbow trout	*Oncorhynchus mykiss*	OR	PRW	NAC		AOS	TOX	FW
756	Young, R.F., Wismer, W.V. and Fedorak, P.M.	2008	Estimating naphthenic acids concentrations in laboratory-exposed fish and in fish from the wild	Chemosphere	73	4	498-505	FISH	Walleye Northern pike Lake whitefish White sucker	*Sander vitreus Esox lucius Coregonus clupeaformis Catostomus commersoni*	OR	LAB,PRW	NAC		AOS	ECO/TOX	FW
757	Zachleder, V. and Tukaj, Z.	1993	EFFECT OF FUEL-OIL AND DISPERSANT ON CELL-CYCLE AND MACROMOLECULAR-SYNTHESIS IN THE CHLOROCOCCAL ALGA SCENEDESMUS-ARMATUS	Marine Biology	117	2	347-353	ALGAE	Microalgae	*Scenedesmus armatus*	DS,FO	DP1,LFO	WHL			TOX	SW
758	Zanette, J., de Almeida, E.A., da Silva, A.Z., Guzenski, J., Ferreira, J.F., Di Mascio, P., Marques, M.R.F. and Bainy, A.C.D.	2011	Salinity influences glutathione S-transferase activity and lipid peroxidation responses in the Crassostrea gigas oyster exposed to diesel oil	Science of the Total Environment	409	10	1976-1983	MOLLUSC	Pacific oyster	*Crassostrea gigas*	FO	DSL	WHL			TOX	SW

RefID	Author(s)	Year	Title	Journal	Volume	Issue	Pages	Taxon	CommonName	Scientific Name	MainProduct	SpecificProduct	ComponentsAnalyzed	Event	Location	StudyType	ExposureMedia
759	Zhang, J.F., Shen, H., Xu, T.L., Wang, X.R., Li, W.M. and Gu, Y.F.	2003	Effects of long-term exposure of low-level diesel oil on the antioxidant defense system of fish	Bulletin of Environmental Contamination and Toxicology	71	2	234-239	FISH	Goldfish	*Carassius auratus*	FO	DSL	WHL			TOX	FW
760	Zheng, M.Y., Ahuja, M., Bhattacharya, D., Clement, T.P., Hayworth, J.S. and Dhanasekaran, M.	2014	Evaluation of differential cytotoxic effects of the oil spill dispersant Corexit 9500	Life Sciences	95	2	108-117	MAMMAL	Mouse Rat Human	*Mus musculus Rattus norvegicus Homo sapiens*	DS	COR	WHL			TOX	SW
761	Zhou, S., Heras, H. and Ackman, R.G.	1997	Role of adipocytes in the muscle tissue of Atlantic salmon (Salmo salar) in the uptake, release and retention of water-soluble fraction of crude oil hydrocarbons	Marine Biology	127	4	545-553	FISH	Atlantic salmon	*Salmo salar*	CO	NSC	WAF			TOX	SW
762	Ziolkowska, A. and Wyszkowski, M.	2010	TOXICITY OF PETROLEUM SUBSTANCES TO MICROORGANISMS AND PLANTS	Ecological Chemistry and Engineering	17	1	73-82	MICROBIA PLANT	Various	Various	BG	VAR	BTX,PAH			LIT	SW
763	Zuijdgeest, A. and Huettel, M.	2012	Dispersants as Used in Response to the MC252-Spill Lead to Higher Mobility of Polycyclic Aromatic Hydrocarbons in Oil-Contaminated Gulf of Mexico Sand	Plos One	7	11	e50549				CO,DS	MAC,COR	PAH	DWH	GM	PHYS	SED,SW

12.0 APPENDIX 2
Abstracts and Hyperlinks

Abstracts and hyperlinks, when available, have been included for each reference and are cross referenced to Appendix 1 using the RefID code. Excel® and .csv versions which include information from Appendix 1 and 2 information can be found at the following URL:
http://open.canada.ca/data/en/dataset/34d8a906-2a6b-43ed-8e0e-9b15e3e50a32

RefID: 1

Author: Acosta-González, A., Martirani-von Abercron, S.-M., Rosselló-Móra, R., Wittich, R.-M., and Marqués, S.

Year: 2015

Title: The effect of oil spills on the bacterial diversity and catabolic function in coastal sediments: a case study on the Prestige oil spill

Journal: Environmental Science and Pollution Research

Hyperlink: http://link.springer.com/article/10.1007/s11356-015-4458-y

Abstract: The accident of the Prestige oil tanker in 2002 contaminated approximately 900 km of the coastline along the northern Spanish shore, as well as parts of Portugal and France coast, with a mixture of heavy crude oil consisting of polycyclic aromatic hydrocarbons, alkanes, asphaltenes and resins. The capacity of the autochthonous bacterial communities to respond to the oil spill was assessed indirectly by determining the hydrocarbon profiles of weathered oil samples collected along the shore, as well as through isotope ratios of seawater-dissolved CO2, and directly by analyses of denaturing gradient gel electrophoresis fingerprints and 16S rRNA gene libraries. Overall, the results evidenced biodegradation of crude oil components mediated by natural bacterial communities, with a bias towards lighter and less substituted compounds. The changes observed in the Proteobacteria, the most abundant phylum in marine sediments, were related to the metabolic profiles of the sediment. The presence of crude oil in the supratidal and intertidal zones increased the abundance of Alpha- and Gammaproteobacteria, dominated by the groups Sphingomonadaceae, Rhodobacteraceae and Chromatiales, whilst Gamma- and Deltaproteobacteria were more relevant in subtidal zones. The phylum Actinobacteria, and particularly the genus Rhodococcus, was a key player in the microbial response to the spill, especially in the degradation of the alkane fraction. The addition of inorganic fertilizers enhanced total biodegradation rates, suggesting that, in these environments, nutrients were insufficient to support significant growth after the huge increase in carbon sources, as evidenced in other spills. The presence of bacterial communities able to respond to a massive oil input in this area was consistent with the important history of pollution of the region by crude oil.

RefID: 2

Author: Adams, J., Bornstein, J.M., Munno, K., Hollebone, B., King, T., Brown, R.S. and Hodson, P.V.

Year: 2014

Title: Identification of compounds in heavy fuel oil that are chronically toxic to rainbow trout embryos by effects-driven chemical fractionation

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.2497/full

Abstract: The present study isolated and identified compounds in heavy fuel oil 7102 (HFO 7102) that are bioavailable and chronically toxic to rainbow trout embryos (Oncorhynchus mykiss). An effects-driven chemical fractionation combined the chemical separation of oil with toxicity testing and chemical analyses of each fraction to identify the major classes of compounds associated with embryo toxicity. Toxicity was assessed with 2 exposure methods, a high-energy chemical dispersion of oil in water, which included oil droplets in test solutions, and water accommodated fractions which were produced by oiled gravel desorption columns, and which did not contain visible oil droplets. Fractions of HFO with high concentrations of naphthalenes, alkanes, asphaltenes, and resins were nontoxic to embryos over the range of concentrations tested. In contrast, fractions enriched with 3- to 4-ringed alkyl polycyclic aromatic hydrocarbons (PAHs) were embryotoxic, consistent with published studies of crude oils and individual alkyl PAHs. The rank order of fraction toxicity did not vary between the exposure methods and was consistent with their PAH content; fractions with higher-molecular weight alkyl PAHs were the most toxic. Exposure of juvenile trout to most fractions of HFO induced higher activities of cytochrome P450 enzymes, with a rank order of potency that varied with exposure method and differed somewhat from that of embryotoxicity. Induction reflected the bioavailability of PAHs but did not accurately predict embryotoxicity. Environ Toxicol Chem 2014;33:825-835. (c) 2013 SETAC

RefID: 3

Author: Adams, J., Sweezey, M. and Hodson, P.V.

Year: 2014

Title: OIL AND OIL DISPERSANT DO NOT CAUSE SYNERGISTIC TOXICITY TO FISH EMBRYOS

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.2397/full

Abstract: Atlantic herring (Clupea harengus) embryos were exposed to water accommodated fractions (WAFs; oil dissolved in water) and chemically enhanced water accommodated fractions (CEWAFs; oil dispersed in water with Corexit 9500A) of Medium South American (MESA) crude oil. The CEWAF was approximately 100-fold more toxic than WAF based on nominal loadings of test solutions (% v/v). In contrast, the ratio of WAF and CEWAF toxicity expressed as measured oil concentrations approximated 1.0, indicating that the higher toxicity of CEWAFs was caused by an increase in exposure to hydrocarbons with chemical dispersion. In a second experiment, the chronic toxicity of Corexit 9500A and chemically dispersed heavy fuel oil 7102 (HFO 7102) to rainbow trout (Oncorhynchus mykiss) embryos was compared to chemically dispersed Nujol, a nontoxic mineral oil. Dispersant alone was toxic, but caused different signs of toxicity than HFO 7102. Nujol at a dispersant-to-oil ratio of 1:20 was nontoxic, suggesting that dispersant was sequestered by oil and not present at toxic concentrations. In contrast, the same nominal loadings of dispersed HFO 7102 caused concentration-dependent increases in toxicity. Both experiments suggest that chemically dispersed oil was more toxic to fish embryos than solutions created by mechanical mixing due to the increased exposure of fish to petroleum hydrocarbons and not to changes in hydrocarbon toxicity. The Nujol control discriminated between the toxicity of oil and chemical dispersant and would be a practical addition to programs of dispersant testing. Environ Toxicol Chem 2014;33:107-114. (c) 2013 SETAC

RefID: 4

Author: Adams, J.E.

Year: 2013

Title: Identification of compounds in heavy fuel oil 7102 that are chronically toxic to rainbow trout (Oncorhynchus mykiss) embryos

Journal: Thesis, Queens University

Hyperlink: http://qspace.library.queensu.ca/handle/1974/7768

Abstract: Spilled heavy fuel oil (HFO) sinks within the water column and accumulates in sediments, affecting aquatic organisms that are not typically exposed to oils that float. Previously, the 3-4 ring alkyl substituted polycyclic aromatic hydrocarbons (PAHs) have been identified as the major toxic components in crude oil. Since HFO is comprised of higher concentrations of 3-4 ringed alkyl PAH and an abundance of 5-6 ringed PAH relative to crude oil, it is predicted to be more toxic to the early life stages of fish. An effects-driven chemical fractionation (EDCF) of HFO 7102 was undertaken to establish the toxicity relative to crude oil, and to identify the compounds that are bioavailable and chronically toxic to the early life stages of fish. In this EDCF, the complex HFO 7102 mixture was separated by low temperature vacuum distillation into three distinct fractions, 2, 3 and 4. Each fraction was assessed using a chronic bioassay to determine whether it contained components that caused toxicity to rainbow trout embryos similar to that of the whole oil. Acute bioassays with juvenile trout demonstrated the presence of compounds that induce cytochrome P450 enzymes, an indicator of exposure to PAH. Fraction 3, the fraction more toxic than the parent mixture, was further separated by cold acetone extraction into fraction 3-1 (PAH-rich extract) and fraction 3-2 (wax residue), and assessed with the same bioassays. Simultaneous chemical analysis with bioassays guided the fractionation, and identified compounds abundant and consistently present in toxic fractions. Due to resistance to dispersion of HFO, a chemical dispersant was used with vigorous mixing to drive the maximum amount of oil into solution to minimize the potential for false negatives and the volume of test material used. The potency of HFO 7102 and its fractions were also measured using water accommodated fractions (WAFs) produced by a continuous flow system of water flowing through oil coated gravel. Both exposure methods traced the toxicity from whole oil into fractions containing higher concentrations of 3-4 ring alkyl PAH, similar to crude oil. This research is the first toxicological assessment of HFO 7102, which is essential for determining the risk of spills of HFO to fish, and whether the risk of oils can be predicted from their alkyl PAH composition.

RefID: 5

Author: Adekunle, I.M., Ajijo, M.R., Adeofun, C.O. and Omoniyi, I.T.

Year: 2010

Title: Response of Four Phytoplankton Species Found in Some Sectors of Nigerian Coastal Waters to Crude Oil in Controlled Ecosystem

Journal: International Journal of Environmental Research

Hyperlink: http://www.bioline.org.br/abstract?id=er10008&lang=en

Abstract: Identification and enumeration of phytoplankton species from Ilaje and Lagos sectors of the Nigerian coastal waters were conducted using standard procedures. Effects of different crude oil concentrations (6 to 50 ppm) on population Of Coscnodiscus centralis, Thalassionema frauenfeldii, Odontella mobiliensis, and Ceratium trichoceros at different exposure periods (6 to 42 h) via microcosm experiments were then assessed. Results showed that the phytoplankton species consisted of diatoms (83.33%) and dinoflagellates (16.67%) whose abundance ranged from 2 to 516 Cell/mL. Crude oil toxicity varied from 0.06 to 36.43% for C.centralis, 1.41 to 35.58% for C.trichoceros, 1.71 to 46.11% for T.frauenfeldii and 0.66 to 44.90% for O.mobiliensis and showed direct relationship (r-+0.81 to +0.97 $p < 0.001$) with concentration but inverse with exposure period ($r = -0.83$ to -0.90; $p < 0.001$). Vulnerability within 24-h contact decreased in the order: T.frauenfeldii > O.mobiliensis > C.centralis > C.trichoceros. Study is a contribution to the scarce data bank on crude oil dose-response assessment on plankton species in Nigeria, demonstrating that influx of crude oil into the Nigerian coastal waters is a risk factor to ecological status.

RefID: 6

Author: Adeyemo, O.K., Kroll, K.J., and Denslow, N.D.

Year: 2015

Title: Developmental abnormalities and differential expression of genes induced in oil and dispersant exposed Menidia beryllina embryos

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X15300527

Abstract: Exposure of fish embryos to relatively low concentrations of oil has been implicated in sub-lethal toxicity. The objective of this study was to determine the effects of the exposure of Menidia beryllina embryos at 30–48 h post-fertilization to the water accommodated fractions of oil (WAF, 200 ppm, v/v), dispersants (20 ppm, v/v, Corexit 9500 or 9527), and mixtures of oil and each of the dispersants to produce chemically enhanced water accommodated fractions (CEWAFs) over a 72-hour period. The polyaromatic hydrocarbon (PAH) and benzene, toluene, ethylene and xylene (BTEX) constituents of the 5X concentrated exposure solutions (control, WAF, dispersants and CEWAFs) were determined and those of the 1× exposures were derived using a dilution factor. PAH, BTEX and low molecular weight PAH constituents greater than 1 ppb were observed in WAF and the dispersants, but at much higher levels in CEWAFs. The WAF and CEWAFs post-weathering were diluted at 1:5 (200 ml WAF/CEWAF: 800 ml 25 ppt saltwater) for embryo exposures. Mortality, heartbeat, embryo normalcy, abnormality types and severities were recorded. The qPCR assay was used to quantify abundances of transcripts of target genes for sexual differentiation and sex determination (StAR, dmrt-1, amh, cyp19b, vtg and chg-L,), growth regulation (ghr) and stress response (cyp1a and Hsp90); and gapdh served as the housekeeping gene. Temperature was 21 ± 1.5 °C throughout the experimental period, while mortality was low and not significantly different ($p = 0.68$) among treatments. Heartbeat was significantly different (0.0034) with the lowest heartbeats recorded in Corexit 9500 (67.5 beats/min) and 9527 (67.1 beats/min) exposed embryos compared with controls (82.7 beats/min). Significantly more treated embryos were in a state of deterioration, with significantly more embryos presenting arrested tissue differentiation compared with controls (p = 0.021). Exposure to WAF, dispersants and CEWAF induced aberrant expression of all the genes, with star, dmrt-1, ghr and hsp90 being significantly down-regulated in CEWAF and cyp19b in Corexit 9527. The cyp1a and cyp19b were significantly up-regulated in CEWAFs and WAF, respectively. The molecular endpoints were most sensitive, especially the expression of star, cyp19b, cyp1a, hsp90 and could therefore be used as early indicators of long term effects of Corexit 9500 and 9527 usage in oil spill management on M. beryllina, a valid sentinel for oil pollution events.

RefID: 7

Author: Agamy, E.

Year: 2013

Title: Sub chronic exposure to crude oil, dispersed oil and dispersant induces histopathological alterations in the gills of the juvenile rabbit fish (Siganus canaliculatus)

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651313001152

Abstract: There is little existing information on the sub-lethal effects of experimental exposure of Arabian Gulf fish to oil pollution. This study investigated the potential sub-lethal effects of the water accommodated fraction (WAF) of light Arabian crude oil, dispersed oil and dispersant (Maxi Clean 2) on the gills of the juvenile rabbit fish (Siganus canaliculatus), observing several histopathological biomarkers at different time points and different doses. These laboratory exposures simulated a range of possible oil pollution events. Significant alterations in four health categories (circulatory, proliferative, degenerative and inflammatory) were identified and form the basis for understanding the short-term response of fish to oil. Evaluations of histopathological lesions in gill tissue were carried out following 3, 6, 9, 12, 15, 18 and 21 days of exposure. The main lesions observed and quantified were lamellar capillary aneurysms, vasodilatation of lamellae, hemorrhage, edema, lifting of lamellar and filamentary epithelium and epithelium necrosis, epithelial and chloride cell hypertrophy and hyperplasia, fusion of adjacent lamellae, epitheliocystis and inflammatory infiltration. Exposure of juvenile fish to WAF, dispersant oil and dispersant caused significant changes in the gill lesions and reaction patterns. Dispersed oil caused the most significant effect followed by WAF and then dispersant. The present study is one of the first which explores the relationship between oil pollution and epitheliocystis and reports that exposure to crude oil and dispersed oil increases the prevalence of epitheliocystis formation under controlled laboratory conditions. (C) 2013 Elsevier Inc. All rights reserved.

RefID: 8

Author: Agler, B.A., Seiser, P.E., Kendall, S.J. and Irons, D.B.

Year: 1994

Title: Marine bird and sea otter population abundance of Prince William Sound, Alaska: trends following the T/V Exxon Valdez oil spill, 1989-93

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33949947.pdf

Abstract: We conducted small boat surveys to estimate marine bird and sea otter (Enlydra lutris) populations in Prince William Sound, Alaska during March and July 1993, using methods developed for the 1989-91 surveys (Klosiewski and Ling 1994). During 1993, we recorded 65 bird and 13 mammal species. We estimated that 402,760 birds over 1990 and 1991. This increase was largely due to an unexplained influx of murres (Urin spp.) followed by a die-off (Kendall et al. 1993, Piatt and van Pelt 1993). We estimated that 83,172 ± 34,794 birds were in the oiled zone, and 319,589 ± 164,048 birds were in the unoiled zone during March. During July 1993, an estimated 371,327 ± 58,189 marine birds were in Prince William Sound. We estimated that 116,219 ± 26,896 birds were in the oiled zone, and 255,108 ± 51,600 birds were in the unoiled zone. The July 1993 estimate was 8-56% higher than the 1989-91 estimates (Klosiewski and Ling 1994) but was 41% lower than the July 1972 estimate (Haddock et al., unpubl. data). assumed that in the absence of oil spill effects, population estimates in the oiled zone would change at the same rate as those in the unoiled zone. The goldeneye (Buceplmla spp.) and black oystercatcher (Huematopus buclmani) populations showed significantly different trends between the oiled and unoiled zones during March, and the surfbird (Aplzrizu vitgutu) population showed significantly different trends between the oiled and unoiled zones in July. The goldeneye and surfbird populations increased at a slower rate in the oiled zone than in the unoiled zone, indicating that continued effects from the oil spill. The black oystercatcher population increased more in the oiled zone than in the unoiled zone. However, the data used to indicate this trend may not be biologically meaningful (March population estimates for black oystercatchers were (15) and must be interpreted with caution. For Prince William Sound as a whole, we examined population trends from 1989-93, using regression analyses. We found significant positive trends for the goldeneye, gull (Lams and Rism spp.), murre (Uria spp.), and waterfowl during March. No significant trend during July in overall abundance of any species or species group was found. We also examined the relative abundance of the species groups seen in Prince William Sound from 1972 to 1993. The most common species group observed during March was waterfowl (x = 47.7% of the total marine bird population), except in 1993, when murres comprised 54.9% of the total. The most common species groups recorded during July were Bruclzyrumphus murrelets (x = 38.3%) and gulls (x = 31.6%). 8,216 L 2,435 for July. We found no difference in the rate of change between the oiled and unoiled zones from 1989-93 for either the March or July population estimates. There was no significant trend in the total number of sea otters in Prince William Sound from 1989-93.

RefID: 9

Author: Akbari, S., Law, A.T. and Shariff, M.

Year: 2004

Title: Toxicity of water soluble fractions of crude oil to fish, Lutjanus argentimaculatus and shrimp, Penaeus monodon

Journal: Iranian Journal of Science and Technology

Hyperlink: http://en.journals.sid.ir/ViewPaper.aspx?ID=140406

Abstract: The acute toxicity of a Malaysian crude oil to red snapper, Lutjanus argentimaculatus, black tiger shrimp and Penaeus monodon were investigated. The animals were exposed to water soluble fractions (WSF) of crude oil in a flow-through bioassay system and the toxicants were analyzed by gas chromatography (GC) and gas chromatography and mass spectrometer (GC-MS),. The 96 h LC(50) values of the WSF of crude oil for fish and shrimp were 3.24 +/- 0.21 and 8.52 +/- 0.89 ppm of WSF of crude oil, respectively. In this investigation, the fish were more sensitive to crude oil than the shrimp, with respect to the similarity in their habitations.

RefID: 10

Author: Ali, N.A., Ahmed, O.E. and Doheim, M.M.

Year: 2014

Title: Evaluation of poly-aromatic hydrocarbons (PAHs) in the aquatic species of Suez Gulf water along El-Sokhna area to the Suez refineries

Journal: Environmental Monitoring and Assessment

Hyperlink: http://link.springer.com/article/10.1007/s10661-013-3455-1

Abstract: The Egyptian Red Sea environment especially along El-Sokhna area to the Suez refineries (Suez) is severely contaminated with organic compounds, as well as overfishing. This may be well contributory to recent serious declines in fish stocks. Fish embryos are also particularly vulnerable to oil exposure, even at extremely low concentrations of less than one part per billion. Consequently, even traces of oil pollution at levels often considered safe for wildlife can cause severe damage to fish. Sixteen polycyclic aromatic hydrocarbons (PAHs) were investigated in ten fish species of aquatic species by high performance liquid chromatography (HPLC). The compositions of PAHs determined in all samples were measured in order to use them as chemical markers for identifying different sources of PAH pollutants in the studied region. The total content of these16 PAHs ranged from 399.616 up to 67,631.779 ng/g wet weight. The data show that these values are considered to be alarmingly high enough to cause lethal toxicity effect by accumulation. All studied aquatic species samples are characterized by relatively high concentrations of the six-membered ring PAHs. The origin of PAHs in the collected samples is either petrogenic, biogenic, or mixed petrogenic and biogenic.

RefID: 11

Author: Almeda, R., Baca, S., Hyatt, C. and Buskey, E.J.

Year: 2014

Title: Ingestion and sublethal effects of physically and chemically dispersed crude oil on marine planktonic copepods

Journal: Ecotoxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs10646-014-1242-6

Abstract: Planktonic copepods play a key function in marine ecosystems, however, little is known about the effects of dispersants and chemically dispersed crude oil on these important planktonic organisms. We examined the potential for the copepods Acartia tonsa, Temora turbinata and Parvocalanus crassirostris to ingest crude oil droplets and determined the acute toxicity of the dispersant Corexit(A (R)) 9500A, and physically and chemically dispersed crude oil to these copepods. We detected ingestion of crude oil droplets by adults and nauplii of the three copepod species. Exposure to crude oil alone (1 A mu L L-1, 48 h) caused a reduction of egg production rates (EPRs) by 26-39 %, fecal pellet production rates (PPRs) by 11-27 %, and egg hatching (EH) by 1-38 % compared to the controls, depending on the species. Dispersant alone (0.05 A mu L L-1, 48 h) produced a reduction in EPR, PPR and EH by 20-35, 12-23 and 2-11 %, respectively. Dispersant-treated crude oil was the most toxic treatment, similar to 1.6 times more toxic than crude oil alone, causing a reduction in EPR, PPR and EH by 45-54, 28-41 and 11-31 %, respectively. Our results indicate that low concentrations of dispersant Corexit 9500A and chemically dispersed crude oil are toxic to marine zooplankton, and that the ingestion of crude oil droplets by copepods may be an important route by which crude oil pollution can enter marine food webs.

RefID: 12

Author: Almeda, R., Bona, S., Foster, C.R. and Buskey, E.J.

Year: 2014

Title: Dispersant Corexit 9500A and chemically dispersed crude oil decreases the growth rates of meroplanktonic barnacle nauplii (Amphibalanus improvisus) and tornaria larvae (Schizocardium sp.)

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0141113614001147

Abstract: Our knowledge of the lethal and sublethal effects of dispersants and dispersed crude oil on merplanktonic larvae is limited despite the importance of planktonic larval stages in the life cycle of benthic invertebrates. We determined the effects of Light Louisiana Sweet crude oil, dispersant Corexit 9500A, and dispersant-treated crude oil on the survival and growth rates of nauplii of the barnacle Amphibalattus improvisus and tornaria larvae of the enteropneust Schizocardium sp. Growth rates of barnacle nauplii and tomaria larvae were significantly reduced after exposure to chemically dispersed crude oil and dispersant Corexit 9500A at concentrations commonly found in the water column after dispersant application in crude oil spills. We also found that barnacle nauplii ingested dispersed crude oil, which may have important consequences for the biotransfer of petroleum hydrocarbons through coastal pelagic food webs after a crude oil spill. Therefore, application of chemical dispersants increases the impact of crude oil spills on meroplanktonic larvae, which may affect recruitment and population dynamics of marine benthic invertebrates.

RefID: 13

Author: Almeda, R., Connelly, T.L. and Buskey, E.J.

Year: 2014

Title: Novel insight into the role of heterotrophic dinoflagellates in the fate of crude oil in the sea

Journal: Scientific Reports

Hyperlink: http://www.nature.com/articles/srep07560?WT.ec_id=SREP-704-20141223

Abstract: Although planktonic protozoans are likely to interact with dispersed crude oil after a spill, protozoan-mediated processes affecting crude oil pollution in the sea are still not well known. Here, we present the first evidence of ingestion and defecation of physically or chemically dispersed crude oil droplets (1–86 μm in diameter) by heterotrophic dinoflagellates, major components of marine planktonic food webs. At a crude oil concentration commonly found after an oil spill (1 μL L−1), the heterotrophic dinoflagellates Noctiluca scintillans and Gyrodinium spirale grew and ingested ~0.37 μg-oil μg-Cdino−1 d−1, which could represent ~17% to 100% of dispersed oil in surface waters when heterotrophic dinoflagellates are abundant or bloom. Egestion of faecal pellets containing crude oil by heterotrophic dinoflagellates could contribute to the sinking and flux of toxic petroleum hydrocarbons in coastal waters. Our study indicates that crude oil ingestion by heterotrophic dinoflagellates is a noteworthy route by which petroleum enters marine food webs and a previously overlooked biological process influencing the fate of crude oil in the sea after spills.

RefID: 14

Author: Almeda, R., Hyatt, C. and Buskey, E.J.

Year: 2014

Title: Toxicity of dispersant Corexit 9500A and crude oil to marine microzooplankton

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651314001687

Abstract: In 2010, nearly 7 million liters of chemical dispersants, mainly Corexit (R) 9500A, were released in the Gulf of Mexico to treat the Deepwater Horizon oil spill. However, little is still known about the effects of Corexit 9500A and dispersed crude oil on microzooplankton despite the important roles of these planktonic organisms in marine ecosystems. We conducted laboratory experiments to determine the acute toxicity of Corexit 9500A, and physically and chemically dispersed Louisiana light sweet crude oil to marine microzooplankton (oligotrich ciliates, tintinnids and heterotrophic dinoflagellates). Our results indicate that Corexit 9500A is highly toxic to microzooplankton, particularly to small ciliates, and that the combination of dispersant with crude oil significantly increases the toxicity of crude oil to microzooplankton. The negative impact of crude oil and dispersant on microzooplankton may disrupt the transfer of energy from lower to higher trophic levels and change the structure and dynamics of marine planktonic communities. (C) 2014 Elsevier Inc. All rights reserved.

RefID: 15

Author: Almeda, R., Wambaugh, Z., Chai, C., Wang, Z., Liu, Z. and Buskey, E.J.

Year: 2013

Title: Effects of Crude Oil Exposure on Bioaccumulation of Polycyclic Aromatic Hydrocarbons and Survival of Adult and Larval Stages of Gelatinous Zooplankton

Journal: PloS One

Hyperlink: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0074476

Abstract: Gelatinous zooplankton play an important role in marine food webs both as major consumers of metazooplankton and as prey of apex predators (e. g., tuna, sunfish, sea turtles). However, little is known about the effects of crude oil spills on these important components of planktonic communities. We determined the effects of Louisiana light sweet crude oil exposure on survival and bioaccumulation of polycyclic aromatic hydrocarbons (PAHs) in adult stages of the scyphozoans Pelagia noctiluca and Aurelia aurita and the ctenophore Mnemiopsis leidyi, and on survival of ephyra larvae of A. aurita and cydippid larvae of M. leidyi, in the laboratory. Adult P. noctiluca showed 100% mortality at oil concentration >= 20 mu L L-1 after 16 h. In contrast, low or non-lethal effects were observed on adult stages of A. aurita and M. leidyi exposed at oil concentration <= 25 mu L L-1 after 6 days. Survival of ephyra and cydippid larva decreased with increasing crude oil concentration and exposition time. The median lethal concentration (LC50) for ephyra larvae ranged from 14.41 to 0.15 mu L L-1 after 1 and 3 days, respectively. LC50 for cydippid larvae ranged from 14.52 to 8.94 mu L L-1 after 3 and 6 days, respectively. We observed selective bioaccumulation of chrysene, phenanthrene and pyrene in A. aurita and chrysene, pyrene, benzo[a] pyrene, benzo[b] fluoranthene, benzo[k] fluoranthene, and benzo[a] anthracene in M. leidyi. Overall, our results indicate that (1) A. aurita and M. leidyi adults had a high tolerance to crude oil exposure compared to other zooplankton, whereas P. noctiluca was highly sensitive to crude oil, (2) larval stages of gelatinous zooplankton were more sensitive to crude oil than adult stages, and (3) some of the most toxic PAHs of crude oil can be bioaccumulated in gelatinous zooplankton and potentially be transferred up the food web and contaminate apex predators.

RefID: 16

Author: Almeda, R., Wambaugh, Z., Wang, Z., Hyatt, C., Liu, Z. and Buskey, E.J.

Year: 2013

Title: Interactions between Zooplankton and Crude Oil: Toxic Effects and Bioaccumulation of Polycyclic Aromatic Hydrocarbons

Journal: PloS One

Hyperlink: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0067212

Abstract: We conducted ship-, shore- and laboratory-based crude oil exposure experiments to investigate (1) the effects of crude oil (Louisiana light sweet oil) on survival and bioaccumulation of polycyclic aromatic hydrocarbons (PAHs) in mesozooplankton communities, (2) the lethal effects of dispersant (Corexit 9500A) and dispersant-treated oil on mesozooplankton, (3) the influence of UVB radiation/sunlight exposure on the toxicity of dispersed crude oil to mesozooplankton, and (4) the role of marine protozoans on the sublethal effects of crude oil and in the bioaccumulation of PAHs in the copepod Acartia tonsa. Mortality of mesozooplankton increased with increasing oil concentration following a sigmoid model with a median lethal concentration of 32.4 mu l L-1 in 16 h. At the ratio of dispersant to oil commonly used in the treatment of oil spills (i.e. 1:20), dispersant (0.25 mu l L-1) and dispersant-treated oil were 2.3 and 3.4 times more toxic, respectively, than crude oil alone (5 mu l L-1) to mesozooplankton. UVB radiation increased the lethal effects of dispersed crude oil in mesozooplankton communities by 35%. We observed selective bioaccumulation of five PAHs, fluoranthene, phenanthrene, pyrene, chrysene and benzo[b]fluoranthene in both mesozooplankton communities and in the copepod A. tonsa. The presence of the protozoan Oxyrrhis marina reduced sublethal effects of oil on A. tonsa and was related to lower accumulations of PAHs in tissues and fecal pellets, suggesting that protozoa may be important in mitigating the harmful effects of crude oil exposure in copepods and the transfer of PAHs to higher trophic levels. Overall, our results indicate that the negative impact of oil spills on mesozooplankton may be increased by the use of chemical dispersant and UV radiation, but attenuated by crude oil-microbial food webs interactions, and that both mesozooplankton and protozoans may play an important role in fate of PAHs in marine environments.

RefID: 17

Author: Al-Yakoob, S., Saeed, T. and Al-Hashash, H.

Year: 1993

Title: Polycyclic aromatic hydrocarbons in edible tissue of fish from the Gulf after the 1991 oil spill

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/0025326X9390037K

Abstract: Concentrations of 10 PAHs were determined in the edible parts of fish collected during April 1992 on Leg IV of the NOAA-R/V Mt. Mitchell scientific cruise from four locations along the western side of the Gulf. The average total amount of PAHs was 105.3 mug kg-1 dry wt, with a range 2.51-563.6 mug kg-1 dry wt. The average concentrations of PAHs in fish from stations E (north Abu Ali), F (south Abu Ali), G (Rennie Shoals) and I (Qatar) were 165.9, 91.7, 55.8 and 108.6 mug kg-1 respectively. The slightly elevated average concentration of total PAHs in samples from station E shows that north Abu Ali was the most oil impacted area. Pyrene and phenanthrene were detected most frequently (in 75% of the fish) whereas chrysene and benz(a)anthracene had the lowest frequency of detection (in 5% of the fish). Based on qualitative classification of PAH carcinogenicity, detected PAHs classified as having sufficient or limited evidence for carcinogenicity [benz(a)pyrene, benz(a)anthracene and chrysenel were lower in concentration and frequency of detection than those classified as having insufficient or no evidence for carcinogenicity (fluoranthene, anthracene, phenanthracene and pyrene).

RefID: 18

Author: Ambrose, P.

Year: 1990

Title: Bumper Salmon Catch After Oil Spill

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/0025326X9090054C

Abstract:

RefID: 19

Author: Anderson, B.S., Arenella-Parkerson, D., Phillips, B.M., Tjeerdema, R.S. and Crane, D.

Year: 2009

Title: Preliminary investigation of the effects of dispersed Prudhoe Bay Crude Oil on developing topsmelt embryos, Atherinopsaffinis

Journal: Environmental Pollution

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0269749108005277

Abstract: Static exposure experiments were conducted to assess the toxicity of dispersed Prudhoe Bay Crude Oil (PBCO) to embryos of the topsmelt (Atherinops affinis). Treatment with the dispersant COREXIT 9500 resulted in greater hydrocarbon concentrations in chemically enhanced water-accommodated fractions (CEWAFs) of oil, relative to the untreated water-accommodated fractions (WAFs). Topsmelt embryo development and survival to hatching was significantly inhibited in CEWAF tests while minimal effects on embryo-larval survival were observed in WAF tests. Increased hydrocarbon concentrations in the CEWAF tests caused cardiovascular and other abnormalities in developing topsmelt embryos. (C) 2008 Elsevier Ltd. All rightsreserved.

RefID: 20

Author: Ansari, Z.A., Saldanha, M.C. and Rajkumar, R.

Year: 1997

Title: Effects of petroleum hydrocarbons on the growth of a microalga, Isochrysis sp. (Chrysophyta)

Journal: Indian Journal of Marine Sciences

Hyperlink: http://drs.nio.org/drs/handle/2264/2009

Abstract: Effects of water soluble fraction of Bombay High crude oil and heavy duty marine diesel on the growth of a microalga were examined and compared. Most concentrations of the oil depressed the growth rate in Isochrysis sp. Marine diesel prevented the growth of the alga in a concentration above 10%, while crude oil at a similar concentration had little effect on the growth. Hydrocarbon would cause environmental damage through selective effects on natural biota in the marine environment.

RefID: 21

Author: Antrim, L.D., Thom, R.M., Gardiner, W.W., Cullinan, V.I., Shreffler, D.K. and Bienert, R.W.

Year: 1995

Title: Effects of petroleum products on bull kelp (Nereocystis luetkeana)

Journal: Marine Biology

Hyperlink: http://link.springer.com/article/10.1007/BF00349274

Abstract: Although research has been conducted on the effects of oil on the giant kelp Macrocystis pyrifera, no similar studies have been completed on bull kelp, Nereocystis luetkeana, the dominant kelp in Washington State, British Columbia, and Alaska. The effects of three petroleum products [diesel fuel, intermediate fuel oil (IFO), and crude oil] were tested before and after weathering on N. leutkeana. Whole plants were exposed to petroleum product for 4 or 24 h and then transferred to the field; observations on the condition of the plants were made daily for 7 d. In addition, controlled bioassays were performed to measure the effects of petroleum exposure on net photosynthetic rate (NP) and respiration rate (R), using light- and dark-bottle techniques. These experiments verified the susceptibility of N. luetkeana tissue to the damaging effects of direct exposure to several oil types. The 4 h exposures to weathered diesel and unweathered IFO, and 24 h exposures to unweathered and weathered diesel and IFO resulted in moderate to severe damage to kelp tissue (i.e., clearly delineated bleached line accompanied by tissue necrosis). Weathered diesel was more toxic than unweathered diesel. The most severe damage to bull kelp was concentrated at the meristematic zone (junction of stipe and bulb) where new tissue growth occurs. Petroleum type significantly affected stipe and blade NP, R, and NP:R ratios. Diesel treatments had a greater negative effect on NP than did the IFO treatments. Based on these experiments, the relative ranking of the damaging effects of petroleum treatment on bull kelp are weathered diesel > unweathered IFO > unweathered diesel > weathered IFO > unweathered crude > weathered crude.

RefID: 22

Author: Ara, K., Aoike, D., Hiromi, J. and Uchida, N.

Year: 2004

Title: Acute toxicity of Bunker C refined oil to the Japanese littleneck clam Ruditapes philippinarum (Bivalvia : Veneridae)

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs00128-004-0290-7

Abstract: Marine pollution caused by oil spills is deadly to many aquatic organisms and their habitats. Once an oil spill happens in the sea and the oil reaches the coastal region, the intertidal zone (e.g. rocky shore, tidal flat) and shallow, estuarine and neritic waters are more susceptible to oil pollution, due to the specific gravity of oil being greater than that of seawater. In these areas, oil permeates the sandy and muddy bottom and sediment, and it remains there for a long time.

RefID: 23

Author: Arfsten, D.P., Schaeffer, D.J. and Mulveny, D.C.

Year: 1996

Title: The effects of near ultraviolet radiation on the toxic effects of polycyclic aromatic hydrocarbons in animals and plants: A review

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651396900019

Abstract: Polycyclic aromatic hydrocarbons (PAHs) are common contaminants of terrestrial and aquatic ecosystems. Traditionally, toxicological studies for defining the potential hazard of PAHs in wildlife have been conducted in the absence of UV radiation. However, recent toxicology studies particularly in the discipline of aquatic toxicology have presented evidence that PAHs may become toxic or substantially more toxic upon coexposure to UV light (300-400 mm). In this paper, a comprehensive review of the literature pertaining to the toxicological interaction of PAHs and UV light in aquatic and terrestrial organisms is presented, It is concluded that the acute phototoxic effects of PAHs should be considered when conducting environmental risk assessments; however, more research needs to be conducted to address the lack of data on the enhancement of UV-induced carcinogenesis by PAH compounds. (C)

1996 Academic Press, Inc.

RefID: 24

Author: Armstrong, D.A., Dinnel, P.A., Orensanz, J.M., Armstrong, J.L., McDonald, T.L., Cusimano, R.F., Nemeth, R.S., Landolt, M.L., Skalski, J.R., Lee, R.F. and Huggett, R.J.

Year: 1995

Title: Status of selected bottomfish and crustacean species in Prince William Sound following the Exxon Valdez oil spill

Journal: Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters

Hyperlink: http://valdezsciences.com/dspArticle.cfm?catID=2&artID=1066&artSecID=1100

Abstract: Exposure and possible adverse effects of the Exxon Valdez oil spill (EVOS) at depth were studied between 1989 and 1991 on several species of crustaceans, molluscs, and finfish that are characterized by ontogenetic shifts in distribution from meroplanktonic larvae to benthic and demersal juveniles and adults. Our approach was to search for 1) evidence of exposure to Exxon Valdez crude oil (EVC) at depth (generally between 20 to 150 m) and 2) measurable perturbations at both the individual and population levels. Primary species targeted were Tanner crab (Chionoecetes bairdi), several pandalid shrimps (Pandalus platyceros, P. hypsinotus, P. borealis), flathead sole (Hippoglossoides elassodon), and several bivalves including scallops (Chlamys rubida) and infaunal clams (Nuculana, Yoldia, and Macoma spp.). Our survey design provided a comparison between variables measured in 'oiled' bays around Knight Island and 'non-oiled' bays at other locations within Prince William Sound. 'Oiled' was defined in terms of degree of shoreline oiling, sediment and tissue hydrocarbon concentrations with the EVC signature, elevated concentrations of fluorescent aromatic compounds (FACs) in bile of flathead sole, and frequency of oil in benthic trawls. Statistical analyses of catch-per-unit-of-effort (CPUE; relative abundance determined by pots and trawls) were focused on detection of differences in trends through time (that is, 'time-by-oil' interaction) rather than on magnitude of differences, thereby avoiding the problem of inherent differences in baseline CPUE levels between bays and the influence of non-random application of oil to bays. Polycyclic aromatic hydrocarbons (PAHs) of petrogenic origin were measured in all bays sampled in this study and levels of PAHs derived from EVC were elevated in the 'oiled' bays following the spill, yet attenuated to less than 200 ng/g sediment by 1991. Total PARS in scallop tissues were higher in oiled bays in 1989 but decreased 15-fold to mean of 16 ng/g by 1990. Clam tissues from 'oiled' bays in 1991 had higher PAH concentrations, but only samples from Bay of Isles had alkylated PAHs (about 90 ng/g) indicative of EVC exposure. Mean concentrations of FACs in flathead sole bile were significantly higher in 'oiled' than 'non-oiled' bays (about 27 and 14 ng/g, respectively) in both 1990 and 1991, and corresponded to elevated tissue levels of PAHs in clams, which are the major prey of sole in these bays. Virtually no evidence of significant adverse effects was detected at either the individual or population levels across all the life history stages sampled. Larval Tanner crabs were widely distributed in the plankton in early summer of 1989 and 1990; adult female fecundity and trends in CPUE of juveniles did not differ significantly between the two categories of bays. In spring of 1990, 16 dead juvenile Tanner crabs were caught in three 'oiled' bays and mortality was significantly correlated with elevated FACs in bile of flathead sole. Such mortality was likely linked to inordinately low bottom-water salinity that spring, and dead crabs were not found on any other cruise prior to or after this event.

Pandalid shrimp were ubiquitous throughout the study area, and no significant differences were measured between oiled and 'non-oiled' bays in trends of CPUE of P. borealis (the best quantified) and fecundity of P. platyceros. Fecundity in the Case of P. hypsinotus was reduced in 1990 compared with 1989 irrespective of bay, but fecundity was also about 308 lower among females from the 'oiled' compared with 'non-oiled' bays. In the case of flathead sole, mean abundance of young-of-the-year fish declined significantly in 'non-oiled' bays and mean abundance of older fish increased significantly in 'oiled' bays. In contrast to lack of evidence of adverse effects on target species caused by the EVOS, substantial declines in fishery landings of several crabs and shrimps had occurred in PWS, some to the point of closure, prior to the spill. Long-term trends in abundance of populations of these species due to natural environmental causes or fishing pressures are likely to be far more important than fluctuations attributable to EVOS.

RefID: 25

Author: Armstrong, S.A., Headley, J.V., Peru, K.M. and Germida, J.J.

Year: 2009

Title: DIFFERENCES IN PHYTOTOXICITY AND DISSIPATION BETWEEN IONIZED AND NONIONIZED OIL SANDS NAPHTHENIC ACIDS IN WETLAND PLANTS

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/09-059.1/full

Abstract: Naphthenic acids (NAs) are composed of alkyl-substituted acyclic and cycloaliphatic carboxylic acids and, because they are acutely toxic to fish, are of toxicological concern. During the caustic hot-water extraction of oil from the bitumen in oil sands deposits, NAs become concentrated in the resulting tailings pond water. The present study investigated if dissipation of NAs occurs in the presence of hydroponically grown emergent macrophytes (Typha latifolia, Phragmites australis, and Scirpus acutus) to determine the potential for phytoremediation of these compounds. Plants were grown with oil sands NAs (pK(a) similar to 5-6) in medium at pH 7.8 (predominantly ionized NAs) and pH 5.0 (predominantly nonionized NAs) to determine if, by altering their chemical form, NAs may be more accessible to plants and, thus, undergo increased dissipation. Whereas the oil sands NA mixture in its nonionized form was more toxic to wetland plants than its ionized form, neither form appeared to be sequestered by wetland plants. The present study demonstrated that plants may selectively enhance the dissipation of individual nonionized NA compounds, which contributes to toxicity reduction but does not translate into detectable total NA dissipation within experimental error and natural variation. Plants were able to reduce the toxicity of a NA system over 30 d, increasing the median lethal concentration (LC50; % of hydroponic solution) of the medium for Daphnia magna by 23.3% +/- 8.1% (mean +/- standard error; nonionized NAs) and 37.0% +/- 2.7% (ionized NAs) as determined by acute toxicity bioassays. This reduction in toxicity was 7.3% +/- 2.6% (nonionized NAs) and 45.0% +/- 6.8% (ionized NAs) greater than that in unplanted systems.

RefID: 26

Author: Aunaas, T., Olsen, A. and Zachariassen, K.E.

Year: 1991

Title: THE EFFECTS OF OIL AND OIL DISPERSANTS ON THE AMPHIPOD GAMMARUS-OCEANICUS FROM ARCTIC WATERS

Journal: Polar Research

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1111/j.1751-8369.1991.tb00680.x/abstract

Abstract: Amphipods of the species Gammarus oceanicus were exposed to water soluble fractions and water emulsions of Statfjord A+B crude oil, the dispersants Finasol OSR-5 and Finasol OSR-12, and combinations of the oil and dispersants. Adding Finasol OSR-12 to the crude oil caused a reduction in the mortality of the amphipods compared with amphipods exposed to the water soluble fraction and the water emulsion of crude oil alone, probably due to a reduced mole fraction of toxic oil components in the mixture of oil and dispersant. Exposure to sublethal concentrations of water soluble fractions increased the respiratory rates of the amphipods in the majority of the exposed groups. The water soluble fractions slightly increased the concentrations of sodium in the haemolymph and in the whole organism. Some exposures gave a significant increase in the relative water content of the amphipods. The water soluble fractions probably increase the membrane permeability to water and ions, leading to an increased influx of water and sodium from the medium. Thc increased respiratory rates are likely to be due to a compensatory extrusion of sodium. Exposure to sublethal concentrations of water emulsions reduced the respiratory rates of the amphipods, probably due to oil droplets adhering to thc gill membranes and thus causing a reduced rate of oxygen diffusion into the organisms. Thc majority of thc exposures to water emulsions increased concentrations of sodium in thc haemolymph as well as in whole organisms. Thus, sodium probably accumulates in the intracellular compartments because thc sodium pumps are restricted by the reduced energy available. This is likely to lead to an osmotic swelling of cells. Reduced total free amino acid concentrations in these amphipods is ascribed to volume regulation of the swollen cells. and a reduced co-transport of sodium and free amino acids from the haemolymph to the intracellular compartments.

RefID: 27

Author: Babcock, M.M., Harris, .PM., Carls, M.G., Brodersen, C.C. and Rice, S.D.

Year: 1998

Title: Mussel Bed Restoration and Monitoring, Exxon Valdez Oil Spill Restoration Final Project Report (Restoration Project 95090)

Journal: National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Auke Bay Laboratory, Juneau, Alaska

Hyperlink:

Abstract: Many mussel beds in the spill area, particularly those on soft sediment, were not cleaned immediately after the Exxon Valdez oil spill in 1989. Consequently these beds had high concentrations of contaminated sediments and tissues. Surveys documented the geographic extent (primarily Prince William Sound and the Kenai Peninsula) and intensity of oiling. Hydrocarbon concentrations declined naturally from 1992-1995 in some, but not all beds. Distribution of oil in sediments was related to tidal elevation, depth, and grain size. Oil concentration in mussels correlated with that in sediment. Mussel condition was adversely affected by oil; prevalence of digestive gland metaplasia, brown cells, and hemocytic infiltrates in gonads increased, and storage cell abundance decreased. However, some physiological responses (byssal thread production, condition index, feeding rate, or glycogen content) in mussels contaminated 3-4 years were not correlated with oil concentration. Bed restoration caused immediate reductions in oil concentration in surface sediment, but these sediments were later partially recontaminated by remaining oil. Restoration efficacy was less evident in mussels; concentration reductions were significant in less than half the beds by the end of study. Mussel densities declined in one-half of the beds after restoration, but density declines were similar in untreated reference beds.

RefID: 28

Author: Babcock, M.M., Harris, P.M., Carls, M.G., Brodersen, C.C. and Rice, S.D.

Year: 1998

Title: Mussel bed restoration and monitoring

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/42244731.pdf

Abstract: Many mussel beds in the spill area, particularly those on soft sediment, were not cleaned immediately after the Exxon Valdez oil spill in 1989. Consequently these beds had high concentrations of contaminated sediments and tissues. Surveys documented the geographic extent (primarily Prince William Sound and the Kenai Peninsula) and intensity of oiling. Hydrocarbon concentrations declined naturally from 1992-1995 in some, but not all beds. Distribution of oil in sediments was related to tidal elevation, depth, and grain size. Oil concentration in mussels correlated with that in sediment. Mussel condition was adversely affected by oil; prevalence of digestive gland metaplasia, brown cells, and hemocytic infiltrates in gonads increased, and storage cell abundance decreased. However, some physiological responses (byssal thread production, condition index, feeding rate, or glycogen content) in mussels contaminated 3-4 years were not correlated with oil concentration. Bed restoration caused immediate reductions in oil concentration in surface sediment, but these sediments were later partially recontaminated by remaining oil. Restoration efficacy was less evident in mussels: concentration reductions were significant in less than half the beds by the end of study. Mussel densities declined in one-half of the beds alter restoration, but density declines were similar in untreated reference beds

RefID: 29

Author: Babcock, M.M., Irvine, G.V., Harris, .PM., Cusick, J.A. and Rice, S.D.

Year: 1996

Title: Persistence of Oiling in Mussel Beds Three and Four Years after the Exxon Valdez Oil Spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: Dense beds of the mussel Mytilus trossulus affected by Exxon Valdez crude oil in Prince William Sound and along the Kenai and Alaska peninsulas were intentionally left untreated during shoreline cleanup activities in 1989-1991. In 1992 and 1993, mussels and sediments from 70 mussel beds in Prince William Sound and 18 beds along the Kenai and Alaska peninsulas were sampled to establish the geographic extent and intensity of Exxon Valdez oil persisteing in mussel beds. Sediments collected in 1992 and 1993 from 31 of the oiled mussel beds in the sound had total petroleum hydrocarbon (TPH) concentrations greater than 10,000 µg/g wet weight. The highest concentrations were in sediments collected from Foul Bay (62,258 ± 1,272 µg TPH/g, mean ± SE). Five of the 18 beds sampled along the Kenai Peninsula showed sediment TPH concentrations greater than 5,000 µg/g. The mean concentration of total polynuclear aromatic hydrocarbons (TPAH) in mussels from these same beds ranged up to 8.30 ± 0.26 µg/g (Squirrel Island) in Prince William Sound and 4.01 ± 1.54 µg/g along the Kenai Peninsula (Morning Cove, Pye Islands). Polynuclear aromatic hydrocarbon fingerprints of mussel tissue collected from surveyed sites indicated the contaminant source was Exxon Valdez oil. In 1993, mean TPH concentrations in sediments and mean TPAH concentrations in mussels were lower by more than 50% compared with these concentrations in 1992. Some beds showed little reduction in oil. Almost all the beds showeing only small decreases in hydrocarbons were in protected, low-energy areas, where there probably was little remobilization of residual oil underlying the beds. This study has produced analytical evidence showing that substantial residual Exxon Valdez oil persists in sediments underlying mussel beds in the area affected by the spill. Residual crude oil is a source of chronic contamination of mussels and their predators. In the more-protected intertidal areas, natural flushing and remobilization of Exxon Valdez oil will be slow; some of these mussel beds potentially can be manually cleaned.

RefID: 30

Author: Bado-Nilles, A., Gagnaire, B., Thomas-Guyon, H., Le Floch, S. and Renault, T.

Year: 2008

Title: Effects of 16 pure hydrocarbons and two oils on haemocyte and haemolymphatic parameters in the Pacific oyster, Crassostrea gigas (Thunberg)

Journal: Toxicology in Vitro

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0887233308001215

Abstract: The in vitro effects of polycyclic aromatic hydrocarbons (PAHs) on haemocyte and haemolymphatic parameters of the Pacific oyster, Crassostrea gigas, were tested using field concentrations (10(-7) and 10(-9) mg mL(-1)) observed in the Marennes-Oleron Basin (Charente-Maritime, France) and high concentrations (10(-3) and 10(-5) mg mL(-1)) observed during oil spills. As a first step, the effects of pollutants, after a 24 h contamination period, were monitored on individual and pooled haemolymph samples and similar results were observed for both sample types. In a second step, haemolymphs from 45 oysters were withdrawn and pooled. Eighteen pollutants were tested in vitro after a 4 and 24 h contamination period and 10 of them showed significant modulations of the five haemocyte parameters tested. Seven pollutants (fluorene, pyrene, anthracene, phenanthrene, chrysene, indeno[1,2,3-c,d]pyrene and heavy fuel oil (HFO)) induced a decrease in haemocyte mortality. Fluorene, pyrene and HFO significantly decreased phagocytosis activity. Percentage of non-specific esterase positive cells, phenoloxidase activity and lysosome presence were increased by naphthalene, benzo[b]fluoranthene and dibenz[a,h]anthracene, respectively. Modulation of immune parameters in the Pacific oyster by PAHs suggested that PAH pollution may be related to enhanced susceptibility to diseases. (C) 2008 Elsevier Ltd. All rights reserved.

RefID: 31

Author: Bado-Nilles, A., Quentel, C., Mazurais, D., Zambonino-Infante, J.L., Auffret, M., Thomas-Guyon, H. and Le Floche, S.

Year: 2011

Title: In vivo effects of the soluble fraction of light cycle oil on immune functions in the European sea bass, Dicentrarchus labrax (Linne)

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651311001850

Abstract: Hydrocarbons are major contaminants that may affect biota at various trophic levels in estuaries and coastal ecosystems. The effects of accidental pollution by light cycle oil (LCO), a refined product of heavy fuel oil, on bioaccumulation, depuration processes and immune-related parameters in the European sea bass, Dicentrarchus labrax, were investigated in the laboratory after 7 days of exposure and a 2-week recovery period. Exposure of fish to the soluble fraction of LCO (1600 ng L(-1)) for 7 days led to the bioaccumulation of some polycyclic aromatic hydrocarbons (PAHs) in muscles: naphthalene, acenaphthene, fluorene, phenanthrene and anthracene. After 7 days of recovery period, half-elimination of naphthalene was reported in fish muscles due to facilitated diffusive loss by the epithelium and a faster elimination rate proven by the presence of a high level of naphthalene biliary metabolites. The other bioaccumulated molecules displayed a slower deputation rate due to their elimination by the formation of hydrophobic metabolites excreted through bile or urine. Three days after the beginning of the recovery period, each contaminated fish showed severe external lesions (tissue necrosis, suppurative exudates, haemorrhagic area). The hypothesis of a possible link with inflammatory phenomenon was supported by (i) an inversion of the leucocyte sub-population percentage, (ii) a significant up-expression in the spleen of the tumour necrosis factor alpha gene, (iii) a significant increase in ACH(50). Moreover, the lack of C3 gene regulation in the spleen suggested a non-renewal of this component. The reduction of phagocytic activity and lysozyme concentration reflected immune suppression. Finally, LCO toxicity in this fish was clearly demonstrated to be related to inflammatory reaction and immune depletion. (C) 2011 Elsevier Inc. All rights reserved.

RefID: 32

Author: Bado-Nilles, A., Quentel, C., Thomas-Guyon, H. and Le Floch, S.

Year: 2009

Title: Effects of two oils and 16 pure polycyclic aromatic hydrocarbons on plasmatic immune parameters in the European sea bass, Dicentrarchus labrax (Linne)

Journal: Toxicology in Vitro

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0887233308002853

Abstract: The in vitro effects of polycyclic aromatic hydrocarbons (PAHs) on two plasmatic immune parameters, lysozyme concentration and haemolytic alternative complement activity, of the European sea bass, Dicentrarchus labrax, were tested using field (10(-7) and 10(-9) mg mL(-1)) and high concentrations (10(-3) and 10(-5) mg mL(-1)) observed during oil spills. Peripheral blood from 105 fish was collected, centrifuged at 1200g, for 10 min, at 4 degrees C and three plasma pools, each of 35 fish, were constituted. Two oils (heavy fuel oil and light cycle oil) and 16 pure PAHs, selected on the basis of the American Environmental Protection Agency list (US EPA), were tested in vitro on the two humoral immune parameters. Only three pure PAHs (anthracene, chrysene and dibenz[a,h]anthracene) modulated lysozyme concentration. Acenaphthene, acenaphthylene, anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, pyrene and light cycle oil modified the haemolytic alternative complement activity after 4 h of incubation. This study investigates the direct effects of several PAHs on fish humoral immune functions and describes the haemolytic complement activity of fish as suitable biomarkers of oil pollution. (C) 2008 Elsevier Ltd. All rights reserved.

RefID: 33

Author: Ball, A. and Truskewycz, A.

Year: 2013

Title: Polyaromatic hydrocarbon exposure: an ecological impact ambiguity

Journal: Environmental Science and Pollution Research

Hyperlink: http://link.springer.com/article/10.1007/s11356-013-1620-2

Abstract: Polyaromatic hydrocarbons (PAHs) represent a fraction of petroleum hydrocarbons and are currently one of the foremost sources of generating energy in today's contemporary society. However, evidence highlighted in this review show that PAH pollution, as a result of oil spills, hazardous PAH-contaminated working environments and technologies which do not efficiently utilise fuels, as well as natural sources of emissions (e.g. forest fires) may have significant health implications for all taxa. The extent of damage to organisms from PAH exposure is dependent on numerous factors including degree and type of PAH exposure, nature of the environment contaminated (i.e. terrestrial or aquatic), the ability of an organism to relocate to pristine environments, type and sensitivity of organism to specific hydrocarbon fractions and ability of the organism to metabolise different PAH fractions. The review highlights the fact that studies on the potential damage of PAHs should be carried out using mixtures of hydrocarbons as opposed to individual hydrocarbon fractions due to the scarcity of individual fractions being a sole contaminant. Furthermore, potential damage of PAH-contaminated sites should be assessed using an entire ecological impact outlook of the affected area.

RefID: 34

Author: Ballachey, B.E.

Year: 1995

Title: Biomarkers of damage to sea otters in Prince William Sound, Alaska following potential exposure to oil spilled from the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33944231.pdf

Abstract: This study was conducted to evaluate several biomarkers of genotoxic damage in sea otters that had potentially been exposed to oil spilled from the &on Valdez. Thirteen adult male sea otters were captured in eaStem (unoiled) Prince William Sound, and 14 in westem (oiled) Prince William Sound in September and October 1991. Blood lymphocytes, sperm and testicular cells were collected from the otters for flow cytometric analyses to measure: 1) DNA content of lymphocytes, 2) nuclear chromatin structure of sperm, and 3) subpopulations of cell types in the testis. Additionally, sperm cells were examined by light microscopy for morphological abnormalities. The DNA content of blood lymphocytes from sea otters in the oiled vs. unoiled areas was not significantly different, although there was greater variation among samples from the oiled area. One measure of sperm cell quality was poorer for male sea otters from the unoiled area, and may have been associated with differences in the age and breeding status of the two groups sampled. Other measures of sperm and testicular cells did not differ between areas. The percentage of sperm exhibiting morphological abnormalities (primarily of the midpiece and tail) was high (>8O%) and similar in both areas. This study did not provide conclusive evidence of genotoxic damage associated with oil exposure in sea otters.

RefID: 35

Author: Ballachey, B.E. and Kloecker, K.A.

Year: 1997

Title: Hydrocarbon residues in tissues of sea otters (Enhydra lutris) collected from Southeast Alaska

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/41846882.pdf

Abstract: Samples of kidney, liver and muscle were taken from 12 sea otters from southeast Alaska, an area considered to be relatively free of petroleum contaminants, and analyzed for hydrocarbon content. Concentrations of aliphatic and aromatic hydrocarbons detected in the samples were low, and similar in all three tissue types. These data provide comparative data for the analysis of hydrocarbon concentrations in samples from sea otters that died following the T/V Exxon Valdez oil spill in Prince William Sound, Alaska.

RefID: 36

Author: Ballachey, B.E. and Kloecker, K.A.

Year: 1997

Title: Hydrocarbons in hair, livers and intestines of sea otters (Enhydra lutris) found dead along the path of the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/37889304.pdf

Abstract: Aliphatic and aromatic hydrocarbons were analyzed in hair, liver and intestinal samples taken from dead sea otters (Enhydra lutris) collected in spring and summer 1989 from Prince William Sound, the Kenai Peninsula and Kodiak Island, along the path of the Emon Valdez oil spill. Hair showed significant differences in hydrocarbon concentrations among the three locations, but few significant differences were noted for liver or intestine samples. The highest concentrations of both aliphatic and aromatic hydrocarbons were measured in hair samples from Prince William Sound. Hair samples from Kenai were also relatively high, and hair samples from Kodiak had the lowest concentrations. The lower molecular weight hydrocarbons in hair samples were absent or present only at very low concentrations, indicating that the oil had weathered by the time the samples were collected. Hydrocarbon concentrations in intestine and liver samples from the three locations were generally similar and low, suggesting that uptake into the tissues was limited, or that hydrocarbons within the tissues had been metabolized by the time samples were collected.

RefID: 37

Author: Ballachey, B.E. and Kloecker, K.A.

Year: 1997

Title: Hydrocarbon residues in tissues of sea otters (Enhydra lutris) collected following the Exxon Valdez oil

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/37889281.pdf

Abstract: Ten moderately to heavily oiled sea otters were collected in Prince William Sound early during the Exxon Valdez oil spill and up to seven tissues from each were analyzed for hydrocarbons. All of the animals had gross pathological lesions consistent with exposure to crude oil as an ultimate cause of death. Aliphatic and aromatic hydrocarbons were detected in all tissues. The alkane series C20 through C30 frequently was observed at relatively high concentrations in all tissue types, as were the aromatic compounds naphthalene, its alkylated derivatives Cl-C4-naphthalene, and biphenyl. Concentrations of aromatic hydrocarbons in fat samples were an order of magnitude higher than in other tissues. The patterns of distribution of these hydrocarbons suggested crude oil as the source of contamination. However, there was variation among oiled otters in the concentrations of individual hydrocarbons, which may be due to differing proximate causes of mortality and varying lengths of time the sea otters survived following oil exposure. The ability of sea otters and other mammals to metabolize the hydrocarbon compounds found in crude oil probably helped to reduce total concentrations of hydrocarbons and changed the distribution of individual hydrocarbons present in tissues. The concentrations of both aliphatic and aromatic hydrocarbons in the tissues of the ten oiled sea otters generally were higher than in tissues from 7 sea otters with no external oiling that were collected from Prince William Sound in 1989 and 1990, or from 12 sea otters collected from an area in southeast Alaska which had not experienced an oil spill.

RefID: 38

Author: Ballachey, B.E., Bodkin, J.L. and Snyder, P.W.

Year: 2003

Title: Lingering oil: bioavailability and effects of prey and predators

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/70849154.pdf

Abstract: Sea otters (Enhydra lutris) in the most heavily oiled areas of western Prince William Sound have not recovered from the EVOS, based on estimates of otter abundance and survival rates, and increased induction of the biomarker for aromatic hydrocarbons, cytochrome P4501A (CYP1A). Exposure of sea otters to lingering oil appears to be a likely mechanism explaining lack of full recovery. This study was initiated to obtain further information on oil exposure, using the cytochrome P450 1A (CYP1A) biomarker and gross and histological observations of the liver, and to examine relations between CYP1A levels and residual oil along shorelines in areas occupied by the sea otters. Previous work (Projects //025, //423 and //534) found that sea otters in oiled areas of western PWS had elevated levels of CYP1A, in blood samples collected in 1996-98 and in blood and liver samples collected in 2001. In summer 2002, we resampled sea otters in oiled and unoiled areas of PWS, to monitor health and blood CYP1A values. Liver was also sampled from these otters for examination of histopathological changes. We observed significantly higher CYP1A levels in sea otters from the oiled area than in those from the unoiled area. Grossly, livers of sea otters from the oiled area generally were swollen and pale in color, whereas livers of sea otters from the unoiled area generally appeared to be normal. However, the incidence of histopathological lesions of the liver was relatively similar in liver samples from both areas. Harlequin duck livers were also collected (captures done as part of Project 02423) for histology; however, those data will be included in the harlequin duck section of the final report for Project //423, in November 2003. Sea otters captured in 2002 were radiotagged and continue to be monitored (Project 030620). Analysis of CYP1A levels in sea otters relative to known locations of residual oil on beaches will be completed when final data from Part I of this project (02585) are available.

RefID: 39

Author: Ballachey, B.E., Bodkin, .JL., Esler, D. and Rice, S.D.

Year: 2014

Title: Lessons from the 1989 Exxon Valdez Oil Spill: A Biological Perspective

Journal: Impacts of Oil Spill Disasters on Marine Habitats and Fisheries in North America

Hyperlink: http://www.crcpress.com/product/isbn/9781466557208

Abstract: Summary: An overview of the evidence for negative and longterm impacts of the Exxon Valdez oil spill on Pink Salmon, Harlequin Duck, and Sea Otter populations. Discussed is the importance of using baseline (pre-spill) data to help understand the longterm impacts of oil spills on marine ecosystems. Furthermore, the authors suggest that development of ecosystem-based toxicology will help predict the chronic, delayed, and indirect longterm risks associated marine oil spills.

RefID: 40

Author: Ballachey, B.E., Bodkin, J.L. and Monson, D.H.

Year: 2013

Title: Quantifying long-term risks to sea otters from the 1989 ‘Exxon Valdez’ oil spill: Reply to Harwell & Gentile (2013)

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v488/p297-301/

Abstract: Recovery of sea otter populations in Prince William Sound (PWS), Alaska, has been delayed for more than 2 decades following the 1989 ‘Exxon Valdez’ oil spill. Harwell & Gentile (2013; Mar Ecol Prog Ser 488:291–296) question our conclusions in Bodkin et al. (2012; Mar Ecol Prog Ser 447:273-287) regarding adverse effects that oil lingering in the environment may have on sea otters. They agree that exposure may continue, but disagree that it constitutes a significant risk to sea otters. In Bodkin et al. (2012), we suggested that subtle effects of chronic exposure were the most reasonable explanation for delayed recovery of the sea otter population in areas of western PWS, where shorelines were most heavily oiled. Here, we provide additional information on the ecology of sea otters that clarifies why the toxicological effects of oral ingestion of oil do not reflect all effects of chronic exposure. The full range of

energetic, behavioral, and toxicological concerns must be considered to appraise how chronic exposure to residual oil may constrain recovery of sea otter populations.

RefID: 41

Author: Ballachey, B.E., Monson, D.H., Kloecker, K.S., Esslinger, G.G., Mohr, F.C., Lipscomb, T.P., Murray, M.J. and Howlin, S.

Year: 2014

Title: Synthesis of Nearshore recovery following the 1989 Exxon Valdez oil spill: sea otter liver pathology and survival in Western Prince William Sound, 2001-2008

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/Store/FinalReports/2007-070808-Final.pdf

Abstract: We examined livers and liver biopsies collected from captured sea otters in WPWS, 2001–2008, to determine whether indicators of liver health correlated with history of oil contamination from the 1989 Exxon Valdez oil spill. Sea otters captured in oiled areas had a significantly higher proportion of livers with gross pathological change, based on visual inspection at the time of capture, than those from unoiled areas. Of the 10 histopathology variables scored on liver biopsies, only two (vacuolar change and pigment) differed between animals from oiled and unoiled areas, and neither correlated with gross pathology scores. Vascular change indicates physiological disturbance, which is consistent with potential effects from oil exposure but also could be influenced by a number of other factors. We concluded that, as of 2008, some differences in liver health were evident between sea otters from oiled and unoiled areas; these differences were consistent with, but not specific to, effects that might be expected with sublethal exposure to lingering Exxon Valdez oil. We also quantified variation in survival of radiomarked sea otters within oiled areas of WPWS in relation to age, sex, body condition, selected blood serum chemistry variables, and histological scores indicative of liver health. Of the variables considered, only the serum enzyme aspartate aminotransferase (AST) and the ratio of serum proteins albumin and globulin (A/G) were correlated with survival, with higher levels of AST and lower levels of A/G associated with increased likelihood of mortality. High AST and low A/G both may be indicative of liver disease. Taken together, results reported here suggest that liver health of sea otters in oiled areas was slightly poorer than those from unoiled areas and, further, that this may have translated to poorer survival through 2008, nearly 2 decades after the spill. More recently collected information indicated that mortality patterns and abundance had returned to pre-spill conditions between 2010 and 2013, suggesting that the effects that we detected through 2008 may have represented the end of effects related to exposure to lingering oil.

RefID: 42

Author: Barata, C., Calbet, A., Saiz, E., Ortiz, L. and Bayona, J.M.

Year: 2005

Title: Predicting single and mixture toxicity of petrogenic polycyclic aromatic hydrocarbons to the copepod Oithona davisae

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/05-189R.1/full

Abstract: In the present study, the acute toxicity of 10 polycyclic aromatic hydrocarbons (PAHs) associated with the Prestige fuel oil spill (Spain, 2002) were evaluated, either as single substances or in mixtures, in adults of the copepod Oithona davisae. All but dimethylphenanthrene had negative effects on O. davisae survival at concentrations below their water solubility, with 48-h median lethal concentrations for naphthalene and pyrene of 56.1 and 0.8 mu mol/L, respectively, making these the least and most toxic compounds. Polycyclic aromatic hydrocarbons had narcotic effects on copepods, as evidenced by the lack of motility at lower concentrations than those causing death. Naphthalene showed the greatest narcotic effects, and phenanthrene showed minor effects. Acute toxicity of the tested PAHs was inversely related (r(2) = 0.9) with their octanol-water partition coefficient, thereby confirming the validity of the baseline quantitative structure-activity regression models for predicting the toxicity of PAH compounds in copepod species. When supplied in mixtures, the toxic effect of PAHs was additive. These results indicate that the many PAHs in an oil spill can be considered unambiguous baseline toxicants (class 1) acting additively as nonpolar narcotics in copepods; hence, their individual and combined toxicity can be predicted using their octanol-water partition coefficient.

RefID: 43

Author: Barbee, G.C., Barich, J., Duncan, B., Bickham, J.W., Matson, C.W., Hintze, C.J., Autenrieth, R.L., Zhou, G.-D., McDonald, T.J., Cizmas, L., Norton, D. and Donnelly, K.C.

Year: 2008

Title: In situ biomonitoring of PAH-contaminated sediments using juvenile coho salmon (Oncorhynchus kisutch)

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S014765130800002X

Abstract: Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous marine and freshwater sediment contaminants. Extensive data exist to confirm that PAHs are toxic to aquatic receptors. However, limited information is available regarding the bioavailability and genotoxicity of sediment PAHs to aquatic organisms. This study investigated an integrated biomonitoring approach using chemical analyses and biomarkers to characterize the bioavailability and genotoxicity of a complex PAH mixture in freshwater lake sediments associated with a former manufactured gas plant (MGP). Sediment PAH genotoxicity was assessed by flow cytometry (FCM), DNA adduct P-32-postlabeling, and erythrocyte micronuclei in juvenile coho salmon (Oncorhynchus kisutch) caged in the water column. Significant PAH-induced genotoxicity was observed with FCM and P-32-postlabeling. but not with erythrocyte micronuclei. Chromosome damage in peripheral blood and hepatic DNA adducts correlated with sediment, but not water column PAH concentrations. Total hepatic DNA adducts in salmon caged nearest the former MGP facility was 39 +/- 6.5 (RAL x 10(9)), while salmon caged in a reference lake had 28 +/- 2.3 total hepatic DNA adducts per 10(9) nucleotides. These results indicate that in situ biomonitoring using biomarkers and caged fish can be a sensitive indicator of genotoxic PAHs in sediments. (c) 2008 Elsevier Inc. All rights reserved.

RefID: 44

Author: Barber, W.E., McDonald, L.L., Erickson, W.P. and Vallarino, M.

Year: 1995

Title: EFFECT OF THE EXXON-VALDEZ OIL-SPILL ON INTERTIDAL FISH - A FIELD-STUDY

Journal: Transactions of the American Fisheries Society

Hyperlink: http://www.tandfonline.com/doi/abs/10.1577/1548-8659%281995%29124%3C0461%3AEOTEVO%3E2.3.CO%3B2

Abstract: The purpose of this study was to evaluate the impact of the March 1989 Exxon Valdez oil spill and subsequent cleanup activities on density, biomass, and species diversity of intertidal fishes in Prince William Sound, Alaska. Intertidal fish were sampled in a quasi-experimental, matched-pairs (oiled-cleaned versus reference sites) design stratified by three habitat types with random selection of oiled-cleaned (O-C) sites. Site pairs were sampled twice in 1990 and in 1991. Of 21 fish taxa, 5 made up 98% and 1 made up 74% of total abundance. There were no significant differences in species diversity between reference and O-C sites. Density, however, was significantly greater at reference sites for all habitats combined for both visits in 1990. In contrast, density in 1991 was about equal at reference and O-C sites. Total biomass for all habitats combined was greater at reference than O-C sites during both visits in 1990, but differences were not statistically significant. In 1991, however, the total biomass at reference and O-C sites was about equal. Forward stepwise multiple logistic regression models indicated that presence of oil was a significant predictor of reduced density at mid-intertidal levels in 1990 but not in 1991. From the general pattern of lower density and biomass on O-C sites in 1990 followed by no significant differences in 1991 and corroborating evidence of multiple-regression modeling, we conclude that the presence of oil and subsequent cleanup activities had a negative impact on intertidal fishes in 1990 and that there was evidence that recovery was underway in 1991.

RefID: 45

Author: Barre, J.S., Bert, T.M. and Van Vleet, E.S.

Year: 1994

Title: TOXICITY OF THE WATER-SOLUBLE FRACTION OF DIESEL FUEL TO POSTSETTLEMENT JUVENILE STONE CRABS (MENIPPE MERCENARIA)

Journal: Bulletin of Marine Science

Hyperlink: http://www.ingentaconnect.com/content/umrsmas/bullmar/1994/00000055/00000001/art00014

Abstract: na

RefID: 46

Author: Barron, M.G. and Holder, E.

Year: 2003

Title: Are exposure and ecological risks of PAHs underestimated at petroleum contaminated sites?

Journal: Human and Ecological Risk Assessment

Hyperlink: http://www.tandfonline.com/doi/pdf/10.1080/10807030390251029

Abstract: Ecological risk assessments conducted under the provisions of the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) typically rely on either U.S. Environmental Protection (USEPA) priority pollutant or Appendix IX analyte lists. These methods quantify only a limited subset of the polycyclic aromatic hydrocarbons (PAHs) and heterocyclic aromatics found in oil and oil process wastes. Advances in analytical chemistry and petroleum fingerprinting techniques now show that the alkylated PAHs found in petroleum are more abundant and more persistent than the non-alkylated PAHs quantified by the traditional analytical methods applied in ecological risk assessments. We performed a screening level evaluation using case studies of PAH contamination from petroleum releases in a take receiving refinery wastes and intertidal sediments exposed to spilled oil to assess the magnitude of underestimation of risks to ben thic invertebrates and wildlife. Risks were assessed using a probabilistic approach and demonstrated that traditional analytical chemistry approaches applied at RCRA and CERCLA sites will underestimate exposure and risks of petrogenic PAHs contaminating aquatic systems. This analysis also shows that the numerical correction factor that has been proposed to account for 'unmeasured' alkylated PAHs can also result in a substantial underestimation of PAH risks from petroleum releases.

RefID: 47

Author: Barron, M.G., Carls, M.G., Short, J.W. and Rice, S.D.

Year: 2003

Title: Photoenhanced toxicity of aqueous phase and chemically dispersed weathered Alaska North Slope crude oil to Pacific herring eggs and larvae

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620220326/full

Abstract: The photoenhanced toxicity of weathered Alaska North Slope crude oil (ANS) was investigated in the eggs and larvae of Pacific herring (Clupea pallasi) with and without the chemical dispersant Corexit(R) 9527. Oil alone was acutely toxic to larvae at aqueous concentrations below 50 mug/L total polycyclic aromatic hydrocarbons (tPAH), and median lethal (LC50s) and effective concentrations (EC50s) decreased with time after initial oil exposure. Brief exposure to sunlight (similar to2.5 h/d for 2 d) significantly increased toxicity 1.5- to 48-fold over control lighting. Photoenhanced toxicity only occurred when oil was present in larval tissue and increased with increasing tPAH concentration in tissue. Ultraviolet radiation A (UVA) treatments were less potent than natural sunlight, and UVA + sunlight caused greater toxicity than sunlight alone. The toxicity of chemically dispersed oil was similar to oil alone in control and UVA treatments, but oil + dispersant was significantly more toxic in the sunlight treatments. The chemical dispersant appeared to accelerate PAH dissolution into the aqueous phase, resulting in more rapid toxicity. In oil + dispersant exposures, the 96-h no-observed-effect concentrations in the UVA + sunlight treatment were 0.2 mug/L tPAH and 0.01 mug/g tPAH. Exposure of herring eggs to oil caused yolk sac edema, but eggs were not exposed to sun and UVA treatment did not cause phototoxicity. These results are consistent with the hypothesis that weathered ANS is phototoxic and that UV can be a significant and causative factor in the mortality of early life stages of herring exposed to oil and chemically dispersed oil.

RefID: 48

Author: Barron, M.G., Carls, M.G., Short, J.W., Rice, S.D., Heintz, R.A., Rau, M. and Di Giulio, R.

Year: 2005

Title: Assessment of the phototoxicity of weathered Alaska North Slope crude oil to juvenile pink salmon

Journal: Chemosphere

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0045653504012123

Abstract: Petroleum products are known to have greater toxicity to the translucent embryos and larvae of aquatic organisms in the presence of ultraviolet radiation (UV) compared to toxicity determined in tests performed under standard laboratory lighting with minimal UV. This study assessed the acute phototoxicity of the water accommodated fractions of weathered Alaska North Slope crude oil (ANS) to juvenile pink salmon, which are a heavily pigmented life stage. Fish in the highest ANS treatments exhibited melanosis, less mobility, reduced startle response, erratic swimming, and loss of equilibrium. Gills from fish exposed to ANS had elevated levels of hydroperoxides in oil-only, UV-only, and oil + UV treatments compared to control fish, which was indicative of increased lipid peroxidation in gill tissue. Under the test conditions of moderate salinity, low UV and high short-term oil exposure there were no indications of photoenhanced toxicity as assessed by elevation of mortality, behavioral impairment, or gill lipid peroxidation in oil + UV treatments. The results of this study suggest that pink salmon may be at less risk from photoenhanced toxicity compared to the translucent early-life stages of several other Alaska species. Published by Elsevier Ltd.

RefID: 49

Author: Barron, M.G., Podrabsky, T., Ogle, S. and Ricker, R.W.

Year: 1999

Title: Are aromatic hydrocarbons the primary determinant of petroleum toxicity to aquatic organisms?

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X98001271

Abstract: Aromatic components of oil, particularly polycyclic aromatic hydrocarbons (PAHs), are generally assumed to be the toxic fraction of spilled petroleum. We evaluated this assumption by analyzing the chemistry and toxicity of water accommodated fractions (WAFs) prepared from three environmentally weathered middle distillate oils differing in aromatic content. Oil toxicity was determined in short-term growth and survival tests with the mysid shrimp, Mysidopsis bahia. Median lethal concentrations (LC50s) ranged from 0.9 to 1.5 mg l(-1) total petroleum hydrocarbons (TPH), and growth-inhibiting concentrations (EC20s) ranged from 0.13 to 1.1 mg l(-1) TPH, Toxicity of the three oils expressed as mu g l(-1) Sigma PAH (sum of 40 PAH analytes; parent and alkyl homologues) ranged from 2.2 to 9.2 mu g l(-1) (LC50s) and from 0.32 to 5.7 mu g l(-1) (EC20s). The test oil with the lowest aromatic content, expressed as either mu g l(-1) PAH or mu g l(-1) naphthalenes in WAF had the greatest toxicity. The test oil WAF with the lowest total PAH concentration also had the lowest concentrations of single PAH analytes measured at concentrations greater than the detection limit. The results of this study demonstrated that low aromatic content oil can be highly toxic and that PAHs were not the major determinant of the toxicity of the three weathered middle distillate oils. (C) 1999 Elsevier Science B.V. All rights reserved.

RefID: 50

Author: Batterton, J.C., Winters, K. and Van Baalen, C.

Year: 1978

Title: Sensitivity of three microalgae to crude oils and fuel oils

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/0141113678900119

Abstract: Four crude oils and five fuel oils have been tested for toxicity with three microalgae—a blue-green, a green and a diatom. The oils were absorbed on filter paper pads and the pads submerged in the growth medium. The crude oils were less inhibitory than equal amounts of fuel oils. Despite initial growth lags, the crude oils allowed growth at 30 µl/20 ml of culture medium (105 cells/ml) while fuel oils were lethal at 10 µl/20 ml. The toxicity patterns of two of the whole fuel oils were different from that seen with their water soluble fractions (WSF); for example, the Baton Rouge fuel oil sample was very toxic to growth of the three test organisms whereas its WSF was relatively innocuous. Photosynthesis of a sensitive organism Chlorella autotrophica, strain 580 (107 cells/ml), was only temporarily depressed by the crude oils (30 µl/20 ml). Four of the fuel oils inhibited photosynthesis, O2 output decreasing to zero without recovery. When the fuel oils were heated in a stream of helium they were detoxified. Chemical analyses of two of the toxic fuel oils before and after heating were compared with analyses of the Montana sample, a largely non-toxic fuel oil, in an effort to determine what types of compounds might be involved. Classes of aromatic compounds which were not accountable for the toxicity observed here include naphthalene, methylnaphthalenes, dibenzothiophenes, phenanthrenes and compounds with volatilities greater than methylnaphthalenes. Paraffinic and asphaltic fractions of fuel oil were also non-toxic. The accumulated chemical data suggest that the toxicity of whole fuel oils is due to the less water soluble types of compounds in the higher boiling aromatic fraction.

RefID: 51

Author: Bechmann, R.K., Larsen, B.K., Taban, I.C., Hellgren, L.I., Moller, P. and Sanni, S.

Year: 2010

Title: Chronic exposure of adults and embryos of Pandalus borealis to oil causes PAH accumulation, initiation of biomarker responses and an increase in larval mortality

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X10003164

Abstract: Adult shrimps (Pandalus borealis) and their embryos were exposed to an oil-water dispersion (OWD) at concentrations of 0.015, 0.06 and 0.25 mg/L using a continuous flow system. Lysosomal membrane stability was analysed in haemocytes using the neutral red retention assay and an alkaline unwinding assay was used to measure DNA damage in hepatopancreas tissue. Exposure to oil induced concentration and time dependent biomarker responses in adult shrimps together with the accumulation of PAH in their tissues. Oil exposure of shrimp embryos caused increased mortality in the resultant larvae, even if the larvae were kept in clean water after hatching. There were minor differences observed in larval stage development times in the first part of the experiments. The fatty acid composition of embryos exposed to oil was different to that of non-exposed larvae. PAH tissue concentration and biomarker responses correlated to the reduced survival of the shrimp larvae. (C) 2010 Published by Elsevier Ltd.

RefID: 52

Author: Beiras, R. and Saco-Alvarez, L.

Year: 2006

Title: Toxicity of seawater and sand affected by the Prestige fuel-oil spill using bivalve and sea urchin embryogenesis bioassays

Journal: Water Air and Soil Pollution

Hyperlink: http://download.springer.com/static/pdf/715/art%3A10.1007%2Fs11270-006-9166-

2.pdf?auth66=1422987620_fa5949b326a990391c65ba1f3ccefa1e&ext=.pdf

Abstract: An evaluation of the toxicity of seawater and sand sampled from an area of the Galician coast (NW Iberian Peninsula), highly impacted by the Prestige fuel-oil spill, was attempted by using marine invertebrate embryogenesis bioassays with bivalves and sea urchins. Water samples were frozen and toxicity testing was delayed until the reproductive season of the sea urchins. Sand samples were elutriated and tested within 13 d from sampling, using bivalves from commercial stocks. Sand elutriates were non toxic for embryos despite visual presence of small tar balls. In contrast, seawater from the most impacted site was highly toxic during the first days after the spill, with complete inhibition of embryogenesis even after 4-fold dilution. In a lower degree toxicity persisted for two months in light-exposed coastal water. These findings stress the impact to water column organisms of the less conspicuous and frequently overlooked water-accommodated fraction, rather than the more visible oil slick.

RefID: 53

Author: Bejarano, A.C. and Barron, M.G.

Year: 2014

Title: Development and Practical Application of Petroleum and Dispersant Interspecies Correlation Models for Aquatic Species

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es500649v

Abstract: Assessing the acute toxicity of oil has generally relied on existing toxicological data for a relatively few standard test species, which has limited the ability to estimate the impacts of spilled oil on aquatic communities. Interspecies correlation estimation (ICE) models were developed for petroleum and dispersant products to facilitate the prediction of toxicity values to a broader range of species and to better understand taxonomic differences in species sensitivity. ICE models are log linear regressions that can be used to estimate toxicity to a diversity of taxa based on the known toxicity value for a surrogate tested species. ICE models have only previously been developed for nonpetroleum chemicals. Petroleum and dispersant ICE models were statistically significant for 93 and 16 unique surrogate-predicted species pairs, respectively. These models had adjusted coefficient of determinations (adj-R-2), square errors (MSE) and positive slope ranging from 0.29 to 0.99, 0.0002 to 0.311, and 0.187 to 2.665, respectively. Based on model cross-validation, predicted values for most ICE models (>90%) were within 5-fold of the measured values, with no influence of taxonomic relatedness on prediction accuracy. A comparison between hazard concentrations (HC) derived from empirical and ICE-based species sensitivity distributions (SSDs) showed that HC values were within the same order of magnitude of each other. These results show that ICE-based SSDs provide a statistically valid approach to estimating toxicity to a range of petroleum and dispersant products with applicability to oil spill assessment.

RefID: 54

Author: Bejarano, A.C., Chandler, G.T., He, L., Cary, T.L. and Ferry, J.L.

Year: 2006

Title: Risk assessment of the National Institute of Standards and Technology petroleum crude oil standard water accommodated fraction: Further application of a copepod-based, full life-cycle bioassay

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/05-365R.1/full

Abstract: The U.S. National Institute of Standards and Technology (NIST) petroleum crude oil was used to generate NIST water-accommodated hydrocarbon fractions (WAFs) for standardized assessment of crude oil effects on the copepod Amphiascus tenuiremis. Effects were assessed using a 96-well microplate, full life-cycle test. Briefly, nauplii (age, 24 h) were reared individually to adults (n >= 120 nauplii/treatment) in microplate wells containing 200 mu l of treatment solution (seawater control [0%] or 10, 30, 50, or 100% NIST-WAF). Nauplii were monitored through development to adulthood, and mature virgin male:female pairs mated in wells containing original treatments (< 30 d). A second bioassay using

0, 10, 30, and 50% WAFs (n >= 60 nauplii/treatment) was conducted to assess the effects of ultraviolet (UV) light on naupliar endpoints (< 16 d). In the first experiment, nauplius-to-copepodite survival in exposures to 100% WAF was 27% +/- 6% lower than in controls (92% +/- 1%), but copepodite-to-adult survival was greater than 90% across all treatments. Analysis of development curves showed that nauplii in the 10% WAF developed into copepodites 25% faster, whereas nauplii in the 50 and 100% WAFs developed 17% slower, than controls. Copepodite development into male and female copepods was significantly delayed (2 and 4 d, respectively) in the 100% WAF compared to controls. Although none of the WAF exposures had significant effects on fertilization success or total viable production (p > 0.05), embryo hatching in the 100% WAF was significantly less (70.0% +/- 21.2%) than that in controls (87.0% +/- 19.4%). Results from the UV bioassay showed that relatively short exposures (< 14 d) to 30 and 50% WAFs in the presence of UV light caused negative effects on copepod survival and development. Naupliar-stage survival and developmental endpoints were the most sensitive indicators of exposure to the NIST crude oil WAF.

RefID: 55

Author: Bejarano, A.C., Levine, E. and Mearns, A.J.

Year: 2013

Title: Effectiveness and potential ecological effects of offshore surface dispersant use during the Deepwater Horizon oil spill: a retrospective analysis of monitoring data

Journal: Environmental Monitoring and Assessment

Hyperlink: http://link.springer.com/article/10.1007/s10661-013-3332-y

Abstract: The Special Monitoring of Applied Response Technologies (SMART) program was used during the Deepwater Horizon oil spill as a strategy to monitor the effectiveness of sea surface dispersant use. Although SMART was implemented during aerial and vessel dispersant applications, this analysis centers on the effort of a special dispersant missions onboard the M/V International Peace, which evaluated the effectiveness of surface dispersant applications by vessel only. Water samples (n = 120) were collected from background sites, and under naturally and chemically dispersed oil slicks, and were analyzed for polycyclic aromatic hydrocarbons (TPAHs), total petroleum hydrocarbons (TPH), and a chemical marker of CorexitA (R) (dipropylene glycol n-butyl ether, DPnB). Water chemistry results were analyzed relative to SMART field assessments of dispersant effectiveness ("not effective," "effective," and "very effective"), based on in situ fluorometry. Chemistry data were also used to indirectly determine if the use of dispersants increased the risk of acute effects to water column biota, by comparison to toxicity benchmarks. TPAH and TPH concentrations in background, and naturally and chemically dispersed samples were extremely variable, and differences were not statistically detected across sample types. Ratios of TPAH and TPH between chemically and naturally dispersed samples provided a quantitative measure of dispersant effectiveness over natural oil dispersion alone, and were in reasonable agreement with SMART field assessments of dispersant effectiveness. Samples from "effective" and "very effective" dispersant applications had ratios of TPAH and TPH up to 35 and 64, respectively. In two samples from an "effective" dispersant application, TPHs and TPAHs exceeded acute benchmarks (0.81 mg/L and 8 mu g/L, respectively), while none exceeded DPnB's chronic value (1,000 mu g/L). Although the primary goal of the SMART program is to provide near real-time effectiveness data to the response, and not to address concerns regarding acute biological effects, the analyses presented here demonstrate that SMART can generate information of value to a larger scientific audience. A series of recommendations for future SMART planning are also provided.

RefID: 56

Author: Bellas, J., Saco-Álvarez, L., Nieto, Ó., Bayona, J.M., Albaigés, J. and Beiras, R.

Year: 2013

Title: Evaluation of artificially-weathered standard fuel oil toxicity by marine invertebrate embryogenesis bioassays

Journal: Chemosphere

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0045653512011411

Abstract: Weathering of petroleum spilled in the marine environment may not only change its physical and chemical properties but also its effects on the marine ecosystem. The objective of this study was to evaluate the toxicity of the water-accommodated fraction (WAF) obtained from a standard fuel oil following an environmentally realistic simulated weathering process for a period of 80 d. Experimental flasks with 40 g L-1 of fuel oil were incubated at 18 degrees C with a 14 h light:10 h dark photoperiod and a photosynthetically active radiation (PAR) intensity of 70 mu E m(-2) s(-1). Samples were taken at four weathering periods: 24 h, 7, 21 and 80 d. WAF toxicity was tested using the sea urchin (Paracentrotus lividus) and mussel (Mytilus galloprovincialis) embryo-larval bioassays and the aromatic hydrocarbons levels (AH) in the WAF were measured by gas chromatography/mass spectrometry. In contrast with the classic assumption of toxicity decrease with oil weathering, the present study shows a progressive increase in WAF toxicity with weathering, being the EC50 after 80 d eightfold lower than the EC50 at day 1, whereas AH concentration slightly decreased. In the long term, inoculation of WAF with bacteria from a hydrocarbon chronicallypolluted harbor slightly reduced toxicity. The differences in toxicity between fresh and weathered fuels could not be explained on the basis of the total AH content and the formation of oxidized derivatives is suggested to explain this toxicity increase. (C) 2012 Elsevier Ltd. All rights reserved.

RefID: 57

Author: Belore, R.

Year: 2010

Title: Technical Data Report-Properties and Fate of Hydrocarbons Associated with Hypothetical Spills in the Confined Channel Assessment Area

Journal: Enbridge Northern Gateway Project. SL Ross Environmental Research Ltd.

Hyperlink: http://www.northerngateway.ca/assets/pdf/tdr/Risk Technical Data Reports/Properties and Fate from Spills atCCAA_TDR.pdf

Abstract:

RefID: 58

Author: Ben-David, M., Blundell, G.M. and Blake, J.E.

Year: 2002

Title: Post-release survival of river otters: Effects of exposure to crude oil and captivity

Journal: Journal of Wildlife Management

Hyperlink: http://www.jstor.org/stable/3802954?origin=crossref&seq=1

Abstract: Few data exist on post-release survival of rehabilitated oiled wildlife, fueling the controversy surrounding wildlife rehabilitation efforts following oil spills. In 1998, we initiated a captive study to assess the effects of exposure to crude oil on physiological and behavioral processes in coastal river otters (Lontra canadensis). This study provided the opportunity to explore the effects of oiling and rehabilitation separately from those of captivity by comparing post-release survival rates of control and oiled river otters held in captivity with those of wild free-ranging otters. Fifteen wild-caught male river otters were assigned to 3 groups, of which 2 were given weathered crude oil in food (i.e., control, low dose, high dose) under controlled conditions at the Alaska Sealife Center. At the end of the rehabilitation period, animals were surgically implanted with radiotransmitters and released at the original site of capture or at an adjacent site in Prince William Sound, Alaska, USA. Concurrently, survival of 55 coastal river otters radiotagged in the wild was monitored in the same geographical area. Our results indicated that the captive, newly released animals (i.e., experimental otters) had a significantly lower survival rate than wild animals. We found no effect from exposure to hydrocarbons once rehabilitation was accomplished, but noted that lower levels of hemoglobin (a likely condition of rehabilitated oiled wildlife) were negatively correlated with survival and likely resulted in death from starvation. Therefore, rehabilitation may be a viable option for animals that have the potential for full recovery. We detected no relationship between location of release or estimated age of the experimental animals and their subsequent survival, although these results may be an artifact of small sample sizes. We recommend that future studies evaluate the effects of the length of captivity on post-release survival to produce additional guidelines for release. Information on the potential for full recovery and the length of the captive period required for achieving this rehabilitation will provide professionals with tools necessary for deciding whether to rehabilitate or euthanize individual animals.

RefID: 59

Author: Ben-David, M., Bowyer, R.T. and Duffy, L.K.

Year: 1999

Title: Responses of river otters to oil contamination: a controlled study of biological stress markers

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/48760021.pdf

Abstract: In spring '97 VHSV prevalence was significantly greater in fish from PWS (15%) than from Sitka (0.8%), but it was higher than in any previous year since 1993. A high viral prevalence in PWS in 1998 (15%) was associated with a population decline in the spring of 1999. The prevalence of Ichthyophonus continued to decrease within the population as a whole due to recruitment of younger fish with lower rates of infection. The prevalence of Ichthyophonus in the '88 year-class remained constant at 26-30% over four years. Studies in PWS demonstrated that closed pounds play a role in transmission of VHSV to susceptible fish, resulting in the rapid spread of virus and frequently causing significant mortality within the pens. Studies on Ichthyophonus hoferi demonstrated that the organism is a potential serious pathogen of herring but no evidence for its role in the herring declines in PWS could be found. Likewise, no evidence for oil-related increased susceptibility to VHSV was found in either wild or lab-reared herring. A natural immunity developed in fish at 2-years-old, about the time of sexual maturity, and fish of all ages developed an acquired immunity following infection and recovery from VHS.

RefID: 60

Author: Ben-David, M., Duffy, L.K. and Bowyer, R.T.

Year: 2001

Title: Biomarker responses in river otters experimentally exposed to oil contamination

Journal: Journal of Wildlife Diseases

Hyperlink: http://www.jwildlifedis.org/doi/abs/10.7589/0090-3558-37.3.489

Abstract: Investigations in Prince William Sound (Alaska, USA) following the Exxon Valdez oil spill (EVOS) revealed that river otters (Lontra canadensis) on oiled shores had lower body mass and elevated values of biomarkers, than did otters living on nonoiled shores. In addition, otters from oiled areas selected different habitats, had larger home ranges, and less diverse diets than animals living in nonoiled areas. These differences between river otters from oiled shores and those from nonoiled areas strongly suggested that oil contamination had an effect on physiological and behavioral responses of otters. In this study, we explored the effects of crude oil contamination on river otters experimentally. We hypothesized that exposure to oil would result in elevated values of biomarkers, indicating induced physiological stress. Fifteen wild-caught male river otters were exposed to two levels of weathered crude oil (i.e., control, 5 ppm/day/kg body mass, and 50 ppm/day/kg body mass) under controlled conditions in captivity at the Alaska Sealife Center in Seward (Alaska, USA). Responses of captive river otters to oil ingestion provided mixed results in relation to our hypotheses. Although hemoglobin (Hb, and associated red blood cells) and white blood cells, and possibly interleukin-6 immunoreactive, responded in the expected manner, other parameters did not. Aspartate aminotransferase, alanine aminotransferase, and haptoglobin (Hp), did not increase in response to oiling or decreased during rehabilitation. Conversely, principle-component analysis identified values of alkaline phosphatase as responding to oil ingestion in river otters. Our results suggested that opposing processes were concurring in the oiled otters. Elevated production of Hp in response to tissue damage by hydrocarbons likely occurred at the same time with increased removal of Hp-Hb complex from the serum, producing an undetermined pattern in the secretion of Hp. Thus, the use of individual biomarkers as indicators of exposure to pollutants may lead to erroneous conclusions because interactions in vivo can be complicated and act in opposite directions. Additionally, the biomarkers used in investigating effects of oiling on live animals usually are related to the heme molecule. Because of the opposing processes that may occur within an animal, data from a suite of heme-related biomarkers may produce results that are difficult to interpret. Therefore, we advocate the exploration and development of other biomarkers that will be independent from the heme cycle and provide additional information to the effect of oiling on live mammals.

RefID: 61

Author: Ben-David, M., Kondratyuk, T., Woodin, B.R., Snyder, P.W. and Stegeman, J.J.

Year: 2001

Title: Induction of cytochrome P450 1A1 expression in captive river otters fed Prudhoe Bay crude oil: evaluation by immunohistochemistry and quantitative RT-PCR

Journal: Biomarkers

Hyperlink: http://informahealthcare.com/doi/abs/10.1080/13547500010014513

Abstract: Numerous studies have explored the relationships between exposure to a variety of environmental contaminants, such as polycyclic aromatic hydrocarbons, and induction of cytochrome P450 1A (CYP1A) in different vertebrates. Few controlled studies, however, simulated chronic long-term exposure with repeated non-lethal sampling of the same individuals, which should better represent repeated exposure incidents in animals inhabiting polluted areas. In this study, we investigated the effects of chronic exposure to crude oil on levels of CYP1A1 in endothelial cells of skin biopsies and peripheral mononuclear blood cells in captive river otters (Lontra canadensis) using repeated sampling of the same individuals. We hypothesized that ingestion of oil would result in an increase in levels of CYP1A1 in both targets, and predicted that the relationship between prolonged exposure and expression of CYP1A1 would reach a plateau indicative of continuous detoxification of hydrocarbons. Fifteen wild-caught male otters were acclimated to captivity, and then fed diets containing no oil (control) or diets containing weathered crude oil at 5 mg day(-1) kg(-1) body weight (low-dose) and 50 mg day(-1) kg(-1) body weight (high-dose), at the Alaska Sealife Center in Seward, Alaska, USA. Expression of CYP1A1 was assessed with immunohistochemical analysis of CYP1A1 protein in skin biopsies and by quantitative RT-PCR analysis of CYP1A1 mRNA in mononuclear blood cells. Both assays revealed a decrease between capture and the transfer to captivity, indicating that the enclosure at the Alaska Sealife Center, and the food we offered to the otters were free of potential inducers of CYP1A1. During the exposure period, increases in CYP1A1 expression were registered by both techniques, followed by a decline in CYP1A1 after oil administration ended. Levels of endothelial CYP1A1 in the high-dose group were comparable to those recorded for wild river otters in PWS in 1996 and 1997. Levels of CPY1A1 mRNA in mononuclear blood cells, however, were well below levels recorded for river otters in Prince William Sound, and no correlation was detected between values obtained from the two methods. Thus, our results from this longitudinal study with repeated sampling of the same individuals provide support for the use of cytochrome P450 1A1 as a biomarker for hydrocarbon exposure. Nonetheless, our results also suggest that the induction process of CYP1A1 may be complicated and interacting with other processes in vivo. Such interactions may obscure our ability to describe specific, quantitative, predictable, dose-response relationships between exposure to hydrocarbons and induction of CYP1A1, which are required of reliable biomarkers. Evaluations of such interactions based on theoretical physiological models in live-animals merit further investigation.

RefID: 62

Author: Bentivegna, C.S., Cooper, K.R., Olson, G., Pena, E.A., Milleman, D.R. and Portier, R.J.

Year: 2015

Title: Chemical and histological comparisons between Brevoortia sp. (menhaden) collected in fall 2010 from Barataria Bay, LA and Delaware Bay, NJ following the DeepWater Horizon (DWH) oil spill

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0141113615300398

Abstract: Body burdens of PAHs were compared to histological effects in menhaden (Family: Clupeidae, Genus: Brevoortia) collected in fall 2010 from Barataria Bay, LA (BBLA) and Delaware Bay, NJ (DBNJ). Barataria Bay was heavily oiled during the DeepWater Horizon (DWH) oil spill, while Delaware Bay although urbanized had no reported recent oil spills. GCMS analyses of pre-spill 2009, BBLA and DBNJ fish found predominantly C2/C3 phenanthrene (1.28–6.52 ng/mg). However, BBLA also contained five higher molecular weight PAHs (0.06–0.34 ng/mg DW). Fluorescent aromatic compound spectroscopy (FACS) of gastrointestinal (GI) tract tissue showed statistically higher levels of hydroxypyrene-like PAHs in DBNJ than BBLA fish. Histopathologic lesions were more prevalent in BBLA than DBNJ fish. The lesion prevalence (gill, trunk kidney, epidermis, stomach) in the BBLA menhaden were significantly higher and more severe than observed in the DBNJ menhaden. Reversible lesions included gill lamellar hyperplasia, adhesions, edema, and epidermal hyperplasia. The increased pigmented macrophage centers were indicative of activated macrophages responding to connective tissue damage or other antigens. The liver hepatic necrosis and renal tissue mineralization may well have undergone repair, but damage to the kidney nephrons and hepatic/biliary regions of the liver would be slower to resolve and apparently remained after elimination of PAHs. Therefore, a direct cause and effect between DWH oil spill and increased lesion prevalence in BBLA menhaden could not be established.

RefID: 63

Author: Bickham, J.W., Mazet, J.A., Blake, J., Smolen, M.J., Lou, Y.G. and Ballachey, B.E.

Year: 1998

Title: Flow cytometric determination of genotoxic effects of exposure to petroleum in mink and sea otters

Journal: Ecotoxicology

Hyperlink: http://link.springer.com/article/10.1023%2FA%3A1008930626834

Abstract: Three experiments were conducted to investigate the genotoxic effects of crude oil on mink and sea otters, In the first experiment, the effects on mink of chronic exposure to weathered Prudhoe Bay crude oil were studied, Female mink were fed a diet that included weathered crude oil for a period of 3 weeks prior to mating, during pregnancy and until weaning. Kits were exposed through lactation and by diet after weaning until 4 months of age. Kidney and liver tissues of the kits were examined using flow cytometry (FCM) and it was found that the genome size was increased in kidney samples from the experimental group compared to the control group. This effect was probably due to some type of DNA amplification and it could have been inherited from the exposed mothers or have been a somatic response to oil exposure in the pups, No evidence of clastogenic effects, as measured by the coefficient of variation (CV) of the G(1) peak, was found in kidney or liver tissue. In the second experiment, yearling female mink were exposed either by diet or externally to crude oil or bunker C fuel oil. Evidence for clastogenic damage was found in spleen tissue for the exposure groups, but not in kidney tissue. No evidence of increased genome size was observed. In the third experiment, blood was obtained from wild-caught sea otters in Prince William Sound. The sea otters represented two populations: one from western Prince William Sound that was potentially exposed to oil from the Exxon Valdez oil spill and a reference population from eastern Prince William Sound that did not receive oil from the spill. The spill had occurred 1.5 years prior to obtaining the blood samples. Although the mean CVs did not differ between the populations, the exposed population had a significantly higher variance of CV measurements and five out of 15 animals from the exposed population had CVs higher than the 95% confidence limits of the reference population, It is concluded that FCM is a sensitive indicator of the clastogenic effects of oil exposure and that haematopoietic tissues and blood are best for detecting clastogenic damage. Moreover, the observed differences in the genome size of the kidney cells mere possibly heritable effects, but this needs further investigation. Lastly, sea otters exposed to spilled oil 1.5 years earlier showed evidence of clastogenic damage in one-third of the individuals sampled.

RefID: 64

Author: Bidwell, J.R., Cherry, D.S. and Merski, A.T.

Year: 2003

Title: Toxicity evaluation of a commercial bioremediation agent mixed with crude oil

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620220111/full

Abstract: The toxicity and efficacy of a bacteria-based commercial bioremediation agent (CBA) was assessed through bioassays with juvenile inland silverside minnows, Menidia beryllina, and flask studies of oil degradation. Addition of the CBA to weathered Alaska, USA North Slope crude oil (ANS-521) prior to testing increased toxicity of the water-soluble fraction (WSF) of the oil in both chronic (growth) and acute (mortality) toxicity tests. Time-course toxicity assessment of the water-soluble fraction of the CBA/oil combination indicated increases in effect after 7 to 14 d of mixing that coincided with elevated concentrations of both alkanes and aromatics in the WSF. Under controlled laboratory conditions, the CBA significantly enhanced degradation of the oil compared with a treatment with nutrients alone. The alkane fraction was degraded by nearly 100% over a 42-d period while the aromatic fraction was decreased by 70%. While toxicity testing is not currently required to list bioremediation agents on the product schedule of the National Oil and Hazardous Substances Pollution Contingency Plan, the potential interaction between bioremediation agents and oil should be further investigated and listing requirements reassessed as necessary. Recommendations for future investigations of this issue include characterization of temporal trends in toxicity of CBA and oil mixtures, use of multiple test methods (battery testing) when evaluating toxicity, comparative evaluations of indigenous versus product-derived microorganisms in efficacy studies, and the use of a comparable oil between studies to facilitate comparison of efficacy and toxicity data for different products.

RefID: 65

Author: Bierkens, J. and Geerts, L.

Year: 2014

Title: Environmental hazard and risk characterisation of petroleum substances: A guided "walking tour" of petroleum hydrocarbons

Journal: Environment International

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0160412014000427

Abstract: Petroleum substances are used in large quantities, primarily as fuels. They are complex mixtures whose major constituents are hydrocarbons derived from crude oil by distillation and fractionation. Determining the complete molecular composition of petroleum and its refined products is not feasible with current analytical techniques because of the huge number of molecular components. This complex nature of petroleum products, with their varied number of constituents, all of them exhibiting different fate and effect characteristics, merits a dedicated hazard and risk assessment approach. From a regulatory perspective they pose a great challenge in a number of REACH processes, in particular in the context of dossier and substance evaluation but also for priority setting activities. In order to facilitate the performance of hazard and risk assessment for petroleum substances the European oil company association, CONCAWE, has developed the PETROTOX and PETRORISK spreadsheet models. Since the exact composition of many petroleum products is not known, an underlying assumption of the PETROTOX and PETRORISK tools is that the behaviour and fate of a total petroleum substance can be simulated based on the physical-chemical properties of representative structures mapped to hydrocarbon blocks (HBs) and on the relative share of each HB in the total mass of the product. To assess how differing chemical compositions affect the simulated chemical fate and toxicity of hydrocarbon mixtures, a series of model simulations were run using an artificial petroleum substance, containing 386 (PETROTOX) or 160 (PETRORISK) HBs belonging to different chemical classes and molecular weight ranges, but with equal mass assigned to each of them. To this artificial petroleum substance a guided series of subsequent modifications in mass allocation to a delineated number of HBs belonging to different chemical classes and carbon ranges was performed, in what we perceived as a guided "walking tour" through the chemical space of petroleum substances. We show that the PETROTOX and PETRORISK predictions reflect changes in mass distribution introduced to selected HBs by affecting hazard and risk estimates in correspondence with what is expected based on physical-chemical properties of individual constituents in the corresponding HBs. (C) 2014 Elsevier Ltd. All rights

RefID: 66

Author: Bilbao, E., Raingeard, D., de Cerio, O.D., Ortiz-Zarragoitia, M., Ruiz, P., Izagirre, U., Orbea, A., Marigomez, I., Cajaraville, M.P. and Cancio, I.

Year: 2010

Title: Effects of exposure to Prestige-like heavy fuel oil and to perfluorooctane sulfonate on conventional biomarkers and target gene transcription in the thicklip grey mullet Chelon labrosus

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X10000809

Abstract: Thicklip grey mullets Chelon labrosus inhabit coastal and estuarine areas where they can be chronically exposed to commonly released pollutants such as polycyclic aromatic hydrocarbons (PAHs) and perfluorinated compounds. These pollutants can also originate from accidental spills, such as the Prestige oil spill in 2002, which resulted in the release of a heavy fuel oil that affected coastal ecosystems in the Bay of Biscay. Peroxisome proliferation (PP), induced biotransformation metabolism, immunosuppression and endocrine disruption are some of the possible biological effects caused by such chemicals. With the aim of studying the effects of organic toxic chemicals on such biological processes at the transcriptional and at the cell/tissue level, juvenile mullets were exposed to the typical mammalian peroxisome proliferator perfluorooctane sulfonate (PFOS), and to fresh (F) and weathered (WF) Prestige-like heavy fuel oil for 2 and 16 days. First, fragments of genes relevant to biotransformation, immune/inflammatory and endocrine disruption processes were cloned using degenerate primers. Fuel oil elicited a significant PP response as proved by the transcriptional upregulation of palmitoyl-CoA oxidase (aox1), peroxisome proliferator activated receptor alpha (ppar alpha) and retinoic X receptor, by the AOX1 activity induction and by the increased peroxisomal volume density. PFOS only elicited a significant induction of AOX1 activity at day 2 and of PPAR alpha mRNA expression at day 16. All treatments significantly increased catalase mRNA expression at day 16 in liver and at day 2 in gill. Cyp1a transcription (liver and gill) and EROD activity were induced in fuel oil treated organisms. In the case of phase II metabolism only hepatic glutathione S-transferase mRNA was overexpressed in mullets exposed to WF for 16 days. Functionally, this response was reflected in a significant accumulation of bile PAH metabolites. WF treated fish accumulated mainly high molecular weight metabolites while F exposure resulted in accumulation of mainly low molecular ones. Fuel oil significantly regulated immune response related complement component 0 and hepcidin transcription followed by a significant regulation of inflammatory response related apolipoprotein-M and fatty acid binding protein mRNAs at day 16. These responses were accompanied by a significant hepatic inflammatory response with lymphocyte accumulations (IRLA) and accumulation of melanomacrophage centers (MMC). PFOS did not elicit any transcriptional response in the studied biotransformation and immune related genes, although histologically significant effects were recorded in IRLA and MMC. A significant reduction of lysosomal membrane stability was observed in all exposed animals. No endocrine disruption effects were observed in liver while brain aromatase mRNA was overexpressed after all treatments at day 2 and estrogen receptor alpha was downregulated under WF exposure at day 16. These results show new molecular and cellular biomarkers of exposure to organic chemicals and demonstrate that in mullets PP could be regulated through molecular mechanisms similar to those in rodents, although the typical mammalian peroxisome proliferator PFOS and heavy fuel oil follow divergent mechanisms of action. (C) 2010 Elsevier B.V. All rights reserved.

RefID: 67

Author: Binark, N., Güven, K.C., Gezgin, T. and Ünlü, S.

Year: 2000

Title: Oil Pollution of Marine Algae

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs0012800083?LI=true

Abstract: Petroleum hydrocarbons are important pollutants of sea and marine organisms. The origin of hydrocarbons are either biogenic (endogenic) which are synthetised by marine organisms or exogenic due to oil pollution accumulated by marine organisms. The hydrocarbons found in algae were biogenic (Clarck and Blumer 1967;Youngblood et al.1971; Rossi et al. 1978; Youngblood and Blumer 1973) or exogenic (George 1961; Farrington and Tripp 1977; Miranov et al. 1981; Knutzen and Sortland 1982; Peckol et al. 1990). Some characteristics used to distinguish the origin of hydrocarbons in the marine ecosystem were the ratios of pristane (Pr)/phytane (Ph), C 17/Pr, C18/Ph and CPI (Carbon Preferences Index) values (Clarck and Finley 1974; Gearing et al. 1976; Farrington and Tripp 1977) and also the existence of alkenes and aromatic compounds.In this work oil pollution was investigated on the surface and inside of algae.

RefID: 68

Author: Birtwell, I.K. and McAllister, C.D.

Year: 2002

Title: Hydrocarbons and their effects on aquatic organisms in relation to offshore oil and gas exploration and oil well blowout scenarios in British Columbia, 1985

Journal: Canadian Technical Report of Fisheries and Aquatic Sciences

Hyperlink: http://waves-vagues.dfo-mpo.gc.ca/waves-vagues/search-recherche/display-afficher/261831

Abstract: NA

RefID: 69

Author: Birtwell, I.K., Fink, R., Brand, D., Alexander, R. and McAllister, C.D.

Year: 1999

Title: Survival of pink salmon (Oncorhynchus gorbuscha) fry to adulthood following a 10-day exposure to the aromatic hydrocarbon water-soluble fraction of crude oil and release to the Pacific Ocean

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f99-134

Abstract: Saltwater-acclimated, coded-wire tagged, and adipose fin clipped pink salmon (Oncorhynchus gorbuscha) fryw ere exposed for 10 days to seawater (control) or 25–54 µg·L–1 (low dose) or 178–349 µg·L–1 (high dose) of thew ater-soluble fraction (WSF) of North Slope crude oil. The WSF was composed primarily of monoaromatics and wasacutely lethal to the fry: 96-h LC50 ranged from 1 to 2.8 mg·L–1. After exposure the fry (30 000 per treatment) werer eleased into the Pacific Ocean to complete their life cycle. The experiment was replicated in 1990, 1991, and 1992.T here was no consistent significant dose-dependent effect of the 10-day exposure to the crude oil WSF on growth ofthe pink salmon prior to their release. Adult pink salmon from this experiment were captured in fisheries and alsorecovered from their natal Quinsam River, British Columbia. Pink salmon from each treatment group were recovered insimilar numbers. Exposure of populations of fry to the WSF of crude oil and release to the Pacfic Ocean did not result in a detectable effect on their survival to maturity. Fry from all treatment groups incurred typically high mortality following release, and there were no discernible effects on survival that were attributable to exposure to the WSF ofcrude oil.

RefID: 70

Author: Blajeski, A., Duffy, .LK. and Bowyer, R.T.

Year: 1996

Title: Differences in faecal profiles of porphyrins among river otters exposed to the Exxon Valdez oil spill

Journal: Biomarkers

Hyperlink: http://informahealthcare.com/doi/abs/10.3109/13547509609079366

Abstract:

RefID: 71

Author: Blum, D.J.W. and Speece, R.E.

Year: 1991

Title: A DATABASE OF CHEMICAL TOXICITY TO ENVIRONMENTAL Bacteria AND ITS USE IN INTERSPECIES COMPARISONS AND CORRELATIONS

Journal: Research Journal of the Water Pollution Control Federation

Hyperlink: http://www.jstor.org/stable/25043983

Abstract:

RefID: 72

Author: Bodkin, J.K., Mulcahy, D.M. and Lensink, C.J.

Year: 1996

Title: Age-specific reproduction in female sea otters (Enhydra lutris) from Southcentral Alaska: analysis of reproductive tracts

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/35755411.pdf

Abstract: We estimated age of sexual maturity and age-specific reproductive rates hy examining carcasses and reproductive tracts from 177 female sea otters (Enhydra lutris)Carcasses were recovered from southcentral Alaska, primarily western Prince WilliamSound, following the the Exon Valdez oil spill in 1989. Sexual maturity was first reachedat age two. The proportion of sexually mature animals increased from 30% at age two to100% at age five. Annual reproductive rates increased from 22% at age two to 78% ar agefive and remained relatively stable (7548%) through age 15. The sex ratio of 55 fetal seaotters was 18 male:37 female and significantly differed from parity. Females younger than eight tended to produce more female fetuses, while older mothers did not. Our estimates ofthe reproductive characteristics of female sea otters obtained by examination of reproductivetracts were similar to those in the literature based on in situ observations or markedi ndividuals.

RefID: 73

Author: Bodkin, J.L. and Udevitz, M.S.

Year: 1995

Title: An intersection model for estimating sea otter mortality from the Exxon Valdez oil spill along the Kenai Peninsula, Alaska

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33944234.pdf

Abstract: We developed an analytical model (intersection model) to estimate the exposure ofsea otters (Enhydra lutris), to oil from the Exon Valdez oil spill. We applied estimated and assumed exposure dependent mortality rates to the Kenai Peninsula sea otter population toprovide examples of the application of the model in estimating sea otter mortality. Thei ntersection model requires three distinct types of data: (1) distribution, abundance, andmovements of oil, (2) abundance and distribution of sea otters, and (3) sea otter mortalityr ates relative to oil exposure. Initial output of the model is an estimate of exposure of ottersto oil. Exposure is measured in amount and duration of oil near an otter's observed location (intersections). The model indicated potential exposure of approximately 1,211 sea otters. By applying mortality rates to exposed otters, acute loss estimates may be generated. Weprovide two examples of the model using different assumptions about the relation betweenexposure and mortality. Our examples were based on the observed survival of otters captured in Prince William Sound and treated at rehabilitation centers. Because of anapparent non-linear relation between the degree of oiling and survival of otters fromrehabilitation, output from our examples are likely biased. Improved acute loss estimatesf rom the model require a better understanding of the fate of otters exposed to oil

andremaining in the wild. The intersection model may have greater application in riskassessment than in damageassessment.

RefID: 74

Author: Bodkin, J.L. and Weltz, F.

Year: 1990

Title: EVALUATION OF SEA OTTER CAPTURE AFTER THE T-V EXXON VALDEZ OIL SPILL PRINCE WILLIAM SOUND ALASKA USA

Journal: U S Fish and Wildlife Service Biological Report

Hyperlink: https://openlibrary.org/books/OL24349175M/Sea_otter_symposium

Abstract:

RefID: 75

Author: Bodkin, J.L., Ballachey, B.E. and Esslinger, G.G.

Year: 2011

Title: Synthesis of nearshore recovery following the 1989 Exxon Valdez oil spill: trends in sea otter population abundance in Western Prince William Sound

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/C/759541793.pdf

Abstract: Sea otters in western Prince William Sound (WPWS) and elsewhere in the Gulf of Alaska suffered wide-spread mortality as a result of oiling following the 1989 T/V Exxon Valdez oil spill. Following the spill, extensive efforts by both public and private scientists have been directed toward identifying and understanding long term consequences of the spill and the process of recovery. We conducted annual aerial surveys of sea otter abundance from 1993-2009 (except for 2001 and 2006) in WPWS. We observed an increasing trend in population abundance at the scale of WPWS through 2000 at an average annual rate of 4%. However, at northern Knight Island where oiling was heaviest and sea otter mortality highest, no increase in abundance was evident by 2000. We continued to see significant increase in abundance at the scale of WPWS between 2001and 2009, with an average annual rate of increase from 1993-2009 of 2.6%. We estimated the 2009 population size of WPWS to be 3,959 (se = 653), nearly 2,000 more than the first post-spill estimate in 1993. Surveys since 2003 have also identified a significant increasing trend at the heavily oiled site in northern Knight Island, averaging about +25% annually and resulting in a 2009 estimated population size of 116 (se=19). Although the 2009 estimate for northern Knight Island remains about 30% less than the pre-spill estimate of 165, we interpret this trend as strong evidence of a trajectory toward recovery of spill-affected sea otter populations in WPWS.

RefID: 76

Author: Bodkin, J.L., Ballachey, B.E., Coletti, H.A., Esslinger, G.G., Kloecker, K.A., Rice, S.D., Reed, J.A. and Monson, D.H.

Year: 2012

Title: Long-term effects of the 'Exxon Valdez' oil spill: sea otter foraging in the intertidal as a pathway of exposure to lingering oil

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v447/p273-287/

Abstract: In this work oil pollution was investigated on the surface and inside of algae

RefID: 77

Author: Bodkin, J.L., Ballachey, B.E., Dean, T.A., Fukuyama, A.K., Jewett, S.C., McDonald, L., Monson, D.H., O'Clair, C.E. and VanBlaricom, G.R.

Year: 2002

Title: Sea otter population status and the process of recovery from the 1989 'Exxon Valdez' oil spill

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v241/p237-253/

Abstract: Sea otter Enhydra lutris populations were severely affected by the 1989 'Exxon Valdez' oil spill in western Prince William Sound, AK, and had not fully recovered by 2000. Here we present results of population surveys and incorporate findings from related studies to identify current population status and factors affecting recovery. Between 1993 and 2000, the number of sea otters in the spill-area of Prince William Sound increased by about 600 to nearly 2700. However, at Knight Island, where oil exposure and sea otter mortality in 1989 was most severe, no increase has been observed. Sea otter reproduction was not impaired, and the age and sex composition of captured otters are consistent with both intrinsic reproduction and immigration contributing to recovery. However, low resighting rates of marked otters at Knight Island compared to an unoiled reference area, and high proportions of young otters in beach cast carcasses through 1998, suggest that the lack of recovery was caused by relatively poor survival or emigration of potential recruits. Significantly higher levels of cytochrome P4501A (CYP1A), a biomarker of hydrocarbons, were found in sea otters at Knight Island from 1996 to 1998 compared to unoiled Montague Island, implicating oil effects in the lack of recovery at Knight Island. Delayed recovery does not appear to be directly related to food limitation. Although food availability was relatively low at both oiled and unoiled areas, we detected significant increases in sea otter abundance only at Montague Island, a finding inconsistent with food as a principal limiting factor. Persistent oil in habitats and prey provides a source of continued oil exposure and, combined with relatively low prey densities, suggests a potential interaction between oil and food. However, sea otters foraged more successfully at Knight Island and young females were in better condition than those at Montague Island. We conclude that progress toward recovery of sea otters in Prince William Sound is evident, but that in areas where initial oil effects were greatest, recovery may be constrained by residual spill effects, resulting from elevated mortality and emigration. It is evident that internal reproduction and immigration of juveniles has been the primary means of population recovery, as opposed to broad scale redistribution of adults from outside affected areas. The result is a recovery period protracted by long-term spill effects on survival and emigration and intrinsic limits to population growth.

RefID: 78

Author: Boehm, P.D., Mankiewicz, P.J., Hartung, R., Neff, J.M., Page, D.S., Gilfillan, E.S., O'Reilly, J.E. and Parker, K.R.

Year: 1996

Title: Characterization of mussel beds with residual oil and the risk to foraging wildlife 4 years after the Exxon Valdez oil spill

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620150806/abstract

Abstract: The grounding of the Exxon Valdez on March 24, 1989, released about 41 million L of crude oil into the waters of Prince William Sound, Alaska, USA, and oiled about 16% of the Prince William Sound shoreline to various degrees. Although winter storms, cleanups, and natural biodegradation have removed the majority of the oil on the shorelines, some residual oil still remains trapped in sediments immediately below mussel beds. This oil was protected from wave action by the dense covering of mussels. Field surveys found that mussels in such beds constituted less than 3% of the mussels available for foraging in two areas that had been extensively oiled in 1989. Levels of polycyclic aromatic hydrocarbons (PAHs) in these mussels were also measured. Mean PAH concentrations in mussel tissues ranged between 20 and 4,000 ng/g dry weight and in sediments between 20 and 26,000 ng/g dry weight. Assuming that the species considered most at risk (i.e., harlequin ducks, black oystercatchers, and sea otters) consumed the mussel proportion of their diets exclusively from such beds (at either the median or 95th percentile of mussel tissue PAH concentration), the estimated PAH dosage they would receive was one to three orders of magnitude below doses known to cause sublethal effects in surrogate species. Considering the low frequency of mussel beds with residual oil, the patchy distribution of remaining weathered oil residues, and the relatively low PAH concentrations in the mussels, the risk of quantifiable injury at the level of an individual bird or otter, or at the population level, is minimal. Furthermore, based on a review of the mussel PAH data in Prince William Sound, the risk to wildlife has been minimal since 1990, 1 year after the spill.

RefID: 79

Author: Boehm, P.D., Neff, J.M,. and Page, D.S.

Year: 2007

Title: Assessment of polycyclic aromatic hydrocarbon exposure in the waters of Prince William Sound after the Exxon Valdez oil spill: 1989-2005

Journal: Marine Pollution Bulletin

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/17239406

Abstract: Summary: The objectives of this paper are twofold: first, to provide a comprehensive synthesis of the magnitude and temporal trends of PAH concentrations in the waters of PWS since the spill and, second, to relate these data to indicators of exposure of and risk to fish from dissolved and dispersed PAH in waters of PWS. The synthesis of all reported TPAH concentrations measured in water samples and those estimated from caged and indigenous, intertidal mussels from Exxon and government studies provides an effective means to assess acute and long-term exposure of and ecological risk to offshore and nearshore water-column organisms. Measured TPAH concentrations in more than 2000 water samples and estimated water TPAH concentrations based on PAH concentrations in more than 2700 mussel samples were incorporated into this synthesis. Concentrations of PAH in the upper water column at scattered locations in the spill zone were elevated in the first few weeks after the spill to levels that probably were high enough to cause harm to some individual marine organisms; however, only nine (9) of the 1288 water samples taken along the spill path in PWS in 1989 contained more than 10 ppb TPAH, the State of Alaska's water-quality standard for total aromatic hydrocarbons. TPAH 352 Baseline / Marine Pollution Bulletin 54 (2007) 339–367concentrations in shallow water adjacent to oiled shorelines were elevated, but, by the time herring spawned along the shore several weeks after the spill, and when herring larvae and juvenile pink salmon were abundant in coastal waters 2 to 3 months after the spill, average concentrations in the water column were less than 0.5 ppb, lower than concentrations known to cause harm to sensitive early life stages of these species. Water column concentrations of TPAH resulting from the spill returned to background levels by 1990, ranging from 0.001 to 0.1 ppb TPAH. On a larger, population-level and ecologically significant scale, TPAH levels in the water column declined rapidly in the spill area and, after the first few weeks, were not high enough to cause population-level harm to even sensitive early life stages of marine organisms, including herring and salmon. TPAH concentrations measured in spill-zone water samples in 2005 do not indicate any detectable release into the water column of buried oil residues known to still exist at several locations in PWS. The findings from this synthesis are consistent with those from other spills and with other measures of exposure determined in other Exxon Valdez related studies.

RefID: 80

Author: Boehm, P.D., Neff, J.M. and Page, D.S.

Year: 2003

Title: Exposure to hydrocarbons 10 years after the Exxon Valdez oil spill: evidence from cytochrome P4501A expression and biliary FACs in nearshore demersal fishes

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0141113602002908

Abstract: Letter to the editor: refers to S0202

RefID: 81

Author: Boehm, P.D., Page, D.S., Brown, J.S., Neff, J.M. and Burns, W.A.

Year: 2004

Title: Polycyclic aromatic hydrocarbon levels in mussels from Prince William Sound, Alaska, USA, document the return to baseline conditions

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/03-514.1/abstract

Abstract: Bioavailable hydrocarbons in the Exxon Valdez oil spill zone in Prince William Sound (PWS; AK, USA) shorelines were at or near background levels in 2002, as indicated by low concentrations of polycyclic aromatic hydrocarbons (PAHs) in mussels (Mytilus trossulus) collected from sites throughout PWS. Total PAH (TPAH) minus parent naphthalene concentrations in mussels collected in 1998 to 2002 from sites oiled in 1989 were at or near reference-site values. Both oiled and reference sites included locations associated with past human and industrial activity (HA). Inclusion of the unoiled HA sites in the range of reference sites that define prespill conditions is consistent with federal regulations. For the period from 1998 to 2002, the geometric mean of TPAH concentrations for 218 mussel samples collected from 72 sites, including four HA sites that had been heavily oiled in 1989, is 54 ng/g dry weight (range, 2-1,190 ng/g). The maximum mussel TPAH concentrations are equivalent to a weathered-oil exposure dose to intertidal foragers that is one to three orders of magnitude less than the doses shown to cause sublethal effects in surrogate species. The geometric mean of TPAH concentrations for mussel samples from 28 locations not oiled in 1989 and unaffected by human use (NHA sites) is 28 ng/g (range, 3-355 ng/g), whereas the geometric mean of TPAH concentrations for mussel samples from 14 locations not oiled in 1989 and affected by human use (HA sites) is 106 ng/g (range, 2-12,056 ng/g). The range of data for the unoiled HA and NHA sites defines the background of bioavailable PAHs to mussels on western PWS shorelines that would have prevailed if the oil spill had not occurred. The low PAH concentrations in mussels from sites known to have subsurface oil residues demonstrates the low bioavailability of these spill remnants and, thus, are a low additional risk to foraging wildlife. The present study shows continuous exposure from four- to six-ring PAHs originating at HA sites in western PWS. At low concentrations, these PAHs are known to cause adverse biological effects. However, in the context of PWS, oiled and HA sites represent a small percentage (similar to0.1-0.2%) of the total PWS shoreline.

RefID: 82

Author: Boehm, P.D., Page, D.S., Brown, J.S., Neff, J.M., Bragg, J.R. and Atlas, R.M.

Year: 2008

Title: Distribution and Weathering of Crude Oil Residues on Shorelines 18 Years After the Exxon Valdez Spill

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es8022623

Abstract: In 2007, a systematic study was conducted to evaluate the form and location of residues of oil buried on Prince William Sound (PWS) shorelines, 18 years after the 1989 Exxon Valdez Oil Spill (EVOS). We took 678 sediment samples from 22 sites that were most heavily oiled in 1989 and known to contain the heaviest subsurface oil (SSO) deposits based on multiple studies conducted since 2001. An additional 66 samples were taken from two sites, both heavily oiled in 1989 and known to be active otter foraging sites. All samples were analyzed for total extractable hydrocarbons (TEH), and 25% were also analyzed for saturated and aromatic hydrocarbon weathering parameters. Over 90% of the samples from all sites contained light or no SSO at all. Of samples containing SSO, 81% showed total polycyclic aromatic hydrocarbon (TPAH) losses greater than 70%, relative to cargo oil, with most having >80% loss. Samples with SSO were observed in isolated patches sequestered by surface boulder and cobble armoring. Samples showing lowest TPAH loss correlated strongly with higher elevations in the intertidal zones. Of the 17 atypical, less-weathered samples having less than 70% loss of TPAH (>30% remaining), only two were found sequestered in the lower intertidal zone, both at a single site. Most of the EVOS oil in PWS has been eliminated due to natural weathering. Some isolated SSO residues remain because they are sequestered and only slowly affected by natural weathering processes that normally would bring about their rapid removal. Even where SSO patches remain, most are highly weathered, sporadically

distributed at a small number of sites, and widely separated from biologically productive lower intertidal zones where most foraging by wildlife occurs.

RefID: 83

Author: Boehm, P.D., Page, D.S., Gilfillan, E.S., Bence, A.E., Burns, W.A. and Mankiewicz, P.J.

Year: 1998

Title: Study of the fates and effects of the Exxon Valdez oil spill on benthic sediments in two bays in Prince William Sound, Alaska. 1. Study design, chemistry, and source fingerprinting

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es9705598

Abstract: This study was conducted to assess the subtidal effects of the Exxon Valdez oil spill in a large embayment in Prince William Sound, AK. A stratified random-sampling design was used to compare stations in an oiled bay, the Bay of Isles, with stations in Drier Bay, a bay that received little impact from the spill. The study included sediment chemistry, benthic ecology, and bioaccumulation elements. Only the results on chemistry of the oil in the bottom sediments are reported here. Analyses of sediment samples revealed four types of polycyclic aromatic hydrocarbons (PAH) in the two bays: (1) Alaska North Slope (ANS) crude oil attributable to the spill, (2) natural oil seep-derived background, (3) pyrogenic, and (4) diagenetic. The Bay of Isles subtidal sediments contained significantly higher levels of weathered ANS-PAH attributable to the spill than did Drier Bay. However, the levels of ANS-PAH in the Bay of Isles were generally lower than those of the petrogenic background PAH naturally present in the subtidal sediments of the sound. This natural petrogenic background PAH component increased in concentration with increasing depth zone (and increasing sediment clay content) for each bay. Drier Bay, a location of past cannery and mining activity, had significantly greater concentrations of pyrogenic PAH than did the Bay of Isles. All sediment PAH concentrations were well below the effects range-low (ER-L) sediment toxicity threshold value of 4000 ng/g for total PAH. The highest sediment total PAH concentration (1500 ng/g) occurred in Drier Bay, and the highest sediment ANS (spill)-PAH concentration (201 ng/g) occurred in the Bay of Isles. There is no evidence far large-scale offshore transport of Exxon Valdez crude to the subtidal sediments.

RefID: 84

Author: Boehm, P.D., Page, D.S., Gilfillan, E.S., Stubblefield, W.A. and Harner, E.J.

Year: 1995

Title: Shoreline Ecology Program for Prince William Sound, Alaska, Following the Exxon Valdez Oil Spill: Part II - Chemistry and Toxicology

Journal: Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters

Hyperlink: http://www.valdezsciences.com/dspArticle.cfm?catID=1&artID=1029&artSecID=1006

Abstract: Part two of a three-part series, this paper describes chemical and toxicological results of a comprehensive shoreline ecology program that was designed to assess recovery in Prince William Sound following the Exxon Valdez oil spill of March 24, 1989. The program is an application of the "sediment quality triad" approach, combining chemical, toxicological, and biological measurements. Other parts of the program are described in Part 1: Study Design and Methods (Page et al , this volume) and Part 3. Biology (Gilfillan et al., this volume). The study was designed so that results could be extrapolated to the entire spill zone in the sound and projected forward in time. It combined one-time sampling of 64 randomly chosen study sites representing four major habitats and four oiling levels (including unoiled reference sites), with periodic sampling at 12 subjectively chosen "fixed" sites. Sediment samples—or when conditions required, filter-wipes from rock surfaces—were collected in each of three intertidal zones and from subtidal stations up to 30-m deep. Oil removal was generally quite rapid: by 1991 the concentration of oil spilled from the Exxon Valdez had been dramatically reduced on the majority of shorelines by both natural processes and cleanup efforts. Moderate concentrations of petroleum - residues remain only in limited, localized areas: however, most of these residues are highly asphaltic, not readily bioavailable, and not toxic to marine life. Acute sediment toxicity from oil (as measured by standard toxicity tests) was virtually absent by 1990-'91, except at a small number of isolated locations. The petroleum residues had degraded below the threshold of acute toxic effects. Measurable polycyclic aromatic hydrocarbon (PAH) levels are, in general, well below those conservatively associated with adverse effects, and biological recovery has been considerably more rapid than the removal of the last chemical remnants. The remaining residues continue to degrade and are, in general, predicted to become indistinguishable from background hydrocarbon levels by 1993 or 1994. Localized residues of weathered oil will no doubt exist beyond 1994 at certain locations, but their environmental significance will be negligible compared with other stresses ongoing in the sound. Samples of nearshore subtidal sediments showed surprisingly low concentrations of oil residue, as an increment to the natural petrogenic hydrocarbon background. Sediment toxicity tests showed that they were essentially non-toxic. It appears that most of the oil leaving the shoreline was swept away and dissipated at sea. It is concluded that long-term ecological effects resulting from shoreline oiling or subtidal contamination are highly unlikely.

RefID: 85

Author: Boehm, P.D., Page, D.S., Neff, J.M. and Brown, J.S.

Year: 2011

Title: Are sea otters being exposed to subsurface intertidal oil residues from the Exxon Valdez oil spill?

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X10005151

Abstract: Twenty years after the Exxon Valdez oil spill, scattered patches of subsurface oil residues (SSOR) can still be found in intertidal sediments at a small number of shoreline locations in Prince William Sound, Alaska. Some scientists hypothesize that sea otters continue to be exposed to SSOR by direct contact when otters dig pits in search of clams. This hypothesis is examined through site-specific examinations where SSOR and otter-dug pits co-occur. Surveys documented the exact sediment characteristics and locations on the shore at the only three subdivisions where both SSOR and otter pits were found after 2000. Shoreline characteristics and tidal heights where SSOR have persisted are not suitable habitat for sea otters to dig pits during foraging. There is clear separation between areas containing SSOR and otter foraging pits. The evidence allows us to reject the hypothesis that sea otters encounter and are being exposed by direct contact to SSOR.

RefID: 86

Author: Boehm, P.D., Page, D.S., Neff, J.M. and Johnson, C.B.

Year: 2007

Title: Potential for sea otter exposure to remnants of buried oil from the exxon valdez oil spill

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es070829e

Abstract: A study was conducted in 2005 and 2006 to examine the hypothesis that sea otters (Enhydra lutris) continue to be exposed to residues of subsurface oil (SSO) while foraging on shorelines in the northern Knight Island (NKI) area of Prince William Sound, Alaska more than 17 years after the Exxon Valdez oil spill. Forty-three shoreline segments, whose oiling history has been documented by prior surveys, were surveyed. These included all shoreline segments reported by a 2003 NOAA random site survey to contain SSO residues in NKI. Sites were surveyed for the presence and location of otter foraging pits. Only one of 29 SSO sites surveyed was identified as an otter foraging site. Most buried SSO residues are confined to tide elevations above +0.8 m above mean lower low water (MLLW), above the range of intertidal clam habitat. More than 99% of documented intertidal otter pits at all sites surveyed are in the lower intertidal zone (-0.2 to +0.8 m above MLLW), the zone of highest clam abundance. The spatial separation of the otter pits from the locations of SSO residues, both with regard to tidal elevation and lateral separation on the study sites, coupled with the lack of evidence of intertidal otter foraging at SSO sites indicates a low likelihood of exposure of foraging otters to SSO on the shores of the NKI area.

RefID: 87

Author: Bookstaver, M., Bose, A. and Tripathi, A.

Year: 2015

Title: Interaction of Alcanivorax borkumensis with a Surfactant Decorated Oil–Water Interface

Journal: Langmuir

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/acs.langmuir.5b00688

Abstract: Alcanivorax borkumensis is a hydrocarbon degrading bacterium linked to oil degradation around oil spill sites. It is known to be a surface bacterium leading to substantial interaction with the oil–water interface. Because of its abundance in oil spill regions, it has great potential to be used actively in oil spill remediation. Dispersants are thought to be important in the creation of oil-in-water emulsions that are meant to aid in the biodegradation process by bacteria. Although it is likely that some sort of dispersant will be used again in the case of another oil spill, to date, no studies have shown the impact of dispersants on the bacteria population. Corexit 9500 was the main dispersant used during the Deepwater Horizon oil spill, but little is known about its effect on the bacteria community. We built an experimental platform to quantitatively measure the transient growth of Alcanivorax borkumensis at the interface of oil and water. To our knowledge, this is the first study of how A. borkumensis interacts with a surfactant decorated oil–water interface. We use COREXIT EC9500A, cetylytrimethylamonium bromide, dioctyl sulfosuccinate sodium salt, L-α-phosphatidylcholine, sodium dodecyl sulfate, and Tween 20 to investigate the impact of dispersants on Alcanivorax borkumensis. We assess the impact of these dispersants on the growth rate, lag time, and maximum concentration of Alcanivorax borkumensis. We show that the charge, structure, and surface activity of these surfactants greatly impact the growth ofA. borkumensis. Our results indicated that out of the surfactants tested only Tween 20 assists Acanivorax borkumensis growth. The results of this study will be important in the decision of dispersant use in the future.

RefID: 88

Author: Booth, A.M., Sutton, P.A., Lewis, C.A., Lewis, A.C., Scarlett, A., Chau, W., Widdows, J. and Rowland, S.J.

Year: 2007

Title: Unresolved complex mixtures of aromatic hydrocarbons: Thousands of overlooked persistent, bioaccumulative, and toxic contaminants in mussels

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es0615829

Abstract: Comprehensive two-dimensional gas chromatography-time-of-flight-mass-spectrometry can be used to resolve and identify individual petroleum-derived hydrocarbons in unresolved complex mixtures (UCMs), such as those accumulated by mussels (Mytilus edulis). Mussels exhibiting a range of scope for growth values were collected from sites around the UK coast. Tissue extracts from mussels exhibiting impaired health contained large amounts of aromatic hydrocarbon UCMs compared to the extracts from healthy mussels. The UCMs (up to 125 mu g g(-1) dry tissue) contained thousands of previously unidentified branched alkyl homologues of known aromatic hydrocarbons such as branched alkylbenzenes (BABs), tetralins (BATs), and indanes and indenes (BINs). The toxicity of few such alkyl branched compounds has been investigated previously, but here we show that a commercial mixture of BABs (C-12-C-14) is toxic to mussels in laboratory tests (11-57 mu g g(-1) dry tissue), reducing feeding rate by up to 40% in 72 h. Thus, some, if not all aromatic UCMs, apparently comprise potent mixtures of persistent, bioaccumulative and toxic compounds which have been overlooked previously.

RefID: 89

Author: Bordbar, L., Emtyazjoo, M. and Farkhani, D.

Year: 2008

Title: Comparison and influence of two newly produced Iranian oil dispersants (Pars1 Pars2) with the Gamlen

OD4000 on rainbow trout

Journal: Journal of Environmental Science and Health

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/18988096

Abstract: Dispersants are the group of chemicals, designed to be sprayed on to the oil slicks to accelerate the process of natural dispersion. In this study, the acute toxicity of two newly produced Iranian oil dispersants (Pars1 Pars2) was evaluated and compared to the Gamlen OD 4000 in different concentrations on 28-32 g of rainbow trout (Oncorhynchus mykiss). The 50% of lethal concentration (LC50) of 96-h acute toxicity of exposed fish were determined by means of Probit value and ANOVA test. Relative effectiveness toxicity (RET) of all oil dispersants according to their LC50 has been measured. Pars1 has the lowest RET (12.56) in contrast to Pars2 (RET = 47.51) and Gamlen OD4000 (RET = 21.34) proved to have the highest efficiency and to be the best one under the laboratory conditions used in this study.

RefID: 90

Author: Bornstein, J.M., Adams, J., Hollebone, B., King, T., Hodson, P.V. and Brown, R.S.

Year: 2014

Title: Effects-driven chemical fractionation of heavy fuel oil to isolate compounds toxic to trout embryos

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.2492/abstract

Abstract: Heavy fuel oil (HFO) spills account for approximately 60% of ship-source oil spills and are up to 50 times more toxic than medium and light crude oils. Heavy fuel oils contain elevated concentrations of polycyclic aromatic hydrocarbons (PAHs) and alkyl-PAHs, known to be toxic to fish; however, little direct characterization of HFO toxicity has been reported. An effects-driven chemical fractionation was conducted on HFO 7102 to separate compounds with similar chemical and physical properties, including toxicity, to isolate the groups of compounds most toxic to trout embryos. After each separation, toxicity tests directed the next phase of fractionation, and gas chromatography-mass spectrometry analysis correlated composition with toxicity, with a focus on PAHs. Low-temperature vacuum distillation permitted the separation of HFO into 3 fractions based on boiling point ranges. The most toxic of these fractions underwent wax precipitation to remove long-chain n-alkanes. The remaining PAH-rich extract was further separated using open column chromatography, which provided distinct fractions that were grouped according to increasing aromatic ring count. The most toxic of these fractions was richest in PAHs and alkyl-PAHs. The results of the present study were consistent with previous crude oil studies that identified PAH-rich fractions as the most toxic. Environ Toxicol Chem 2014;33:814-824. (c) 2013 SETAC

RefID: 91

Author: Boudreau, M., Sweezey, M.J., Lee, K., Hodson, P.V. and Courtenay, S.C.

Year: 2009

Title: TOXICITY OF ORIMULSION-400 (R) TO EARLY LIFE STAGES OF ATLANTIC HERRING (CLUPEA HARENGUS) AND MUMMICHOG (FUNDULUS HETEROCLITUS)

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/08-280.1/full

Abstract: The toxicity of Orimulsion-400 (R) (PDVSA-BITOR), an emulsion of 70% bitumen in 30% water, was tested during the embryonic development of Atlantic herring (Clupea harengus) and mummichog (Fundulus heteroclitus) in duplicate experiments. Air injection and different salinities were included in the herring assays to examine their effects on Orimulsion-400 toxicity. Water-accommodated fractions (WAFs) of no. 6 fuel oil were tested in the mummichog assays to compare Orimulsion-400 toxicity with that of a heavy fuel oil. Concentrations of Orimulsion-400 as low as 0.001% (v/v) were harmful to both species. In herring, the more sensitive of the two species, this concentration produced 100% abnormal larvae. Similar abnormalities, including pericardial edema and spinal deformities, the same signs of toxicity caused by heavy fuel oils and polycyclic aromatic hydrocarbons (PAHs), were produced in both herring and mummichog. Fish exposed to Orimulsion-400 also suffered from increased mortality, reduced heart rates, premature hatch, and reduced lengths compared to control fish. Orimulsion-400 was approximately 300-fold more toxic than the WAFs of no. 6 fuel oil. Salinity had few clear effects on Orimulsion-400 toxicity, but aeration of test solutions greatly reduced toxicity by causing bitumen to coalesce and float. Aeration also removed toxic chemicals such as PAHs. The present study suggests that in the event of a spill, Orimulsion-400 could impair fish recruitment, but that strong wave action would reduce toxicity by accelerating the removal of emulsified bitumen from the water column.

RefID: 92

Author: Bowman, D.T., Slater, G.F., Warren, L.A. and McCarry, B.E.

Year: 2014

Title: Identification of individual thiophene-, indane-, tetralin-, cyclohexane-, and adamantane-type carboxylic acids in composite tailings pore water from Alberta oil sands

Journal: Rapid Communications in Mass Spectrometry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/rcm.6996/abstract

Abstract: RATIONALE: Naphthenic acids (NAs) accumulate in oil sands process-affected water (OSPW) as a result of the water-based extraction processes, and represent one of the toxic fractions in OSPW. They exist as a complex mixture and so the development of an analytical method to characterize and quantify individual acids has been an on-going challenge. The multidimensional separation technique of two-dimensional gas chromatography (GC x GC) has the potential to provide a fingerprint of the sources of NAs and can potentially resolve individual analytes for target analysis. However, the identity and toxicity of a large proportion of the acids present in tailing waters are still unknown. METHODS: Comprehensive two-dimensional gas chromatography/time-of-flight mass spectrometry (GCxGC/TOFMS) was used to characterize NAs in a pore water sample from a Syncrude composite tailings (CT) deposit in Fort McMurray, Alberta, Canada. The extractable organic acid fraction was derivatized with diazomethane and the structures of selected resolved esters were elucidated through interpretation of their electron ionization (EI) mass spectra and, if available, confirmed by comparison with the spectra of reference standards. RESULTS: The high resolving power of the GCxGC/TOFMS technique allowed for the structural elucidation of numerous as yet unidentified acids in the CT pore water sample such as carboxylic acids containing a thiophene, indane, tetralin or cyclohexane moiety. Seventeen members of the previously reported class of adamantane-type carboxylic acids in oil sands process water could also be identified in the sample. CONCLUSIONS: This study underlines the complexity of naphthenic acid isomer distributions in composite tailings and provides a useful inventory of individual acids. Copyright (C) 2014 John Wiley & Sons, Ltd.

RefID: 93

Author: Bowyer, R.T., Blundell, G.M., Ben-David, M., Jewett, S.C., Dean, T.A. and Duffy, L.K.

Year: 2003

Title: Effects of the Exxon Valdez Oil Spill on River Otters: Injury and Recovery of a Sentinel Species

Journal: Wildlife Monographs

Hyperlink: http://www.jstor.org/stable/3830746

Abstract: Integration of individual-based and population-level studies is essential to understanding effects of pollution on populations and ecosystems. Here we provide an example of such integration from our exploration of effects of the Exxon Valdez oil spill (EVOS) on river otters (Lontra canadensis) inhabiting the terrestrial-marine interface in Prince William Sound, Alaska, USA. Our research was divided into 2 phases: an early phase (1989-92) immediately following the oil spill; and a late phase (1996-99), which focused on potential chronic effects of oil contamination in the Sound. We used a variety of measurements that considered the physiological status and health of individual river otters, as well as aspects of their ecology, behavior, and demography. We then conducted meta-analysis to explore interactions between individual-based and population-level data in demonstrating injury and subsequent recovery of otters from ill effects of EVOS. During both phases of our studies, we first conducted intensive research at 2 study sites, which we believed to be oiled and nonoiled, and then expanded our investigations throughout similar areas of Prince William Sound. Nonetheless, our data are best interpreted as differences between heavily oiled areas and lightly oiled sites because later information indicated that our reference sites were lightly oiled. Thus we refer to heavily oiled sites as oiled and lightly oiled sites as "nonoiled." In the later phase, we were part of a broader ecosystem-based project (Nearshore Vertebrate Predators) designed to assess long-term effects of EVOS on a suite of key organisms, and to determine whether those species had recovered from that catastrophic accident. We used radiotelemetry to locate carcasses of animals that died from natural causes, and documented that searching beaches immediately following the spill was not a reliable method for locating dead river otters. Our early research (1989-92) demonstrated that river otters living in oiled areas had lower body mass ($P < 0.04$) and elevated biomarkers ($P < 0.05$) in their blood (e.g., haptoglobin [Hp], interleukin-6 immunoreactive [IL-6 ir], aspartate aminotransferase [AST]) than otters inhabiting "nonoiled" areas. Likewise, otters from oiled areas had higher levels of fecal porphyrins ($P < 0.001$), ate a less-diverse diet ($P <0.001$), had home ranges ($P < 0.05$), and selected habitats differently ($P < 0.01$) than otters living in areas that were not heavily oiled. A mark-recapture analysis based on radiotracers in otter faces during 1990 indicated no difference ($P > 0.10$) between density of otters in Herring Bay (oiled) or Esther Passage ("nonoiled"), but no prespill data were available. Likewise, by 1992, biomarkers (Hp, IL-6 ir, AST) did not differ ($P > 0.05$) between oiled and "nonoiled" areas. During the later phase of research, hydrocarbons on the pelage of river otters and the elevation of endothelial P450-1A, a biomarker sensitive to hydrocarbon exposure, indicated that river otters were exposed to oil still present in Prince William Sound. Nonetheless, body mass of otters continued to increase on oiled areas over time ($P < 0.05$), and eventually did not differ from otters living in "nonoiled" sites ($P > 0.05$). All blood biomarkers (Hp, IL-6 ir, AST) were markedly reduced from the early phase of our research, and no longer differed ($P > 0.10$) between oiled and "nonoiled" sites. We used principal component analysis (PCA) to determine that few differences existed in an array of blood characteristics for otters inhabiting oiled and "nonoiled" sites, and those differences that did exist likely were related to diet. Corpoporphyrin III, a key biomarker in heme synthesis, was reduced ($P=0.008$) from post-spill collections made in 1990 in the oiled area, and no longer differed ($P > 0.05$) between oiled and "nonoiled" areas in 1996. We used stable isotope analysis to investigate differences in diet of river otters inhabiting oiled and "nonoiled" areas in 1996-97. When we controlled for otters inhabiting extensive freshwater habitats (which did not ccur in our early studies), no differences in diet or the trophic level of otters were identified ($P > 0.20$) for otters living in oiled versus "nonoiled" sites. Similarly, density of marine fishes (≥8 cm in total length) on underwater transects did not differ ($P=0.97$) between oiled and "nonoiled" areas, although an area by year interaction occurred ($P=0.01$). Habitat selection by otters also was altered from the early phase; river otters on both study areas selected vegetated slopes that were not steep, and selected sites with more understory (brush) and greater exposure; selection for those characteristics was more pronounced in the oiled area. Otters on both sites avoided (use < availability) gravel and small rocks. Although selected variables differed between oiled and "nonoiled" sites ($P < 0.001$), the direction of selection did not differ between areas. Moreover, tidal slope did not enter any of the models, in contrast to our early studies, indicating that differences in selection were not related to avoidance of oiled shores. Home-range size declined ($P < 0.05$) for otters living in oiled areas, and no longer differed ($P > 0.7$) from animals inhabiting "nonoiled" sites. We enumerated populations from oiled and "nonoiled" areas using a combination of live-captured individuals and DNA fingerprinting using microsatellite from otter feces at latrines. We also performed a conventional reconstruction based on age structure to calculate population size in 1997. Those methods indicated that most animals in the population were recruited following the oil spill and both methods characterized slowly ($\lambda = 1.03$-1.06) growing or stable population in the oiled area. Age structure of river otters in the Sound differed neither between oiled and "nonoiled" areas ($P > 0.36$), nor from a harvested population of river otters in Maine ($P > 0.49$). Finally, survivorship of river otters did not differ ($P > 0.2$) between oiled and "nonoiled" areas of Prince William Sound and was high compared with data on other otter populations in North America. Our data indicate that although river otters continued to be exposed to low levels of crude oil, effects of that exposure were no longer sufficient to cause obvious injury. We cautiously conclude that river otters have recovered from the more pernicious effects of EVOS. Based on our experiences in this research, we provide theoretical considerations for use of biomarkers in wildlife studies and describe statistical approaches, including principal component analysis of blood variables, which may assist researchers with interpreting complicated results of multiple variables and datasets.

Likewise, we describe how dose-response curves should be used in understanding population-level responses to pollutants. We hope that this monograph will provide valuable insights for other wildlife biologists on the process of integration of toxicological data with that of ecological data useful for studying effects of pollution on wildlife populations and their habitats.

RefID: 94

Author: Bowyer, R.T., Testa, J.W. and Faro, J.B.

Year: 1995

Title: HABITAT SELECTION AND HOME RANGES OF RIVER OTTERS IN A MARINE-ENVIRONMENT - EFFECTS OF THE EXXON-VALDEZ OIL-SPILL

Journal: Journal of Mammalogy

Hyperlink: http://jmammal.oxfordjournals.org/content/76/1/1

Abstract: We studied habitat selection and home ranges of river otters (Lutra canadensis) living along the coastlines of Prince William Sound, Alaska, following the Exxon Valdez oil spill in late March 1989. Deposition of feces by otters at latrine sites that were heavily oiled was significantly less than for nonoiled sites in Herring Bay in June and July, but not during August 1989. Finer-scale measurements of habitat showed selection differed significantly on oiled (Herring Bay) and nonoiled (Esther Passage) study areas in 1990; otters selected steeper tidal slopes and sites with larger rocks on oiled than on nonoiled areas, based on characteristics of latrines and random sites. We believe otters avoided shallower slopes and protected areas with smaller rocks and gravel where oil persisted the longest. Thus, differences in habitat selection ostensibly were the result of a reduction in habitat availability caused by oil contamination. Otters on both study areas strongly selected old-growth forest; commercially logged areas in Esther Passage had no otter latrines. River otters on both areas also selected vegetated slopes (approaches to latrine sites) that were less steep. Home ranges of otters were about twice as large on the oiled area as on the nonoiled area, again suggesting that habitat for otters was reduced as a result of the oil spill. These outcomes were detected >1 year after the oil spill and suggest that there may be chronic effects of the oil spill on river otters.

RefID: 95

Author: Bowyer, R.T., Testa, J.W., Faro, J.B., Schwartz, C.C,. and Browning, J.B.

Year: 1994

Title: CHANGES IN DIETS OF RIVER OTTERS IN PRINCE WILLIAM SOUND, ALASKA - EFFECTS OF THE EXXON-VALDEZ OIL-SPILL

Journal: Canadian Journal of Zoology

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/z94-133

Abstract: We studied the effects of the Exxon Valdez oil spill on the diets of river otters (Lutra canadensis) from oiled and nonoiled areas of Prince William Sound, Alaska, U.S.A., in 1989 and 1990. On the basis of identification of prey remains in their feces, otters fed principally on marine, bottom-dwelling fishes. Marine gastropods, bivalves, and crustaceans composed most of the invertebrates in the diet of otters; freshwater and terrestrial food items seldom occurred in their feces. The diets of otters included 149 different taxa, most of which rarely occurred in their feces. Sixty-five taxa occurred greater than or equal to 5 times in our combined data set. Species richness and diversity of prey remains in otter feces were similar on oiled and nonoiled study areas in late winter(April) 1989 (before the oil spill) and during summer (June-October) 1989 following the spill. By summer (July-September) 1990, however, there were significant declines in the richness and diversity of species (mostly bony fish, molluscs, and bivalves) in otter diets on the oiled area. Likewise, the relative abundance of prey remains in otter feces showed strong differences between areas and years, and an area by year interaction. Members of the Perciformes and Archaeogastropoda declined from 1989 to 1990 on the oiled area while they increased on the nonoiled site; Malacostraca exhibited the opposite pattern. These outcomes, when considered with other data on body mass and blood chemistry, strongly suggest that some effects of the oil spill on otters were delayed.

RefID: 96

Author: Braddock, J.F. and Richter, Z.

Year: 1995

Title: Microbiology of subtidal sediments: monitoring microbial populations

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33964083.pdf

Abstract: An increase in the biodegradation activity of naturally occurring populations of microorganisms can lead to substantial removal of petroleum from the environment. Therefore,measurements of microbial populations are an important component of contaminated site assessment studies. Following the Exxon Valdez oil spill in 1989, we measured numbers of hydrocarbon degrading microorganisms and hydrocarbon mineralization potentials of microorganisms in oiled andunoiled surface sediments from the shore through 100 m depth offshore. We found both temporal and spatial variations in numbers and activity of hydrocarbon-degrading microorganisms withstatistically significant higher values at the oiled sites than at reference sites. In the summer of 1993we returned to ten study sites within Prince William Sound to monitor the changes in the numbersand activities of hydrocarbon-degrading microorganisms at these sites with time. In 1993 thenumbers and activities of hydrocarbon-degrading microorganisms were generally very low at all sites although elevated populations and activities were measured in intertidal sub-surface samples atseveral sites (Northwest Bay, Herring Bay and Sleepy Bay) with observable sub-surface oiling.

RefID: 97

Author: Braddock, J.F., Lindstrom, J.E., Yeager, T.R., Rasley, B.T. and Brown, E.J.

Year: 1996

Title: Patterns of Microbial Activity in Oiled and Unoiled Sediments in Prince William Sound

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: Perturbations of microbial communities generally result in shifts in the composition of the microbial population and lead to differences in their activities. An increase in the biodegredation activity of naturally occrring populations of microorganisms can lead to substantial removal of petroleum from the environment. For these reasons, measurements of microbial populations are an important component of contaminated site assessment studies. Over a 3-year period following the Exxon Valdez oil spill in Prince William Sound, Alaska, we measured numbers of hydrocarbonpdegrading microorganisms and hydrocarbon mineralization potentials of microoganisms in oiled and unoiled surface sediments from the shore through 100-m depth offshore. We used these techniques to assess the response of microbial populations to oiling. We present here the data from two oiled sites and two reference sites as an example of how these techniques can be used to monitor changes in sediment microbial populations with time after perturbation (oiling). We found both temporal and spatial variations in numbers and activity of hdrocarbon-degrading microorganisms, with higher values at the oiled sites than at reference sites.

RefID: 98

Author: Braddock, J.F., Rasley, B.T., Yeager, T.R., Lindstrom, J.E. and Brown, E.J.

Year: 1992

Title: Hydrocarbon mineralization potentials and microbial populations in marine sediments following the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33963597.pdf

Abstract: An increase in the biodegradation activity of naturally occurring populations of microorganisms can lead to substantial removal of petroleum from the environment. Therefore, measurements of microbial populations are an important component of contaminated site assessment studies. Following the Exxon Valdez oil spill in 1989, we measured numbers of hydrocarbon degrading microorganisms and hydrocarbon mineralization potentials of microorganisms in oiled and unoiled surface sediments from the shore through 100 m depth offshore. We found both temporal and spatial variations in numbers and activity of hydrocarbon-degrading microorganisms with statistically significant higher values at the oiled sites than at reference sites. The microbial data indicate mobilization between 1989 and 1990 of oil from the intertidal to surface sediments at 20, 40 and 100 m depths offshore. Microbial assays were relatively inexpensive and sensitive measures of the distribution of oil following the spill.

RefID: 99

Author: Brakstad, O.G., Throne-Holst, M., Netzer, R., Stoeckel, D.M. and Atlas, R.M.

Year: 2015

Title: Microbial communities related to biodegradation of dispersed Macondo oil at low seawater temperature with Norwegian coastal seawater

Journal: Microbial Biotechnology

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1111/1751-7915.12303/full

Abstract: The Deepwater Horizon (DWH) accident in 2010 created a deepwater plume of small oil droplets from a deepwater well in the Mississippi Canyon lease block 252 ('Macondo oil'). A novel laboratory system was used in the current study to investigate biodegradation of Macondo oil dispersions (10 μm or 30 μm median droplet sizes) at low oil concentrations (2 mg l−1) in coastal Norwegian seawater at a temperature of 4–5°C. Whole metagenome analyses showed that oil biodegradation was associated with the successive increased abundances of Gammaproteobacteria, while Alphaproteobacteria (Pelagibacter) became dominant at the end of the experiment. Colwellia and Oceanospirillales were related to n-alkane biodegradation, while particularly Cycloclasticus and Marinobacter were associated with degradation of aromatic hydrocarbons (HCs). The larger oil droplet dispersions resulted in delayed sequential changes of Oceanospirillales and Cycloclasticus, related with slower degradation of alkanes and aromatic HCs. The bacterial successions associated with oil biodegradation showed both similarities and differences when compared with the results from DWH field samples and laboratory studies performed with deepwater from the Gulf of Mexico.

RefID: 100

Author: Brand, D.G., Fink, R., Bengeyfield, W., Birtwell, I.K. and McAllister, C.D.

Year: 2001

Title: Salt water-acclimated pink salmon fry (Oncorhynchus gorbuscha) develop stress-related visceral lesions after 10-day exposure to sublethal concentrations of the water-soluble fraction of north slope crude oil

Journal: Toxicologic Pathology

Hyperlink: http://tpx.sagepub.com/content/29/5/574.short

Abstract: Pink salmon fry, Oncorhynchus gorbuscha, after a 10-day exposure to one of two sublethal concentrations (25-54 mug.L-1 or 178-348 mug.L-1) of the water-soluble fractions from Alaska North Slope crude oil, possessed morphologic and stress induced lesions in their hepatic, head kidney and gill tissues. Analysis of livers from oil-exposed fry revealed a variety of hepatocellular changes, including steatosis, nuclear pleomorphism, megalocytosis and necrosis. Epithelial proliferation of the bile ducts also occurred. An increase in the head kidney's interrenal cell nuclear diameter, a biomarker for stress responses, was correlated with hydrocarbon exposure. Gill abnormalities such as eqithelial lifting, fusion, mucous cell hyperplasia and vascular constriction were found in all test groups, but were more severe in fry given the high water soluble fraction of crude oil. The study demonstrated that sublethal exposure to the water-soluble fraction of crude oil results in multiple microscopic lesions (in several viscera) that are consistent with a pronounced response to environmental stress.

RefID: 101

Author: Brannon, E.L. and Maki, A.W.

Year: 1996

Title: The Exxon Valdez oil spill: Analysis of impacts on the Prince William Sound pink salmon

Journal: Reviews in Fisheries Science

Hyperlink:

Abstract: In the 6 years following the Exxon Valdez oil spill in March 1989, a number of field and laboratory studies have been conducted to assess spill-related effects on all critical life stages of the Prince William Sound pink salmon population. In many cases, the results of these studies are in close agreement, but in others they are not. The conclusions arrived at by various investigators must be resolved because both an understanding of oil-spill effects in the marine environment and the response of the pink salmon population to such spills are critical to comprehending and responding to spills in the future. This paper examines results from all available studies of the Exxon Valdez oil spill and summarizes the extent of documented effects. Results show that the low concentrations of petroleum that actually entered the water column, the limited number of streams actually oiled, and the flushing of the intertidal incubation areas of those streams kept the hydrocarbon concentrations in the water and stream sediments well below the toxicity threshold for pink salmon. These data and the fact that 3 of the 6 postspill years have established all-time record adult run sizes indicate that the Exxon Valdez spill posed only a low level of risk to this species, and support the conclusion that specific oil-related effects on the pink salmon population in Prince William Sound are not detectable.

RefID: 102

Author: Brannon, E.L., Collins, K., Cronin, M.A., Moulton, L.L., Maki, A.L. and Parker, K.R.

Year: 2012

Title: Review of the Exxon Valdez Oil Spill Effects on Pink Salmon in Prince William Sound, Alaska

Journal: Reviews in Fisheries Science

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/10641262.2011.643697

Abstract: The Exxon Valdez oil spill that occurred in Prince William Sound, Alaska, in March of 1989 was the largest crude oil spill in the United States at that time, and it was anticipated to have disastrous effects on the ecology and fisheries of that coastal region. The large pink salmon returns to the sound, a major commercial species in Alaska, were of great concern. The Exxon Valdez Oil Spill Trustee Council, a council of government agencies formed to assess the impact of the spill for recovery purposes, concluded that pink salmon in Prince William Sound were damaged by the oil, based on investigations of the Alaska Department of Fish and Game and the National Marine Fisheries Service. Agency scientists claimed that the oil increased incubation mortality of pink salmon and those exposed to oil experienced less growth, higher long-term mortality, and reduced reproductive success. This contrasted with data and conclusions of the non-agency scientists led by the University of Idaho researchers that showed no impact of oil on incubating eggs or on juvenile pink salmon in marine waters, and no reduction in egg viability of returning adults. In this article the authors re-examine the evidence and resolve the problems that resulted in the different interpretation of research conducted by agency and non-agency scientists. The resolution has far reaching implications on ascertaining the impacts of marine oil spills.

RefID: 103

Author: Brannon, E.L., Collins, K., Moulton, L., Parker, K.R.

Year: 2001

Title: Review of studies on oil damage to Prince William Sound pink salmon

Journal: International Oil Spill Conference Proceedings

Hyperlink:

Abstract: In the tenth year following the Exxon Valdez oil spill, differences of opinion still exist about injuries to pink

salmon. It was alleged that exposure to oil reduced growth of fry and induced mortality in eggs. The authors reexamined the allegation that injury occurred and have concluded that insufficient consideration was given to other factors that affected results in the studies from which these allegations were drawn. The inability to track temperature differences and the unknown ages of fry precluded assessment of oil effects on growth during early marine residence. Reported higher egg mortality and long-term injury alleged to have resulted from oil exposure during incubation were confounded by the mortality of eggs that occurred as an artifact of the sampling procedure, unrelated to oil effects. The authors concluded that injury to incubating pink salmon embryos and reduced fry growth were based on an incomplete assessment of other factors that influenced these results. This evidence is supported by other research that has disclosed no oil effects on incubating eggs. Among these were studies that showed measured oil concentrations reaching the incubation substrate were 14 to 7,600 times below the lethal threshold. The seven largest runs in the history of Prince William Sound (PWS), Alaska have returned in the 10 years following the spill, which ultimately demonstrated the lack of measurable effect of the oil spill on pink salmon. The authors suggest that the allegation of oil-induced injury to PWS pink salmon needs to be reconsidered in light of these analyses.

RefID: 104

Author: Brannon, E.L., Collins, K.C.M., Moulton, L.L. and Parker, K.R.

Year: 2001

Title: Resolving allegations of oil damage to incubating pink salmon eggs in Prince William Sound

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f01-055

Abstract: The Exxon Valdez Oil Spill Trustee Council concluded that oil caused mortality of pink salmon (Oncorhynchus gorbuscha) eggs in Prince William Sound streams. Their conclusion was based primarily on Alaska Department of Fish and Game (ADF&G) studies which reported that mean mortality of embryos in eggs was higher in oiled than non-oiled streams when sampled shortly after spawning completion. However, developing embryos are vulnerable to shock mortality for a period of 20 days after fertilization, and the embryos in eggs from the latest spawners were still in the sensitive period at the time sampling took place. We argue that the original ADF&G analysis should have included sample timing in statistical comparisons of mortality between streams. Analysis of a subset of the ADF&G data showed that sampling shock was a major source of embryo mortality in these samples, and that source of mortality in the original survey would likely have been mistakenly interpreted as an oiling effect. Compensating for sample timing removed all statistical evidence for an oiling effect in the data subset. We conclude that the ADF&G study design confounded the ability to assess for the effect of oil exposure on pink salmon eggs.

RefID: 105

Author: Brannon, E.L., Collins, K.M., Brown, J.S., Neff, J.M., Parker, K.R. and Stubblefield, W.A.

Year: 2006

Title: Toxicity of weathered Exxon Valdez crude oil to pink salmon embryos

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/05-129R1.1/abstract;jsessionid=7944F0F9DBA2382284F6D5CFBF9D7FBF.f03t02

Abstract: Research was conducted at the University of Idaho (Moscow, ID, USA) on the toxicity of weathered Exxon Valdez crude oil to embryos of pink salmon from 2001 to 2003 for the purpose of comparing these data with those from the National Oceanic and Atmospheric Administration Fisheries Laboratory at Auke Bay (AK, USA). Mortality reported at Auke Bay for embryos chronically exposed to very low concentrations of aqueous solutions of weathered oil, measured as dissolved polycyclic aromatic hydrocarbons (PAHs), was inconsistent with that in other published research. Using the Auke Bay experimental design, we found that toxicity is not evident in pink salmon embryos until chronic exposure to laboratory weathered and naturally weathered oil concentrations exceeding 1,500 and 2,250 ppm, respectively, representing a total PAH tissue burden in excess of 7, 100 ppb. Effluent hydrocarbons also drop well below concentrations sufficient to cause harm over the time frame of a few weeks, regardless of oiling level. Resolution of differences with Auke Bay involved the source of contributing hydrocarbons. The experimental design did not exclude dispersed oil droplets from the aqueous solution; thus, toxicity was not limited to the dissolved hydrocarbon fraction. The implications of the present results are discussed regarding the toxic risk of weathered oil to pink salmon embryos in streams of Prince William Sound (AK, USA).

RefID: 106

Author: Brannon, E.L., Collins, K.M., Brown, J.S., Neff, J.M., Parker, K.R. and Stubblefield, W.A.

Year: 2008

Title: Authors' reply to "Comment on "toxicity of weathered exxon valdez crude oil to pink salmon embryos""

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/08-033.1/abstract

Abstract: Letter to the editor - refers to Ref S0009

RefID: 107

Author: Brannon, E.L., Collins, K.M., Cronin, M.A., Moulton, L.L., Parker, K.R. and Wilson, W.

Year: 2007

Title: Risk of weathered residual Exxon Valdez oil to pink salmon embryos in Prince William Sound

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/06-414R.1/abstract

Abstract: It has been hypothesized that pink salmon eggs incubating in intertidal streams transecting Prince William Sound (PWS) beaches oiled by the Exxon Valdez oil spill were exposed to lethal doses of dissolved hydrocarbons. Since polycyclic aromatic hydrocarbon (PAH) levels in the incubation gravel were too low to cause mortality, the allegation is that dissolved high-molecularweight hydrocarbons (HPAH) leaching from oil deposits on the beach adjacent to the streams were the source of toxicity. To evaluate this hypothesis, we placed pink salmon eggs in PWS beach sediments containing residual oil from the Exxon Valdez oil spill and in control areas without oil. We quantified the hydrocarbon concentrations in the eggs after three weeks of incubation. Tissue PAH concentrations of eggs in oiled sediments were generally < 100 ppb and similar to background levels on nonoiled beaches. Even eggs in direct contact with oil in the sediment resulted in tissue PAH loads well below the lethal threshold concentrations established in laboratory bioassays, and very low concentrations of HPAH compounds were present. These results indicate that petroleum hydrocarbons dissolved from oil deposits on intertidal beaches are not at concentrations that pose toxic risk to incubating pink salmon eggs. The evidence does not support the hypothesis that interstitial pore water in previously oiled beaches is highly toxic.

RefID: 108

Author: Brannon, E.L., Cronin, M.A., Maki, A.W., Moulton, L.L. and Parker, K.R.

Year: 2013

Title: Oiling Effects on Pink Salmon

Journal: Oil in the Environment: Legacies and Lessons of the Exxon Valdez Spill

Hyperlink:

Abstract: Book Chapter (no abstract)

RefID: 109

Author: Brannon, E.L., Maki, A.W., Moulton, L.L. and Parker, K.R.

Year: 2006

Title: Results from a sixteen year study on the effects of oiling from the Exxon Valdez on adult pink salmon returns

Journal: Marine Pollution Bulletin

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/16487548

Abstract: For sixteen years following the 1989 Exxon Valdez oil spill adult returns of pink salmon in Prince William Sound, Alaska were monitored to assess spill effects on survival. No evidence of spill effects was detected for either intertidal or whole-stream spawning fish. From 1989 through 2004 mean densities for oiled and reference streams tracked each other, illustrating similar responses of oiled and reference stream adult populations to naturally changing oceanographic and climactic conditions. Hatchery fish strayed into the study streams, but similar incursions occurred in oiled and reference streams, and their presence was compensated for to eliminate their influence on determining the success of the returning natural populations. These results, showing no detectable effects of oiling on pink salmon spawning populations, are supported by published field studies on pink salmon incubation success in oiled streams. (c) 2005 Elsevier Ltd. All rights reserved.

RefID: 110

Author: Brannon, E.L., Moulton, L.L., Gilbertson, L.G., Maki, A.W., snd Skalski, J.R.

Year: 1995

Title: An assessment of oil-spill effects on pink salmon populations following the Exxon Valdez oil spill - Part 1: Early Life History

Journal: Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters

Hyperlink: http://www.valdezsciences.com/dspArticle.cfm?catID=2&artID=1032&artSecID=1017

Abstract: Pink salmon, Oncorhynchus gorbuscha, is the main salmon species of commercial importance in Prince William Sound. Unlike other Pacific salmon, they have a two-year life cycle and have adapted to spawn in the intertidal reaches of numerous small streams throughout the oil-spill area. Thus, they represent the species at highest potential risk for spill-related injury. This paper discusses results of field programs initiated within a few days of the spill and designed to assess spill effects on critical early life stages of pink salmon in postspill years. Samples of water and stream sediments from throughout the spill area were used to define the exposure of pink salmon to residual hydrocarbons from the spill. Mean sediment concentrations of polycyclic aromatic hydrocarbons (PAH) up to 300 ppb were measured in oiled streams in 1989 and generally followed a downward trend toward background in 1990 and 1991. These PAH concentrations were then used in regression analyses of potential effects on key early life stages of pink salmon. Water samples taken from both nearshore feeding and rearing areas and offshore migratory areas show that hydrocarbon concentrations were from one to four orders of magnitude lower than concentrations reported in the literature to cause acute or chronic effects on fish species. The postspill field and laboratory studies of pink salmon early life stages included examination of potential effects on 1989, 1990, and 1991 eggs, fry, and juveniles. Generally high survival, ranging from 77% to 100%, was observed in both oiled and reference streams in 1989, and a weak correlation was indicated with stream sediment PAH at only one of the three tide levels sampled (12 feet). In 1990, egg viability was 90.6% from reference streams and 91.1% from oiled streams, as determined through incubation studies. Mean condition index, kD, was 1.76 for fry from reference streams and 1.79 from oiled streams, indicating normal developmental timing.Study results show that no substantial effects on critical early life stages of pink salmon in Prince William Sound are attributable to the spill. Results of incubation experiments with eggs from the spill-affected area provide no indication of sterility or abnormal development. Our results are consistent with the pink salmon returns in 1990 and 1991 that yielded returns over three times the size of the parental year class.

RefID: 111

Author: Brannon, E.L., Quinn, T.P., Whitman, R.P., Nevissi, A.E., Nakatani, R.E. and McAuliffe, C.D.

Year: 1986

Title: HOMING OF ADULT CHINOOK SALMON AFTER BRIEF EXPOSURE TO WHOLE AND DISPERSED CRUDE-OIL

Journal: Transactions of the American Fisheries Society

Hyperlink: http://www.tandfonline.com/doi/abs/10.1577/1548-8659(1986)115%3C823%3AHOACSA%3E2.0.CO%3B2

Abstract: Adult chinook salmon Oncorhynchus tshawytscha that had returned to the University of Washington, Seattle, hatchery were exposed for 1 h to either whole Prudhoe Bay crude oil, a chemical dispersant, or chemically dispersed oil in fresh water. The oil exposure concentrations were higher than under oil spill conditions measured in the field. Members of the treatment groups and similarly handled controls were held for 1 d after exposure and then displaced downstream. Neither frequency of homing (72% overall) nor days to return to the hatchery (mean = 3.2 d) were affected by the treatments. Retention of some treated fish at the hatchery determined that longevity was sufficient to prevent significant bias in estimates of homing. Later in the season, homing speed increased and longevity decreased, but homing frequency remained relatively constant.

RefID: 112

Author: Brennan, K.

Year: 1998

Title: Hydrocarbon injury assessment - Kodiak and Alaska Peninsula herring, Exxon Valdez Oil Spill State/Federal Natural Resource Damage Assessment Annual Report (Fish/Shellfish Study Number 12)

Journal: EVOS Trustee Council

Hyperlink: http://jlc-web.uaa.alaska.edu/client/arlis/search/detailnonmodal/ent:$002f$002fSD_ILS$002f341$002fSD_ILS:341776/ada?qu=%22Hydrocarbon+Injury+Assessment+-+Kodiak+and+Alaska+Peninsula+herring%22&te=ILS

Abstract: Pacific herring spawning aggregations were monitored by aerial surveys during 1989. The estimated spawning biomass in the Kodiak area was approximately 9,550 tons; however, the variability of this estimate is unknown and probably large. The historical record of pre-spawning and spawning aggretations was mapped and the records of herring length at age data from spawning areas from 1981 to 1990 have been summarized.

RefID: 113

Author: Brody, A.J., Ralls, K. and Siniff, D.B.

Year: 1996

Title: Potential impact of oil spills on California sea otters: Implications of the Exxon Valdez spill in Alaska

Journal: Marine Mammal Science

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1111/j.1748-7692.1996.tb00304.x/abstract

Abstract: Based on the survival of sea otters held at rehabilitation centers during the 1989 Exxon Valdez oil spill in Alaska, we built two models of otter mortality. One was based on the relationship between mortality and distance from spill origin, the other was based on the relationship between mortality and time from the spill origin. These models are simplistic and are meant as first steps in arriving at realistic risk estimates and in providing a conceptual framework for relating oil spills and sea otter mortality. Using the distance model, we simulated the impact of an Exxon Valdez event occurring at different locations along the California coast. A spill at the Monterey Peninsula had the greatest impact, exposing 90% of the California sea otter population to oil and killing at least 50% of the individuals. The time model was used to predict the mortality of otters exposed to oil of various ages and for various periods of time. It suggested that efforts to rehabilitate otters should be discontinued 20-30 d after a spill. The limitations of the data available from the Exxon Valdez spill emphasize the importance of being prepared to conduct appropriate research during the next oil spill in sea otter habitat.

RefID: 114

Author: Brown, D.W., Burrows, D.G., Sloan, C.A., Pearce, R.W., Pierce, S.M., Bolton, J.L., Tilbury, K., Dana, K.L., Chan, S.L. and Varanasi, U.

Year: 1996

Title: Survey of Alaskan subsistence invertebrate seafoods collected in 1989-1991 to determine exposure to oil spilled from the Exxon Valdez

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: In response to native Alaskans' concerns, subsistence seafoods were analyzed to deter-mine levels of contamination and to assess the safety of consuming these foods after the Exxon Valdez oil spill. This article includes the results of analyses from approximately 1,000 samples of blue mussels Mytilus edulis, butter clams Saxodomus giganteus, Pacific littlenecks Protothaca staminea, and chitons (order Neoloricata). Between July 1989 and August 1991. samples of invertebrate species were collected from 80 stations near 22 native Alaskan subsistence seafood collection areas inside Prince William Sound and along the Kenai and Alaska peninsulas. Invertebrates were also collected from two sites far away from the spill to serve as reference samples. Samples were analyzed for aromatic contaminants consisting of aromatic hydrocarbons and dibenzothiophenes that are components of the Prudhoe Bay crude oil spilled by the Exxon Valdez. Samples from some stations at Chenega, Windy Bay, Kodiak (Village), and Old Harbor consistently had more than 100 ng/g wet weight of total aromatic contaminants (moderately or highly contaminated). Generally. molluscs sampled from the majority of stations and from the reference areas near Angoon and Yakutat were not contaminated or were only minimally contaminated with aromatic contaminants (concentrations were less than 100 ng/g wet weight). In an advisory opinion, the Food and Drug Administration, in conjunction with the Alaska Oil Spill Health Task Force, indicated that little risk was involved in consumption of the subsistence seafoods studied, as long as visibly oiled organisms were avoided. Because invertebrates can serve as sentinel organisms for evaluating the decline in concentrations of aromatic contaminants over time, continued analyses of these organisms arc also important for monitoring recovery from oil contamination.

RefID: 115

Author: Brown, E.D. and Baker, T.T.

Year: 1998

Title: Injury to Prince William Sound herring following the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/41577659.pdf

Abstract: Studies were conducted in 1989 through 1991 to determine injury to herring in Prince William Sound following the Exxon Vafdez oil spill. About half the herring eggs deposited in 1989 were exposed to Exxon Vafdez oil. Survival to hatch was not impacted, but there were substantial sublethal effects (acceleration of embryo development, morphological deformities and cytogenetic abnormalities) in newly hatched larvae and reduced survival from hatch to free swimming. These correlated well with oil exposure in adjacent mussels and paralleled experimental laboratory observations. The relationship of oil to histopathological lesions in feeding larvae from oiled areas was supported by laboratory studies. An estimated 40 - 80 % of the 1989 year class was impacted by oil at toxic levels. Egg/larval mortality was twice as great in oiled areas and larval growth half that of unoiled areas. Adult reproductive tissue damage could not be tied to oil. Severe focal hepatocellular necrosis in 20% of adult herring examined from oiled areas (none in unoiled areas) was probably due to viral hemorrhagic septicemia induced by exposure of carrier fish to Exxon Yaidez oil, and consistent with later laboratory studies. Polynuclear aromatic hydrocarbons, probably Exxon Valdez oil in origin, were detected in adult herring tissues.

RefID: 116

Author: Brown, E.D., Baker, T.T., Hose, J.E., Kocan, R.M., Marty, G.D., McGurk, M.D., Norcross, B.L. and Short, J.

Year: 1996

Title: Injury to the Early Life History Stages of Pacific Herring in Prince William Sound after the Exxon Valdez Oil Spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: The Exxon Valdez oil spill occurred a few weeks before Pacific Herring Clupea pallasi spawned in Prince William Sound. About half of the egg biomass was deposited within the oil trajectory, and an estimated 40 to 50% sustained oil exposure during early development. The resulting 1989 year-class displayed sublethal effects in newly hatched larvae, primarily premature hatch, low weights, reduced growth, and increased morphologic and genetic abnormalities. Genetic endpoints, especially anaphase aberration rates, were highly correlated with site-specific Exxon Valdez oil concentrations. Responses were specific and sensitive to this oil exposure. In newly hatched larvae, anaphase aberration rates were elevated at oiled sites, and in pelagic larvae genetic damage was greatest near oiled areas of southwestern Prince William Sound. Genetic damage in larvae from oiled areas progressively decreased during the 6-week study, but site-specific measures of instantaneous mortality suggest that a significant reduction (52.3%) in larval production occurred in 1989. Althought approximately equal egg biomass was deposited in non-oiled and oiled areas, we estimated that oiled areas produced only 0.016 x 109 pelagic larvae compared with 11.82 x 109 non-oiled areas. Despite the estimated substantial decrease in larval production, reduced abundance in the 1989-year class recruiting as 4-year-old adults in 1993 could not be estimated because natural processes affecting recruitment are poorly understood; however, the 1989 year-class was a minority of the 1993 spawning population, one of the smallest cohorts observed in Prince William Sound, and it returned to spawn with an adult herring population reduced by approximately 75%, apparently because of a widespread epizootic.

RefID: 117

Author: Brown, E.D., Norcross, B.L. and Short, J.W.

Year: 1996

Title: An introduction to studies on the effects of the Exxon Valdez oil spill on early life history stages of Pacific herring, Clupea pallasi, in Prince William Sound, Alaska

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f96-211

Abstract:

RefID: 118

Author: Bue, B.G., Sharr, S. and Seeb, J.E.

Year: 1998

Title: Evidence of Damage to Pink Salmon Populations Inhabiting Prince William Sound, Alaska, Two Generations after the Exxon Valdez Oil Spill

Journal: Transactions of the American Fisheries Society

Hyperlink: http://www.tandfonline.com/doi/abs/10.1577/1548-8659%281998%29127%3C0035%3AEODTPS%3E2.0.CO%3B2

Abstract: Our investigations into the effects of the 1989 Exxon Valdez oil spill in Prince William Sound, Alaska, suggest that chronic damage occurred to some populations of pink salmon Oncorhynchus gorbuscha. Significantly elevated embryo mortalities were observed from 1989 through 1993 in populations inhabiting streams previously contaminated by oil. No statistically detectable difference in embryo mortality was observed in 1994 and 1995. We assessed the possible influence of the natural environment on these findings by collecting gametes from adults returning to contaminated and to uncontaminated streams, transporting the gametes to a hatchery where intrastream crosses were made, and incubating the resulting embryos under identical environmental conditions. Significantly increased embryo mortality was detected for embryos originating from the oil contaminated lineages in 1993 but not in 1994, which indicated that the significant differences detected in the field in 1989–1993 were not induced by naturally occurring environmental variables.

RefID: 119

Author: Bue, B.G., Sharr, S., Moffitt, S.D. and Craig, A.K.

Year: 1996

Title: Effects of the Exxon Valdez Oil Spill on Pink Salmon Embryos and Preemergent Fry

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: We examined pink salmon Oncorynchus gorbuscha preemergent fry mortality, embryo mortality, and survival from embryo to preemergent fry in intertidal and upstream areas of Prince William Sound that were affected by the Exxon Valdez oil spill. No change in preemergent fry density or increase in numbers of dead fry was detected within 1 month of the spill. Pink salmon embryo mortality was elevated in oil-affected streams during fall of each year from 1989 through 1992 ($P < 0.023$ for all years). In 1989 increased embryo mortality was detected in the lower intertidal zones, and in 1990 elevated mortalities were observed at the highest intertidal zone. In 1991 embryo mortality was significantly higher in all intertidal zones, as well as upstream of oil contamination. The same patterns of mortalities were observed in 1992, although they were not as extreme as that observed in 1991. However, no difference in survival of embryo to preemergent fry was detected for the 1989-1991 brood years.

RefID: 120

Author: Burridge, T.R. and Shir, M.A.

Year: 1995

Title: The comparative effects of oil dispersants and oil/dispersant conjugates on germination of the marine macroalga Phyllospora comosa (Fucales: Phaeophyta)

Journal: Marine Pollution Bulletin

Hyperlink: https://www.researchgate.net/publication/223816113_The_comparative_effects_of_oil_dispersants_and_oildispersant_conjugates_on_germination_of_the_marine_macroalga_Phyllospora_comosa_%28Fucales_Phaeophyta%29

Abstract: Germination inhibition of the marine macrophyte Phyllospora comosa was utilized as a sub-lethal endpoint to assess and compare the effects of four oil dispersants and dispersed diesel fuel and crude oil combinations, Inhibition of germination by the water-soluble fraction of diesel fuel increased following the addition of each of the dispersants; the nominal 48-h EC(50) concentration of diesel fuel declined from 6800 to approximately 400 mu l l(-1) nominal for each dispersed combination. This contrasted with elude oil, where the addition of two dispersants resulted in an enhanced germination rate and an increase in nominal EC(50) concentrations from 130 mu l l(-1) for the undispersed crude to 4000 and 2500 mu l l(-1). The results indicate that, while germination inhibition of P. comosa may be enhanced by the chemical dispersal of oil, the response varies with type of both oil and oil dispersant.

RefID: 121

Author: Calbet, A., Saiz, E. and Barata, C.

Year: 2007

Title: Lethal and sublethal effects of naphthalene and 1,2-dimethylnaphthalene on the marine copepod Paracartia grani

Journal: Marine Biology

Hyperlink: http://link.springer.com/article/10.1007%2Fs00227-006-0468-0

Abstract: Here we evaluate the effects of two quantitatively very important components of the water soluble fractions of fuel oils (naphthalene and 1,2-dimethylnaphthalene, hereafter NAPH and C2-NAPH, respectively) on the survival, feeding and egg production rates, and viability of eggs of the coastal copepod Paracartia (Acartia) grani. Acute toxicity responses resulted in lethal concentrations (LC50) of 2,535 and 161 mu g l(-1) for NAPH and C2-NAPH, respectively, with no evidence of narcotic effects. Hydrocarbon-specific differences in the toxicity response indicate that sublethal effects (EC50) on feeding by C2-NAPH were likely driven by induced mortality, whereas NAPH has direct negative effects on feeding. Sublethal effects on egg production rates followed a similar detrimental pattern to the one exhibited by feeding rates, suggesting that the lower egg production rates were mediated by the decrease in feeding rates. At the exposure time tested (24 h), the 50% reduction effective concentrations (EC50) determined for sublethal effects were relatively high in comparison with hydrocarbons' concentrations found under natural circumstances. Long exposure (4 days) of P. grani adults to the tested hydrocarbons at concentrations well below the recorded EC50, however, had no significant effects on feeding, egg production and hatching rates. The viability of the eggs was either not affected or only slightly influenced when healthy eggs were incubated under very high concentrations (up to 6,400 and 700 mu g l(-1) NAPH and C2-NAPH, respectively). The significance of the effects of oil spills on marine zooplankton communities is discussed in light of the results presented in this study.

RefID: 122

Author: Cameron, J.A. and Smith, R.L.

Year: 1980

Title: ULTRASTRUCTURAL EFFECTS OF CRUDE-OIL ON EARLY LIFE STAGES OF PACIFIC HERRING

Journal: Transactions of the American Fisheries Society

Hyperlink: http://www.tandfonline.com/doi/abs/10.1577/1548-8659(1980)109%3C224%3AUEOCOO%3E2.0.CO%3B2

Abstract: Eggs of Pacific herring, Clupea harengus pallasi, collected from Prince William Sound, Alaska were exposed to Prudhoe Bay crude oil for 4–144 hours, then returned to uncontaminated seawater for further development. Newly hatched larvae from both control and experimental groups showed no gross abnormalities. Transmission electron microscropy revealed inter- and intracellular spaces in brain and muscle tissues of exposed organisms but not in those of controls. Many mitochondria in the body muscle of exposed organisms were swollen, some with deteriorating cristae structure.

RefID: 123

Author: Cancio, I., Orbea, A., Volkl, A., Fahimi, H.D. and Cajaraville, M.P.

Year: 1998

Title: Induction of peroxisomal oxidases in mussels: Comparison of effects of lubricant oil and benzo(a)pyrene with two typical peroxisome proliferators on peroxisome structure and function in Mytilus galloprovincialis

Journal: Toxicology and Applied Pharmacology

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/9512728

Abstract: Marine mussels are used as bioindicators of water pollution in marine and estuarine environments in the so-called "Mussel Watch" programs because of their capacity to accumulate numerous organic xenobiotics including aromatic hydrocarbons. in this study, we have analyzed the effects of two xenobiotics [benzo(a)pyrene and the water accommodated fraction of a lubricant oil] and two typical (rodent) peroxisome proliferators (clofibrate and dioctyl phthalate) on structure and function of peroxisomes in digestive glands of mussels Mytilus galloprocincialis, either following water exposure (for 1, 7, and 21 days) or after direct injection through the adductor muscle (for 1 and 7 days). The activities of catalase (CAT), acyl-CoA oxidase (AOX), and D-amino acid oxidase were determined in whole homogenates of digestive glands. In addition, stereological methods were applied on sections stained histochemically for demonstration of catalase activity in order to quantify the morphological changes of peroxisomes. The peroxisomal acyl-CoA oxidase and D-amino acid oxidase were increased in mussels injected for 7 days with benzo(a)pyrene, phthalate, and clofibrate and a similar trend was noted for benzo(a)pyrene and lubricant oil in water exposure experiments (21 days). The catalase activity was reduced or unchanged depending on the mode of exposure of animals. By stereology, significant increases of numerical and volume densities of peroxisomes were found in animals injected for 7 days with lubricant oil or clofibrate. These observations indicate that peroxisomal oxidases in mussels are induced at moderate rates in response to different xenobiotics and that their determination could provide a (sensitive) marker for detection of effects of some toxic pollutants, particularly the lubricant oils which in addition induce significant structural alterations of mussel peroxisomes. (C) 1998 Academic Press.

RefID: 124

Author: Carls, M.G.

Year: 2006

Title: Nonparametric identification of petrogenic and pyrogenic hydrocarbons in aquatic ecosystems

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es052498g

Abstract: Novel nonparametric models developed herein discriminated between oiled and nonoiled or pyrogenic and oiled sources better than traditionally used diagnostic ratios and can outperform previously published oil identification models. These methods were compared using experimental and environmental hydrocarbon data (sediment, mussels, water, and fish) associated with the Exxon Valdez oil spill. Several nonparametric models were investigated, one designed to detect petroleum in general, one specific to Alaska North Slope crude oil (ANS), and one designed to detect pyrogenic PAH. These ideas are intended as guidance; nonparametric models can easily be adapted to fit the specific needs of a variety of petrogenic and pyrogenic sources. Oil identification was clearly difficult where composition was modified by physical or biological processes; model results differed most in these cases, suggesting that a multiple model approach to source discrimination may be useful where data interpretation is contentious. However, a combined nonparametric model best described a broad range of hydrocarbon sources, thus providing a useful new analytical assessment tool.

RefID: 125

Author: Carls, M.G. and Harris, P.M.

Year: 2004

Title: Monitoring of oiled mussel beds in Prince William Sound and the Gulf of Alaska

Journal: EVOS Trustee Council

Hyperlink: http://library.alaska.gov/asp/edocs/2006/01/ocm62735875.pdf

Abstract: Exxon Valdez oil trapped in intertidal sediment in Prince William Sound degraded slowly, was biologically available for at least a decade, and was toxic for at least 9 years. Habitat condition controlled the biological availability of oil. Exposure duration was short where mussels were only exposed to oil in water (months) and long (6 to 10 years) at locations where oil remained in sediment. Limited evidence suggests some oiling extended outside previously reported slick boundaries; polynuclear aromatic hydrocarbon (PAH) sources were verified with three independent petrogenic composition models. After an initial peak, oil concentrations typically declined in sediment and mussels, although distribution was non-uniform and variability was often high. Oil may persist in some intertidal sediment for >50 years, but declines in mussel tissue suggest it became less available to surface organisms and this community is recovering. Attempts to manually accelerate hydrocarbon loss from mussel beds were equivocal, demonstrating that removal of oil from intertidal sediment is difficult. Exposure to residual oil may explain why some vertebrate populations (pigeon guillemots, Cepphus columba, and sea otters, Enhydra lutris) that forage in the most heavily impacted areas have not yet fully recovered from the spill.

RefID: 126

Author: Carls, M.G. and Meador, J.P.

Year: 2009

Title: A Perspective on the Toxicity of Petrogenic PAHs to Developing Fish Embryos Related to Environmental Chemistry

Journal: Human and Ecological Risk Assessment

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/10807030903304708

Abstract: Numerous studies demonstrate polynuclear aromatic hydrocarbons (PAHs) dissolved from weathered crude oil adversely affect fish embryos at 0.5 to 23 mu/l. This conclusion has been challenged by studies that claim (1) much lower toxicity of weathered aqueous PAHs; (2) direct contact with dispersed oil droplets plays a significant role or is required for toxicity; (3) that uncontrolled factors (oxygen, ammonia, and sulfides) contribute substantively to toxicity; (4) polar compounds produced by microbial metabolism are the major cause of observed toxicity; and (5) that based on equilibrium models and toxic potential, water contaminated with weathered oil cannot be more toxic per unit mass than effluent contaminated with fresh oil. In contrast, several studies demonstrate high toxicity of weathered oil; shifts in PAH composition were consistent with dissolution (not particle ablation), embryos accumulated dissolved PAHs at low concentrations and were damaged, and assumed confounding factors were inconsequential. Consistent with previous empirical observations of mortality and weathering, temporal shifts in PAH composition (oil weathering) indicate that PAHs dissolved in water should (and do) become more toxic per unit mass with weathering because high molecular weight PAHs are more persistent and toxic than the more abundant low molecular weight PAHs in whole oil.

RefID: 127

Author: Carls, M.G. and Thedinga, J.F.

Year: 2010

Title: Exposure of pink salmon embryos to dissolved polynuclear aromatic hydrocarbons delays development, prolonging vulnerability to mechanical damage

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S014111360900172X

Abstract: Exposure to dissolved polynuclear aromatic hydrocarbons (PAHs) from crude oil delays pink salmon (Oncorhynchus gorbuscha) embryo development, thus prolonging their susceptibility to mechanical damage (shock) Exposure also caused mortality, edema, and anemia consistent with previous studies Hatching and yolk consumption were delayed, indicating the rate of embryonic development was slowed by PAH exposure. The net result was that exposed embryos were more susceptible to shock than normal, unexposed embryos Susceptibility to shock was protracted by 4-6 d for more than a month in embryos exposed to exponentially declining, dissolved PAH concentrations in water passed through oiled rock, the initial total PAH concentration was 22.4 mu g L(-1) and the geometric mean concentration was 4 5 mu g L(-1) over the first 20 d Protracted susceptibility to shock caused by exposure to PAHs dissolved from oil could potentially increase the reported incidence of mortality in oiled stream systems, such as those in Prince William Sound after the Exxon Valdez oil spill, if observers fail to discriminate between direct mortality and shock-induced mortality Published by Elsevier Ltd

RefID: 128

Author: Carls, M.G., Babcock, M.M., Harris, P.M., Irvine, G.V., Cusick, J.A. and Rice, S.D.

Year: 2001

Title: Persistence of oiling in mussel beds after the Exxon Valdez oil spill

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0141113600001033

Abstract: Persistence and weathering of Exxon Valdez oil in intertidal mussel (Mytilus trossulus) beds in Prince William Sound (PWS) and along the Gulf of Alaska was monitored from 1992 to 1995. Beds with significant contamination included most previously oiled areas in PWS, particularly within the Knight

Island group and the Kenai Peninsula. In sediments, yearly mean concentrations of total petroleum hydrocarbons ranged from <60 μg/g in reference beds to 62,258 μg/g wet wt., or approximately 0 to 523 μg/g dry wt. total polynuclear aromatic hydrocarbons (TPAHs). In mussels, mean TPAH concentrations ranged up to 8.1 μg/g dry wt. Hydrocarbon concentrations declined significantly with time in some, but not all mussels and sediments, and should reach background levels within three decades of the spill in most beds. In 1995, mean hydrocarbon concentration was greater than twice background concentration in sediments from 27 of 34 sites, and in mussels from 18 of 31 sites.

RefID: 129

Author: Carls, M.G., Harris, P.M. and Rice, S.D.

Year: 2004

Title: Restoration of oiled mussel beds in Prince William Sound, Alaska

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0141113603001090

Abstract: Natural loss of hydrocarbons was often low from mussel (Mytilus trossulus) beds (which were typically not cleaned after the Exxon Valdez oil spill), thus this habitat remained a long-term source of oil. Consequently, experimental restoration of nine contaminated beds was attempted in 1994; mussels were removed, contaminated surface sediment was replaced (33 metric tons), and original mussels were returned. Hydrocarbon concentrations and mussel populations were monitored for 5 years thereafter. Post-restoration mussel population fluctuations were indistinguishable from regional changes. Increased short-term oil loss was apparent, but long-term (5 year) improvement was equivocal and difficult to distinguish from natural losses. By 1999, oil concentrations in mussels were typically at baseline levels in restored and oiled reference beds; concentrations in replaced sediment were elevated in one third of restored beds, indicating recontamination from underlying or surrounding sediment. Our results suggest mussel relocation is feasible but suggest oil, might more effectively be removed from sediment mechanically or chemically than manually. Published by Elsevier Ltd.

RefID: 130

Author: Carls, M.G., Heintz, R.A. and Rice, S.D.

Year: 2003

Title: Have wild pink salmon and their habitat recovered from persistent Exxon Valdez oil contamination?

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/70788606.pdf

Abstract: A decade after the Exxon Valdez spill, intertidal pink salmon natal habitat and groundwater movement in Prince William Sound, Alaska, was examined for evidence of lingering oil, the potential for hydrocarbon transfer to developing eggs, and exposure of eggs to oil. The potential consequences of oil exposure during development were further examined using bioassays. Polynuclear aromatic hydrocarbons consistent with Exxon Valdez oil were verified in the water of one of six streams; concentrations increased downslope and cytochrome P4501A in eggs was similarly induced. Because only previously heavily oiled streams were sampled, we infer that most pink salmon spawning habitat in Prince William Sound either has recovered or is recovering. Fluorescent tracer dyes injected into beaches near two of these streams during ebb tides were subsequently observed throughout most of the intertidal portion of each watershed, including surface and subsurface stream water, demonstrating the potential for transfer of dissolved oil constituents from surrounding oiled sediment to developing eggs. Exposure of pink salmon embryos from five brood years to dissolved polynuclear aromatic hydrocarbons demonstrated that cytochrome P4501A induction is related to a variety of lethal and sublethal responses, including abnormalities, reduced growth, poorer predator avoidance, and diminished marine survival. Our results not only demonstrate habitat recovery, they also demonstrate why recovery was not immediate and that the spill likely had a lasting negative impact on wild pink salmon populations in intervening years.

RefID: 131

Author: Carls, M.G., Holland, L., Larsen, M., Collier, T.K., Scholz, N.L. and Incardona, J.P.

Year: 2008

Title: Fish embryos are damaged by dissolved PAHs, not oil particles

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X08001094

Abstract: To distinguish the toxicity of whole oil droplets from compounds dissolved in water, responses of zebrafish embryos exposed to particulate-laden, mechanically dispersed Alaska North Slope crude oil (mechanically dispersed oil (MDO)) were compared to those of embryos protected from direct oil droplet contact by an agarose matrix. Most polycyclic aromatic hydrocarbons (PAHs) in MDO were contained in oil droplets; about 16% were dissolved. The agarose precluded embryo contact with particulate oil but allowed diffusive passage of dissolved PAHs. The incidence of edema, hemorrhaging, and cardiac abnormalities in embryos was dose-dependent in both MDO and agarose and the biological effects in these compartments were identical in character. Although mean total PAH (TPAH) concentrations in MDO were about 5–9 times greater than in agarose, dissolved PAH concentrations were similar in the two compartments. Furthermore, mean differences in paired embryo responses between compartments were relatively small (14–23%, grand mean 17%), typically with a larger response in embryos exposed to MDO. Therefore, the embryos reacted only to dissolved PAHs and the response difference between compartments is explained by diffusion. Averaged over 48 h, the estimated mean TPAH concentration in agarose was about 16% less than the dissolved TPAH concentration in MDO. Thus, PAHs dissolved from oil are toxic and physical contact with oil droplets is not necessary for embryotoxicity.

RefID: 132

Author: Carls, M.G., Holland, L., Larsen, M., Lum, J.L., Mortensen, D.G., Wang, S.Y. and Wertheimer, A.C.

Year: 1996

Title: Growth, Feeding, and Survival of Pink Salmon Fry Exposed to Food Contaminated with Crude Oil

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: Growth of pink salmon fry Oncorynchus gorbuscha was reduced by oil-contaminated food in an 8-week laboratory experiment, and feeding and survival were reduced at high oil concentrations (34.8 mg total oil per gram of food). Total concentrations of Alaska North Slope crude oil in the food ranged from 0.00 (control) to 34.8 mg/g. In the hightest oil treatment, mortality became significant after 2 weeks and increased rapidly until fry began feeding on clean food. Growth reductions in exposed fry were significant after 1 week in mid- (2.8 mg/g) and high-oil treatments and became more pronounced over time. The estimated feeding rate was inhibited only in the highest oil treatment, but increased in the lowest oil concentration (0.37 mg/g). Althought feeding rate did not decline in the low- and mid-oil treatments, growth was significantly reduced in these groups. This suggests that changes in growth caused by oil were not caused simply by starvation, but rather were the result of increased metabolic demand or reduced assimilation efficiency. Results of this experiment support the hypothesis that juvenlie pink salmon in Prince William Sound were contaminated with hydrocarbons from the 1989 Exxon Valdez oil spill by ingesting oiled prey and that this contamination was reponsible for reduced growht of fry in oiled habitats.

RefID: 133

Author: Carls, M.G., Hose, J.E., Thomas, R.E. and Rice, S.D.

Year: 2000

Title: Exposure of Pacific herring to weathered crude oil: Assessing effects on ova

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620190624/full

Abstract: In order to determine if exposure to Exxon Valdez oil would adversely affect progeny, reproductively mature Pacific herring were confined in water contaminated with weathered crude oil. Progeny were generally not affected by a 16-d parental exposure to initial aqueous concentrations of less than or equal to 58 mu g/L total polynuclear aromatic hydrocarbons (PAHs), yielding concentrations of up to 9.7 mu g/g in ova. In contrast, previous research indicated that a 16-d direct exposure of herring eggs to similarly weathered oil was detrimental to developing embryos at total initial PAH concentrations of 9 mu g/L. Progeny of exposed fish could have been insulated from toxic effects for two reasons. First, as an apparent result of partitioning and metabolism in parental tissues, lower concentrations and less toxic PAHs were preferentially accumulated by ova (primarily naphthalenes; 84-92%). Second, peak exposure concentrations occurred before cell differentiation. The opposite was true for directly exposed eegs; the more toxic multi-ring PAHs (e.g., phenanthrenes and chrysenes) and alkyl-substituted homologues were accumulated, and internal concentrations increased during cell division, differentiation, and organ development. Thus, Pacific herring embryos are more critically sensitive to oil pollution than are gametes.

RefID: 134

Author: Carls, M.G., Johnson, S.W., Thomas, R.E. and Rice, S.D.

Year: 1997

Title: Health and reproductive implication of exposure of Pacific herring (Clupea pallasi) adults and eggs to weathered crude oil, and reproductive condition of herring stock in Prince William Sound six years after the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/37889135.pdf

Abstract: Herring spawned in Prince William Sound a few weeks after the Exxon Valdez oil spill: all life stages were potentially exposed. In 1993, the herring population in Prince William Sound collapsed, suggesting possible reproductive impairment. Reproductive condition of herring in Prince William Sound was assessed in 1995: adult herring and eggs were also experimentally exposed to oil. In laboratory tests, pre-spawn herring were negatively impacted by exposure to oil, principally by suppression of the immune system and increased expression of disease. Induction of aryl hydrocarbon hydroxylase, suppression of leukocytes, increased prevalence of viral hemorrhagic septicemia virus, and mortality were correlated with polynuclear aromatic hydrocarbon concentration. However, exposure of adult herring caused negligible damage in progeny at high concentrations (58 ppb aqueous polynuclear aromatic hydrocarbon). In contrast, exposure of incubating eggs to comparably weathered oil caused significant morphological defects at 9 ppb and effects of more weathered oil were significant at concentrations as low as 0.2 ppb polynuclear aromatic hydrocarbons: chromosomal aberrations were observed at 0.7 ppb. Most larvae with genetic defects would likely die due to concomitant morphological abnormalities. There was no evidence of oil-related reproductive impairment in Prince William Sound herring six years after the spill.

RefID: 135

Author: Carls, M.G., Larsen, M.L. and Holland, L.G.

Year: 2015

Title: Spilled Oils: Static Mixtures or Dynamic Weathering and Bioavailability?

Journal: PLoS ONE

Hyperlink: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0134448

Abstract: Polynuclear aromatic hydrocarbons (PAHs) from sequestered MV Selendang Ayu oil were biologically available in 2008, 3.6 y after it was spilled along Unalaska Island, Alaska. Thermodynamically driven weathering was the most probable mechanism of organism exposure to PAHs. Alkane and PAH composition in oil changed over time as smaller constituents were preferentially lost, indicative of weathering. In contrast, composition of the largest compounds (biomarkers) including triterpanes, hopanes, and steranes remained unchanged. Smaller molecules (the PAHs) lost from stranded oil were observed in indigenous mussels and passive samplers deployed in July 2008. Concentration and composition of PAHs were significantly different than in a non-oiled reference area and patterns observed in mussels were repeated in passive samplers deployed in three zones (intertidal, subtidal, and water). Thus, hydrocarbons lost from one compartment (sequestered whole oil) were detectable in another (mussels and passive samplers) implying aqueous transfer. Quantities of mobile oil constituents were small, yielding uptake concentrations that are likely inconsequential for mussels, but the sensitivity provided by bioaccumulation and passive sampler uptake ensured that dissolved hydrocarbons were detectable.

RefID: 136

Author: Carls, M.G., Marty, G.D. and Hose, J.E.

Year: 2001

Title: Synthesis of the toxicological and epidemiological impacts of the Exxon Valdez oil spill on Pacific herring in Prince William Sound, Alaska

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/50544913.pdf

Abstract: The objectives of this project were to determine the effect of exposure of pink salmonembryos to weathered crude oil on subsequent marine growth and survival, and to examine theeffect of oil exposure and other factors on the straying behavior of pink salmon. The projectrelied on extensive marking of pink salmon fry from controlled exposure groups and from wildstocks: a total of 478,749 fry were marked and released at the tagging sites in 1996. Treatment groups were incubated in oiled gravel simulating conditions in contaminated streams in Prince William Sound after the Exxon Valdez oil spill, resulting in initial aqueous exposures for totalpolynuclear aromatic hydrocarbons of <5.2 and <19.4 parts per billion (ppb) for a low and highdose, respectively. Control fish were incubated in gravel without oil. Superficially healthy frywere marked by removing the adipose fin and inserting coded-wire tags after volitionallyemigrating from the incubators. Pink salmon from two wild stocks, an intertidal and an upstream spawning stock, were also marked by removing the adipose fin and inserting coded-wire tags as they emigrated to seawater. To examine the effect of coded-wire tags on survival and straying, some pink salmon fry from the control incubators and from the upstream spawning stock weremarked by removing the adipose fin and a pelvic fin. Marks were recovered from fisheries, natal streams, and streams up to 60 km of the natal streams, to provide the statistical power todiscriminate long-term effects of oil exposure and to quantify straying and the precision ofstraying estimates.Embryonic exposure to oil produced sublethal effects in pink salmon that led to reducedgrowth and marine survival at concentrations in the low ppb. Oil exposure as embryos resultedi n significant reductions in juvenile marine growth and in survival to adults at exposures <5.2 ppb. Marine survival was reduced by 15% for fish exposed to <5.2 ppb, and 38% for fish exposed at <19.4 ppb. These data demonstrate that the contributions of delayed mortality are asignificant component to total mortality resulting from exposure to oil, and indicate the potential for much greater population level effects to pink salmon from the Exxon Valdez oil spill than previous estimates. Overall straying of returning pink salmon that were not exposed to oil, adjusted forsampling effort, was 5.1% within a 45 km radius of the natal watershed. The proportion of adultfish observed to have strayed was higher for the exposed than the control groups, but thedifferences among treatments were not statistically significant, and the proportion did notincrease with dose. Estimated straying of tagged fish was 9.2% for the intertidal stock, moret han double the 3.7% rate estimated for tagged fish from the upstream-spawning stock. Coded-ivwire tags did have a significant effect on observed straying; estimated straying rates averaged2.6% higher for CWT fish than for their fin-clipped siblings. Although tagging and oil may influence straying to some degree, the magnitude of straying associated with these factors doesnot explain the high straying rates (average 25%, range 9 to 53%) observed in Prince William Sound following the oil spill. Incubation environment and natal watershed characteristics appear to be major determinants of the natural straying of pink salmon, and of the regional differencesobserved in straying rates between southeastern Alaska and Prince William Sound.

RefID: 137

Author: Carls, M.G., Marty, G.D. and Hose, J.E.

Year: 2002

Title: Synthesis of the toxicological impacts of the Exxon Valdez oil spill on Pacific herring (Clupea pallasi) in Prince William Sound, Alaska, USA

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f01-200

Abstract: Pacific herring (Clupea pallasi) in Prince William Sound (PWS) were affected by two major events in the past decade: the Exxon Valdez oil spill in 1989 and a 75% collapse in the adult population in 1993. In this review we compare and reinterpret published data from industry and government sources. Combining site-specific estimates of exposure and recent laboratory effects thresholds, 0.4-0.7 mu.L-1 total polynuclear aromatic hydrocarbons, we conclude that 25-32% of the embryos were damaged in PWS in 1989. Significant effects extended beyond those predicted by visual observation of oiling and by toxicity information available in 1989. Oil-induced mortality probably reduced recruitment of the 1989 year class into the fishery, but was impossible to quantify because recruitment was generally low in other Alaskan herring stocks. Significant adult mortality was not observed in 1989; biomass remained high through 1992 but declined precipitously in winter 1992-1993. The collapse was likely caused by high population size, disease, and suboptimal nutrition, but indirect links to the spill cannot be ruled out. These concepts have broad application to future oil spill assessments. For example, safety standards for dissolved aromatics should reflect the previously unrecognized high toxicity of polynuclear aromatic hydrocarbons to adequately protect critical life stages.

RefID: 138

Author: Carls, M.G., Marty, G.D., Meyers, T.R., Thomas, R.E. and Rice, S.D.

Year: 1998

Title: Expression of viral hemorrhagic septicemia virus in prespawning Pacific herring (Clupea pallasi) exposed to weathered crude oil

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f98-116

Abstract: Expression of subclinical viral infection in response to toxicant exposure has not previously been reported, but evidence presented herein indicates that activation of viral hemorrhagic septicemia virus (VHSV) may occur in Pacific herring (Clupea pallasi) exposed to crude oil encountered after an oil spill. Decreased incidence of hepatic inflammatory cells as a function of total polynuclear aromatic hydrocarbon (TPAH) concentration was evidence for immunosuppression in exposed fish, and decreased immune surveillance is a possible mechanism by which subclinical VHSV could be reactivated. Adult Pacific herring of unknown status regarding infection by VHSV were captured from the wild and exposed to weathered crude oil for 16-18 days. TPAH concentration in tissue, VHSV prevalence, and mortality were correlated with dose. Histopathologic lesions were significantly correlated with TPAH concentration and prevalence of VHSV, but not gender or length. Significant lesions included increased hepatocellular necrosis, splenic thrombosis, and decreased inflammation in the liver.

RefID: 139

Author: Carls, M.G., Rice, S.D. and Hose, J.E.

Year: 1999

Title: Sensitivity of fish embryos to weathered crude oil: Part I. Low-level exposure during incubation causes malformations, genetic damage, and mortality in larval Pacific herring (Clupea pallasi)

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620180317/full

Abstract: Pacific herring eggs were exposed for 16 d to weathered Alaska North Slope crude oil. Exposure to an initial aqueous concentration of 0.7 parts per billion (ppb) polynuclear aromatic hydrocarbons (PAHs) caused malformations, genetic damage, mortality, and decreased size and inhibited swimming. Total aqueous PAH concentrations as low as 0.4 ppb caused sublethal responses such as yolk sac edema and immaturity consistent with premature hatching. Responses to less weathered oil, which had relatively lower proportions of high molecular weight PAH, generally paralleled those of more weathered oil, but lowest observed effective concentrations (LOECs) were higher (9.1 ppb), demonstrating the importance of composition. The LOEC for more weathered oil (0.4 ppb) was similar to that observed in pink salmon (1.0 ppb), a species with a very different development rate; by inference, other species may be similarly sensitive to weathered oil. Our methods simulated conditions observed in Prince William Sound (PWS) following the Exxon Valdez oil (EVO) spill. Biological effects were identical to those observed in embryolarval herring from PWS in 1989 and support the conclusion that EVO caused significant damage to herring in PWS. Previous demonstration by our laboratory that most malformed or precocious larvae die corroborates the decreased larval production measured after the spill.

RefID: 140

Author: Carls, M.G., Rice, S.D. and Thomas, R.E.

Year: 1995

Title: The impact of exposure of adult pre-spawn herring (Clupea harangues pallasi) on subsequent progeny, Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project 94166)

Journal: EVOS Trustee Council

Hyperlink: http://jlc-web.uaa.alaska.edu/client/arlis/search/detailnonmodal/ent:$002f$002fSD_ILS$002f232$002fSD_ILS:232768/one?qu=impact+of+exposure+of+adult+pre-spawn+herring

Abstract: The Exxon Valdez oil spill in Prince William Sound may have impaired reproduction and caused disease in herring stock. The primary objective of this laboratory study was to determine if exposure of parent fish would cause genetic damage in progeny. Reproductively ripe adult herring were exposed to oil in water to determine the presence or absence of direct toxic effects, damage to gonads, reduced resistance to disease, and genetic damage in larvae. Because it was not practical to measure germ line damage directly in the laboratory, efforts were focused on detection of chromosomal damage in the actively dividing somatic cells in the pectoral fins of larvae. Hydrocarbons accumulated in tissues of exposed herring, and mixed function oxidase activity was induced in liver tissue. Prevalence of viral hemorrhagic septicemia virus in adult herring increased as a function of oil concentration. Parental exposure to oil did not affect progeny. Parameters not affected included egg fertility, hatching success, hatch timing, embryo death, larval health (95 to 99% not moribund or dead within 24 h of hatch), larval swimming, larval abnormalities, stage of larval development at hatch, anaphase-telophase abnormalities, number of mitotic figures, number of pycnotic cells, and number of multinucleated or karyorrhectic cells.

RefID: 141

Author: Carls, M.G., Rice, S.D., Marty, G.D. and Naydan, D.K.

Year: 2004

Title: Pink salmon spawning habitat is recovering a decade after the Exxon Valdez oil spill

Journal: Transactions of the American Fisheries Society

Hyperlink: http://www.tandfonline.com/doi/abs/10.1577/T03-125.1

Abstract: Intertidal sediment surrounding many spawning streams for pink salmon Oncorhynchus gorbuscha in western Prince William Sound, Alaska, was contaminated by the Exxon Valdez oil spill in 1989. Biochemical and egg-dig evidence suggested that oil reduced the survival of pink salmon embryos for several years. Previous research also demonstrated that dissolved oil can be transferred to developing embryos from surrounding oiled sediment via drainage of interstitial water as a result of tidal cycling and hydraulic gradients. In this study, completed a decade after the spill, we sampled stream water for the presence of oil using passive membrane sampling devices, collected sediment and pink salmon eggs for hydrocarbon analysis, and examined alevins for induction of cytochrome P4501A (CYP1A). Polynuclear aromatic hydrocarbons (PAHs) consistent with Exxon Valdez oil were present in the water of one of six heavily impacted streams; total PAH concentrations in the stream were greatest in the lower intertidal zone. Similarly distributed total PAHs in a second stream suggested possible contamination. Oil was not detected in the remaining four streams. Induction of CYPIA in pink salmon alevins from the two contaminated streams was lowest in water above mean high tide and increased downstream. Because our samples were all selected from heavily oiled streams, we infer that most pink salmon spawning habitat either has recovered or is recovering.

RefID: 142

Author: Carls, M.G., Thomas, R.E., Lilly, M.R. and Rice, S.D.

Year: 2003

Title: Mechanism for transport of oil-contaminated groundwater into pink salmon redds

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v248/p245-255/

Abstract: Groundwater movement from oil-contaminated intertidal beaches to surface and subsurface water of salmon streams in Prince William Sound, Alaska, was studied to determine if transport of dissolved petroleum hydrocarbons to incubating pink salmon eggs (Oncorhynchus gorbuscha) was plausible. Beaches surrounding 31 % of the streams in the Sound were extensively oiled in 1989; salmon egg mortality was elevated even though little oil was observed in stream gravel. In 2000, fluorescent tracer dyes injected into 2 of these beaches during ebb tides were subsequently observed throughout most of the intertidal portion of each watershed, including surface and subsurface (hyporheic) stream water. Mean horizontal groundwater flow was rapid through the porous gravel (4 to 7 m h(-1)) and was driven by hydraulic gradients within beach groundwater. When different dyes were simultaneously released at ebb tide on opposite sides of a stream, each dye was detected in the beach opposite release within the first tidal ebb. Dye was moved vertically upward at least 0.5 m by subsequent incoming tides. Thus, tidal cycles and resultant hydraulic gradients provide a mechanism for groundwater transport of soluble and slightly soluble contaminants (such as oil) from beaches surrounding streams into the hyporheic zone where pink salmon eggs incubate.

RefID: 143

Author: Carls, M.G., Wertheimer, A.C., Short, J.W., Smolowitz, R.M. and Stegeman, J.J.

Year: 1996

Title: Contamination of juvenile pink and chum salmon by hydrocarbons in Prince William Sound after the Exxon Valdez oils spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: Juvenile pink salmon Oncorhynchus gorbuscha and chum salmon O. keta were collected from oiled nearshore marine habitats in Prince William Sound in 1989 and 1990 to determine if they were contaminated by exposure to Exxon Valdez crude oil. For comparison, fish were also collected from non-oiled, control areas located as close as possible to oiled areas. Mussels were routinely sampled to obtain site-specific measures of biological availability of hydrocarbons. Mussels were contaminated with polynuclear aromatic hydrocarbons (PAHs) in oiled areas in 1989 (6,942 ± 1,427 ng/g); much lower concentrations were observed in control locations (25 ± 13 ng/g). Contamination of mussel tissues persisted into 1990, but but at greatly reduced concentrations. In 1989, PAH concentrations were significantly greater in pink salmon tissues from oiled areas (181 ± 28 ng/g) than from non-oiled areas (54 ± 8 ng/g). In 1990, PAH concentrations (51 ± 7 ng/g) were not significantly different in oiled and non-oiled locations. Most of the PAHs found in pink salmon and mussel tissues were also found in Exxon Valdez crude oil. As may be expected after a single perturbation, PAH concentrations in mussels and pink salmon increased to peak levels after the spill and then declined. Cytochrome P4501A was significantly induced in juvenile pink and chum salmon from oiled location sin 1989 but not in 1990.

Based on these observations, we conclude that Exxon Valdez crude oil caused these differential changes in PAH concentrations and induced cytochrome P4501A enzyme activity. The degree of contamination of visceral tissues and the frequency of tissue types staining for P4501A indicated that ingestion of whole oil was an important route of contamination for juvenile pink and chum salmon. We believe contamination of juvenile salmon was physiologically significant and contributed to the reduced growth observed in juvenile pink salmon from oiled areas of Prince William Sound in 1989.

RefID: 144

Author: Carrera-Martinez, D., Mateos-Sanz, A., Lopez-Rodas, V. and Costas, E.

Year: 2011

Title: Adaptation of microalgae to a gradient of continuous petroleum contamination

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X10004261

Abstract: In order to study adaptation of microalgae to petroleum contamination, we have examined an environmental stress gradient by crude oil contamination in the Arroyo Minero River (AMR), Argentina. Underground crude oil has constantly leaked out since 1915 as a consequence of test drilling for possible petroleum exploitation. Numerous microalgae species proliferated in AMR upstream of the crude oil spill. In contrast, only four microalgal species were detected in the crude oil spill area. Species richness increases again downstream. Microalgae biomass in the crude oil spill area is dominated by a mesophile species, Scenedesmus sp. Effects of oil samples from AMR spill on photosynthetic performance and growth were studied using laboratory cultures of two Scenedesmus sp. strains. One strain (Se-co) was isolated from the crude oil spill area. The other strain (Se-pr) was isolated from a pristine area without petroleum contamination. Crude oil has undetectable effects on Se-co strain. In contrast crude oil rapidly destroys Se-pr strain. However, Se-pr strain can adapt to low doses of petroleum (<= 3% v/v total hydrocarbons/water) by means of physiological acclimatization. In contrast, only rare crude oil-resistant mutants are able to grow under high levels of crude oil (>= 10% v/v total hydrocarbons/water). These crude oil-resistant mutants have arisen through rare spontaneous mutations that occur prior to crude oil exposure. Species richness in different areas of AMR is closely connected to the kind of mechanism (genetic adaptation vs. physiological acclimatization) that allows adaptation. Resistant-mutants are enough to assure the survival of microalgal species under catastrophic crude oil spill. (C) 2010 Elsevier B.V. All rights reserved.

RefID: 145

Author: Caudle, K.L. and Maricle, B.R.

Year: 2014

Title: Physiological relationship between oil tolerance and flooding tolerance in marsh plants

Journal: Environmental and Experimental Botany

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0098847214001191

Abstract: Coastal salt marshes are highly susceptible to accidental oil spills. Oil can cover root tissues, inhibiting gas exchange and increasing root oxygen stress. This is similar to flooding; both conditions reduce the availability of oxygen to a plant. Therefore, it was hypothesized that tolerance to both flooding and oil are related in plants, as both impede gas exchange between roots and their environment. We investigated effects of oil on respiration and photosynthesis in nine marsh species ranging from flooding sensitive (hypothesized oil sensitive) to flooding tolerant (hypothesized oil tolerant). Plants were subjected to 6 L m(-2) light motor oil in greenhouse experiments for six weeks. Oil exposure caused root oxygen deficiency in all but the most flooding tolerant species. Alcohol dehydrogenase activities increased in roots of flooding sensitive species and moderately flooding tolerant plants under oil exposure, indicating oxygen stress. In contrast, flooding tolerant plants showed no sign of oxygen deficiency under oil treatment. Additionally, decreases in photosynthetic rates were measured in some species following oil exposure. Photosynthesis was reduced by non-stomatal limitations, suggesting toxic effects of oil. It was concluded that tolerance to oil relates to flooding tolerance when measured in terms of biochemical enzyme activity. Root alcohol dehydrogenase activity was a sensitive indicator of oil susceptibility, whereas leaf-level photosynthesis was less sensitive to oil. Relating flooding and oil tolerance based on physiological measures could help future efforts to protect marsh plants prior to an oil spill as well as manage coastal marshes following an oil spill.

RefID: 146

Author: Celewycz, A.G. and Wertheimer, A.C.

Year: 1996

Title: Prey Availability to Juvenile Salmon after the Exxon Valdez Oil Spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: The impact of the Exxon Valdez oil spill on potential prey resources of juvenile salmon was studied from April to June 1989 (zooplankton and epibenthic crustaceans) and 1990 (zooplankton only). Eight locations were sampled: two each in oiled and non-oiled bays, and two each in oiled and non-oiled corridors in western Prince William Sound. Zooplankton were sampled with 10-m hauls of an epibenthic sled at three nearshore habitat types: low-, medium-; and steep-gradient beaches. We did not detect any reduction in abundance of either zooplankton or epibenthic crustaceans important in the diet of juvenile salmon as a result of the Exxon Valdez oil spill. Density, biomass, and diversity (number of taxa) of zooplankton did not differ significanty between oiled and non-oiled locations in either 1989 or 1990. Biomass of harpacticoid copepods and all epibenthic crustaceans was significantly greater in oiled than in non-oiled locations. Diversity of epibenthic crustaceans, however, was similar in oiled and non-oiled locations. We conclude that the Exxon Valdez oil spill did not reduce the available prey resources of juvenile salmon in western Prince William Sound.

RefID: 147

Author: Chakraborty, R., Borglin, S.E., Dubinsky, E.A., Andersen, G.L. and Hazen, T.C.

Year: 2012

Title: Microbial response to the MC-252 oil and Corexit 9500 in the Gulf of Mexico

Journal: Frontiers in Microbiology

Hyperlink: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3468841/

Abstract: The Deepwater Horizon spill released over 4.1 million barrels of crude oil into the Gulf of Mexico. In an effort to mitigate large oil slicks, the dispersant Corexit 9500 was sprayed onto surface slicks and injected directly at the wellhead at water depth of 1,500 m. Several research groups were involved in investigating the fate of the MC-252 oil using newly advanced molecular tools to elucidate microbial interactions with oil, gases, and dispersant. Microbial community analysis by different research groups revealed that hydrocarbon degrading bacteria belonging to Oceanospirillales, Colwellia, Cycloclasticus, Rhodobacterales, Pseudoalteromonas, and methylotrophs were found enriched in the contaminated water column. Presented here is a comprehensive overview of the ecogenomics of microbial degradation of MC-252 oil and gases in the water column and shorelines. We also present some insight into the fate of the dispersant Corexit 9500 that was added to aid in oil dispersion process. Our results show the dispersant was not toxic to the indigenous microbes at concentrations added, and different bacterial species isolated in the aftermath of the spill were able to degrade the various components of Corexit 9500 that included hydrocarbons, glycols, and dioctyl sulfosuccinate.

RefID: 148

Author: Chao, M., Shen, X., Lun, F., Shen, A. and Yuan, Q.

Year: 2012

Title: Toxicity of Fuel Oil Water Accommodated Fractions on Two Marine Microalgae, Skeletonema costatum and Chlorela spp

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007/s00128-012-0525-y

Abstract: In this paper, the acute toxicity of four fuel oils including F120, F180, F380 and No.-20 was evaluated by exposing the marine microalgae Chlorela spp. (Chlorophyta) and Skeletonema costatum (Bacillariophyta) in the fuel oil water accommodated fractions (WAF). The bioassay showed that F180 WAF was the most toxic to both microalgae. The 96 h EC50 value of F180 WAF for Skeletonema costatum and Chlorela spp. was 9.41 and 13.63 mg/L expressed in concentration of total petroleum hydrocarbons, respectively. WAFs of F120, F180 and F380 were more toxic to Skeletonema costatum than to Chlorela spp. In contrast, No.-20 WAF did not show significant toxicity for both Skeletonema costatum and Chlorela spp.

RefID: 149

Author: Chase, D.A. Edwards, D.S., Qin, G., Wages, M.R., Willming, M.M., Anderson, T.A. and Maul, J.D.

Year: 2013

Title: Bioaccumulation of petroleum hydrocarbons in fiddler crabs (Uca minax) exposed to weathered MC-252 crude oil alone and in mixture with an oil dispersant

Journal: Science of the Total Environment

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0048969712015112

Abstract: The Deepwater Horizon accident in the Gulf of Mexico resulted in a sustained release of crude oil, and weathered oil was reported to have washed onto shorelines and marshes along the Gulf coast. One strategy to minimize effects of tarballs, slicks, and oil sheen, and subsequent risk to nearshore ecosystem resources was to use oil dispersants (primarily Corexit (R) 9500) at offshore surface and deepwater locations. Data have been generated reporting how Corexit 9500 and other dispersants may alter the acute toxicity of crude oil (Louisiana sweet crude) to marine organisms. However, it remains unknown how oil dispersants may influence bioaccumulation of petroleum hydrocarbons in nearshore crustaceans. We compare bioaccumulation of petroleum hydrocarbons in fiddler crabs (Uca minax) from exposures to the water accommodated fraction (WAF) of weathered Mississippi Canyon 252 oil (similar to 30 d post spill) and chemically-enhanced WAF when mixed with Corexit (R) EC9500A. Whole body total petroleum hydrocarbon (TPH) concentrations were greater than background for both treatments after 6 h of exposure and reached steady state at 96 h. The modeled TPH uptake rate was greater for crabs in the oil only treatment (k(u) = 2.51 mL/g/h vs. 0.76 mL/g/h). Furthermore, during the uptake phase TPH patterns in tissues varied between oil only and oil+dispersant treatments. Steady state bioaccumulation factors (BAFs) were 19.0 mL/g and 14.1 mL/g for the oil only and oil+Corexit treatments, respectively. These results suggest that the toxicokinetic mechanisms of oil may be dependent on oil dispersion (e.g., smaller droplet sizes). The results also indicate that multiple processes and functional roles of species should be considered for understanding how dispersants influence bioavailability of petroleum hydrocarbons. (C) 2012 Elsevier B.V. All rights reserved.

RefID: 150

Author: Cheney, M.A., Liu, J., Amei, A., Zhao, X., Joo, S.W. and Qian, S.

Year: 2009

Title: A comparative study on the uptake of polycyclic aromatic hydrocarbons by Anodonta californiensis

Journal: Environmental Pollution

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0269749108004417

Abstract: Uptake of polycyclic aromatic hydrocarbons (PAHs) by the freshwater bivalve mollusc Anodonta californiensis was examined in the presence and absence of surfactant in order to gain further insight into mixture toxicity and to predict whether certain mixtures have negative and/or positive effects on aquatic organisms. In the presence of surfactant, the uptake of anthracene or chrysene was higher than that of naphthalene, given the same concentration in the solution. In the absence of surfactant, the trend was similar, but the uptakes were increased by approximately 100% compared to those in the presence of surfactant. On the uptake of naphthalene, the presence of anthracene showed only minor influence. The uptake of anthracene was affected by both naphthalene and chrysene. The uptake of chrysene was influenced by neither naphthalene nor anthracene. There was no observable displacement of divalent cations from the surface of the gill membrane by any of the PAHs studied. (C) 2008 Elsevier Ltd. All rights reserved.

RefID: 151

Author: Claireaux, G., Desaunay, Y., Akcha, F., Auperin, B., Bocquene, G., Budzinski, F.N., Cravedi, J.P., Davoodi, F., Galois, R., Gilliers, C., Goanvec, C., Guerault, D., Imbert, N., Mazeas, O., Nonnotte, G., Nonnotte, L., Prunet, P., Sebert, P. and Vettier, A.

Year: 2004

Title: Influence of oil exposure on the physiology and ecology of the common sole Solea solea: Experimental and field approaches

Journal: Aquatic Living Resources

Hyperlink: http://journals.cambridge.org/download.php?file=%2FALR%2FALR17_03%2FS0990744004000439a.pdf&code=f2852c8a89bdce6ab38b329bcd41b762

Abstract: Evaluating the ecological impact of an oil spill is a complex issue requiring coherently articulated examination of the sequence of interactions that link the cell, where contaminants exert their effects, to the ecosystem, where interactions with human activities arise. This sequence of interactions traverses the frontiers between scientific disciplines (chemistry, toxicology, physiology, and fisheries ecology). Using the common sole (Solea solea L.) as a model species for the coastal habitats polluted by the "Erika" oil spill, our research project attempted to define indices of functional integrity that characterised the consequences of fuel exposure at the different biological levels. The coupling of field observations with experimental laboratory work revealed how functional alterations which are readily observable within individuals and their organs are progressively obscured as investigation progresses towards more complex organisational levels. Some of the approaches and indices are proposed as instruments for evaluating the impact of contamination by hydrocarbons.

RefID: 152

Author: Clark Jr, R.C., Patten, B.G. and DeNike, E.E.

Year: 1978

Title: Observations of a Cold-Water Intertidal Community After 5 Years of a Low-Level, Persistent Oil Spill from the General M.C. Meigs

Journal: Journal of the Fisheries Research Board of Canada

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f78-125

Abstract: A rich and productive intertidal community was exposed continually for over 5 yr to small quantities of a Navy Special fuel oil from the unmanned troopship General M.C. Meigs that came aground on the Washington coast in January 1972. Observations of animal and plant populations and their petroleum hydrocarbon uptake patterns showed early evidence of contamination and the persistence of the oil spill throughout the study period. Abnormal and dead urchins, and loss of algal fronds and pigment were observed in localized areas near the wreck for at least 1 yr. Within 2 mo of the accident, paraffinic hydrocarbons had been taken up by prominent members of the community and continued to appear in certain species even after 5 yr. Although changes were seen in certain species during the early days of this persistent low-level pollution incident, the community balance in this rocky, intertidal ecosystem does not appear to have been markedly altered

RefID: 153

Author: Colavecchia, M.V., Backus, S.M., Hodson, P.V. and Parrott, J.L.

Year: 2004

Title: Toxicity of oil sands to early life stages of fathead minnows (Pimephales promelas)

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/03-412/full

Abstract: The present study examines the effects of exposure to oil sands on the early life stages (ELS) of fathead minnows (Pimephales promelas). Sediments within and outside natural oil sand deposits were collected from sites along the Athabasca River (AB, Canada). The ELS toxicity tests were conducted with control water, natural oil sands, reference sediments, and oil-refining wastewater pond sediments. Eggs and larvae were exposed to 0.05 to 25.0 g sediment/L and observed for mortality, hatching, malformations, growth, and cytochrome P4501 A induction as measured by immunohistochemistry. Natural bitumen and wastewater pond sediments caused significant hatching alterations and exposure-related increases in ELS mortality, malformations, and reduced size. Larval deformities included edemas, hemorrhages, and spinal malformations. Exposure to reference sediments and controls showed negligible embryo mortality and malformations and excellent larval survival. Sediment analyses using gas chromatography-mass spectrometry revealed high concentrations of alkyl-substituted polyaromatic hydrocarbons (PAHs) compared to unsubstituted PAHs in natural oil sands (220-360 mug/g) and oil-mining wastewater pond sediments (1,300 mug/g). The ELS sediment toxicity tests are rapid and sensitive bioassays that are useful in the assessment of petroleum toxicity to aquatic organisms.

RefID: 154

Author: Colavecchia, M.V., Hodson, P.V. and Parrott, J.L.

Year: 2007

Title: The relationships among CYP1A induction, toxicity, and eye pathology in early life stages of fish exposed to oil sands

Journal: Journal of Toxicology and Environmental Health

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/15287390701384726

Abstract: Exposure of the early life stages of fish to oil sands constituents is associated with mortality and larval malformations such as edemas, hemorrhages, and skeletal, craniofacial, and eye defects. In fathead minnow (Pimephales promelas) and white sucker (Catostomus commersoni) larvae, indices of total eye pathology increased significantly following oil sands exposure. Structural, cytoplasmic, inflammatory, and degenerative eye alterations included poor retinal differentiation, microphthalmia, optic fissures, dysphasic retinas and lenses, inflammatory infiltrates, retinal epithelial lifting, and necrotic foci. Cytochrome P-4501A (CYP1A) was expressed in ocular (retina, lens) and kidney endothelial tissues, as indicated by immunohistochemistry. Although the kinetics of exposure-response curves for mortality and CYP1A expression were similar in both species, species differences in the magnitude and sensitivity of the responses were observed. Oil sands were twofold more toxic to fathead minnows (TPAH LC50 = 47-330 mu g/g) than to white sucker (TPAH LC50 = 95-860 mu g/g) larvae. For both species, larval mortality was significantly related to CYP1A protein concentrations in kidneys, and severity of these effects rose with oil sands exposure. The relationships among eye damage, mortality, and CYP1A indices warrants further investigation, and may lead to the use of CYP1A induction as an indicator of adverse effects rather than just contaminant exposure.

RefID: 155

Author: Colavecchia, M.V., Hodson, P.V. and Parrott, J.L.

Year: 2006

Title: CYP1A induction and blue sac disease in early life stages of white suckers (Catostomus commersoni) exposed to oil sands

Journal: Journal of Toxicology and Environmental Health

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/15287390500362154

Abstract: The objectives of this study were to evaluate the influence of natural oil sands on the early developmental stages of white sucker (Catostomus commersoni) and to determine whether biochemical responses in this species were similar to native fish caught in the Athabasca Oil Sands area. Early life stage (ELS) sediment toxicity tests were conducted using controls, reference sediments, natural oil sands, and industrially contaminated (wastewater pond) sediments collected from sites along the Athabasca River, Alberta (Canada). Eggs and larvae were observed for mortality, hatching, deformities, growth, and cytochrome P-4501A (CYP1A) activity using immunohistochemistry. E-Nat-, S-Nat-, and wastewater pond sediment-exposed groups showed significant premature hatching, reduced growth, and exposure-dependent increases in ELS mortality and larval malformations relative to controls. The most common larval deformities included edemas (pericardial, yolk sac, and subepidermal), hemorrhages, and spinal defects. Juveniles exposed to oil sands and wastewater pond sediments (96 h) demonstrated significantly increased 7-ethoxyresorufin-O-deethylase (EROD) activity (30-to50-fold) as compared to controls. Reference sediment-exposed groups and water controls demonstrated reliable embryo and larval survival, minimal malformations, and negligible CYP1A staining. These observed signs of blue sac disease (ELS mortality, malformations, growth reductions, CYP1A activity induction) may produce deleterious reproductive effects in natural fish populations exposed to oil sands mixtures.

RefID: 156

Author: Collier, T.K., Anulacion, B.F., Arkoosh, M.R., Dietrich, J.P., Incardona, J.P., Johnson, L.L., Ylitalo, G.M. and Myers, M.S.

Year: 2014

Title: Effects on Fish of Polycyclic Aromatic Hydrocarbons (PAHS) and Naphthenic Acid Exposures

Journal: Fish Physiology

Hyperlink: http://www.sciencedirect.com/science/article/pii/B9780123982544000042

Abstract: Polycyclic aromatic hydrocarbons (PAHs) are derived from both natural and anthropogenic sources and are released from a wide range of industries and everyday activities. Unlike many other organic chemical contaminants that are manufactured and regulated, PAHs continue to be released on a global scale because of the world's dependence on fossil fuels. This chapter briefly reviews the transformation of PAHs in the aquatic environment, highlighting their efficient metabolism in fish and focuses on evidence that links PAH exposure to a wide range of biological dysfunctions in fish. These dysfunctions include neoplasia, reduced reproductive success and other types of endocrine disruption, immunotoxicity, postlarval growth and somatic condition, transgenerational impacts, and finally, recent findings showing that the embryonic development of fish is severely affected by extremely low concentrations of PAH exposure. A brief review of the effects of naphthenic acids on fish is also included because these compounds are increasingly recognized as major factors in the toxicity of process waters from a variety of petroleum sources, most notably the immense oil sands deposits found in Alberta, Canada.

RefID: 157

Author: Collier, T.K., Krone, C.A., Krahn, M.M., Stein, J.E., Chan, S.L. and Varanasi, U.

Year: 1996

Title: Petroleum exposure and associated biochemical effects in subtidal fish after the Exxon Valdez oil spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: After the axon Valdez oil spill, petroleum exposure in subtidal fish species was assessed by determining levels of fluorescent aromatic compounds (FACs) in fish bile. The biochemical effects of this exposure were assessed by ill induction of a specific cytochrome P450, cytochrome P-4501A (CYPIA), and levels of deoxyribonucleic acid (DNA) adducts by 32P-postlabeling. These studies were conducted at sites inside Prince William Sound and along the Kenai and Alaska peninsulas. The species examined were Dolly Varden Salvelinus malma, yellowfin sole Pleuronectes asper, rock sole P. bilineatus, flathead sole Hippoglossoides elassodon, and walleye pollock Theragra chalcogramma. For the Dolly Varden, a littoral-zone species, exposure was greatest in the 1989 sampling and dropped considerably by 1990; however, for nearshore benthic species (i.e., yellowfin, rock, and flathead soles), exposure continued into 1990 and 1991. Walleye pollock showed evidence of exposure when they were first sampled in 1990, at sites more than 640 km from where the Exxon Valdez went aground. Generally, CYPIA induction showed temporal trends that were similar to trends in FAC data, and was shown to be a useful measure of oil exposure, however, in two of the most heavily exposed species, there was no evidence of increased formation of petroleum-derived DNA adducts. Overall, the results show a continuing exposure of several subtidal fish species, suggesting that petroleum contamination of subtidal areas needs to be considered in assessing the impacts of major oil spills. Still to be determined are the potential impacts on fishery resources of long-term exposure to petroleum, albeit at moderate to low levels.

RefID: 158

Author: Costa, D.P. and Kooyman, G.L.

Year: 1982

Title: Oxygen consumption, thermoregulation, and the effect of fur oiling and washing on the sea otter, Enhydra lutris.

Journal: Canadian Journal of Zoology

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/z82-354

Abstract: The relative importance of a water-repellent fur was assessed by changes in oxygen consumption and in body and subcutaneous temperatures before and after oiling and washing in 15 °C water. In addition, changes in posture and in five sea otters were measured while immersed in water from 5 to 30 °C. Measurements were made in an enclosed water bath with Vo2 determined by open-flow respirometry. Core body and subcutaneous temperatures were telemetered. Resting was 11.7 mL O2·kg−1·min−1 and did not significantly increase with decreasing temperature. Average and active increased with decreasing temperature. Average (16.0 mL O2·kg−1·min−1) increased 41% (22.0 mL O2·kg−1·min−1) after oiling 20% of the total fur surface and more than doubled (32.6 mL O2·kg−1·min−1) after washing. Oiling and washing reduced the fur's insulating quality. The result was an energetic liability, since the average maintenance doubled in 15 °C water; this temperature is above typical water temperatures for this species, which range from 0 °C (Alaska) to 12 °C (California). Average returned to control levels after a minimum of 8 days.

RefID: 159

Author: Couillard, C.M.

Year: 2002

Title: A microscale test to measure petroleum oil toxicity to mummichog embryos

Journal: Environmental Toxicology

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/tox.10049/abstract

Abstract: A test was developed to compare the toxicity of different petroleum oils to mummichog (Fundulus heteroclitus) embryos. Fertilized eggs were incubated for 11 days at 22.5degreesC directly on the surface of oil-contaminated sand without a superficial water layer. The mortality rates, the stage of development, and the prevalence of malformations were determined. No effect was found in controls incubated on sand with water and mineral oil as compared with controls on sand with water alone. Two weathered oils, an Alaska North Slope crude oil (ANCO) and a Mesa light crude oil (MLCO), produced similar symptoms of toxicity: retarded growth and development, pericardial edema, hemostasis, hemorrhages, and spinal deformities. These symptoms are consistent with those observed in other fish species exposed to petroleum oils, suggesting that the results of the bioassay would be applicable to other species. MLCO was more embryotoxic than ANCO. The minimal oil concentrations causing a significant reduction in body length were 4.5 mug oil/g sand for MLCO and 12.7 mug oil/g for ANCO, indicating the assay is sensitive. The slopes and the intercepts of the relationships between concentration and growth did not differ in three dose-response experiments conducted with each oil, indicating that the assay is reliable. Finally, the bioassay is less costly than other available options to assess the toxicity of petroleum oils to marine fish embryos. Further work to improve the standardization of the assay will involve comparison of the toxicity of petroleum oils with reference toxicants and selection of a standard substrate. (C) 2002 Wiley Periodicals, Inc.

RefID: 160

Author: Couillard, C.M., Lee, K., Légaré, B. and King, T.L.

Year: 2005

Title: Effect of dispersant on the composition of the water-accommodated fraction of crude oil and its toxicity to larval marine fish

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/04-267R.1/full

Abstract: Newly hatched mummichog (Fundulus heteroclitus) were exposed in a 96-h static renewal assay to water-accommodated fractions of dispersed crude oil (DWAF) or crude oil (WAF) to evaluate if the dispersant-induced changes in aqueous concentrations of polycyclic aromatic hydrocarbons (PAH) affected larval survival, body length, or ethoxyresorufin-O-deethylase (EROD) activity. Weathered Mesa light crude oil (0.05-1 g/L) and filtered seawater with or without the addition of Corexit 9500 were used to prepare DWAF and WAF At 0.2 g/L, the addition of dispersant caused a two- and fivefold increase in the concentrations of total PAH (&USigma; PAH) and high-molecular-weight PAH (HMWPAH) with three or more benzene rings. Highest mortality rates (89%) were observed in larvae exposed to DWAF (0.5 g/L; &USigma; PAH, 479 ng/ml). A reduction in body length was correlated with increased levels of &USigma; PAH (r(2) = 0.65, p = 0.02) and not with HMWPAH. The EROD activity increased linearly with HMWPAH (r(2) = 0.99, p = 0.001) and not with &USigma; PAH. Thus, chemical dispersion increased both the &USigma; PAH concentrations and the proportion of HMWPAH in WAF Dispersed HMWPAH were bioavailable, as indicated by a significantly increased EROD activity in exposed mummichog larvae, and this may represent a significant hazard for larval fish.

RefID: 161

Author: Craig, A.K., Willette, T.M., Evans, D.G. and Bue, B.G.

Year: 2002

Title: Injury to pink salmon embryos in Prince William Sound - field monitoring

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/51611533.pdf

Abstract: We examined pink salmon embryo mortality in oil-contaminated and reference streams in Prince William Sound. Pink salmon embryo mortalities were significantly greater in oiled than in reference streams during 1989-1993 (P<O.O20). Results from controlled incubation studies conducted in 1993 and 1994 were consistentwith results obtained from field sampling indicating that natural environmental differences between oiled and reference streams did not cause differences in embryo mortality. From 1994 through 1996, embryo mortalities were not significantly different (mO.400) between oiled and reference streams. In 1997, embryo mortalities were again significantly greater (P=O.O17) in oiled than in reference streams possibly due to a minor shift in the location of stream deltas or sampling-induced mechanical shock. Weconducted several statistical analyses of our embryo mortality data to evaluate whether sampling-induced mechanical shock affected our results. Our analysis using samplingdate as a covariate indicated no significant effect of sampling-induced mechanical shock on our results. However, analyses using a measure of the difference between spawnt iming and sampling date (Day 75) as a covariate indicated that sampling-induced mechanical shock may have affected our results. But, questions regarding the usefulnessof Day 75 as a measure of embryo sensitivity to mechanical shock in specific years and lack of sufficient run timing data in most years leaves us unable to conclusivelydetermine the magnitude of the effect.

RefID: 162

Author: Cretney, W.J., Wong, C.S., Green, D.R. and Bawden, C.A.

Year: 1978

Title: Long-Term Fate of a Heavy Fuel Oil in a Spill-Contaminated B.C. Coastal Bay

Journal: Journal of the Fisheries Research Board of Canada

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f78-096

Abstract: The fate of accidently spilled No. 5 fuel oil in a small coastal bay in British Columbia was observed 6 times during 4 yr. The oil's composition was first changed by loss of the lower molecular weight components by evaporation and dissolution. Biodegradation accounted for almost complete removal of n-alkanes in the 1st yr. Pristane and phytane were biodegraded more slowly, but were almost completely gone in 4 yr. The non-n-alkane components in the nC28–30 range seem to be the most resistant to degradation of all the components resolved in the gas chromatograms. The resistance to degradation of these components indicates their potential for long-term studies of oil spills.

RefID: 163

Author: Croce, B. and Stagg, R.M.

Year: 1997

Title: Exposure of Atlantic salmon parr (Salmo salar) to a combination of resin acids and a water soluble fraction of diesel fuel oil: A model to investigate the chemical causes of Pigmented Salmon Syndrome

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620160922/abstract

Abstract: Pigmented Salmon Syndrome is a pollutant-induced hemolytic anemia and hyperbilirubinemia. As part of an investigation of this condition, S2 Atlantic salmon parr (Saline salar) were exposed to a diesel fuel oil, water soluble fraction (WSF) in combination with a mixture of three resin acids (isopimaric, dehydroabietic, and abietic acids) in a continuous-flow freshwater system. The total nominal concentrations of resin acids in the exposure tanks were 10, 50, and 100 mu g/L; the diesel WSF was generated in situ and provided a mean hydrocarbon concentration of 2.0 +/- 0.1 mg/L (n = 12) during the 9-d exposure period. Exposure to the diesel WSF alone depressed liver bilirubin UDP-glucuronosyl transferase (UDPGT) activity and induced phenol UDPGT activity. Exposure to the diesel WSF in the absence or presence of resin acids induced liver cytochrome P4501A and increased the concentrations in the plasma of the enzymes lactate dehydrogenase, alkaline phosphatase, and glutamic oxaloacetic transaminase. The combined exposure to diesel WSF with either 50 or 100 mu g/L total resin acid caused significant elevations in the concentrations of bilirubin in the plasma and many of these fish had yellow pigmentation on the ventral surface and around the gill arches. The results demonstrate that exposure to combinations of two groups of contaminants can result in the manifestation of toxic effects not apparent From exposure to either of these chemicals in isolation.

RefID: 164

Author: Cronin, M.A. and Bickham, J.W.

Year: 1998

Title: A population genetic analysis of the potential for a crude oil spill to induce heritable mutations and impact natural populations

Journal: Ecotoxicology

Hyperlink: http://link.springer.com/article/10.1023/A:1008887712459

Abstract: The primary environmental impact following an oil spill typically is acute toxicity to fish and wildlife. However, multigenerational effects through toxicant-induced heritable mutations might also occur. Some polycyclic aromatic hydrocarbon (PAH) components of crude oil are potentially mutagenic, although specific components and doses that induce mutations are poorly known. We applied population genetics concepts to assess the extent of mortality and the persistence of deleterious heritable mutations resulting from exposure to potential mutagens, such as crude oil. If lethal mutations are induced, the population will experience some mortality, but the mutations are quickly removed or reduced to low frequency by natural selection. This occurs within one or a few generations when mutations are dominant or partially recessive. Totally recessive alleles persist in low frequency for many generations, but result in relatively little impact on the population, depending on the number of mutated loci. We also applied population genetics concepts to assess the potential for heritable mutations induced by the Exxon Valdez oil spill in Prince William Sound, Alaska, to affect pink salmon populations. We stress that breeding units (e.g., streams with distinct spawning populations of salmon) must be considered individually to assess heritable genetic effects. For several streams impacted by the oil spill, there is inconsistency between observed egg mortality and that expected if lethal heritable mutations had been induced by exposure to crude oil. Observed mortality was either higher or lower than expected depending on the spawning population, year, and cohort considered. Any potential subtle effect of lethal mutations induced by the Exxon Valdez oil spill is overridden by natural environmental variation among spawning areas. We discuss the need to focus on population-level effects in toxicological assessments because fish and wildlife management focuses on populations, not individuals.

RefID: 165

Author: Cronin, M.A. and Maki, A.W.

Year: 2004

Title: Assessment of the genetic toxicological impacts of the Exxon Valdez oil spill on pink salmon (Oncorhynchus gorbuscha) may be confounded by the influence of hatchery fish

Journal: Ecotoxicology

Hyperlink: http://link.springer.com/article/10.1023%2FB%3AECTX.0000037202.33461.d0

Abstract:

RefID: 166

Author: Cronin, M.A., Wickliffe, J.K., Dunina, Y. and Baker, R.J.

Year: 2002

Title: K-ras oncogene DNA sequences in pink salmon in streams impacted by the Exxon Valdez oil spill: No evidence of oil-induced heritable mutations

Journal: Ecotoxicology

Hyperlink: http://link.springer.com/article/10.1023%2FA%3A1016391919495

Abstract: It was hypothesized in previous studies that the Exxon Valdez oil spill in Prince William Sound, Alaska, induced heritable mutations and resulted in mortality of pink salmon (Oncorhynchus gorbuscha) embryos. In one of these studies, laboratory exposure of pink salmon embryos to crude oil resulted in apparent mutation-induction in exon 1 and exon 2 of the K-ras oncogene, but no fish from the area impacted by the oil spill were analyzed. We assessed K-ras exon 1 and exon 2 DNA sequences in pink salmon from five streams that were oiled and five streams that were not oiled by the Exxon Valdez oil spill in Prince William Sound, and two streams with natural oil seeps and one stream without seeps on the Alaska Peninsula. Of the 79 fish analyzed for exon 1 and the 89 fish analyzed for exon 2, none had the nucleotide substitutions representing the mutations induced in the laboratory study. Other variable nucleotides occurred in similar proportions in oiled and non-oiled streams and probably represent natural allelic variation. These data do not support the hypothesis that heritable mutations in the K-ras gene were induced by the Exxon Valdez oil spill or oil seeps.

RefID: 167

Author: Crowe, K.M., Newton, J.C., Kaltenboeck, B. and Johnson, C.

Year: 2014

Title: OXIDATIVE STRESS RESPONSES OF GULF KILLIFISH EXPOSED TO HYDROCARBONS FROM THE DEEPWATER HORIZON OIL SPILL: POTENTIAL IMPLICATIONS FOR AQUATIC FOOD RESOURCES

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.2427/full

Abstract: Ecosystem effects of polycyclic aromatic hydrocarbons (PAHs) remain under investigation following the Gulf of Mexico Deepwater Horizon oil spill. Fundulus grandis, an established indicator of aquatic ecosystem health, was investigated because this species shares genes and biochemical pathways with higher trophic-level fish and plays an important role in the gulf food chain. Oxidative stress responses including hepatic cytochrome P4501A (CYP1A) and serum antioxidant capacity were evaluated in fish exposed to PAHs. Fish were exposed to water-accommodated fractions (WAFs) of crude oil (7.0 +/- 0.10mg/L C6-C28) after which solutions were diluted below the level of detection over 8h using 15 ppt aerated artificial seawater. Before euthanasia, fish remained in aquaria for 12h, 24h, or 48h. Three replicate experiments were conducted at each time point using unexposed fish as experimental controls. Significant differences ($p<0.05$) in CYP1A induction were observed in exposed versus control fish at 24h. Expression of CYP1A increased by 25%, 66%, and 23% in exposed fish at 12h, 24h, and 48h, respectively. Significant increases were observed in antioxidant capacity of nonenzymatic antioxidants in exposed versus control fish at each time point. Given the activity of CYP1A, radicals formed during PAH detoxification likely resulted in increased oxidant load requiring elevated antioxidant defenses. Research is needed to determine the duration of oxidative stress responses considering the potential for lipid oxidation in exposed fish or species feeding on exposed fish. (c) 2013 SETAC

RefID: 168

Author: Da Silva, A.Z., Zanette, J., Ferreira, J.F., Guzenski, J., Marques, M.R.F. and Bainy, A.C.D.

Year: 2005

Title: Effects of salinity on biomarker responses in Crassostrea rhizophorae (Mollusca, Bivalvia) exposed to diesel oil

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/16216631

Abstract: Crassostrea rhizophorae is a euryhaline oyster that inhabits mangrove areas, which are widely distributed along the Brazilian coast. The aim of this study was to investigate the effects of salinity (9, 15, 25, and 35ppt) on the activities of glutathione S-transferase (GST), glucose 6-phosphate dehydrogenase (G6PDH), catalase (CAT), and acetylcholinesterase (AChE) in the digestive gland of this species after exposure to diesel oil for 7 days at nominal concentrations of 0.01, 0.1, and 1 ml L(-1) and after depuration for 24 h and 7 days. GST activity increased in a diesel oil concentration-dependent manner at salinities 25 and 15 ppt and remained slightly elevated even after depuration periods of 24 h and 7 days. No changes were observed in the activities of G6PDH, CAT, and AChE in the oysters exposed to diesel and depurated. Based on these results, GST activity in the digestive gland of C rhizophorae might be used as a biomarker of exposure to diesel oil in sites where the salinity is between 15 and 25 ppt, values usually observed in mangrove ecosystems. (c) 2005 Elsevier Inc. All rights reserved.

RefID: 169

Author: Dahlheim, M.E.

Year: 1994

Title: Assessment of injuries and recovery monitoring of Prince William Sound killer whales using photo-identification techniques

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/F/34458738.pdf

Abstract: Photo-identification studies of individual killer whales inhabiting Prince William Sound were collected from 1989-91 and from July to September 1993 to determine the impact of the spill on whale abundance and distribution (1989-1991) and monitor recovery (1993). Concurrent photo-identification studies were also conducted in Southeast Alaska to determine if PWS killer whales were displaced to other areas between 1989 and 1991. Despite inc~ effort, the number of encounters with PWS killer whales appears to be decreasing. Analysis of photographic data revealed 14 animals missing from AB pod over the three-year period. Mortality rates for AB pod ranged from 3.1 % in 1988 to 19.4% in 1989, 20.7% in 1990, and 4.3% in 1991. Zero mortality occurred in 1992 and 1993. Mortality rates on the order of 20% are unprecedented for North Pacific killer whales. No new calves were born into AB pod in 1989 or 1990. There was one calf born in 1991, two born in 1992, and one born in 1993. AB pod size in 1988 was 36; in late 1993 the pod had 26 members. The cause(s) of the disappearance of 14 killer whales from AB pod is unknown. We assume, that the whales are dead from natural causes, a result of interactions with fisheries, from the spill, or a combination of these causes.

RefID: 170

Author: Dahlheim, M.E. and Matkin, C.O.

Year: 1993

Title: Assessment of injuries to killer whales in Prince William Sound

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/34458819.pdf

Abstract: Photo-identification studies of individual killer whales inhabiting Prince William Sound were collected from 1989-91 to determine the impact of the spill on whale abundance and distribution. Concurrent photo-identification studies were also conducted in Southeast Alaska to determine if PWS killer whales were displaced to other areas. Despite increased effort, the number of encounters with PWS killer whales appears to be decreasing. Analysis of photographic data revealed 14 animals missing from AB pod over the three-year period. Mortality rates for AB pod ranged from 3.1% in 1988 to 19.4% in 1989, 20.7% in 1990, and 4.3% in 1991. Mortality rates on the order of 20% are unprecedented for North Pacific killer whales. No new calves were born into AB pod in 1989 or 1990. There was one calf born in 1991 and two born in 1992. AB pod size in 1988 was 36; in late 1992 the pod had 25 members. The cause(s) of the disappearance of 14 killer whales from AB pod is unknown. We assume, that the whales are dead from natural causes, a result of interactions with fisheries, from the spill, or a combination of these causes.

RefID: 171

Author: Dahlheim, M.E. and Matkin, C.O.

Year: 1994

Title: Assessment of injuries to Prince William Sound killer whales

Journal: Marine mammals and the Exxon Valdez

Hyperlink: http://www.amazon.com/Marine-Mammals-Valdez-Thomas-Loughlin/dp/0124561608

Abstract:

RefID: 172

Author: Dahlheim, M.E. and von Ziegesar, O.

Year: 1993

Title: Effects of the Exxon Valdez oil spill on the abundance and distribution of humpback whales (Megaptera novaeangliae) in Prince William Sound

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/34458592.pdf

Abstract: Photo-identification studies of Prince William Sound humpback whales were conducted from May to September in 1989 and 1990 to assess the impact of the spill on humpback whale life history and ecology. In 1989, concurrent studies were conducted in Southeast Alaska on humpback whales to determine if whales avoided contaminated waters of Prince William Sound and moved to other northern feeding areas. In 1989, photographic analysis of Prince William Sound humpbacks resulted in the identification of 59 whales. In 1990, 66 whales were documented. More whales were seen in these two seasons than any year previous to the spill. The increase in whale sightings may have been due to the increase in effort during the 1989 and 1990 season. Because of the difference in survey effort before and after the spill, it is impossible to determine if there was a difference in the number of humpback whales using the Sound. Distribution varied among years and may be related to prey distribution. Only one Prince William Sound humpback whale was documented to move from Prince William Sound to southeastern Alaska during the 1989 season. Calving rates during 1989 and 1990 were not significantly different than in previous years. No reports of dead stranded humpback whales occurred during the study period. No observations were made of humpback whales swimming through oil.

RefID: 173

Author: Danish, E.Y.

Year: 2010

Title: Ecological impact from chemicals in the Arabian Gulf due to Gulf oil spill

Journal: Water and Environment Journal

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1111/j.1747-6593.2008.00145.x/abstract

Abstract: This paper presents a systematic methodology to assess ecological impact from chemicals released because of oil spills in the Arabian Gulf. The methodology proposed here compiles data on chemical behaviour and their partitioning in water and sediment and their impact on ecological entities present in the Arabian Gulf region. The proposed methodology is supported through a case study. This paper also evaluates marine impact of chemicals in the Arabian Gulf from the oil spills and their toxicity data. The main emphasis in the paper is on how to best use the available data for decision-making purposes. A case study of the Gulf Oil spill of 1991 was used to demonstrate the methodology with limited parameters but it can be generalized if more concentration data and their partitioning numbers are

RefID: 174

Author: Dauvin, J.C. and Ruellet, T.

Year: 2007

Title: Polychaete/amphipod ratio revisited

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X06003250

Abstract: In this paper, we reexamine the opportunistic polychaete/amphipod ratio, modifying it to allow estuarine and coastal communities to be divided into the five classes suggested by the European Water Framework Directive (WFD). The resulting biological index, called the BOPA index, considers the total number of individuals collected in the samples, the frequency of opportunistic polychaetes, and the frequency of amphipods (except the genus Jassa). After comparing this new index to AMBI and BENTIX, two other indices that have been proposed in the literature, we tested it in two situations involving soft-bottom communities in the English Channel (Bay of Morlaix and Bay of Seine). Our results show that the BOPA index is simple to use. Amphipods and opportunistic polychaetes (21 species, nine genus and two families from the AZTI list for a total of 3459 taxa) are easy to identify, providing that both the number of these organisms in a sample and the total number of individuals collected (independent of the sampling surface) is known. The BOPA is appropriate for use in the poorest communities whose total number of individuals exceeds 20 individuals.

RefID: 175

Author: Davis, H.K., Moffat, C.F. and Shepherd, N.J.

Year: 2002

Title: Experimental Tainting of Marine Fish by Three Chemically Dispersed Petroleum Products, with Comparisons to the Braer Oil Spill

Journal: Spill Science & Technology Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S1353256102000439

Abstract: Fish tainting thresholds, and rates of development and loss of taint, have been measured using two salmonid and two shellfish species exposed to three petroleum products in a study concurrent with the examination of fish affected by the spillage of oil from the wreck of MV Braer. The range of (24 h) fish tainting thresholds varied from 0.098 to 0.331 mg/l for trout exposed to the three oils, and was no greater than the difference between the values obtained for the diesel oil used in this study and another sample examined previously by the same group. Thresholds were little different for salmon and trout exposed to the same (Forties) crude oil but, although the lowest tainting threshold was observed with mussels (0.032 mg/l), crabs appeared to show some resistance to tainting. The rate of induction of oil into fin-fish and mussels produced a readily detectable taint within 6 h of exposure to oil-contaminated water, but rates of uptake, and losses after transfer to clean water, contrasted with the measured fish tainting thresholds for the three different products. Diesel-derived taint persisted for over 10 weeks, much longer than both the medium fuel oil and the Forties crude oil-derived taints, and depuration time increased with oil loading and duration of exposure. Data from analyses of hydrocarbons in depurating salmon are presented, and criteria used to declare fish to be tainted or untainted are discussed. Crown Copyright (C) 2002 Published by Elsevier Science Ltd. All rights reserved.

RefID: 176

Author: Davis, J.C.

Year: 1989

Title: Nestucca oil spill : Department of Fisheries and Oceans report on spill response

Journal: DFO Report (WAVES Catalog #173303)

Hyperlink: http://waves-vagues.dfo-mpo.gc.ca/waves-vagues/search-recherche/display-afficher/173303

Abstract: This report provides an overview of the Department's response to the spill and its impact on fisheries and marine mammals.

RefID: 177

Author: Davis, J.E. and Anderson, S.S.

Year: 1976

Title: Effects of oil pollution on breeding Grey Seals

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/0025326X76901879

Abstract: Marine mammals are probably frequently exposed to floating oil but little is known about the effect oil pollution has on them. Oil stranded on the shore in Pembrokeshire, West Wales in September 1974 coincided with the start of the Grey Seal breeding season there. Observations have been made on the effect the oil had on the newborn pups and their mothers.

RefID: 178

Author: Day, B.

Year: 2006

Title: Ecological effects to benthic infauna from lingering oil 15 years after the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://library.alaska.gov/asp/edocs/2006/09/ocm70145838.pdf

Abstract: In 2001, Short et al. (2004) identified residual oil from the 1989 Exxon Valdez oil spill in intertidal sediments. In the current study, five pairs of intertidal stations, each composed of one oiled and one nearby unoiled station (as identified by concurrent National Marine Fisheries Service studies), were evaluated for potential ecological impacts due to subsurface lingering oil. Oiled sediments were not toxic in the larval mussel bioassay using Mytilus edulis galloprovincialis, where development and survival in the 100% elutriate were equivalent to the unoiled stations and the controls. Significant toxicity was observed in the 28-day amphipod bioassay using Leptocheirus plumulosus, where survival at the oiled stations was 0% while survival in the unoiled stations ranged from 37 to 84%. Survival was inversely related to sediment PAH and positively related to percent fines (p

RefID: 179

Author: de Hoop, L., Schipper, A.M., Leuven, R.S.E.W., Huijbregts, M.A.J., Olsen, G.H., Smit, M.G.D. and Hendriks, A.J.

Year: 2011

Title: Sensitivity of Polar and Temperate Marine Organisms to Oil Components

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es202296a

Abstract: Potential contamination of polar regions due to increasing oil exploitation and transportation poses risks to marine species. Risk assessments for polar marine species or ecosystems are mostly based on toxicity data obtained for temperate species. Yet, it is unclear whether toxicity data of temperate organisms are representative for polar species and ecosystems. The present study compared sensitivities of polar and temperate marine species to crude oil, 2-methylnaphthalene, and naphthalene. Species sensitivity distributions (SSDs) were constructed for polar and temperate species based on acute toxicity data from scientific literature, reports, and databases. Overall, there was a maximum factor of 3 difference in sensitivity to oil and oil components, based on the means of the toxicity data and the hazardous concentrations for 5 and 50% of the species (HC5 and HC50) as derived from the SSDs. Except for chordates and naphthalene, polar and temperate species sensitivities did not differ significantly. The results are interpreted in the light of physiological characteristics, such as metabolism, lipid fraction, lipid composition, antioxidant levels, and resistance to freezing, that have been suggested to influence the susceptibility of marine species to oil. As a consequence, acute toxicity data obtained for temperate organisms may serve to obtain a first indication of risks in polar regions.

RefID: 180

Author: De Laender, F., Olsen, G.H., Frost, T., Grøsvik, B.E., Grung, M., Hansen, B.H., Hendriks, A J., Hjorth, M., Janssen, C.R., Klok, C., Nordtug, T., Smit, M., Carroll, J. and Camus, L.

Year: 2011

Title: Ecotoxicological Mechanisms and Models in an Impact Analysis Tool for Oil Spills

Journal: Journal of Toxicology and Environmental Health

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/15287394.2011.550567

Abstract: In an international collaborative effort, an impact analysis tool is being developed to predict the effect of accidental oil spills on recruitment and production of Atlantic cod (Gadus morhua) in the Barents Sea. The tool consisted of three coupled ecological models that describe (1) plankton biomass dynamics, (2) cod larvae growth, and (3) fish stock dynamics. The discussions from a series of workshops are presented in which variables and parameters of the first two ecological models were listed that may be affected by oil-related compounds. In addition, ecotoxicological algorithms are suggested that may be used to quantify such effects and what the challenges and opportunities are for algorithm parameterization. Based on model exercises described in the literature, survival and individual growth of cod larvae, survival and reproduction of zooplankton, and phytoplankton population growth are denoted as variables and parameters from the ecological models that might be affected in case of an oil spill. Because toxicity databases mostly (67%) contain data for freshwater species in temperate environments, parameterization of the ecotoxicological algorithms describing effects on these endpoints in the subarctic marine environment is not straightforward. Therefore, it is proposed that metadata analyses be used to estimate the sensitivity of subarctic marine species from available databases. To perform such analyses and reduce associated uncertainty and variability, mechanistic models of varying complexity, possibly aided by new experimental data, are proposed. Lastly, examples are given of how seasonality in ecosystems may influence chemical effects, in particular in the subarctic environment. Food availability and length of day were identified as important characteristics as these determine nutritional status and phototoxicity, respectively.

RefID: 181

Author: de Soysa, T.Y., Ulrich, A., Friedrich, T., Pite, D., Compton, S.L., Ok, D., Bernardos, R.L., Downes, G.B., Hsieh, S., Stein, R., Lagdameo, M.C., Halvorsen, K., Kesich, L.R. and Barresi, M J.F.

Year: 2012

Title: Macondo crude oil from the Deepwater Horizon oil spill disrupts specific developmental processes during zebrafish embryogenesis

Journal: BMC Biology

Hyperlink: http://www.biomedcentral.com/1741-7007/10/40

Abstract: Background: The Deepwater Horizon disaster was the largest marine oil spill in history, and total vertical exposure of oil to the water column suggests it could impact an enormous diversity of ecosystems. The most vulnerable organisms are those encountering these pollutants during their early life stages. Water-soluble components of crude oil and specific polycyclic aromatic hydrocarbons have been shown to cause defects in cardiovascular and craniofacial development in a variety of teleost species, but the developmental origins of these defects have yet to be determined. We have adopted zebrafish, Danio rerio, as a model to test whether water accumulated fractions (WAF) of the Deepwater Horizon oil could impact specific embryonic developmental processes. While not a native species to the Gulf waters, the developmental biology of zebrafish has been well characterized and makes it a powerful model system to reveal the cellular and molecular mechanisms behind Macondo crude toxicity. Results: WAF of Macondo crude oil sampled during the oil spill was used to treat zebrafish throughout embryonic and larval development. Our results indicate that the Macondo crude oil causes a variety of significant defects in zebrafish embryogenesis, but these defects have specific developmental origins. WAF treatments caused defects in craniofacial development and circulatory function similar to previous reports, but we extend these results to show they are likely derived from an earlier defect in neural crest cell development. Moreover, we demonstrate that exposure to WAFs causes a variety of novel deformations in specific developmental processes, including programmed cell death, locomotor behavior, sensory and motor axon pathfinding, somitogenesis and muscle patterning. Interestingly, the severity of cell death and muscle phenotypes decreased over several months of repeated analysis, which was correlated with a rapid drop-off in the aromatic and alkane hydrocarbon components of the oil. Conclusions: Whether these teratogenic effects are unique to the oil from the Deepwater Horizon oil spill or generalizable for most crude oil types remains to be determined. This work establishes a model for further investigation into the molecular mechanisms behind crude oil mediated deformations. In addition, due to the high conservation of genetic and cellular processes between zebrafish and other vertebrates, our work also provides a platform for more focused assessment of the impact that the Deepwater Horizon oil spill has had on the early life stages of native fish species in the Gulf of Mexico and the Atlantic Ocean.

RefID: 182

Author: De Vogelaere, A.P. and Foster, M.S.

Year: 1994

Title: DAMAGE AND RECOVERY IN INTERTIDAL FUCUS-GARDNERI ASSEMBLAGES FOLLOWING THE EXXON-VALDEZ OIL-SPILL

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v106/

Abstract: In March 1989, the 'Exxon Valdez' spilled over 10 million gallons (ca 38 million 1) of crude oil into Prince William Sound, Alaska, USA. The spill was followed by massive clean-up using hot sea-water at high pressure as well as other mechanical and chemical techniques. We studied initial damage and subsequent recovery in the upper margin of the Fucus gardneri assemblage on protected shores by comparing sites that were unoiled, oiled and cleaned with hot water at high pressure, and oiled but less intensely cleaned. F. gardneri cover averaged 80 % on unoiled sites but < 1 % on all oiled and cleaned sites 18 mo after the spill. The abundances of barnacles, littorine snails and limpets varied among sites and species, and this variation was associated in part with differences in their life histories. F. gardneri cover was still extremely low on oiled and cleaned sites 2.5 yr after the spill. Holdfasts that persisted after cleaning did not resprout. F. gardneri recruitment was lowest at intensely cleaned sites, and most recruits occurred in cracks near adults. Recruits were less abundant under adult canopies but placing canopies over recruits did not decrease their survivorship over 5 mo. Natural weathering of tar was rapid, with most marked patches gone in less than 1 yr. We conclude that intense mechanical cleaning following this oil spill increased damage and slowed recovery. Such methods should be avoided if reduction of environmental damage is the primary objective of post-spill management decisions. The recovery of F. gardneri at its upper margin might be enhanced by devices that retain moisture and increase substratum rugosity.

RefID: 183

Author: Dean, T.A., Bodkin, J.L., Jewett, S.C., Monson, D.H. and Jung, D.

Year: 2000

Title: Changes in sea urchins and kelp following a reduction in sea otter density as a result of the Exxon Valdez oil spill

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v199/p281-291/

Abstract: Interactions between sea otters Enhydra lutris, sea urchins Strongylocentrotus droebachiensis, and kelp were investigated following the reduction in sea otter density in Prince William Sound, Alaska, after the Exxon Valdez oil spill in 1989. At northern Knight Island, a heavily oiled portion of the sound, sea otter abundance was reduced by a minimum of 50% by the oil spill, and from 1995 through 1998 remained at an estimated 66% lower than in 1973. Where sea otter densities were reduced, there were proportionally more large sea urchins. However, except in some widely scattered aggregations, both density and biomass of sea urchins were similar in an area of reduced sea otter density compared with an area where sea otters remained about 10 times more abundant. Furthermore, there was no change in kelp abundance in the area of reduced sea otter density. This is in contrast to greatly increased biomass of sea urchins and greatly reduced kelp density observed following an approximate 90% decline in sea otter abundance in the western Aleutian Islands. The variation in community response to a reduction in sea otters may be related to the magnitude of the reduction and the non-linear response by sea urchins to changes in predator abundance. The number of surviving sea otters may have been high enough to suppress sea urchin populations in Prince William Sound, but not in the Aleutians. Alternatively, differences in response may have been due to differences in the frequency or magnitude of sea urchin recruitment. Densities of small sea urchins were much higher in the Aleutian system even prior to the reduction in sea otters, suggesting a higher rate of recruitment.

RefID: 184

Author: Dean, T.A., Jewett, S.C., Laur, D.R. and Smith, R.O.

Year: 1996

Title: Injury to epibenthic invertebrates resulting from the Exxon Valdez oil spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: Injuries to subtidal populations of epibenthic invertebrates in Prince William Sound were assessed by comparing densities of dominant species at oiled versus non-oiled (control) sites between 1990 and 1993. Dominant taxa included five species of sea stars and one species of crab. Population densities of leather star Dermasterias imbricata, and helmet crab Telmessus cheiragonus were smaller at oiled sites than at controls in 1990. The same general pattern was observed in most habitats and depths sampled. There was possible injury to slender arm stars Evasterias troschelii, although the evidence for this was less convincing. The sunflower sea star Pycnopodia helianthoides was found in greater abundance at control sites within eelgrass beds, but in greater abundance at oiled sites in other habitats. Densities of two other species of sea stars did not differ between sites and were apparently unaffected by oiling. In shallow portions of bays, populations of Dermasterias and Telmessus were fully recovered by 1993; however, recovery was less than complete within eelgrass beds. There were no significant differences in the density of either Dermasterias or Telmessus between oiled and control eelgrass sites in 1993, but average densities remained more than twice as high at the controls. Polycyclic aromatic hydrocarbon (PAH) concentrations were higher at oiled sites, confirming our classification of sites with respect to oiling. There was a general correspondence between level of injury to epifaunal invertebrates and PAH concentrations. Injury was greatest and PAH levels were highest in shallow waters in eelgrass beds and bays. Levels of both injury and PAHs declined between 1990 and 1993. It was unclear whether the injuries were the result of acute toxicity of oil, sublethal effects of oiling, collateral injury from cleanup activities, or a combination of these factors.

RefID: 185

Author: Dean, T.A., Stekoll, M.S. and Smith, R.O.

Year: 1996

Title: Kelps and oil: The effects of the Exxon Valdez oil spill on subtidal algae

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: This study examined possible changes in the subtidal macroalgal populations as a result of the Exxon Valdez oil spill. The abundance and size distribution of dominant subtidal algae were measured in Prince William Sound 1 year after the spill. Population density, biomass, and cover were compared between oiled and control sites within each of three habitats: sheltered bays, moderately exposed points, and very exposed points with a surface canopy of Nereocystis luetkeana. Dominant macroalgae in these habitats were the kelps Aganun cribrosum, Laminaria saccharina, L. groenlandica, and N. luetkeana. There were no differences in the total density, biomass, or percentage cover macroalgae between oiled and control sites. However, at least one of the dominant kelp species within each habitat was more abundant at the oiled sites. In addition, there were generally more small plants at oiled sites, suggesting recent recruitment or slower growth there. Recruitment at oiled site may have been indicative of recovery from recent oil-related disturbance. Although these data suggest possible injury to kelps as a result of the spill, there were no apparent long-term impacts on subtidal populations of macroalgae.

RefID: 186

Author: Dean, T.A., Stekoll, M.S., Jewett, S.C., Smith, R.O. and Hose, J.E.

Year: 1998

Title: Eelgrass (Zostera marina L.) in Prince William Sound, Alaska: Effects of the Exxon Valdez oil spill

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X97001847

Abstract: Possible injury to, and recovery of, populations of eelgrass, Zostera marina L., in Prince William Sound were assessed following the Exxon Valdez oil spill by comparing populations at oiled vs reference sites between 1990 and 1995. Eelgrass beds in heavily oiled bays were exposed to moderate concentrations of hydrocarbons. In 1990, a year after the spill, concentrations of total polycyclic aromatic hydrocarbons averaged nearly 4000 ng g−1 dry weight of sediment at oiled sites compared to less than 700 ng g−1 at reference sites. Injuries to eelgrass, if any, appeared to be slight and did not persist for more than a year after the spill. There were possible effects on the average density of shoots and flowering shoots, as these were 24 and 62% lower at oiled than at reference sites in 1990 (p < 0.10 for both). However, there were no differences between oiled and reference sites with respect to eelgrass biomass, seed density, seed germination or the incidence of normal mitosis in seedlings, and there were no signs of the elimination of eelgrass beds. Populations recovered from possible injuries by 1991, as there was a sharp decline in hydrocarbon concentrations and there were no differences in shoot or flowering shoot densities between oiled and reference sites in 1990 or subsequent years.

RefID: 187

Author: Debenest, T., Turcotte, P., Gagné, F., Gagnon, C. and Blaise, C.

Year: 2012

Title: Ecotoxicological impacts of effluents generated by oil sands bitumen extraction and oil sands lixiviation on Pseudokirchneriella subcapitata

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X12000409

Abstract: The exploitation of Athabasca oil sands deposits in northern Alberta has known an intense development in recent years. This development has raised concern about the ecotoxicological risk of such industrial activities adjacent to the Athabasca River. Indeed, bitumen extraction generated large amounts of oil sands process-affected water (OSPW) which are discharged in tailing ponds in the Athabasca River watershed. This study sought to evaluate and compare the toxicity of OSPW and oil sands lixiviate water (OSLW) with a baseline (oil sands exposed to water: OSW) on a microalgae, Pseudokirchneriella subcapitata, at different concentrations (1.9, 5.5, 12.25, 25 and 37.5%, v/v). Chemical analyses of water-soluble contaminants showed that OSPW and OSLW were enriched in different elements such as vanadium (enrichment factor, EF = 66 and 12, respectively), aluminum (EF = 64 and 15, respectively), iron (EF = 52.5 and 17.1, respectively) and chromium (39 and 10, respectively). The toxicity of OSPW on cells with optimal intracellular esterase activity and chlorophyll autofluorescence (viable cells) (72 h-IC 50% < 1.9%) was 20 times higher than the one of OSW (72 h-IC 50% > 37.5%, v/v). OSLW was 4.4 times less toxic (IC 50% = 8.5%, v/v) than OSPW and 4.5 times more toxic than OSW. The inhibition of viable cell growth was significantly and highly correlated (<-0.7) with the increase of arsenic, beryllium, chromium, copper, lead, molybdenum and vanadium concentrations. The specific photosynthetic responses studied with JP-test (rapid and polyphasic chlorophyll a fluorescence emission) showed a stimulation of the different functional parameters (efficiency of PSII to absorb energy from photons, size of effective PSII antenna and vitality of photosynthetic apparatus for energy conversion) in cultures exposed to OSPW and OSLW. To our knowledge, our study highlights the first evidence of physiological effects of OSPW and OSLW on microalgae. Crown Copyright (C) 2012 Published by Elsevier B.V. All rights reserved.

RefID: 188

Author: Debruyn, A.M.H., Wernick, B.G., Stefura, C., McDonald, B.G., Rudolph, B.L., Patterson, L. and Chapmant, P.M.

Year: 2007

Title: In situ experimental assessment of lake whitefish development following a freshwater oil spill

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es0709425

Abstract: Wabamun Lake (Alberta, Canada) has been subject to ongoing contamination with polycyclic aromatic hydrocarbons (PAHs) from multiple sources for decades and in August 2005 was exposed to ca. 149 500 L of bunker C oil following a train derailment. We compared the pattern, frequency, and severity of deformity in larvae of lake whitefish (Coregonus clupeaformis) incubated in situ in areas of Wabamun Lake exposed only to "background" PAH contamination and in areas additionally exposed to PAHs from the oil. All sites in the lake (including reference areas) showed incidences of deformity higher than are typically observed in laboratory studies. A small number of oil-exposed sites showed higher incidences of some teratogenic deformities and a tendency to exhibit deformities of higher severity than sites not exposed to oil. The frequency of moderate to severe deformities in 8 of 16 classes was correlated with PAH exposure. Nonmetric multivariate ordination of deformity data revealed a general pattern of increasing incidence and severity of several skeletal (lordosis, scoliosis) and craniofacial (ocular, jaw) deformities at sites with relatively high exposure to oil-derived PAHs. A simultaneous consideration of incidence, severity, and pattern of deformity enabled us to detect a consistent (overall similar to 5% above background) response to the oil despite high variability and high background deformity rates in this historically contaminated environment.

RefID: 189

Author: Deepthike, H.U., Tecon, R., Van Kooten, G., Van Der Meer, J.R., Harms, H., Wells, M. and Short, J.

Year: 2009

Title: Unlike PAHs from Exxon Valdez Crude Oil, PAHs from Gulf of Alaska Coals are not Readily Bioavailable

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es900734k

Abstract: In the wake of the 1989 Exxon Valdez oil spill, spatially and temporally spill-correlated biological effects consistent with polycyclic aromatic hydrocarbon (PAH) exposure were observed. Some works have proposed that confounding sources from local source rocks, prominently coals, are the provenance of the PAHs. Representative coal deposits along the southeast Alaskan coast (Kulthieth Formation) were sampled and fully characterized chemically and geologically. The coals have variable but high total organic carbon content, technically classifying as coals and coaly shale, and highly varying PAH contents. Even for coals with high PAH content (∼4000 ppm total PAHs), a PAH-sensitive bacterial biosensor demonstrates nondetectable bioavailability as quantified, based on naphthalene as a test calibrant. These results are consistent with studies indicating that materials such as coals strongly diminish the bioavailability of hydrophobic organic compounds and support previous work suggesting that hydrocarbons associated with the regional background in northern Gulf of Alaska marine sediments are not appreciably bioavailable.

RefID: 190

Author: Deepthike, H.U., Tecon, R., Van Kooten, G., Van Der Meer, J.R., Harms, H., Wells, M. and Short, J.

Year: 2010

Title: Response to Comment on "Unlike PAHs from Exxon Valdez Crude Oil, PAHs from Gulf of Alaska Coals are not Readily Bioavailable"

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es100176k

Abstract: Refers to T0035

RefID: 191

Author: Degange, A.R. and Lensink, C.J.

Year: 1990

Title: DISTRIBUTION AGE AND SEX COMPOSITION OF SEA OTTER CARCASSES RECOVERED DURING THE RESPONSE TO THE T-V EXXON VALDEZ OIL SPILL

Journal: U S Fish and Wildlife Service Biological Report

Hyperlink: https://openlibrary.org/books/OL24349175M/Sea_otter_symposium

Abstract: Nearly 900 sea otter (Enhydra lutris) carcasses were recovered in or adjacent to coastal areas affected by the Exxon Valdez oil spill. The time of carcass recovery and the condition of carcasses indicate that most oil spill-induced mortality occurred early in the response period. In fact, by 19 May about 70% of the carcasses had been found. The majority of the carcasses (56%) were from Prince William Soimd, suggesting that mortality was more acute there than in other geographic areas. Examination of the recovered carcasses indicated that more adult female sea otters were killed by the oil in Prince William Sound and along the Kenai Peninsula than other sex and age cohorts, reflecting greater abvmdance of adult females in those regions. Many of the adult females in those areas were pregnant or lactating. Pups made up a higher proportion of the carcasses collected in the western portion of the spill zone, reflecting the advanced pupping chronology at the time the search effort reached the AlaskaPeninsula and the Kodiak Archipelago.

RefID: 192

Author: DeGange, A.R., Douglas, D.C., Monson, D.H. and Robbins, C.M.

Year: 1995

Title: Surveys of sea otters in the Gulf of Alaska in response to the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33944234.pdf

Abstract:

RefID: 193

Author: Degange, A.R., Monson, D.H., Irons, D.B., Robbins, C.M. and Douglas, D.C.

Year: 1990

Title: DISTRIBUTION AND RELATIVE ABUNDANCE OF SEA OTTERS IN SOUTH-CENTRAL AND SOUTHWESTERN ALASKA USA BEFORE OR AT THE TIME OF THE T-V EXXON VALDEZ OIL SPILL

Journal: U S Fish and Wildlife Service Biological Report

Hyperlink: https://openlibrary.org/books/OL24349175M/Sea_otter_symposium

Abstract: Surveys of sea otters (Enhydra lutris) conducted before, immediately after, or at the time of the Exxon Valdez oil spill were used to guide otter capture efforts and assess the immediate effects of the spill. Shoreline counts (by boat) of sea otters in Prince William Sound in 1984 suggested that a minimum of 4,500 sea otters inhabited nearshore waters of Prince William Sound. Areas of highest density within the western portion of Prince William Sound included the Bainbridge Island area, Montague Island, Green Island, and Port Wells. About 1,330 sea otters were counted from helicopters along the coast of the Kenai Peninsula. Highest densities of sea otters were found along the western end of the Kenai Peninsula. At Kodiak Island, about 3,500 sea otters were counted in coastal surveys from helicopters. Highest densities of sea otters were found in Perenosa Bay in northern Afognak Island, and in waters between Afogneik, Kodiak, and Raspberry Islands. Along the Alaska Peninsula, about 6,500 sea otters were counted between Kamishak Bay and Unimak Pass. Areas of concentration included the Izembek Lagoon airea. False Pass, the Pavlof Islands, Hallo Bay, and Kujulik Bay. Line transect surveys conducted offshore of the coastal strips indicate that at the time of the surveys relatively high densities of sea otters existed offshore at Kodiak Island and along the Alaska Peninsula, but not on the Kenai Peninsula.

RefID: 194

Author: Della Torre, C., Tornambè, A., Cappello, S., Mariottini, M., Perra, G., Giuliani, S., Amato, E., Falugi, C., Crisari, A., Yakimov, M.M. and Magaletti, E.

Year: 2012

Title: Modulation of CYP1A and genotoxic effects in European seabass (Dicentrarchus labrax) exposed to weathered oil: A mesocosm study

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S014111361100095X

Abstract: The aim of this study was to assess medium-term toxicity of weathered oil on European seabass. A mesocosm system reproducing an oil spill at sea was applied. Fish were collected after 48 h, 7, 30 and 60 days. Cyp1a gene transcription, EROD and UDPGT activities, bile PAHs metabolites and micronuclei frequency were investigated. A progressive disappearance of low molecular weight n-alkanes and PAHs in the water of the mesocosm occurred during the experimentation. Fishes exposed to oil displayed a significant increase of cyp1a expression and EROD activity during the entire experiment as well as higher concentrations of PAHs metabolites in bile. Micronulei frequency resulted significantly higher during all experiment in oil exposed sea bass compared to controls. The results highlight the environmental risk associated with the release of oil products at sea and confirm the adopted parameters as useful tools for studying the impact of accidental oil spills on fish. (C) 2011 Elsevier Ltd. All rights reserved.

RefID: 195

Author: Demes, K., Chang, S., Quayle, M., Withers, D., Raymond, J. and Stevens, D.

Year: 2013

Title: Economic and Biophysical Impacts of Oil Tanker Spills Relevant to Vancouver, Canada A Literature Review

Journal: Report

Hyperlink: http://vancouvereconomic.com/userfiles/file/Attachments/VEC Report - Impacts of Oil Tanker Spills Relevant to Vancouver.pdf

Abstract: In anticipation of potentially substantial increases in oil tanker traffic in Burrard Inlet in the coming years, the City of Vancouver and Vancouver Economic Commission commissioned the University of British Columbia in 2013 to prepare a literature review of likely economic and biophysical impacts of oil spills, to provide an objective and scientifically sound platform to inform future planning, policy development and decision-making. Some 400 published papers and reports were reviewed, covering aspects of oil spills ranging from impacts on marine life to effects on human health, and economy. Emphasis was placed on key oil spills with traits relevant to potential oil tanker spills in the Vancouver context.The literature review did not identify any studies that investigated a situation with similar economic, biophysical, geographical and political traits to the Lower Mainland. However, studies on key global oil spills, as well as available research on background factors in the Vancouver region, suggest several key findings. The review that follows elaborates on these.

RefID: 196

Author: Dew, W.A., Hontela, A., Rood, S.B. and Pyle, G.G.

Year: 2015

Title: Biological effects and toxicity of diluted bitumen and its constituents in freshwater systems

Journal: Journal of Applied Toxicology

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/jat.3196/abstract

Abstract: Approximately 50 billion cubic meters of bitumen resides within the oil sands region of Alberta, Canada. To facilitate the transport of bitumen from where it is extracted to where it is processed, the bitumen is diluted with natural gas condensate ('dilbit'), synthetic crude from hydrocracking bitumen ('synbit'), or a mixture of both ('dilsynbit'). A primary consideration for the effects of diluted bitumen products on freshwater organisms and ecosystems is whether it will float on the water surface or sink and interact with the stream or lake sediments. Evidence from a spill near Kalamazoo, MI, in 2010 and laboratory testing demonstrate that the nature of the spill and weathering of the dilbit, synbit or dilsynbit prior to and during contact with water will dictate whether the product floats or sinks. Subsequent toxicological data on the effects of dilbit and other diluted bitumen products on freshwater organisms and ecosystems are scarce. However, the current literature indicates that dilbit or bitumen can have significant effects on a wide variety of toxicological endpoints. This review synthesizes the currently available literature concerning the fate and effects of dilbit and synbit spilled into freshwater, and the effects of bitumen and bitumen products on aquatic organisms and ecosystems. Dilbit is likely to provide ecological impacts that are similar to and extend from those that follow from exposure to lighter crude oil, but the prospect of bitumen settling after binding to suspended sediments elevates the risk for benthic impacts in streams and lakes.

RefID: 197

Author: Djomo, J.E., Dauta, A., Ferrier, V., Narbonne, J.F., Monkiedje, A., Njine, T. and Garrigues, P.

Year: 2004

Title: Toxic effects of some major polyaromatic hydrocarbons found in crude oil and aquatic sediments on Scenedesmus subspicatus

Journal: Water Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0043135403005906

Abstract: The green alga, Scenedesmus subspicatus was exposed for 7 days to a series of PAHs (polyaromatic hydrocarbons) of increased molecular weight from two to five rings [naphthalene (Nap), anthracene (Ant), phenanthrene (Phe), pyrene (Pyr) and benzo(a)pyrene (BaP)]. The toxicity measured as population growth inhibition by individual PAH to the S. subspicatus followed the order: BaP > Pyr > Ant > Phe > Nap. These results confirmed that the toxicity potential of PAHs seems to be strongly influenced by their physico-chemical properties (aqueous solubility, K,,, coefficient of volatilization, etc.) and the conditions of algae culture (light, presence of nitrate ions, etc.). Consequently, Nap, Phe and Ant having low K-ow values and low coefficient of volatilization values were less toxic than BaP with the highest k(ow) value, indicating for example why Nap with the lowest EC50 value was nearly 2 x 10(5). times lower than that of BaP. Moreover, nitrate ions seemed to act directly on the degree of hydroxylated radical reactivity of PAHs, since BaP always remained the most toxic of the compounds tested. The results were also agreed with the QSAR model for toxicity prediction of PAHs to many aquatic organisms. (C) 2003 Elsevier Ltd. All rights reserved.

RefID: 198

Author: Donaldson, W. and Byersdorfer, S.

Year: 1998

Title: Sea Urchin Injury: Assessment of impacts of oil on green sea urchins, Strongylocentrotus droebachiensis, in the Kodiak Island area, Exxon Valdez Oil Spill State/Federal Natural Resource Damage Assessment Annual Report (Fish/Shellfish Study Number 26)

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/index.cfm?FA=searchResults.projectInfo&Project_ID=1259

Abstract: A total of 4,719 green sea urchins, Strongylocentrotus droeachiensis, were examined from 2 oiled and 4 non-oiled sites around Kodiak Island. Urchins ranged in size and estimated age from 8 mm (0.75 yrs) to 85 mm (6.0+ yrs). Histological and hydrocarbon tissue samples were collected at 6 sites for laboratory analysis. Divers did not observe any subtidal oil. In the contracted report attached as Appendix I, purple sea urchins were exposed to elutriates of sediments from areas oiled by the Exxon Valdez oil spill. Elutriates ofsamples collected from Bay of Isles in Fall 1990 were toxic to purple sea urchins. Purple and green sea urchins were exposed to water soluble fractions (WSF) of crude oil. WSF was more toxic to green than to purple sea urchins. Fertilization ofgreen sea urchins was reduced by exposure to 3.2% WSF or greater. Weathered oil affected fertilization less. WSF to 32%'was not toxic to purple sea urchin embryons. WSF greater than or equal to 56% was toxic to green sea urchin embryos. Results indicated possible effects ofthe Exxon Valdez oil spill on sea urchin populations, but hydrocarbon contents ofsediment and WSF samples were not determined preventing conclusive impact assessment.

RefID: 199

Author: Donkin, P., Smith, E.L. and Rowland, S.J.

Year: 2003

Title: Toxic effects of unresolved complex mixtures of aromatic hydrocarbons accumulated by mussels, Mytilus edulis, from contaminated field sites

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es021053e

Abstract: Exposure of marine mussels (Mytilus edulis) to an unresolved complex mixture (UCM) of aromatic hydrocarbons isolated from a crude oil has been shown to reduce their feeding rate by 40%. The present study was undertaken to determine whether UCMs bioaccumulated by mussels in the field are also toxic. The feeding rate of mussels derived from polluted sites increased when they were placed in clean water, pointing to a loss of toxic agents from the tissues. At the end of the depuration period, water in which mussels from an oil-polluted site had been held contained a UCM. Steam-distillation extracts of the tissues of mussels taken from several polluted sites were shown to be highly toxic to the feeding activity of juvenile mussels. The tissues of mussels from these sites contained UCMs. Nontoxic steam distillates from clean mussels did not. Steam-distillation extracts of mussels from an oil-polluted site were fractionated by normal-phase high-performance liquid chromatography. A fraction, largely comprising a "monoaromatic" UCM, reduced the feeding rate of juvenile mussels by 70%. Two later-eluting fractions containing aromatic UCMs also produced smaller depressions in feeding rate. These results support our contention that some aromatic UCM hydrocarbons constitute a forgotten pollutant burden in the marine environment.

RefID: 200

Author: Doroff, A.M. and A.R. DeGange.

Year: 1995

Title: Experiments to determine drift patterns and rates of recovery of sea otter carcasses following the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33944233.pdf

Abstract: Two experiments were conducted to evaluate efforts to recover sea otter (Enhydra lutris) carcasses following the Exxon Valdez oil spill. The first study was implemented during sea otter rescue and carcass recovery activities to assess the probability of carcass recovery. Twenty-five previously recovered sea otter carcasses were marked with flipper tags and released near northern Kodiak Island between 27 May and 3 June 1989. Five were recovered, for a recovery rate of 20%. In the second study, 30 radio-monitored floats designed to assess drift characteristics of floating sea otter carcasses were deployed in early summer 1990. During a 43-day monitoring period, 27 were known to have washed ashore, 25 in Prince William Sound (PWS) and two on the Gulf of Alaska coast of Montague Island. Final location of one float could not be precisely determined due to an intermittent, weak signal, but it was in the general location of Knight Island in western PWS. Contact was lost with two of the floats, despite extensive searches throughout PWS and the Kenai Peninsula. These studies suggest that many more sea otters may have died from the spill than were recovered, and that some sea otters succumbing to oil exposure in PWS could have drifted outside of PWS and never been recovered. These studies do not address the following factors influencing the recoverability of sea otters dying as a result of the spill: 1) drift patterns of carcasses in heavy oil; 2) the proportion of sea otter carcasses sinking, 3) the persistence of floating and beach-cast sea otter carcasses, and 4) the behavior of oiled sea otters prior to death in nearshore and offshore areas.

RefID: 201

Author: Doroff, A.M. and Bodkin, J.L.

Year: 1996

Title: Sea otter foraging behavior and hydrocarbon concentrations in prey following the Exxon Valdez oil spill in Prince William Sound, Alaska

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/41843708.pdf

Abstract: In summer 1991, sea otter foraging success and prey composition were determined by visual observation at 2 sites affected by shoreline oiling during the Exxon Valdez oil spill and at a non-oiled site in western Prince William Sound, Alaska. Prey species were also determined by scat analysis at Green Island. Bivalve prey were collected subtidally at each study site to determine petroleum hydrocarbon concentrations in sea otter prey. The proportion of successful dives did not differ among sites for adults or between adults and juveniles. The mean number of prey captured per dive was 1.2 and did not differ among study sites. Size class of sea otter prey was similar among study sites: >96% of the prey items were estimated to be <9 cm. Adults differed in the proportion of dives retrieving clams, crabs, and mussels among study sites. Clams were retrieved on 34%, 61% and 44% of successful foraging dives observed at Squirrel, Green, and Montague islands, respectively. Saxidomus giganteus was the most frequently identified clam species. Mussels and crabs contributed ≥20% of the total prey items recovered by otters at each study site. Juvenile sea otters in the Green Island site had a significantly higher proportion of dives resulting in the capture of mussels than did adults: no differences were detected in the proportion of dives resulting in clam or crab. Other species contributed 4% at each study site. Sea otter scat collected at Green Island contained primarily mussels and clams. Tissue samples of subtidal sea otter prey from oiled sites did not appear to differ from the non-oiled site in concentrations of alkanes, aromatics, or unresolved complex mixture.

RefID: 202

Author: Doroff, A.M. and Bodkin, J.L.

Year: 1994

Title: Sea otter foraging behavior and hydrocarbon levels in prey

Journal: Marine mammals and the Exxon Valdez

Hyperlink: http://www.amazon.com/Marine-Mammals-Valdez-Thomas-Loughlin/dp/0124561608

Abstract:

RefID: 203

Author: Downs, C.A., Shigenaka, G., Fauth, J.E., Robinson, C.E. and Huang, A.

Year: 2002

Title: Cellular physiological assessment of bivalves after chronic exposure to spilled Exxon Valdez crude oil using a novel molecular diagnostic biotechnology

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es011433k

Abstract: The objective of this study was to determine the cellular physiological status of the bivalves Mya arenaria and Mytilus trossulus in an area experiencing a 10-yr chronic exposure of spilled Exxon Valdez crude oil in Prince William Sound Bivalves were collected from.,well-characterized oiled and unoiled sites. We used a novel biotechnology (Environmental Cellular Diagnostic S stem) to determine (i) if bivalves Were Physiologically stressed, (ii) the nature of the altered physiological state, and (iii) whether the bivalves were responding to an exposure of polyaromatic hydrocarbons (PAH). Molecular diagnostic analysis indicated that bivalve's at the oiled site were experiencing both oxidative and xenobiotic stress, resulting in increased. protein turnover and chaperone activity. Bivalves from the impacted area were responding specifically to a PAH-xenobiotic exposure and accumulating protein-PAH adducts. Finally, species-specific responses were observed that could be related to the habitat preferences of each species We conclude that bivalves inhabiting a site impacted by crude oil from. the 1989 Exxon Valdez spill showed clear indications,of cellular physiological stress.

RefID: 204

Author: Driskell, W.B., Fukuyama, A.K., Houghton, J.P., Lees, D.C., Mearns, A.J. and Shigenaka, G.

Year: 1996

Title: Recovery of Prince William Sound Intertidal Infauna From Exxon Valdez Oiling and Shoreline Treatments, 1989 Through 1992

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: In 1989, following the massive crude oil spill from the T/V Exxon Valdez, a sampling program was established to assess effects on and track the recovery of low-intertidal infauna from mixed grave-sand-silt (mixed-soft) beaches. At some sites, effects from oiling were compounded by impacts from high-pressure hot-water washing used in shoreline cleanup.Total abundance, speciess richness, species diversity, and abundance of several major taxa (polychaetes, bivalves, and gastropods) were significantly lower in hot-water-washed beaches than in unoiled beaches. Infauna at oiled sites that were not hot-water washed rebounded quickly following the disturbance. Althought all study sites showed some degree of recovery by 1992, recovery of infauna at sites that were cleaned still lagged significantly behind the oiled sites.

RefID: 205

Author: Driskell, W.B., Ruesink, J.L., Lees, D.C., Houghton, J.P. and Lindstrom, S.C.

Year: 2001

Title: LONG-TERM SIGNAL OF DISTURBANCE: FUCUS GARDNERI AFTER THE EXXON VALDEZ OIL SPILL

Journal: Ecological Applications

Hyperlink: http://www.esajournals.org/doi/abs/10.1890/1051-0761%282001%29011%5B0815%3ALTSODF%5D2.0.CO%3B2

Abstract: We followed long-term dynamics of a conspicuous intertidal brown alga, Fucus gardneri, for seven years after the 1989 Exxon Valdez oil spill (EVOS) in Prince William Sound, Alaska, USA. We compared percent cover of Fucus over time at sites that had been oiled, some of which were washed with high-pressure hot water, relative to sites that had experienced neither oil nor cleanup activities (reference sites). Fucus cover at spill-disturbed sites was initially reduced due to toxic effects of oil and cleanup but rapidly increased to above normal levels and then subsequently dropped in 1994?1995. The changes in cover at spill-disturbed sites were dramatic (≥50% decline year-to-year) and synchronous across all quadrats at a site. In contrast, reference sites demonstrated little synchrony. We examined two possible mechanisms that could generate synchronous fluctuations at spill-disturbed sites, i.e., (1) plant?herbivore coupling, in which limpet or snail grazing would reduce Fucus populations (hypothesis tested by analyzing abundances from 1990 to 1996), and (2) a single cohort of Fucus recruiting soon after the spill that would monopolize space for several years before declining synchronously (hypothesis tested by analyzing size frequency in 1996). We found no evidence for the first mechanism but support for the latter. The persistent patterns in size structure and dynamics in Fucus after EVOS suggest that full recovery had not occurred by 1996, even though Fucus cover at spill-disturbed sites was similar to reference areas within a few years of the spill.

RefID: 206

Author: Duarte, H.O. and Droguett, E.L.

Year: 2015

Title: Quantitative ecological risk assessment of accidental oil spills on ship routes nearby a marine national park in Brazil

Journal: Human and Ecological Risk Assessment: An International Journal

Hyperlink: http://www.tandfonline.com/doi/full/10.1080/10807039.2015.1067760

Abstract: Fernando de Noronha (FN) is a marine protected area off the coast of Brazil. The study of risks caused by nearby ship routes is new to authorities concerned with preserving FN. We identify nearby ship routes that cause FN to be potentially exposed to oil spills from tankers. A coral species is chosen as a bioindicator of the ecosystem's health, which aids quantitative approaches. We simulate oil leakage scenarios with pessimistic occurrence frequencies and corals' mortality in case of accident. A metapopulation coral model is integrated to quantify measures of ecological risk under the potential occurrence of accidental scenarios. The categorization of risk results according to the International Union for the Conservation of Nature quantitative criteria shows that risks are negligible. Due to the considerable uncertainty in the results, we propose a more conservative categorization of risks based not on total metapopulation extinction, but on half loss. As a result, risks were considered not acceptable. The presented methodology and results are useful in supporting authorities in their preservation efforts such as the prioritization of sources of hazard as well as selection of the best cost-effective conservation measures for maintaining good environmental health on a realistic budget, using this methodology as an exploratory tool.

RefID: 207

Author: Dubansky, B., Whitehead, A., Miller, J.T., Rice, C.D. and Galvez, F.

Year: 2013

Title: Multitissue Molecular, Genomic, and Developmental Effects of the Deepwater Horizon Oil Spill on Resident Gulf Killifish (Fundulus grandis)

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es400458p

Abstract: The Deepwater Horizon oil rig disaster resulted in crude oil contamination along the Gulf coast in sensitive estuaries. Toxicity from exposure to crude oil can affect populations of fish that live or breed in oiled habitats as seen following the Exxon Valdez oil spill. In an ongoing study of the effects of Deepwater Horizon crude oil on fish, Gulf killifish (Fundulus grandis) were collected from an oiled site (Grande Terre, LA) and two reference locations (coastal MS and AL) and monitored for measures of exposure to crude oil. Killifish collected from Grande Terre had divergent gene expression in the liver and gill tissue coincident with the arrival of contaminating oil and up-regulation of cytochrome P4501A (CYP1A) protein in gill, liver, intestine, and head kidney for over one year following peak landfall of oil (August 2011) compared to fish collected from reference sites. Furthermore, laboratory exposures of Gulf killifish embryos to field-collected sediments from Grande Terre and Barataria Bay, LA, also resulted in increased CYP1A and developmental abnormalities when exposed to sediments collected from oiled sites compared to exposure to sediments collected from a reference site. These data are predictive of population-level impacts in fish exposed to sediments from oiled locations along the Gulf of Mexico coast.

RefID: 208

Author: Duesterloh, S., Short, J.W. and Barron, M.G.

Year: 2002

Title: Photoenhanced toxicity of weathered Alaska north slope crude oil to the calanoid copepods Calanus marshallae and Metridia okhotensis

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es020685y

Abstract: This study investigated the synergistic toxicity of aqueous polyaromatic compounds (PAC) dissolved from crude oil and ultraviolet radiation (UV) in natural sunlight to the calanoid copepods Calanus marshallae and Metridia okhotensis. These copepods were first exposed to low doses (similar to2 mug of total PAC/Q of the water-soluble fraction of weathered Alaska North Slope crude oil for 24 h and subsequently to low or high levels of natural sunlight. Responses included mortality, impairment of swimming ability, and discoloration of lipid sacs. There was 80-100% mortality and morbidity of C. marshallae exposed to UV and oil as compared to less than 10% effect in oil-only or UV-only treatments. In M. okhotensis, 100% mortality occurred in the UV and oil treatment, 43% mortality and 27% morbidity in the UV-only treatment, and less than 5% effect in the oil-only treatment. Bioaccumulation factors were similar to8000 for C. marshallae and similar to2000 for M. okhotensis. The interaction of the effect of PAC and UV radiation was highly significant ($P < 0.005$) in both experiments.

RefID: 209

Author: Duffy, L.K.

Year: 1999

Title: APEX Project: Alaska Predator Ecosystem Experiment in Prince William Sound and the Gulf of Alaska, Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project 98163)

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/index.cfm?FA=searchResults.projectInfo&Project_ID=361

Abstract: The Alaska Predator Ecosystem Experiment (APEX) is a five-year study of the effect of food resources on seabirds from the Exxon Valdez oil spill (EVOS) in Prince William Sound and Cook Inlet. The study examines historical data, forage fish resources, seabird reproduction and colony and population dynamics to address this issue. Research to date strongly suggests a basic shift in ecosystem structure occurred after the late 1970's, with a decrease in species nutritious to seabirds and an increase in species less rich in lipids. This resulted in population declines for several forage species and may help explain the subsequent failure of seabird species to recover from EVOS mortality. Current work aims at extending and refining these conclusions, understanding the factors that may trigger such major shifts, identifying critical areas in Prince William Sound for fish and seabird interactions, and developing a means of monitoring the Northern Gulf of Alaska.

RefID: 210

Author: Duffy, L.K., Bowyer, R.T., Testa, J.W. and Faro, J.B.

Year: 1994

Title: CHRONIC EFFECTS OF THE EXXON-VALDEZ OIL-SPILL ON BLOOD AND ENZYME CHEMISTRY OF RIVER OTTERS

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620130414/abstract

Abstract: River otters (Lutra canadensis) living in marine environments of Prince William Sound, Alaska, and exposed to crude oil from the Exxon Valdez spill in March 1989 showed elevated levels of blood haptoglobins, and interleukin-6 ir, as well as elevated activities of aspartate aminotransferase, alanine aminotransferase, and creatine kinase in summer 1991. Stepwise logistic regression, using a subset of these and other blood proteins and enzyme activities as potential independent variables, correctly classified 86.4% of 22 otters as inhabiting oiled or nonoiled areas. River otters abandoned latrine sites (an index to their abundance) over three times more often in oiled than in nonoiled areas, suggesting there may have been a delayed response in river otter populations to exposure to crude oil. Ours is the first clear model for the long-term effects of an oil spill on blood parameters of a free-ranging mammal using a nonlethal methodology. These effects occurred two years after the spill and following a major effort to clean oil from the shorelines of Prince William Sound.

RefID: 211

Author: Duffy, L.K., Bowyer, R.T., Testa, J.W. and Faro, J.B.

Year: 1993

Title: DIFFERENCES IN BLOOD HAPTOGLOBIN AND LENGTH-MASS RELATIONSHIPS IN RIVER OTTERS (LUTRA-CANADENSIS) FROM OILED AND NONOILED AREAS OF PRINCE-WILLIAM-SOUND, ALASKA

Journal: Journal of Wildlife Diseases

Hyperlink: http://www.jwildlifedis.org/doi/abs/10.7589/0090-3558-29.2.353

Abstract: Significant differences in levels of blood haptoglobin occurred between river otters (Lutra canadensis) inhabiting oiled (xBAR = 361 mg/100 ml, SD = 38, n = 6) and nonoiled (xBAR = 306 mg/100 ml, SD = 87, n = 8) areas of Prince William Sound, Alaska (USA) following the Exxon Valdez oil spill in 1989. Additionally, male river otters from oiled areas had significantly lower body mass (1.13 kg) than male otters from nonoiled areas. We propose oil-related causes for these differences.

RefID: 212

Author: Duffy, L.K., Bowyer, R.T., Testa, J.W. and Faro, J.B.

Year: 1994

Title: EVIDENCE FOR RECOVERY OF BODY-MASS AND HAPTOGLOBIN VALUES OF RIVER OTTERS FOLLOWING THE EXXON-VALDEZ OIL-SPILL

Journal: Journal of Wildlife Diseases

Hyperlink: http://www.jwildlifedis.org/doi/abs/10.7589/0090-3558-30.3.421?=

Abstract: Levels of blood haptoglobin (Hp) and interleukin-6 immunoreactive protein (IL-6 ir) were significantly elevated in river otters (Lutra canadensis) inhabiting oiled areas of Prince William Sound, Alaska (USA) following the Exxon Valdez oil spill in 1989. By May and June 1992, however, such differences were not apparent. Mean body mass of otters, adjusted for sex, age-class, and total length with analysis of covariance, differed between oiled and non-oiled areas from 1990 to 1992, but were nearly identical by May and June 1992. We propose that river otters may be recovering from chronic effects that we observed in 1990 and 1991 following the 1989 Exxon Valdez oil spill, but further research is necessary to test this hypothesis.

RefID: 213

Author: Duffy, L.K., Hecker, M.K., Blundell, G.M. and Bowyer, R.T.

Year: 1999

Title: An analysis of the fur of river otters in Prince William Sound, Alaska: oil related hydrocarbons 8 years after the Exxon Valdez oil spill

Journal: Polar Biology

Hyperlink: http://download.springer.com/static/pdf/613/art%3A10.1007%2Fs003000050332.pdf?auth66=1422917530_6b8e822d133d8b2e7e3b96c8e2a354a9&ext=.pdf

Abstract: Approximately 8 years after the Exxon Valdez oil spill, river otters (Lutra canadensis) were trapped from the shoreline in both oiled (Knight Island) and nonoiled (Jackpot Bay) areas of Prince William Sound, Alaska. Captive river otters were wiped with isopropanol-soaked gauze and the gauze extracts were analyzed by gas chromatography with mass spectrometry detection. Differences in pentacosane (C-25) levels in the fur were observed between the oiled and nonoiled sites, while lower molecular weight aliphatics and aromatics were absent. These data are useful when evaluating the role of fur grooming in the long-term exposure of river otters to hydrocarbons and the expression of P450-1A in Knight Island otters.

RefID: 214

Author: Duncan, P.B. and Hooten, A.J.

Year: 1996

Title: Influence of residual and applied oil on intertidal algal recruitment

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: We studied the effect of stranded oil on algal recruitment in rocky intertidal communities in two locations in Prince William Sound, Alaska, between 1989 and 1992. Rocks collected from two oiled beaches and ceramic tiles were used as substrates for recruitment, and tarred and clean substrates were paired for each experiment. Two other treatments—caged tiles and tiles painted black-were used to examine how grazers and dark color affected recruitment. Recruitment of biota consistently reduced on tarred substrates (by 50-100%), despite changes in location, experimental methods, and year. In all cases, tarred halves of rocks and tarred tiles had significantly lower algal cover than did clean surfaces. Similar reductions were observed for limpets and checkered periwinkles Littorina scutulata, indicating that the depressed algal recruitment was not caused by grazers feeding preferentially on tarred substrates. Cages did not successfully exclude grazers. Inside the cages, littorines, algae, and rockweed germlings Fucus sp. were more abundant and their recruitment was again significantly reduced on tarred tiles. Paint had no effect on recruitment, indicating that dark coloration could not account for the inhibition of recruitment by tar. The relationship between residual tar and recruitment success can be used in cleanup decisions for rocky shores if consideration is given to substrate composition, exposure to weathering, potential effects of cleaning on the established community, and availability of dispersing propagules.

RefID: 215

Author: Dupuis, A. and Ucan-Marin, F.

Year: 2015

Title: A literature review on the aquatic toxicology of petroleum oil:An overview of oil properties and effects to aquatic biota

Journal: Fisheries and Oceans Canada, Canadian Science Advisory Secretariat research document

Hyperlink: http://publications.gc.ca/site/eng/481102/publication.html

Abstract: This literature review gives an overview of petroleum oil:1) Production, transport and historical spills in Canada,2) Physical and chemical properties relevant to aquatic toxicity and,3) Lethal and sublethal effects on fish and other aquatic biota. Canada has large oil reserves. A significant proportion of total reserves are associated withAlberta's oil sands. Both conventional and unconventional oil production occurs in Canada andunconventional oil production is dominated by recovery of bitumen from oil sands deposits.Currently, total annual export of petroleum oil by pipeline is substantially greater than exports by marine and rail transportation systems. Historical spills of petroleum oil occurred from pipelines, rail and marine transport methods. Spills have been known to occur in both freshwater andmarine ecosystems.Physical properties and other environmental conditions (e.g. weathering, temperature, presenceof sediments, etc.) influence the fate and behaviour of spilled oil in the environment. Chemicalproperties vary widely across the different classes of petroleum oil. In all oils, aromatichydrocarbon components are associated with harmful effects in aquatic biota. Monoaromatichydrocarbons, i.e., benzene, toluene, ethylbenzene and xylene, are often associated with acutetoxicity. Meanwhile, polycyclic aromatic hydrocarbons can cause both acute and sublethaltoxicity.Several classes of harmful effects have been documented in the literature based on laboratorystudies and from observations after oil spill accidents. Exposure to petroleum oil can causes everal biological effects including increased mortality, early-life stage developmental defects,r educed reproductive capacity, genetic damage, impaired immune function and diseaser esistance, and changes in behaviour. Many publications reported that early-life stages (embryos and larvae) of fish are more sensitive to oil exposure than adults.S everal recommendations are made for future research to address knowledge gaps on the effects of oil on aquatic biota. Research should address the lack of information on the effects ofoil sands products (e.g., diluted bitumen, synthetic crude oil) on aquatic biota. Research is also needed to study the fate, behaviour and effects on aquatic biota of oil spills in ice-coveredCanadian waters.

RefID: 216

Author: Durako, M..J, Kenworthy, W.J., Fatemy, S.M.R., Valavi, H. and Thayer, G.W.

Year: 1993

Title: Assessment of the toxicity of Kuwait crude oil on the photosynthesis and respiration of seagrasses of the northern Gulf

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/0025326X9390028I

Abstract: Photosynthetic and respiratory responses of leaf tissues of the seagrasses Halophila ovalis, H. stipulacea, and Halodule uninervis exposed for 12–18 h to unweathered Kuwait crude oil were measured using an oxygen electrode system to assess the possibility of acute toxicity. Leaf tissues were incubated in natural seawater (control treatment) or in the water-soluble fraction of a 1% (weight:volume) solution of Kuwait crude oil in seawater (oil treatment). Photosynthesis vs. irradiance (PI) responses exhibited typical light-saturation kinetics. One-way analysis of variance detected no significant treatment effects on the PI characteristics: α, Pmax, Ik, or Ic. Respiration rates were also not significantly affected by short-term exposure to the oil treatment. In addition, no significant among-species differences in PI characteristics or respiration were detected, possibly reflecting the low metabolic state for these subtropical species during Leg II sampling when water temperatures were 16–19°C. These results support our observations that the Gulf War oil spill primarily impacted intertidal communities rather than the submergent plant communities of the northern Gulf region.

RefID: 217

Author: Durako, M.J., Kenworthy, W.J., Fatemy, S.M.R., Valavi, H. and Thayer, G.W.

Year: 1993

Title: ASSESSMENT OF THE TOXICITY OF KUWAIT CRUDE-OIL ON THE PHOTOSYNTHESIS AND RESPIRATION OF SEAGRASSES OF THE NORTHERN GULF

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/0025326X9390028I

Abstract: Photosynthetic and respiratory responses of leaf tissues of the seagrasses Halophila ovalis, H. stipulacea, and Halodule uninervis exposed for 12-18 h to unweathered Kuwait crude oil were measured using an oxygen electrode system to assess the possibility of acute toxicity. Leaf tissues were incubated in natural seawater (control treatment) or in the water-soluble fraction of a 1% (weight:volume) solution of Kuwait crude oil in seawater (oil treatment). Photosynthesis vs. irradiance (PI) responses exhibited typical light-saturation kinetics. One-way analysis of variance detected no significant treatment effects on the PI characteristics: alpha, P(max), I(k), or I(c). Respiration rates were also not significantly affected by short-term exposure to the oil treatment. In addition, no significant among-species differences in PI characteristics or respiration were detected, possibly reflecting the low metabolic state for these subtropical species during Leg II sampling when water temperatures were 16-19-degrees-C. These results support our observations that the Gulf War oil spill primarily impacted intertidal communities rather than the submergent plant communities of the northern Gulf region.

RefID: 218

Author: Dussauze, M., Camus, L., Le Floch, S., Pichavant-Rafini, K., Geraudie, P., Coquille, N., Amerand, A., Lemaire, P. and Theron, M.

Year: 2014

Title: Impact of dispersed fuel oil on cardiac mitochondrial function in polar cod Boreogadus saida

Journal: Environmental Science and Pollution Research

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/24532208

Abstract: In this study, impact of dispersed oil on cardiac mitochondrial function was assessed in a key species of Arctic marine ecosystem, the polar cod Boreogadus saida. Mature polar cod were exposed during 48 h to dispersed oil (mechanically and chemically) and dispersants alone. The increase observed in ethoxyresorufin-O-deethylase activity and polycyclic aromatic hydrocarbon metabolites in bile indicated no difference in contamination level between fish exposed to chemical or mechanical dispersion of oil. Oil induced alterations of O-2 consumption of permeabilised cardiac fibres showing inhibitions of complexes I and IV of the respiratory chain. Oil did not induce any modification of mitochondrial proton leak. Dispersants did not induce alteration of mitochondrial activity and did not increase oil toxicity. These data suggest that oil exposure may limit the fitness of polar cod and consequently could lead to major disruption in the energy flow of polar ecosystem.

RefID: 219

Author: Eberhardt, L.L. and Garrott, R.A.

Year: 1997

Title: Sea otter mortality from the Exxon Valdez oil spill: Evaluation of an estimate from boat-based surveys - Response

Journal: Marine Mammal Science

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1111/j.1748-7692.1997.tb00641.x/abstract

Abstract: Response to T0087

RefID: 220

Author: Ebert, T.A. and Lees, D.C.

Year: 1996

Title: Growth and Loss of Tagged Individuals of the Predatory Snail Nucella lamellosa in Areas within the Influence of the Exxon Valdez Oil Spill in Prince William Sound

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: Growth and recapture rates of tagged individuals of the predatory frilled dogwinkle Nucella lamellosa were studied at areas in Prince William Sound, Alaska, that were within the influence of the Exxon Valdez oil spill. Snails were individually taqgged with small plastic fish tags in spring and summer 1991, measured with caliers, and released at three types of sites: (1) unoiled, (2) oiled, and (3) oiled and washed with hot water. Sites were searched again in September 1991 and in July 1992 and all tagged individuals were measured. The Brody-Bertalanffy function was used as the basic growth model and was modified to accommodate seasonal variation in growth. Analysis showed a strong seasonal component to growth, with minimum growth during the winter. Growth was highest at sites that had not experienced oiling and was lowest at oiled locations. When growth of frilled dogwinkle was adjusted for degree of exposure to open sea conditions, growth was similar at unoiled and "oiled-and-washed" sites and higher than at oiled sites. Recapture rates of tagged snails were highest at unoiled sites and lowest at oiled locations; recapture rates at sites washed with hot water were intermediate. We conclude that oil from the Exxon Valdez depressed growth and recapture rates of tagged frilled dogwinkle in Prince William Sound and that treatment of oiled beaches with hot water improved growth conditions for frilled dogwinkle but did not return the site to an unoiled state with respect to recapture rates.

RefID: 221

Author: Ekanem, A.P., Asuquo, F.E. and Ndick, E.J.

Year: 2011

Title: Toxicity of Crude Oil to Fresh Water Shrimp, Macrobrachium macrobrachion and Macrobrachium vollenhovenii From Nigerian Coastal Water

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs00128-011-0229-8

Abstract: The water soluble fraction (WSF) of crude oil was tested against Macrobrachium macrobrachion and Macrobrachium vollenhovenii, at 2, 4, 6, 8 and 10 mg/L in glass aquaria stocked with ten animals for 96 h under observations for changes. Moribund swimming, restlessness, respiratory difficulties, depigmentation and mortalities were observed in the WSF exposure groups, but not in the controls. LC(50) values were estimated at 5 +/- A 1.76 and 4 +/- A 1.76 mg/L for M. macrobrachion and M. vollenhovenii respectively. There was no significant difference in mortalities between the two species (p > 0.05), leading to the conclusion that the WSF of crude oil in the Nigerian coastal waters may be equally toxic to M. macrobrachion and M. vollenhovenii.

RefID: 222

Author: Eldridge, M.B., Echeverria, T. and Whipple, J.A.

Year: 1977

Title: ENERGETICS OF PACIFIC HERRING (CLUPEA-HARENGUS-PALLASI) EMBRYOS AND LARVAE EXPOSED TO LOW CONCENTRATIONS OF BENZENE, A MONOAROMATIC COMPONENT OF CRUDE-OIL

Journal: Transactions of the American Fisheries Society

Hyperlink: http://www.tandfonline.com/doi/abs/10.1577/1548-8659%281977%29106%3C452%3AEOPHCH%3E2.0.CO%3B2

Abstract: Interest in the energetic processes of critical early life stages of Pacific herring (Clupea harengus pallasi) and the potential effects from sublethal exposure to benzene, a monoaromatic component of crude oil, led to a series of experiments which examined metabolism of herring embryos, yolk-sac larvae, and post-yolk-sac larvae. Yolk caloric content was 6,020 cal/g or 1.3 calories per egg. This energy was consumed rapidly during incubation; total yolk absorption occurred 12 days after fertilization. Anabolic rates varied but at no time was there an energy deficit. Oxygen consumption of embryos increased prior to hatching, then a 10-fold rise was seen in newly hatched yolk-sac larvae. Exogenous calories were estimated from ingested rotifers and were less definable than endogenous energy due to variable grazing rates. Sublethal concentrations of benzene caused (a) significantly less embryonic tissue growth, (b) significantly different oxygen consumption in embryos, and (c) significantly greater assimilation in feeding larvae. It is believed activity of larvae played an important role in accounting for increased metabolism of later stages.

RefID: 223

Author: El-Sheekh, M.M., El-Naggar, A.H., Osman, M.E.H. and Haieder, A.

Year: 2000

Title: Comparative studies on the green algae Chlorella homosphaera and Chlorella vulgaris with respect to oil pollution in the river Nile

Journal: Water Air and Soil Pollution

Hyperlink: http://link.springer.com/article/10.1023%2FA%3A1005268615405

Abstract: The effect of oil pollution on growth and metabolic activities of the fresh water algae Chlorella homosphaera and C. vulgaris was studied. The study was conducted on two locations in the river Nile, one is oil polluted and the other is not polluted. The assemblage of the different algal groups was monitored in both locations. Chlorophyta was more dominant than Cyanophyta and Bacillariophyta in both locations during all seasons except in winter when Bacillariophyta is the most dominant group. The presence of crude oil or its refinery products (solar and lubricating) in the culture media of algae markedly influenced their growth, proteins and nucleic acid contents. The toxicity of oil was a concentration dependent. The low concentrations stimulated growth, protein content and nucleic acids, whereas high concentrations had an inhibitory effect. Although DNA and RNA responded similarly to crude oil in the two tested organisms, DNA showed more sensitivity than RNA to solar oil. Lubricating oil had a little phytotoxic effect on nucleic acids. Different species of algae response differentially to oil pollution; Chlorella vulgaris can be referred to as oil-sensitive, while Chlorella homosphaera can tolerate relatively higher concentrations of oil.

RefID: 224

Author: Elston, R.A. and Meyers, T.R.

Year: 2009

Title: Effect of viral hemorrhagic septicemia virus on Pacific herring in Prince William Sound, Alaska, from 1989 to 2005

Journal: Diseases of Aquatic Organisms

Hyperlink: http://www.int-res.com/abstracts/dao/v83/n3/p223-246/

Abstract: We critically review the role of viral hemorrhagic septicemia virus (VHSV) in the 1992-1993 collapse of the Prince William Sound (PWS) herring fishery. VHSV was detected in samples of moribund Pacific herring from PWS in spring 1993 when about 63 % of the expected fish failed to appear. A low prevalence and severity of VHSV were observed in adult pre-spawning PWS herring in most of the years from 1994 to 2002. The North American strain of VHSV became established about 500 yr ago in many northeast Pacific marine fish species, including herring. In Alaska, the typical annual prevalence of VHSV in pre-spawning herring ranges from 0 to 17 %. New threshold analysis of a 9 yr study indicates that only about half of the virus-infected adult fish in PWS were clinically affected; ulcers formerly attributed to VHS have been overestimated by a factor of about 3. We conclude that VHSV was not a primary causative factor in the PWS herring population collapse or in its failure to recover. Because older age classes of herring were not disproportionately missing in 1993, the protozoan Ichthyophonus hoferi was also not a likely cause of losses. The 'Exxon Valdez' oil spill occurred in PWS, Alaska, USA, in 1989.

Evidence for interaction of oil and VHSV expression is also evaluated. A study exposing herring to varying concentrations of weathered crude oil showed increasing prevalences of VHSV correlated with oil concentration; however, repeated experiments with juvenile and adult fish failed to corroborate these results or link oil to VHSV infection in herring.

RefID: 225

Author: Environment Canada, Fisheries and Oceans Canada, and Natural Resources Canada

Year: 2013

Title: Properties, Composition and Marine Spill Behaviour, Fate and Transport of Two Diluted Bitumen Products from the Canadian Oil Sands

Journal: Federal Government Technical Report

Hyperlink:

Abstract: Effective spill response depends on good scientific understanding of petroleum product behaviour in the environment (e.g., movement and changes in physical properties and chemical composition of the oil). This study reports the early research simulating diluted bitumen products spilled at sea. This work was undertaken by the Government of Canada as part of the first phase of a strategy to implement a world class prevention, preparedness and response regime for oil spills from ships. The behaviour of the diluted bitumen products was studied under laboratory conditions in three phases. First, the properties and composition of two samples representative of products currently being shipped in Canada were measured before (fresh) and after (weathered) exposure to environmental conditions. Secondly, the potential for evaporation, exposure to light, mixing with saltwater, and sediments in the saltwater to affect whether diluted bitumen products float or sink in saltwater was examined. Finally, the effectiveness of two existing spill treating agents meant to disperse spilled oil products was evaluated.This work is a collaborative effort between the Emergencies Science and Technology Section, Environment Canada; the Centre for Offshore Oil, Gas and Energy Research, Fisheries and Oceans Canada; and CanmetENERGY, Natural Resources Canada. As well as the laboratory and wave-tank experiments, a literature review was conducted to identify knowledge gaps on the physical and chemical properties of conventional and non-conventional heavy oils, and their fate and behaviour in marine environments. The use and effectiveness of oil spill treating agents is also reviewed for heavy oils.Two diluted bitumen products, Access Western Blend (AWB) and Cold Lake Blend (CLB), were selected for study as the highest-volume products transported by pipeline in Canada for 2012–2013. The physical characteristics and chemical composition of each product were measured to aid in potential spill preparation and response.The major results of the studies were:Like conventional crude oil, both diluted bitumen products floated on saltwater (free of sediment), even after evaporation and exposure to light and mixing with water; When fine sediments were suspended in the saltwater, high-energy wave action mixed the sediments with the diluted bitumen, causing the mixture to sink or be dispersed as floating tarballs;Under conditions simulating breaking waves, where chemical dispersants have proven effective with conventional crude oils, a commercial chemical dispersant (Corexit 9500) had quite limited effectiveness in dispersing dilbit; Application of fine sediments to floating diluted bitumen was not effective in helping to disperse the products;The two diluted bitumen products display some of the same behaviours as conventional petroleum products (i.e. fuel oils and conventional crude oils), but also significant differences, notably for the rate and extent of evaporation.Beyond informing subsequent studies, these results will also immediately help inform spill responders and computer models to better understand and predict the fate and behaviour of these non-conventional petroleum products in the marine environment. Better understanding the potential impacts of a non-conventional oil spill on the marine ecosystem, assists decision makers in making appropriate spill response and remediation choices. This suite of scientific research and activities will advance the knowledge of non-convention petroleum products; provide a better understanding of the potential consequences of a spill of diluted bitumen petroleum product on the marine ecosystem, and information to assist in response and remediation efforts.

RefID: 226

Author: Estes, J.A.

Year: 1991

Title: CATASTROPHES AND CONSERVATION - LESSONS FROM SEA OTTERS AND THE EXXON-VALDEZ

Journal: Science

Hyperlink: http://www.sciencemag.org/content/254/5038/1596.citation

Abstract:

RefID: 227

Author: Etkin, D.S., Joeckel, J., Hayward Walker, A., Scholz, D., Moore, C., Baker, C., Hatzenbuhler, D., Patton, R.G., Lyman, E. and Culpepper, D.

Year: 2015

Title: Washington State 2014 Marine and Rail Oil Transportation Study

Journal: Report

Hyperlink: http://www.ecy.wa.gov/programs/spills/OilMovement/2014MRStudy.html

Abstract: Significant changes in the transportation of crude oil are occurring in Washington State. In particular, transportation methods and oil types have been changing. Historically, 90% of crude oil bound for refineries was delivered by tank ship. In 2014, pipeline and rail delivery made up more than 30% of the oil imports, while vessel delivery was reduced to less than 70%. The properties of some of the oils being transported also raise planning and response concerns. This report contains the results of the Marine and Rail Oil Transportation Study authorized by the Legislature in April 2014. The objective of the study was to analyze the risks to public health and safety and to the environment associated with the transport of oil in Washington. In the study, the Washington State Emergency Management Division, surveyed local and tribal planning and fire districts on the readiness of local jurisdictions to respond to an oil-by-rail incident. The Washington State Utilities and Transportation Commission reviewed safety records of almost 350 rail crossings. The Washington State Department of Ecology reviewed oil spill prevention and readiness measures in place at the federal and state levels. The January 2015 Salish Sea workshop was conducted, focusing on oil spill risk in the geographic region of the Salish Sea. Comments from hundreds of people were collected through information-gathering workshops, government-to-government meetings with tribes and tribal organizations, and meetings with communities across the state. This report contains 43 findings and recommendations for legislative, regulatory, or voluntary actions. The recommendations propose ways to maximize public safety and protect the environment, tribal treaty rights, and the state's natural and economic resources. The report also identifies gaps in information which future studies should address. Seven of the appendices in the report contain detailed information on oil transport by rail, facilities and vessels, spill planning and response, properties of oil, and the fate of oil when spilled.

RefID: 228

Author: EVOS Trustee Council

Year: 2014

Title: Exxon Valdez Oil Spill Final and Annual Reports

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/Universal/Documents/Publications/FinalAndAnnualReports.pdf

Abstract: Since 1989, the Exxon Valdez Oil Spill Trustee Council (EVOSTC) has funded projects to assesst he impacts of the oil spill and restore the environment. Over the years, projects have includednatural resource damage assessment (NRDA) studies, restoration projects and Gulf EcosystemMonitoring and Research Program (GEM) projects. To date the Council has published thesef inal reports in three series: - Exxon Valdez Oil Spill State/Federal Natural Resource Damage Assessment Final Reports - Exxon Valdez Oil Spill Restoration Project Final Reports - Exxon Valdez Oil Spill Gulf Ecosystem Monitoring and Research Project FinalReports

RefID: 229

Author: Fadely, B.S., Castellini, J.M. and Castellini, M.A.

Year: 1997

Title: Recovery of harbor seals from EVOS: condition and health status

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/index.cfm?FA=searchResults.projectInfo&Project_ID=1069

Abstract: The objectives of this project were to establish the criteria to evaluate the health and body condition of harbor seals (Phoca vitulina) within Prince William Sound and the Gulf of Alaska in special reference to potential problems induced by the Exxon Valdez Oil Spill. We constructed plasma chemistry and hematology reference ranges based on nearly 300 samples collected during 1991 - 1996, that can be used to screen seals for clinically significant conditions. Analyses of variance found up to half of the total variation in blood parameters could be attributed to handling, individual, regional, seasonal, or interannual effects. Power analysis modeling of interannual and interregional comparisons showed that small differences in blood variables could be detected with high statistical power, and that these differences were similar in magnitude to effects produced by handling or individual factors. We have determined that some of the seals sampled during this project exhibited indications of clinical conditions. Seal blubber from Prince William Sound was found to be more energy dense than blubber from southeast Alaska seals, and energy density also varied with gender, season and body mass. Condition indices of blubber content and body size did not show conclusive differences among the two regions.

RefID: 230

Author: Fadely, B.S., Castellini, M.A. and Castellini, J.M.

Year: 1996

Title: Harbor seals and EVOS: blubber and lipids as indices of food limitation, Exxon Valdez Oil Spilll Restoration Project Annual Report (Restoration Project 95131)

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/index.cfm?FA=searchResults.projectInfo&Project_ID=958

Abstract: The hypothesis presented for testing in Broad Agency Announcement (BAA) 52ABNF400 104 was that food limitation could have a multi-level impact on marine mammals, affecting their reproductive success, juvenile survival, and adult body condition. We proposed to approach the request from a unique perspective: If food limitation does indeed impact reproductive success, juvenile survival or adult body condition, then it follows that there should be differences in body condition of adult harbor seals before and after EVOS and within and outside of the EVOS area. This BAA/NOAA study utilized blubber analysis methods to test body condition status of harbor seals. Blubber provides insulation and is also a critical fuel source for marine mammals. Therefore, its quality and energy density are prime descriptive characteristics of the energy available to the animal. The project was designed with two major components: the analysis of contemporary blubber samples from animals inside and outside of Prince William Sound and the study of archived blubber samples collected before the EVOS event. Simultaneous work on body condition and health status of harbor seals continues under project 97001.

RefID: 231

Author: Faro, J.B., Bowyer, R.T., Testa, J.W. and Duffy, L.K.

Year: 1994

Title: River otter component of the oiled mussel-bed study

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/35840641.pdf

Abstract: Our objective was to determine if physiological and morphological differencespreviously detected in river otters from oiled and nonoiled areas could be affected by mussel beds, and whether these differences would persist or subside with time. Differences in levels of blood haptoglobin and Interleukin-6 ir, which previously were elevated in river otters(Lurru canadensis) inhabiting oiled when compared to nonoiled areas of Prince WilliamSound, Alaska, were not observed in summer 1992. River otters from oiled areas continuedto regain body size from levels noted in 1990; adjusted mean body mass of otters from oiledand nonoiled areas were nearly identical by summer 1992. Consequently, no adverse effectsin 1992 could be attributed to oiled mussel beds from areas where river otters were captured. Likewise, oiled mussel beds may not have been a factor contributing to documenteddifferences in these variables in 1990 and 1991. We propose that river otters may be recovering from chronic effects that we observed in 1990 and 1991 following the 1989 ExonValdez oil spill.

RefID: 232

Author: Faro, J.B., Bowyer, R.T., Testa, J.W. and Duffy, L.K.

Year: 1994

Title: Assessment of injury to river otters in Prince William Sound, Alaska, following the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/index.cfm?FA=searchResults.projectInfo&Project_ID=1362

Abstract: River otters (Lutra canadensis) were killed by direct effects of the Exxon Valdez oil spill, but the magnitude of that loss is unknown due to lack of pre-spill data. A time lag in spill effects is reflected by the reduction in species richness and diversity in the summer diets of otters in oiled areas between 1989 and 1990. Otters from oiled areas had higher haptoglobin levels in both 1990 and 1991. In 1991, increases in Ildir levels from otters in oiled habitats may have indicated a compromised immune system. Male otters captured in oiled areas in 1990 had significantly lower body mass than otters from nonoiled areas. Otters from oiled areas had home ranges that were twice as large as those from a non-spill area. Differences in rates of fecal deposition between oiled and nonoiled latrine sites in 1989 suggest otters used heavily oiled areas less often. Otters avoided shorelines with shallow slopes on the oiled area, whereas they strongly preferred these slopes on nonoiled sites, suggesting that otters lost habitat as a result of the spill. Otters abandoned latrine sites in 1991 over three times more often in oiled areas, suggesting there may have been a delayed response to crude oil exposure.

RefID: 233

Author: Feder, H.M.

Year: 1995

Title: Injury to deep benthos

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/Store/FinalReports/1992-ST02B-Final.pdf

Abstract: This study was designed to assess the possible injury by petroleum, derived from the Exxon Valdez oil spill to benthic infaunal resources within Prince William Sound in water deeper than 20 m. The sampling plan was developed to coordinate with several other concurrent programs within Prince William Sound. Analyses of benthic biological data collected from 14 bays in Prince William Sound in 1990 at 40, 100 and > 100 m, by univariate and multivariate techniques, demonstrated no obvious disturbance effects on the benthic biota 16 months after the oil spill. In all multivariate analyses, the major environmental variables related to the composition of benthic assemblages were sediment parameters such as percent silt, clay, mud, percent water and amount of nitrogen and carbon in sediment. Although limited amounts of petroleum hydrocarbons and presence of hydrocarbon degrading bacteria were detected at some sites at 40 and 100 m in 1989 and 1990, minor or no impact was sustained by benthic fauna of the deep benthos within the Sound. It is apparent that the current speed within Prince William Sound during the oil spill was sufficient to flush out toxic fractions of the oil spill before they could damage the fauna within the deep benthos.

RefID: 234

Author: Feder, H.M. and Blanchard, A.

Year: 1998

Title: The deep benthos of Prince William Sound, Alaska, 16 months after the Exxon Valdez oil spill

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X97874206

Abstract: In 1990, 16 months after the T/V Exxon Valdez oil spill (EVOS) in Prince William Sound, Alaska, an assessment of the benthic macrofauna and associated environmental parameters at 40 and 100 m was made. Assessment of the biota and environmental data demonstrated patterns in deep benthic assemblages reflective of oceanographic conditions, as indicated by sediment differences, rather than EVOS toxicity. Comparison of polynuclear aromatic hydrocarbons (PAH) and δ13C values in sediments between stations within the oil trajectory and reference stations outside of the trajectory showed no significant differences. This investigation uncovered no signals of disturbance 16 months after the EVOS. These results agree with conclusions of studies of intertidal and shallow subtidal regions following the EVOS that demonstrated disturbance effects decreasing with depth.

RefID: 235

Author: Fernandez, N., Cesar, A., Salamanca, M.J. and Delvalls, T.A.

Year: 2006

Title: Toxicological characterisation of the aqueous soluble phase of the Prestige fuel-oil using the sea-urchin embryo bioassay

Journal: Ecotoxicology

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/17072768

Abstract: The soluble components of fuel oil are generally assumed to be the fraction that is toxic for organisms living in the water column. We have used a liquid phase bioassay with embryos of sea urchin to assess the toxicity of the water-soluble fraction (elutriate) of the fuel oil spilled when the tanker Prestige sank on 13 November 2002. Two methodologies to obtain elutriates were carried out in order to compare the effect of the extraction method on the measured toxicity. Analyses of Sigma 16PAHs (naphthalene, acenaphtylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, Indeno(1,2,3-c-d)pyrene, benzo(a)pyrene, dibenz(a,h)anthracene and benzo(ghi)perylene) and four metals (copper, cadmium, lead and zinc) were conducted and linked to the biological response. The effective concentration that provoked a delay in the successful embryogenesis of 50% of population (EC50) was 2.3% of fuel oil. No differences in final toxicity between the two elutriation treatments were found, although the rotated extraction seemed to be more effective than magnetic stirring in transferring contaminants from the fuel oil to the water. Toxicity was mainly associated with the low-weight PAHs (2-4 benzene rings).

RefID: 236

Author: Ferrando, A., Gonzalez, E., Franco, M., Commendatore, M., Nievas, M., Militon, C., Stora, G., Gilbert, F., Esteves, J.L. and Cuny, P.

Year: 2015

Title: Oil spill effects on macrofaunal communities and bioturbation of pristine marine sediments (Caleta Valdés, Patagonia, Argentina): experimental evidence of low resistance capacities of benthic systems without history of pollution

Journal: Environmental Science and Pollution Research

Hyperlink: http://link.springer.com/article/10.1007/s11356-015-4167-6

Abstract: The Patagonian coast is characterized by the existence of pristine ecosystems which may be particularly sensitive to oil contamination. In this study, a simulated oil spill at acute and chronic input levels was carried out to assess the effects of contamination on the macrobenthic community structure and the bioturbation activity of sediments sampled in Caleta Valdés creek. Superficial sediments were either noncontaminated or contaminated by Escalante crude oil and incubated in the laboratory for 30 days. Oil contamination induced adverse effects on macrobenthic community at both concentrations with, for the highest concentration, a marked decrease of approximately 40 and 55 % of density and specific richness, respectively. Besides the disappearance of sensitive species, some other species like Oligochaeta sp. 1, Paranebalia sp., and Ostracoda sp. 2 species have a higher resistance to oil contamination. Sediment reworking activity was also affected by oil addition. At the highest level of contamination, nearly no activity was observed due to the high mortality of macroorganisms. The results strongly suggest that an oil spill in this protected marine area with no previous history of contamination would have a deep impact on the non-adapted macrobenthic community.

RefID: 237

Author: Ferrante, P.

Year: 1990

Title: FOOD PROCUREMENT AND FEEDING OF SEA OTTERS DURING THE T-V EXXON VALDEZ OIL SPILL

Journal: U S Fish and Wildlife Service Biological Report

Hyperlink: https://openlibrary.org/books/OL24349175M/Sea_otter_symposium

Abstract: The T/V Exxon Valdez spilled 11 million gallons of crude oil in Prince William Sound on 24 March 1989. During spring and summer 1989, 339 sea otters (Enhydra lutris) were captured and taken to otter rehabilitation facilitites for treatment of various medical problems. These sea otters were severely stressed by oil contamination and removal from their natural environment. Adequate nutrition was an important factor in their recovery. I discuss requirements and duties concerning food preparation and handling. In addition, I discuss food procurement from distributors, food types, expense, transportation, food storage, refrigerators, freezers, ice, methods of thawing frozen food, and equipment used in providing food for the rescue operation. Because of its high metabolic rate, a captive sea otter consumes about 15% of its body weight each day. As the exact nutrient requirement of the sea otter is not known, a variety of food was offered. Otter pups require special food, and preparation of pup food requires intensive labor. The facilities were staffed on a 24-h basis.

RefID: 238

Author: Fleeger, J.W., Shirley, T.C., Carls, M.G., Todaro, M.A.

Year: 1996

Title: Meiofaunal recolonization experiment with oiled sediments

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: To gain insight into long-term studies of the effects of the Exxon Valdez oil spill on the meiobenthos, a colonization experiment was initiated in 1990. Unweathered Exxon Valdez crude oil was mixed with azoic sediment to prepare low (26 ± 3 μg g-1 total aromatics) and high (210 ± 12 μg g-1 total aromatics) treatments of oiled sediments. The resulting mixtures, and azoic sediment without oil as a control, were added to triplicate colonization trays and buried flush with the surface of two beaches near mean low water in Herring Bay, Prince William Sound, Alaska. Hydrocarbon concentrations tended to decline with time. Trays and ambient sediments were sampled by coring and harpacticoid copepod species enumerated on days 0, 1, 2 and 28. Harpacticoids (more than 40 species) were mostly phytal associates from surrounding eelgrass beds. Colonization was rapid (approaching ambient levels in 1-2 d), especially in control and low-oil treatments. High-oil treatments exhibited significantly reduced densities of total harpacticoids and of two rapidly colonizing species (Halectinosoma sp. and Mesochra pygmaea) especially on days 1 and 2. Two slower colonizers (Paralaophonte perplexa and Amphiascus minutus) were unaffected by oil additions. Detrended correspondence analysis identified oil effects on the harpacticoid assemblage among the treatment-date collections. Ambient samples from all dates segregated from experimentals and were tightly clustered. Day 1 and 2 low- and high-oil treatments clustered together as did control, low-, and high-oil sediments from day 28. Control day 1 and 2 collections were intermediate. Thus, results suggest that an oil effedt on migration and colonization was detectable, but for fewer than 28 d.

RefID: 239

Author: Fodrie, F.J., Able, K.W., Galvez, F., Heck, K.L. Jr, Jensen, O.P., López-Duarte, P.C., Martin, C.W., Turner, R.E. and Whitehead, A.

Year: 2014

Title: Integrating Organismal and Population Responses of Estuarine Fishes in Macondo Spill Research

Journal: BioScience

Hyperlink: http://bioscience.oxfordjournals.org/content/64/9/778.abstract

Abstract: Syntheses of research spanning diverse taxa, ecosystems, timescales, and hierarchies are crucial for understanding the cumulative impacts of the Macondo oil spill in the Gulf of Mexico. Four years after the spill, responses of estuarine fishes to oil pollution have been studied at organismal through population levels, and there is an emerging mismatch between consistent negative impacts detected among individual organisms and absence of measurable negative impacts among populations. To reconcile this apparent contradiction, we draw on lessons learned from this and previous spills to consider two classes of mechanisms: factors obscuring negative population impacts despite known organismal responses (e.g., high spatiotemporal variability, offsetting food-web cascades, fishery closures, temporal lags) and factors dampening population-level costs despite known organismal responses (e.g., behavioral avoidance, multiple compensatory pathways). Thus, we highlight critical knowledge gaps that should form the basis of current and future oil-spill research priorities to assess ecosystem responses to basin-scale disturbance.

RefID: 240

Author: Fraker, M.A.

Year: 2013

Title: Killer Whale (Orcinus orca) Deaths in Prince William Sound, Alaska, 1985-1990

Journal: Human and Ecological Risk Assessment

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/10807039.2012.719385

Abstract: During 19851990, two groups of killer whales in Prince William Sound, Alaska, experienced unusually high rates of mortality, while seven others did not. Those affected were AB pod, part of the southern Alaska population of resident (fish-eating) killer whales, and the AT1 transient (marine mammaleating) group, a very small, reproductively isolated population that last reproduced in 1984. In 19851986, several AB pod members were shot by fishermen defending their catch from depredation, which explains some of the deaths. Understanding the other deaths is complicated by the Exxon Valdez oil spill (March 1989) and uncertainties about the causes and times of the deaths. For AB pod, possible factors involved in the post-spill mortalities are delayed effects of bullet wounds, continued shooting, oil exposure, and consequences of being orphaned. For the AT1 group, possible factors are oil exposure, small population size, old age, and high-contaminant burdens. An analysis of possible effects of inhalation of volatile organic compounds, contact with the oil slick, and ingestion of oil with water or prey did not reveal route(s) of exposure that could explain the mortalities. The cause(s) of the killer whale deaths recorded following the oil spill remain uncertain.

RefID: 241

Author: Franco, M.A., Viñas, L., Soriano, J.A., de Armas, D., González, J.J., Beiras, R., Salas, N., Bayona, J.M. and Albaigés, J.

Year: 2006

Title: Spatial distribution and ecotoxicity of petroleum hydrocarbons in sediments from the Galicia continental shelf (NW Spain) after the Prestige oil spill

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X0500456X

Abstract: The distribution of aliphatic and aromatic hydrocarbons was determined in surface sediments collected at 36 stations along the Galicia continental shelf (NW Spain), following the Prestige oil spill. Sampling was performed in December 2002, just after the accident, and in February and September 2003. Concentrations of PAHs (Sigma 13 parent components) were in the range of 0.9-422 mu g/kg dw, the highest values being close to coastal urban areas (e.g. Pontevedra and A Coruna), whereas in the stations of the area most heavily impacted by the spill (off Costa da Morte) concentrations were in the range of 14.8-89.6 mu g/kg dw, with a certain predominance of alkylated compounds, which may suggest a mixture of petrogenic and pyrolytic sources. The detailed study of petrogenic molecular markers (e.g. steranes and triterpanes) showed the occurrence of an old (weathered) petrogenic chronic pollution in the shelf sediments but not of the Prestige oil, with the possible exception of few stations in the area of Costa da Morte. This was attributed to the heavy nature of the spilled oil that was barely dispersed in the water column and mainly stranded on the coast or sedimented in the form of oil patches. The addition of increasing amounts of fuel oil to a representative sediment sample showed that the molecular indices were indicative of the presence of the Prestige oil when the amount was above 1 g/kg of sediment. The toxicity of selected samples (showing the higher PAH concentrations) was tested using the bivalve embryogenesis bioassay. Embryogenesis success reached high values in all cases (80 88%, with 86% in the control), indicating a lack of toxicity in the sediments and supporting the conclusion that the patchiness of the fuel eventually reaching the seafloor reduced its impact on the benthic communities of the Galician shelf. (c) 2005 Elsevier Ltd. All rights reserved.

RefID: 242

Author: Frank, R.A., Fischer, K., Kavanagh, R., Burnison, B.K., Arsenault, G., Headley, J.V., Peru, K.M., Van der Kraak, G. and Solomon, K.R.

Year: 2009

Title: Effect of Carboxylic Acid Content on the Acute Toxicity of Oil Sands Naphthenic Acids

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es8021057

Abstract: Fractions of methylated naphthenic acids (NAs) isolated from oil sands process-affected water were collected utilizing Kugelrohr distillation and analyzed by proton nuclear magnetic resonance ((1)H NMR) spectroscopy. (1)H NMR analysis revealed that the ratio of methyl ester hydrogen atoms to remaining aliphatic hydrogen atoms increased from 0.130 to 0.214, from the lowest to the greatest molecular weight (MW) fractions, respectively, indicating that the carboxylic acid content increased with greater MW. Acute toxicity assays with exposure to monocarboxyl NA-like surrogates demonstrated that toxicity increased with increasing MW (D. magna LC(50) values of 10 +/- 1.3 mM and 0.59 +/- 0.20 mM for the respective lowest and highest MW NA-like surrogates); however, with the addition of a second carboxylic acid moiety, the toxicity was significantly reduced (D. magna LC(50) values of 10 +/- 1.3 mM and 27 +/- 2.2 mM for the respective monocarboxyl and dicarboxyl NA-like surrogates of similar MW). Increased carboxylic acid content within NA structures of higher MW decreases hydrophobicity and, consequently, offers a plausible explanation as to why lower MW NAs in oil sands process-affected water are more toxic than the greater MW NAs.

RefID: 243

Author: Frank, R.A., Kavanagh, R., Kent Burnison, B., Arsenault, G., Headley, J.V., Peru, K.M., Van Der Kraak, G. and Solomon, K.R.

Year: 2008

Title: Toxicity assessment of collected fractions from an extracted naphthenic acid mixture

Journal: Chemosphere

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0045653508005614

Abstract: Recent expansion within the oil sands industry of the Athabasca Basin of Alberta, Canada has led to increased concern regarding process-affected wastewaters produced during bitumen extraction. Naphthenic acids (NAs) have been identified as the primary toxic constituents of oil sands process-affected waters (OSPW) and studies have shown that with time, microbial degradation of lower molecular weight NAs has led to a decrease in observed toxicity. As earlier studies identified the need for an "unequivocal demonstration" of lower molecular weight NAs being the primary contributors to mixture toxicity, a study was initiated to fractionate an extracted NA mixture by molecular weight and to assess each fraction's toxicity. Successful molecular weight fractionation of a methylated NA mixture was achieved using a Kugelrohr distillation apparatus, in which fractions collected at higher boiling points contained NAs with greater total carbon content as well as greater degree of cyclicity. Assays with Vibrio fischeri bioluminescence (via Microtox assay) revealed that the lowest molecular weight NAs collected had higher potency (EC50: 41.9 ± 2.8 mg l−1) than the highest molecular weight NAs collected (EC50: 64.9 ± 7.4 mg l−1). Although these results support field observations of microbial degradation of low molecular weight NAs decreasing OSPW toxicity, it is not clear why larger NAs, given their greater hydrophobicity, would be less toxic.

RefID: 244

Author: Frantzen, M., Falk-Petersen, I.B., Nahrgang, J., Smith, T..J, Olsen, G.H., Hangstad, T.A. and Camus, L.

Year: 2012

Title: Toxicity of crude oil and pyrene to the embryos of beach spawning capelin (Mallotus villosus)

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X11002700

Abstract: Due to a northward shift in oil and gas activities, there is an increasing need to understand the potential anthropogenic impacts of oil-related compounds on sub-Arctic and Arctic organisms, particularly those in coastal habitats. Capelin (Mallotus villosus), a key fish species in the Barents Sea ecosystem, undertakes aggregated spawning at both intertidal and subtidal coastal localities in northern Norway. To investigate the sensitivity of capelin embryos to oil compounds, newly fertilized capelin eggs were collected from a spawning beach and exposed until hatch (32 days) to either the water soluble fraction of crude oil or the single PAH compound, pyrene. Threshold levels for egg mortality, development and hatching success were determined. Concentrations of 40 mu g/L crude oil (Sigma 26 PAHs) and 55 mu g/L pyrene significantly increased embryonic mortality rates and decreased hatching success, compared with controls, indicating that a potential oil spill in the vicinity of capelin spawning grounds may cause significant impacts. No significant incidence of adverse effects such as yolk sac oedema, pericardia oedema, haemorrhages, craniofacial abnormalities, premature hatch or inhibited growth was observed. Histological studies of hatched larvae did not reveal specific sublethal effects in tissues and organs. Developmental delays and subsequent embryo death were noticed at the period of eye pigmentation in affected groups. Early life-history stages of capelin are sensitive indicators of PAH impacts, but the mechanisms responsible for the toxic effects require further investigation. (C) 2011 Elsevier B.V. All rights reserved.

RefID: 245

Author: Freese, J.L. and O'Clair, C.E.

Year: 1995

Title: Injury to crabs outside Prince William Sound

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33963598.pdf

Abstract: Commercial Dungeness crab fisheries exist near Kodiak Island and the eastern Alaska Peninsula. Both areas lie within the trajectory of the 1989 Emon Vnldez oil spill. Thirty nine sites in the region were sampled in 1989 and 1990 to assess petroleum hydrocarbon contamination of crab tissues and benthic sediments with which crabs were associated. Female crabs were found in small numbers at 15 sites. Eight of these sites exhibited low levels of petroleum hydrocarbons in the sediments. Only two of the eight sites showed oil contamination that could be linked convincingly to the Exxon Valdez oil spill. None of the crab tissue samples showed evidence of contamination by petroleum hydrocarbons.

RefID: 246

Author: Fried, S.M., Bue, B.G., Sharp, D. and Sharr, S.

Year: 1998

Title: Injury to spawning areas and an evaluation of spawning escapement enumeration of pink salmon in Prince William Sound, Alaska

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/42725188.pdf

Abstract: This project will complete the analysis of data from NRDA and restoration studies designed to improve the accuracy of wild pink salmon escapement estimates. Estimates of aerial survey bias and stream life from 1990 and 1991 studies represent a major advance in escapement estimation procedures. Results will dramatically improve past and future escapement estimates in Prince William Sound and will lead to more accurate and precise stock specific fisheries management. The commercial fishery in Prince William Sound is of major economic importance and also plays a major role in regulating populations of salmon in Prince William Sound. Wild stocks which were injured by the Exxon Valdez oil spill play a major role in the Prince William Sound ecosystem and are frequently intercepted in mixed stock fisheries dominated by hatchery fish. Accurate and timely estimates of spawning escapements are critical for biologists who seek to ensure reproductive success for wild populations by manipulating fisheries.

RefID: 247

Author: Frost, K.J. and Lowry, L.F.

Year: 1994

Title: Assessment of injury to harbor seals in Prince William Sound, Alaska, and adjacent areas following the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33088421.pdf

Abstract: In the weeks following the Exxon Valdez oil spill (EVOS) harbor seals, Phoca vitulina richardsi, swam through oil and inhaled aromatic hydrocarbons as they breathed at the air/water interface. Some pups were born on oiled haulouts and nursed on oiled mothers. By May over 80% of the seals in oiled areas had oiled pelage. Heavily oiled seals were observed to be sick, lethargic, or unusually tame. Concentrations of fluorescent aromatic compounds in bile clearly indicated that most seals from oiled areas had been exposed to hydrocarbons. Microscopic examination of tissues revealed severe neurological lesions in a heavily oiled seal collected 35 days post spill. Similar but milder lesions were found in the brains of seals collected three months post-spill. Before the EVOS, harbor seals in Prince William Sound were declining at an average annual rate of 12% in both oiled and unoiled areas. Aerial surveys in 1989 indicated a 43% decline at oiled sites versus an 11% decline at unoiled sites. By 1992 there were still 34% fewer seals at oiled sites than before the spill. The proportion of pups in the oiled area in 1989 was significantly lower than in subsequent years. Total spill-caused mortality in Prince William Sound was estimated to be 300 seals.

RefID: 248

Author: Frost, K.J., Lowry, L.F. and Ver Hoef, J.M.

Year: 1999

Title: MONITORING THE TREND OF HARBOR SEALS IN PRINCE WILLIAM SOUND, ALASKA, AFTER THE EXXON VALDEZ OIL SPILL

Journal: Marine Mammal Science

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1111/j.1748-7692.1999.tb00815.x/abstract

Abstract: We used aerial counts to monitor the trend in numbers of harbor seals, Phoca vitulina richardsi, in Prince William Sound, Alaska, following the 1989 Exxon Valdez oil spill. Repetitive counts were made at 25 haul-out sites during the annual molt period each year from 1990 through 1997. A generalized linear model indicated that time of day, date, and time relative to low tide significantly affected seal counts. When Poisson regression was used to adjust counts to a standardized set of survey conditions, results showed a highly significant decline of 4.6% per year. Unadjusted counts indicated a slight, but not statistically significant, decline in the number of seals. The number of harbor seals on the trend-count route in eastern and central PWS has been declining since at least 1984, with an overall population reduction of 63% through 1997. Programs to monitor long-term changes in animal population sizes should account for factors that can cause short-term variations in indices of abundance. The inclusion of such factors as covariates in models can improve the accuracy of monitoring programs.

RefID: 249

Author: Fukuyama, A.K., Shigenaka, G. and Coats, D.A.

Year: 2014

Title: Status of intertidal infaunal communities following the Exxon Valdez oil crossMark spill in Prince William Sound, Alaska

Journal: Marine Pollution Bulletin

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/24923812

Abstract: Intertidal infaunal communities were sampled in Prince William Sound, Alaska from 1990-2000 to evaluate impacts and recovery from the Exxon Valdez oil spill. Initial findings suggested that the spill and cleanup depressed abundances of all taxonomic groups. By 1992, abundances of major taxonomic categories at disturbed sites had either converged or paralleled populations at Unoiled sites. Abundances of littleneck clams, Leukoma (Protothaca) staminea, slowly increased at Treated sites and converged with Unoiled sites by 2000. Infaunal population differences positively correlated with fine-grained sediments at Treated sites. We believe that sediment fines removal during cleanup, and subsequent slow natural replenishment, impeded the return of the environment to pre-spill conditions. This suggests physical recovery of spill-affected beaches is an important precursor to biological recovery. (C) 2014 Elsevier Ltd. All rights reserved.

RefID: 250

Author: Fukuyama, AK, Shigenaka, G and Hoff, RZ

Year: 2000

Title: Effects of residual Exxon Valdez oil on intertidal protothaca staminea: Mortality, growth, and bioaccumulation of hydrocarbons in transplanted clams

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X00000552

Abstract: Effects of residual Exxon Valdez oil on the intertidal clam, Protothaca staminea, were studied using reciprocal experimental transplants of clams between unoiled and oiled sites. Individually tagged clams were transplanted in 1994 and collected in 1995 and 1996, Mortality, growth, and tissue chemistry data were collected from reference unoiled and oiled clams, clams transplanted from an oiled to unoiled site, and clams moved from an unoiled to oiled site. Greatest mortality occurred in clams originating from the oiled site. Best growth occurred in clams moved from the oiled site to the unoiled area, Largest tissue burdens of hydrocarbons occurred in oiled site clams, There was indication of depuration of hydrocarbons when oiled site clams were transplanted to the unoiled site. Clams transplanted from the unoiled site to oiled site accumulated hydrocarbons after one year. Our results indicate that residual oil, 5-6 years following the EV oil spill, affected survival and growth rates of clams. (C) 2000 Elsevier Science Ltd. All rights reserved.

RefID: 251

Author: Fuller, C., Bonner, J., Page, C., Ernest, A., McDonald, T. and McDonald, S.

Year: 2004

Title: Comparative toxicity of oil, dispersant, and oil plus dispersant to several marine species

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/03-548.1/abstract

Abstract: Dispersants are a preapproved chemical response agent for oil spills off portions of the U.S. coastline, including the Texas-Louisiana coast. However, questions persist regarding potential environmental risks of dispersant applications in nearshore regions (within three nautical miles of the shoreline) that support dense populations of marine organisms and are prone to spills resulting from human activities. To address these questions, a study was conducted to evaluate the relative toxicity of test media prepared with dispersant, weathered crude oil, and weathered crude oil plus dispersant. Two fish species, Cyprinodon variegatus and Menidia beryllina, and one shrimp species, Antericamysis bahia (formerly Mysidopsis bahia), were used to evaluate the relative toxicity of the different media under declining and continuous exposure regimes. Microbial toxicity was evaluated using the luminescent bacteria Vibrio fisheri. The data suggested that oil media prepared with a chemical dispersant was equal to or less toxic than the oil-only test medium. Data also indicated that continuous exposures to the test media were generally more toxic than declining exposures. The toxicity of unweathered crude oil with and without dispersant was also evaluated using Menidia beryllina under declining exposure conditions. Unweathered oil-only media were dominated by soluble hydrocarbon fractions and found to be more toxic than weathered oil-only media in which colloidal oil fractions dominated. Total concentrations of petroleum hydrocarbons in oil-plus-dispersant media prepared with weathered and unweathered crude oil were both dominated by colloidal oil and showed no significant difference in toxicity. Analysis of the toxicity data suggests that the observed toxicity was a function of the soluble crude oil components and not the colloidal oil.

RefID: 252

Author: Gagné, F., André, C., Turcotte, P., Gagnon, C., Sherry, J. and Talbot, A.

Year: 2013

Title: A comparative toxicogenomic investigation of oil sand water and processed water in rainbow trout hepatocytes

Journal: Archives of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs00244-013-9888-2

Abstract: The purpose of this study was to compare the expression of gene transcripts involved in toxic stress in rainbow trout hepatocytes exposed to oil sand water (OSW), lixiviate (OSLW), and processed water (OSPW). We pose the hypothesis that the changes in gene expression responses in cells exposed to a simulated oil sand extraction procedure (OSPW) differ from the gene expression responses of OSLW and OS. Rainbow trout hepatocytes were exposed to increasing concentrations of OSW, OSLW, and OSPW for 48 h at 15 °C. Cell viability was assessed by measuring membrane permeability, total RNA levels, and gene expression using an array of 16 genes involved in xenobiotic biotransformation (GST, CYP1A1, CYP3A4, MDR), metal homeostasis and oxidative stress (MT, SOD, and CAT), estrogenicity (VTG, ER[beta]), DNA repair (LIG, APEX, UNG, and OGG), cell growth (GADD45 and PCNA), and glycolysis (GAPDH). The results showed that the toxicogenomic properties of OSPW differed from those of OSLW and OSW. Gene transcripts that were influenced by OSW and OSLW, and strongly expressed in OSPW, were MT, CAT, GST (induction), CYP1A1, VTG, UNG/OGG, and PCNA. These genes are therefore considered not entirely specific to OSPW but to water in contact with OS. We also found gene transcripts that responded only with OSPW: SOD, GST (inhibition), MDR (inhibition), CYP3A4, GAPDH, GADD45, and APEX. Of these gene transcripts, the ones strongly associated with toxicity (loss of cell viability and RNA levels) were CYP3A4, GST, and GAPDH. Genes involved in DNA repair were also strongly related to the loss of cell viability but responded to both OSLW and OSPW. The observed changes in cell toxicity and gene expression therefore support the hypothesis that OSPW has a distinct toxic fingerprint from OSLW and OSW.

RefID: 253

Author: Gagné, F., Douville, M., André, C., Debenest, T., Talbot, A., Sherry, J., Hewitt, L.M., Frank, R.A., McMaster, M.E., Parrott, J. and Bickerton, G.

Year: 2012

Title: Differential changes in gene expression in rainbow trout hepatocytes exposed to extracts of oil sands process-affected water and the Athabasca River

Journal: Comparative Biochemistry and Physiology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S1532045612000051

Abstract: The oil sands region of northern Alberta represents the world's largest reserves of bitumen, and the accelerated pace of industrial extraction activity has raised concern about the possible impacts on the Athabasca River and its tributaries. An ecotoxicogenomic study was undertaken on Oncorhynchus mykiss trout hepatocytes exposed to extracts of water samples near the oil sand development area, as well as to oil sands process-affected water (OSPW) extracts using the quantitative reverse transcriptase polymerase chain reaction technique. The expression of the following genes (mRNA) was monitored to track changes in xenobiotic biotransformation (CYP1A1, CYP3A4, glutathione S-transferase, multi-drug resistance transporter), estrogenicity (estrogen receptor and vitellogenin), oxidative stress (superoxide dismutase and metallothionein) and DNA repair activity (DNA ligase). The extent of DNA-aromatic hydrocarbon adducts was also determined in cells by immuno-staining. A comparative analysis of gene expression between the river/lake and OSPW samples revealed that CYP3A4, metallothioneins, DNA ligase and GST genes, were specifically expressed by OSPW. Cells exposed to OSPW, commercial naphthenic acids, and benzo(a)pyrene showed increased polyaromatic hydrocarbon DNA-adducts, as determined by cell immunofluorescence analysis. Other genes were induced by all types of water samples, although the induction potential was stronger in OSPW most of the time (e.g., VTG gene was expressed nearly 15-fold by surface waters from the lake and river samples but increased to a maximum of 31-fold in OSPW). A multivariate discriminant function analysis revealed that the lake and river water samples were well discriminated from the OSPW. The CYP3A4 gene was the most highly expressed gene in cells exposed to OSPW and responded less to the lake or river water in the Athabasca River area. This study identified a suite of gene targets that responded specifically to OSPW extracts, which could serve as toxicogenomic fingerprints of OSPW contamination. Crown Copyright (C) 2012 Published by Elsevier Inc. All rights reserved.

RefID: 254

Author: Gagnon, M.M. and Holdway, D.A.

Year: 1999

Title: Metabolic enzyme activities in fish gills as biomarkers of exposure to petroleum hydrocarbons

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/10499994

Abstract: Metabolic effects of low-level exposure of Atlantic salmon (Salmo salar) to the water accommodated fraction (WAF) of crude oil and to dispersed crude oil were studied. Aerobic enzymes citrate synthase and cytochrome C oxidase, and anaerobic enzyme lactate dehydrogenase were measured in gills during a 4-day exposure to low concentrations of dispersed Bass Strait crude oil and WAF, and during the following 8 days of depuration in clean seawater. Relative to pre-exposure levels, citrate synthase and lactate dehydrogenase exhibited a significant inhibition of activity during exposure to the WAF of crude oil, and to dispersed crude oil, while activity of cytochrome C oxidase remained unchanged. Citrate synthase activities returned to preexposure levels after 4 days following termination of exposure for the WAF-exposed fish, and after 2 days for the dispersed-oil-exposed fish. After the termination of exposure to both treatments, lactate dehydrogenase activity remained low relative to levels measured prior to exposure, which indicated that the activity of this enzyme may be a sensitive medium to long-term biomarker of exposure to petroleum-contaminated water bodies. (C) 1999 Academic Press.

RefID: 255

Author: Gardiner, W.W., Word, J.Q., Word, J.D., Perkins, R.A., McFarlin, K.M., Hester, B W., Word, L.S. and

Ray, C. M.

Year: 2013

Title: The acute toxicity of chemically and physically dispersed crude oil to key arctic species under arctic conditions during the open water season

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.2307/abstract

Abstract: The acute toxicity of physically and chemically dispersed crude oil and the dispersant Corexit 9500 were evaluated for key Arctic species. The copepod Calanus glacialis, juvenile Arctic cod (Boreogadus saida), and larval sculpin (Myoxocephalus sp.) were tested under conditions representative of the Beaufort and Chukchi Seas during the ice-free season. The toxicity of 3 water-accommodated fractions (WAF) of Alaska North Slope crude oil was examined with spiked, declining exposures. A dispersant-only test was conducted with the copepod C. glacialis. Each preparation with oil (WAF, breaking wave WAF [BWWAF], and chemically enhanced WAF [CEWAF]) produced distinct suites of hydrocarbon constituents; the total concentrations of oil were lowest in WAF and highest in CEWAF preparations. The relative sensitivity for the different species and age classes was similar within each WAF type. Median lethal concentration values based on total petroleum hydrocarbons ranged from 1.6mg/L to 4.0mg/L for WAF and BWWAF treatments and from 22mg/L to 62mg/L for CEWAF. For Corexit 9500 exposures, median lethal concentration values ranged from 17mg/L to 50mg/L. The differences in the relative toxicity among the accommodated fractions indicated that the majority of petroleum hydrocarbons in the CEWAF are in less acutely toxic forms than the components that dominate the WAF or BWWAF. Further evaluation showed that the parent polycyclic aromatic hydrocarbon compounds, specifically naphthalene, were highly correlated to acute toxicity. Environ Toxicol Chem 2013;32:2284-2300. (c) The Authors. Environmental Toxicology and Chemistry published by Wiley Peridoicals, Inc., on behalf of SETAC. This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

RefID: 256

Author: Garrott, R.A., Eberhardt, L.L. and Burn, D.M.

Year: 1993

Title: Mortality of sea otters in Prince William Sound following the Exxon Valdez oil spill

Journal: Marine Mammal Science

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1111/j.1748-7692.1993.tb00468.x/abstract

Abstract: This paper presents an estimate of the total number of sea otters that died as a direct consequence of the oil spill that occurred when the T/V Exxon Valdez grounded in Prince William Sound, Alaska on 24 March 1989. We compared sea otter counts conducted from small boats throughout the Sound during the summers of 1984 and 1985 to counts made after the spill during the summer of 1989. We used ratio estimators, corrected for sighting probability, to calculate otter densities and population estimates for portions of the Sound affected by the oil spill. We estimated the otter population in the portion of Prince William Sound affected by the oil was 6,546 at the time of the spill and that the post-spill population in the summer of 1989 was 3,898, yielding a loss estimate of approximately 2,650. Bootstrapping techniques were used to approximate confidence limits on the loss estimate of about 500–5,000 otters. The wide confidence limits are a result of the complex scheme required to estimate losses and limitations of the data. Despite the uncertainty of the loss estimate it is clear that a significant fraction of the otters in the spill zone survived. We observed otters persisting in relatively clean embayments throughout the oil spill zone suggesting that the highly convoluted coastline of Prince William Sound produced refuges that allowed some sea otters in the oil spill area to survive.

RefID: 257

Author: Garshelis, D.L.

Year: 1997

Title: Sea otter mortality estimated from carcasses collected after the Exxon Valdez oil spill

Journal: Conservation Biology

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1046/j.1523-1739.1997.96062.x/abstract

Abstract: Large numbers of sea otters (Enhydra lutris) dies following the 1989 Exxon Valdez oil spill. Two previous studies estimated spill-related mortality, one from the difference between counts of otters before and after the spill, and the other from the recovery rate of tagged carcasses that had been released at sea. I used a derivative of the second approach, but revised it to account for (1) moribund offers that had hauled out on shore; (2) carcasses that were collect at sea; and (3) differences in search effort in different areas of the spill-considerations that were not addressed previously. The mortality estimation procedure presented here, and applied to Prince William Sound, Alaska, had six input parameters, two with fixed values (the number of spill-related carcasses collected [391] and the number of otters taken alive that died in captivity [84]) and four that were assigned a range of values (the recovery rate for carcasses on the beach [60-90%], the proportion of recovered carcasses that were onshore [70-95%]), the proportion of offshore deaths recovered onshore (20-50%), and the proportion of moribund otters that hauled out (20-60%). Empirical estimates for these parameters were not available after the spill, but a range of plausible values for each was delimited using other available data. Randomly-selected combinations of values within these ranges produce mortality estimates for the sound ((x) over bar = 750, 5-95% quantiles approximate to 600-1000) that were lower than indicated by previous studies. These lower estimates do not diminish the tragic nature of the mortality, but instead highlight the significance of both the process and informational basis in producing estimates of catastrophic loss. Estimates of loss based on faulty or inadequate data may mislead investigations of population recovery and may jeopardize public trust in scientific assessments of future catastrophes.

RefID: 258

Author: Garshelis, D.L. and Estes, J.A.

Year: 1997

Title: Sea otter mortality from the Exxon Valdez oil spill: Evaluation of an estimate from boat-based surveys

Journal: Marine Mammal Science

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1111/j.1748-7692.1997.tb00640.x/abstract

Abstract: Letter to the editor re: S0136

RefID: 259

Author: Garshelis, D.L. and Johnson, C.B.

Year: 2013

Title: Prolonged recovery of sea otters from the Exxon Valdez oil spill? A re-examination of the evidence

Journal: Marine Pollution Bulletin

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/23639486

Abstract: Sea otters (Enhydra lutris) suffered major mortality after the Exxon Valdez oil spill in Prince William Sound, Alaska, 1989. We evaluate the contention that their recovery spanned over two decades. A model based on the otter age-at-death distribution suggested a large, spill-related population sink, but this has never been found, and other model predictions failed to match empirical data. Studies focused on a previously-oiled area where otter numbers (similar to 80) stagnated post-spill; nevertheless, post-spill abundance exceeded the most recent pre-spill count, and population trends paralleled an adjacent, unoiled-lightly-oiled area. Some investigators posited that otters suffered chronic effects by digging up buried oil residues while foraging, but an ecological risk assessment indicated that exposure levels via this pathway were well below thresholds for toxicological effects. Significant confounding factors, including killer whale predation, subsistence harvests, human disturbances, and environmental regime shifts made it impossible to judge recovery at such a small scale. (C) 2013 Elsevier Ltd. All rights reserved.

RefID: 260

Author: Garshelis, D.L. and Johnson, C.B.

Year: 2001

Title: Sea otter population dynamics and the Exxon Valdez oil spill: disentangling the confounding effects

Journal: Journal of Applied Ecology

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1046/j.1365-2664.2001.00563.x/abstract

Abstract: 1. Oil that spilled after the grounding of the Exxon Valdez in 1989 killed large numbers of sea otters in western Prince William Sound, Alaska, USA. However, our boat-based counts of sea otters during 1990-96 at oiled sites were as high or higher than boat-based counts in the same area in the early 1980s. 2. Another study reported a significant decline in sea otter numbers after the spill, but our reanalysis of that data produced results very similar to ours. Counts of otters were higher than pre-spill counts in the oiled area; the only detectable decline was in the northern part of the sound, outside the area of oiling. 3. We suggest that otter numbers in the western sound may have been increasing during the late 1980s, masking the loss due to the spill. Direct evidence for such an increase is lacking because no counts were conducted during this period. However, for several years after the spill pup production was higher than normal, which, if characteristic of the period immediately pre-spill, could have spurred a population increase. 4. Heightened pup production may have been caused by increased food supplies: after the spill, otters obtained more and larger clams per dive and spent less time feeding per day than in the early 1980s. 5. We postulate that in the early 1980s clams were still recovering from the uplift caused by the 1964 earthquake, which resulted in massive clam mortality and habitat change in the western sound. Lingering effects of previous catastrophic events, like the earthquake and even 19th-century fur harvests, have hampered attempts to assess the impacts of the oil spill on sea otter population dynamics. The effects of uncontrolled and unreplicated environmental incidents, even major disasters, may be difficult to assess because of confounding factors.

RefID: 261

Author: Geffard, O., Budzinski, H. and LeMenach, K.

Year: 2004

Title: Chemical and ecotoxicological characterization of the "Erika" petroleum: Bio-tests applied to petroleum water-accommodated fractions and natural contaminated samples

Journal: Aquatic Living Resources

Hyperlink: http://www.alr-journal.org/articles/alr/abs/2004/03/alrErika13/alrErika13.html

Abstract: spills are an important source of PAHs in marine and coastal areas and comprise a short- and long-term threat for aquatic organisms. Some PAHs are known to be toxic, in particular mutagenic and/or carcinogenic, and their toxicological effects must be evaluated. Here, the impact of the "Erika" oil spill, which occurred at the end of 1999, was studied by combining chemical (PAH analyses) and toxicological approaches (biological effect assessment). "Erika" elutriates have been found to be more toxic than the elutriate obtained with a crude oil, Bal 250, inducing deleterious effects in Mytilus galloprovincialis and Crassostrea gigas embryos and in Isochrysis galbana algae. The embryotoxicity test in mussel is more sensitive than growth test in I. galbana. Naphthalenic compounds make up more than 95% of total PAHs quantified in elutriates. "Erika" elutriates are enriched with naphthalene, methyl-naphthalene, anthracene and higher-molecular-weight compounds. On the contrary, Bal 250 elutriate is characterized by the highest dibenzothiophene, methyl-dibenzothiophene and dimethyl-dibenzothiophene levels. Weathering does not highly affect the toxicity of the "Erika" oil. This study also confirms the potential impact of the "Erika" fuel on the biological quality of sea water and sediments from Traict du Croisic on the Atlantic coast of France.

RefID: 262

Author: Geiger, H.J., Bue, B.G., Sharr, S., Wertheimer, A.C. and Willette, T.M.

Year: 1996

Title: A Life history approach to estimating damage to Prince William Sound Pink Salmon caused by the Exxon Valdez oils spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: The 1989 Exxon Valdez oil spill resulted in contamination of the habitat of juvenile pink salmon Oncorhynchus gorbuscha, including approximately 31% of the spawning streams and much of the nearshore marine rearing habitat in the southwest portion of Prince William Sound in 1990. In this study we combined the results of other studies to evaluate the loss of returning wild adult pink salmon attributable to the Exxon Valdez oil spill. We estimated that approimately 1.9 million wild adult pink salmon failed to return to Prince William Sound in 1990, primarily because of a lack of growth in the critical nearshore life stage when they entered seawater in spring 1989 during the height o f the spill. This number of fish was approximately 28% of the potential wild-stock production from the southwestern part of the sound returning in 1990. We estimated that 60,000 wild adult pink salmon failed to return in 1991 and 70,000 in 1992 because of direct poisoning of salmon in the embryo stage. In both 1991 and 1992 this was 6% or less of the potential wild-stock production in hte southwestern part of the sound and less than 2% of the potential wild production in the entire sound.

RefID: 263

Author: Geiger, J.G. and Buikema Jr, A.L.

Year: 1982

Title: Hydrocarbons Depress Growth and Reproduction of Daphnia pulex (Cladocera)

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f82-113

Abstract: Daphnia pulex were acutely and chronically exposed to water-soluble fractions of hydrocarbons. In acute studies, the most-to-least toxic were coal-tar creosote, No. 2 fuel oil, naphthalene, and phenanthrene. During chronic studies, Daphnia were monitored for molting frequency, growth rates, production of total and live young, number of nonviable eggs, partial and full abortions, and whether or not abortions occurred prior to completion of embryonic development. For creosote and phenanthrene, marked reduction occurred in growth rates, number of broods, and impairment of molting, and an increase occurred in abortion rates. No. 2 fuel oil produced similar effects, but results were less significant. Naphthalene only produced a slight reduction in growth rate at the concentrations studied. It is hypothesized that the effect on growth and reproduction may be due to PAH-induced disturbance on some aspect of metabolic control of reproduction and molting.

RefID: 264

Author: Gilbert, F., Stora, G. and Cuny, P.

Year: 2015

Title: Functional response of an adapted subtidal macrobenthic community to an oil spill: macrobenthic structure and bioturbation activity over time throughout an 18-month field experiment

Journal: Environmental Science and Pollution Research

Hyperlink: http://link.springer.com/article/10.1007/s11356-014-3906-4

Abstract: An experimental oil spill was carried out in order to assess in situ responses of a macrobenthic community of shallow subtidal sediments historically exposed to petroleum contamination. Both structural and functional (bioturbation activity) parameters of the community, subjected or not to a pulse acute contamination (25,000 ppm), were studied for 18 months. No difference in the community structure was detected between contaminated and control sediments, from 6 to 18 months of experimentation. Vertical distributions of organisms, however, were affected by the presence of oil contamination leading to a deeper burial of some polychaete species. In the same time, changes in sediment-reworking activity and

more especially a deeper particle burying in sediments subjected to acute oil contamination were shown. These results highlight the need to complete the analysis of community structure by assessing functional aspects, such as bioturbation activity, a process integrating various aspects of benthic behaviour (e.g. feeding, locomotion, burrow building) in order to estimate real (structural and functional) and long-term effects of oil contamination on benthic communities.

RefID: 265

Author: Gilde, K. and Pinckney, J.L.

Year: 2012

Title: Sublethal Effects of Crude Oil on the Community Structure of Estuarine Phytoplankton

Journal: Estuaries and Coasts

Hyperlink: http://link.springer.com/article/10.1007%2Fs12237-011-9473-8

Abstract: While the ecological impacts of crude oil exposure have been widely studied, its sublethal effects on phytoplankton community structure in salt marsh estuaries have not been well documented. The purpose of this study was to simulate oil spill conditions using a microcosm design to examine short-term (2 day) changes in phytoplankton community composition and total biomass following exposure to crude oil obtained from the Deepwater Horizon oil spill and a mixture of Texas crude oils. Microcosm experiments were performed in situ in North Inlet Estuary near Georgetown, SC. A control and six replicated experimental treatments of crude oil additions at final concentrations of 10, 50, or 100 mu l l(-1) of either Deepwater Horizon spill oil or the Texas crude mixture were incubated under in situ conditions. Photopigments were analyzed using high-performance liquid chromatography and community composition was determined using ChemTax. Total phytoplankton biomass (as chl a) declined with increasing crude oil concentrations. Prasinophytes, the most abundant microalga in both experiments, showed no response to oil exposure in one experiment and a significant negative response in the other. Diatoms euglenophytes and chlorophytes appeared relatively resistant to oil contamination at the exposure levels used in this study, maintaining or increasing their relative abundance with increasing oil concentrations. Chlorophytes and cyanobacteria increased in relative abundance while cryptophyte abundance decreased with increasing oil concentrations. The results of these experiments suggest that low levels of crude oil exposure may reduce total biomass and alter phytoplankton community composition with possible cascade effects at higher trophic levels in salt marsh estuaries.

RefID: 266

Author: Gilfillan, E.S., Page, D.S., Harner, E.J. and Boehm, P.D.

Year: 1995

Title: Shoreline Ecology Program for Prince William Sound, Alaska, Following the Exxon Valdez Oil Spill: Part III - Biology

Journal: Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters

Hyperlink: http://www.valdezsciences.com/dspArticle.cfm?catID=7&artID=1064&artSecID=1098

Abstract: This study describes the biological results of a comprehensive shoreline ecology program designed to assess ecological recovery in Prince William Sound following the Exxon Valdez oil spill on March 24, 1989. The program is an application of the "sediment quality triad" approach, combining chemical, toxicological, and biological measurements. The study was designed so that results could be extrapolated to the entire spill zone in Prince William Sound. The spill affected four major shoreline habitat types in Prince William Sound: pebble/gravel, boulder/cobble, sheltered bedrock, and exposed bedrock. The study design had two components: (1) one-time stratified random sampling at 64 sites representing four habitats and four oiling levels (including unoiled reference sites) and (2) periodic sampling at 12 nonrandomly chosen sites that included some of the most heavily oiled locations in the sound. Biological communities on rock surfaces and in intertidal and shallow subtidal sediments were analyzed for differences resulting from oiling in each of 16 habitat/tide zone combinations. Statistical methods included univariate analyses of individual species abundances and community parameter variables (total abundance, species richness, and Shannon diversity), and multivariate correspondence analysis of joint species abundances.The communities of animals and plants inhabiting the bedrock and coarse sediments on Prince William Sound shorelines responded much differently to oiling than communities in soft-sediment environments that were the subject of a majority of shoreline studies conducted after other oil spills. Sedimentary environments in Prince William Sound did not become anaerobic but showed evidence of increased biological activity as the oil residue became a source of organic carbon-without the usual succession of opportunistic invaders. Similarly, some bedrock sites showed increases in abundance, species richness, and diversity, as the spaces created by oiling were recolonized. This was to be expected in a high-energy environment dominated by "patch dynamics"; the rock surfaces and sediments support a mosaic of species that are adapted to rapidly colonize new spaces created by wave action and other physical factors. Two measures of ecological shoreline recovery are reported: an upper-limit estimate based on univariate analyses of community parameters and a lower-limit estimate based on multivariate correspondence analysis of community structure. Overall, the results indicate that between 73% and 91% of the oiled shoreline in Prince William Sound was ecologically recovered (i.e., it was indistinguishable from reference) in the summer of 1990. These results reflect rapid recovery of the biological communities and are consistent with chemical and toxicological studies (this volume), which found that hydrocarbon-related toxicity was virtually absent in the shoreline sediments by 1990-1991.

RefID: 267

Author: Gilfillan, E.S., Suchanek, T.H., Boehm, P.D., Harner, E.J., Page, D.S. and Sloan, N.A.

Year: 1995

Title: Shoreline Impacts in the Gulf of Alaska Region Following the Exxon Valdez Spill

Journal: Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters

Hyperlink: http://www.valdezsciences.com/dspArticle.cfm?catID=7&artID=1030&artSecID=1007

Abstract: Forty-eight sites in the Gulf of Alaska region (GOA-Kodiak Island, Kenai Peninsula, and Alaska Peninsula) were sampled in July/August 1989 to assess the impact of the March 24, 1989, Exxon Valdez oil spill on shoreline chemistry and biological communities hundreds of miles from the spill origin. In a 1990 companion study, 5 of the Kenai sites and 13 of the Kodiak and Alaska Peninsula sites were sampled 16 months after the spill. Oiling levels at each site were estimated visually and/or quantified by chemical analysis. The chemical analyses were performed on sediment and/or rock wipe samples collected with the biological samples. Additional sediment samples were collected for laboratory amphipod toxicity tests. Mussels were also collected and analyzed for hydrocarbon content to assess hydrocarbon bioavailability. Biological investigations at these GOA sites focused on intertidal infauna, epifauna, and macroalgae by means of a variety of common ecological techniques. For rocky sites the percentage of hard substratum covered by biota was quantified. At each site, up to 5 biological samples (scrapes of rock surfaces or sediment cores) were collected intertidally along each of 3 transects, spanning tide levels from the high intertidal to mean-lowest-low-water (zero tidal datum). Organisms (down to 1.0 mm in size) from these samples were sorted and identified. Community parameters including organism abundance, species richness, and Shannon diversity were calculated for each sample. As expected for shores so far from the spill origin, oiling levels were substantially lower, and beached oil was more highly weathered than in Prince William Sound (PWS). Samples of oiled GOA shoreline sediment were not statistically more toxic in bioassay tests than sediment from unoiled reference sites. As a consequence of the lower oil impact, the biological communities were not as affected as those in the sound. Biological impacts, although present in 1989 in the GOA, were localized, which is consistent with the patchy and discontinuous nature of much of the oiling in GOA. Some organisms were locally reduced or eliminated in oiled patches but survived in unoiled patches nearby. In areas where oiling occurred, impacts were generally limited to middle and upper intertidal zones.Analyses of mussel samples indicate that by 1990 little of the shoreline oil remained bioavailable to epifauna. Quantifiable measures of the overall health and vitality of shoreline biological communities, such as organism abundance, species richness, and Shannon diversity for sediment infauna, show few significant differences between oiled and reference sites in 1990.

RefID: 268

Author: Glegg, G.A. and Rowland, S.J.

Year: 1996

Title: The Braer oil spill - Hydrocarbon concentrations in intertidal organisms

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/0025326X96849654

Abstract: The concentrations of non-specific narcotic toxins such as the aromatic hydrocarbons toluene, naphthalene and phenanthrene were determined in specimens of limpets (Patella vulgata) and razor shells (Ensis spp.) collected from Shetland at the time of the Braer oil spin (84 000 t of Gullfaks production crude) and 3, 6 and 15 months after the spill. The analytical methods involved the use of deuterated analogues of the toxins to account for losses of analytes during recovery by steam distillation and determination by cryogenic GC-MS selected ion monitoring of molecular ions, Although the organisms were impacted by oil, the concentrations of total determinants in dead razor shells collected just after tbe oil spill were below the tissue effective concentrations for 50% reduction in filtering activity (TEC(50)) for mussels (the most valid toxicological data available for comparative purposes). A portion of the unresolved monoaromatic hydrocarbons of Gullfaks crude would probably add to the burden of toxins, but this was not measured in this study, The distribution of aromatic hydrocarbons in the organisms (phenanthrenes > naphthalenes > toluene) was the reverse of that in the oil and correlates with the expected bioconcentration behaviour of hydrophobic organics whereby less water soluble compounds with higher octanol-water partition coefficients are concentrated. Concentrations of naphthalene to methylphenanthrenes in limpets collected in January at the time of the spill from sites close to the wreck were wen below the TEC(50) values for mussels but comparison with the lower concentrations in limpets from a more remote site in Shetland indicated that the oil had impacted organisms near to tbe spill, consistent with intertidal survey data. Comparison with limited literature data for limpets and more extensive data for mussels also supported this conclusion, as did the identification of the oil residues in the limpets by biomarker fingerprinting. As with the razor shells, bioconcentration of the more hydrophobic compounds was observed. Concentrations in Shetland limpets generally decreased with increasing distance from the spill site. Concentrations of aromatic hydrocarbons decreased with time after the spill, such that by July concentrations were at what can reasonably be assumed to be background levels, comparable to the concentrations found at all times in the more remote site, Concentrations in a limited number of samples collected 15 months after the spill, following a further winter of storms in which sediment-sorbed oil could have been reintroduced to the limpets, showed no Increase. Copyright (C) 1996 Elsevier Science Ltd

RefID: 269

Author: Goff, K.L., Headley, J.V., Lawrence, J.R. and Wilson, K.E.

Year: 2013

Title: Assessment of the effects of oil sands naphthenic acids on the growth and morphology of Chlamydomonas reinhardtii using microscopic and spectromicroscopic techniques

Journal: Science of the Total Environment

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/23178771

Abstract: Naphthenic acid fraction components (NAFCs) are thought to be a primary agent of toxicity in oil sands process waters (OSPWs) produced by industrial activity in Canada's Athabasca oil sands. They are a complex, poorly characterized mixture of compounds whose mechanisms of toxicity are not well understood. In this work, it was discovered that the unicellular green algae Chlamydomonas reinhardtii are much more tolerant of NAFCs than predicted based on comparison to Chlamydomonas spp. isolated from the OSPW tailings ponds, with exponential growth occurring at 100 mg L-1 NAFC. Two cell wall mutants of C. reinhardtii exhibited greater tolerance to NAFC exposure. NAFC exposure induced changes in growth form and morphology were most pronounced in wild-type cells. Confocal scanning laser microscopy and Fourier-transform infrared spectromicroscopy indicated changes in cell wall surface proteins and their confirmation after exposure to NAFCs. Such alterations of cell wall proteins are consistent with the effects of surfactants on green algae, and indicate a possible role for classic naphthenic acids in the NAFC mixture to cause surfactant-mediated toxicity. The much greater tolerance to NAFCs under laboratory conditions indicates the likelihood that NAFCs do not act alone as agents of toxicity in algae such as C. reinhardtii, rather they seem to act in combination with other environmental factors to potentiate toxicity.

RefID: 270

Author: Gohlke, J.M., Doke, D., Tipre, M., Leader, M. and Fitzgerald, T.

Year: 2011

Title: A Review of Seafood Safety after the Deepwater Horizon Blowout

Journal: Environmental Health Perspectives

Hyperlink: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3237364/

Abstract: Background: The Deepwater Horizon (DH) blowout resulted in fisheries closings across the Gulf of Mexico. Federal agencies, in collaboration with impacted Gulf states, developed a protocol to determine when it is safe to reopen fisheries based on sensory and chemical analyses of seafood. All federal waters have been reopened, yet concerns have been raised regarding the robustness of the protocol to identify all potential harmful exposures and protect the most sensitive populations. Objectives: We aimed to assess this protocol based on comparisons with previous oil spills, published testing results, and current knowledge regarding chemicals released during the DH oil spill. Methods: We performed a comprehensive review of relevant scientific journal articles and government documents concerning seafood contamination and oil spills and consulted with academic and government experts. Results: Protocols to evaluate seafood safety before reopening fisheries have relied on risk assessment of health impacts from polycyclic aromatic hydrocarbon (PAH) exposures, but metal contamination may also be a concern. Assumptions used to determine levels of concern (LOCs) after oil spills have not been consistent across risk assessments performed after oil spills. Chemical testing results after the DH oil spill suggest PAH levels are at or below levels reported after previous oil spills, and well below LOCs, even when more conservative parameters are used to estimate risk. Conclusions: We recommend use of a range of plausible risk parameters to set bounds around LOCs, comparisons of post-spill measurements with baseline levels, and the development and implementation of long-term monitoring strategies for metals as well as PAHs and dispersant components. In addition, the methods, results, and uncertainties associated with estimating seafood safety after oil spills should be communicated in a transparent and timely manner, and stakeholders should be actively involved in developing a long-term monitoring strategy.

RefID: 271

Author: Gómez Gesteira, J.L. and Dauvin, J.-C.

Year: 2000

Title: Amphipods are Good Bioindicators of the Impact of Oil Spills on Soft-Bottom Macrobenthic Communities

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X00000461

Abstract: The Amoco Cadiz oil spill in 1978, and the Aegean Sea oil spill in 1992, affected soft-bottom communities, respectively from the Bay of Morlaix (western English Channel) and from the Ría de Ares and Betanzos in the north-western Iberian peninsula. These infralittoral communities on muddy fine sand showed similar species composition and structure and occurred in similar hydro-climatic conditions. The effects of the spills were identical in both areas with the disappearance of the amphipods especially those from the amphipod genus Ampelisca with a very low colonization of these species during the four years after the spill. The recovery rate of the amphipods was slow but progressive. In such communities no proliferation of opportunistics was observed after the stress. In the sites, where polychaetes dominated before the spill, they remained dominant, whereas other sites showed very low total abundances during the two years after the spill due to the absence of compensation for the disappearance of these crustaceans. In fact, there was a very low impact of the spill on polychaetes, but a high one on amphipods. In the future, it is suggested to focus monitoring after a spill only on a single amphipod group proposed as a bioindicator for detecting the impact of pollution. A polychaete/amphipod ratio is proposed to reflect temporal change of soft-bottom communities analogous to the nematode/copepod previously suggested for the meiobenthos. Detailed knowledge of the qualitative and quantitative structure of a benthic community is still needed in order to identify very precisely the effect of a pollution event.

RefID: 272

Author: González-Doncel, M., González, L., Fernandez-Torija, C., Navas, J.M. and Tarazona, J.V.

Year: 2008

Title: Toxic effects of an oil spill on fish early life stages may not be exclusively associated to PAHs: Studies with Prestige oil and medaka (Oryzias latipes)

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X08000684

Abstract: Polycyclic aromatic hydrocarbons (PAHs) are assumed to be the primary determinant of oil petroleum toxicity. Since the PAH content in Prestige oil was relatively high, we investigated the effects of different oil fractions (crude or weathered oil -0.05 to 50 g/L, and shaken or sonicated water accommodated fractions, WAFs, 25-100%, v/v) on the embryo-larval development of medaka (Oryzias latipes). Concentrations of Sigma 16PAHs analyzed in the incubation medium were highest in the shaken WAF followed by the crude oil, the sonicated WAF and the weathered oil. Both oils (>= 0.25 g/L) induced developmental abnormalities whereas no significant effects were seen in the WAF exposures. In vivo morphometric analysis of the surface of the gallbladder during advanced embryo organogenesis (192 h post-fertilization, hpf) revealed significant dilation in both WAF exposures (> 3 x 10(4) mu m(2) at >= 25%, v/v, compared to < 1.7 x 10(4) mu m(2) at 0%, v/v) followed by the crude oil (> 2.2 x 10(4) mu m(2) at >= 0.05 g/L). Fluorescent aromatic compounds were observed in the gallbladder and the yolk sac of 168-hpf embryos exposed to all oil fractions. Results suggest the presence of components in both oils capable of penetrating the chorion and inducing a toxicity not observed in the WAFs. Hence, the hazard and risk assessment of Prestige oil should not be based solely on the presence of PAHs since proximity or direct contact may induce toxicity not associated exclusively to these compounds. This research offers a new hypothesis for explaining the reported biological observations, which could be correlated to direct oil exposure rather than the traditional mechanism of waterborne PAH exposure. Further research is needed to identify those oil components responsible for toxicity. (c) 2008 Elsevier B.V. All rights reserved.

RefID: 273

Author: Greer, C.D., Hodson, P.V., Li, Z., King, T. and Lee, K.

Year: 2012

Title: Toxicity of crude oil chemically dispersed in a wave tank to embryos of Atlantic herring (Clupea harengus)

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.1828/abstract

Abstract: Tests of crude oil toxicity to fish are often chronic, exposing embryos from fertilization to hatch to oil solutions prepared using standard mixing procedures. However, during oil spills, fish are not often exposed for long periods and the dynamic nature of the ocean is not easily replicated in the lab. Our objective was to determine if brief exposures of Atlantic herring (Clupea harengus) embryos to dispersed oil prepared by standard mixing procedures was as toxic as oil dispersed in a more realistic model system. Embryos were first exposed to chemically dispersed Alaska North Slope crude and Arabian light crude oil for 2.4h to 14d from fertilization to determine if exposure time affected toxicity. Toxicity increased with exposure time, but 2.4h exposures at realistic concentrations of oil induced blue-sac disease and reduced the percentage of normal embryos at hatch; there was little difference in toxicity between the two oils. Secondly, oil was chemically dispersed in a wave tank to determine if the resultant oil solutions were as toxic to herring embryos as laboratory-derived dispersed oil using a single exposure period of 24h. Samples taken 15min postdispersion were more toxic than laboratory-prepared solutions, but samples taken at 5, 30, and 60min postdispersion were less toxic. Overall, the laboratory- and wave tank-derived solutions of dispersed oil provided similar estimates of toxicity despite differences in the methods for preparing test solutions, suggesting that laboratory and wave tank data are a reliable basis for ecological risk assessments of spilled oil. Environ. Toxicol. Chem. 2012;31:13241333. (c) 2012 SETAC

RefID: 274

Author: Gulec, I., Leonard, B. and Holdway, D.A.

Year: 1997

Title: Oil and dispersed oil toxicity to amphipods and snails

Journal: Spill Science & Technology Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S1353256197000030

Abstract: Acute 96-h LC50 values of the water-accommodated fraction (WAF) of crude oil, dispersants (Corexit 9500 and Corexit 9527) and dispersed oil combinations were determined in semi-static bioassays with seawater, using the amphipod Allorchestes compressa (Dana). Sub-lethal bioassays (suppression of burying behaviour over 30 min and 24 h exposure) were also conducted for these toxicants, using the marine sand snail Polinices conicus (Lamarck) as the test organism. Sodium dodecyl sulphate (SDS) and zinc sulphate were used as reference toxicants and identical bioassays were conducted using these compounds. The mean (n = 4) 96 h LC50 (SE) values for WAF of crude oil, Corexit 9527, Corexit 9500, dispersed oil (9527) and dispersed oil (9500) were 311,000 ppm (5760), 3.03 ppm (0.05), 3.48 ppm (0.03), 16.2 ppm (2.8) and 14.8 ppm (0.8), respectively. The mean (n = 4) 30 min EC50 (SE) values were 190,000 ppm (5600), 50.2 ppm (2.1), 58.9 ppm (3.1), 65.4 ppm (1.95) and 56.3 ppm (1.9) for WAF of crude oil, Corexit 9527, Corexit 9500, dispersed oil (9527) and dispersed oil (9500), respectively. These values reduced to 43,800 ppm (1400), 33.8 ppm (0.7), 42.3 ppm (1.1), 26.3 ppm (1.3) and 24.9 ppm (1.4) after 24 h exposure for WAF of crude oil, Corexit 9527, Corexit 9500, dispersed oil (9527) and dispersed oil (9500), respectively. These LC50 and EC50 values indicated that dispersed oil combinations were significantly more toxic to these organisms than WAF of crude oil. Caution should thus be used when deciding to use chemical dispersion as a remedial action for an oil spill in temperate inshore Australian waters. (C) 1998 Elsevier Science Ltd. All rights reserved.

RefID: 275

Author: Gundlach, E.R., Domeracki, D.D. and Thebeau, L.C.

Year: 1982

Title: Persistence of METULA oil in the strait of Magellan six and one-half years after the incident

Journal: Oil and Petrochemical Pollution

Hyperlink: http://www.sciencedirect.com/science/article/pii/S014371278290463X

Abstract: NA

RefID: 276

Author: Gundlach, E.R., Page, D.S., Neff, J.M. and Boehm, P.D.

Year: 2013

Title: Shoreline Biota

Journal: Oil in the Environment: Legacies and Lessons of the Exxon Valdez Spill

Hyperlink:

Abstract: Book Chapter (no abstract)

RefID: 277

Author: Hagen, M.O., Garcia-Garcia, E., Oladiran, A., Karpman, M., Mitchell, S., El-Din, M.G., Martin, J.W, and Belosevic, M.

Year: 2012

Title: The acute and sub-chronic exposures of goldfish to naphthenic acids induce different host defense responses

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X11003535

Abstract: Naphthenic acids (NAs) are believed to be the major toxic component in oil sands process-affected water (OSPW) produced by the oil sands mining industry in Northern Alberta, Canada. We recently reported that oral exposure to NAs alters mammalian immune responses, but the effect of OSPW or NAs on the immune mechanisms of aquatic organisms has not been fully elucidated. We analyzed the effects of acute and sub-chronic NAs exposures on goldfish immune responses by measuring the expression of three pro-inflammatory cytokine genes, antimicrobial functions of macrophages, and host defense after challenge with a protozoan pathogen (Trypanosoma carassii). One week after NAs exposure, fish exhibited increased expression of pro-inflammatory cytokines (IFN gamma, IL-1 beta 1,TNF-alpha 2) in the gills, kidney and spleen. Primary macrophages from fish exposed to NAs for one week, exhibited increased production of nitric oxide and reactive oxygen intermediates. Goldfish exposed for one week to 20 mg/L NAs were more resistant to infection by T. carassii. In contrast, sub-chronic exposure of goldfish (12 weeks) to NAs resulted in decreased expression of pro-inflammatory cytokines in the gills, kidney and spleen. The sub-chronic exposure to NAs reduced the ability of goldfish to control the T. carassii infection, exemplified by a drastic increase in fish mortality and increased blood parasite loads. This is the first report analyzing the effects of OSPW contaminants on the immune system of aquatic vertebrates. We believe that the bioassays depicted in this work will be valuable tools for analyzing the efficacy of OSPW remediation techniques and assessment of diverse environmental pollutants. (C) 2011 Elsevier B.V. All rights reserved.

RefID: 278

Author: Hall, A.J., Watkins, J. and Hiby, L.

Year: 1996

Title: The impact of the 1993 Braer oil spill on grey seals in Shetland

Journal: Science of The Total Environment

Hyperlink: http://www.sciencedirect.com/science/article/pii/0048969796050905

Abstract: Signs of acute respiratory distress were reported in moulting grey seals (Halichoerus grypus) hauled out on Lady's Holm, Shetland, following the Braer oil spill in January, 1993. Behavioural observations carried out between 16 January and 13 February 1993 showed that the proportion of animals exhibiting a discharge of nasal mucus was significantly higher than the proportion at a control site in the north (Papa Stour). The proportion of animals affected on Lady's Holm increased for up to one month following the spill. However, the time lag between exposure and peak response was approximately 30 days, longer than may be expected for an acute effect. The proportion of non-specific signs of respiratory distress in unexposed Shetland seals was assessed from observations made between 16 January and 25 January 1994. Symptoms similar to those seen in 1993 were also reported during this period, but the proportion of affected animals was higher in 1993. Symptoms were not observed at a grey seal moult site on the east coast of England in March 1993 and 1994. Grey seals moulting in Shetland during the time of the oil spill may have been acutely affected by exposure to hydrocarbons, but without sufficient baseline data on the occurrence of respiratory distress in grey seals it is difficult to determine the proportion attributable to other causes.

RefID: 279

Author: Hamdan, L.J. and Fulmer, P.A.

Year: 2011

Title: Effects of COREXIT (R) EC9500A on bacteria from a beach oiled by the Deepwater Horizon spill

Journal: Aquatic Microbial Ecology

Hyperlink: http://www.int-res.com/abstracts/ame/v63/n2/p101-109/

Abstract: Hydrocarbon-degrading bacteria are important for controlling the fate of natural and anthropogenic hydrocarbons in the marine environment. In the wake of the Deepwater Horizon spill in the Gulf of Mexico, microbial communities will be important for the natural attenuation of the effects of the spill. The chemical dispersant COREXIT (R) EC9500A was widely deployed during the response to the Deepwater Horizon incident. Although toxicity tests confirm that COREXIT (R) EC9500A does not pose a significant threat to invertebrate and adult fish populations, there is limited information on its effect on microbial communities. We determined the composition of the microbial community in oil that had been freshly deposited on a beach in Louisiana, USA, as a result of the Deepwater Horizon spill. The metabolic activity and viability in cultures obtained from oil samples were determined in the absence and presence of COREXIT (R) EC9500A at concentrations ranging from 0.001 to 100 mg ml(-1). In length heterogeneity PCR (LH-PCR) fingerprints of oil samples, the most abundant isolates were those of Vibrio, followed by hydrocarbon-degrading isolates affiliated with Acinetobacter and Marinobacter. We observed significant reductions in production and viability of Acinetobacter and Marinobacter in the presence of the dispersant compared to controls. Of the organisms examined, Marinobacter appears to be the most sensitive to the dispersant, with nearly 100% reduction in viability and production as a result of exposure to concentrations of the dispersant likely to be encountered during the response to the spill (1 to 10 mg ml-1). Significantly, at the same concentration of dispersant, the non-hydrocarbon-degrading Vibrio isolates proliferated. These data suggest that hydrocarbon-degrading bacteria are inhibited by chemical dispersants, and that the use of dispersants has the potential to diminish the capacity of the environment to bioremediate spills.

RefID: 280

Author: Hampson, G.R. and Moul, E.T.

Year: 1978

Title: No. 2 Fuel Oil Spill in Bourne, Massachusetts: Immediate Assessment of the Effects on Marine Invertebrates and a 3-Year Study of Growth and Recovery of a Salt Marsh

Journal: Journal of the Fisheries Research Board of Canada

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f78-123

Abstract: On October 9, 1974 the oil barge Bouchard 65 loaded with 73 000 barrels of oil spilled what was initially thought by the Coast Guard to be a few barrels and later raised to an undetermined amount of No. 2 fuel oil off the west entrance of the Cape Cod Canal in Buzzards Bay, Massachusetts (anchor site C, Fig. 1). Within the following 2-wk period, oil from the barge was found contained along the west side of Bassett's Island and inner Red Brook Harbor, a distance of 5.0 km from the site of the spillage. Qualitative samples of dead and moribund marine invertebrates were collected in tide pools and slight depressions along the beaches. A collection consisting of 4360 invertebrates comprising 105 species, plus 2 species of fish were found in 8 samples. Noticeable effects of the oil on the salt-marsh plant community were also observed. A detailed quantitative examination was begun to determine the effects of the oil on various components of the affected salt-marsh community in Winsor Cove compared to a selected control site. From data collected in September 1977, the marsh grass in the lower intertidal zone in Winsor Cove has shown an inability to reestablish itself by either reseeding or rhizome growth. The associated sediments show a correspondingly high concentration of petroleum hydrocarbons impregnated in the peat substrate. Erosion rates measured in the affected area, as a result of the 3-yr period of marsh degeneration, were 24 times greater than the control site. Microscopic algae were collected during the sampling period and those present were considered least sensitive to environmental changes. Examination of the interstitial fauna found in the study area in the summer of 1977 showed an extremely reduced number of individuals and species.

RefID: 281

Author: Han, J., Won, E.J., Hwang, D.S., Shin, K.H., Lee, Y.S., Leung, K.M.Y., Lee, S.J. and Lee, J.S.

Year: 2014

Title: Crude oil exposure results in oxidative stress-mediated dysfunctional development and reproduction in the copepod Tigriopus japonicus and modulates expression of cytochrome P450 (CYP) genes

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X14001568

Abstract: In this study, we investigated the effects of the water-accommodated fraction (WAF) of crude oil on the development and reproduction of the intertidal copepod Tigriopus japonicus through life-cycle experiments. Furthermore, we investigated the mechanisms underlying the toxic effects of WAF on this benthic organism by studying expression patterns of cytochrome P450 (CYP) genes. Development of T. japonicus was delayed and molting was interrupted in response to WAF exposure. Hatching rate was also significantly reduced in response to WAF exposure. Activities of antioxidant enzymes such as glutathione S-transferase (GST), glutathione reductase (GR), and catalase (CAT) were increased by WAF exposure in a concentration-dependent manner. These results indicated that WAF exposure resulted in oxidative stress, which in turn was associated with dysfunctional development and reproduction. To evaluate the involvement of cytochrome P450 (CYP) genes, we cloned the entire repertoire of CYP genes in T. japonicus (n = 52) and found that the CYP genes belonged to five different clans (i.e., Clans 2, 3, 4, mitochondrial, and 20). We then examined expression patterns of these 52 CYP genes in response to WAF exposure. Three TJ-CYP genes (CYP3024A2, CYP3024A3, and CYP3027C2) belonging to CYP clan 3 were significantly induced by WAF exposure in a time- and concentration-dependent manner. We identified aryl hydrocarbon responsive elements (AhRE), xenobiotic responsive elements (XREs), and metal response elements (MRE) in the promoter regions of these three CYP genes, suggesting that these genes are involved in detoxification of toxicants. Overall, our results indicate that WAF can trigger oxidative stress and thus induce dysfunctional development and reproduction in the copepod T. japonicus. Furthermore, we identified three TJ-CYP genes that represent potential biomarkers of oil pollution. (C) 2014 Elsevier B.V. All rights reserved.

RefID: 282

Author: Hannam, M.L., Bamber, S.D., Galloway, T.S., Moody, A.J. and Jones, M.B.

Year: 2010

Title: Effects of the model PAH phenanthrene on immune function and oxidative stress in the haemolymph of the temperate scallop Pecten maximus

Journal: Chemosphere

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0045653509014726

Abstract: Phenanthrene, a major component of crude oil, is one of the most abundant PAHs in aquatic ecosystems, and is readily bioavailable and toxic to a range of marine invertebrates. Within bivalves, the haemolymph acts as a transfer medium for these pollutants and their metabolic products, leaving haemocytes susceptible to deleterious effects. Using a suite of biological endpoints, this study determined the Sublethal (7-d exposure to 50, 100 and 200 mu g L(-1)) effects of phenanthrene on several oxidative stress and immunological parameters in the haemolymph of the commercially-important scallop Pecten maximus. Phenanthrene exposure (200 mu g L(-1)) resulted in immune modulation with significant reductions in cell membrane stability ($P < 0.05$) and phagocytosis ($P < 0.05$), and a significant increase in the number of total haemocytes ($P < 0.05$). Oxidative stress was also observed with a significant decrease in total glutathione ($P < 0.05$) and significantly increased levels of lipid peroxidation in the haemolymph ($P < 0.05$). Changes in the cellular and biochemical endpoints observed in this study illustrate their potential use in assessing the subtle effects of contaminant exposure. Whilst previous reports have suggested a link between free radical generation and immune suppression in vertebrates, this is the first instance where oxidative stress and immune function have been measured together in the haemolymph of a bivalve mollusc, demonstrating a possible link between PAH-induced oxidative stress and the subsequent inhibition in haemocyte immune function. (C) 2010 Elsevier Ltd. All rights reserved.

RefID: 283

Author: Hansen, B.H., Altin, D., Bonaunet, K. and Øverjordet, I.B.

Year: 2014

Title: Acute Toxicity of Eight Oil Spill Response Chemicals to Temperate, Boreal, and Arctic Species

Journal: Journal of Toxicology and Environmental Health

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/15287394.2014.886544

Abstract: The objectives of this study were to (1) determine the acute toxicity of selected shoreline washing agents (SWA) and dispersants, and (2) assess interspecies differences in sensitivity to the products. Eight shoreline washing agents (Hela saneringsv AE ske, Bios, Bioversal, Absorrep K212, and Corexit 9580) and chemical dispersants (Corexit 9500, Dasic NS, and Gamlen OD4000) were tested on five marine species, algae Skeletonema costatum, planktonic copepod species Acartia tonsa (temperate species), Calanus finmarchicus (boreal species) and Calanus glacialis (Arctic species), and benthic amphipod Corophium volutator. For most products, A. tonsa was the most sensitive species, whereas C. volutator was the least sensitive; however, these species were exposed through different media (water/sediment). In general, all copepod species displayed a relatively similar sensitivity to all products. However, A. tonsa was somewhat more sensitive than other copepods to most of the tested products. Thus, A. tonsa appears to be a candidate species for boreal and Arctic copepods for acute toxicity testing, and data generated on this species may be used as to provide conservative estimates. The benthic species (C. volutator) had a different sensitivity pattern relative to pelagic species, displaying higher sensitivity to solvent-based SWA than to water-based SWA. Comparing product toxicity, the dispersants were in general most toxic while the solvent-based SWA were least toxic to pelagic species.

RefID: 284

Author: Hansen, B.H., Altin, D., Olsen, A.J. and Nordtug, T.

Year: 2012

Title: Acute toxicity of naturally and chemically dispersed oil on the filter-feeding copepod Calanus finmarchicus

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651312003107

Abstract: Following oil spills in the marine environment, natural dispersion (by breaking waves) will form micron-sized oil droplets that disperse into the pelagic environment. Enhancing the dispersion process chemically will increase the oil concentration temporarily and result in higher bioavailability for pelagic organisms exposed to oil-dispersant plume. The toxicity of dispersed oil to pelagic organisms is a critical component in evaluating the net environmental consequences of dispersant use or non-use in open waters. To assess the potential for environmental effects, numerical models are being used, and for these to reliably predict the toxicity of chemically dispersed oil, it is essential to know if the dispersant affects the specific toxicity of the oil itself. In order to test the potential changes in specific toxicity of the oil due to the presence of chemical dispersant, copepods (Calanus finmarchicus) were subjected to a continuous exposure of chemically (4 percent Dasic w/w dispersant) and naturally dispersed oil (same droplet size range and composition) for four days. On average the addition of dispersant decreased 96 h LC50-values by a factor of 1.6, while for LC10 and LC90 these factors were 2.9 and 0.9, respectively. This indicates that after 96 h of exposure the dispersant slightly increased the specific toxicity of the oil at median and low effect levels, but reduced the toxicity at high effect levels. Decreased filtrations for the exposed groups were confirmed using particle counting and fluorescence microscopy. However, no differences in these endpoints were found between chemically and naturally dispersed oil. The ultimate goal was to evaluate if models used for risk and damage assessment can use similar specific toxicity for both chemically and naturally dispersed oil. The slight differences in toxicity between chemically and naturally dispersed oil suggest that risk assessment should be based on the whole concentration response curve to ensure survival of C. finmarchicus. (C) 2012 Elsevier Inc. All rights reserved.

RefID: 285

Author: Hansen, B.H., Nordtug, T., Altin, D., Booth, A., Hessen, K.M. and Olsen, A J.

Year: 2009

Title: Gene Expression of GST and CYP330A1 in Lipid-Rich and Lipid-Poor Female Calanus finmarchicus (Copepoda: Crustacea) Exposed to Dispersed Oil

Journal: Journal of Toxicology and Environmental Health

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/15287390802537313

Abstract: The copepod Calanus finmarchicus is a marine ecological key species in the Northern Atlantic food web. This species was exposed to an artificially weathered North Sea oil dispersion (oil droplets and water-soluble fractions [WSF]) and a filtered dispersion (containing only WSF) in serial dilution. Female copepods were divided into lipid-rich and lipid-poor for each exposure followed by gene expression analyses of glutathione S-transferase (GST) and cytochrome P-450 330A1 (CYP330A1). Lipid-rich copepods exhibited elevated transcription of GST and reduced transcription of CYP330A1 after exposure to both dispersed oil and WSF. In contrast, lipid-poor copepods exhibited increased transcription of CYP330A1 following exposure to WSF but not the dispersion. Data suggested that small lipid storage promotes increased bioavailability of accumulated oil compounds. Variations in response in CYP330A1 gene expression indicate that oil constituents may exert different modes of toxic action in copepods depending on their reproductive stages. The contribution of oil droplets to the observed effects seemed to be low as GST gene expression was similar after exposure to both dispersed oil and WSF. However, feeding rate in copepods exposed to dispersed oil was reduced, and this may have decreased the uptake of oil constituents via the diet. Although quantitatively higher mortality was observed in copepods exposed to the highest dispersion levels, this may result from smothering of animals by oil droplets. Furthermore, increasing dilution of both the dispersions and the WSF altered their distributions and chemical composition, which may influence the bioavailability of spilled crude oil to pelagic marine organisms.

RefID: 286

Author: Harding, L.E.; Englar, J.R.

Year: 1989

Title: The Nestucca oil spill : fate and effects to May 31, 1989

Journal: Canada. Environmental Protection Service. Pacific and Yukon Region Regional program report (Vancouver, B.C.);89-01

Hyperlink:

Abstract: Approximately 875,000 litres of Bunker C fuel were spilled off the Washington coast during the early morning of December 23,1988. The oil was first reported on the British Columbia coast near Carmanah Point on December 31, 1989, and progressed north, arriving as small patches at Cape Scott on about January 14.Oiling was reported as far south as Victoria, and traces of Nestucca oil landed on islands off the northern mainland near Bella Bella. Within this area, a total of 150 km of coastline were affected, mostly with light to moderate stranding of oil dispersed along high tide lines. At least two km were heavily oiled. Most oiling in B.C. was confined to outer islands and headlands. Oiled locations were characterized by light to moderate distribution of patches of oil scattered along the high tide zones in discrete areas of accumulation. Subtidal accumulations occurred in two locations. Significant accumulations of oil (i.e., numerous locations of Class 4-5, moderate to heavy oiling; see text for definitions) occurred in Barkley Sound, Long Beach, the mouth of Clayoquot Sound, Estevan Point, Nootka Island, Kyuquot Sound and Brooks Peninsula. These areas contained important seabird, fish, shellfish and marine mammal habitats. Shorelines of six provincial Ecological Reserves were lightly (scattered patches) oiled. Approximately 3,500 dead seabirds were found in B.C. and 9,000 in Washington. The Canadian Wildlife Service (CWS) is analyzing data to estimate the number of birds that actually died, and studies are continuing to determine if any B.C. breeding populations were affected. Some seals, sea lions and river otters were found dead and others were observed to be oiled, but no deaths attributable to oil were confirmed in these species. One sea otter is known to have died from oil. Studies by the Department of Fisheries and Oceans (DFO) will determine if there has been any impact on the populations. The grey whales migrated through the area without incident during March -

April. Crabs were contaminated with oil in and near the entrances to Clayoquot Sound, resulting in an extended (until June 26) closure of crab fishing in some important crab fishery areas. Barkley Sound was closed to all commercial bivalve harvesting for several weeks following the spill and the area of the coast between Amphitrite Point and Estevan Point was closed for a similar period for gooseneck barnacle and mussel commercial harvesting. These closures were precautionary to prevent contaminated products from entering the market and were lifted after extensive laboratory testing of shellfish samples. Salmon habitat and most salmon and shellfish farms were located in protected bays and inlets, away from the exposed outer coastline where most of the oiling occurred. Some wild shellfish stocks were slightly contaminated. Herring altered their historically documented spawning locations in Barkley Sound and studies are continuing to determine if this change was oil-related. However, the commercial catch quotas were met and there was no evidence of tainting of herring products.

RefID: 287

Author: Harris, P.M., Rice, S.D., Babcock, M.M. and Brodersen, C.C.

Year: 1996

Title: Within-Bed Distribution of Exxon Valdez Crude Oil in Prince William Sound Blue Mussels and Underlying Sediments

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: The distribution of Exxon Valdez crude oil in sediments and its relationship to oiling in blue mussels Mytilus trossulus was examined in six Prince William Sound mussel beds in 1992. Distribution of oil in sediments within each bed was patchy and was related to several factors, including sample location on the beach, sample depth, and sediment grain size. Concentrations of total petroleum hydrocarbons as high as 30,000-40,000 µg/g wet weight were found within a few meters of concentrations two orders of magnitude less. The distribution of total polynuclear aromatic hydrocarbons (TPAH) in mussels overlying the sediments was also patchy. Concentration levels in mussels roughly followed concentrations in underlying sediments, but correlation at specific sampling points was low. Generally, TPAH in mussels averaged 1% or less of the TPAH in shallow sediments from the same area of the bed. Similar proportions of individual analytes relative to TPAH in mussels, shallow sediments, and Exxon Valdez crude oil indicate that the latter was the source of contamination in sediment and mussels, that the oil in the sediments has only moderately weathered, and that oil taken in by mussels was particulate. Mussels depurate petroleum hydrocarbons rapidly if not chronically exposed; the contaminated sediments were the continuous source of Exxon Valdez crude oil in mussel tissues. The pattern of oil distribution in mussels and in sediments within a mussel bed implies that it was dispersed from sediments into surrounding water and was taken up by nearby mussels. The chronic recontamination of mussels by Exxon Valdez crude oil in the sediments underlying them and the uneven distribution of this oil throughout mussel beds have important implications for studies monitoring concentrations and effects of oil remaining in mussel beds and for any mussel-bed restoration.

RefID: 288

Author: Harris, R.K., Moeller, R.B., Lipscomb, T.P., Pletcher, J.M., Haebler, R.J., Tuomi, P.A., McCormick, C.R., Degange, A.R., Mulcahy, D. and Williams, T.D.

Year: 1990

Title: IDENTIFICATION OF A HERPES-LIKE VIRUS IN SEA OTTERS DURING REHABILITATION AFTER THE T-V EXXON VALDEZ OIL SPILL

Journal: U S Fish and Wildlife Service Biological Report

Hyperlink: https://openlibrary.org/books/OL24349175M/Sea_otter_symposium

Abstract: During implantation of radiotelemetry devices in sea otters (Enhydra lutris) at the Seward Otter Rehabilitation Center, surgical team members noted ulcers in the oral cavity of each of five animeds examined. Oral lesions were identified in 25 of 27 otters examined at the center. Histological evaluation of the lesions revealed focal areas of mucosal epithelial necrosis with associated intranuclear viral inclusion bodies. A herpes-like virus was subsequently identified ultrastructurally. The concern of releasing a virus of unknown origin and virulence into a naive wild otter population prompted management decisions restricting the movement of otters and jeopardizing the scheduled release of the otters on 27 July 1989. A team of veterinarians and otter capture personnel captured and examined 12 free-living adult otters off the coast of the southern Kenai Peninsula. Viral-induced oral lesions were identified in many of these animals establishing that the virus was indigenous to sea otters living in Alaskan waters; rehabilitated otters were released back into the wild.

RefID: 289

Author: Harrison, P.J., Cochlan, W.P., Acreman, J.C., Parsons, T.R., Thompson, P.A. and Dovey, H.M.

Year: 1986

Title: The effects of crude oil and Corexit 9527 on marine phytoplankton in an experimental enclosure

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/0141113686900024

Abstract: The effects of a dispersant, Corexit 9527, plus Prudhoe Bay crude oil and the effects of the dispersant only on natural assemblages of marine phytoplankton in three large experimental ecosystem enclosures (CEEs) were studied. The oil and dispersant were added to a layer between 2 and 4 m depth yielding initial concentrations of 4·5 and 2·0 mg litre−1, respectively. The enclosures remained undisturbed for the 17-day experiment except for sampling at 2- or 3-day intervals. Nutrient concentrations, nitrogen transport rates, chlorophyll a, primary productivity, phytoplankton sinking rates, species composition and cell numbers were followed over the course of the experiment. In the enclosure with oil and dispersant, diatom growth was suppressed and the phytoplankton were dominated by microflagellates such as haptophytes, chrysophytes and a prasinophyte. The diatoms appeared healthy under the microscope and the total number of species was similar species that was affected by the oil. Pennate diatoms, amoebae, zooflagellattes (e.g. bodonids) were more abundant than in the control enclosure. The phytoplankton successions in the enclosure receiving only dispersant and in the control enclosure were very similar, but markedly different from that in the oil-plus-dispersant enclosure. A diatom bloom commenced in both the control and the enclosure receiving only dispersant by day 2 and collapsed by day 11 due to nutrient exhaustion (nitrate and silicate). Nitrate was not exhausted in the enclosure containing oil and dispersant until the end of the experiment (day 17) and consequently primary productivity and nitrogen transport rates increased with time. This observation is in contrast with the control and dispersant only enclosures where primary productivity and nitrogen transport rates declined dramatically in the middle of the experiment due to the exhaustion of nitrate and silicate.

RefID: 290

Author: Hartwick, E.B., Wu, R.S.S., and Parker, D.B.

Year: 1982

Title: Effects of a crude oil and an oil dispersant (Corexit 9527) on populations of the littleneck clam (protothaca staminea)

Journal: Marine Environmental Research

Hyperlink:

Abstract: Field and laboratory experiments were carried out to investigate the effects of Alberta crude oil and an oil dispersant (Corexit 9527) on the larval settlement, survival, siphon activities and behaviour of the littleneck clam (Protothaca staminea). Corexit 9527 was much more toxic than crude oil, and the highest toxicity was obtained when Corexit 9527 was mixed with crude oil. Siphon activities were impaired and abnormal behaviour was exhibited when adult clams were treated with 100 ppm Corexit 9527, 1000 ppm crude oil or a combination of both. Larval settlement was not affected when the substratum was treated with 1000ppm crude oil but was retarded when the substratum was treated with a mixture of 1000 ppm oil and 100 ppm Corexit 9527. Gas chromatograms also showed that the retention time and depth of penetration of hydrocarbons in the substratum was increased when Corexit 9527 was used with crude oil.

RefID: 291

Author: Harvey, H.R., Taylor, K.A., Pie, H.V. and Mitchelmore, C.L.

Year: 2014

Title: Polycyclic aromatic and aliphatic hydrocarbons in Chukchi Sea biota and sediments and their toxicological response in the Arctic cod, Boreogadus saida

Journal: Deep-Sea Research Part II-Topical Studies in Oceanography

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0967064513002877

Abstract: As part of the Chukchi Sea Offshore Monitoring in Drilling Area-Chemical and Benthos (COMIDA CAB) project, we determined the distribution and concentrations of aliphatic n-alkanes and polycyclic aromatic hydrocarbons (PAHs) in surface sediments (O-1 cm) among 52 sites across the Chukchi Sea and in muscle tissues of the benthic Northern whelk, Neptunea heros, collected opportunistically. In addition, downcore profiles of contaminants were determined at three targeted sites to establish historic patterns. Baseline responses of PAH exposure and its potential toxicological effects were examined in the common Arctic cod, Boreogadus saida, through measures of cytochrome P4501A/ ethoxyresorufin O-deethylase (CYP1A/EROD), glutathione-S-transferase (GST), and Cu/Zn superoxide dismutase (SOD) activity in liver tissue. The total concentration of PAHs in surface sediments throughout the study area, including parent and alkyl-homologs, were very low (< 1600 ng g(-1) dry wt) except for a single station, where values were 2-20-fold greater than at other baseline sites (2956 ng g(-1) dry wt). Alkyl-substituted PAHs were the dominant form in all surface (54-93%) and subsurface sediments (50-81% of the total), with a general decrease in total PAH concentrations observed downcore. In biota, larger Neptunea showed lower total concentrations of PAHs in foot muscles (4.5-10.7 ng g(-1) wet wt) compared to smaller animals; yet aliphatic n-alkane (C-19-C-33) concentrations (0.655-5.20 mu g g(-1) wet wt) increased in larger organisms with distributions dominated by long-chain (C-23-C-33) hydrocarbons. In B. saida, CYP1A1, GST, and SOD enzyme levels were comparable to baseline levels previously reported in other pristine systems. Of the three assays, only SOD had a significant correlation between gene expression and enzyme activity. (C) 2013 Elsevier Ltd. All rights reserved.

RefID: 292

Author: Harvey, J.T. and Dahlheim, M.E.

Year: 1994

Title: Cetaceans in oil

Journal: Marine mammals and the Exxon Valdez

Hyperlink: http://www.amazon.com/Marine-Mammals-Valdez-Thomas-Loughlin/dp/0124561608

Abstract:

RefID: 293

Author: Harwell, M.A. and Gentile, J.H.

Year: 2014

Title: Assessing Risks to Sea Otters and the Exxon Valdez Oil Spill: New Scenarios, Attributable Risk, and Recovery

Journal: Human and Ecological Risk Assessment

Hyperlink: http://www.tandfonline.com/doi/full/10.1080/10807039.2013.828513

Abstract: The Exxon Valdez oil spill occurred more than two decades ago, and the Prince William Sound ecosystem has essentially recovered. Nevertheless, discussion continues on whether or not localized effects persist on sea otters (Enhydra lutris) at northern Knight Island (NKI) and, if so, what are the associated attributable risks. A recent study estimated new rates of sea otter encounters with subsurface oil residues (SSOR) from the oil spill. We previously demonstrated that a potential pathway existed for exposures to polycyclic aromatic hydrocarbons (PAHs) and conducted a quantitative ecological risk

assessment using an individual-based model that simulated this and other plausible exposure pathways. Here we quantitatively update the potential for this exposure pathway to constitute an ongoing risk to sea otters using the new estimates of SSOR encounters. Our conservative model predicted that the assimilated doses of PAHs to the 1-in-1000th most-exposed sea otters would remain 1-2 orders of magnitude below the chronic effects thresholds. We re-examine the baseline estimates, post-spill surveys, recovery status, and attributable risks for this subpopulation. We conclude that the new estimated frequencies of encountering SSOR do not constitute a plausible risk for sea otters at NKI and these sea otters have fully recovered from the oil spill.

RefID: 294

Author: Harwell, M.A. and Gentile, J.H.

Year: 2013

Title: Quantifying long-term risks to sea otters from the 1989 'Exxon Valdez' oil spill: Comment on Bodkin et al. (2012)

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v488/p291-296/

Abstract: Bodkin et al. (2012; Mar Ecol Prog Ser 447:273-287) assessed the frequency at which sea otters Enhydra lutris might encounter subsurface oil residues from the 'Exxon Valdez' oil spill. They concluded that a pathway exists for exposures of sea otters to residual oil in the intertidal zone, and imply that this pathway has delayed recovery of sea otters. We agree that the potential exposure pathway exists, and the Bodkin et al. (2012) estimates of the frequency of encountering subsurface oil residues (4 to 10 times per year) comport with our previously published studies (2 to 7 times per year). However, we disagree that this pathway constitutes a significant risk to sea otters. We discuss results from our quantitative ecological risk assessment using an individual-based model that specifically simulated this pathway of exposures to a population of 500000 sea otters. This conservative model predicted that assimilated doses of polycyclic aromatic hydrocarbons in subsurface oil residues to the 1-in-1000th most-exposed sea otters would be 1 to 2 orders of magnitude below the chronic effects thresholds that we established using USEPA data and methodology. When we artificially increased the rate of encountering subsurface oil residues, it required 4 to 10 encounters per day to reach effects levels. We conclude that the subsurface oil residues from the oil spill could not plausibly be responsible for any individual- or population-level effect on the sea otters at northern Knight Island.

RefID: 295

Author: Harwell, M.A., Gentile, J.H. and Parker, K.R.

Year: 2013

Title: Characterizing Ecological Risks, Significance, and Recovery

Journal: Oil in the Environment: Legacies and Lessons of the Exxon Valdez Spill

Hyperlink:

Abstract: Book Chapter (no abstract)

RefID: 296

Author: Harwell, M.A., Gentile, J.H. and Parker, K.R.

Year: 2012

Title: Quantifying population-level risks using an individual-based model: Sea otters, Harlequin Ducks, and the Exxon Valdez oil spill

Journal: Integrated Environmental Assessment and Management

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/ieam.1277/abstract

Abstract: Ecological risk assessments need to advance beyond evaluating risks to individuals that are largely based on toxicity studies conducted on a few species under laboratory conditions, to assessing population-level risks to the environment, including considerations of variability and uncertainty. Two individual-based models (IBMs), recently developed to assess current risks to sea otters and seaducks in Prince William Sound more than 2 decades after the Exxon Valdez oil spill (EVOS), are used to explore population-level risks. In each case, the models had previously shown that there were essentially no remaining risks to individuals from polycyclic aromatic hydrocarbons (PAHs) derived from the EVOS. New sensitivity analyses are reported here in which hypothetical environmental exposures to PAHs were heuristically increased until assimilated doses reached toxicity reference values (TRVs) derived at the no-observed-adverse-effects and lowest-observed-adverse-effects levels (NOAEL and LOAEL, respectively). For the sea otters, this was accomplished by artificially increasing the number of sea otter pits that would intersect remaining patches of subsurface oil residues by orders of magnitude over actual estimated rates. Similarly, in the seaduck assessment, the PAH concentrations in the constituents of diet, sediments, and seawater were increased in proportion to their relative contributions to the assimilated doses by orders of magnitude over measured environmental concentrations, to reach the NOAEL and LOAEL thresholds. The stochastic IBMs simulated millions of individuals. From these outputs, frequency distributions were derived of assimilated doses for populations of 500?000 sea otters or seaducks in each of 7 or 8 classes, respectively. Doses to several selected quantiles were analyzed, ranging from the 1-in-1000th most-exposed individuals (99.9% quantile) to the median-exposed individuals (50% quantile). The resulting families of quantile curves provide the basis for characterizing the environmental thresholds below which no population-level effects could be detected and above which population-level effects would be expected to become manifest. This approach provides risk managers an enhanced understanding of the risks to populations under various conditions and assumptions, whether under hypothetically increased exposure regimes, as demonstrated here, or in situations in which actual exposures are near toxic effects levels. This study shows that individual-based models are especially amenable and appropriate for conducting population-level risk assessments, and that they can readily be used to answer questions about the risks to individuals and populations across a variety of exposure conditions. Integr Environ Assess Manag 2012; 8: 503522. (c) 2012 SETAC

RefID: 297

Author: Harwell, M.A., Gentile, J.H., Johnson, C.B., Garshelis, D.L. and Parker, K.R.

Year: 2010

Title: A Quantitative Ecological Risk Assessment of the Toxicological Risks from Exxon Valdez Subsurface Oil Residues to Sea Otters at Northern Knight Island, Prince William Sound, Alaska

Journal: Human and Ecological Risk Assessment

Hyperlink: http://www.tandfonline.com/doi/full/10.1080/10807039.2010.501230

Abstract: A comprehensive, quantitative risk assessment is presented of the toxicological risks from buried Exxon Valdez subsurface oil residues (SSOR) to a subpopulation of sea otters (Enhydra lutris) at Northern Knight Island (NKI) in Prince William Sound, Alaska, as it has been asserted that this subpopulation of sea otters may be experiencing adverse effects from the SSOR. The central questions in this study are: could the risk to NKI sea otters from exposure to polycyclic aromatic hydrocarbons (PAHs) in SSOR, as characterized in 2001-2003, result in individual health effects, and, if so, could that exposure cause subpopulation-level effects? We follow the U.S. Environmental Protection Agency (USEPA) risk paradigm by: (a) identifying potential routes of exposure to PAHs from SSOR; (b) developing a quantitative simulation model of exposures using the best available scientific information; (c) developing scenarios based on calculated probabilities of sea otter exposures to SSOR; (d) simulating exposures for 500,000 modeled sea otters and extracting the 99.9% quantile most highly exposed individuals; and (e) comparing projected exposures to chronic toxicity reference values. Results indicate that, even under conservative assumptions in the model, maximum-exposed sea otters would not receive a dose of PAHs sufficient to cause any health effects; consequently, no plausible toxicological risk exists from SSOR to the sea otter subpopulation at NKI.

RefID: 298

Author: Hatlen, K., Sloan, C.A., Burrows, D.G., Collier, T.K., Scholz, N.L. and Incardona, J.P.

Year: 2010

Title: Natural sunlight and residual fuel oils are an acutely lethal combination for fish embryos

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X10001141

Abstract: The majority of studies characterizing the mechanisms of oil toxicity in fish embryos and larvae have focused largely on unrefined crude oil. Few studies have addressed the toxicity of modern bunker fuels, which contain residual oils that are the highly processed and chemically distinct remains of the crude oil refinement process. Here we use zebrafish embryos to investigate potential toxicological differences between unrefined crude and residual fuel oils, and test the effects of sunlight as an additional stressor. Using mechanically dispersed oil preparations, the embryotoxicity of two bunker oils was compared to a standard crude oil from the Alaska North Slope. In the absence of sunlight, all three oils produced the stereotypical cardiac toxicity that has been linked to the fraction of tricyclic aromatic compounds in an oil mixture. However, the cardiotoxicity of bunker oils did not correlate strictly with the concentrations of tricyclic compounds. Moreover, when embryos were sequentially exposed to oil and natural sunlight, the bunker oils produced a rapid onset cell-lethal toxicity not observed with crude oil. To investigate the chemical basis of this differential toxicity, a GC/MS full scan analysis was used to identify a range of compounds that were enriched in the bunker oils. The much higher phototoxic potential of chemically distinct bunker oils observed here suggests that this mode of action should be considered in the assessment of bunker oil spill impacts, and indicates the need for a broader approach to understanding the aquatic toxicity of different oils. Published by Elsevier B.V.

RefID: 299

Author: Hayakawa, K., Nomura, M., Nakagawa, T., Oguri, S., Kawanishi, T., Toriba, A., Kizu, R., Sakaguchi, T. and Tamiya, E.

Year: 2006

Title: Damage to and recovery of coastlines polluted with C-heavy oil spilled from the Nakhodka

Journal: Water Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0043135406000091

Abstract: The damage to and recovery of the Japanese coastline from Suzu, Ishikawa Prefecture to Mikuni, Fukui Prefecture was investigated visually over three years after a C-heavy oil spill from the Russian tanker “Nakhodka” in the Japan Sea on January 2, 1997. The beached C-heavy oil tended to remain for a long time on coasts of bedrock and boulder/cobble/pebble but it was removed rapidly from coasts of gravel/sand and man-made structures such as concrete tetrapods. On the coasts of the latter type, wave energy appeared to be the main force removing the oil. One year after the spill, C-heavy oil tended to remain strongly on the sheltered coasts of bedrock and boulder/cobble/pebble. Even on coasts of this type, the contamination was remarkably absent by 2 years after the spill. The concentration levels of polycyclic aromatic hydrocarbons (PAHs) in oil lumps, sand and seawater were monitored during 3 years following the spill. The concentrations of PAHs having 2 or 3 rings decreased more quickly than did those of PAHs having 4 or more rings, suggesting that volatilization was the main cause of the decrease. On the other hand, the concentrations of PAHs having 4 to 6 rings did not start to decrease until 7 months after the spill. The main cause of the decrease seemed to be photolysis. The concentration of BaP in seawater off the polluted coasts was high 1 month after the spill and then decreased. Three years after the spill, the level fell to the sub ng/L level, which was as low as the level in seawater along unpolluted clean coasts in Japan. The concentration of BaP in greenling was higher than the normal level only during the first two months after the spill. These results suggest that the coastlines in Ishikawa and Fukui Prefectures that were polluted with C-heavy oil recovered in 3 years.

RefID: 300

Author: Haynes, E., Rutecki, T., Murphy, M. and Urban, D.

Year: 1995

Title: Impacts of the Exxon Valdez oil spill on bottomfish and shellfish in Prince William Sound

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33088144.pdf

Abstract: Trawl surveys were conducted in Prince William Sound and adjacent waters in 1989 and 1990 to 1) determine abundance of important bottomfish and shellfish species and 2) assess the incidence of oil contamination. Surveys in 1989 compared catch per unit effort (CPUE) with a 1978 survey and estimated biomass by random sampling. Compared to 1978, CPUE was greater for seven species and lower for four species. Biomass was generally greatest in heavily oiled areas. Significant oil contamination was detected in fish bile in both 1989 and 1990, and contamination was more widespread in 1990 than in 1989. In 1989, five of six species tested and 29% of bile samples were contaminated or possibly contaminated. In 1990, all six species tested and 39% of bile samples were contaminated. Contaminated fish were mostly from oiled areas in 1989, but were from throughout Prince William Sound in both oiled and non-oiled areas in 1990. Although relating hydrocarbon metabolites in bile to effects on bottomfish populations may be impossible, the persistent contamination of demersal fishes 1 year after the spill indicates that effects of the oil spill may be long term and should be monitored closely.

RefID: 301

Author: Headley, J.V. and McMartin, D.W.

Year: 2004

Title: A review of the occurrence and fate of naphthenic acids in aquatic environments

Journal: Journal of Environmental Science and Health

Hyperlink: http://www.tandfonline.com/doi/abs/10.1081/ESE-120039370

Abstract: Naphthenic acids are comprised of a large collection of saturated aliphatic and alicyclic carboxylic acids found in hydrocarbon deposits (petroleum, oil sands bitumen, and crude oils). Naphthenic acids enter surface water systems primarily through effluent discharge, but also through groundwater mixing and erosion of riverbank oil deposits. Of the possible environmental receptors (i.e., air, soil, and water), the most significant is water. Ambient levels of naphthenic acids in northern Alberta rivers in the Athabasca Oil Sands are generally below 1 mg L-1. However, tailings pond waters may contain as high as I 10 mg L-1. The complexity of natural naphthenic acids in petroleum deposits poses an analytical challenge as reflected by the several techniques reported for quantitation of naphthenic acids in the environment. Although naphthenic acids are known to be persistent biomarkers used in identification of oil source maturation, little is established regarding their relative degradation pathways in aquatic environments. Published research related to the potential for microbiological degradation and adsorption to typical Athabasca Oil Sands soils reveal that naphthenic acids are likely to persist in the water column and, with prolonged exposure, accumulate in sediments. However, other than a very general knowledge of environmental persistence, the occurrence and fate of naphthenic acids has been sparsely studied. This article brings together some of those environmental persistence results, as well as detailed information regarding the origin of naphthenic acids in tailings ponds, chemistry and toxicological considerations, current analytical methods for aquatic sampling, and areas of future remediation research.

RefID: 302

Author: Heintz, R.A.

Year: 2001

Title: Effects of oiled incubation substrate on pink salmon reproduction. Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project 01476)

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/index.cfm?FA=searchResults.projectInfo&Project_ID=495

Abstract: Populations are maintained through successful reproduction; this study is designed to determine if exposure to oil impairs pink salmon reproduction. This experiment began in the fall of 1998 when pink salmon eggs were incubated in oil contaminated water. Fish that survived exposure were marked and released in the spring of 1999. They reached maturity at sea and returned to spawn in the fall of 2000. Return rates confirmed previous observations of reduced marine survival among exposed fish, but evaluations of offspring (F1) survival rates did not indicate any reproductive impact. The F1 were incubated in clean water until spring 2001 when they were marked and released. They will mature and return to the hatchery in the fall of 2002 and their reproductive ability will be evaluated by generating an F2 generation. A diminished ability to produce the F2 generation represents a genetic effect of oil transmitted to unexposed generations. Such an effect was demonstrated for similarly treated pink salmon in 1997, but corroborating data do not exist. This project is designed to retest that experiment; if diminished reproductive ability is corroborated, it would demonstrate a significant and unanticipated effect of oil pollution.

RefID: 303

Author: Heintz, R.A., Rice, S. and Bue, B.

Year: 1996

Title: Field and laboratory evidence for reduced fitness in pink salmon that incubate in oiled gravel

Journal: Proceedings of the Contaminant Effects on Fish Symposium, International Congress of the Biology of Fishes

Hyperlink:

Abstract:

RefID: 304

Author: Heintz, R.A., Rice, S.D., Carls, M.G. and Short, J.W.

Year: 2012

Title: SENSITIVITY OF PINK SALMON (ONCORHYNCHUS GORBUSCHA) EMBRYOS TO WEATHERED CRUDE OIL

Journal: Environmental Toxicology and Chemistry

Hyperlink:

Abstract: Letter to the editor - refers to Ref S0173

RefID: 305

Author: Heintz, R.A., Rice, S.D., Carls, M.G. and Short, J.W.

Year: 2012

Title: SENSITIVITY OF PINK SALMON (ONCORHYNCHUS GORBUSCHA) EMBRYOS TO WEATHERED CRUDE OIL

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.1731/full

Abstract: Letter to the editor - refers to Ref S0173

RefID: 306

Author: Heintz, R.A., Rice, S.D., Wertheimer, A.C., Bradshaw, R.F., Thrower, F.P., Joyce, J.E. and Short, J.W.

Year: 2000

Title: Delayed effects on growth and marine survival of pink salmon Oncorhynchus gorbuscha after exposure to crude oil during embryonic development

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v208/p205-216/

Abstract: We report delayed effects on the growth and marine survival of pink salmon Oncorhynchus gorbuscha, which were exposed to oil as embryos under conditions similar to those observed after the 'Exxon Valdez' oil spill. Pink salmon eggs were incubated in water that became contaminated with polynuclear aromatic hydrocarbons (PAHs) after percolating through gravel coated with weathered oil. Weathering ensured that the PAH composition of the water was dominated by alkyl-substituted naphthalenes and larger compounds. Most survivors of the exposures appeared healthy, and were released to the marine environment with coded-wire tags. Their survival was evaluated when they returned at maturity 2 yr later. Other survivors, also healthy in appearance, were retained in net pens to measure delayed effects on growth during the early juvenile stage. Pink salmon exposed to an initial concentration of total PAH equal to 5.4 ppb experienced a 15 % decrease in marine survival compared to unexposed salmon. A delayed effect on growth was measured in juvenile salmon that survived embryonic exposure to doses as low as 18 ppb PAH. Reductions in juvenile growth could account for the reduced marine survival observed in the released fish. The demonstration of delayed effects on growth and survival support claims of delayed effects in pink salmon after the 'Exxon Valdez' oil spill, and indicate the potential for population-level effects resulting from embryonic exposure to oil.

RefID: 307

Author: Heintz, R.A., Short, J.W. and Rice, S.D.

Year: 1999

Title: Sensitivity of fish embryos to weathered crude oil: Part II. Increased mortality of pink salmon (Oncorhynchus gorbuscha) embryos incubating downstream from weathered Exxon Valdez crude oil

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620180318/full

Abstract: We incubated pink salmon embryos under three exposure conditions, direct contact with oil-coated gravel. effluent from oil-coated gravel, and direct contact with gravel coated with very weathered oil (VWO). Embryo mortalities and polynuclear aromatic hydrocarbon (PAH) accumulation in embryo tissues during the direct-contact and effluent exposure experiments were not significantly different, indicating that PAH accumulation was mediated by aqueous transport. Mortality rates for embryos exposed initially to a total PAH concentration (TPAH) of 1.0 ppb were significantly higher than controls when the PAH were derived from VWO. The same aqueous TPAH concentration failed to increase mortality rates when the PAH were derived from less weathered oil, indicating that toxicity of effluents from the VWO was primarily associated with the larger PAH. We conclude that water quality standards for TPAH above 1.0 ppb may fail to protect fish embryos. Further, pink salmon embryos incubating in Prince William Sound after the Exxon Valdez oil spill may have accumulated lethal concentrations of PAH from interstitial water that was contaminated when it percolated through oil reservoirs located upstream from salmon redds.

RefID: 308

Author: Heintz, R.A., Short, J.W., Rice, S.D. and Carls, M.G.

Year: 2008

Title: Comment on "toxicity of weathered exxon valdez crude oil to pink salmon embryos"

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/07-236.1/abstract

Abstract: Letter to the editor - refers to Ref S0009

RefID: 309

Author: Hemmer, M.J., Barron, M.G. and Greene, R.M.

Year: 2011

Title: COMPARATIVE TOXICITY OF EIGHT OIL DISPERSANTS, LOUISIANA SWEET CRUDE OIL (LSC), AND CHEMICALLY DISPERSED LSC TO TWO AQUATIC TEST SPECIES

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.619/abstract

Abstract: The present study describes the acute toxicity of eight commercial oil dispersants, South Louisiana sweet crude oil (LSC), and chemically dispersed LSC. The approach used consistent test methodologies within a single laboratory in assessing the relative acute toxicity of the eight dispersants, including Corexit 9500A, the predominant dispersant applied during the DeepWater Horizon spill in the Gulf of Mexico. Static acute toxicity tests were performed using two Gulf of Mexico estuarine test species, the mysid shrimp (Americamysis bahia) and the inland silversides (Menidia beryllina). Dispersant-only test solutions were prepared with high-energy mixing, whereas water-accommodated fractions of LSC and chemically dispersed LSC were prepared with moderate energy followed by settling and testing of the aqueous phase. The median lethal concentration (LC50) values for the dispersant-only tests were calculated using nominal concentrations, whereas tests conducted with LSC alone and dispersed LSC were based on measured total petroleum hydrocarbon (TPH) concentrations. For all eight dispersants in both test species, the dispersants alone were less toxic (LC50s: 2.9 to > 5,600 mu l/L) than the dispersant LSC mixtures (0.4-13 mg TPH/L). Louisiana sweet crude oil alone had generally similar toxicity to A. bahia (LC50: 2.7 mg TPH/L) and M. beryllina (LC50: 3.5 mg TPH/L) as the dispersant LSC mixtures. The results of the present study indicate that Corexit 9500A had generally similar toxicity to other available dispersants when tested alone but was generally less toxic as a mixture with LSC. Environ. Toxicol. Chem. 2011;30:2244.2252. (C) 2011 SETAC

RefID: 310

Author: Hepler, K.R., Hansen, P.A. and Bernard, D.R.

Year: 1994

Title: Impact of oil spilled from the Exxon Valdez on survival and growth of Dolly Varden and cutthroat trout in Prince William Sound, Alaska

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/index.cfm?FA=searchResults.projectInfo&Project_ID=763

Abstract: Five emigrating populations of Dolly Varden and cutthroat trout were intercepted in 1989-1991 during seaward migration to Prince William Sound following the Exxon Valdez oil spill; two into the spill area, three into non-spill areas. Study populations were comprised of tagged adults and subadults. Survival rates were estimated with log-linear models of capture histories of tagged fish. We used a two-stage simulation based on bootstrapping and Monte Carlo techniques to compare average survival rates in study populations that were and were not associated with spilled oil. Growth and survival rates were significantly lower in study populations associated with spilled oil. Growth from 1989-1990 was on average less in study populations that emigrated into the spill area: 24% and 22% less for recaptured subadult and adult Dolly Varden and 36% and 43% less for subadult and adult cutthroat trout. This difference persisted through 1991 for cutthroat trout. Averages of estimated survival rates from 1989-1990 were less in populations associated with spilled oil: 36% and 40% less for subadult and adult Dolly Varden and 28% less for adult cutthroat trout. Results are consistent with the occurrence of a deleterious impact on growth and survival of emigrating species, although unable to be confirmed as results emanated from observation, not experiment.

RefID: 311

Author: Hepler, K.R., Hansen, P.A. and Bernard, D.R.

Year: 1996

Title: Impact of oil spilled from the Exxon Valdez on survival and growth of Dolly Varden and cutthroat trout in Prince William Sound

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: When crude oil spilled from the grounded tanker Exxon Valdez into Prince William Sound, Alaska, in late March 1989, anadromous Dolly Varden Salvelinus malma and cutthroat trout Oncorhynchus clarki were residing in lakes. Five populations of each species were intercepted with five weirs in 1989, 1990, and 1991 during their annual seaward emigration in the spring. Two populations emigrated into the wake of the spill, while three emigrated into waters free of spilled crude oil. Because anadromous Dolly Varden and cutthroat trout feed during the summer near the shores of Prince William Sound, fish emigrating into the path of the spill spent their summers near stranded oil and possibly ingested contaminated food. Of the 11,995 Dolly Varden and cutthroat trout marked at weirs in 1989 and the 41,550 marked in 1990, 24% and 18% were recaptured in 1990 and 1991. Almost all (97%) recaptured emigrants were recaptured at the same weirs in 1990 and 1991 at which they were released 1 year earlier. However, on average an estimated 39% of survivors of both species evaded recapture in 1990 at fish-tight weirs that year. In populations associated with spilled oil, growth from 1989-1990 was 24% and 22% slower for recaptured subadult and adult Dolly Varden, respectively, and 36%-43% slower for subadult and adult cutthroat trout, respectively. These differences persisted through 1991 for cutthroat trout, but not for Dolly Varden; growth was slower during 1990 -1991 for recaptured Dolly Varden in populations not associated with oil. Estimates of mean length by age-group for emigrating cutthroat trout in 1989 indicated that their growth had been uniform across Prince William Sound before the spill. Although averages of estimated survival rates from 1989 to 1990 are less in study populations associated with spilled oil (32% and 22% less for subadult and adult Dolly Varden, respectively, and 28% less for adult cutthroat trout), none of the differences arc statistically significant. Chronic starvation and direct exposure to petrogenic hydrocarbons are hypothesized as the pathways by which spilled crude oil could have slowed the growth of Dolly Varden and cutthroat trout.

RefID: 312

Author: Hicken, C.E., Linbo, T.L., Baldwin, D.H., Willis, M.L., Myers, M.S., Holland, L., Larsen, M., Stekoll, M.S., Rice, S.D., Collier, T.K., Scholz, N.L. and Incardona, J.P.

Year: 2011

Title: Sublethal exposure to crude oil during embryonic development alters cardiac morphology and reduces aerobic capacity in adult fish

Journal: Proceedings of the National Academy of Sciences of the United States of America

Hyperlink: http://www.pnas.org/content/108/17/7086.short

Abstract: Exposure to high concentrations of crude oil produces a lethal syndrome of heart failure in fish embryos. Mortality is caused by cardiotoxic polycyclic aromatic hydrocarbons (PAHs), ubiquitous components of petroleum. Here, we show that transient embryonic exposure to very low concentrations of oil causes toxicity that is sublethal, delayed, and not counteracted by the protective effects of cytochrome P450 induction. Nearly a year after embryonic oil exposure, adult zebrafish showed subtle changes in heart shape and a significant reduction in swimming performance, indicative of reduced cardiac output. These delayed physiological impacts on cardiovascular performance at later life stages provide a potential mechanism linking reduced individual survival to population-level ecosystem responses of fish species to chronic, low-level oil pollution.

RefID: 313

Author: Highsmith, R.C., Rucker, T.L., Stekoll, M.S., Saupe, S.M., Lindeberg, M.R., Jenne, R.N. and Erickson, W.P.

Year: 1996

Title: Impact of the Exxon Valdez Oil Spill on Intertidal Biota

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: The Coastal Habitat Injury Assessment (CHIA) study was initiated to assess injury to biological resources in intertidal habitats affected by the Exxon Valdez oil spill. Intertidal communities were subjected to the most intense impacts of the spill and of subsequent cleanup operations. An understanding of the effects of the oil spill and cleanup on the intertidal zone is critical in determining the extent of injury and the recovery potential of the affected areas. The CHIA study encompassed the three major geographic areas affected by the spill: Prince William Sound, Cook Inlet-Kenai Peninsula, and Kodiak-Alaska Peninsula. Randomly selected oiled sites from various habitats were matched with non-oiled, reference sites. All epibenthic organisms and infauna were sampled and quantified. The results indicate that injury occurred to a wide range of taxa and community types. This article only reports the effects on the dominant taxa in the intertidal zone. The affected dominant taxa were the brown alga Fucus gardneri, the limpet Tectura persona, the barnacles Chthamalus dalli, Semibalanus balanoides, and Balanus glandula, the mussel Mytilus trossolus, two species of littorines--Sitka periwinkle Littorina sitkana and checkered periwinkle L. scutulata--and oligochaetes. Although abundnces and biomasses of C. dalli and oligochaetes were enhanced after the spill, other major taxa were negatively affected by the spill either as a direct result of exposure or treatment or indirectly because of loss of habitat or food. Observed differences between oiled and reference populations varied across regions, habitats, and tidal heights. Differences for several taxa were still apparent as of our last observation in 1991, implying incomplete recovery.

RefID: 314

Author: Highsmith, R.C., Stekoll, M.S., Barber, W.E., McDonald, L., Strickland, D. and Erickson, W.P.

Year: 1994

Title: Comprehensive assessment of coastal habitat

Journal: EVOS Trustee Council

Hyperlink: http://jlc-web.uaa.alaska.edu/client/arlis/search/detailnonmodal/ent:$002f$002fSD_ILS$002f1649$002fSD_ILS:1649517/ada?qu=Comprehensive+assessment+of+coastal+habitat&te=ILS

Abstract: The Coastal Habitat Injury Assessment Study was initiated to assess injury to intertidal habitats impacted by the Exxon Valdez oil spill. The study, conducted from 1989-1991, encompassed three major geographic areas impacted by the spill: Prince William Sound, Cook Inlet-Kenai Peninsula and Kodiak-Alaska Peninsula. Oiled sites were selected randomly and matched with non-oiled sites and classified into sheltered rocky, exposed rocky, coarse textured or estuarine habitat. Statistically significant differences between oiled and non-oiled sites were interpreted as impact due to the spill and/or clean-up activities. Most observed differences varied across regions, habitats and tidal heights. Algae, especially the perennial Fucus, was generally negatively impacted on oiled sites. Conversely, an increase in annual and ephemeral species in the lower intertidal occurred. Limpets, mussels, littorines, and the high cockscomb prickleback were injured by the spill, while oligochaetes and a single barnacle species were enhanced at most tidal heights following the spill. Although intertidal communities showed widespread impact from oiling clean-up activities for algal, invertebrate and fish components, data revealed that most habitats were recovering but had not fully recovered by 1991

RefID: 315

Author: Hilborn, R.

Year: 1996

Title: Detecting population impacts from oil spills: A comparison of methodologies

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: Five alternative methods for determining oil spill impacts at the population level are compared: (1) counts of dead animals, (2) pre- and postspill comparison of abundance, (3) oiled versus non-oiled comparison of abundance. (4) oiled versus non-oiled comparison of vital rates, and (5) direct experimental oiling. Counts of dead animals do not provide evidence of population-level impact. Pre-and postspill comparisons of abundance have very low statistical power and require substantial baseline data. Oiled versus non-oiled comparisons suffer from lack of randomization of oiling treatments. Experimental oiling must be shown to be comparable to the actual infield oil exposure. A strong MC for oil impacts will usually require several of these types of data. It is suggested that traditional hypothesis tests are inappropriate for determination of oil spill impacts and that explicit calculation of the likelihood of different levels of impact is more appropriate.

RefID: 316

Author: Hilborn, R. and Eggers, D.

Year: 2000

Title: A review of the hatchery programs for pink salmon in Prince William Sound and Kodiak Island, Alaska

Journal: Transactions of the American Fisheries Society

Hyperlink: http://www.tandfonline.com/doi/abs/10.1577/1548-8659%282000%29129%3C0333%3AAROTHP%3E2.0.CO%3B2

Abstract: Five hatcheries in Prince William Sound, Alaska, release more than 500 million juvenile pink salmon Oncorhynchus gorbuscha each year, constituting one of the largest salmon hatchery programs in the world. Before the program was initiated in 1974, pink salmon catches were very low, averaging 3 million fish per year between 1951 and 1979. Since 1980 the catch has averaged more than 20 million fish per year. However, catches in three other areas in Alaska with substantial fisheries for pink salmon (southeast Alaska, Kodiak Island, and the southern Alaska Peninsula) also increased equivalently during the same period, and the hatchery production did not become the dominant factor in Prince William Sound until the mid-1980s, long after the wild population had expanded. A hatchery program in the Kodiak area provides useful contrast to the Prince William Sound program because it is smaller and more isolated from the major wild-stock-producing areas of Kodiak Island. The evidence suggests that the hatchery program in Prince William Sound replaced rather than augmented wild production. Two likely causes of the replacement were a decline in wild escapement associated with harvesting hatchery stocks and biological impacts of the hatchery fish on wild fish. Published papers disagree on the impact of the 1989 Exxon Valdez oil spill, but none of the estimates would account for more than a 2% reduction in wild-stock abundance, and the decline in wild stocks began well before the oil spill. No evidence in the Kodiak area program suggests any impact on wild stocks. This analysis suggests that agencies considering the use of hatcheries for augmenting salmonids or other marine species should be aware of the high probability that wild stocks may be adversely affected unless the harvesting of the hatchery fish is isolated from the wild stocks and the hatchery and wild fish do not share habitat during their early ocean life.

RefID: 317

Author: Hing, L.S., Ford, T., Finch, P., Crane, M. and Morritt, D.

Year: 2011

Title: Laboratory stimulation of oil-spill effects on marine phytoplankton

Journal: Aquatic Toxicology

Hyperlink: https://www.researchgate.net/publication/50375788_Laboratory_stimulation_of_oil-spill_effects_on_marine_phytoplankton

Abstract: Continuous culture conditions designed to achieve a dynamic equilibrium between phytoplankton growth and nutrient input were established for Phaeodactylum tricornutum, Isochrysis galbana and Chlorella salina. The technique was used to determine the no observed effect concentration (NOEC) and lowest observed effect concentration (LOEC) for algae after spiking with diesel oil. P. tricornutum (NOEC = 0.25 mg/l, LOEC = 0.3 mg/l) was more sensitive than I. galbana (NOEC = 2.5 mg/l, LOEC = 2.6 mg/l), while C. salina (NOEC =16.0 mg/l, LOEC = 17.0 mg/l)was the most tolerant. Continuous renewal of medium ensured that experimental conditions remained stable throughout the test period and is a more environmentally relevant method for assessing the effects of many contaminants. (C) 2011 Elsevier B.V. All rights reserved.

RefID: 318

Author: Hjermann, D.Ø., Melsom, A., Dingsør, G.E., Durant, J.M., Eikeset, A.M., Røed, L.P., Ottersen, G., Storvik, G. and Stenseth, N.C.

Year: 2007

Title: Fish and oil in the Lofoten-Barents Sea system: synoptic review of the effect of oil spills on fish populations

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v339/p283-299/

Abstract: The Lofoten-Barents Sea area, which contains some of the most valuable fish stocks of the Atlantic Ocean, is being considered for offshore oil production. We review the effects of a hypothetical oil spill on fishes in this area, with a focus on effects on the egg and larval stage of the 3 dominating fish stocks: NE Arctic cod Gadus morhua, Barents Sea capelin Mallotus villosus, and Norwegian spring-spawning herring Clupea harengus. In particular, we emphasise that the long-term population impact of an oil spill depends on ecological and oceanographic factors, some of which have been poorly explored. Among these are (1) effects of the physical state of the ocean, especially mesoscale circulation features, on the advection of oil and fish larvae, (2) effects of the spatial distribution of spawners, (3) effects of harvesting on stock structure and length of the spawning season, (4) effects of natural mortality and species interactions subsequent to an oil spill, and (5) chronic sublethal effects from persistent oil residues.

RefID: 319

Author: Hoffmann, A. and Hansen, P.

Year: 1994

Title: Injury to demersal rockfish and shallow reef habitats in Prince William Sound, 1989-1991

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33087781.pdf

Abstract: Demersal rockfish tissues were collected at four sites (two oiled and two unoiled) in Prince William Sound in both 1990 and 1991 and at four sites (two oiled and two unoiled) along the outer Kenai Peninsula in 1990. Analysis of hydrocarbon data showed that there was a significantly higher incidence of hydrocarbons in outer Kenai Peninsula in 1990. Analysis of hydrocarbon data showed the bile of rockfish from oiled areas than unoiled areas in 1989 (P=O.O05), however there were no significant differences in 1990 were scored by pathologists, and in 1991, 26 different lesions were scored, indicating there were significant differences between unoiled and oiled sites in two of the nine lesion scores, liver lipidosis (P=O.O086) and liver glycogen depletion (P=O.O005) in 1990; and two of the 26 lesion scores, liver lipidosis (P=O.O006) and kidney lymphocytes (P=O.O005) in 1991. No differences in lesion scores were seen between sites on the outer Kenai Peninsula in 1990. After histopathologic examination, the pathologists accurately "predicted" which sites were oiled based on qualitative analysis of semiquantitative lesion scores for all four sites in Prince William Sound. Subsequent principal component analysis indicated differences in oiled and unoiled sites in both 1990 and 1991. Differences were more definitively indicated in 1991than in 1990 using this analysis.

RefID: 320

Author: Hoffmann, A. and Hansen, P.

Year: 1994

Title: Injury to Demersal Rockfish and Shallow Reef Habitats in Prince William Sound, 1989~1991, Subtidal Study Number 6 (Fish/Shellfish Study Number 17), Final Report

Journal: EVOS Trustee Council

Hyperlink: http://jlc-web.uaa.alaska.edu/client/arlis/search/detailnonmodal/ent:$002f$002fSD_ILS$002f230$002fSD_ILS:230244/ada?qu=%22Injury+to+demersal+rockfish+and+shallow+reef+habitats%22

Abstract: Demersal rockfish tissues were collected at four sites (two oiled and two unoiled) in Prince William

Sound in both 1990 and 1991 and at four sites (two oiled and two unoiled) in Prince William Sound in both 1990 and 1991 and at four sites (two oiled and two unoiled) along the outer Kenai Peninsula in 1990. Analysis of hydrocarbon data showed that there was a significantly higher incidence of hydrocarbons in the bile of rockfish from oiled areas than unoiled areas in 1989 (P=0.005), however there were no significant differences in 1990 (P=0.933) or 1991 (P=0.844). In 1990, nine histopathologic lesions were scored by pathologists, and in 1991, 26 different lesions were scored, indicating there were significant differences between unoiled and oiled sites in two of the nine lesion scores, liver lipidosis (P=0.0086) and liver glycogen depletion (P=0.0005) in 1990; and two of the 26 lesion scores, liver lipidosis (P=0.0006) and kidney lymphocytes (P=0.0005) in 1991. No differences in lesion scores were seen between sites on the outer Kenai Peninsula in 1990. After histopathologic examination, the pathologists accurately "predicted" which sites were oiled based on qualitative analysis of semiquantitative lesion scores for all four sites in Prince William Sound. Subsequent principal component analysis indicated differences in oiled and unoiled sites in both 1990 and 1991. Differences were more definitively indicated in 1991 than in 1990 using this analysis.

RefID: 321

Author: Holdway, D.A.

Year: 2002

Title: The acute and chronic effects of wastes associated with offshore oil and gas production on temperate and tropical marine ecological processes

Journal: Marine Pollution Bulletin

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/11954735

Abstract: A review of the acute and chronic effects of produced formation water (PFW), drilling fluids (muds) including oil-based cutting muds, water-based cutting muds, ester-based cutting muds and chemical additives, and crude oils associated with offshore oil and gas production was undertaken in relation to both temperate and tropical marine ecological processes. The main environmental effects are summarized. often in tabular form. Generally. the temporal and spatial scales of these studies, along with the large levels of inherent variation in natural environments, have precluded our ability to predict the potential long-term environmental impacts of the offshore oil and gas production industry. A series of critical questions regarding the environmental effects of the offshore oil and gas production industry that still remain unanswered are provided for future consideration. (C) 2002 Elsevier Science Ltd. All rights reserved.

RefID: 322

Author: Holland-Bartels, L.

Year: 1996

Title: Mechanisms of impact and potential recovery of nearshore vertebrate predators, Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project 95025)

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/index.cfm?FA=searchResults.projectInfo&Project_ID=1005

Abstract: The project, Mechanisms of Impact and Potential Recovery of Nearshore Vertebrate Predators (NVP), was approved in March 1995 and a pilot field season was initiated during the summer to develop statistically valid sampling protocols for invertebrates and fish prey items and describe subtidal study area habitats through sidescan sonar technologies so that final protocols could be developed for the full field seasons (1996-1998). In addition to these preliminary efforts, field seasons were initiated for sea otter and harlequin duck components. The NVP study areas are: 1) oiled - northern Knight and Naked Islands, and 2) unoiled - northwestern Montague Island and Jackpot Bay. A full aerial survey of western PWS to estimate sea otter abundance was completed, mortality surveys were conducted to estimate age class distribution of sea otters dying as compared to pre- (1976-84; 1989) and post- (1989-94) spill age distributions, 6 adult sea otters were captured to obtain blood for preliminary investigations of immune response, and surveys were completed to estimate reproductive output of sea otters in the two study areas. On the basis of these preliminary data, 1) continued lower population densities exist in the oiled study area and 2) a relatively high proportion of prime aged animals occurred in the annual mortality in the western sound. Over 200 harlequin ducks from Montague Island and 160 from Knight Island were captured. Body condition of all birds was determined and total body electrical conductivity (TOBEC) was measured on 267 individuals to develop a noninvasive condition index. Finally, eighty-nine of these birds (all adult females) were implanted with radio transmitters and monitored to determine comparative survival between oiled versus non-oiled populations. Differences exist between areas in patterns of body weight variation through molt, winter survival of females, and blood chemistry. In addition to the biological data collection, a detailed data management program and data archives were established and a review of interactions of sea otters and their ecosystems (Van Blaricom et al. 1995) was completed.

RefID: 323

Author: Hom, T., Varanasi, U., Stein, J.E., Sloan, C.A., Tilbury, K.L. and Chan, S.L.

Year: 1996

Title: Assessment of the Exposure of Subsistence Fish to Aromatic Compounds after the Exxon Valdez Oil Spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: Previous research has shown that fish have the capacity to biotransform many aromatic compounds (ACs) to polar metabolites that are readily accumulated in the gall bladder for excretion and to greatly limit the deposition of ACs or their metabolites in edible muscle tissue. Accordingly, a rapid and sensitive method, developed in our laboratory for screening bile for fluorescent aromatic compounds (FACs) that are components of petroleum, was used to assess exposure of fish to ACs after the Exxon Valdez oil spill. The results of analysis of bile from nearly 500 fish provided evidence that many fish were exposed to ACs after the oil spill. Edible flesh samples from fishes showing a range of biliary FACs were analyzed for the presence of ACs by gas chromatography-mass spectrometry. Concentrations of FACs in bile of bottomfishes and salmon from areas affected by oil ranged from 10 to 17,000 ng phenanthrene equivalents/mg bile protein; however, no appreciable concentratons of ACs were detected in muscle of bottomfishes (<1 ng/g wet weight, parts per billion [ppb]), and, although concentrations of ACs in muscle of salmon were somewhat higher (most samples ranged from 0 to 20 ppb), they rarely exceeded 100 ppb. These findings were used by the Alaskan Oil Spill Health Task Force in arriving at an advisory opinion that consumption of the flesh of fish from areas affected by the oil spill posed minimal risk to native Alaskans. Furthermore, these results were used to verify findings of earlier laboratory studies on the pathways of metabolism and disposition of ACs in fish that were important in formulating a focused, scientific basis for the present investigation of oil-impacted subsistence fisheries.

RefID: 324

Author: Hook, S.E. and Osborn, H.L.

Year: 2012

Title: Comparison of toxicity and transcriptomic profiles in a diatom exposed to oil, dispersants, dispersed oil

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X12002329

Abstract: Dispersants are commonly used to mitigate the impact of oil spills, however, the ecological cost associated with their use is uncertain. The toxicity of weathered oil, dispersed weathered oil, and the hydrocarbon-based dispersant Slickgone NS (R), to the diatom Phaeodactylum tricornutum has been examined using standardized toxicity tests. The assumption that most toxicity occurs via narcosis was tested by measuring membrane damage in diatoms after exposure to one of the petroleum products. The mode of toxic action was determined using microarray-based gene expression profiling in diatoms after exposure to one of the petroleum products. The diatoms were found to be much more sensitive to dispersants than to the water accommodated fraction (WAF), and more sensitive to the chemically enhanced WAF (CEWAF) than to either the WAF itself or the dispersants. Exposure to dispersants and CEWAF caused membrane damage, while exposure to WAF did not. The gene expression profiles

resulting from exposure to all three petroleum mixtures were highly similar, suggesting a similar mode of action for these compounds. The observed toxicity bore no relationship to PAH concentrations in the water column or to total petroleum hydrocarbon (TPH), suggesting that an undescribed component of the oil was causing toxicity. Taken together, these results suggest that the use of dispersants to clean up oil spills will dramatically increase the oil toxicity to diatoms, and may have implications for ecological processes such as the timing of blooms necessary for recruitment. Crown Copyright (C) 2012 Published by Elsevier B.V. All rights reserved.

RefID: 325

Author: Hook, S.E., Lampi, M.A., Febbo, E.J., Ward, J.A. and Parkerton, T.F.

Year: 2010

Title: Temporal patterns in the transcriptomic response of rainbow trout, Oncorhynchus mykiss, to crude oil

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X10001943

Abstract: Time is often not characterized as a variable in ecotoxicogenomic studies In this study, temporal changes in gene expression were determined during exposure to crude oil and a subsequent recovery period Juvenile rainbow trout, Oncorhynchus mykiss, were exposed for 96 h to the water accommodated fractions of 0.4, 2 or 10 mg l(-1) crude oil loadings. Following 96 h of exposure, fish were transferred to recovery tanks. Gill and liver samples were collected after 24 and 96 h of exposure, and after 96 h of recovery for RNA extraction and microarray analysis Fluorescently labeled cDNA was hybridized against matched controls, using salmonid cDNA arrays. Each exposure scenario generated unique patterns of altered gene expression. More genes responded to crude oil in the gill than in the liver In the gill, 1137 genes had altered expression at 24 h, 2003 genes had altered expression levels at 96 h of exposure, yet by 96 h of recovery, no genes were significantly altered in expression. In the liver at 10 mg l(-1), only five genes were changed at 24 h, yet 192 genes had altered expression after 96 h recovery At 2 mg l(-1) in the liver, many genes had altered regulation at all three time points The 0 4 mg l(-1) loading also showed 289 genes upregulated at 24 h after exposure. The Gene Ontology terms associated with altered expression in the liver suggested that the processes of protein synthesis, xenobiotic metabolism, and oxidoreductase activity were altered. The concentration-responsive expression profile of cytochrome P450 1A, a biomarker for oil exposure, did not predict the majority of gene expression profiles in any tissue or dose, since direct relationships with dose were not observed for most genes While the genes and their associated functions agree with known modes of toxic action for crude oil, the gene lists obtained do not match our previously published work, presumably due to array analysis procedures These results demonstrate that changes in gene expression with time and dose may be complicated, and should be characterized in controlled laboratory settings before attempts are made to interpret responses in field-collected organisms Further, processes for analyzing microarray data need to be developed such that standardized gene lists are developed, or that analysis does not rely on lists of significantly altered genes before arrays can be further evaluated as a monitoring tool. Crown Copyright (C) 2010 Published by Elsevier B.V All rights reserved

RefID: 326

Author: Hook, S.E., Lampi, M.A., Febbo, E.J., Ward, J.A. and Parkerton, T.F.

Year: 2010

Title: HEPATIC GENE EXPRESSION IN RAINBOW TROUT (ONCORHYNCHUS MYKISS) EXPOSED TO DIFFERENT HYDROCARBON MIXTURES

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.245/abstract

Abstract: Traditional biomarkers for hydrocarbon exposure are not induced by all petroleum substances. The objective of this study was to determine if exposure to a crude oil and different refined oils would generate a common hydrocarbon-specific response in gene expression profiles that could be used as generic biomarkers of hydrocarbon exposure. Juvenile rainbow trout (Oncorhynchus mykiss) were

exposed to the water accommodated fraction (WAF) of either kerosene, gas oil, heavy fuel oil, or crude oil for 96 h. Tissue was collected for RNA extraction and microarray analysis. Exposure to each WAF resulted in a different list of differentially regulated genes, with few genes in common across treatments. Exposure to crude oil WAF changed the expression of genes including cytochrome P4501A (CYP1A) and glutathione-S-transferase (GST) with known roles in detoxification pathways. These gene expression profiles were compared to others from previous experiments that used a diverse suite of toxicants. Clustering algorithms successfully identified gene expression profiles resulting from hydrocarbon exposure. These preliminary analyses highlight the difficulties of using single genes as diagnostic of petroleum hydrocarbon exposures. Further work is needed to determine if multivariate transcriptomic-based biomarkers may be a more effective tool than single gene studies for exposure monitoring of different oils. Environ. Toxicol. Chem. 2010;29:2034-2043. (C) 2010 SETAC

RefID: 327

Author: Hook, S.E., Osborn, H.L., Spadaro, D.A. and Simpson, S.L.

Year: 2014

Title: Assessing mechanisms of toxicant response in the amphipod Melita plumulosa through transcriptomic profiling

Journal: Aquatic Toxicology

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/24334007

Abstract: This study describes the function of transcripts with altered abundance in the epibenthic amphipod, Melita plumulosa, following whole-sediment exposure to a series of common environmental contaminants. M. plumulosa were exposed for 48 h to sediments spiked and equilibrated with the following contaminants at concentrations predicted to cause sublethal effects to reproduction: porewater ammonia 30 mg L-1; bifenthrin at 100 mu g kg(-1); fipronil at 50 mu g kg(-1); 0.6% diesel; 0.3% crude oil; 250 mg Cu kg(-1); 400 mg Ni kg(-1); and 400 mg Zn kg(-1). RNA was extracted and hybridized against a custom Agilent microarray developed for this species. Although the microarray represented a partial transcriptome and not all features on the array could be annotated, unique transcriptomic profiles were generated for each of the contaminant exposures. Hierarchical clustering grouped the expression profiles together by contaminant class, with copper and zinc, the petroleum products and nickel, and the pesticides each forming a distinct cluster. Many of the transcriptional changes observed were consistent with patterns previously described in other crustaceans. The changes in the transcriptome demonstrated that contaminant exposure caused changes in digestive function, growth and moulting, and the cytoskeleton following metal exposure, whereas exposure to petroleum products caused changes in carbohydrate metabolism, xenobiotic metabolism and hormone cycling. Functional analysis of these gene expression profiles can provide a better understanding of modes of toxic action and permits the prediction of mixture effects within contaminated ecosystems. Crown Copyright (C) 2013 Published by Elsevier B.V. All rights reserved.

RefID: 328

Author: Hooten, A.J. and Highsmith, R.C.

Year: 1996

Title: Impacts on Selected Intertidal Invertebrates in Herring Bay, Prince William Sound, after the Exxon Valdez Oil Spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: Population densities of several species of invertebrates were determined at seven pairs of matched oiled and control sites in Herring Bay, Knight Island, Prince William Sound, from 1990 to 1993. Significantly lower population densities were observed for two limpet species and the Sitka periwinkle Littorina sitkana in the middle and upper intertidal zones but remained incomplete in the upper intertidal zone for the limpet, Tectura persona at sheltered rocky and coarse-textured sites and for the Sitka periwinkle at sheltered rocky sites.

RefID: 329

Author: Hoover-Miller, A., Parker, K.R. and Burns, J.J.

Year: 2001

Title: A reassessment of the impact of the Exxon Valdez oil spill on harbor seals (Phoca vitulina richardsi) in Prince William Sound, Alaska

Journal: Marine Mammal Science

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1111/j.1748-7692.2001.tb00983.x/abstract

Abstract: Analyses of population trends and movements of harbor seals in Prince William Sound (PWS) casts doubt on published findings that 302 seals were killed by the Exxon Valdez oil spill in 1989. Assumptions that seals have 100% fidelity to a haul-out, that they were not displaced by the spill and associated disturbances, and that population trends throughout PWS varied similarly, except for oil spill effects, are not supported. Survey efforts to account for missing seals in 1989 were incomplete, too late in the year, and geographically limited. Basic assumptions required for statistical comparisons of oiled and unoiled haul-outs were violated. Fourteen dead seals, mostly pups, were recovered in PWS. Cause of death in most instances could not be determined, nor could the proportion that would have died naturally. Evidence does not support high unsubstantiated mortality, but is more consistent with seals avoiding or moving away from some oiled haul-outs. Interpretation of survey results requires consideration of temporal and regional variation. "Route A" surveys of central and eastern PWS do not represent population trends in western PWS or at glacial haul-outs. To adequately monitor population trends of PWS as a whole, broader sampling must be conducted on a routine basis.

RefID: 330

Author: Horel, A., Mortazavi, B. and Sobecky, P.A.

Year: 2012

Title: Responses of microbial community from northern Gulf of Mexico sandy sediments following exposure to deepwater horizon crude oil

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.1770/abstract

Abstract: In the present study, microbial community responses to exposure to unweathered Macondo Well crude oil and conventional diesel in a sandy beach environment were determined. Biodegradation was assessed in mesocosm experiments with differing fuel amounts (2,000 and 4,000?mg/kg) and with or without inorganic nutrient amendment. Carbon dioxide production was measured daily for 42?d. Aerobic alkane, total hydrocarbon, and polycyclic aromatic hydrocarbon (PAH) degraders were enumerated in treated and control mesocosms and changes in their abundances were measured weekly. Hydrocarbon mineralization occurred in all treatments. In the inorganic nutrient-amended treatments, the degradation rates were 2.31 and 2.00 times greater in the 2,000?mg/kg diesel and crude oil treatments, respectively, and 3.52 (diesel) and 4.14 (crude) times higher for the fuel types at the 4,000?mg/kg fuel concentrations compared to unamended treatments. Microbial lag phases were short (<3?d) and alkane and total hydrocarbon degrader numbers increased by five orders of magnitude compared to the uncontaminated treatments within 7?d in most treatments. Hydrocarbon degrader numbers in diesel and in crude oil treatments were similar; however, the PAH degraders were more abundant in the crude oil relative to diesel treatment. These findings indicate that hydrocarbon degradation by extant microbial populations in the northern Gulf of Mexico sandy beach environments can be stimulated and enhanced by inorganic nutrient addition. Environ. Toxicol. Chem. 2012; 31: 10041011. (c) 2012 SETAC

RefID: 331

Author: Hose, J.E. and Brown, E.D.

Year: 1998

Title: Field applications of the piscine anaphase aberration test: lessons from the Exxon Valdez oil spill

Journal: Mutation Research-Fundamental and Molecular Mechanisms of Mutagenesis

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/9672658

Abstract: Several large-scale genotoxicity assessments have been performed in coastal marine areas that have demonstrated either localized or widespread genetic effects resulting from human activity. One common assessment method is the anaphase aberration test, a measurement of abnormal chromosome division, using embryolarval fishes. It can be used to detect the presence of mutagens within a poorly characterized complex mixture or monitor specific genotoxins and is easily adapted for laboratory screening. One comprehensive marine genotoxicity assessment was conducted using Pacific herring (Clupea pallasi) following the Exxon Valdez oil spill (EVOS) in Prince William Sound (PWS), AK in late March 1989, In early May, genetic damage was detected at many sites within the oil trajectory and was correlated with concentrations of polycyclic aromatic hydrocarbons characteristic of Exxon Valdez oil (EVO) in intertidal mussels. Effects were related spatially and temporally to oil exposure. Anaphase aberration rates decreased throughout May and June 1989, and by 1991, genotoxicity was undetectable. The abundance of the 1989 herring year class in PWS is significantly reduced; this is the first reported example linking genotoxicity to subsequent population level effects. This review describes the methodology for the anaphase aberration test using fish eggs, its applications for large-scale assessments and supportive laboratory studies, and its limitations for prediction of higher level effects on populations. (C) 1998 Elsevier Science B,V. All rights reserved.

RefID: 332

Author: Hose, J.E., McGurk, M.D., Marty, G.D., Hinton, D.E., Brown, E.D. and Baker, T.T.

Year: 1996

Title: Sublethal effects of the (Exxon Valdez) oil spill on herring embryos and larvae: morphological, cytogenetic, and histopathological assessments, 1989 1991

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f96-174

Abstract: Following the Exxon Valdez oil spill in Prince William Sound, Alaska, in March 1989, Pacific herring (Clupea pallasi) larvae were evaluated for sublethal damage. From 1989 to 1991, egg masses were collected from oiled and unoiled beaches and incubated to hatch. Newly hatched herring larvae were assessed for morphological (skeletal, craniofacial, and finfold) deformities, cytogenetic abnormalities (anaphase-telophase aberrations), and histopathological lesions. In 1989, herring larvae from both oiled areas (Rocky Bay on Montague Island and Naked Island) had significantly more morphological deformities and cytogenetic abnormalities than did larvae from the unoiled location (Fairmont Bay). The extent of morphological and cytogenetic damage was correlated with oil exposure in adjacent native bay mussels. Larvae had no oil-related histopathological lesions. In 1990 and 1991, oil-related developmental and genetic effects were undetectable.

RefID: 333

Author: Houghton, J.P., Fukuyama, A.K., Lees, D.C., Hague, P.J. and Cumberland, H.L.

Year: 1992

Title: Evaluation of the condition of Prince William Sound shorelines following the Exxon Valdez oil spill and subsequent shoreline treatment: Volume 2, 1991 Biological Monitoring Survey

Journal: NOAA Technical Memorandum

Hyperlink:

Abstract: It has been estimated that some 40 percent (4.4 million gallons) of the crude oil spilled from the tanker Exxon Valdez on March 24, 1989, was deposited on beaches in Prince William Sound. During and after shoreline cleanup activities, concerns were raised regarding the potential effects on intertidal habitats and biota of shoreline treatments, especially those using high-pressure hot-water washes. The overall objectives of this study have been to evaluate recovery of important intertidal and shallow subtidal habitats and resources from the effects of oiling and shoreline treatment and to assess the influence of high-pressure hot-water treatments on the nature and rates of recovery.

RefID: 334

Author: Houghton, J.P., Gilmour, R., Lees, D.C. and Driskell, W.B.

Year: 1995

Title: Hard shelled clam recovery from Exxon Valdez oiling and shoreline treatment

Journal: International Oil Spill Conference Proceedings

Hyperlink:

Abstract: Native littleneck clams (Protothaca staminea) from Prince William Sound were sampled to evaluate recovery from the March 1982 Exxon Valdez oil spill. Hydraulic washing flushed quantities of material from upper elevations, often burying the lower beaches in sediment with few fines and little organic carbon. Sampling at stations representing several degrees of oiling and treatment disturbance showed that hydraulically washed beaches had significantly lower clam densities in 1990. Recruitment has been very limited on washed beaches; as a result, clam densities remained very depressed through 1992 compared with those on unoiled beaches and on beaches that were oiled but not washed.

RefID: 335

Author: Houghton, J.P., Gilmour, R., Lees, D.C., Driskell, W.B., Lindstrom, S.C. and Mearns, A.

Year: 1997

Title: PRINCE WILLIAM SOUND INTERTIDAL BIOTA SEVEN YEARS LATER: HAS IT RECOVERED?

Journal: International Oil Spill Conference Proceedings

Hyperlink:

Abstract: Eight years of quantitative biological and chemical data have been analyzed for trends in recovery of biota inhabiting beaches in Prince William Sound following the 1989 Exxon Valdez oil spill and subsequent shoreline treatments. Sampling has focused on biota at sheltered rocky and mixed-soft sites subjected to three degrees of disturbance (unoiled, oiled but not hot-water washed, and oiled/hot-water washed). Only epibiota on sheltered rocky habitats are covered in this paper. The majority of community dominants survived 1989 on oiled rocky shores that were not high-pressure, hot-water washed. These areas appeared to be nearly completely recovered by 1991, although subsequent monitoring has revealed oscillations in species abundances that exceed those on unoiled beaches. Hot-water treatments used in 1989 had severe short-term impacts on intertidal epibenthos. Some high-pressure, hot-water-treated rocky shores stripped of biota in 1989 showed very slow colonization through 1995; other areas that appeared to be nearly recovered in 1992 suffered severe declines in dominant taxa in 1995. The dominant age class of rockweed, which began life following hot-water treatment, matured in 1993 and died off in 1994 and 1995, resulting in declines of associated fauna. A new cycle of rockweed colonization has begun, and some recovery of rockweed and associated fauna was observed in 1996.

RefID: 336

Author: Houghton, J.P., Lees, D.C., Driskell, W.B. and Lindstrom, S.C.

Year: 1997

Title: Evaluation of the condition of Prince William Sound shorelines following the Exxon Valdez oil spill and subsequent shoreline treatment: Volume 1, 1995 Biological Monitoring Survey

Journal: NOAA Technical Memorandum

Hyperlink:

Abstract: This document is the sixth annual progress report on studies designed to investigate the ecological implications of shoreline treatments on intertidal and shallow subtidal marine life of Prince William Sound, Alaska, following the March 1989 spill from the tank vessel Exxon Valdez. This program addresses two areas of great uncertainty and concern about the effect of oil on shorelines: 1. The length of time required for oil-damaged ecosystems to recover. 2. The effects of shoreline treatment methods on marine life and the extent to which treatment affects recovery. It is imperative that information regarding shoreline recovery from the Exxon Valdez spill and the various treatments applied be made available to decision makers before the next such incident occurs. This need to obtain and disseminate information is the general rationale for the present study initiated by the National Oceanic and Atomospheric Administration (NOAA) under Contract No. 50ABNC-2-00050. Funding in 1995 was provided by NOAA and the Restitution Fund established as part of the settlement between the Exxon Valdez Oil Spill Trustees Council and Exxon.

RefID: 337

Author: Houghton, J.P., Lees, D.C., Driskell, W.B., Lindstrom, S.C. and Mearns, A.J.

Year: 1996

Title: Recovery of Prince William Sound Intertidal Epibiota From Exxon Valdez Oiling and Shoreline Treatments, 1989 Through 1992

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: Biological and chemical data from 4 years of quantitative monitoring have been analyzed for trends in recovery of biota inhabiting beaches in Prince William Sound from the effects of the 1989 Exxon Valdez oil spill and subsequent cleanup. Stratified random sampling was used from April 1989 through July 1992 to assess biota at sheltered rocky sites subjected to three degrees of disturbance (unoiled, oiled but not hot-water washed, and oiled plus hot-water washed) in 1989. Hot-water treatments used to remove crude oil from the beaches of the sound in 1989 have had severe short-term impacts on intertidal epibenthos. Some high-pressure hot-water treated rocky shores that were stripped of biota in 1989 showed little colonization by 1990. On other oiled rocky shores that were not high-pressure hot-water washed, the majority of the epibiotal community dominants, including rockweed, mussels, barnacles, limpets, drills, and littorines, survived. Several significant differences were noted between the epibiota on unoiled shores and on oiled shores that were not hot-water treated; an even greater number of significant differences in epibiota was noted between those oiled beaches that had not been treated and those that had been treated. In May 1991 epibiotal populations on oiled and untreated shores were still depressed below those on unoiled shores. By July 1991 most high-pressure hot-water washed rocky shores showed some recovery, having been colonized by opportunistic species with planktonic larvae; new growth from remnants of the original biota also contributed to recovery. No significant differences remained between unoiled stations and those that had been oiled and not treated; some significant differences remained between the biota of unoiled and hot-water washed shores. Effects of high-pressure hot-water treatments applied in 1989 remained visible in intertidal assemblages in some areas through 1992. By July 1992 recovery of most rocky shores had progressed considerably, and few differences remained betwen the unoiled and the high-pressure hot-water washed categories. Individual hot-water washed sites still showed altered community structure that is attributed to the treatment, however, and full recovery of intertidal epibiota is still several years away in these areas.

RefID: 338

Author: Huang, Y.J., Jiang, Z.B., Zeng, J.N., Chen, Q.Z., Zhao, Y.Q., Liao, Y.B., Shou, L. and Xu, X.Q.

Year: 2011

Title: The chronic effects of oil pollution on marine phytoplankton in a subtropical bay, China

Journal: Environmental Monitoring and Assessment

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/20640504

Abstract: To evaluate the effects of crude oil water accommodated fraction (WAF) on marine phytoplankton community, natural phytoplankton collected seasonally from the Yueqing bay were exposed to eight groups of crude oil WAF for 15 days under laboratory conditions. Chlorophyll a and cell density were measured, and species of phytoplankton were identified every 24 h to reflect the change of phytoplankton community. The results showed that (1) High concentrations (>= 2.28 mg l(-1)) of oil

pollution would greatly restrain phytoplankton growth ($p < 0.001$), decrease chlorophyll a content and cell density, whereas low concentrations (<= 1.21 mg l (-1)) did not restrain its growth but rather promoted the phytoplankton growth. (2) The biodiversity, evenness, and species number of phytoplankton were all significantly influenced by crude oil WAF in all seasons ($p < 0.001$). (3) The dominant species changes were different under different pollutant concentrations in different seasons. Different species had different tolerances to the oil pollution, thus leading to abnormal succession.

RefID: 339

Author: Huggett, R.J., Neff, J.M., Stegeman, J.J., Woodin, B., Parker, K.R. and Brown, J.S.

Year: 2006

Title: Biomarkers of PAH exposure in an intertidal fish species from Prince William Sound, Alaska: 2004-2005

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es0608489

Abstract: Polycyclic aromatic hydrocarbon (PAH) exposure biomarkers were measured in high cockscomb prickleback (Anoplarchus purpurescens) fish collected from both previously oiled and unoiled shore in Prince William Sound (PWS), Alaska, to test the hypothesis that fish living in the nearshore environment of the sound were no longer being exposed to PAH from the Exxon Valdez oil spill. Pricklebacks spend their entire lives in the intertidal zone of rocky shores with short-term movements during feeding and breeding restricted to an area of about 15 meters in diameter. Fish were assayed for the PAH exposure biomarkers, bile fluorescent aromatic compounds (FAC), and liver ethoxyresorufin 0-deethylase (EROD) activity (a measure of cytochrome P450 1A (CYP1A) monooxygenase activity). Bile FAC concentrations and EROD activities were low and not significantly different in fish from previously oiled and unoiled sites. The similar low EROD activity and bile FAC concentrations in fish from oiled and unoiled shores, supports the hypothesis that these low-level biomarker responses were not caused by exposure of the fish to residues of the spilled oil.

RefID: 340

Author: Hughes, J.B.

Year: 1999

Title: Cytological-cytogenetic analyses of winter flounder embryos collected from the benthos at the barge North Cape oil spill

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X99800095

Abstract: The oil barge North Cape ran aground on Moonstone Beach in Rhode Island on January 19, 1996, spilling 828 000 gallons (U.S.) of a combination of diesel and home heating oils. Samples of winter flounder embryos were collected from salt ponds in the area of the spill using an epibenthic sled, An examination of the field-sampled embryos based on gross morphology, levels of moribund embryos, mitotic index, and chromosomal anomalies found that: a significant number exhibited high levels of one or more of these conditions when compared with flounder embryos raised under laboratory-controlled conditions. No chorion damage was noted in embryos collected from the field nor were there any significant findings of lordosis or scoliosis, The cumulative impact on winter flounder embryos of North Cope oil exposure was an estimated 51% reduction in the number of embryos surviving to the larval stage. (C) 1999 Elsevier Science Ltd. All rights reserved.

RefID: 341

Author: Hulathduwa, Y.D. and Brown, K.M.

Year: 2006

Title: Relative importance of hydrocarbon pollutants, salinity and tidal height in colonization of oyster reefs

Journal: Marine Environmental Research

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/16814855

Abstract: The relative effects of hydrocarbon pollutants, salinity and tidal height on the invertebrates and fish that inhabit oyster reefs were studied along the Louisiana Gulf of Mexico coastline. Dried oyster shell (cultch) was first exposed to crude oil in the laboratory. In a series of experiments, plastic trays filled with control and oil-exposed cultch were then deployed at two locations differing in salinity, in two seasons and at two tidal levels. In experiments on hydrocarbon, salinity, and seasonal effects, trays were colonized for one month. To examine the effects of colonization time, half of the trays were retrieved after two and the rest after five weeks. Salinity dramatically affected oyster reef assemblages, with species richness and total abundance halved at the estuarine site. Hydrocarbon effects were less prominent, whether cultch was dosed with light or heavy crude oil. The sub-tidal site had higher colonization rates, but colonization interval did not affect colonization, and seasonal differences occurred only at the higher-diversity, sub-tidal site. To determine effects of cleaners, Corexit 9580 was applied alone and with oil on cultch, and trays were colonized for one month. At high concentrations, the cleaner ameliorated hydrocarbon effects. In general, hydrocarbon effects were less prominent than salinity and aerial exposure in explaining colonization of oyster reef assemblages. Gas chromatography/mass spectrometry analysis of oyster shells after one month immersion revealed considerable losses of oil, especially with higher flow at the inter-tidal site. Sediment on shell also diluted oil. We argue that oyster reef assemblages should recover from small-scale spills, unless they occur during periods of reproduction and dispersal. (c) 2006 Elsevier Ltd. All rights reserved.

RefID: 342

Author: Hwang, H.M., Stanton, B., Mcbride, T. and Anderson, M.J.

Year: 2014

Title: POLYCYCLIC AROMATIC HYDROCARBON BODY RESIDUES AND LYSOSOMAL MEMBRANE DESTABILIZATION IN MUSSELS EXPOSED TO THE DUBAI STAR BUNKER FUEL OIL (INTERMEDIATE FUEL OIL 380) SPILL IN SAN FRANCISCO BAY

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/24435959

Abstract: Following the spill of bunker fuel oil (intermediate fuel oil 380, approximately 1500-3000 L) into San Francisco Bay in October 2009, polycyclic aromatic hydrocarbon (PAH) concentrations in mussels from moderately oiled areas increased up to 87 554ng/g (dry wt) and, 3 mo later, decreased to concentrations found in mussels collected prior to oiling, with a biological half-life of approximately 16 d. Lysosomal membrane destabilization increased in mussels with higher PAH body burdens. Environ Toxicol Chem 2014;33:1117-1121. (c) 2014 SETAC

RefID: 343

Author: Hylland, K.

Year: 2006

Title: Polycyclic aromatic hydrocarbon (PAH) ecotoxicology in marine ecosystems

Journal: Journal of Toxicology and Environmental Health

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/15287390500259327

Abstract: Low levels of oil and hence polycyclic aromatic hydrocarbons (PAHs) are naturally present in the marine environment, although levels have increased significantly following human extraction and use of oil and gas. Other major anthropogenic sources of PAHs include smelters, the use of fossil fuels in general, and various methods of waste disposal, especially incineration. There are two major sources for PAHs to marine ecosystems in Norway: the inshore smelter industry, and offshore oil and gas production activities. A distinction is generally made between petrogenic (oil-derived) and pyrogenic (combustion-derived) PAHs. Although petrogenic PAHs appear to be bioavailable to a large extent, pyrogenic PAHs are often associated with soot particles and less available for uptake into organisms. There is extensive evidence linking sediment-associated PAHs to induction of phase-I enzymes, development of DNA

adducts, and eventually neoplastic lesions in fish. Most studies have focused on high-molecular-weight, carcinogenic PAHs such as benzo[a] pyrene. It is less clear how two- and three-ring PAHs affect fish, and there is even experimental evidence to indicate that these chemicals may inhibit some components of the phase I system rather than produce induction. There is a need for increased research efforts to clarify biological effects of two- and three-ring PAHs, PAH mixtures, and adaptation processes in marine ecosystems.

RefID: 344

Author: Incardona, J.P., Carls, M.G., Day, H.L., Sloan, C.A., Bolton, J.L., Collier, T.K. and Scholz, N.L.

Year: 2009

Title: Cardiac Arrhythmia Is the Primary Response of Embryonic Pacific Herring (Clupea pallasi) Exposed to Crude Oil during Weathering

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es802270t

Abstract: Teleost embryos develop a syndrome characterized by edema when exposed to water that weathers substrates contaminated with crude oil. Previous studies using zebrafish demonstrated that crude oil exposure causes cardiogenic edema, and that the most abundant polycyclic aromatic hydrocarbons (PAHs) in weathered crude oils (tricyclic fluorenes, dibenzothiophenes, and phenanthrenes) are cardiotoxic, causing arrhythmia through a pathway that does not require activation of the aryl hydrocarbon receptor (AHR) We demonstrate. here for Pacific herring, a species impacted by the Exxon Valdez oil spill, that the developing heart is the primary target of crude oil exposure. Herring embryos exposed to the effluent of oiled gravel columns developed dose-dependent edema and irregular cardiac arrhythmia soon after the heartbeat was established. At a dose that produced cardiac dysfunction in 100% of exposed embryos, tissue levels of tricyclic PAHs were below 1 mu mol/kg, suggesting a specific, high affinity target in the heart. These findings have implications for understanding the mechanism of tricyclic PAH cardiotoxicity, the development of biomarkers for the effects of PAH exposure in fish and, understanding the long-term impacts of oil spills and other sources of PAH pollution in aquatic environments.

RefID: 345

Author: Incardona, J.P., Carls, M.G., Teraoka, H., Sloan, C.A., Collier, T.K. and Scholz, N.L.

Year: 2005

Title: Aryl hydrocarbon receptor-independent toxicity of weathered crude oil during fish development

Journal: Environmental Health Perspectives

Hyperlink: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1315066/

Abstract: Polycyclic aromatic hydrocarbons (PAHs), derived largely from fossil fuels and their combustion, are pervasive contaminants in rivers, lakes, and nearshore marine habitats. Studies after the Exxon Valdez oil spill demonstrated that fish embryos exposed to low levels of PAHs in weathered crude oil develop a syndrome of edema and craniofacial and body axis defects. Although mechanisms leading to these defects are poorly understood, it is widely held that PAH toxicity is linked to aryl hydrocarbon receptor (AhR) binding and cytochrome P450 1A (CYP1A) induction. Using zebrafish embryos, we show that the weathered crude oil syndrome is distinct from the well-characterized AhR-dependent effects of dioxin toxicity. Blockade of AhR pathway components with antisense morpholino oligonucleotides demonstrated that the key developmental defects induced by weathered crude oil exposure are mediated by low-molecular-weight tricyclic PAHs through AhR-independent disruption of cardiovascular function and morphogenesis. These findings have multiple implications for die assessment of PAH impacts on coastal habitats.

RefID: 346

Author: Incardona, J.P., Collier, T.K. and Scholz, N.L.

Year: 2004

Title: Defects in cardiac function precede morphological abnormalities in fish embryos exposed to polycyclic aromatic hydrocarbons

Journal: Toxicology and Applied Pharmacology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0041008X04000110

Abstract: Fish embryos exposed to complex mixtures of polycyclic aromatic hydrocarbons (PAHs) from petrogenic sources show a characteristic suite of abnormalities, including cardiac dysfunction, edema, spinal curvature, and reduction in the size of the jaw and other craniofacial structures. To elucidate the toxic mechanisms underlying these different defects, we exposed zebrafish (Danio rerio) embryos to seven non-alkylated PAHs, including five two- to four-ring compounds that are abundant in crude oil and two compounds less abundant in oil but informative for structure-activity relationships. We also analyzed two PAH mixtures that approximate the composition of crude oil at different stages of weathering. Exposure to the three-ring PAHs dibenzothiophene and phenanthrene alone was sufficient to induce the characteristic suite of defects, as was genetic ablation of cardiac function using a cardiac troponin T antisense morpholino oligonucleotide. The primary etiology of defects induced by dibenzothiophene or phenanthrene appears to be direct effects on cardiac conduction, which have secondary consequences for late stages of cardiac morphogenesis, kidney development, neural tube structure, and formation of the craniofacial skeleton. The relative toxicity of the different mixtures was directly proportional to the amount of phenanthrene, or the dibenzothiophene-phenanthrene total in the mixture. Pyrene, a four-ring PAH, induced a different syndrome of anemia, peripheral vascular defects, and neuronal cell death, similar to the effects previously described for potent aryl hydrocarbon receptor ligands. Therefore, different PAH compounds have distinct and specific effects on fish at early life history stages. (C) 2004 Elsevier Inc. All rights reserved.

RefID: 347

Author: Incardona, J.P., Gardner, L.D., Linbo, T.L., Brown, T.L., Esbaugh, A.J., Mager, E.M., Stieglitz, J.D., French, B.L., Labenia, J.S., Laetz, C A., Tagal, M., Sloan, C.A., Elizur, A., Benetti, D.D., Grosell, M., Block, B.A. and Scholz, N.L.

Year: 2014

Title: Deepwater Horizon crude oil impacts the developing hearts of large predatory pelagic fish

Journal: Proceedings of the National Academy of Sciences of the United States of America

Hyperlink: http://www.pnas.org/content/111/15/E1510.abstract

Abstract: The Deepwater Horizon disaster released more than 636 million L of crude oil into the northern Gulf of Mexico. The spill oiled upper surface water spawning habitats for many commercially and ecologically important pelagic fish species. Consequently, the developing spawn (embryos and larvae) of tunas, swordfish, and other large predators were potentially exposed to crude oil-derived polycyclic aromatic hydrocarbons (PAHs). Fish embryos are generally very sensitive to PAH-induced cardiotoxicity, and adverse changes in heart physiology and morphology can cause both acute and delayed mortality. Cardiac function is particularly important for fast-swimming pelagic predators with high aerobic demand. Offspring for these species develop rapidly at relatively high temperatures, and their vulnerability to crude oil toxicity is unknown. We assessed the impacts of field-collected Deepwater Horizon (MC252) oil samples on embryos of three pelagic fish: bluefin tuna, yellowfin tuna, and an amberjack. We show that environmentally realistic exposures (1-15 mu g/L total PAH) cause specific dose-dependent defects in cardiac function in all three species, with circulatory disruption culminating in pericardial edema and other secondary malformations. Each species displayed an irregular atrial arrhythmia following oil exposure, indicating a highly conserved response to oil toxicity. A considerable portion of Gulf water samples collected during the spill had PAH concentrations exceeding toxicity thresholds observed here, indicating the potential for losses of pelagic fish larvae. Vulnerability assessments in other ocean habitats, including the Arctic, should focus on the developing heart of resident fish species as an exceptionally sensitive and consistent indicator of crude oil impacts.

RefID: 348

Author: Incardona, J.P., Swarts, T.L., Edmunds, R.C., Linbo, T.L., Aquilina-Beck, A., Sloan, C.A., Gardner, L.D., Block, B.A. and Scholz, N.L.

Year: 2013

Title: Exxon Valdez to Deepwater Horizon: Comparable toxicity of both crude oils to fish early life stages

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X13002191

Abstract: The 2010 Deepwater Horizon disaster in the Gulf of Mexico was the largest oil spill in United States history. Crude oils are highly toxic to developing fish embryos, and many pelagic fish species were spawning in the northern Gulf in the months before containment of the damaged Mississippi Canyon 252 (MC252) wellhead (April July). The largest prior U.S. spill was the 1989 grounding of the Exxon Valdez that released 11 million gallons of Alaska North Slope crude oil (ANSCO) into Prince William Sound. Numerous studies in the aftermath of the Exxon Valdez spill defined a conventional crude oil injury phenotype in fish early life stages, mediated primarily by tokicity to the developing heart. To determine whether this type of injury extends to fishes exposed to crude oil from the Deepwater Horizon MC252 incident, we used zebrafish to compare the embryotoxicity of ANSCO alongside unweathered and weathered MC252 oil. We also developed a standardized protocol for generating dispersed oil water-accommodated fractions containing microdroplets of crude oil in the size range of those detected in subsurface plumes in the Gulf. We show here that MC252 oil and ANSCO cause similar cardiotoxicity and photo-induced toxicity in zebrafish embryos. Morphological defects and patterns of cytochrome P450 induction were largely indistinguishable and generally correlated with polycyclic aromatic compound (PAC) composition of each oil type. Analyses of embryos exposed during different developmental windows provided additional insight into mechanisms of crude oil cardiotoxicity. These findings indicate that the impacts of MC252 crude oil on fish embryos and larvae are consistent with the canonical ANSCO cardiac injury phenotype. For those marine fish species that spawned in the northern Gulf of Mexico during and after the Deepwater Horizon incident, the established literature can therefore inform the assessment of natural resource injury in the form of potential year-class losses. Published by Elsevier B.V.

RefID: 349

Author: Incardona, J.P., Vines, C.A., Anulacion, B.F., Baldwin, D.H., Day, H.L., French, B.L., Labenia, J.S., Linbo, T.L., Myers, M.S., Olson, O.P., Sloan, C.A., Sol, S., Griffin, F.J., Menard, K., Morgan, S G., West, J.E., Collier, T.K., Ylitalo, G.M., Cherr, G.

Year: 2012

Title: Unexpectedly high mortality in Pacific herring embryos exposed to the 2007 Cosco Busan oil spill in San Francisco Bay

Journal: Proceedings of the National Academy of Sciences of the United States of America

Hyperlink: http://www.pnas.org/content/109/2/E51.abstract

Abstract: In November 2007, the container ship Cosco Busan released 54,000 gallons of bunker fuel oil into San Francisco Bay. The accident oiled shoreline near spawning habitats for the largest population of Pacific herring on the west coast of the continental United States. We assessed the health and viability of herring embryos from oiled and unoiled locations that were either deposited by natural spawning or incubated in subtidal cages. Three months after the spill, caged embryos at oiled sites showed sublethal cardiac toxicity, as expected from exposure to oil-derived polycyclic aromatic compounds (PACs). By contrast, embryos from the adjacent and shallower intertidal zone showed unexpectedly high rates of tissue necrosis and lethality unrelated to cardiotoxicity. No toxicity was observed in embryos from unoiled sites. Patterns of PACs at oiled sites were consistent with oil exposure against a background of urban sources, although tissue concentrations were lower than expected to cause lethality. Embryos sampled 2 y later from oiled sites showed modest sublethal cardiotoxicity but no elevated necrosis or mortality. Bunker oil contains the chemically uncharacterized remains of crude oil refinement, and one or more of these unidentified chemicals likely interacted with natural sunlight in the intertidal zone to kill herring embryos. This reveals an important discrepancy between the resolving power of current forensic analytical chemistry and biological responses of keystone ecological species in oiled habitats.

Nevertheless, we successfully delineated the biological impacts of an oil spill in an urbanized coastal estuary with an overlapping backdrop of atmospheric, vessel, and land-based sources of PAC pollution.

RefID: 350

Author: Incardona, J.P., Vines, C.A., Linbo, T.L., Myers, M.S., Sloan, C.A., Anulacion, B.F., Boyd, D., Collier, T.K., Morgan, S., Cherr, G N. and Scholz, N.L.

Year: 2012

Title: Potent Phototoxicity of Marine Bunker Oil to Translucent Herring Embryos after Prolonged Weathering

Journal: Plos One

Hyperlink: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0030116

Abstract: Pacific herring embryos (Clupea pallasi) spawned three months following the Cosco Busan bunker oil spill in San Francisco Bay showed high rates of late embryonic mortality in the intertidal zone at oiled sites. Dead embryos developed to the hatching stage (e. g. fully pigmented eyes) before suffering extensive tissue deterioration. In contrast, embryos incubated subtidally at oiled sites showed evidence of sublethal oil exposure (petroleum-induced cardiac toxicity) with very low rates of mortality. These field findings suggested an enhancement of oil toxicity through an interaction between oil and another environmental stressor in the intertidal zone, such as higher levels of sunlight-derived ultraviolet (UV) radiation. We tested this hypothesis by exposing herring embryos to both trace levels of weathered Cosco Busan bunker oil and sunlight, with and without protection from UV radiation. Cosco Busan oil and UV co-exposure were both necessary and sufficient to induce an acutely lethal necrotic syndrome in hatching stage embryos that closely mimicked the condition of dead embryos sampled from oiled sites. Tissue levels of known phototoxic polycyclic aromatic compounds were too low to explain the observed degree of phototoxicity, indicating the presence of other unidentified or unmeasured phototoxic compounds derived from bunker oil. These findings provide a parsimonious explanation for the unexpectedly high losses of intertidal herring spawn following the Cosco Busan spill. The chemical composition and associated toxicity of bunker oils should be more thoroughly evaluated to better understand and anticipate the ecological impacts of vessel-derived spills associated with an expanding global transportation network.

RefID: 351

Author: Ingvarsdóttir, A., Bjørkblom, C., Ravagnan, E., Godal, B.F., Arnberg, M., Joachim, D.L. and Sanni, S.

Year: 2012

Title: Effects of different concentrations of crude oil on first feeding larvae of Atlantic herring (Clupea harengus)

Journal: Journal of Marine Systems

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0924796311002557

Abstract: Studies have shown that exposure to Polycyclic Aromatic Hydrocarbons (PAHs) and other oil related components alter normal fish larvae development and can cause increased mortality in early life stages. Modelling of results from controlled laboratory exposure experiments will help relate typical oil exposure parameters (biomarkers) to field observations and are valuable tools for oil exposure monitoring and risk assessment. Post yolk sack larval stages of Atlantic herring were exposed to different concentrations of dispersed Arctic crude oil. The selected nominal concentrations were 0.015, 0.040, 0.060, 0.250 and 0.750 mg l(-1) raw dispersed oil (0.129, 0.373, 0.496, 2.486 and 6.019 mu g l(-1) Total Polycyclic Aromatic Hydrocarbons (TPAH) respectively), and control seawater in flow through systems. The larvae were exposed for 12 days and daily mortality recorded in all treatments. Thereafter, the larvae were transported to two large (3001) rearing tanks, one for control/trace oil and one for oil exposed larvae. The larvae were allowed to recover for 8 weeks after exposure, and mortality and morphological factors then assessed, giving preliminary information on recovery of Atlantic herring larvae after oil exposure. Throughout the testing period, there was a general trend for higher mortality of herring larvae in the oil exposure concentrations than in control, and significantly higher mortality was found in all oil concentrations than in the control after 12 days. We did not detect a clear dose related mortality for our test concentrations, except for the highest concentration. There was no difference found in mortality rates of the herring larvae from either the oil or control/trace oil batch during the recovery phase during the following 60 days. Morphological observations of the herring larvae after 2 months recovery in clean seawater showed that the oil exposed larvae had morphological features that could be described as deformities, and growth was found to be significantly impaired for the oil exposed group when compared to the control/trace oil group.

RefID: 352

Author: Irie, K., Kawaguchi, M., Mizuno, K., Song, J.Y., Nakayama, K., Kitamura, S. and Murakami, Y.

Year: 2011

Title: Effect of heavy oil on the development of the nervous system of floating and sinking teleost eggs

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X11002207

Abstract: Heavy oil (HO) on the sea surface penetrates into fish eggs and prevents the normal morphogenesis. To identify the toxicological effects of HO in the context of the egg types, we performed exposure experiments using floating eggs and sinking eggs. In the course of development, HO-exposed embryos of floating eggs showed abnormal morphology, whereas early larva of the sinking eggs had almost normal morphology. However, the developing peripheral nervous system of sinking eggs showed abnormal projections. These findings suggest that HO exposed fishes have problems in the developing neurons, although they have no morphological malformations. Through these observations, we conclude that HO is strongly toxic to floating eggs in the morphogenesis, and also affect the neuron development in both floating and sinking eggs.

RefID: 353

Author: Irvine, G.V., Mann, D.H. and Short, J.W.

Year: 1996

Title: Geomorphic position, weathering, and possible biotic impacts of oil mousse persisting on a high energy coastline distant from the Exxon Valdez spill

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/index.cfm?FA=searchResults.projectInfo&Project_ID=1498

Abstract: We describe the geomorphic settings and polynuclear aromatic hydrocarbon (PAH) alteration through time of Exxon Valdez oil stranded as mousse on the coastline of Katmai National Park and Preserve, 480-640 km from the site of the spill. At these distal sites, wave energy is higher and coastal geomorphology is fundamentally different from Prince William Sound. Oil has persisted on beaches with an armour of large lag boulders where it has weathered little since arriving five years ago, in 1989. Comparisons of mousse sampled in 1989, 1992, and 1994 indicate only negligible changes in polynuclear aromatic hydrocarbon (PAH) abundances for 22 of 25 samples collected. Five-year old oil strongly resembles 11-day old Exxon Valdez crude sampled after the spill. The slowness of chemical weathering of the oil is related to: 1) oil arriving in the form of mousse, and 2) the stranding of oil high in the intertidal zone under boulders where it is protected most from wave action, wind, and sunlight. Although, the biotic effects of oil persisting on the Katmai coast probably are slight, persistent oil still has the potential to affect biota if it is released through disturbance of the armoring substrate, e.g., through unusually high energy wave events.

RefID: 354

Author: Irvine, G.V., Mann, D.H. and Short, J.W.

Year: 2002

Title: Residual oiling of armored beaches and mussel beds in the Gulf of Alaska

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/53816623.pdf

Abstract: Stranded Exxon Valdez oil has persisted for 10 years at two types of sites in the Gulf of Alaska distant (up to 640 km) from the spill origin. Both mussel beds and boulder-armored beaches resampled in 1999 showed continuing oil contamination. Oil has persisted in both types of habitats due to armoring of substrates beneath the mussels and boulders. The oil contamination on the armored beaches is generally more extensive and shows less overt change in the last 4-5 years than that in the mussel beds. In both habitats, the weathering of the oil has been slower than originally expected. Especially striking is the general lack of weathering of stranded oil on armored beaches over the last 10 years. Oil at five of the six armored-beach sites 10 years after the spill is chemically equivalent to 11-day old Exxon Valdez oil. The formation of oil mousse allowed for long-distance transport of less-weathered oil. Long-term persistence of oil in these habitats should cause reconsideration of response activities after spills, and may influence the Ecological Sensitivity Indices applied to these habitats.

RefID: 355

Author: Irvine, G.V., Mann, D.H. and Short, J.W.

Year: 2007

Title: Monitoring lingering oil from the Exxon Valdez Spill in Gulf of Alaska armored beaches and mussel beds sixteen years post-spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/164438488.pdf

Abstract: Stranded Exxon Valdez oil has persisted for 16 years at boulder-armored beach sites along national park coastlines bordering the Gulf of Alaska. These sites are up to 640 km from the spill origin and were contaminated by oil mousse, a viscous water-in-oil emulsion. Although surface oil has continued to decline, subsurface oiling persists in patches. Especially striking is the general lack of weathering of stranded oil on armored beaches over the last 16 years. At three of the four sites where oil was sampled in 2005, the oil was compositionally similar to 11- day old Exxon Valdez oil, even after 16 years. The formation of mousse allowed less-weathered oil to be transported long distances. The sequestration of the oil beneath a boulder armor, coupled with the stability of the boulder armoring (investigated by examining movement of marked boulders), has contributed to the lengthy persistence of this stranded oil. Opportunistic sampling of several previously studied oiled mussel beds indicates continued contamination of at least one of the sites by not very weathered Exxon Valdez oil. Long-term persistence of oil in these habitats should cause reconsideration of response activities after spills, and may influence the Environmental Sensitivity Indices applied to these habitats.

RefID: 356

Author: Irvine, G.V., Mann, D.H. and Short, J.W.

Year: 1999

Title: Multi-year persistence of oil mousse on high energy beaches distant from the Exxon Valdez spill origin

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X98001155

Abstract: For at least 5 yr after the Exxon Valdez spill, relatively unweathered oil mousse has persisted on the exposed rocky shores of Shelikof Strait 500 km from Prince William Sound, Alaska. Previously it was thought that oil would be rapidly removed from such geomorphic settings by wave action. Oil mousse persists at sites in Katmai National Park and Preserve (NP&P) where it was stranded high in the intertidal zone under a lag of large boulders, These boulders armor the beach, preventing waves from disturbing the substrate and its included oil. Weathering of this stranded mousse has been slight mousse sampled in 1989, 1992 and 1994 show negligible changes in polynuclear aromatic hydrocarbons compared to 11-day old Exxon Valdez crude. The preservation of this oil is due to its transport as mousse bob whose interiors largely escape weathering, followed by its sheltering in the interstices of boulder-armored beaches. The transport of mousse may allow for the long distance dispersal of less weathered, and hence still toxic oil. Our findings suggest that the low ecological sensitivity ratings previously applied to exposed, rocky shorelines need to be modified. The biological threat posed by oil stranded on the Katmai NP&P coast probably is slight because of its small amount and sequestered state. However, it still possesses the ability to be chemically toxic and could be released through disturbance of the armoring boulders by unusually high wave events.

RefID: 357

Author: Jenssen, B.M.

Year: 1996

Title: An overview of exposure to, and effects of, petroleum oil and organochlorine pollution in Grey seals (Halichoerus grypus)

Journal: Science of The Total Environment

Hyperlink: http://www.sciencedirect.com/science/article/pii/0048969796050899

Abstract: Most incidences involving oil pollution of grey seals (Halichoerus grypus) seem to have occurred at the breeding sites. Because of the high concentration of animals at this time, even small oil spills will pollute many animals. As a result of chronic low-level pollution from coastal ship traffic and discharges from offshore petroleum activity in the North Sea, ∼ 50% of the grey seal pups at the largest breeding colony in Norway are polluted each year by oil. In this case, as well as in other similar cases of spills at breeding colonies, oil has produced little visible disturbance to the seals behaviour and there has been little mortality. The effects and mortality may, however, be more serious following a spill of crude oil, where animals may be affected by inhalation of toxic volatile compounds. High body burdens of PCBs and DDTs seem to have caused skull-bone lesions and occlusions of the uteri in grey seals in the Baltic Sea. Exposure to these persistent compounds has also been suspected to be the cause of reduction in the population of Baltic grey seals. There are indications that thyroid hormone and vitamin A status of grey seal pups are affected by the low exposure concentrations experienced at the Norwegian coast (∼ 120 of the concentration detected in grey seal pups from the Baltic Sea). This gives serious cause for concern about the effects that chronic low-level exposure to persistent organochlorine pollutants may have on individuals and on populations of grey seals.

RefID: 358

Author: Jewett, S.C. and Dean, T.A.

Year: 1997

Title: Effects of the Exxon Valdez oil spill on eelgrass communities in Prince William Sound, Alaska, 1990-95

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/41863126.pdf

Abstract: Injuries to the shallow subtidal eelgrass community were observed in the heavily oiled portions of Western Prince William Sound following the Exxon Valdez oil spill. In 1990, average concentrations of polynuclear aromatic hydrocarbons (PAH) exceeded 4,900 ng/g in shallow subtidal sediments adjacent to heavily oiled shorelines. Concentrations up to 23,000 ng/g were observed in individual samples. High PAH concentrations were associated with observed differences in communities at oiled vs. reference sites. Dominant taxa within the eelgrass community, including infaunal amphipods, infaunal bivalves, helmet crabs, and leather stars were less abundant at oiled than at reference sites in 1990. Other taxa, including several families of opportunistic or stress-tolerant infaunal polychaetes and gastropods, epifaunal polychaetes and mussels, and small cod, were more abundant at oiled sites. By 1995, there was apparent recovery of most community constituents. PAH concentrations declined to less than 230 ng/g, and fewer differences in taxa abundance existed between oiled and reference sites. However, not all taxa had recovered fully. Some evidence of slight hydrocarbon contamination still existed at some sites, and three infaunal bivalves, two amphipods, a crab, and a sea star were still more abundant at reference sites than at oiled sites.

RefID: 359

Author: Jewett, S.C., Dean, T.A. and Laur, D.R.

Year: 1996

Title: Effects of the Exxon Valdez Oil Spill on Benthic Invertebrates in an Oxygen-Deficient Embayment in Prince William Sound, Alaska

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: The possible impacts of the Exxon Valdez oil spill on the infaunal and epibenthic community within a heavily oiled fjordic embayment in western Prince William Sound, Alaska, were examined. Initial observations within this embayment in fall 1989 revealed numerous dead and dying organisms. The infauna within the embayment was represented by a relatively rich assemblage of 24 taxa. By fall 1990, the infaunal community was reduced to only six taxa and was dominated by a single polychaete species. The observations of dead organisms in 1989 and the decline of the benthic community between 1989 and 1990 were coincident with high concentrations of hydrocarbons in the sediments. By 1991, hydrocarbon concentrations were greatly reduced, very few dead organisms were observed, and the benthic community had recovered to include 32 taxa. These data suggest a possible adverse impact of oiling in 1989 and 1990, followed by recovery. However, sampling in fall 1993 again revealed a greatly impoverished community (four taxa), concomitant with low hydrocarbon concentrations in the sediment and depleted dissolved oxygen in the bottom waters. These data suggest that although the Exxon Valdez oil spill may have been, in part, responsible for the dead organisms and the impoverished infaunal community in the years subsequent to the spill, such reductions of benthic infauna can occur as a result of naturalhypoxia-anoxia.

RefID: 360

Author: Jewett, S.C., Dean, T.A., Smith, R.O. and Blanchard, A.

Year: 1999

Title: 'Exxon Valdez' oil spill: impacts and recovery in the soft-bottom benthic community in and adjacent to eelgrass beds

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v185/p59-83/

Abstract: We assessed impacts of the 'Exxon Valdez' oil spill on benthic communities within and adjacent to eelgrass beds in Prince William Sound, Alaska, USA. The concentration of total polynuclear aromatic hydrocarbons (TPAHs),'benthic community composition, diversity, biomass, and abundance were compared between matched pairs of oiled and reference sites in 1990 (approx. 16 mo after the spill), and in 1991, 1993, and 1995. TPAHs in sediments were high (up to 15 300 ng g(-1)) at sites adjacent to oiled shorelines in 1990, but declined sharply thereafter. Some reference sites in 1990-91 also had elevated TPAHs in sediments and signatures matching Exxon Valdez oil, but concentrations were significantly lower than at oiled sites. Based on classification and ordination analyses, communities of infauna and small epifauna at some oiled sites in 1990 differed from communities at reference sites, and from the same sites in subsequent years. Percent sand and mud and concentration of total chrysenes (PAH analytes indicative of crude oil) explained significant proportions of the temporal and spatial variation in benthic community structure. Total abundance and biomass of epifauna were generally higher at oiled sites, primarily because of higher densities of epifaunal bivalves. Otherwise, there were few consistent community-wide responses to oiling in diversity, richness, total abundance, total biomass, or the abundances of major taxonomic groups (e.g. polychaetes or bivalves). We attribute the lack of a stronger community-wide response to the varying sensitivities of constituent taxa to oil and organic enrichment. Over half of the dominant families differed with respect to abundance at oiled versus reference sites. Most, including 9 families of polychaetes, were more abundant at oiled sites. Most of these were stress-tolerant or opportunistic, and their increase was likely due to organic enrichment. Negative impacts were most evident in oil-sensitive amphipods, especially the families Isaeidae and Phoxocephalidae. There were consistently more of these amphipods at reference sites, and abundances at oiled sites were likely

reduced as a result of oil toxicity. Most of these differences between oiled and reference sites persisted through 1995, 6 yr after the spill. We suspect that these differences are a result of the spill, but we rely on post-spill comparisons to infer impacts, and our conclusions rely on the untestable assumption of equality between oiled and reference sites in the absence of a spill. Future assessments of the impacts of oil spills or other accidental environmental disturbances could benefit from pre-impact studies that provide objective criteria for selection of matched pairs of sites, thereby supporting the assumption of equality in the absence of the disturbance.

RefID: 361

Author: Jewett, S.C., Dean, T.A., Smith, R.O., Stekoll, M., Haldorson, L.J., Laur, D.R. and McDonald, L.

Year: 1995

Title: Effects of the Exxon Valdez oil spill on shallow subtidal communities in Prince William Sound, Alaska 1989-93

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/41842609.pdf

Abstract: Injuries to several of the dominant taxa in the nearshore subtidal community were observed in the heavily oiled portions of western Prince William Sound following the Exxon Valdez oil spill of March 1989. The initial effects were most pronounced in more protected eelgrass and silled fjord habitats, where PAH (polycyclic aromatic hydrocarbon) concentrations in sediments exceeded 1000 ng· g-1 in 1990. The taxa impacted most included eelgrass, infaunal amphipods, several infaunal mollusks, helmet crabs, and leather stars. All were more abundant at unoiled control sites than at oiled sites in 1990. Several opportunistic or stress-tolerant infaunal species, several of the dominant suspension-feeding epifaunal taxa, and several fish species that feed on these epifauna were more prevalent in oiled areas. By 1993, PAH concentrations in sediments declined to less than 100 ng· g-1, and there were far fewer differences between oiled and control sites with respect to the abundance of dominant plant, invertebrate, and fish taxa. However, not all taxa had recovered fully. Within eelgrass beds, there was still evidence of organic enrichment of sediments as indicated by greater infaunal abundance at oiled sites, and some large epibenthic invertebrates were still more abundant at control sites.

RefID: 362

Author: Jewett, S.C., Dean, T.A., Woodin, B.R., Hoberg, M.K. and Stegeman, J.J.

Year: 2002

Title: Exposure to hydrocarbons 10 years after the Exxon Valdez oil spill: evidence from cytochrome P4501A expression and biliary FACs in nearshore demersal fishes

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0141113602000934

Abstract: Three biomarkers of hydrocarbon exposure, CYP1A in liver vascular endothelium, liver ethoxyresorufin O-deethylase (EROD), and biliary fluorescent aromatic compounds (FACs), were examined in the nearshore fishes, masked greenling (Hexagrammos octogrammus) and crescent gunnel (Pholis laeta), collected in Prince William Sound, Alaska, 7–10 years after the Exxon Valdez oil spill (EVOS). All biomarkers were elevated in fish collected from sites originally oiled, in comparison to fish from unoiled sites. In 1998, endothelial CYP1A in masked greenling from sites that were heavily oiled in 1989 was significantly higher than in fish collected outside the spill trajectory. In 1999, fishes collected from sites adjacent to intertidal mussel beds containing lingering Exxon Valdez oil had elevated endothelial CYP1A and EROD, and high concentrations of biliary FACs. Fishes from sites near unoiled mussel beds, but within the original spill trajectory, also showed evidence of hydrocarbon exposure, although there were no correlations between sediment petroleum hydrocarbon and any of the biomarkers. Our data show that 10 years after the spill, nearshore fishes within the original spill zone were still exposed to residual EVOS hydrocarbons.

RefID: 363

Author: Jewett, S.C., Hoberg, M.K., Dean, T.A., Woodin, B.R. and Stegeman, J.J.

Year: 2003

Title: Exposure to hydrocarbons 10 years after the Exxon Valdez oil spill: evidence from cytochrome P4501A expression and biliary FACs in nearshore demersal fishes

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S014111360200291X

Abstract: Authors' response: Letter to the editor: refers to S0203

RefID: 364

Author: Jiang, X., Wang, G. and Lin, Q.

Year: 2008

Title: Reduction of hydrocarbon contamination on viability of Acartia pacifica benthic resting eggs

Journal: Chinese Journal of Oceanology and Limnology

Hyperlink: http://link.springer.com/article/10.1007%2Fs00343-008-0091-7

Abstract: The potential effect of hydrocarbon contamination on the hatching success of benthic resting eggs of Acartia pacifica in Xiamen Bay was investigated experimentally. The number of nauplii emerging from the sediment samples decreased with increasing Fuel Oil #0 concentration. The estimated rate of mortality increased markedly with the increase of Fuel Oil #0 concentration. Successive fuel Oil #0 concentrations from 50 mg/kg to 5000 mg/kg reduced the number of hatched nauplii by 3.8%-100%. The mortality of A. pacifica resting eggs due to Fuel Oil #0 contamination did not significantly increase as time progressed at each concentration level. The LC50 values of resting eggs, changing from 237.12 to 279.59 mg/kg, remained at an almost stable level in two months. The number of A. pacifica nauplii that hatched from the sediment at 10 degrees C was higher than those from the sediment at 30 degrees C, which indicates that the toxicity of Fuel Oil #0 on A. pacifica resting eggs increases with increasing temperature.

RefID: 365

Author: Jiang, Z., Huang, Y., Chen, Q., Zeng, J. and Xu, X.

Year: 2012

Title: Acute toxicity of crude oil water accommodated fraction on marine copepods: the relative importance of acclimatization temperature and body size

Journal: Marine environmental research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0141113612001420

Abstract: Recent oil spillage accidents around the world greatly increase harmful risks to marine ecology. This study evaluated the influences of petroleum water accommodated fraction (WAF) on 15 typical species of marine copepods collected from a subtropical bay in East China Sea at different seasons. Copepods showed impaired swimming ability, restlessness, loss of balance, anoxic coma, and even death when they were acutely exposed to the crude oil WAF under laboratory conditions. The LC50 values (expressed in total petroleum hydrocarbon concentration) indicated that the tolerances of copepods to WAF decreased significantly ($P < 0.05$) with increased exposure duration and natural water temperatures (acclimatization temperature). The sensitivity of the copepods was species-specific ($P < 0.01$), and there was a significant ($P < 0.05$) positive correlation between the 48-h LC50 and body size. Therefore, the small copepod species confront more survival challenges under oil contamination stress, especially in the warm months or regions. (C) 2012 Elsevier Ltd. All rights reserved.

RefID: 366

Author: Johnson, D.K. and Rustin, L.R.

Year: 2013

Title: Bibliography of Exxon Valdez Oil Spill Publications

Journal: Oil in the Environment: Legacies and Lessons of the Exxon Valdez Spill

Hyperlink: http://www.cambridge.org/ca/academic/subjects/life-sciences/natural-resource-management-agriculture-horticulture-and/oil-environment-legacies-and-lessons-exxon-valdez-oil-spill?format=AR

Abstract: A bibliography of 1718 citations of the Exxon Valdez oil spill. The included citations represent full-text documents of peer-reviewed research and dissertations for which citations are available through online indexing servies. As such, abstracts, poster presentations, and news articles were excluded. Due to practical constraints, the final and annual reports issued by the Exxon Valdez Oil Spill Trustee Council as well as most government and technical reports were excluded.

RefID: 367

Author: Johnson, S.W., Carls, M.G., Stone, R.P., Brodersen, C.C. and Rice, S.D.

Year: 1997

Title: Reproductive success of Pacific herring, Clupea pallasi, in Prince William Sound, Alaska, six years after the Exxon Valdez oil spill

Journal: Fishery Bulletin

Hyperlink: http://fishbull.noaa.gov/954/954toc.htm

Abstract: The Exxon Valdez oil spill occurred just prior to the spring migration of Pacific herring, Clupea pallasi, from offshore feeding grounds to nearshore spawning areas in Prince William Sound PWS), Alaska. Most or all of the life stages of herring in PWS may have been exposed to oil after the March 1989 spill. Delayed impacts from the spill were suspected as one possible cause in the unprecedented crash of the adult herring population in 1993 and stimulated studies to assess reproductive success. In spring 1995, mature herring were collected from four sites in PWS and from three uncontaminated sites in southeast Alaska (SE) to determine if reproductive impairment was evident in PWS herring six years after the spill. Herring were artificially spawned and their eggs were reared in a laboratory until hatching. Observed response parameters included fertilization success, hatching times, hatching success, as well as larval viability, swimming ability and spinal abnormalities. Responses of all year classes combined or those restricted to the same year class did not differ significantly between regions (P>0.50); the best and worst responses generally occurred in the SE. Within each site, response of the 1989 year class (most likely impacted by the oil spill in PWS) generally did not differ significantly from any other year class. To verify macroscopic observations, a subset of larvae from the 1989 year class was also inspected microscopically for yolk and pericardial abnormalities, and yolk volume was measured-but no significant regional differences were observed for any of these morphological categories. Based on the parameters examined in this study, evidence of reproductive impairment of Pacific herring in PWS by the spill was not detected in 1995, and the chances of detecting any oil-related effects against natural background variation appeared to be negligible.

RefID: 368

Author: Jones, D., Scarlett, A.G., West, C.E. and Rowland, S.J.

Year: 2011

Title: Toxicity of Individual Naphthenic Acids to Vibrio fischeri

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es201948j

Abstract: Numerous studies have suggested that the toxicity of organic compounds containing at least one carboxylic acid group and broadly classified as "naphthenic acids", is of environmental concern. For example, the acute toxicity of the more than 1 billion m(3) of oil sands process-affected water and the hormonal activity of some offshore produced waters has been attributed to the acids. However, experimental evidence for the toxicity of the individual acids causing these effects has not been very forthcoming. Instead, most data have been gathered from assays of incompletely characterized extracts of the water, which may contain other toxic constituents. An alternative approach is to assay the individual identified toxicants. Since numerous petroleum-derived naphthenic acids and some in oil sands process water, have recently been identified, we were able to measure the toxicity of some individual acids to the bioluminescent bacterium, Vibrio fischeri. Thirty-five pure individual acids were either synthesized or purchased for this purpose. We also used the US EPA ECOSAR computer model to predict the toxicity of each acid to the water flea, Daphnia magna. Both are well-accepted toxicological screening end points. The results show how toxic some of the naphthenic acids really are (e.g., V. fischeri Effective Concentrations for 50% response (EC(50)) 0.004 to 0.7 mM) and reveal the influence of hydrophobicity and aqueous solubility on the toxicities. Comparison with measured toxicities of other known, but more minor, constituents of oil sands process water, such as polycyclic aromatic hydrocarbons and alkylphenols, helps place these toxicities into a wider context. Given the reported toxicological effects of naphthenic acids to other organisms (e.g., fish, plants), the toxicities of the acids to further end points should now be determined.

RefID: 369

Author: Jonker, M.T.O., Brils, J.M., Sinke, A.J.C., Murk, A.J. and Koelmans, A.A.

Year: 2006

Title: Weathering and toxicity of marine sediments contaminated with oils and polycyclic aromatic hydrocarbons

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/05-296R.1/abstract

Abstract: Many sediments are contaminated with mixtures of oil residues and polycyclic aromatic hydrocarbons (PAHs), but little is known about the toxicity of such mixtures to sediment-dwelling organisms and the change in toxicity on weathering. In the present study, we investigated the effects of a seminatural, two-year weathering period on PAH/oil chemistry and toxicity in a marine sediment that had been spiked with three different oils (a gas oil, a lubricating oil, and a crude oil; all tested at five concentrations). Toxicity of bioavailable, pore water-accommodated oil/PAH fractions was quantified using a bacterial (Vibrio fischeri) assay and the in vitro chemical-activated luciferase expression assay (DR-CALUX; using conditions to detect PAHs). Results of chemical analyses pointed to (microbial) degradation of all three oils: Sediment oxygen demand during weathering increased with increasing oil concentration, total oil concentrations decreased to between 17 and 29% of initial levels, and resolved n-alkanes were depleted in weathered oil fractions. Furthermore, a shift in the relative importance of different boiling-point fraction ranges of the oils was observed on weathering. Generally, the lowest fraction range (C-10-C-16) disappeared, whereas the relative proportion of the highest (C-28-C-40) fraction range increased considerably. Remarkably, for the gas oil, this fraction shift was dependent on the oil concentration in sediment. Similarly, degradation of PAHs was strongly affected by the sedimentary oil content, indicating that the presence of oil stimulated PAH degradation. This phenomenon applied to both low- and high-molecular-weight PAHs, although the first group (3- and 4-ring PAHs) was degraded most. Results from the V. fischeri and DR-CALUX assay showed that in most cases, pore-water toxicity decreased on weathering. Combining the assay responses with chemical data indicated that the observed toxicity probably was not caused by the analyzed PAHs but, rather, by specific oil constituents instead.

RefID: 370

Author: Jung, J.H., Yim, U.H., Han, G.M. and Shim, W.J.

Year: 2009

Title: Biochemical changes in rockfish, Sebasres schlegeli, exposed to dispersed crude oil

Journal: Comparative Biochemistry and Physiology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S1532045609000933

Abstract: This paper describes the response of the ovoviviparous rockfish, Sebastes schlegeli, to hydrocarbons in the water-accommodated fraction (WAF) of crude oil, in the presence or absence of oil dispersants. Concentrations of cytochrome P-450 1A (CYP1A) and levels of its catalytic activity ethoxyresorufin O-deethylase (EROD) in rockfish exposed to WAF at concentrations of 0.1% and 1% were significantly increased by the addition of a dispersant, Corexit 9500 after 48 h exposure. After 72 h exposure, the levels of CYP1A and EROD activity were significantly increased in 0.1% and 0.01% chemically enhanced WAF (CEWAF) (Corexit 9500 and Hiclean II dispersant). Bile samples from fish exposed to WAF alone had low concentrations of hydrocarbon metabolites, exemplified by 1-hydroxypyrene. After 72 h exposure, hydrocarbon metabolites in bile from fish exposed to WAF in the presence of either Corexit 9500 or Hiclean II were significantly higher compared with fish exposed to WAF alone or control fish. These experiments confirm that the use of oil dispersants will increase the exposure of ovoviviparous fish to hydrocarbons in oil. (C) 2009 Elsevier Inc. All rights reserved.

RefID: 371

Author: Karydis, M.

Year: 1981

Title: THE TOXICITY OF CRUDE-OIL FOR THE MARINE ALGA SKELETONEMA-COSTATUM (GREVILLE) CLEVE IN RELATION TO NUTRIENT LIMITATION

Journal: Hydrobiologia

Hyperlink: http://link.springer.com/article/10.1007%2FBF00006623

Abstract: The toxicity of crude oil in relation to nutrient limitation was studied in Skeletonema costatum cultures. The addition of 100 mg/l of crude oil, although slightly toxic for the algae grown in complete media, was eventually lethal for the algae growing in phosphorus and nitrogen limited media, indicating the importance of those two nutrients for the algal resistance to oil pollution problems. Less severe effects of crude oil were observed in the silicon limited media, suggesting that the adsorptive properties of silica play an important role in the uptake and intracellular distribution of hydrocarbons. Chl a and carbon uptake were found to be more sensitive parameters for assessing hydrocarbon toxicity than cell counting.

RefID: 372

Author: Kauss, P., Hutchinson, T.C., Soto, C., Hellebust, J. and Griffiths, M.

Year: 1973

Title: The Toxicity of Crude Oil and its Components to Freshwater Algae

Journal: International Oil Spill Conference Proceedings

Hyperlink: http://ioscproceedings.org/doi/abs/10.7901/2169-3358-1973-1-703

Abstract: ABSTRACT Field and laboratory experiments have been conducted to determine the toxicity of crude oil to freshwater algae. In the field, experiments were continued for a two year period and changes in the abundance and species composition of phytoplankton tabulated. Species were found to differ markedly in their response to an oil spill varying from considerable suppression of growth to stimulation. In the laboratory, the effects of aqueous extracts of seven crude oils on a selected test species, Chlorella vulgaris, were determined. Marked differences in toxicity, as indicated by reduced growth, were found to exist between oils. Work with oil extracts of different ages suggests that the short-term toxicity of oils is due to the rapid loss of volatile compounds. Differences in the toxicity of selected aromatic components of crude oils benzene, toluene, o-xylene and naphthalene were observed and are believed to relate to an increase in methylation. Aqueous crude oil and naphthalene depressed the 14C-NaHC03 uptake (i.e. photosynthesis) of Chlamydomonas angulosa. 14C-naphthalene was rapidly taken up by Chlamydomonas cells. However, release of this compound was much slower, and, in unwashed cells, seemingly dependent upon cell division. Possible mechanisms of crude oil toxicity are discussed.

RefID: 373

Author: Kavanagh, R.J., Frank, R.A., Oakes, K.D., Servos, M.R., Young, R.F., Fedorak, P.M., MacKinnon, M.D., Solomon, K.R., Dixon, D.G. and Van Der Kraak, G.

Year: 2011

Title: Fathead minnow (Pimephales promelas) reproduction is impaired in aged oil sands process-affected waters

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X10004042

Abstract: Large volumes of fluid tailings are generated during the extraction of bitumen from oil sands. As part of their reclamation plan, oil sands operators in Alberta propose to transfer these fluid tailings to end pit lakes and, over time, these are expected to develop lake habitats with productive capabilities comparable to natural lakes in the region. This study evaluates the potential impact of various oil sands process-affected waters (OSPW) on the reproduction of adult fathead minnow (Pimephales promelas) under laboratory conditions. Two separate assays with aged OPSW (>15 years) from the experimental ponds at Syncrude Canada Ltd. showed that water containing high concentrations of naphthenic acids (NAs; >25 mg/l) and elevated conductivity (>2000 mu S/cm) completely inhibited spawning of fathead minnows and reduced male secondary sexual characteristics. Measurement of plasma sex steroid levels showed that male fathead minnows had lower concentrations of testosterone and 11-ketotestosterone whereas females had lower concentrations of 17 beta-estradiol. In a third assay, fathead minnows were first acclimated to the higher salinity conditions typical of OSPW for several weeks and then exposed to aged OSPW from Suncor Energy Inc. (NAs similar to 40 mg/l and conductivity similar to 2000 mu S/cm). Spawning was significantly reduced in fathead minnows held in this effluent and male fathead minnows had lower concentrations of testosterone and 11-ketotestosterone. Collectively, these studies demonstrate that aged OSPW has the potential to negatively affect the reproductive physiology of fathead minnows and suggest that aquatic habitats with high NAs concentrations (>25 mg/l) and conductivities (>2000 mu S/cm) would not be conducive for successful fish reproduction. (C) 2010 Elsevier B.V. All rights reserved.

RefID: 374

Author: Kawaguchi, M., Song, J.Y., Irie, K., Murakami, Y., Nakayama, K. and Kitamura, S.

Year: 2011

Title: Disruption of Sema3A expression causes abnormal neural projection in heavy oil exposed Japanese flounder larvae

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X11000269

Abstract: It has been well known that oil spills cause serious problems in the aquatic organisms. In particular, some species of teleosts, which develop on the sea surface thought to be affected by heavy oil (HO). During the embryogenesis, the nervous system is constructed. Therefore, it is important to study the toxicological effects of HO on the developing neurons. We exposed HO to eggs of Japanese flounder (Paralichthys olivaceus) and investigated the neural disorder. In larvae exposed by HO at the concentration of 8.75 mg/L, the facial and lateral line nerves partially entered into the incorrect region and the bundle was defasciculated. Furthermore, in the HO-exposed larvae, Sema3A, a kind of axon guidance molecule, was broadly expressed in second pharyngeal arch, a target region of facial nerve. Taken together, we suggested the possibility that the abnormal expression of Sema3A affected by HO exposure causes disruption of facial nerve scaffolding. (C) 2011 Elsevier Ltd. All rights reserved.

RefID: 375

Author: Kawaguchi, M., Sugahara, Y., Watanabe, T., Irie, K., Ishida, M., Kurokawa, D., Kitamura, S., Takata, H., Handoh, I.C., Nakayama, K. and Murakami, Y.

Year: 2012

Title: Nervous system disruption and concomitant behavioral abnormality in early hatched pufferfish larvae exposed to heavy oil

Journal: Environmental Science and Pollution Research

Hyperlink: http://link.springer.com/article/10.1007%2Fs11356-012-0833-0

Abstract: Spills of heavy oil (HO) over the oceans have been proven to have an adverse effect on marine life. It has been hypothesized that exposure of early larvae of sinking eggs to HO leads largely to normal morphology, whereas abnormal organization of the developing neural scaffold is likely to be found. HO-induced disruption of the nervous system, which controls animal behavior, may in turn cause abnormalities in the swimming behavior of hatched larvae. To clarify the toxicological effects of HO, we performed exposure experiments and morphological and behavioral analyses in pufferfish (Takifugu rubripes) larvae. Fertilized eggs of pufferfish were exposed to 50 mg/L of HO for 8 days and transferred to fresh seawater before hatching. The hatched larvae were observed for their swimming behavior, morphological appearance, and construction of muscles and nervous system. In HO-exposed larvae, we did not detect any anomaly of body morphology. However, they showed an abnormal swimming pattern and disorganized midbrain, a higher center controlling movement. Our results suggest that HO-exposed fishes suffer developmental disorder of the brain that triggers an abnormal swimming behavior and that HO may be selectively toxic to the brain and cause physical disability throughout the life span of these fishes.

RefID: 376

Author: Kazlauskienė, N. and Taujanskis, E.

Year: 2011

Title: Effects of Crude Oil and Oil Cleaner Mixture on Rainbow Trout in Early Ontogenesis

Journal: Polish Journal of Environmental Studies

Hyperlink: http://www.pjoes.com/abstracts/2011/Vol20/No02/34.html

Abstract: The aim of our study was to investigate acute and chronic effects of the oil cleaner Simple Green (SG), crude oil (oil), crude oil and SG mixture (oil-SG) on rainbow trout (Oncorhynchus mykiss) in early development stages (embryos, larvae). The acute effects of SG, oil, and oil-SG mixture on rainbow trout embryos and larvae were investigated. The 96-hour LC(50) values for embryos/larvae were: SG - 1,270/1,040; oil - 39,280/21,610; and oil-SG - 24,430/14,040 mg/l. Larvae were more sensitive for these toxicants than embryos. The chronic effect of oil-SG mixture on rainbow trout in early stages of development showed that the mixture slightly increased the mortality of embryos, and influenced more the mortality of larvae. The mortality of larvae depends on the duration of exposure and oil concentration in the mixture. Comparative studies on the acute and chronic effects of oil and the oil-SG mixture on rainbow trout in early stages of development showed that the mixture has a more toxic effect on embryos and larvae than oil alone.

RefID: 377

Author: Kazlauskienė, N., Svecevičius, G., Petrauskienė, L. and Vosylienė, M.Z.

Year: 2010

Title: Behavioural Responses of Medicinal Leech and Rainbow Trout Exposed to Crude Oil and Heavy Fuel Oil in Ontogenesis

Journal: Polish Journal of Environmental Studies

Hyperlink: http://www.pjoes.com/abstracts/2010/Vol19/No02/22.html

Abstract: Our study investigated the behavioural responses of medicinal leech and rainbow trout at different ontogenetic levels under the effect of crude oil (CO) and heavy fuel oil (HFO), performed comparative analysis of the sensitivity of animal responses, evaluated the specificity of these responses, and determined "safe" toxicant concentrations. Comparison of sensitivity of behavioural responses of leech and fish revealed that the most sensitive response to long-term exposure to CO was leech locomotor activity, while the most sensitive parameter to HFO was the coughing rate in juvenile fish. Our study showed that the sensitivity and specificity of behavioural responses of aquatic animals at different phylogenetic and ontogenetic levels can be successfully used to evaluate the toxicity of ambient water polluted with oil hydrocarbons.

RefID: 378

Author: Kazlauskienė, N., Svecevicius, G., Vosylienė, M.Z., Marciulionienė, D. and Montvydienė, D.

Year: 2004

Title: Comparative study on sensitivity of higher plants and fish to heavy fuel oil

Journal: Environmental Toxicology

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/tox.20048/abstract

Abstract: Laboratory tests were conducted on higher plants [garden cress (Lepidium sativum), great duckweed (Spirodela polyrrhiza), and Tradescantia clone BNL 02] and fish [rainbow trout (Oncorhynchus mykiss) at all stages of development: eggs, larvae and adults] to estimate their sensitivity to heavy fuel oil (HFO). A number of biological indices (survival, growth, and physiological and morphological parameters) as well as the genotoxic impact (Tradescantia) of HFO was evaluated by acute and chronic toxicity tests. Fish were found to be more sensitive to the toxic effect of HFO than were higher plants. EC50 values obtained for higher plants ranged from 8.7 g/L (L. sativum) to 19.8 g/L (Tradescantia), and maximum-acceptable-toxicant concentration (MATC) values ranged from 0.1 to 1.0 g/L of total HFO for L. sativum and Tradescantia, respectively. The 96-h LC50 values ranged from 0.33 g/L, for larvae, to 2.97 g/L, for adult fish, and the MATC value for fish was found to be equal to 0.0042 g/L of total HFO. To evaluate and predict the ecological risk of the overall effects of oil spills, studies should be performed using a set of acute and chronic bioassays that include test species of different phylogenetic levels with the most sensitive morphological, physiological, and genotoxic indices. (C) 2004 Wiley Periodicals, Inc.

RefID: 379

Author: Kennedy, C.J.

Year: 2014

Title: Multiple Effects of Oil and Its Components in Fish

Journal: Impacts of Oil Spill Disasters on Marine Habitats and Fisheries in North America

Hyperlink:

Abstract: The effects of oil pollution on fisheries have been of concern for decades, mainly the visible impacts of large-scale oil spills into freshwater and marine environments. concern is not misplaced, but equal or greater impacts on fish may occur from the persistent contamination of water bodies through the use of petroleum products. Each of these exposure scenarios can result in very different effects, of both a short- and long-term nature. The evaluation of ecological risks from exposure to chemical mixtures such as petroleum presents one of the most difficult challenges of our time for toxicological research and risk assessment for two reasons. First exposure to petroleum mixtures occur across multimedia environments (sediment, water, and air) and capturing relevant and realistic exposure concentrations is difficult. Second, petroleum is an inconsistent and complex chemical mixture that changes with time in the environment. Because of this, two evaluation and research approaches for such mixtures are usually followed: (1) evaluation of complex mixtures as though they are single entities and (2) a component-based approach in which certain individual chemicals in a mixture are considered to estimate the toxicity of the mixture. This chapter takes both approaches and provides a comprehensive overview to understanding the toxicity of oil and its individual components to fish.

RefID: 380

Author: Kennedy, C.J. and Farrell, A.P.

Year: 2005

Title: Ion homeostasis and interrenal stress responses in juvenile Pacific herring, Clupea pallasi, exposed to the water-soluble fraction of crude oil

Journal: Journal of Experimental Marine Biology and Ecology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0022098105001553

Abstract: Juvenile Pacific herring, Clupea pallasi, were exposed both acutely (96 h) and chronically (9 weeks) to three concentrations of the water-soluble fraction (WSF) of North Slope crude oil. Mean (+/- S.E.) total PAH (TPAH) concentrations at the beginning of the acute exposure experiment were: 9.7 +/- 6.5, 37.9 +/- 8.6 and 99.3 +/- 5.6 mu g/L. TPAH concentrations declined with time and the composition of the WSF shifted toward larger and more substituted PAHs. Significant induction of hepatic cytochrome P450 content, ethoxyresorufm O-deethylase and glutathione-S-transferase activities in WSF-exposed fish indicated that hydrocarbons were biologically available to herring. Significant but temporary, elevations in plasma cortisol (4.9-fold and 8.5-fold increase over controls in the 40 and 100 mu g/L groups, respectively), lactate (2.2-fold and 3. 1 -fold over controls in the 40 and 100 mu g/L groups) and glucose (1.3-fold, 1.4-fold and 1.6-fold over controls in the 10, 40 and 100 mu g/L groups) occurred in fish exposed acutely to WSF. All values returned to baseline levels by 96 h. Similar responses were seen with the first of several sequential WSF pulses in the chronic exposure study. Subsequent WSF pulses resulted in muted cortisol responses and fewer significant elevations in both plasma lactate and glucose concentrations. Hematocrit, leucocrit, hemoglobin concentration and liver glycogen content were not affected by acute or chronic WSF exposure. Plasma [Cl-], [Na+] and [K+] were significantly higher in the 100 mu g/L WSF-exposed group by 96 h compared to control fish, and continued to be elevated through the entire chronic exposure period. Unlike the measured stress parameters, ionoregulatory dysfunction was not modulated by WSF pulses. The results of this study suggest that chronic exposure to WSF affects at least two important physiological systems in herring: the ability of fish to maintain ion homeostasis and the interrenally-mediated organismal stress response. (c) 2005 Elsevier B.V. All rights reserved.

RefID: 381

Author: Kennedy, C.J. and Farrell, A.P.

Year: 2006

Title: Effects of exposure to the water-soluble fraction of crude oil on the swimming performance and the metabolic and ionic recovery postexercise in pacific herring (Clupea pallasi)

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/05-504R.1/abstract

Abstract: The swimming performance and recovery from exercise were determined in juvenile Pacific herring (Clupea pallasi) following exposure to the water-soluble fraction (WSF) of North Slope crude oil for more than eight weeks. Total polycyclic aromatic hydrocarbon concentrations (mean +/- standard error) at the beginning of exposures were as follows: control, 0.2 +/- 0.1 mu g/L; low, 9.6 +/- 2.5 mu g/L; medium, 40.7 +/- 6.9 mu g/L; and high, 120.2 +/- 11.4 mu g/L. Biological availability of hydrocarbons was confirmed by a significant induction of hepatic cytochrome P450 content and ethoxyresorufin-O-deethylase activity. Critical swimming speed (Ucrit) was significantly reduced in fish exposed to the highest concentration of WSF for 96 h (11% +/- 3.7% reduction) and at the two highest concentrations at four weeks (16% +/- 3.6% and 29% +/- 5.4% reductions) and eight weeks (11% +/- 3.8% and 40% +/- 5.7% reductions). Mortality occurred in all groups 24 h following Ucrit swim trials, with significantly higher mortalities observed in fish exposed to WSF in a concentration- and time-dependent manner (maximum mortality of 72.2% +/- 5.5% in the eight-week, high-exposure group). Burst swimming alone resulted in increased plasma cortisol, lactate, Na+, and Cl- concentrations and decreased muscle glycogen levels that returned to baseline values by 24 h. An interpretation of the effect of WSF exposure on postexercise metabolic recovery was complicated by pre-exercise alterations in several parameters. The time courses and magnitudes of several key postexercise parameters, including plasma cortisol, lactate, and muscle glycogen, were significantly altered by exposure to WSF. The present study clearly shows that hydrocarbon exposure can reduce the swimming ability of fish and their ability to recover from exhaustive exercise.

RefID: 382

Author: Kennedy, C.J. and Farrell, A.P.

Year: 2008

Title: Immunological alterations in juvenile Pacific herring, Clupea pallasi, exposed to aqueous hydrocarbons derived from crude oil

Journal: Environmental Pollution

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0269749107004551

Abstract: The effects of acute and subchronic aqueous hydrocarbon exposures in the ppb range (0.2-127 mu g/L total PAH) on the immune system in Pacific herring (Clupea pallasi) were examined through specific immunocompetency assays and a host resistance model using Listonella anguillarum. Short-term hydrocarbon exposure at the highest concentration significantly enhanced respiratory burst activity (RBA) in macrophages and decreased plasma lysozyme concentrations, however, subchronic exposure (4-57 d) reduced RBA. Fish in the high exposure group were also less susceptible to the pathogen L. anguillarum following acute hydrocarbon exposure; however, this group was the most susceptible following subchronic exposures. These results are explained by a measured transient physiological stress response and long-term effects on ionoregulation. This study illustrates that hydrocarbon-elicited effects are dynamic and that toxic outcomes with respect to the teleost immune system depend on chemical concentrations and composition, exposure durations and the specific pathogen challenge. (C) 2007 Elsevier Ltd. All rights reserved.

RefID: 383

Author: Khan, N., Warith, M.A. and Luk, G.

Year: 2007

Title: A comparison of acute toxicity of biodiesel, biodiesel blends, and diesel on aquatic organisms

Journal: Journal of the Air & Waste Management Association

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/17385594

Abstract: The increased demand of alternative energy sources has created interest in biodiesel and biodiesel blends; biodiesel is promoted as a diesel substitute that is safer, produces less harmful combustion emissions, and biodegrades more easily. Like diesel spills, biodiesel can have deleterious effects on the aquatic environments. The effect of neat biodiesel, biodiesel blends, and diesel on Oncorhynchus mykiss and Daphnia magna was evaluated using acute toxicity testing. Static nonrenewal bioassays of freshwater organisms containing B100, B50, B20, B5, and conventional diesel fuel were used to compare the acute effects of biodiesel to diesel. Mortality was the significant end point measured in this study; percent mortality and lethal concentration (LC50) at different exposure times were determined from the acute toxicity tests performed. Trials were considered valid if the controls exhibited > 90% survival. Based on percentage of mortality and LC50 values, a toxicity ranking of fuels was developed.

RefID: 384

Author: Khan, R.A.

Year: 1990

Title: PARASITISM IN MARINE FISH AFTER CHRONIC EXPOSURE TO PETROLEUM-HYDROCARBONS IN THE LABORATORY AND TO THE EXXON VALDEZ OIL-SPILL

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2FBF01701799

Abstract: Crude oil or its water soluble components are known to induce histopathological effects in fish following chronic exposure (McCain et al. 1978; Solangi and Overstreet 1982; Haensly et al. 1982; Khan and Kiceniuk 1984). Fish tend to harbour a variety of parasites, most of which under natural conditions cause little or no apparent harm. However, after chronic exposure to petroleum hydrocarbons, the prevalence and intensity of parasitism increases substantially (Skinner 1982; Khan 1987; Khan and Kiceniuk 1988),. Trichodinid ciliates are mainly ectoparasitic protozoans on the gills of fish. Since a previous study showed that chronic exposure to crude oil fractions resulted in increased parasitism (Khan and Kiceniuk 1988), a study owas initiated to ascertain the relationship between trichodinid infections and exposure of fish to crude oil or its fractions in the laboratory and subsequently, in the Gulf of Alaska following the

Exxon Valdez oil spill.

RefID: 385

Author: Khan, R.A.

Year: 1991

Title: EFFECT OF OIL-CONTAMINATED SEDIMENT ON THE LONGHORN SCULPIN (MYOXOCEPHALUS-OCTODECEMSPINOSUS) FOLLOWING CHRONIC EXPOSURE

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2FBF01689454

Abstract: One of the most common pollutants in coastal marine areas is petroleum that is discharged conntinually from bilges and tankers. Fish which inhabit the littoral zone are usually exposed to a variety of pollutants, including petroleum, that originate from urban and industrial waste. The longhorn sculpin, Muoxocephalus octodecemspinosus, is one of the fish species that inhabits littoral areas adjacent to wharves and fish processing plants where it feeds on discarded offal (Scott and Scott 1988). Discharged crude oil has been reported to contaminate and persisit in sediment for long periods and is known to affect fish in a variety of ways (Connell and Miller 1981). A previous study noted that chronic exposure to water-soluble fractions of crude oil produced minor effects in the longhorn sculpin (Kiceniuk et al. 1982). The present study was conducted to ascertain the effect of oil-contaminated sediment, following long-term exposure, on body weight, organs, tissues and parasitofauna of the sculpin and the potential use of its parasites as indicators of pollution.

RefID: 386

Author: Khan, R.A. and Nag, K.

Year: 1993

Title: ESTIMATION OF HEMOSIDEROSIS IN SEABIRDS AND FISH EXPOSED TO PETROLEUM

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007/BF00196550

Abstract: Many seabirds die each year after exposure to petroleum hydrocarbons (Piatt and Lensink 1990; Khan and Ryan 1991). Crude oil, following ingestion, induces hemolytic anemia which occurs 4 to 5 d later (Leighton et al. 1983). A recent study reported the presence of hemosiderin in hte liver of common murres (Uria aalge) at intervals up to 42 d after oil-contamination (Khan and Ryan 1991). Hemosiderosis has also been reported in plaice, Pleuronectes platessa, following the Amoco Cadiz oil spill off the coast of France (Haensly et al. 1982) and after experimental exposure of Atlantic cod, Gadus morhua, and longhorn sculpin, Myoxocephalus octodecemspinosus, to petroleum (Khan and Kiceniuk 1984; Khan 1991).

RefID: 387

Author: Khan, R.A. and Payne, J.F.

Year: 2005

Title: Influence of a crude oil dispersant, corexit 9527, and dispersed oil on capelin (Mallotus villosus), Atlantic cod (Gadus morhua), longhorn sculpin (Myoxocephalus octodecemspinosus), and cunner (Tautogolabrus adspersus)

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs00128-005-0717-9?LI=true

Abstract: na

RefID: 388

Author: Kim, H.N., Park, C., Chae, Y.S., Shim, W.J., Kim, M., Addison, R.F.,and Jung, J.H.

Year: 2013

Title: Acute toxic responses of the rockfish (Sebastes schlegeli) to Iranian heavy crude oil: Feeding disrupts the biotransformation and innate immune systems

Journal: Fish & Shellfish Immunology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S1050464813005433

Abstract: To clarify the toxic effects of Iranian Heavy Crude Oil (IHCO) from the "Hebei spirit" oil spill, innate immune. toxic effects defending on biotransformation pathway have been investigated on fish exposed to IHCO. Juvenile rockfish were exposed to IHCO in gelatin capsules by feeding. The effects on multiple fish biotransformation enzymes (Cytochrome P4501A and glutathione-S-transferase) and the expression level of the several immune response genes, including interleukin-1beta, granulocyte colony-stimulating factor and Cathepsin L, were measured in the liver, spleen and kidney. The tissue-specific expression patterns of these genes demonstrated that the highest expression levels of Cytochrome P4501A, glutathione-S-transferase, interleukin-1beta, granulocyte colony-stimulating factor, interferon stimulated gene 15 and Cathepsin L were found in the liver and that the TNF receptor was high in spleen. The oil-fed fish had significantly higher concentrations of biliary fluorescent metabolites and Cytochrome P4501A expression during the initial stage (12 similar to 48 h after exposure) than those in the liver and kidney of the sham group. Similarly, the highest mRNA expression levels of interleukin-1beta and granulocyte colony-stimulating factor were detected in the liver at the early stages of exposure (12 h after exposure). Following exposure, the levels of interferon stimulated gene 15 and granulocyte colony-stimulating factor mRNA remained high at 120 h after exposure in the liver but the levels of interleukin-1beta and Cathepsin L gradually decreased to an expression level equal to or less than the sham group. Our data suggest that the innate immune and hepatodetoxification responses in oil-fed fish were induced at the initial stage of exposure to the IHCO at the same time but several immune-related genes decreased to less than that of the sham group after the initial stage of response. Therefore, immune disturbances in fish exposed to IHCO may allow the pathogens, including the infectious diseases, to more easily affect the oil exposed fish. (C) 2013 Elsevier Ltd. All rights reserved.

RefID: 389

Author: King, T.L., Robinson, B., Boufadel, M. and Lee, K.

Year: 2014

Title: Flume tank studies to elucidate the fate and behavior of diluted bitumen spilled at sea

Journal: Marine pollution bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X14002689

Abstract: An economical alternative to conventional crudes, Canadian bitumen, harvested as a semi-liquid, is diluted with condensate to make it viable to transport by pipeline to coastal areas where it would be shipped by tankers to global markets. Not much is known about the fate of diluted bitumen (dilbit) when spilled at sea. For this purpose, we conducted dilbit (Access Western Blend; AWB and Cold Lake Blend; CLB) weathering studies for 13 days in a flume tank containing seawater. After six days of weathering, droplets detached from the AWB slick and were dense enough to sink in seawater. The density of CLB also increased, but at a slower rate compared to AWB, which was attributed to the high concentration of alkylated polycyclic aromatic hydrocarbons in it, which are more resistant to weathering. An empirical, Monod-type model was introduced and was found to closely simulate the increase in oil density with time. Such a model could be used within oil spill models.; acents Does diluted bitumen (dilbit) sink or float when spilled at sea? acents The chemical composition of dilbit products affects how they naturally weather. After 7days, Access Western Blend submerged in seawater. Mono-type model closely simulated the increase in oil density with time.

RefID: 390

Author: Knag, A.C., Sebire, M., Mayer, I., Meier, S., Renner, P. and Katsiadaki, I.

Year: 2013

Title: In vivo endocrine effects of naphthenic acids in fish

Journal: Chemosphere

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0045653513011491

Abstract: Oil pollution from various sources, including exploration, production and transportation, is a growing global concern. The-highest toxicity of hydrocarbon pollutants is associated with the water-soluble phase compounds, including naphthenic acids, a known component found in all hydrocarbon deposits. Recently, naphthenic acids (NAs) have shown estrogenic and anti-androgenic effects in vitro. For this reason we investigated the potential effects of two commercial mixtures of naphthenic acids on fish in vivo, using the three-spined stickleback (Gasterosteus aculeatus) as a model species. Anti-androgenic and estrogenic properties of tested compounds were evaluated using the androgenized female stickleback screen (AFSS) and a variant of the 21-d fish screen (TG230) respectively. One-dimensional gas chromatography-mass spectrometry (GC-MS) showed that the complex commercial NAs mixtures were dominated by acyclic carboxylic acids. In one experiment (freshwater) we found a clear effect of NA exposure on spiggin levels; this was contrary to our hypothesis since NAs enhanced the androgenic potency of DHT (when co-administered) without inducing spiggin when tested in the absence of DHT. Exposure to NAs did not have a statistically significant effect on vitellogenin (Vtg) production in male stickleback, although the Vtg responses were increasing with increasing exposure concentrations. This study shows that in contrast to previous in vitro data, NAs did not exhibit either estrogenic or anti-androgenic properties in vivo, at the concentrations tested. On the contrary, at least in freshwater, NAs appear to have an overall androgenic effect that is not mediated via the androgen receptor involved in spiggin synthesis. Possible reasons for this discrepancy between in vitro and in vivo results as well as between our studies are discussed. (C) 2013 Elsevier Ltd. All rights reserved.

RefID: 391

Author: Ko, J.Y. and Day, J.W.

Year: 2004

Title: A review of ecological impacts of oil and gas development on coastal ecosystems in the Mississippi Delta

Journal: Ocean & Coastal Management

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0964569104000973

Abstract: We review the multiple ecological impacts of oil and gas development on coastal ecosystems in the Mississippi Delta. This area has one of the greatest developments of oil and gas production in the world. This activity has generated significant impacts on coastal ecosystems due to the toxicity of spilled oil and the secondary and indirect effects of petroleum-related activities, such as alteration of hydrology. Effects on plant communities include disruption of plant-water relationships, direct impacts to plant metabolism, toxicity to living cells, and reduced oxygen exchange between the atmosphere and the soil. Effects on consumers include growth inhibition, reduced production, altered metabolic systems, and biomagnification of hydrocarbon compounds. Petroleum-related activities have contributed significantly to wetland loss in the Delta. Subsidence was increased by 2-3 times due to fault activation. Canals altered natural hydrology by altering water flow pathways, increasing saltwater intrusion, and reducing overland flow and sediment inputs. The combination of these factors increased plant stress and plant death. (c) 2005 Elsevier Ltd. All rights reserved.

RefID: 392

Author: Kocan, R.M., Hose, J.E., Brown, E.D. and Baker, T.T.

Year: 1996

Title: Pacific herring (Clupea pallasi) embryo sensitivity to Prudhoe Bay petroleum hydrocarbons: Laboratory evaluation and in situ exposure at oiled and unoiled sites in Prince William Sound

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f96-173

Abstract: Pacific herring (Clupea pallasi) embryos were exposed to oil-water dispersions of Prudhoe Bay crude oil in artificial seawater. The original extract contained 9.67 mg/L high molecular weight and 64 mg/L low molecular weight hydrocarbons. From this stock, concentrations of oil-water dispersions were made ranging from 9.67 to 0.01 mg/L. Pilot studies demonstrated that over 85% of the low molecular weight hydrocarbons evaporated during the first 24 h of each exposure. Seawater with and without oil-water dispersions showed constant values of 10.2-10.4 mg O-2/L, a pH of 8.4, and salinity of 29.7-30.3 parts per thousand. Genetic damage was the most sensitive biomarker for oil exposure, followed by physical deformities, reduced mitotic activity, lower hatch weight, and premature hatching. Oil had its greatest effect on the blastodisc and gastrula stages. Embryos deployed in Prince William Sound 3 years after the Exxon Valdez oil spill yielded a greater proportion of abnormal ($p < 0.002$) and lower weight ($p < 0.01$) larvae at previously oiled sites than at unoiled sites. Although there is no unequivocal evidence that oiled sites pose a long-term hazard to herring embryo or larval survival, a more comprehensive in situ study is warranted in light of the data obtained during this study.

RefID: 393

Author: Kocan, R.M., Marty, G.D. and Kennedy, C.J.

Year: 1999

Title: Investigations of disease factors affecting declines of Pacific herring populations in Prince William Sound

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/45289021.pdf

Abstract: In spring '97 VHSV prevalence was significantly greater in fish from PWS (15%) than from Sitka (0.8%), but it was higher than in any previous year since 1993. A high viral prevalence in PWS in 1998 (15%) was associated with a population decline in the spring of 1999. The prevalence of Ichthyophonus continued to decrease within the population as a whole due to recruitment of younger fish with lower rates of infection. The prevalence of Ichthyophonus in the '88 year-class remained constant at 26-30% over four years. Studies in PWS demonstrated that closed pounds play a role in transmission of VHSV to susceptible fish, resulting in the rapid spread of virus and frequently causing significant mortality within the pens. Studies on Ichthyophonus hoferi demonstrated that the organism is a potential serious pathogen of herring but no evidence for its role in the herring declines in PWS could be found. Likewise, no evidence for oil-related increased susceptibility to VHSV was found in either wild or lab-reared herring. A natural immunity developed in fish at 2-years-old, about the time of sexual maturity, and fish of all ages developed an acquired immunity following infection and recovery from VHS.

RefID: 394

Author: Kocan, R.M., Marty, G.D., Okihiro, M.S., Brown, E.D. and Baker, T.T.

Year: 1996

Title: Reproductive success and histopathology of individual Prince William Sound Pacific herring 3 years after the Exxon Valdez oil spill

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f96-175

Abstract: Adult Pacific herring (Clupea pallasi) collected in 1992 from a site previously oiled by the Exxon Valdez oil spill exhibited a lower percent hatch and produced fewer morphologically normal larvae than fish from a previously unoiled site. Possible explanations for these reproductive differences include (i) exposure to residual oil, (ii) homing of previously oil-injured fish, (iii) homing of different strains of herring, and (iv) physical or chemical characteristics of each exposure site unrelated to oil. Differences in microscopic tissue lesions were also observed and were marginally significant between sites. Granulomatous inflammation occurred only in females from previously oiled sites, and this plus increased splenic congestion were negatively correlated to production of normal larvae. Scores for macrophage aggregates in spleen, liver, and kidney were greater in fish from previously oiled sites, particularly in males, but differences were related to age rather than exposure history. Because most of the lesions related to reproductive success were acute or subacute, differences in tissue damage could not be directly related to previous oil exposure.

RefID: 395

Author: Korn, S., Moles, D.A. and Rice, S.D.

Year: 1979

Title: Effects of Temperature on the Median Tolerance Limit of Pink Salmon and Shrimp Exposed to Toluene, Naphthalene, and Cook Inlet Crude Oil

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2FBF01685464

Abstract: Marine animals may be more susceptible to oil spills inAlaskan and other cold waters than they would be in warmer watersbecause of direct and indirect effects of low temperatures on thephysical behavior of oil and the sensitivity of animals. Oil-water solutions probably remain at toxic concentrations for longerperiods of time at lower temperatures because of reducedvolatility and biodegradation of oil in seawater. Sensitivity ofanimals to oil should differ at different temperatures, but thedirection (increased or decreased sensitivity) and magnitude mayvary by species. We do not know how reduced temperatures changeuptake, metabolism, and excretion of petroleum hydrocarbons byinvertebrates or fishes.Information on the influence of temperatures on survival ofanimals exposed to oil is sparse and inconclusive. RICE et al.(1977a) made general comparisons of the median tolerance limits(TLm's) to oil reported for several species of shrimp and fishes from the Gulf of Mexico and Alaska and found the Alaskan species had consistently lower TLm's. However, differences in species and oils tested render direct comparisons based on temperaturedifferences inconclusive.We measured the effects of temperature on the TLm's of pinksalmon (Oncorhynchus gorbuscha) fry and shrimp (Eualus spp. and Pandalus goniurus) exposed to toluene, naphthalene, and the watersolublef raction (WSF) of Cook Inlet crude oil. We used static exposures in which the initial concentration of the toxicant declines with time, a situation that would also occur with an oil spill. Both the persistence of oil and the physiology of animalsare affected by temperature, and the measured TLm's are the netresult of both variables operating simultaneously. Toluene, amononuclear, and naphthalene, a dinuclear aromatic hydrocarbon, were tested because they represent aromatic Compounds implicatedas major contributors to oil toxicity (ANDERSON et al. 1974, RICEet al. 1976).

RefID: 396

Author: Kovalenko, K.E., Ciborowski, J.J.H., Daly, C., Dixon, D.G., Farwell, A.J., Foote, A.L., Frederick, K.R., Costa, J.M.G., Kennedy, K., Liber, K., Roy, M.C., Slama, C.A. and Smits, J.E.G.

Year: 2013

Title: Food web structure in oil sands reclaimed wetlands

Journal: Ecological Applications

Hyperlink: http://www.esajournals.org/doi/abs/10.1890/12-1279.1

Abstract: Boreal wetlands play an important role in global carbon balance. However, their ecosystem function is threatened by direct anthropogenic disturbance and climate change. Oil sands surface mining in the boreal regions of Western Canada denudes tracts of land of organic materials, leaves large areas in need of reclamation, and generates considerable quantities of extraction process-affected materials. Knowledge and validation of reclamation techniques that lead to self-sustaining wetlands has lagged behind development of protocols for reclaiming terrestrial systems. It is important to know whether wetlands reclaimed with oil sands process materials can be restored to levels equivalent to their original ecosystem function. We approached this question by assessing carbon flows and food web structure in naturally formed and oil sands-affected wetlands constructed in 1970-2004 in the postmining landscape. We evaluated whether a prescribed reclamation strategy, involving organic matter amendment, accelerated reclaimed wetland development, leading to wetlands that were more similar to their natural marsh counterparts than wetlands that were not supplemented with organic matter. We measured compartment standing stocks for bacterioplankton, microbial biofilm, macrophytes, detritus, and zoobenthos; concentrations of dissolved organic carbon and residual naphthenic acids; and microbial production, gas fluxes, and aquatic-terrestrial exports (i.e., aquatic insect emergence). The total biomass of several biotic compartments differed significantly between oil sands and reference wetlands. Submerged macrophyte biomass, macroinvertebrate trophic diversity, and predator biomass and richness were lower in oil sands-affected wetlands than in reference wetlands. There was insufficient evidence to conclude that wetland age and wetland amendment with peat-mineral mix mitigate effects of oil sands waste materials on the fully aquatic biota. Although high variability was observed within most compartments, our data show that 20-year-old wetlands containing oil sands material have not yet reached the same level of function as their reference counterparts.

RefID: 397

Author: Koyama, J. and Kakuno, A.

Year: 2004

Title: Toxicity of heavy fuel oil, dispersant, and oil-dispersant mixtures to a marine fish, Pagrus major

Journal: Fisheries Science

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1111/j.1444-2906.2004.00845.x/abstract

Abstract: This study examines the toxicity of three dispersants and heavy fuel oil to a marine fish, red sea bream (Pagrus major). Also studied was the toxicity of a mixture of heavy fuel oil and the least toxic of the three dispersants. The 24-h LC50 of all three dispersants were at least 1500 mg/L; these dispersants appeared relatively less toxic to marine fish than others studied in the past. The mean lethal oil concentration of the water-accommodated oil fraction was 325 mug/L. Mixtures of oil and dispersant were more toxic than dispersant or oil alone. Large amounts of dispersant decreased the toxicity of the mixture for the marine fish. Use of a dispersant-to-oil percentage of 20%, which is recommended by the manufacturer because of its efficiency in oil emulsification and dispersion, yielded higher 24-h oil concentrations and resulted in a higher mortality rate than did the L se A higher percentages of dispersant. The application of dispersant to oil in coastal areas, especially with higher activities of fisheries and aquaculture like Japan, must be considered carefully in the context of the benefits versus environmental cost.

RefID: 398

Author: Krahn, M.M., Burrows, D.G., Ylitalo, G.M., Brown, D.W., Wigren, C.A., Collier, T.K., Chan, S.L. and Varanasi, U.

Year: 1992

Title: MASS-SPECTROMETRIC ANALYSIS FOR AROMATIC-COMPOUNDS IN BILE OF FISH SAMPLED AFTER THE EXXON-VALDEZ OIL-SPILL

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es00025a012

Abstract: After the Exxon Valdez oil spill, the exposure of marine organisms to petroleum had to be determined. Gas chromatography/mass spectrometry was used to identify metabolites of aromatic compounds (ACs), such as alkylated naphthols, phenanthrols, and dibenzothiophenols, in the hydrolyzed bile of five salmon (Oncorhynchus gorbuscha) and four pollock (Theragra chalcogramma) captured in Prince William Sound several months after the oil spill. These metabolites were not found in control fish sampled from areas not impacted by the oil. The metabolites were identified by comparison to those from the hydrolyzed bile of a halibut (Hippoglossus stenolepis) which had been injected with weathered Prudhoe Bay crude oil. The dibenzothiophenols are proposed as promising marker compounds for identifying the exposure of fish to certain crude oils. In addition, a high-performance liquid chromatographic method to screen bile for metabolites of ACs was validated for use in estimating the exposure of fish to petroleum.

RefID: 399

Author: Kuhl, A.J., Nyman, J.A., Kaller, M.D. and Green, C.C.

Year: 2013

Title: DISPERSANT AND SALINITY EFFECTS ON WEATHERING AND ACUTE TOXICITY OF SOUTH LOUISIANA CRUDE OIL

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.2346/abstract

Abstract: Chemical dispersants are an important technology in the remediation of oil spills in the aquatic environment, facilitating degradation of crude oil and salinity is an important factor in dispersant effectiveness. The aim of the present study was to explore the role of salinity on the degradation chemistry of crude oil polycyclic aromatic hydrocarbons (PAHs) and acute toxicity of the water-accommodated fraction (WAF) of the dispersant COREXIT 9500A and chemically dispersed crude oil on a common estuarine fish. Laboratory microcosms were designed at salinities of 4 parts per thousand (ppt), 12 ppt, or 18 ppt and spiked with crude oil, COREXIT 9500A, or a combined exposure to crude oil and COREXIT and allowed to biodegrade for 1 wk, 4 wk, and 16 wk. The WAF was harvested for analytical PAH analysis and acute toxicity testing in juvenile Fundulus grandis. Compared with undispersed oil, COREXIT exponentially increased the PAH concentrations in the WAF for up to 16 wk; hopane-normalized concentrations indicated that biodegradation was slowed for the first 4 wk. Dispersed crude oil and COREXIT were acutely toxic following 1 wk of biodegradation with no correlation between PAH concentrations and crude oil WAF mortality. Both dispersant and dispersant oil mixtures remained toxic for at least 4 wk at the lowest salinity tested, suggesting increased sensitivity or reduced biodegradation of toxic components in low-saline environments. At the lowest salinity, oil dispersed with COREXIT was more toxic than either the COREXIT alone or oil alone, even after 16 wk of biodegradation. Environ Toxicol Chem 2013;32:2611-2620. (c) 2013 SETAC

RefID: 400

Author: Lacaze, E., Devaux, A., Bruneau, A., Bony, S., Sherry, J. and Gagné, F.

Year: 2014

Title: Genotoxic potential of several naphthenic acids and a synthetic oil sands process-affected water in rainbow trout (Oncorhynchus mykiss)

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X14001489

Abstract: The exploitation of oil sands has raised major environmental concerns, particularly regarding the presence of high concentration in contaminants such as polycyclic aromatic hydrocarbons (PAHs) and naphthenic acids (NAs) in oil sands process-affected water (OSPW). The purpose of this study was, first to evaluate the genotoxic impact of OSPW-related compounds such as NAs and PAHs in a salmonid species and secondly to assess if OSPW exposure leads to genotoxicity. For this purpose, rainbow trout hepatocytes were exposed in vitro to environmentally relevant concentrations of synthetic NAs, naphtalene, benzo(a)pyrene, and extracts of synthetic OSPW (generated by a laboratory bitumen extraction) and of oil sands leaching water (OSLW, mimicking leaching of oil sands in river water). Primary DNA damage was assessed by the formamidopyrimidine-DNA glycolyase (Fpg)-modified comet assay. Genotoxicity was observed in hepatocytes exposed to several NAs, mixture of them, OSPW and OSLW extracts. The chemical structure of NAs influences the genotoxicity potential: among the NAs tested, the most cyclic NA was the most genotoxic. It also appears that genotoxicity was more marked for OSPW than for OSLW. Because exposure to OSPW led to oxidative DNA damage, while after exposure to several NAs, these types of DNA damage were limited, the NAs tested in this study could not be qualified as the only major contaminants responsible for OSPW genotoxicity. Notwithstanding, it should be noteworthy that exposure to NAs resulted in genotoxic impact at concentrations lower than those documented by literature for fresh OSPW. Further research is needed to explore the relationships between the chemical structure of NAs and their genotoxicity in the light of the distribution of NAs in fresh OSPW samples as well as in surface waters.

RefID: 401

Author: Landrum, P.F., Chapman, P.M., Neff, J. and Page, D.S.

Year: 2013

Title: Influence of exposure and toxicokinetics on measures of aquatic toxicity for organic contaminants: A case study review

Journal: Integrated Environmental Assessment and Management

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/ieam.1388/abstract

Abstract: This theoretical and case study review of dynamic exposures of aquatic organisms to organic contaminants examines variables important for interpreting exposure and therefore toxicity. The timing and magnitude of the absorbed dose change when the dynamics of exposure change. Thus, the dose metric for interpreting toxic responses observed during such exposure conditions is generally limited to the specific experiment and cannot be extrapolated to either other experiments with different exposure dynamics or to field exposures where exposure dynamics usually are different. This is particularly true for mixture exposures, for which the concentration and composition and, therefore, the timing and magnitude of exposure to individual components of different potency and potentially different mechanisms of action can vary. Aquatic toxicology needs studies that develop temporal thresholds for absorbed toxicant doses to allow for better extrapolation between conditions of dynamic exposure. Improved experimental designs are required that include high-quality temporal measures of both the exposure and the absorbed dose to allow better interpretation of data. For the short term, initial water concentration can be considered a conservative measure of exposure, although the extent to which this is true cannot be estimated specifically unless the dynamics of exposure as well as the toxicokinetics of the chemicals in the exposure scenario for the organism of interest are known. A better, but still limited, metric for interpreting the exposure and, therefore, toxicity is the peak absorbed dose, although this neglects toxicodynamics, requires appropriate temporal measures of accumulated dose to determine the peak concentration, and requires temporal thresholds for critical body residue for each component of the mixture. Integr Environ Assess Manag 2013; 9: 196210. (c) 2012 SETAC

RefID: 402

Author: Lane, S.M., Smith, C.R., Mitchell, J., Balmer, B.C., Barry, K.P., McDonald, T., Mori, C.S., Rosel, P.E., Rowles, T.K., Speakman, T.R., Townsend, F.I., Tumlin, M.C., Wells, R.S., Zolman, E.S. and Schwacke, L.H.

Year: 2015

Title: Reproductive outcome and survival of common bottlenose dolphins sampled in Barataria Bay, Louisiana, USA, following the Deepwater Horizon oil spill

Journal: Proceedings of the Royal Society B

Hyperlink: http://rspb.royalsocietypublishing.org/content/282/1818/20151944

Abstract: Common bottlenose dolphins (Tursiops truncatus) inhabit bays, sounds and estuaries across the Gulf of Mexico. Following the Deepwater Horizon oil spill, studies were initiated to assess potential effects on these ecologically important apex predators. A previous study reported disease conditions, including lung disease and impaired stress response, for 32 dolphins that were temporarily captured and given health assessments in Barataria Bay, Louisiana, USA. Ten of the sampled dolphins were determined to be pregnant, with expected due dates the following spring or summer. Here, we report findings after 47 months of follow-up monitoring of those sampled dolphins. Only 20% (95% CI: 2.50–55.6%) of the pregnant dolphins produced viable calves, as compared with a previously reported pregnancy success rate of 83% in a reference population. Fifty-seven per cent of pregnant females that did not successfully produce a calf had been previously diagnosed with moderate–severe lung disease. In addition, the estimated annual survival rate of the sampled cohort was low (86.8%, 95% CI: 80.0–92.7%) as compared with survival rates of 95.1% and 96.2% from two other previously studied bottlenose dolphin populations. Our findings confirm low reproductive success and high mortality in dolphins from a heavily oiled estuary when compared with other populations. Follow-up studies are needed to better understand the potential recovery of dolphins in Barataria Bay and, by extension, other Gulf coastal regions impacted

RefID: 403

Author: Laramore, S., Krebs, W. and Garr, A.

Year: 2014

Title: Effects of macondo canyon 252 oil (naturally and chemically dispersed) on larval Crassostrea virginica (gmelin, 1791)

Journal: Journal of Shellfish Research

Hyperlink: http://www.bioone.org/doi/pdf/10.2983/035.033.0305

Abstract: A series of acute and sublethal experiments were conducted to examine the potential effects of exposure to water-accommodated fractions (WAFs) of Macondo Canyon 252 crude oil and chemically enhanced (Corexit 9500A dispersant) water-accommodated fractions (CEWAFs) on embryogenesis, larval development, growth, and survival of the eastern oyster, Crassostrea virginica. Nominal exposure concentrations for acute experiments were 0, 100, 200, 400, 800 and 1,200 mg/L for WAFs, and 0, 6.25, 12.5, 25, 50, 100, and 200 mg/L for CEWAFs. Calculated total polycyclic aromatic hydrocarbon (TPAH) values were 0, 22.5, 45, 90, 181, and 271 mu g/L for WAFs, and 0, 4.5, 8.9, 17.8, 35.7, 71, and 142 mu g/L for CEWAFs. The exposure concentration for sublethal experiments was 16 mg/L CEWAF. Total polycyclic aromatic hydrocarbon concentrations represent moderate to high levels of TPAH reported during the Deepwater Horizon (DWH) event. Exposure to acute concentrations of 1 or both of these contaminants was shown to decrease fertilization success (>= 100 mg/L CEWAF), hinder trochophore (>= 100 mg/L WAF, 12.5 mg/L CEWAF) and D-stage(>= 200 mg/L WAF, >= 25 mg/L CEWAF) development, increase the risk of D-stage developmental abnormalities (>= 100 mg/L WAF, >= 100 mg/L CEWAF), and decrease survival of D-stage (1,092 to 261.8 mg/L WAF, 24-96 h LC50; 177.6 to 24.8 mg/L CEWAF, 24-96 h LC50) and eyed (81.9 to 14.5 mg/L CEWAF; 24-96 h LC50) larvae. Exposure to CEWAFs, in general, resulted in increased toxicity over WAFs, likely as a result of the increased bioavailability of hydrocarbons. In contrast to acute exposures, short-term (24-h) sublethal exposure of D-stage larvae to CEWAFs (16 mg/L) had no impact on survival or growth. Although concentrations used represent possible TPAH exposure levels based on maximum reported values, these findings do not imply that oyster larvae were exposed to similar concentrations during or after the DWH event.

RefID: 404

Author: Laramore, S., Shawl, A. and Krebs, W.

Year: 2012

Title: Toxic effects of crude oil and the corexit 9500 dispersant on conch (Strombus gigas), oyster (Crassostrea virginica) and shrimp (Penaeus duorarum) larvae

Journal: Journal of Shellfish Research

Hyperlink: http://www.bioone.org.ezproxy.library.ubc.ca/doi/abs/10.2983/035.031.0124

Abstract: Static acute toxicity tests were conducted on ecological and economically important invertebrate larvae with artificially weathered crude oil, dispersant and dispersed oil (1:10 ratio) to determine LC50 values following short term exposure. Larvae exposed included conch veligers (2, 4 and 6 lobed stages), oyster veligers (D and "eyed" stages), shrimp larvae (nauplii, zoea 1, mysis 1 and PL6 stages). Dispersed oil was more toxic than crude oil for larvae at all stages of development and as toxic as the dispersant alone at 48 hours for most larvae. The dispersant was equally toxic to all invertebrate larvae at all life stages. LC50 levels for the dispersant ranged from a high of 36 ppm (2 lobed conch veligers) at 24 hours to <1.25 ppm at 72 hours (shrimp zoea 1). Survival decreased with an increase in exposure time and younger stages were generally more sensitive than older stages. Shrimp were more sensitive to oil and dispersed oil than conch or oysters. Zoea 1 shrimp were the most sensitive to the contaminants (81 ppm oil, 15 ppm mix, 4 ppm dispersant; 24 hours). Eyed oyster larvae were the most resistant (>1200 ppm oil, 97 ppm mix, 23 ppm dispersant; 24 hours).

RefID: 405

Author: Laur, D. and Haldorson, L.

Year: 1996

Title: Coastal habitat studies: The effect of the Exxon Valdez oil spill on shallow subtidal fishes in Prince William Sound

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: Fish communities were monitored in shallow (<20 m) depths of paired oiled And non-oiled (control) study sites within Prince William Sound in 1990 using diving transect technique. Habitats studied were defined by dominant macrophytes, including eelgrass Zostera marina and Laminaria-Agarum. In eelgrass, young-of-the-year Pacific cod Gadus macrocephalus were the most abundant fish in both oiled and control sites: they occurred at significantly higher densities at oiled sites. In Laminaria-Agarum habitats, the Arctic shanny Stichaeus punctatus and small sculpins were the most common fishes, and young-of-the-year Arctic shannies were more abundant in shallow depths at oiled sites. In both eelgrass and Laminaria-Agarum habitats, oiled sites had overall higher abundances of fishes than did control sites mainly because of the higher numbers of young-of-the-year fishes. Young-of-the-year Pacific cod from oiled eelgrass sites tended to have higher volumes of stomach contents and had eaten proportionally more mollusk larvae than had fish from control sites, where crustaceans were more common in diets. Differences in diet appear related to the relative availability of prey in oiled versus control eelgrass study sites, suggesting that increased abundance of young-of-the-year Pacific cod at oiled study sites is related to the increased diversity and abundance of epifaunal prey taxa. Increased numbers of young-of-the-year fishes at oiled sites could also be the result of enhanced supply of planktonic larvae or decreases in predation at oiled sites.

RefID: 406

Author: Law, R.J., Kelly, C., Baker, K., Jones, J., McIntosh, A.D. and Moffat, C.F.

Year: 2002

Title: Toxic equivalency factors for PAH and their applicability in shellfish pollution monitoring studies

Journal: Journal of Environmental Monitoring

Hyperlink: http://pubs.rsc.org/en/Content/ArticleLanding/2002/EM/b200633m

Abstract: Fish and shellfish are exposed to a wide range of polycyclic aromatic hydrocarbons (PAH) following oil spills at sea, and can become contaminated as a result. Finfish have a more effective mixed-function oxidase enzyme system than shellfish, and are therefore able to metabolise and excrete PAH more effectively than the invertebrates. Thus, contamination by high-molecular weight PAH, including those with carcinogenic potential and so of concern with regard to human consumers, is therefore usually observed in shellfish, and particularly in bivalve molluscs. Oil spills are not the sole source of PAH, however, as parent compounds are also generated by a wide range of combustion processes. In this paper, consideration is given to monitoring data gathered following recent oil spills (both of crude oil and diesel fuel), alongside data from other studies. These include studies conducted around a former gasworks site and downstream of an aluminium smelter in the UK, and from mussel monitoring studies undertaken in the UK and the USA (including the Exxon Valdez oil spill and the National Status and Trends programme), and in other countries in Europe. For comparative purposes the PAH concentrations are summed and also expressed as benzo[a]pyrene equivalents, their relative concentrations being weighted in relation to the carcinogenic potential of individual PAH compounds using toxic equivalency factors (TEF). Our aim was to assess the utility of this approach in fishery resource monitoring and control following oil spills. Certainly this approach seems useful from the data assessed in this study, and the relative ranking of the various studies seems to reflect the relative degree of concern for human consumers due to the differing contamination sources. As a simple tool for control purposes it is equally applicable to PAH derived from oil spills, and from industrial and combustion sources.

RefID: 407

Author: Leclair, L.A., MacDonald, G.Z., Phalen, L.J., Koellner, B., Hogan, N.S. and van den Heuvel, M.R.

Year: 2013

Title: The immunological effects of oil sands surface waters and naphthenic acids on rainbow trout (Oncorhynchus mykiss)

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X13002178

Abstract: There is concern surrounding the immunotoxic potential of naphthenic acids (NAs), a major organic constituent in waters influenced by oil sands contamination. To assess the immunological response to NAs, rainbow trout (Oncorhynchus mykiss) waterborne exposures were conducted with oil sands-influenced waters, NAs extracted and purified from oil sands tailings waters, and benzo[a]pyrene (BaP) as a positive control. After a 7 d exposure, blood, spleen, head kidney, and gill samples were removed from a subset of fish in order to evaluate the distribution of thrombocytes, B-lymphocytes, myeloid cells, and T-lymphocytes using fluorescent antibodies specific for those cell types coupled with flow cytometry. The remaining trout in each experimental tank were injected with inactivated Aeromonas salmonicida and held in laboratory water for 21 d and subjected to similar lymphatic cell evaluation in addition to evaluation of antibody production. Fluorescent metabolites in bile as well as liver CYP1A induction were also determined after the 7 and 21 d exposure. Oil sands waters and extracted NAs exposures resulted in an increase in bile fluorescence at phenanthrene wavelengths, though liver CYP1A was not induced in those treatments as it was with the BaP positive control. Trout in the oil sands-influenced water exposure showed a decrease in B- and T-lymphocytes in blood as well as B-lymphocytes and myeloid cells in spleen and an increase in B-lymphocytes in head kidney. The extracted NAs exposure showed a decrease in thrombocytes in spleen at 8 mg/L and an increase in T-lymphocytes at 1 mg/L in head kidney after 7 d. There was a significant decrease in antibody production against A. salmonicida in both oil sands-influenced water exposures. Because oil sands-influenced waters affected multiple immune parameters, while extracted NAs impacts were limited, the NAs tested here are likely not the cause of immunotoxicity found in the oil sands-influenced water. (C) 2013 Elsevier B.V. All rights reserved.

RefID: 408

Author: Lee, K., Boufadel, M., Chen, B., Foght, J., Hodson, P., Swanson, S. and Venosa, A.

Year: 2015

Title: Expert Panel Report on the Behaviour and Environmental Impacts of Crude Oil Released into Aqueous Environments

Journal: Royal Society of Canada Report

Hyperlink: https://rsc-src.ca/en/expert-panels/rsc-reports/behaviour-and-environmental-impacts-crude-oil-released- into-aqueous

Abstract: A solid scientific understanding of the behaviour and environmental impacts of crude oil if accidentally released into aqueous environments can make an important contribution to the identification of optimal strategies for spill preparedness, spill response, and environmental remediation. A panel of experts is asked to review the state of the science on how various kinds of conventional and unconventional crude oils transported in North America interact with the surface waters and associated sediments (suspended, shoreline, ocean/lake/river floor) in marine, estuarine and freshwater settings under a wide range of environmental conditions.

RefID: 409

Author: Lee, K., Prince, R.C., Greer, C.W., Doe, K.G., Wilson, J.E.H., Cobanli, S.E., Wohlgeschaffen, G.D., Alroumi, D., King, T. and Tremblay, G.H.

Year: 2003

Title: Composition and Toxicity of Residual Bunker C Fuel Oil in Intertidal Sediments After 30 Years

Journal: Spill Science & Technology Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S1353256103000148

Abstract: In 1970, approximately 2000 m3 of Bunker C crude oil impacted 300 km of Nova Scotia's coastline following the grounding of the tanker Arrow. Only 10% of the contaminated coast was subjected to cleanup, the remainder was left to cleanse naturally. To determine the long-term environmental impact of residual oil from this spill event, samples of sediment and interstitial water were recovered in 1993, 1997 and 2000 from a sheltered lagoon in Black Duck Cove. This heavily oiled site was intentionally left to recover on its own. Visual observations and chemical analysis confirmed that substantial quantities of the weathered cargo oil were still present within the sediments at this site. However, direct observations of benthic invertebrate abundance suggest that natural processes have reduced the impacts of the residual oil. To confirm this hypothesis, sediment and interstitial water samples from Black Duck Cove were assessed with a comprehensive set of biotests and chemical assays. Residual oil in the sediments had limited effect on hepatic CYP1A protein levels and mixed function oxygenase (MFO) induction in winter flounder (Pleuronectes americanus). No toxicity was detected with the Microtox solid phase test (Vibrio fischeri). Significant sediment toxicity was detected by the amphipod survival test (Eohaustorius estuarius) in four out of the eight contaminated sediments. Interstitial water samples were deemed non-toxic by the Microtox 100% test (Vibrio fischeri) and the echinoid fertilization test (Lytechinus pictus). Sediment elutriates were also found to be non-toxic in the grass shrimp embryo-larval toxicity (GSELTOX) test (Palaemonetes pugio). Recovery at this contaminated site is attributed to natural processes that mediated biodegradation and physical removal of oil from the sediments. In support of the latter mechanism, mineralization experiments showed that all test sediments had the capacity for hexadecane, octacosane and naphthalene degradation, while chemical analysis confirmed that the Bunker C oil from the Arrow had undergone substantial biodegradation.

RefID: 410

Author: Lee, K.W., Shim, W.J., Yim, U.H. and Kang, J.H.

Year: 2013

Title: Acute and chronic toxicity study of the water accommodated fraction (WAF), chemically enhanced WAF (CEWAF) of crude oil and dispersant in the rock pool copepod Tigriopus japonicus

Journal: Chemosphere

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0045653513002099

Abstract: We determined the toxicity of the water accommodated hydrocarbon fraction (WAF), two chemically enhanced WAFs (CEWAFs; CEWAF-C, Crude oil + Corexit 9500 and CEWAF-H, Crude oil + Hiclean) of crude oil and two dispersants (Corexit 9500 and Hiclean) to the rock pool copepod Tigriopus japonicus. In the acute toxicity test, Corexit 9500 was the most toxic of all the chemicals studied. The nauplius stage of T. japonicus was more susceptible to the toxic chemicals studied than the adult female. The toxicity data using the nauplius stage was then considered as baseline to determine the spiking concentration of chemicals for chronic toxicity tests on the copepod. As the endpoints in the chronic toxicity test, survival, sex ratio, developmental time and fecundity of the copepod were used. All chemicals used in this study resulted in increased toxicity in the F-1 generation. The lowest-observed-adverse-effect (LOAE) concentrations of WAF, CEWAF-H, CEWAF-C, Hiclean and Corexit 9500 were observed to be 50%, 10%, 0.1%, 1% and 1%, respectively. The results in present study imply that copepods in marine may be negatively influenced by spilled oil and dispersant. (C) 2013 Elsevier Ltd. All rights reserved.

RefID: 411

Author: Lee, R.F. and Page, D.S.

Year: 1997

Title: Petroleum hydrocarbons and their effects in subtidal regions after major oil spills

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X97000787

Abstract: The question often arises after large oil spills as to the extent and effect of oil entering the subtidal zones adjacent to heavily oiled shorelines. Estimates for a number of large spills suggest that 1 to 13% of the spilled oil can enter subtidal regions. Hydrocarbon concentrations in these subtidal zones are generally orders of magnitude lower than shoreline sediments. For example, in the Exxon Valdez oil spill, subtidal sediment hydrocarbon concentrations attributable to the spill were very low in the first year after the spill and barely detectable in the second year, The conditions necessary to produce high concentrations of hydrocarbons in the subtidal region include large amounts of oil in a semi-enclosed estuary or bay and high concentrations of line particulate matter to associate with hydrocarbons to allow them to disperse and sink, Such conditions do not often occur after spills, with some exceptions, such as low energy tidal estuaries in the Amoco Cadiz spill in Brittany, France, More commonly sea floor sediment hydrocarbon concentrations, where sediment-associated hydrocarbons have settled, are generally near to background levels, due to dilution and weathering. A number of methods have been used to evaluate the biological effects of oil spills on subtidal fauna. These include toxicity to amphipods, increases in the concentrations of fluorescent aromatic metabolites in the bile of fish, histopathology of fish, increases in opportunistic species and infaunal succession. Sediments collected from the subtidal zone below heavily oiled shorelines of the Exxon Valdez spill showed low toxicity using standard amphipod bioassays. Well documented effects on the subtidal biota adjacent to heavily oiled shorelines are the increases in the number of hydrocarbon degrading microbes which are fed on by opportunistic species of meiofauna which in turn are food for macrofauna. The documented biological effects of oil in the subtidal region are generally of short duration and recovery back to an equilibrium or 'normal' condition is typically quite rapid. (C) 1997 Elsevier Science Ltd.

RefID: 412

Author: Lees, D.C. and Driskell, W.B.

Year: 2007

Title: Assessment of bivalve recovery on treated mixed-soft beaches in Prince William Sound, Alaska

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/180774340.pdf

Abstract: National Oceanic and Atmospheric Administration treatment effects studies from 1989 through 1997 suggested that bivalve assemblages on beaches in Prince William Sound treated with high-pressure washing were severely injured in terms of abundance, species composition, and function. Restoration Project 040574 assessed the generality and persistence of this apparent injury to this assemblage. We found that the initial conclusions were accurate, indicating that a considerable proportion of mixed-soft beaches in treated areas of the sound remained extremely disturbed and that these beaches are functionally impaired in terms of their ability to support foraging by humans and damaged nearshore vertebrate predators such as sea otters 13 years after the spill. Large, long-lived hard-shell clams remained 66% less abundant at Treated sites than at Reference sites. We also found that standard sediment properties did not appear implicated in lagging recovery. But, based on several lines of evidence, we deduced that a major cause for the delay was the disruption of surface armoring (a stratified organization of mixed-soft shoreline sediments common in southcentral Alaska), an effect of beach washing. Based on the apparent recovery trajectory, we predict that recovery to pre-spill status will take several more decades. We also found that sedimentary components and the biota in the armored mixed-soft sediments in Prince William Sound do not respond according to traditionally described paradigms for homogeneous sediments.

RefID: 413

Author: Lees, D.C., Driskell, W.B. and Houghton, J.P.

Year: 1999

Title: Response of Infaunal Bivalves to the Exxon Valdez Oil Spill andRelated Shoreline Treatment

Journal: International Oil Spill Conference Proceedings

Hyperlink:

Abstract: Infaunal bivalves monitored in Prince William Sound intertidal sediments between 1990 through 1996 appear to have been affected more by shorelinetreatment than by exposure to oil. Lower numbers were observed at oiled buttreated (Category 3) sites whereas highest numbers were observed at reference (Category 1) sites. Species richness, very similar at reference and oiled but untreated (Category 2) sites after 1990, declined slightly during the study. Abundance, also quite similar at reference and Category 2 sites, peaked in 1992 or 1993 and then gradually declined through the remaining years. In contrast, averages for Category 3 sites exhibited no apparent trends representing recovery. Differences in both variables were highly significant between reference and Category 2 sites, on one hand, and Category 3 sites, on the other hand.

RefID: 414

Author: Lees, D.C., Houghton, J.P. and Driskell, W.B.

Year: 1996

Title: Short-Term Effects of Several Types of Shoreline Treatment on Rocky Intertidal Biota in Prince William Sound

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: Studies conducted in Prince William Sound during 1989 assessed short-term biological effects of treatment methds being considered or employed to treat oil-contaminated beaches. Treatment alternatives evaluated included (1) low-pressure warmwater wash (LP-WW), (2) high-pressure hot-water wash (HP-HW), (3) the dispersant Corexit 7664, and (4) the beach cleaner Corexit 9580 M2. Effects on the biota were assessed on the basis of changes in abundance of dominant taxa and in magnitude of selected assemblage attributes (e.g., percent cover by algae or animals and number of taxa) and, in some cases, observed mortality of organisms in the treatment areas. Significant reductions in one or more assemblage or population attributes and increases in the percent of dead mussels were observed following HP-HW treatment. These included heavy mortality in rockweed and mussels. Generally, the programs were not designed to allow discrimination among the potential causes of damage. However, temperature appeared to cause significant mortality in the dominant plants and in grazing and filter-feeding animals at HP-HW sites. In contrast, available data suggest that neither chemical nor LP-WW treatments caused significant thermal impacts in the intertidal biota. An intermediate level of changes, both increases and decreases, accompanied the chemical and LP-WW treatments, whereas the highest percentage of changes, nearly all decreases, accompanied HP-HWs. The severe and persistent effects observed in many areas subjected to HP-HW throughout the spill area were still conspicuous in our most recent survey in the sound (July 1995). The observed displacement and mortality of clams and mussels suggest that physical and possibly chemical effects may have been substantial in some cases. Althought dispersant and beach cleaner treatments appeared to be accompanied by the smallest number of significant changes in abundance, this conclusion is weak because the LP-WW that accompanied chemical applications during the tests was less rigorous than when performed alone. Moreover, the surveys were not focused on enumerating abundance of the types of organisms that toxicity data indicate are more susceptible to the types of chemical tested. In fact, probable dosages applied appear to substantially exceed published LC50s (median lethal concentrations) for Corexit 7664 and later formulations of Corexit for many types of crustaceans and molluscs relevant to intertidal assemblages in Prince William Sound.

RefID: 415

Author: Lemiere, S., Cossu-Leguille, C., Bispo, A., Jourdain, M.J., Lanhers, M.C., Burnel, D. and Vasseur, P.

Year: 2005

Title: DNA damage measured by the single-cell gel electrophoresis (comet) assay in mammals fed with mussels contaminated by the 'Erika' oil-spill

Journal: Mutation Research-Genetic Toxicology and Environmental Mutagenesis

Hyperlink: http://www.sciencedirect.com/science/article/pii/S1383571804002992

Abstract: This research aimed to estimate potential genotoxicity for consumers resulting from the ingestion of seafood contaminated with polycyclic aromatic hydrocarbons (PAHs) released into the marine environment after the 'Erika' shipwreck along the coasts of south Brittany, in France. Mussels (Mytilus sp.) collected from sites on the Atlantic coast that were affected by the oil slick in various degrees, were used to feed rats daily for 2 and 4 weeks. DNA damage was measured by use of the Comet assay in the liver, bone marrow and blood of rats receiving food contaminated with 312 mu g of 16 PAHs/kg dry weight (d.w.) equivalent to 33.8 mu g TEQs (toxic equivalent quantities to benzo(a)pyrene (BaP))/kg d.w. mussels, 569 mu g/kg d.w. (83.6 mu g TEQs/kg) and 870 mu g/kg d.w. (180.7 mu g TEQs/kg). A dose-effect-time relationship was observed between the amount of DNA damage in the liver and bone marrow of the rats and the PAH contamination level of the mussels. Genotoxicity increased during the period between 15 and 30 days in rats that received food at the highest two PAH levels. On the other hand, no significant change in liver and bone marrow of rats fed with mussels containing 33.8 mu g TEQs/kg d.w. was recorded at 30 days compared with 15 days, indicating efficient DNA repair capacity at low levels of exposure. No signs of genotoxicity were found in peripheral blood. Globally, the observed effects were rather moderate. These results show that oil-contaminated food caused DNA damage in predators, and underline the bioavailability to consumers of pollutants in mussels contaminated with fuel oil. The usefulness of the Comet assay as a sensitive tool in biomonitoring studies analyzing responses of PAH transfer through food webs was also confirmed. (c) 2004 Elsevier B.V. All rights reserved.

RefID: 416

Author: Lewis, C., Pook, C. and Galloway, T.

Year: 2008

Title: Reproductive toxicity of the water accommodated fraction (WAF) of crude oil in the polychaetes Arenicola marina (L.) and Nereis virens (Sars)

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X08002464

Abstract: Accidental pollution incidents are common in the marine environment and are often caused by oil-related activities. Here the potential of such an incident to disrupt reproduction in two polychaete species is investigated, using an environmentally relevant preparation of weathered Forties crude oil, i.e. the water accommodated fraction (WAF). Oocytes were collected and exposed to three concentrations of WAF for 1 h prior to the addition of sperm, so that fertilization took place under exposure conditions. Fertilization success was significantly reduced in both species by an exposure to WAF concentrations equivalent to 0.38 mg L-1 PAHs, to just 26.8% in Arenicola marina compared to 76% in Nereis virens. The effects of WAF exposure on fertilization were greatly enhanced at lower sperm concentrations in N. virens, with a complete lack of fertilization reactions observed at sperm concentrations of 10(3) sperm per mL We therefore suggest a mechanism of toxicity related to sperm swimming behaviour, resulting in reduced sperm:egg collision rates. WAF was found to reduce post-fertilization development rates and have teratogenic effects on early embryonic stages in both species, which exhibited abnormal cleavage patterns and high levels of fluctuating asymmetry. These results illustrate how the presence of crude oil in its soluble form in seawater at the time of a spawning event for either A. marina or N. virens could impact on fertilization success with implications for the fertilization ecology of these free spawning marine invertebrates. (C) 2008 Elsevier B.V. All rights reserved.

RefID: 417

Author: Lewis, M. and Pryor, R.

Year: 2013

Title: Toxicities of oils, dispersants and dispersed oils to algae and aquatic plants: Review and database value to resource sustainability

Journal: Environmental Pollution

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0269749113002352

Abstract: Phytotoxicity results are reviewed for oils, dispersants and dispersed oils. The phytotoxicity database

consists largely of results from a patchwork of reactive research conducted after oil spills to marine waters. Toxicity information is available for at least 41 crude oils and 56 dispersants. As many as 107 response parameters have been monitored for 85 species of unicellular and multicellular algae, 28 wetland plants, 13 mangroves and 9 seagrasses. Effect concentrations have varied by as much as six orders of magnitude due to experimental diversity. This diversity restricts phytotoxicity predictions and identification of sensitive species, life stages and response parameters. As a result, evidence-based risk assessments for most aquatic plants and petrochemicals and dispersants are not supported by the current toxicity database. A proactive and experimentally-consistent approach is recommended to provide threshold toxic effect concentrations for sensitive life stages of aquatic plants inhabiting diverse ecosystems. Published by Elsevier Ltd.

RefID: 418

Author: Lin, C.Y., Anderson, B.S., Phillips, B.M., Peng, A.C., Clark, S., Voorhees, J., Wu, H.D.I., Martin, M.J., McCall, J., Todd, C.R., Hsieh, F., Crane, D., Viant, M.R., Sowby, M.L. and Tjeerdema, R.S.

Year: 2009

Title: Characterization of the metabolic actions of crude versus dispersed oil in salmon smolts via NMR-based metabolomics

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X09003087

Abstract: With maritime transport of crude oil from Alaska to California, there is significant potential for a catastrophic spill which could impact migrating salmon. Therefore, this study compared the lethal and sublethal metabolic actions of the water-accommodated fraction (WAF) and the chemically enhanced WAF (CEWAF, via Corexit 9500) of Prudhoe Bay crude oil in smolts of Chinook salmon (Onchorhyncus tshawytscha). After 96-h exposure to the CEWAF, the resulting LC50 was some 20 times higher (i.e., less toxic) than that of the WAF. Muscle and liver samples from surviving fish were collected and low-molecular weight metabolites were analyzed using one-dimensional (1)H and projections of two-dimensional (1)H J-resolved NMR. Principal component analysis (PCA), employed to analyze NMR spectra and identify most variance from the samples, revealed age-related metabolic changes in the fish within the replicated studies, but few consistent metabolic effects from the treatments. However, ANOVA results demonstrated that the dose-response metabolite patterns are both metabolite- and organ-dependent. In general, exposure to either WAF or CEWAF resulted in an increase of amino acids (i.e., valine, glutamine and glutamate) and a decrease of both organic osmolytes (i.e., glycerophosphorylcholine) and energetic substrates (i.e., succinate). The simultaneous increase of formate and decrease of glycerophosphorylcholine in the liver, or the decrease of glycerophosphorylcholine in muscle, may serve as sensitive sublethal biomarkers for WAF or CEWAF exposures. respectively. In conclusion, dispersant treatment significantly decreased the lethal potency of crude oil to salmon smolts. and the NMR-based metabolomics approach provided a sensitive means to characterize the sublethal metabolic actions. Published by Elsevier B.V.

RefID: 419

Author: Lindstrom, J.E. and Braddock, J.F.

Year: 2002

Title: Biodegradation of petroleum hydrocarbons at low temperature in the presence of the dispersant Corexit 9500

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X02000504

Abstract: Our study examined the effects of Corexit 9500 and sediment on microbial mineralization of specific aliphatic and aromatic hydrocarbons found in crude oil. We also measured gross mineralization of crude oil, dispersed crude oil and dispersant by a marine microbial consortium in the absence of sediment. When provided as carbon sources, our consortium mineralized Corexit 9500 the most rapidly, followed by fresh oil, and finally weathered oil or dispersed oil. However, mineralization in short term assays

favored particular components of crude oil (2-methyl-naphthalene > dodecane > phenanthrene > hexadecane > pyrene) and was not affected by addition of nutrients or sediment (high sand, low organic carbon). Adding dispersant inhibited hexadecane and phenanthrene mineralization but did not affect dodecane and 2-methyl-naphthalene mineralization. Thus, the effect of dispersant on biodegradation of a specific hydrocarbon was not predictable by class. The results were consistent for both high and low oiling experiments and for both fresh and weathered oil. Overall, our results indicate that environmental use of Corexit 9500 could result in either increases or decreases in the toxicity of residual oil through selective microbial mineralization of hydrocarbons. (C) 2002 Elsevier Science Ltd. All rights reserved.

RefID: 420

Author: Lipscomb, T.P., Harris, R.K., Moeler,R.B., Pletcher, J.M., Haebler, R.J. and Ballachey, B.E.

Year: 1996

Title: Histopathologic lesions associated with crude oil exposure in sea otters

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/35755790.pdf

Abstract: Following the Exxon Valdez oil spill in Prince William Sound, Alaska, sea otters (Enhydra lutris) that appeared oiled, were in danger of becoming oiled, or were behaving abnormally were captured and taken to rehabilitation centers. Oil exposure was assessed by visual examination on arrival at the centers. Tissues from 51 oiled sea otters and from 6 unoiled sea otters that died in rehabilitation centers were examined histologically. Pulmonary interstitial emphysema, gastric erosion and hemorrhage, centrilobular hepatic necrosis, and hepatic and renal lipidosis were common in oil exposed otters and were absent or uncommon in unoiled otters. Histologic examinations were performed on tissues from 5 sea otters found dead with external oil present shortly after the spill. Hepatic and renal lipidosis was common, and pulmonary interstitial emphysema was found. Necropsies were performed on 214 sea otters that had been collected and frozen in the period following the oil spill. Histologic examination was not performed. Pulmonary interstitial emphysema and gastric erosion and hemorrhage were common in animals with external oil present; these lesions were found much less frequently in animals without detectable external oil. Tissues from 6 apparently normal sea otters collected from an area not affected by the oil spill were examined histologically, and none of these lesions were found. We conclude that pulmonary interstitial emphysema, gastric erosion and hemorrhage, centrilobular hepatic necrosis, and hepatic and renal lipidosis were associated with exposure to crude oil in sea otters.

RefID: 421

Author: Lipscomb, T.P., Harris, R.K., Moeller, R.B., Pletcher, J.M., Haebler, R.J. and Ballachey, B.E.

Year: 1993

Title: HISTOPATHOLOGIC LESIONS IN SEA OTTERS EXPOSED TO CRUDE-OIL

Journal: Veterinary Pathology

Hyperlink: http://alaska.usgs.gov/science/biology/nearshore_marine/pubs/Lipscomp_etal_sea_ott_lesions_Vet_Path_1993.pdf

Abstract: Following the Exxon Valdez oil spill in Prince William Sound, Alaska, sea otters (Enhydra lutris) that appeared to be contaminated with oil, that were in danger of becoming contaminated, or that were behaving abnormally were captured and taken to rehabilitation centers. Exposure to oil was assessed by visual examination when otters arrived at the centers. Degree of oil exposure was graded according to the following criteria: oil covering greater than 60% of the body-heavily contaminated; oil covering 30-60% of the body-moderately contaminated; oil covering less than 30% of the body or light sheen on fur-lightly contaminated. If there was no oil visible, otters were considered uncontaminated. Tissues from 51 oil-contaminated sea otters (14 males, 37 females) and from six uncontaminated sea otters (three males, three females) that died in rehabilitation centers were examined histologically. Among oil-contaminated sea otters, 19/46 had interstitial pulmonary emphysema, 13/40 had gastric erosion and hemorrhage, 11/47 had centrilobular hepatic necrosis, 14/47 had periportal to diffuse hepatic lipidosis, and 10/42 had renal tubular lipidosis. Of the uncontaminated sea otters, 1/6 had gastric erosion and hemorrhage and

1/6 had diffuse hepatic lipidosis. Histologic examinations were performed on tissues from five sea otters (three males, two females) found dead with external oil present 15 to 16 days after the spill. Periportal hepatic lipidosis and renal tubular lipidosis were found in 3/5, and interstitial pulmonary emphysema was found in 1/5. Tissues from six apparently normal sea otters (four males, two females) collected from an area not affected by an oil spill were examined histologically, and none of these lesions were found. We conclude that interstitial pulmonary emphysema, centrilobular hepatic necrosis, and hepatic and renal lipidosis of sea otters were associated with exposure to crude oil. Gastric erosion and hemorrhage may have been associated with stress of captivity and/or oil exposure.

RefID: 422

Author: Lipscomb, T.P., Harris, R.K., Rebar, A.H., Ballachey, B.E. and Haebler, R.J.

Year: 1996

Title: Pathological studies of sea otters

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/35756344.pdf

Abstract: Following the Exxon Valdez oil spill, sea otters were captured and taken to rehabilitation centers. Oil exposure was assessed by visual examination on arrival at the centers. Records of 21 oiled otters that died within 10 days of arrival at the centers were reviewed to define the laboratory abnormalities and clinical syndromes associated with these deaths. The most common terminal syndrome was shock, characterized by hypothermia, lethargy and often hemorrhagic diarrhea. Accompanying laboratory abnormalities included leukopenia, lymphopenia, anemia, azotemia, hyperkalemia, hypoproteinemia/hypoalhuminemia, elevated serum transaminases, and hypoglycemia. Heavily oiled otters developed shock more rapidly and had greater numbers of laboratory abnormalities, suggesting that oil exposure was an important contributing factor. Tissues from 51 oiled and 6 unoiled sea otters that died in the centers were examined histologically. Pulmonary interstitial emphysema, gastric erosion and hemorrhage, centrilobular hepatic necrosis, and hepatic and renal lipidosis were common in oiled otters and were absent or uncommon in unoiled otters. Histologic examinations were performed on tissues from 5 oiled otters found dead shortly after the spill. Hepatic and renal lipidosis was common, and pulmonary interstitial emphysema was found. Necropsies were performed on 214 sea otters that were collected and frozen following the oil spill. Pulmonary interstitial emphysema and gastric erosion and hemorrhage were common in oiled animals, and were less frequent in unoiled animals. Tissues from 6 sea otters collected from a nonoiled area were examined, and none of these lesions were found. We conclude that pulmonary interstitial emphysema, gastric erosion and hemorrhage, centrilobular hepatic necrosis, and hepatic and renal lipidosis were associated with exposure to crude oil in sea otters.

RefID: 423

Author: Liu, B., Romaire, R.P., Delaune, R.D. and Lindau, C.W.

Year: 2006

Title: Field investigation on the toxicity of Alaska North Slope crude oil (ANSC) and dispersed ANSC crude to Gulf killifish, Eastern oyster and white shrimp

Journal: Chemosphere

Hyperlink: http://www.sciencedirect.com/science/article/pii/S004565350500857X

Abstract: A field investigation was conducted on a Louisiana Spartina alterniflora shoreline to evaluate the toxic effects of crude oil (Alaska North Slope crude oil, ANSC) and dispersed oil (ANSC + dispersant Corexit 9500) on three aquatic species indigenous to the Gulf of Mexico: Fundulus grandis (Gulf killifish), Crassostrea virginica (Eastern oyster), and Litopenaeus setiferus (white shrimp). Results indicated that total hydrocarbons concentration value in oiled treatments decreased rapidly in 3 h and were below 1 ppm at 24 h after initial treatment. Corexit 9500 facilitated more ANSC fractions to dissolve and disperse into the water column. L. setiferus showed short-term sensitivity to the ANSC and ANSC + 9500 at 30 ppm. However, most test organisms (> 83%) of each species survived well after 24 h exposure to the treatments. Laboratory tests conducted concurrent with the field investigation indicated that concentrations of crude oil higher than 30 ppm were required for any significant toxic effect on the juvenile organisms tested.

RefID: 424

Author: Lively, J.A.A. and Mckenzie, J.

Year: 2014

Title: Toxicity of the Dispersant Corexit 9500 to Early Life Stages of Blue Crab, Callinectes sapidus

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://download.springer.com/static/pdf/85/art%3A10.1007%2Fs00128-014-1370-y.pdf?auth66=1422994929_87386436db0a6ebbd397a1e5093391e0&ext=.pdf

Abstract: The Deepwater Horizon well released 4.4 million barrels of light crude oil offshore of Louisiana into one of the world's largest and most productive blue crab (Callinectes sapidus) fisheries. The objectives of this paper were to determine the toxicity of the dispersant Corexit (R) 9500A used in the 2010 oil spill on juvenile and larval blue crabs, and the long-term effects of sublethal acute exposure. Only the highest treatment levels of dispersant significantly increased mortality in larval and juvenile blue crabs (100 mg/L and 1,000 mg/L, respectively). This correlated to concentrations well above levels found in the Gulf of Mexico following the spill. Smaller and younger crabs showed higher mortality than older and larger crabs. This research indicates direct application of dispersants on crab larvae could cause acute mortality, but dilution through diffusion and natural weathering processes would minimize long-term effects.

RefID: 425

Author: Lo, C.C., Brownlee, B.G. and Bunce, N.J.

Year: 2006

Title: Mass spectrometric and toxicological assays of Athabasca oil sands naphthenic acids

Journal: Water Research

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/16434073

Abstract: This work concerns the analysis of model naphthenic acids and authentic naphthenic acids from the tailings ponds of the Athabasca tar sands. A first objective was to compare atmospheric pressure chemical ionization mass spectrometry (APCI-MS) with the previously studied electrospray mass spectrometry (ESI-MS) in this analysis. APCI-MS had a wider range of quantitation than ESI-MS, but its detection limit was poorer and model compounds showed greater variation in calibration sensitivity. A second objective was fractionation of naphthenic acids from tailings pond water and analysis by the Microtox (R) toxicity assay. Fractionation on the basis of solubility gave fractions that did not differ significantly either in their congener distribution by ESI-MS or in their response to the Microtox assay. When partial separation was achieved by anion exchange chromatography, fractions with a higher proportion of multi-ring structures exhibited lower toxic potency. This finding is consistent with field observations that indicate that the toxic potency of tailings ponds water declines as the samples age-multi-ring structures are more highly branched and therefore more resistant to microbial degradation.

RefID: 426

Author: Lockhart, W.L., Duncan, D A., Billeck, B.N., Danell, R.A. and Ryan, M J.

Year: 1996

Title: Chronic toxicity of the 'water-soluble fraction' of Norman Wells crude oil to juvenile fish

Journal: Spill Science & Technology Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S1353256197000248

Abstract: Young rainbow trout were exposed to Norman Wells crude oil for periods as long as 55 d. Mortality was light for the first few days, but it continued throughout exposure with more rapid and increased mortality at the higher exposure levels. The mortality was generally exacerbated by the presence of oil dispersants Corexit 7664 or 9600. Fish surviving the 55-day experiment showed severe fin erosion and apparent 'flooding', since mean body water content was increased from about 84% to over 90%. We hypothesize that the oil affected the ability of the fish to regulate their water content. (C) 1997 Elsevier

RefID: 427

Author: Logan, D.T.

Year: 2007

Title: Perspective on ecotoxicology of PAHs to fish

Journal: Human and Ecological Risk Assessment

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/10807030701226749

Abstract: This article provides a perspective on recent research on the effects of PAHs on fish. Fish are visible members of aquatic communities that are vulnerable to PAH contamination. The ecotoxicology of fish and PAHs can be complex. Fish are a diverse group that can have complicated life cycles and behavior and can be exposed to PAH-contaminated sediments and water by a variety of routes, including respiration; ingestion of food, sediment, and detritus; and dermal absorption. PAHs are a complex group of chemicals with similar chemical structure but a variety of chemical and physical attributes and are usually produced and occur in the environment as mixtures. Individual PAHs may elicit a variety of effects in different fish species, and different PAHs may elicit different effects in any single fish species. The variation in both fish and PAHs is reflected in the wide range of adverse effects observed in fish exposed to PAHs. Some observed effects include narcosis, mortality in all life stages, decrease in growth, lower condition factor, edema, cardiac dysfunction, a variety of deformities, lesions and tumors of the skin and liver, cataracts, damage to immune systems and compromised immunity, estrogenic effects, bioaccumulation, bioconcentration, trophic transfer, and biochemical changes, some of which can be used as biomarkers.

RefID: 428

Author: Long, S.M. and Holdway, D.A.

Year: 2002

Title: Acute toxicity of crude and dispersed oil to Octopus pallidus (Hoyle, 1885) hatchlings

Journal: Water Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0043135401005206

Abstract: There is an increasing risk of a major oil spill in Australian waters over the next 20 years but there have been few studies on the impact of oil spills, and subsequent remedial action, on native Australian fauna. Octopus pallidus is a native Australian octopus species found in south-eastern Australia. The aim of the experiment was to investigate the effects of acute exposure to crude and dispersed crude oil and 4-chlorophenol (a reference toxicant) on recently hatched O. pallidus by calculating the 48-h LC50. Water-accommodated fraction (WAF) of Bass Strait crude oil was prepared using a ratio of one part crude oil to nine parts filtered seawater and mixing for 23 h. Dispersed-WAF was prepared using a ratio of one part Corexit 9527 to 50 parts crude oil and an oil to water ratio of one to nine and mixing for 23 h. Mean (SE) 48 h LC50 values were 0.39 (0.04), 1.83 (0.64) and 0.89 (0.08) ppm for WAF, dispersed-WAF and 4 chlorophenol, respectively. These results demonstrate that addition of the chemical dispersant Corexit 9527 to WAF does not increase the toxicity of WAF to O. pallidus hatchlings. (C) 2002 Elsevier Science Ltd. All rights reserved.

RefID: 429

Author: Loughlin, T.R.

Year: 1994

Title: Tissue hydrocarbon levels and the number of cetaceans found dead after the spill

Journal: Marine mammals and the Exxon Valdez

Hyperlink: http://www.amazon.com/Marine-Mammals-Valdez-Thomas-Loughlin/dp/0124561608

Abstract:

RefID: 430

Author: Loughlin, T.R., Ballachey, B.E. and Wright, B.A.

Year: 1996

Title: Overview of studies to determine injury caused by the Exxon Valdez oil spill to marine mammals

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: Marine mammal damage assessment studies after the Exxon Valdez oil spill concentrated on sea otters Enhydra lutris, harbor seals Phoca vitulina, Steller sea lions Eumetopias jubatus, killer whales Orcinus orca, and humpback whales Megaptera novaeangliae. Sea otters and harbor seals were the most affected marine mammal; it was estimated that several thousand otters and several hundred harbor seals died within months of the spill. Steller sea lion, harbor seal, and sea otter numbers were monitored using aerial surveys. Studies of humpback whales and killer whales used photoidentification techniques to determine changes in abundance, distribution, mortality, and natality. Tissues from animals found dead in spill and control areas were analyzed for hydrocarbon levels. Sea otters, sea lions and harbor seals had elevated hydrocarbon levels, but only sea otters and harbor seals showed population declines associated with the spill. Humpback whales were not severely affected by the Exxon Valdez oil spill. Killer whale numbers in the resident AB pod declined after the spill. Coincidental evidence supports the oil spill as the causative agent.

RefID: 431

Author: Lowry, L.F.

Year: 1990

Title: ALASKA'S ROLE IN MITIGATING THE EFFECTS OF THE T-V EXXON VALDEZ OIL SPILL ON SEA OTTERS

Journal: U S Fish and Wildlife Service Biological Report

Hyperlink: https://openlibrary.org/books/OL24349175M/Sea_otter_symposium

Abstract: Sea otters (Enhydra lutris), like other marine mammals but unlike other resident species of wildlife, are managed by Federal agencies, not by the State of Alaska. Much of the habitat essential to the sea otter population is State-owned tidal and submerged lands. It was this nearshore habitat in Prince William Sound and adjacentparts of the Gulf of Alaska that was most severely affected by the T/V Exxon Valdez oil spill. Three State resource agencies were involved in response to the spill—the Alaska Department of Environmental Conservation, Alaska Depaiiznent of Natural Resources, and Alaska Department of Fish emd Game (ADF&G). The ADF&G had a particular interest in sea otters because its charge is the conservation and management of fish and wildlife and their habitats. The Division of Habitat of the ADF&G participated in the development of the Alaska Regional Response Team's Wildlife Protection Guidelines for Alaska, which were used in establishing the sea otter rescue program. The Division of Habitat evaluated the importance of habitats and effects of the spill on them, and made recommendations for mitigating measures and cleanup priorities and techniques. The ADF&G Division of Wildlife Conservation conducted on-site evaluations of the distribution of oil and its effects on marine wildlife during the spill, and made recommendations for mitigation and cleanup. The staff of the ADF&G were not directly involved in the sea otter capture and rehabilitation efforts, but were consulted regarding whether to implement the program and during the development of the sea otter release strategy. Particular concerns of the ADF&G in regard to the release of rehabilitated sea otters were the need to ensure that released sea otters did not introduce disease into wild populations, the selection of

appropriate areas for release, and the need to adequately monitor the fate of released animals.

RefID: 432

Author: Lucas, Z. and Freedman, B.

Year: 1989

Title: The effects of experimental spills of natural gas condensate on three plant communities on Sable Island, Nova Scotia, Canada

Journal: Oil and Chemical Pollution

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0269857989800152

Abstract: We examined the effects of an experimental oiling with natural gas condensate on three plant communities on Sable Island, a sandy, temperate island located 160 km east of Nova Scotia in the Atlantic Ocean. The plant communities were: (i) a dune grassland dominated by Ammophila breviligulata; (ii) a herbaceous beach community dominated by Honckenya peploides; and (iii) a heath dominated by Empetrum nigrum, Myrica pensylvanica, Rosa virginiana, and Vaccinium angustifolium. The experimental treatments were: (i) control; (ii) sprayed with 6·3 litres of condensate/25 m2 and (iii) sprayed with 12·5 litres/25 m2. Initially, in all three communities there was a severe herbicidal effect on most above-ground plant tissues that were directly impacted by the condensate. However, below-ground perennating tissues were little affected by the hydrocarbon treatment, and the vigorous regeneration that issued from these tissues allowed an essentially complete recovery of most species after one or two post-spill growing seasons.

RefID: 433

Author: Luechmann, K.H., Dafre, A.L., Trevisan, R., Craft, J.A., Meng, X., Mattos, J.J., Zacchi, F.L., Dorrington, T.S., Schroeder, D.C. and Bainy, A.C.

Year: 2014

Title: A light in the darkness: New biotransformation genes, antioxidant parameters and tissue-specific responses in oysters exposed to phenanthrene

Journal: Aquatic Toxicology

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/24813265

Abstract: Phenanthrene (PHE), a major component of crude oil, is one of the most abundant polycyclic aromatic hydrocarbons (PAHs) in aquatic ecosystems, and is readily bioavailable to marine organisms. Understanding the toxicity of PAHs in animals requires knowledge of the systems for xenobiotic biotransformation and antioxidant defence and these are poorly understood in bivalves. We report, for the first time, new transcripts and tissue-specific transcription in gill and digestive gland from the oyster Crassostrea brasiliana following 24 h exposure to 100 and 1000 mu g L-1 PHE, a model PAH. Six new cytochrome P450 (CYP) and four new glutathione S-transferase (GST) genes were analysed by means of quantitative reverse transcription PCR (qRT-PCR). Different antioxidant endpoints, including both enzymatic and non-enzymatic parameters, were assessed as potential biomarkers of oxidative stress. GST activity was measured as an indicator of phase II biotransformation. Rapid clearance of PHE was associated with upregulation of both phase land II genes, with more pronounced effects in the gill at 1000 mu g L-1 PHE. After 24 h of exposure, PHE also caused impairment of the antioxidant system, decreasing non-protein thiols and glutathione levels. On the other hand, no change in antioxidant enzymes was observed. PHE treatment (100 mu g L-1) significantly decreased GST activity in the gill of exposed oysters. Both CYP and GST were transcribed in a tissue-specific manner, reflecting the importance of the gill in the detoxification of PAHs. Likewise, the antioxidant parameters followed a similar pattern. The data provide strong evidence that these genes play key roles in C. brasiliana biotransformation of PHE and highlight the importance of gill in xenobiotic metabolism. (C)2014 Elsevier B.V. All rights reserved.

RefID: 434

Author: Luechmann, K.H., Mattos, J.J., Siebert, M.N., Dorrington, T.S., Toledo-Silva, G., Stoco, P.H., Grisard, E.C. and Bainy, A.C.

Year: 2012

Title: Suppressive subtractive hybridization libraries prepared from the digestive gland of the oyster Crassostrea brasiliana exposed to a diesel fuel water-accommodated fraction

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/22505345

Abstract: Diesel fuel can cause adverse effects in marine invertebrates by mechanisms that are not clearly understood. The authors used suppressive subtractive hybridization to identify genes up- and downregulated in Crassostrea brasiliana exposed to diesel fuel. Genes putatively involved in protein regulation, innate immune, and stress response, were altered by diesel challenge. Three genes regulated by diesel were validated by quantitative real-time polymerase chain reaction. This study sheds light on transcriptomic responses of oysters to diesel pollution. Environ. Toxicol. Chem. 2012;31:12491253. (c) 2012 SETAC

RefID: 435

Author: Luechmann, K.H., Mattos, J.J., Siebert, M.N., Granucci, N., Dorrington, T.S., Bicego, M.C., Taniguchi, S., Sasaki, S.T., Daura-Jorge, F.G. and Bainy, A.C.

Year: 2011

Title: Biochemical biomarkers and hydrocarbons concentrations in the mangrove oyster Crassostrea brasiliana following exposure to diesel fuel water-accommodated fraction

Journal: Aquatic Toxicology

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/21963596

Abstract: Understanding the toxic mechanisms by which organisms cope to environmental stressful conditions is a fundamental question for ecotoxicology. In this study, we evaluated biochemical responses and hydrocarbons bioaccumulation of the mangrove oyster Crassostrea brasiliana exposed for 96 h to four sublethal concentrations of diesel fuel water-accommodated fraction (WAF). For that purpose, enzymatic activities (SOD, CAT, GPx, GR, G6PDH, GST and GGT). HSP60 and HSP90 immunocontent and lipid peroxidation (LPO) levels were determined in the gill and digestive gland of oysters and related to the hydrocarbons accumulated in the whole soft tissues. The results of this study revealed clear biochemical responses to diesel fuel WAF exposure in both tissues of the oyster. The capacity of C. brasiliana to bioaccumulate aliphatic and aromatic hydrocarbons in a dose-dependent manner is a strong indication of its suitability as a model in biomonitoring programs along the Brazilian coast, which was also validated by the response of the antioxidant defenses, phase II biotransformation and chaperones. HSP60 levels and GGT activity were the most promising biomarkers in the gill, while GST and GR activities stood out as suitable biomarkers for the detection of diesel toxicity in the digestive gland. The decrease of SOD activity and HSP90 levels may also reflect a negative effect of diesel exposure regardless the tissue. The present results provide a sound preliminary report on the biochemical responses of C. brasiliana challenged with a petroleum by-product and should be carefully considered for use in the monitoring of oil and gas activities in Brazil. (C) 2011 Elsevier B.V. All rights reserved.

RefID: 436

Author: Lyons, B.P., Pascoe, C.K. and McFadzen, I.R.B.

Year: 2002

Title: Phototoxicity of pyrene and benzo a pyrene to embryo-larval stages of the pacific oyster Crassostrea gigas

Journal: Marine Environmental Research

Hyperlink:

Abstract: There is a growing body of evidence to suggest that certain polycyclic aromatic hydrocarbons (PAHs) pose a greater hazard to aquatic organisms than previously demonstrated, due to their potential to cause photo-induced toxicity when exposed to ultraviolet (UV) radiation. The consequences of photo-induced toxicity are reported here for embryo-larval stages of the pacific oyster Crassostrea gigas, following exposure to pyrene and benzo[a]pyrene. During laboratory investigations, significant increases in toxicity were observed in the presence of environmentally attainable levels of UV-radiation, compared with embryos exposed to PAH alone, at levels previously deemed to have little acute biological effect. The phototoxicity of pyrene and benzo[a]pyrene completely inhibited the development to the D-shell larval stage when embryos were simultaneously exposed to 5 mug 1(-1) PAH and ultraviolet light (UVB = 6.3 +/- 0.1 muW/cm(2) and UVA=456.2 +/- 55 muW/cm(2)). A linear relationship was also demonstrated for benzo[a]pyrene phototoxicity with decreasing UV light intensity. Crown Copyright (C) 2002 Published by Elsevier Science Ltd. All rights reserved.

RefID: 437

Author: Lyons, M.C., Wong, D.K.H., Mulder, I., Lee, K. and Burridge, L.E.

Year: 2011

Title: The influence of water temperature on induced liver EROD activity in Atlantic cod (Gadus morhua) exposed to crude oil and oil dispersants

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/21239060

Abstract: Juvenile Atlantic cod were exposed to either the water-accommodated fraction (WAF) or the chemically enhanced water-accommodated fraction (CEWAF) of Mediterranean South American (MESA), a medium grade crude oil at three different temperatures. Two concentrations of each mixture were tested, 0.2% and 1.0% (v/v) at 2, 7 and 10 degrees C. Corexit 9500 was the chemical dispersant tested. The liver enzyme ethoxyresorufin-O-deethylase (EROD) was measured during a 72-h exposure. The WAF of oil had significant (P < 0.05) effect on enzyme activity compared to controls at only one sampling time: 48 h at 10 degrees C. Exposure of CEWAF of oil resulted in significantly (P < 0.05) elevated EROD activity compared to controls. The level of EROD induction was temperature related with higher induction being observed in cod exposed to CEWAF at higher temperatures. Total polycyclic aromatic hydrocarbon (PAH) concentrations in exposure water were significantly higher in chemically dispersed mixtures. While PAH concentrations were lower in the 2 degrees C water compared to 7 or 10 degrees C (8.7 vs 11.9 mu g mL(-1)), the level of EROD induction was approximately 9 and 12 times lower at 2 degrees C compared to 7 or 10 degrees C, respectively, suggesting the metabolic rate of the cod plays a role in the enzyme response. These data suggest the risk of negative impacts associated with exposure to chemically dispersed oil may be affected by water temperature and that risk assessment of potential effects of WAF or CEWAF should consider the effects of water temperature on the physiology of the fish as well as the effectiveness of dispersants. Crown Copyright (C) 2010 Published by Elsevier Inc. All rights reserved.

RefID: 438

Author: MacDonald, G.Z., Hogan, N.S., Koellner, B., Thorpe, K.L., Phalen, L.J., Wagner, B.D. and van den Heuvel, M.R.

Year: 2013

Title: Immunotoxic effects of oil sands-derived naphthenic acids to rainbow trout

Journal: Aquatic Toxicology

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/23159729

Abstract: Naphthenic acids are the major organic constituents in waters impacted by oil sands. To investigate their immunotoxicity, rainbow trout (Oncorhynchus mykiss) were injected with naphthenic acids extracted from aged oil sands tailings water. In two experiments, rainbow trout were injected intraperitoneally with 0, 10, or 100 mg/kg of naphthenic acids, and sampled after 5 or 21 d. Half of the fish from the 21 d exposure were co-exposed to inactivated Aeromonas salmonicida (A.s.) to induce an immune response. A positive control experiment was conducted using an intraperitoneal injection of 100 mg/kg of benzo[a]pyrene, a known immune suppressing compound. T-lymphocytes, B-lymphocytes, thrombocytes, and myeloid cells were counted in blood and lymphatic tissue using flow cytometry. In the 5 d exposure, there was a reduction in blood leucocytes and spleen thrombocytes at the 100 mg/kg dose. However, at 21 d, leucocyte populations showed no effects of exposure with the exception that spleen thrombocyte populations increase at the 100 mg/kg dose. In the 21 d exposure, B- and T-lymphocytes in blood showed a significant Dose x A.s, interaction, indicating stimulated blood cell proliferation due to naphthenic acids alone as well as due to A.s. Naphthenic acid injections did not result in elevated bile fluorescent metabolites or elevated hepatic EROD activity. In contrast to naphthenic acids exposures, as similar dose of benzo[a]pyrene caused a significant decrease in B- and T-lymphocyte absolute counts in blood and relative B-lymphocyte counts in spleen. Results suggest that the naphthenic acids may act via a generally toxic mechanism rather than by specific toxic effects on immune cells. (C) 2012 Elsevier B.V. All rights reserved.

RefID: 439

Author: Macdonald, R.W., Morton, B. and Johannessen, S.C.

Year: 2003

Title: A review of marine environmental contaminant issues in the North Pacific: The dangers and how to identify them

Journal: Environmental Reviews

Hyperlink: http://www.nrcresearchpress.com/doi/pdf/10.1139/a03-017

Abstract: Chemical contaminants in the North Pacific Ocean include hydrocarbons,persistent organic pollutants, metals, persistent solids, and domestic pollutants. Here, we review contaminant research conducted over the past decade, finding that the effects ofcontaminants cannot be considered in isolation from other major factors causing change toNorth Pacific ecosystems. Climate change, over-fishing, habitat destruction, eutrophication, and the introduction of exotic species interact with one another and alter contaminantpathways. Climate change and over-fishing are perceived as the main threats to the remoten orthern marginal seas, the central North Pacific, and the west coast of North America,with contaminants engendering local concern, especially in semi-enclosed bodies of water. Climate change receives less attention in Asian waters, probably because widespread habitatdestruction and contamination provide, by themselves, an impending ecological disaster.A systematic approach is urgently required to recognize and prioritize the threats to NorthPacific coastal ecosystems. This should include box models, case studies, proxy records, andtime series. The ocean should be monitored as a system, including physical media (water,sediment) and the full trophic range of the food web, and tissues should be preserved ina rchives to provide a resource for understanding emerging concerns.
Finally, the developmentof ecological indicators is urgently required to provide a robust warning system based on the health of the marine ecosystems themselves. It is time to conduct a multi-national assessmentof the North Pacific Ocean to develop a common, factual awareness of the threats loomingover our coastal waters

RefID: 440

Author: MacFarlane, G.R., Reid, D J. and Esguerra, C.A.

Year: 2004

Title: Sublethal behavioral effects of the water accommodated fractions of crude oil to gastropod molluscs

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/15266701

Abstract:

RefID: 441

Author: Macías-Zamora, J.V., Meléndez-Sanchéz, A.L., Ramírez-Álvarez, N., Gutiérrez-Galindo, E.A. and Orozco-Borbón, M.V.

Year: 2014

Title: On the effects of the dispersant Corexit 9500((c)) during the degradation process of n-alkanes and PAHs in marine sediments

Journal: Environmental Monitoring and Assessment

Hyperlink: http://link.springer.com/article/10.1007%2Fs10661-013-3438-2

Abstract: In many coastal countries, oil spill contingency plans include several alternatives for removal of the spilled oil from the ocean. Frequently, these plans include dispersants. Because this process applies chemical substances that may add toxicity to oil that already contains toxic compounds, it is, at times, a controversial method to fight oil pollution. Additionally, local conditions may result in particular complications. We investigated the possible effects of the dispersant Corexit 9500A (c) under conditions similar to those of subtropical oceans. We used fuel oil #6+ diesel as the test mixture. Under certain conditions, at least part of the dispersed oil may reach the sediment, particularly if the dispersant is applied in coastal waters. Nine experimental units were used in this experiment. Similar conditions of water temperature, salinity, air fluxes into the experimental units, and hydrocarbon concentrations in sediments were used. Two treatments and one control, each one with three replicates, were carried out. We concentrated our investigation on sediment, although measurements of water were also taken. Our results suggest that once the oil has penetrated the sediment, no significant differences exist between oil that contains dispersant and oil without dispersant. Noticeable degradation of aliphatic hydrocarbons occurred mainly in the low molecular weight aliphatic hydrocarbons and not in the others. Apparently, degradation of aromatics was easier than that of alkanes. However, some differences were noticed for the degradation of PAHs in the sediment, suggesting a faster degradation under particular conditions in aerobic environments such as under this experiment.

RefID: 442

Author: Macinnis-Ng, C.M.O. and Ralph, P.J.

Year: 2003

Title: In situ impact of petrochemicals on the photosynthesis of the seagrass Zostera capricorni

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X0300290X

Abstract: We used photosynthetic activity (measured as chlorophyll a fluorescence) and photosynthetic pigment concentrations to assess the effect of pulsed exposures of aged crude oil (Champion Crude), dispersant (VDC) and an oil + dispersant mixture on the seagrass Zostera capricorni Aschers in laboratory and field experiments, using custom-made chambers. Samples were exposed for 10 It to 0.25% and 0.1% concentrations of aged crude oil and dispersant as well as mixtures of 0.25% oil + 0.05% dispersant and 0.1% oil + 0.02% dispersant. During this time and for the subsequent four day recovery period, the maximum and effective quantum yields of photosystem II (Fv/Fm and DeltaF/Fm' respectively) were measured. In the laboratory experiments, both values declined in response to oil exposure and remained low during the recovery period. Dispersant exposure caused a decline in both values during the recovery period, while the mixture of aged crude oil + dispersant had little impact on both quantum yields. In situ samples were less sensitive than laboratory samples, showing no photosynthetic impact due to dispersant and oil + dispersant mixture. Despite an initial decline in DeltaF/Fm', in situ oil-exposed samples recovered by the end of the experiment. Chlorophyll pigment analysis showed only limited ongoing impact in both laboratory and field situations. This study suggests that laboratory experiments may overestimate the ongoing impact of petrochemicals on seagrass whilst the dispersant VDC can reduce the impact of oil on seagrass photosynthesis. (C) 2003 Elsevier Ltd. All rights reserved.

RefID: 443

Author: Madill, R.E.A., Brownlee, B.G., Josephy, P.D. and Bunce, N.J.

Year: 1999

Title: Comparison of the Ames Salmonella assay and Mutatox genotoxicity assay for assessing the mutagenicity of polycyclic aromatic compounds in porewater from Athabasca oil sands mature fine tailings

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es981343o

Abstract: The oil sands in the Athabasca region of northeastern Alberta, Canada, represent a significant hydrocarbon resource that is currently exploited by mining, followed by separation of bitumen from sand using hot water flotation. This process generates large quantities of bitumen-contaminated tailings. Current research involves an assessment of whether the tailings ponds can ultimately be converted to biologically productive lakes, with one unresolved issue being the toxicity of the polycyclic aromatic compounds (PACs) that might be released from the tailings. In this paper, we have identified several polycyclic aromatic hydrocarbons in the porewater from oil sands mature fine tailings and have compared the responses of 17 PACs in the Ames and Mutatox genotoxicity assays. The Mutatox assay was unsuitable as a surrogate for the Ames test in this application; poor(50%) concordance between the hive assays occurred because the mechanism of light emission in the Mutatox assay is un certain, leading to positive responses that could not be unambiguously associated with genotoxicity. Benzo[a]pyrene equivalency factors (BEFs) in the Ames assay were determined for a large number of PACs, from this work and from literature data, to express the genotoxic potencies of environmental mixtures in terms of benzo[a]pyrene equivalent concentrations (BEQs). In the case of porewater samples obtained from the mature fine tailings, even extracts concentrated 10,000-fold we re below the detection limit of 1 mu g/L BEQ, consistent with the value of 0.14 mu g/L calculated using BEFs of PACs identified in the porewater.

RefID: 444

Author: Madison, B.N., Hodson, P.V. and Langlois, V.S.

Year: 2015

Title: Diluted bitumen causes deformities and molecular responses indicative of oxidative stress in Japanese medaka embryos

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X15001782

Abstract: This study characterized the toxicity and physiological effects of unweathered diluted bitumen (Access Western Blend dilbit; AWB) to fish. Embryos of Japanese medaka (Oryzias latipes) were exposed for 17 days to dilutions of physically-dispersed (water accommodated fraction; WAF) and chemically-dispersed (chemically-enhanced WAF; CEWAF) dilbit. AWB dilbit exposure was not lethal to medaka, but resulted in a high prevalence of blue sac disease (BSD), impaired development, and abnormal or un-inflated swim bladders at hatch. Physiological effects were indicated by the relative mRNA levels of key genes associated with, among others, cell cycling and the response to mutations (p53), xenobiotic metabolism (ahr, arnt2), phase I (cyp1a) and II processes associated with oxidative stress (cat, g6pdh, hsp70, gst, gpx, gsr, nfe2, and sod). AWB dilbit treatment increased p53 and cyp1a transcript levels (1.5-fold and >15-fold, respectively), with significant, but less pronounced changes in indicators of oxidative stress and metabolism. The exposure-related changes in embryotoxicity and mRNA synthesis were consistent with metabolism of polycyclic aromatic hydrocarbons (PAHs) to reactive and toxic metabolites. Medaka embryos responded similarly to WAF and CEWAF treatments, but CEWAF was about 100 times more efficient in delivering toxic concentrations of PAHs. The toxicity of chemically-dispersed nujol, a non-toxic mineral oil used as an experimental control, suggested that a portion of the observed effects of AWB could be attributed to excess dispersant in solution. This first study of the physiological effects of dilbit toxicity to fish embryos provides a baseline to compare toxicity between dilbit and conventional crude oils, and the groundwork for the development of molecular biomarkers of the sensitivity and level of risk of native Canadian fish species to dilbit exposure.

RefID: 445

Author: Mager, E.M., Esbaugh, A.J., Stieglitz, J.D., Hoenig, R., Bodinier, C., Incardona, J.P., Scholz, N.L., Benetti, D.D. and Grosell, M.

Year: 2014

Title: Acute Embryonic or Juvenile Exposure to Deepwater Horizon Crude Oil Impairs the Swimming Performance of Mahi-Mahi (Coryphaena hippurus)

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es501628k

Abstract: The Deepwater Horizon incident likely resulted in exposure of commercially and ecologically important fish species to crude oil during the sensitive early life stages. We show that brief exposure of a water-accommodated fraction of oil from the spill to mahi-mahi as juveniles, or as embryos/larvae that were then raised for similar to 25 days to juveniles, reduces their swimming performance. These physiological deficits, likely attributable to polycyclic aromatic hydrocarbons (PAHs), occurred at environmentally realistic exposure concentrations. Specifically, a 48 h exposure of 1.2 +/- 0.6 mu g L-1 Sigma PAHs (geometric mean +/- SEM) to embryos/larvae that were then raised to juvenile stage or a 24 h exposure of 30 +/- 7 mu g L-1 Sigma PAHs (geometric mean +/- SEM) directly to juveniles resulted in 37% and 22% decreases in critical swimming velocities (U-crit), respectively. Oil-exposed larvae from the 48 h exposure showed a 4.5-fold increase in the incidence of pericardial and yolk sac edema relative to controls. However, this larval cardiotoxicity did not manifest in a reduced aerobic scope in the surviving juveniles. Instead, respirometric analyses point to a reduction in swimming efficiency as a potential alternative or contributing mechanism for the observed decreases in U-crit.

RefID: 446

Author: Mahon, S., Addison, R.F. and Willis, D.E.

Year: 1987

Title: Effects of Scotian shelf natural gas condensate on the mummichog

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/0025326X87905716

Abstract: The 96h LC50 of the water soluble fraction (WSF) of natural gas condensate from the Sable Is., N.S. area to Fundulus heteroclitus was between 4 and 5 µg · ml−1 naphthalene equivalents (initial concentration). Behavioural responses in the fish to sub-lethal concentrations of WSF were similar to those recorded for crude and fuel oils. Induction of the hepatic mixed function oxidase enzyme enthoxyresorufin O-de-ethylase (EROD) in sexually immature fish occurred at WSF concentrations below the LC50, but during the prespawning period no induction occurred. EROD activity in unexposed fish showed seasonal variation consistent with differences in its inducibility.

RefID: 447

Author: Maki, A.W., Brannon, E.J., Gilbertson, L.G., Moulton, L.L. and Skalski, J.R.

Year: 1995

Title: An assessment of oil-spill effects on pink salmon populations following the Exxon Valdez oil spill - Part II: Adults and escapement

Journal: Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters

Hyperlink: http://www.valdezsciences.com/dspArticle.cfm?catID=2&artID=1034&artSecID=1024

Abstract: This paper presents results of a field program designed to monitor the status of wildstock pink salmon populations in Prince William Sound following the Exxon Valdez oil spill. Field counts of spawning salmon were conducted each year from 1989 through 1992 to test for spill effects on the distribution and abundance of pink salmon adults spawning in selected streams in the southwestern portion of Prince William Sound, including streams from the most heavily oiled areas. Counts of whole-stream and intertidal escapement density were statistically compared for 40 study streams in 1989 and for a subset of those streams in successive years. Measurements of residual hydrocarbons were made from stream-bed sediments to test for correlations with spawning behavior Adult pink salmon in the postspill years of 1990 and 1991, progeny of the year classes considered most vulnerable to the oil spill, returned in high numbers, with the wildstock spawners exceeding their parent year returns. In 1989, adult returns reflected the relatively weak run for that year with a mean spawner density of 0.68 fish/m2 in reference streams and 0.69 fish/m2 in oiled streams. In 1990, mean escapement density for reference streams was 1.40 fish/m2 and 1.55 fish/m2 for oiled streams, indicating the strongest run of the four study years.

Trends in polycyclic aromatic hydrocarbon (PAH) concentrations for the majority of oiled streams show a general decline from 1989 to background levels by 1990. The measured PAH concentrations indicate low-level exposure to residual hydrocarbons that have not produced detectable differences in spawning behavior or escapement between streams from oiled areas compared with unoiled streams. In Part I of this paper, elements of the early lifestage survival of potentially affected year classes of pink salmon were examined by Brannon et al. (this volume). Conclusions indicate measures of early lifestages were largely indistinguishable between oiled and unoiled streams. The early lifestage data, in combination with observations of the strength of postspill returns and analyses of escapement reported herein, are the basis for the conclusion that changes in the wildstock pink salmon population in Prince William Sound could not be attributed to the oil spill.

RefID: 448

Author: Mann, K.H. and Clark, R.B.

Year: 1978

Title: SESSION III. Summary and Overview: Long-Term Effects of Oil Spills on Marine Intertidal Communities

Journal: Journal of the Fisheries Research Board of Canada

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f78-128

Abstract:

RefID: 449

Author: Manzetti, S.

Year: 2012

Title: Ecotoxicity of polycyclic aromatic hydrocarbons, aromatic amines, and nitroarenes through molecular properties

Journal: Environmental Chemistry Letters

Hyperlink: http://link.springer.com/article/10.1007%2Fs10311-012-0368-0

Abstract: Air, marine, and terrestrial pollution are continuously critical issues to be solved in environmental sciences. Particularly with the recent disaster in the Mexico Gulf and the risk of oil spills from the continuous offshore drilling activities in the North Sea, ecotoxicological profiling requires great attention. Fjord ecosystems are particularly neglected marine ecosystems, which require better surveillance and ecotoxicological profiling. In this context, this study focuses on exploring three potential indicators for aquatic stress [polycyclic aromatic hydrocarbons (PAHs), aromatic amines (AAs), and nitroarenes (NAs)] by the study of their molecular and sub-molecular properties. The results show that the aromatic amine, 4-aminobiphenyl, gains a particularly reactive electronic potential, which can be summarized as a large change in LUMO+2 and HOMO-1 electron orbitals upon metabolic activation in the organism. This change in orbitals increases the overall electrostatic energy of the molecule, inducing a high affinity for DNA-adduct formation. Electronic analysis on nitroarenes shows in addition why 1,6-dinitropyrene is more stable than 1,8-dinitropyrene, and how the electrons favor nitrenium activation on the 6th and 8th carbon. Further analysis shows also that PAHs have a present correlation with hormonal similarity, and that their resemblance to estrogen can be correlated to mutagenicity, contributing to increased ecotoxicity. The electronic analysis of these three types of fossil pollutants shows how their toxicity is exerted from the electronic level and which structural features that determine the level of reactivity and toxicity. The summation of the background and electronic properties of these molecular toxins elucidates that PAHs, aromatic amines, and nitroarenes are all of equal importance as stress indicators for fjord systems, with particular emphasis on PAHs, which also exert hormonal structural similarities as a probable base of their carcinogenic mechanisms.

RefID: 450

Author: Martin, J.D., Adams, J., Hollebone, B., King, T., Brown, R.S, and Hodson, P.V.

Year: 2014

Title: Chronic toxicity of heavy fuel oils to fish embryos using multiple exposure scenarios

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.2486/abstract;jsessionid=1A66DD510CB9B3A3130F5C45B00B8F1F.f04t03

Abstract: The chronic toxicity to rainbow trout (Oncorhynchus mykiss) embryos of heavy fuel oil (HFO) 6303, weathered HFO 6303, HFO 7102, and medium South American (MESA) crude oil was assessed by different exposure regimes. These included water accommodated fractions (WAF; water in contact with floating oil), chemically enhanced WAF (CEWAF; oil dispersed with Corexit 9500), and effluent from columns of gravel coated with stranded oil. Heavy fuel oil WAF was nontoxic and did not contain detectable concentrations of hydrocarbons, likely because the high density and viscosity of HFO prevented droplet formation. In contrast, chemically dispersed HFO and effluent from columns of stranded HFO contained measurable concentrations of alkyl polycyclic aromatic hydrocarbons (PAH), coincident with embryo toxicity. These exposure regimes enhanced the surface area of oil in contact with water, facilitating oil-water partitioning of hydrocarbons. Heavy fuel oil was consistently more toxic to fish than crude oil and the rank order of alkyl PAH concentrations in whole oil were sufficient to explain the rank order of toxicity, regardless of exposure method. Thus, the propensity of HFO to sink and strand in spawning shoals creates a long-term risk to developing fish because of the sustained release of PAHs from HFO to interstitial waters. Further, PAH monitoring is key to accurate risk assessment. Environ Toxicol Chem 2014;33:677-687. (c) 2013 SETAC

RefID: 451

Author: Martinez-Gómez, C., Vethaak, A.D., Hylland, K., Burgeot, T., Kohler, A., Lyons, B.P., Thain, J., Gubbins, M.J. and Davies, I.M.

Year: 2010

Title: A guide to toxicity assessment and monitoring effects at lower levels of biological organization following marine oil spills in European waters

Journal: Archives of Environmental Contamination and Toxicology

Hyperlink: http://icesjms.oxfordjournals.org/content/67/6/1105

Abstract: The usefulness of applying biological-effects techniques (bioassays and biomarkers) as tools to assist in evaluating damage to the health of marine ecosystems produced by oil spills has been demonstrated clearly during recent decades. Guidelines are provided for the use of biological-effects techniques in oil spill pollution monitoring for the NE Atlantic coasts and the NW Mediterranean Sea. The emphasis is on fish and invertebrates and on methods at lower levels of organization (in vitro, suborganismal, and individual). Guidance is provided to researchers and environmental managers on: hazard identification of the fuel oil released; selection of appropriate bioassays and biomarkers for environmental risk assessment; selection of sentinel species; the design of spatial and temporal surveys; and the control of potential confounding factors in the sampling and interpretation of biological-effects data. It is proposed that after an oil spill incident, a monitoring programme using integrated chemical and biological techniques be initiated as soon as possible for ecological risk assessment, pollution control, and monitoring the efficacy of remediation. This can be done by developing new biomonitoring programmes or by adding appropriate biological-effects methods to the existing monitoring programmes.

RefID: 452

Author: Martínez-Jerónimo, F., Villaseñor, R., Ríos, G. and Espinosa-Chavez, F.

Year: 2005

Title: Toxicity of the crude oil water-soluble fraction and kaolin-adsorbed crude oil on Daphnia magna (Crustacea : Anomopoda)

Journal: Ices Journal of Marine Science

Hyperlink: http://link.springer.com/article/10.1007%2Fs00244-003-0220-4

Abstract: Crude oil is a complex mixture of hydrocarbons entering aquatic environments from accidental or normal marine and transportation activities. Toxicologic crude oil analysis is usually performed on the basis of the water-soluble fraction. However, this yields only a partial estimate of the damage caused by these contaminants because a substantial hydrophobic amount can be adsorbed onto suspended solids (biotic and abiotic), which directly affects filter-feeding species and permits bioaccumulation through trophic relationships. This study determined the acute toxic damage sustained after 48 hours caused by seven types of crude oil from Tabasco, Mexico on the cladoceran Daphnia magna. Comparisons were documented based on the responses of D. magna from application of the water-soluble fraction and exposure to entire crude oil samples adsorbed on kaolin clay. Oil-sorbed kaolin was more toxic than the water-soluble fraction in acute exposure. This confirms that tests of the water-soluble fraction tend to underestimate the toxic damage that can be produced in natural environments. Furthermore, chronic toxicity (21 days) was evaluated for crude oil samples adsorbed on kaolin at sublethal concentrations as established from Application Factors (AF) criteria. Results showed that in most cases, it is impossible to predict safe concentrations on the basis of LC50 values because samples with lower acute toxicity exercised a greater influence on D. magna reproduction and survival when subjected to chronic exposure.

RefID: 453

Author: Marty, G.D.

Year: 2008

Title: Effects of the Exxon Valdez oil spill on Pacific herring in Prince William Sound, Alaska

Journal: Toxicology of Fishes

Hyperlink: http://www.crcpress.com/product/isbn/9780415248686

Abstract: Summary: Oil spilled from the Exxon Valdez caused significant damage to Pacific herring larvae and adults in 1989. Decreased concentrations of oil in the water column by 1990 were correlated with an absence of significant effects in Pacific herring in 1990 and beyond. Severe population decline occurred just 4 years after the spill, but direct links to the spill were not detected. Because Pacific herring commonly are infected with a potentially deadly virus (viral hemorrhagic septicemia virus), and stress results in virusoutbreaks, Pacific herring are unusually sensitive to spilled oil or other abnormal stressors during physiologically demanding periods of their life cycle such as spring spawning. As a result, oil spills that overlap with Pacific herring spawning are likely to cause greater population damage than oil spills that occur at other times of the year.

RefID: 454

Author: Marty, G.D., Hoffmann, A., Okihiro, M.S., Hepler, K. and Hanes, D.

Year: 2003

Title: Retrospective analysis: bile hydrocarbons and histopathology of demersal rockfish in Prince William Sound, Alaska, after the Exxon Valdez oil spill

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0141113603000436

Abstract: Demersal rockfish are the only fish species that have been found dead in significant numbers after major oil spills, but the link between oil exposure and effect has not been well established. After the 1989 Exxon Valdez oil spill in Prince William Sound, Alaska, several species of rockfish (Sebastes spp.) front oiled and reference sites were analyzed for hydrocarbon metabolites in bile (1989-1991) and for microscopic lesions (1990 and 1991). Biliary hydrocarbons consistent with exposure to Exxon Valdez oil were elevated in 1989, but not in 1990 or 1991. Significant microscopic findings included pigmented macrophage aggregates and hepatic megalocytosis, fibrosis, and lipid accumulation. Site differences in microscopic findings were significant with respect to previous oil exposure in 1991 ($P=0.038$), but not ill 1990. However, differences in microscopic findings were highly significant with respect to age and species in both years ($P<0.001$). We conclude that demersal rockfish were exposed to Exxon Valdez oil in 1989, but differences in microscopic changes in 1990 and 1991 were related more to age and species

differences than to previous oil exposure. (C) 2003 Elsevier Ltd. All rights reserved.

RefID: 455

Author: Marty, G.D., Hose, J.E., McGurk, M.D., Brown, E.D. and Hinton, D.E.

Year: 1997

Title: Histopathology and cytogenetic evaluation of Pacific herring larvae exposed to petroleum hydrocarbons in the laboratory or in Prince William Sound, Alaska, after the Exxon Valdez oil spill

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f97-091

Abstract: Following the 1989 Exxon Valdez oil spill in Prince William Sound, Alaska, USA, Pacific herring (Clupea pallasi) larvae sampled from oiled sites had ascites, pericardial edema, and genotoxic damage. Laboratory study confirmed that these lesions were consistent with oil exposure. Pacific herring larvae were trawled from two oiled and two unoiled sites in Prince William Sound in May 1989. Larvae from oiled sites were shorter, had ingested less food, had slower growth (oiled, 0.07-0.10 mm/day; unoiled, 0.15-0.18 mm/day), and had higher prevalence of cytogenetic damage (oiled, 56-84%; unoiled, 32-40%) and ascites (oiled, 16%; unoiled, 1%) than from unoiled sites. In the laboratory experiment Pacific herring eggs were exposed to an oil-water dispersion of Prudhoe Bay crude oil (initial concentrations of 0.0, 0.10, 0.24, 0.48, and 2.41 mg/L) and sampled for histopathology <24 h after hatching. Effects were significant at the 0.48 mg/L dose (Dunnett's procedure, $P < 0.05$). Lesions included ascites; hepatocellular vacuolar change and degeneration or necrosis of skeletal myocytes, retinal cells, and developing brain cells. Lesions in field-sampled larvae were consistent with higher mortality rates documented in lan ae from oiled sites.

RefID: 456

Author: Marty, G.D., Okihiro, M.S. and Hinton, D.E.

Year: 2000

Title: Fish histopathology damage assessment after the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/45280904.pdf

Abstract: Tissue samples from 4 fish species were examined for microscopic lesions after the Exxon Valdez oil spill: 1) Dolly Varden char Salvelinus mulmu adults (1990 only); 2) Pacific herring Clupeu hurengus larvae (1989 and 1990) and adults (1989 - 1992); 3) several rockfish Sebastes spp. adults (1990 and 1991); and 4) pink salmon Oncorhynchus gorbuscha larvae (1989 - 1991) and adults (1990). For each group of fish, samples from both oiled and reference sites were examined. In Dolly Varden char, hepatic lipidosis and megalocytosis were the major histopathologic markers separating exposed from reference sites. In adult herring in 1989, hepatocellular necrosis occurred in fish from exposed sites only. In larval herring in 1989, ascites prevalence was significantly greater in fish from oiled sites. Adult pink salmon had no lesions significantly related to oil exposure. Larval and juvenile pink salmon had few lesions; those most likely related to oil exposure were renal tubular necrosis and vascular thrombosis. In rockfish species from 1990 and 1991, hepatocellular lipidosis and macrophage aggregates in the liver, spleen, and kidney were the major histopathologic markers separating exposed from reference sites; based on lack of documented exposure, however, these probably resulted from site differences other than oil exposure.

RefID: 457

Author: Marty, G.D., Okihiro, M.S., Brown, E.D., Hanes, D. and Hinton, D.E.

Year: 1999

Title: Histopathology of adult pacific herring in Prince William Sound, Alaska, after the Exxon Valdez oil spill

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f98-178

Abstract: Pacific herring (Clupea pallasi) sampled from oiled sites in Prince William Sound, Alaska, U.S.A., 3 weeks after the 1989 Exxon Valdez oil spill had multifocal hepatic necrosis and significantly increased tissue concentrations of polynuclear aromatic hydrocarbons (PAH). By comparison, Pacific herring from reference sites in 1989 and from all sites in 1990 and 1991 did not have hepatic necrosis or increased PAH concentrations. Adult Pacific herring were sampled for histopathology of liver, spleen, and kidney from oiled and reference sites in April (1989 and 1991) and October (1990 and 1991). Increased scores for macrophage aggregates contributed to significant differences in 1990, but these differences probably resulted from sampling older fish from the oiled site. Naphthalenes were the predominant PAH in all tissue samples. The development of hepatic necrosis and the predominance of naphthalenes in samples from 1989 is consistent with recent laboratory study in which crude oil exposure resulted in dose-dependent expression of viral hemorrhagic septicemia virus (VHSV). We conclude that Pacific herring were exposed to Exxon Valdez oil in 1989 and that development of hepatic necrosis in exposed fish probably was a result of VHSV expression.

RefID: 458

Author: Marty, G.D., Short, J.W., Dambach, D.M., Willits, N.H., Heintz, R.A., Rice, S.D., Stegeman, J.J. and Hinton, D.E.

Year: 1997

Title: Ascites, premature emergence, increased gonadal cell apoptosis, and cytochrome P4501A induction in pink salmon larvae continuously exposed to oil-contaminated gravel during development

Journal: Canadian Journal of Zoology

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/z97-120

Abstract: Development of pink salmon (Oncorhynchus gorbuscha) incubating in gravel contaminated with weathered Prudhoe Bay crude oil was retarded at concentrations as low as 55.2 mu g oil/g gravel. Larvae exposed to various levels of oil contamination were sampled 4 weeks before emergence, at emergence, and 13 days after emergence for histopathology (quantitative and semiquantitative) and cytochrome P4501A (CYP1A) induction (using immunohistochemical staining). A subset of postemergent fish was not fed. Hydrocarbon analysis by gas chromatography and mass spectroscopy revealed that tissue uptake of polynuclear aromatic hydrocarbons (PAH) was mediated by oil's dissolution in water, with significant biological effects when the peak total PAH concentration in water was as low as 4.4 mu g/L. Oil-related effects included induction of CYP1A, development of ascites, and increased mortality. Several oil-related changes were indicative of premature emergence. Compared with control fish, for example, exposed fish of the same age and emerging on the same day had greater amounts of yolk and hepatocellular glycogen, increased apoptosis of gonadal cells and midventral skin cells, and less food in the gastrointestinal tract. Histological features were similar within groups of larvae sampled 4 weeks before and 13 days after emergence, and oil-induced changes were not affected by feeding during the first 13 days after emergence. Increased gonadal cell apoptosis may be related to later reproductive impairment documented in field studies of pink salmon up to 4 years after the Exxon Valdez oil spill.

RefID: 459

Author: Matkin, C.O., Ellis, G.M., Dahlheim, M.E. and Zeh, J.

Year: 1994

Title: Status of killer whales in Prince William Sound, 1985-1992

Journal: Marine mammals and the Exxon Valdez

Hyperlink: http://www.amazon.com/Marine-Mammals-Valdez-Thomas-Loughlin/dp/0124561608

Abstract:

RefID: 460

Author: Matkin, C.O., Saulifis, E.L., Ellis, G.M., Olesiuk, P. and Rice, S.D.

Year: 2008

Title: Ongoing population-level impacts on killer whales Orcinus orca following the 'Exxon Valdez' oil spill in Prince William Sound, Alaska

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v356/p269-281/

Abstract: Killer whales were photographed in oil after the 1989 'Exxon Valdez' oil spill, but preliminary damage assessments did not definitively link mortalities to the spill and could not evaluate recovery. In this study, photo-identification methods were used to monitor 2 killer whale populations 5 yr prior to and for 16 yr after the spill. One resident pod, the AB Pod, and one transient population, the AT1 Group, suffered losses of 33 and 41%, respectively, in the year following the spill. Sixteen years after 1989, AB Pod had not recovered to pre-spill numbers. Moreover, its rate of increase was significantly less than that of other resident pods that did not decline at the time of the spill. The AT1 Group, which lost 9 members following the spill, continued to decline and is now listed as depleted under the Marine Mammal Protection Act. Although there may be other contributing factors, the loss of AT1 individuals, including reproductive-age females, accelerated the population's trajectory toward extinction. The synchronous losses of unprecedented numbers of killer whales from 2 ecologically and genetically separate groups and the absence of other obvious perturbations strengthens the link between the mortalities and lack of recovery, and the 'Exxon Valdez' oil spill.

RefID: 461

Author: Mazet, J.A,, Gardner, I.A., Jessup, D.A. and Lowenstine, L.J.

Year: 2001

Title: Effects of petroleum on mink applied as a model for reproductive success in sea otters

Journal: Journal of Wildlife Diseases

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/11763732

Abstract: Ranch-reared mink (Mustela vison) were used as a model in an experimental trial to investigate the potential effects of exposure to two petroleum products on sea otters (Enhydra lutris). Mink were exposed either dermally on one occasion 60 days prior to breeding or via low level contamination of their diets daily from 30 days prior to breeding (January 1994) until weaning of kits (June 1994). For dermal exposure, we placed mink in either a slick of Alaskan North Slope crude oil (n = 24) or bunker C fuel oil (n = 24) on sea water or sea water alone (n = 10) for 1 min. For dietary exposure, we fed mink rations containing 500 ppm of either Alaskan North Slope crude oil (n = 24) or bunker C fuel oil (n = 24; control, n = 15). The number of liveborn kits did not differ significantly among mink exposed dermally (5.0 kits/female for crude oil and 6.5 kits/female for bunker C fuel oil) and unexposed controls (5.3 kits/female). However, only 2.3 and 0.7 kits were produced per female for those exposed through the diet to crude oil and bunker C fuel oil, respectively. Females with reduced reproductive success had no clinical signs of toxicosis or behavioral abnormalities. In addition, kits of females exposed through the diet had poor survival to weaning. Once mature, kits born to females exposed to bunker C fuel oil in the diet had significantly reduced reproductive success (3.4 kits/female) although their only exposure to the petroleum products was in utero or during nursing. Therefore, it is possible that sea otter populations consuming contaminated food sources or colonizing previously oiled habitats will have reduced reproductive success.

RefID: 462

Author: McGurk, M.D. and Brown, E.D.

Year: 1996

Title: Egg-larval mortality of Pacific herring in Prince William Sound, Alaska, after the Exxon Valdez oil spill

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f96-172

Abstract: We tested the hypothesis that instantaneous daily rates of egg-larval mortality of Pacific herring, Clupea pallasi, were greater at two oil-exposed sites than at two nonexposed sites. Egg-larval mortality is defined as the ratio of larval density at hatch to mean egg density divided by the number of elapsed days between the dates of the two estimates. There were significant differences between sites in egg density, small differences between sites in mean larval length, and no oil-related differences between sites in the rates of larval growth and loss. However, mean egg-larval mortality in the two oiled areas was twice as great as in the two nonoiled areas, and larval growth rates were about half those measured in populations from other areas of the north Pacific Ocean. These findings support the hypothesis of oil injury to herring embryos and larvae.

RefID: 463

Author: McGurk, M.D., Warburton, H.D., Parker, T.B., Litke, M. and Marliave, J.B.

Year: 1993

Title: Effects of the Exxon Valdez oil spill on survival of Pacific herring eggs and viability of their larvae

Journal: Canadian Technical Report of Fisheries and Aquatic Sciences

Hyperlink: http://waves-vagues.dfo-mpo.gc.ca/waves-vagues/search-recherche/display-afficher/149984

Abstract: On March 24, 1989, the oil tanker Exxon Valdez spilled 250,000 barrels of Prudhoe Bay crude oil onto the surface of Prince William Sound, Alaska. During the first 60 hgours the spill was confined to the center of the Sound. Then, a violent storm sent the slick moving rapidly southeast. By the fourth day (March 27), the slick was 60 km long and had begun passing throught the Naked Island archipelago and by Knight Island. The slick began to exit the Sound by the end of the seventh day (March 30). The spill coincided with the spawning period of Pacific herring (Clupea pallasi) in the sound. Adult herring were first observed near their spawning grounds ab out one week after the spill (Alaska Department of Fish and Game 1991). Spawners were concentrated in four major areas. The Northeast area and the North areas were not touched by the spill, but the Naked Island archipelago and the northern tip of Montague Island were in the path of the spill. Previous research has shown that groth and mortality of free-swimming herring larvae were not significantly different between oiled and non-oiled areas of the Sound (McGurk et al. 1993), suggesting that any effect of the oil spill on herring may have been restricted to the egg stage. We tested this hypothesis by measuring survival, hatching schedule and viability of herring eggs collected from oiled and non-oiled areas of the Sound and incubated in laboratory aquaria.

RefID: 464

Author: McIntosh, S., King, T., Wu, D. and Hodson, P.V.

Year: 2010

Title: Toxicity of dispersed weathered crude oil to early life stages of Atlantic herring (Clupea harengus)

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.134/abstract

Abstract: Reports of the chronic toxicity of dispersed crude oil to early life stages of fish perpetuate uncertainty about dispersant use. However, realistic exposures to dispersed oil in the water column are thought to be much briefer than exposures associated with chronic toxicity testing. To address this issue, the toxicity of dispersed weathered oil to early life stages of Atlantic herring (Clupea harengus) was tested for short exposure durations, ranging from 1 to 144h. Toxicity was a function of concentration and duration of exposure, as well as of the life stage exposed. Medium South American crude oil dispersed with Corexit 9500 caused blue sac disease in embryos, but not in free-swimming embryos. The age of embryos was negatively correlated with their sensitivity to oil; those freshly fertilized were most sensitive. Sensitivity increased after hatch, with free-swimming embryos showing signs of narcosis. Gametes were also tested; dispersed oil dramatically impaired fertilization success. For exposures of less than 24 h, gametes and free-swimming embryos were the most sensitive life stages. For those of more than 24 h, young embryos (<1 d old) were most sensitive. The results are presented as statistical models that could assist decisions about dispersant use in the vicinity of fish spawning habitats. Environ. Toxicol. Chem. 2010;29:1160-1167. (C) 2010 SETAC

RefID: 465

Author: McKenzie, N., Yue, S., Liu, X., Ramsay, B.A. and Ramsay, J.A.

Year: 2014

Title: Biodegradation of naphthenic acids in oils sands process waters in an immobilized soil/sediment bioreactor

Journal: Chemosphere

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0045653514001787

Abstract: Aqueous extraction of bitumen in the Alberta oil sands industry produces large volumes of oil sands process water (OSPW) containing naphthenic acids (NAs), a complex mixture of carboxylic acids that are acutely toxic to aquatic organisms. Although aerobic biodegradation reduces NA concentrations and OSPW toxicity, treatment times are long, however, immobilized cell reactors have the potential to improve NA removal rates. In this study, two immobilized soil/sediment bioreactors (ISBRs) operating in series were evaluated for treatment of NAs in OSPW. A biofilm was established from microorganisms associated with sediment particles from an OSPW contaminated wetland on a non-woven textile. At 16 months of continuous operation with OSPW as the sole source of carbon and energy, 38 +/- 7% NA removal was consistently achieved at a residence time of 160 h at a removal rate of 2.32 mg NAs L-1 d(-1). The change in NA profile measured by gas chromatography-mass spectrometry indicated that biodegradability decreased with increasing cyclicity. These results indicate that such treatment can significantly reduce NA removal rates compared to most studies, and the treatment of native process water in a bioreactor has been demonstrated. Amplification of bacterial 16S rRNA genes and sequencing using Ion Torrent sequencing characterized the reactors' biofilm populations and found as many as 235 and 198 distinct genera in the first and second bioreactor, respectively, with significant populations of ammonium- and nitrite-oxidizers. (C) 2014 Elsevier Ltd. All rights reserved.

RefID: 466

Author: Meier, S., Morton, H.C., Nyhammer, G., Grøsvik, B.E., Makhotin, V., Geffen, A., Boitsov, S., Kvestad, K.A., Bohne-Kjersem, A., Goksøyr, A., Folkvord, A., Klungsøyr, J. and Svardal, A.

Year: 2010

Title: Development of Atlantic cod (Gadus morhua) exposed to produced water during early life stages Effects on embryos, larvae, and juvenile fish

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0141113610001170

Abstract: Produced water (PW) contains numerous toxic compounds of natural origin such as dispersed oil metals alkylphenols (APs) and polycyclic aromatic hydrocarbons (PAHs) In addition PW also contains many different chemicals which have been added during the oil production process In the study described here cod were exposed to real PW collected from an oil production platform in the North Sea This was done in order to best recreate the most realistic field-exposure regime in which fish will be affected by a wide range of chemicals The biological effects found in this study therefore cannot be assigned to one group of chemicals alone but are the result of exposure to the complex chemical mixture found in real PW Since APs are well known to cause endocrine disruption in marine organisms we focused our chemical analysis on APs in an attempt to better understand the long-term effects of APs from PW on the biology of fish In this study cod were exposed to several concentrations of real PW and 17 beta-oestradiol (E-2) a natural oestrogen at different developmental stages Cod were exposed to PW either during the embryo and early larvae stage (up to 3 months of age) or during the early juvenile stage (from 3 to 6 months of age) Results showed that in general APs bioconcentrate in fish tissue in a dose and developmental stage dependent manner during PW exposure However juveniles appeared able to effectively metabolise the short chain APs Importantly PW exposure had no effect on embryo survival or hatching success However 1% PW clearly interfered with the development of normal larval pigmentation After hatching most of the larvae exposed to 1% PW failed to begin feeding and died of starvation This inability to feed may be linked to the increased incidence of jaw deformities seen in these larvae In addition cod exposed to 1% PW had significantly higher levels of the biomarkers vitellogenin and CYP1A in plasma and liver respectively No similar effects were seen in cod exposed to either 01% or 001% PW (c) 2010 Elsevier Ltd All rights reserved

RefID: 467

Author: Melbye, A.G., Brakstad, O.G., Hokstad, J.N., Gregersen, I.K., Hansen, B.H., Booth, A.M., Rowland, S.J. and Tollefsen, K.E.

Year: 2009

Title: CHEMICAL AND TOXICOLOGICAL CHARACTERIZATION OF AN UNRESOLVED COMPLEX MIXTURE-RICH BIODEGRADED CRUDE OIL

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/08-545.1/abstract;jsessionid=E19778278653FA43C62FB56CB74364A9.f04t01

Abstract: Chemical and toxicological characterization of unresolved complex mixtures in the water-soluble fraction of an artificially weathered Norwegian Sea crude oil was determined by a combination of chemical analysis and toxicity testing in fish in vitro bioassays. The water-soluble fraction of the crude oil was separated into 14 increasingly polar fractions by preparative high-pressure liquid chromatography. The in vitro toxicity (7-ethoxyresorufin O-deethylase activity, estrogenicity, and metabolic inhibition) of these fractions was characterized in a primary culture of liver cells (hepatocytes) from rainbow trout (Oncorhynchus mykiss). The main contributor to toxicity was one of the most polar fractions, accounting gravimetrically for more than 70% of the organic material in the water-soluble fraction and dominated by an unresolved complex mixture. Chemical analysis by gas chromatography-mass spectrometry and comprehensive two-dimensional gas chromatography-time of flight-mass spectrometry identified a large number of cyclic and aromatic sulfoxide compounds and low amounts of benzothiophenes (<0.1% of total mass) in this fraction. Commonly monitored toxic components of crude oil (e. g., naphthalenes, polycyclic aromatic hydrocarbons, and alkylated phenols) eluted in less polar fractions, characterized by somewhat lower toxicity. Normalization of in vitro responses to the mass in each fraction demonstrated a more even distribution of toxicity, indicating that toxicity in the individual fractions was related to the amount of material present. Although polar and nonpolar compounds contribute additively to crude oil toxicity, the water-soluble fraction was dominated by polar compounds because of their high aqueous solubility and the high oil-water loading. Under these conditions, the polar unresolved complex mixture-rich fraction might account for a large portion of crude oil toxicity because of its high abundance in the water-soluble fraction.

RefID: 468

Author: Meudec, A., Poupart, N., Dussauze, J. and Deslandes, E.

Year: 2007

Title: Relationship between heavy fuel oil phytotoxicity and polycyclic aromatic hydrocarbon contamination in Salicornia fragilis

Journal: Science of the Total Environment

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0048969707004068

Abstract: Greenhouse experiments were carried out to study the effects of heavy fuel oil contamination on the growth and the development of Salicornia fragifis Ball and Tutin, a salt-marsh edible species. Plants were sampled in spring at the "Aber du Conquet" (Finistere, France), and artificially exposed by coating shoot sections with N degrees 6 fuel oil or by mixing it in their substratum. The impact of petroleum on plant development was followed by phytotoxicity assessments and PAH shoots assays. The plants exhibited visual symptoms of stress, i.e. chlorosis, yellowing, growth reduction and perturbations in developmental parameters. The contamination of plants by shoot coating appeared to be less than through soil. Moreover, the increase of the degree of pollution induced more marked effects on plants, likely because of the physical effects of fuel. However, bioaccumulation of PAHs in shoot tissues was also found to be significant, even at very low levels of contamination, and highly related to the conditions of exposure to oil. The strong relationships between the PAH contents of Salicornia plants and growth reduction suggest a chemical toxicity of fuel oil, compounds like PAHs being known to inhibit physiological processes in plants.

RefID: 469

Author: Middaugh, D.P., Shelton, M.E., McKenney, C.L. Jr., Cherr, G., Chapman, P J. and Courtney, L.A.

Year: 1998

Title: Preliminary observations on responses of embryonic and larval Pacific herring, Clupea pallasi, to neutral fraction biodegradation products of weathered Alaska North Slope oil

Journal: Aquatic Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs002449900303

Abstract: Weathered Alaska North Slope crude oil (ANS 521) was subjected to biodegradation in vigorously stirred incubations for 14 days at 15 +/- 1 degrees C in 20 parts per thousand salinity sterilized seawater, amended with nutrients and inoculated with a hydrocarbon-degrading microorganism (EI2V) isolated from an oil-contaminated beach in Prince William Sound, Alaska. A total of 13.7 mg/L water-soluble neutral fraction (WSF) was recovered from the incubation of weathered ANS 521. Toxicity/teratogenicity tests were conducted with WSF recovered from the biodegradation system using embryonic and larval Pacific herring, Clupea pallasi. Exposures fl;ere begun at 4, 48, and 96 h postfertilization of herring eggs. Exposure concentrations were 1, 10, and 100% of the original concentration of WSF recovered from incubations (redissolved in 20 parts per thousand salinity sterile seawater at 15 +/- 1 degrees C)., Sterile 20 parts per thousand salinity seawater without the addition of redissolved neutral fraction was used as a control, Significant (p less than or equal to 0.05) embryo mortality or teratogenic responses were observed at WSF concentrations of 10 and 100%. On days 5 through 8 of embryogenesis, counts of heart contraction rates were significantly lower (p less than or equal to: 0.05) at the 100% WSF concentration for embryos exposed beginning at 4 and 48 h postfertilization. Grow-out of larvae from selected exposures was conducted, High mortality was noted in larvae exposed to the 10% WSF concentration beginning at 4 and ?8 h postfertilization., Most of these larvae died 5 to 8 days after hatching when they elicited vertebral displacements at a time concurrent with the onset of feeding behavior.

RefID: 470

Author: Milinkovitch, T., Godefroy, J., Theron, M. and Thomas-Guyon, H.

Year: 2011

Title: Toxicity of dispersant application: Biomarkers responses in gills of juvenile golden grey mullet (Liza aurata)

Journal: Environmental Pollution

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0269749111002430

Abstract: Dispersant use in nearshore areas is likely to increase the exposure of aquatic organisms to petroleum. To measure the toxicity of this controversial response technique, golden grey mullets (Liza aurata) were exposed to mechanically dispersed oil, chemically dispersed oil, dispersant alone in seawater, water-soluble fraction of oil and to seawater as a control treatment. Several biomarkers were assessed in the gills (enzymatic antioxidant activities, glutathione content, lipid peroxidation) and in the gallbladder (polycylic aromatic hydrocarbons metabolites). The significant differences between chemically dispersed oil and water soluble fraction of oil highlight the environmental risk to disperse an oil slick when containment and recovery can be conducted. The lack of significance between chemically and mechanically dispersed oil suggests that dispersant application is no more toxic than the natural dispersion of the oil slick. The results of this study are of interest in order to establish dispersant use policies in nearshore areas.

RefID: 471

Author: Milinkovitch, T., Imbert, N., Sanchez, W., Le Floch, S. and Thomas-Guyon, H.

Year: 2013

Title: Toxicological effects of crude oil and oil dispersant: Biomarkers in the heart of the juvenile golden grey mullet (Liza aurata)

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651312004046

Abstract: Dispersant use is a controversial oil spill response technique in coastal areas. Using an experimental approach, this study evaluated the toxicity of dispersant use upon juveniles of golden grey mullet (Liza aurata). Fish were exposed for 48 h to either dispersant only, chemically dispersed oil, mechanically dispersed oil, the water soluble fraction of oil or to control conditions. Following exposure and a depuration period, biomarkers were assessed in fish hearts, namely the total glutathione content and the activity of four enzymes (glutathione S-transferase, superoxide dismutase, catalase and glutathione peroxides). Comparing biomarker responses between the different treatments, this study revealed that 48 h exposure to dispersed oil (whether mechanically or chemically dispersed) resulted in a toxicity that was still detectable after a 14 days depuration period. Comparing biomarkers responses after an exposure to chemically and mechanically dispersed oil, this study suggests that chemical dispersion of the oil slick would not be more toxic than its natural dispersion under certain turbulent meteorological conditions (e.g. waves). Furthermore, the results indicated that the heart could be a target organ of interest in further studies investigating the toxicity of hydrocarbons. This study, which has been integrated into the DISCOBIOL project (Dispersant et techniques de lutte en milieu coder: effets biologiques et apport a la reglementation), presents information of interest when attempting to provide a framework for dispersant applications in coastal areas. (C) 2012 Elsevier Inc. All rights reserved.

RefID: 472

Author: Milinkovitch, T., Kanan, R., Thomas-Guyon, H. and Le Floch, S.

Year: 2011

Title: Effects of dispersed oil exposure on the bioaccumulation of polycyclic aromatic hydrocarbons and the mortality of juvenile Liza ramada

Journal: Science of the Total Environment

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0048969711000465

Abstract: Dispersing an oil slick is considered to be an effective response to offshore oil spills. However, in nearshore areas, dispersant application is a controversial countermeasure: environmental benefits are counteracted by the toxicity of dispersant use. In our study, the actual toxicity of the dispersant response technique in the nearshore areas was evaluated through an experimental approach using juvenile Liza ramada. Fish were contaminated via the water column (i) by chemically dispersed oil, simulating dispersant application, (ii) by dispersant, as an internal control of chemical dispersion, (iii) by mechanically dispersed oil, simulating only the effect of natural mixing processes, without dispersant application, and (iv) by the water soluble fraction of oil, simulating the toxicity of an oil slick before recovery. Bioconcentrations of polycyclic aromatic hydrocarbons (PAH) and mortality were evaluated, and related to both total petroleum hydrocarbon (TPH) and polycyclic aromatic hydrocarbon (PAH) concentrations in seawater. Fish exposed to chemically dispersed oil showed both a higher bioconcentration of PAH and a higher mortality than fish exposed to either the water soluble fraction of oil or the mechanically dispersed oil. These results suggest that (i) dispersion is a more toxic response technique than containment and recovery of the oil slick; (ii) in turbulent mixing areas, dispersant application increases the environmental risk for aquatic organisms living in the water column. Even if the experimental aspects of this study compel us to be cautious with our conclusions, responders could consider these results to establish a framework for dispersant use in nearshore areas. (C) 2011 Elsevier B.V. All rights reserved.

RefID: 473

Author: Milinkovitch, T., Thomas-Guyon, H., Lefrançois, C. and Imbert, N.

Year: 2013

Title: Dispersant use as a response to oil spills: toxicological effects on fish cardiac performance

Journal: Fish Physiology and Biochemistry

Hyperlink: http://link.springer.com/article/10.1007%2Fs10695-012-9696-z

Abstract: Dispersant use is a controversial technique used to respond to oil spills in nearshore areas. In order to assess the toxicity of this technique, this study evaluated the cardiac toxicological effects on juvenile golden grey mullets Liza aurata exposed for 48 h to either dispersant alone, chemically dispersed oil, mechanically dispersed oil, the water-soluble fraction of oil or a control condition. Following exposure, the positive inotropic effects of adrenaline were assessed in order to evaluate a potential impairment on the cardiac performance. The results revealed an impairment of the positive inotropic effects of adrenaline for all the contaminants (single dispersant, dispersed and undispersed oil, water-soluble fraction of oil). This suggests that: (1) cardiac performance is a valuable parameter to study the physiopathological effects of dispersed oil; (2) dispersant application is likely to impair cardiac performance.

RefID: 474

Author: Militon, C., Jézéquel, R., Gilbert, F., Corsellis, Y., Sylvi, L., Cravo-Laureau, C., Duran, R. and Cuny, P.

Year: 2015

Title: Dynamics of bacterial assemblages and removal of polycyclic aromatic hydrocarbons in oil-contaminated coastal marine sediments subjected to contrasted oxygen regimes

Journal: Environmental Science and Pollution Research

Hyperlink: http://link.springer.com/article/10.1007/s11356-015-4510-y

Abstract: To study the impact of oxygen regimes on the removal of polycyclic aromatic hydrocarbons (PAHs) in oil-spill-affected coastal marine sediments, we used a thin-layer incubation method to ensure that the incubated sediment was fully oxic, anoxic, or was influenced by oxic-anoxic switches without sediment stirring. Hydrocarbon content and microbial assemblages were followed during 60 days to determine PAH degradation kinetics and microbial community dynamics according to the oxygenation regimes. The highest PAH removal, with 69 % reduction, was obtained at the end of the experiment under oxic conditions, whereas weaker removals were obtained under oscillating and anoxic conditions (18 and 12 %, respectively). Bacterial community structure during the experiment was determined using a dual 16S rRNA genes/16S rRNA transcripts approach, allowing the characterization of metabolically active bacteria responsible for the functioning of the bacterial community in the contaminated sediment. The shift of the metabolically active bacterial communities showed that the selection of first responders belonged to Pseudomonas spp. and Labrenzia sp. and included an unidentified Deltaproteobacteria—irrespective of the oxygen regime—followed by the selection of late responders adapted to the oxygen regime. A novel unaffiliated phylotype (B38) was highly active during the last stage of the experiment, at which time, the low-molecular-weight (LMW) PAH biodegradation rates were significant for permanent oxic- and oxygen-oscillating conditions, suggesting that this novel phylotype plays an active role during the restoration phase of the studied ecosystem.

RefID: 475

Author: Miljeteig, C., Olsen, A.J., Nordtug, T., Altin, D. and Jenssen, B.M.

Year: 2013

Title: Sublethal Exposure to Crude Oil Enhances Positive Phototaxis in the Calanoid Copepod Calanus finmarchicus

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es4037447

Abstract: We investigated the effects of exposure to sublethal concentrations of the water accommodated fraction (WAF) of fresh crude oil on phototactic behavior of the calanoid copepod Calanus finmarchicus

(Gunnerus) copepodite stage 5 (C5). Exposure was conducted in closed bottle systems, and behavior was tested in a tailored setup. Exposure times were 24, 48, 72, and 96 h, and the chosen exposure concentration was 25% of the recorded LC50 value for the WAF (309 +/- 32 mu g/L total hydrocarbon, including 20.37 +/- 0.51 mu g/L total PAH). The exposure significantly increased the positive phototactic behavior of the copepods after 24 h exposure and a similar significant effect was observed for all exposure durations. Additionally, experiments were conducted with nonexposed copepods with low lipid reserves. The main effect of the exposure was a shift in the response to light toward a more positive phototaxis, similar to that observed in nonexposed C. finmarchicus with low lipid reserves. The observed change in phototactic behavior observed in these studies suggests that the depth distribution of this species could be altered following an oil spill. Thus, further research is warranted to determine the possible interactive effects of light and oil spill exposures on Calanus population dynamics under field conditions.

RefID: 476

Author: Mitchell, F.M. and Holdway, D.A.

Year: 2000

Title: The acute and chronic toxicity of the dispersants Corexit 9527 and 9500, water accommodated fraction (WAF) of crude oil, and dispersant enhanced WAF (DEWAF) to Hydra viridissima (green hydra)

Journal: Water Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S004313549900144X

Abstract: The acute and chronic toxicities of the dispersants Corexit 9527 and Corexit 9500 to green hydra (Hydra viridissima) were determined. The mean (SE) 96 h LC50 values for Corexit 9527 and Corexit 9500 were 230 (4.8) ppm and 160 (2.3) ppm. The 7-day no-observed-effect-concentration (NOEC) and lowest-observed-effect-concentration (LOEC) values based on population growth rates were <15 and 15 ppm for Corexit 9527 and 13 and 43 ppm for Corexit 9500. The mean (SE) 96 h LC50 values for water accommodated fraction (WAF) of Bass Strait crude oil, Corexit 9527 dispersant enhanced WAF (DEWAF) and Corexit 9500 DEWAF were 0.7 (0.1) ppm total petroleum hydrocarbons (TPH), 9.0 (0.5) and 7.2 (0.1) ppm TPH. The NOEC and LOEC Values based on 7-day population growth rates were: 0.6 and >0.6 ppm TPH for WAF, <0.6 and 0.6 ppm TPH for Corexit 9527 DEWAF, and 2 and 4 ppm TPH for Corexit 9500 DEWAF. (C) 1999 Elsevier Science Ltd. All rights reserved.

RefID: 477

Author: Mohr, F.C., Lasley, B. and Bursian, S.

Year: 2008

Title: Chronic oral exposure to bunker C fuel oil causes adrenal insufficiency in ranch mink (Mustela vison)

Journal: Archives of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs00244-007-9021-5

Abstract: Animals living in the near-shore marine environment are predisposed to contact with chemical contaminants through land- and ocean-based activities. The release of petroleum hydrocarbons into the marine environment is a stressor to this environment and its resident wildlife. The stress response to chemical threats is dependent on an intact hypothalamic-pituitary-adrenal axis, which also may be a target to the effects of these chemicals. Ranch mink (Mustela vison) were used as surrogates for sea otters (Enhydra lutris) to examine the development of adrenal hypertrophy after chronic, oral exposure to low concentrations of bunker C fuel oil. Animals were fed three different concentrations of fuel oil (48, 520, and 908 ppm) or mineral oil (control) for 60-62 days. At the end of the exposure, blood and fecal samples were collected and organs were weighed and examined microscopically. In all fuel oil groups, exposure resulted in adrenal hypertrophy, an adaptation suggestive of adrenal activation. However, concentrations of serum and fecal glucocorticoids and serum progesterone were not elevated over control values. Hematologic parameters and serum chemistries showed no changes consistent with increased adrenal activity. In addition, adrenal glands from animals fed the higher concentrations of fuel oil contained large numbers of heavily vacuolated cells. We conclude that petroleum hydrocarbons are inducing an adrenal insufficiency that leads to the adaptive enlargement of the gland. This would increase the susceptibility of fuel oil-exposed animals to the deleterious effects of other environmental stressors.

RefID: 478

Author: Moles, A.

Year: 1980

Title: SENSITIVITY OF PARASITIZED COHO SALMON FRY TO CRUDE-OIL, TOLUENE, AND NAPHTHALENE

Journal: Transactions of the American Fisheries Society

Hyperlink: http://www.tandfonline.com/doi/abs/10.1577/1548-8659%281980%29109%3C293%3ASOPCSF%3E2.0.CO%3B2

Abstract:

RefID: 479

Author: Moles, A. and Rice, S.D.

Year: 1983

Title: EFFECTS OF CRUDE-OIL AND NAPHTHALENE ON GROWTH, CALORIC CONTENT, AND FAT-CONTENT OF PINK SALMON JUVENILES IN SEAWATER

Journal: Transactions of the American Fisheries Society

Hyperlink: http://www.tandfonline.com/doi/abs/10.1577/1548-8659%281983%29112%3C205%3AEOCOAN%3E2.0.CO%3B2

Abstract:

RefID: 480

Author: Moles, A., Babcock, M.M. and Rice, S.D.

Year: 1987

Title: EFFECTS OF OIL EXPOSURE ON PINK SALMON, ONCORHYNCHUS-GORBUSCHA, ALEVINS IN A SIMULATED INTERTIDAL ENVIRONMENT

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/0141113687900730

Abstract: Pink salmon, Oncorhynchus gorbuscha, alevins (5 and 60 days after hatching) were continuously or intermittently exposed for 30 days to the water-soluble fraction (WSF) of Cook Inlet crude oil in fresh water or in a simulated freshwater-seawater cycle. Alevins exposed to 0·7−2·4 mg/liter WSF in the simulated tidal cycle were more sensitive to oil, had reduced yolk reserves, and accumulated more hydrocarbons than did alevins exposed to the same concentrations in fresh water. Alevins in fresh water were more sensitive to continuous than to intermittent exposures. In all exposures, 60-day alevins were more severely affected than were 5-day alevins.

RefID: 481

Author: Moles, A., Rice, S.D. and Korn, S.

Year: 1979

Title: Sensitivity of Alaskan Freshwater and Anadromous Fishes to Prudhoe Bay Crude Oil and Benzene

Journal: Environment International

Hyperlink: http://www.tandfonline.com/doi/abs/10.1577/1548-8659(1979)108%3C408%3ASOAFAA%3E2.0.CO%3B2

Abstract: The sensitivity of various species and life stages of Alaskan freshwater and anadromous fishes to benzene and the water-soluble fraction of Prudhoe Bay crude oil was determined with 96-hour toxicity tests. Freshwater juveniles of the six salmonid species tested had similar sensitivities. Median tolerance limits (TLm's) of these salmonids for crude oil ranged from 2.7 to 4.4 mg/liter; TLm's of benzene ranged from 11.7 to 14.7 µl/liter. Threespine sticklebacks and, to a lesser extent, slimy sculpins were more tolerant than salmonids and had larger TLm's: Threespine sticklebacks had a crude-oil TLm of 10.4 mg/liter and a benzene TLm of 24.8 µl/liter; slimy sculpins had a crude-oil TLm of 6.44 mg/liter and a benzene TLm of 15.4 µl/liter. Eggs of pink salmon and coho salmon were quite tolerant to crude oil (TLm > 12 mg/liter) and benzene (TLm = 339–542 µl/liter). Emergent fry were the most sensitive freshwater stage (crude-oil TLm = 8.0 mg/liter; benzene TLm = 12.3–17.1 µl/liter). Out-migrant salmonids tested in seawater were twice as sensitive as out-migrant salmonids tested in fresh water, apparently because of the additional stress of entering seawater and the physiological changes associated with this transition. Freshwater TLm's were 2.3–8.0 mg/liter for crude oil and 10.8–17.1 µl/liter for benzene. Corresponding seawater sensitivities were 1.1–3.6 mg/liter for crude oil and 5.5–8.5 µl/liter for benzene.

RefID: 482

Author: Monahan, T.P. and Maki, A.W.

Year: 1993

Title: The Exxon Valdez 1989 wildlife rescue and rehabilitation program

Journal: International Oil Spill Conference Proceedings

Hyperlink: http://ioscproceedings.org/doi/abs/10.7901/2169-3358-1991-1-131

Abstract: During 1989 the Exxon-operated bird and sea otter rehabilitation program was the largest and most comprehensive effort of its kind ever attempted. In total, eight centers were established, with three for otters, four for birds, and one for raptors. In total, over 140 boats and five aircraft were dedicated to this operation. Costs directly associated wth this effort were approximately $45 million. This paper describes the types of facilities used to treat these animals, the expertise of the people staffing these centers, and the techniques developed. Also discussed are the relative bird and otter release rates and some of the key findings and lessons from this program.

RefID: 483

Author: Monnett, C. and Rotterman, L.M.

Year: 1995

Title: Movements of weanling and adult female sea otters in Prince William Sound, Alaska after the T/V Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33944239.pdf

Abstract: Ninety-six adult female sea otters and 64 weanling sea otters were instrumented with implanted radio-transmitters in Prince William Sound during 1989-1990 and monitored until November, 1991. Observations of the movements of adult female and weanling sea otters in Prince William Sound indicated no tendency for individuals to emigrate from, or immigrate to, the area affected by oil spilled from the Exxon Valdez. This finding indicates that the study groups of sea otters categorized as "western Prince William Sound oil-spill treatment" otters and "eastern prince William Sound control" otters are indeed distinct groups of individuals. No tendency was observed for recently weaned sea otters to exhibit a preference for habitat units based on the likelihood that they would encounter spilled oil therein. Finally, data reported herein suggest that the recovery of the sea otter population in the oil spill affected region of Prince William Sound will likely be a direct function of the rates of survival and reproduction of the sea otters in the affected habitat with little or no influence from emigration or immigration.

RefID: 484

Author: Monnett, C. and Rotterman, L.M.

Year: 1995

Title: Mortality and reproduction of female sea otters in Prince William Sound, Alaska

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33944236.pdf

Abstract: Ninety-six female sea otters were instrumented with implanted radio-transmitters in Prince William Sound, Alaska, during 1989-1990. Females in eastern Prince William Sound exhibited a lower survival rate than those in western Prince William Sound. No differences were observed between rates of pupping or between rates of survival of dependent pups for sea otters in the two areas.

RefID: 485

Author: Monson, D.H. and Ballachey, B.

Year: 1995

Title: Age distributions of sea otters found dead in Prince William Sound, Alaska following the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/36716277.pdf

Abstract: Age distributions of sea otters (Enhydra lutris) found dead on beaches in western Prince William Sound, Alaska, from 1976 to 1984, were compared to those of sea otters found dead from 1989 to 1993, following the Exxon Valdez oil spill. The age distribution of sea otters recovered in western Prince William Sound prior to the spill was bimodal and composed of primarily young and old animals. The ratio of "young" (≤ 1 year old) to "prime-age" (2-8 years old) to "old" (≥ 9 years old) sea otters was 44:17:39 (N=145). In contrast, the age distribution of otters recovered in western Prince William Sound during spill respons efforts (1989) was 30:47:23 (N=379), and in 1990-1991 was 33:43:24 (N=66). The high proportion of prime-age otters recovered immediately following the spill indicates significant losses occurred within a segment of the population which normally experiences very low mortality. The high proportion of prime-age otters recovered in 1990-1991 may be evidence of a prolonged, spill-related effect on the western Prince William Sound sea otter population. The age distribution of sea otters collected in 1992-1993 was 37:17:46 (N=35) indicating that sea otter mortality in western Prince William Sound is returning to a normal, bimodal pattern.

RefID: 486

Author: Monson, D.H., Doak, D.F., Ballachey, B.E. and Bodkin, J.L.

Year: 2011

Title: Could residual oil from the Exxon Valdez spill create a long-term population "sink" for sea otters in Alaska?

Journal: Ecological Applications

Hyperlink: http://www.esajournals.org/doi/abs/10.1890/11-0152.1

Abstract: Over 20 years ago, the Exxon Valdez oil tanker spilled 42 million L of crude oil into the waters of Prince William Sound, Alaska, USA. At the time of the spill, the sea otter (Enhydra lutris) population inhabiting the spill area suffered substantial acute injuries and loss. Subsequent research has resulted in one of the best-studied species responses to an oil spill in history. However, the question remains: Is the spill still influencing the Prince William Sound sea otter population? Here we fit time-varying population models to data for the sea otter population of western Prince William Sound to quantify the duration and extent of mortality effects from the spill. We hypothesize that the patchy nature of residual oil left in the environment has created a source-sink population dynamic. We fit models using the age distributions of both living and dying animals and estimates of sea otter population size to predict the number of sea otters in the hypothesized sink population and the number lost to this sink due to chronic exposure to residual oil. Our results suggest that the sink population has remained at just over 900 individuals (95% CI: 606-960) between 1990 and 2009, during which time prime-age survival remained 2-6% below pre-spill levels. This reduced survival led to chronic losses of; 900 animals over the past two decades, which is similar in magnitude to the number of sea otter deaths documented in western Prince William Sound during the acute phase of the spill. However, the unaffected source population appears to be counterbalancing these losses, with the model indicating that the sea otter population increased from; 2150 individuals in 1990 to nearly 3000 in 2009. The most optimistic interpretation of our results suggests that mortality effects dissipated between 2005 and 2007. Our results suggest that residual oil can affect wildlife populations on time scales much longer than previously believed and that cumulative chronic effects can be as significant as acute effects. Further, source-sink population dynamics can explain the slow recovery observed in the spill-affected western Prince William Sound sea otter population and are consistent with available data.

RefID: 487

Author: Monson, D.H., Doak, D.F., Ballachey, B.E..,, Johnson, A and Bodkin, J.L.

Year: 2000

Title: Long-term impacts of the Exxon Valdez oil spill on sea otters, assessed through age-dependent mortality patterns

Journal: Proceedings of the National Academy of Sciences of the United States of America

Hyperlink: http://www.pnas.org/content/97/12/6562.full

Abstract: We use age distributions of sea otters (Enhydra lutris) found dead on beaches of western Prince William Sound, Alaska, between 1976 and 1998 in conjunction with time-varying demographic models to test for lingering effects from the 1989 Exxon Valdez oil spill. Our results show that sea otters in this area had decreased survival rates in the years following the spill and that the effects of the spill on annual survival increased rather than dissipated for older animals. Otters born after the 1989 spill were affected less than those alive in March 1989, but do show continuing negative effects through 1998. Population-wide effects of the spill appear to have slowly dissipated through time, due largely to the loss of cohorts alive during the spill. Our results demonstrate that the difficult-to-detect long-term impacts of environmental disasters may still be highly significant and can be rigorously analyzed by using a combination of population data, modeling techniques, and statistical analyses.

RefID: 488

Author: Moreira, C.B., Rodrigues, R.V., Romano, L.A., Gusmão, E.P., Seyffert, B.H., Sampaio, L. A. and Miranda-Filho, K.C.

Year: 2014

Title: Genotoxicity and histological alterations in grey mullet Mugil liza exposed to petroleum water-soluble fraction (PWSF)

Journal: Environmental Science and Pollution Research

Hyperlink: http://link.springer.com/article/10.1007%2Fs11356-013-2440-0

Abstract: Petroleum hydrocarbons are considered one of the main organic chemicals found in water bodies. In the present study, the median lethal concentration (LC50) was estimated for mullet Mugil liza after acute exposure to petroleum water-soluble fraction (PWSF). Furthermore, histopathological studies and micronuclei frequency were also performed in order to observe deleterious effects of medium-term exposition to PWSF. Mullets (25 +/- 2.3 g) were exposed to chronic concentrations (1.7, 3.5 and 7 % of PWSF), plus the control group, for 14 and 7 days of clearance time. Throughout the experimental period (1, 4, 14 and 21 days), blood samples were collected for analysis of micronucleus (MN) and liver and gills for histopathological study. For these procedures, seven fish were sampled per concentration tested. The LC50-96 h was estimated at 37.5 % of the PWSF. The time required for MN induction was 96 h of exposure. The time of clearance was sufficient to achieve a MN frequency similar to that of the control group. Histopathological studies showed severe changes in the gill and liver tissues. The most relevant histopathology in the gills was telangiectasia. Hepatic histopathology such as cholestasis, dilated sinusoids and inflammatory infiltrates were commonly described. The MN test and histological study effectively detected damages caused by medium-term exposition to the PWSF, and despite the toxicity, a few days without exposure can minimize PWSF genotoxicity in juveniles of M. liza.

RefID: 489

Author: Moreira, S.M., Moreira-Santos, M., Ribeiro, R. and Guilhermino, L.

Year: 2004

Title: The 'Coral bulker' fuel oil spill on the north coast of Portugal: Spatial and temporal biomarker responses in Mytilus galloprovincialis

Journal: Ecotoxicology

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/15673211

Abstract: In December 2000, the ship 'Coral Bulker' ran aground at the entrance of the port of Viana do Castelo (North-west coast of Portugal). A large amount of fuel oil was spilled and part of it reached the shore. To evaluate the spatial and temporal impact of this oil spill, a field study, and several laboratory toxicity tests were performed using Mytilus galloprovincialis as biological indicator of environmental contamination and the biomarkers glutathione S-transferases (GSTs) and acetylcholinesterase (ACHE) as indicative criteria. Fifteen days after the oil spill, mussels collected at stations located near the ship presented higher and lower values of GSTs and AChE activity, respectively. These results, and those obtained in the laboratory toxicity tests, evidence that these biomarkers were sensitive indicators of exposure to this kind of pollution and were able to monitor a spatial impact of the oil spill of at least 10 km, confirming the higher level of contamination near the ship and a contamination gradient along the sampling stations. One year after the accident, such a contamination gradient was no longer evident. This study highlight the potential suitability of a biomarker approach for assessing spatial and temporal impacts of marine pollution accidents, such as fuel oil spills, suggesting the inclusion of these biomarkers in risk assessment studies, as cost-effective and early warning recognized tools. Major advantages and limitations of the biomarker approach used in this study are further discussed.

RefID: 490

Author: Mos, L., Cooper, G.A., Serben, K., Cameron, M. and Koop, B.F.

Year: 2008

Title: Effects of diesel an survival growth, and gene expression in rainbow trout (Oncorhynchus mykiss) fry

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es702215c

Abstract: Diesel spills are all too frequent disturbances of freshwater ecosystems, largely as a result of the quantities transported and consumed. Assessing the risk that such events may pose to aquatic life remains a difficult process, because of the complexity of this hydrocarbon mixture and our limited knowledge of its toxicity. A diesel spike experiment with rainbow trout (Oncorhynchus mykiss) fry was carried out to fill this knowledge gap. Survival, growth, and gene expression changes were assessed and toxicity thresholds were determined. Whereas the biological end points were consistent in the determination of (sub)lethal doses, microarrays supplied additional information on the mechanism of toxicity (oxygen deprivation) and potential long-term effects (feminization, immune system alterations) of diesel exposure on salmonids. Hemoglobins, prostaglandins, cytochromes, and gluthathion-S-transferases were among the molecular biomarkers proposed for use in future risk assessments based on microarray results. By bridging traditional toxicity testing with recent microarray technologies, this study shows the potential of genomics tools in ecotoxicity studies as well as industrial applications, including risk assessment, in the near future.

RefID: 491

Author: Mulcahy, D.M. and Ballachey, B.E.

Year: 1994

Title: Hydrocarbon residues in sea otter tissues

Journal: Marine mammals and the Exxon Valdez

Hyperlink: http://www.amazon.com/Marine-Mammals-Valdez-Thomas-Loughlin/dp/0124561608

Abstract:

RefID: 492

Author: Munson, D.

Year: 1996

Title: Shoreline assessment and oil removal in Prince William Sound, Alaska

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/38839657.pdf

Abstract: During the summer of 1994 a five person crew from the village of Chenega under the direction of an on site manager from the Alaska Department of Environmental Consewation conducted manual treatment, debris and rebar removal and ground surveys at 11 subdivisions in Prince William Sound. Fourteen sites within 4 different shoreline subdivisions with persistent surface asphalt were manually treated to accelerate natural degradation. Approximately 2000 quare meters of asphalted oil were broken and tilled. Rebar and back-stakes were removed from Applegate Island. Removal of flagging and other miscellaneous shoreline debris left by cleanup and damage assessment crews was undertaken as possible. Six additional shoreline subdivisions near the village of Chenega were assessed because of the ongoing concern for subsistence and recreational resources within close proximity to the village. The six shoreline subdivisions assessed were also assessed in the 1993 Shoreline Assessment (Restoration Project 93038) and were known to have some of the heaviest oiling in the area. A comparison of the sites from 1993 to 1994 showed that little to no improvement had occurred at these sites. The same labor crew, on site manager and logistical support for the shoreline treatment and assessment tasks above were used to accomplish the Mussel Bed Restoration Project (94090) in cooperation with the National Oceanic and Atmospheric Administration.

RefID: 493

Author: Munson, D., Fay, G., Easton, D. and Ginter, J.

Year: 1998

Title: Chenega Shoreline Restoration. Exxon Valdez Oil Spill Restoration Project Final Report (Restoration Project 97291)

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/index.cfm?FA=searchResults.projectInfo&Project_ID=711

Abstract: Five cobble-boulder armored shoreline segments in the vicinity of the village of Chenega Bay in Prince William Sound were treated in the summer of 1997 to reduce levels of residual oil from the 1989 Exxon Valdez spill. The treatment involves injecting a d-limonene based cleaning agent (PES-51) into beach substrates using an air knife to free residual oil, followed by ambient temperature seawater flushing and collecting the oil and cleaning agent mixture with standard oil spill recovery techniques. Treatment was completed over a 33-day period. 9,490 square meters were treated producing a total of 20,007 pounds of oiled sorbent materials. Visual observations and physical measurements show removal of 50% of the surface oil in 1997. However, rearrangement of boulders by winter storms thoroughly altered the parts of the beach where oil was uncovered and available for either sampling or cleaning. This implies that much less than 50% of the total oil entrained in these beaches was removed. No obvious catastrophic effect on the biota of the beaches involved was detected. Beach mussels took up significant levels of oil and d-limonene, and mussels moored in the water column outside cleaning operations took up traces, but all mussels had depurated them by September, 1997. Almost no measurable oil or surfactant escaped into the surrounding water column. Any physical damage to intertidal biota was too subtle to be observed against naturalvariability.

RefID: 494

Author: Murakami, Y., Kitamura, S., Nakayama, K., Matsuoka, S. and Sakaguchi, H.

Year: 2008

Title: Effects of heavy oil in the developing spotted halibut, Verasper variegatus

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X0800129X

Abstract: It is well known that heavy oil (HO) on the sea surface causes serious problems in the aquatic environment. In particular, some species of teleosts which develop on the sea surface are thought to be affected by the HO which flows out from tankers or coastal industry. However, the toxicological effects of HO are not fully understood. We performed exposure experiments using the Pleuronectiformean fish, spotted halibut (Verasper variegatus), which is an important fishery resource in Japan. In course of the development, HO-exposed embryos showed remarkable delay in developmental processes including somite formation. We further observed abnormal development of the head morphology. Notably, treated embryos had relatively small eyes and craniofacial structures. These findings strongly suggest that HO seriously affects the cell proliferation and differentiation of the embryo. In addition, HO-exposed embryos showed abnormal neuronal development. We also performed the exposure in the larval stage. Treatment of post-hatching larvae with HO resulted in significantly greater mortality compared with controls. Through these observations, we finally conclude that HO is strongly toxic to halibut in their early life stages. (c) 2008 Elsevier Ltd. All rights reserved.

RefID: 495

Author: Murphy, M.L., Heintz, R.A., Short, J.W., Larsen, M.L. and Rice, S.D.

Year: 1998

Title: Recovery of pink salmon spawning areas after the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/40478717.pdf

Abstract: To assess recovery of pink salmon (Oncorhynchus gorbuscha) spawning habitat in Prince William Sound after the Exxon Valdez oil spill, we analyzed sediment samples from stream deltas from 1989-1991 and 1995. In 1989, petroleum hydrocarbon concentration at 172 stream deltas (1-8 samples each) was bimodally distributed: 85 deltas had no detectable petroleum hydrocarbons (detection limit 2 pg/g); 87 deltas had 2-45,OOO pg/g. In 1995, petroleum hydrocarbons were still detected at eight of nine oiled streams we resampled, with mean concentration up to 242 pg/g. The polynuclear aromatic hydrocarbon (PAH) fraction was also analyzed to determine origin and toxic potential. The PAH in 1995 consisted mostly of the more toxic compounds with high molecular weight. Composition was consistent with weathered Exxon Valdez oil, and total PAH concentration ranged up to 1,300 ng/g. Interpolation between 1989 and 1995 indicated that PAH concentration exceeded 3,800 ng/g (minimum sediment concentration that reduces salmon embryo survival in the laboratory) at some stream deltas through 1993, but all streams were below this level by 1994. We conclude that tidal leaching of residual PAH into incubation substrate could explain persistent impaired embryo survival in pink salmon through 1993, and that spawning habitat had recovered by 1994.

RefID: 496

Author: Murphy, M.L., Heintz, R.A., Short, J.W., Larsen, M.L. and Rice, S.D.

Year: 1999

Title: Recovery of pink salmon spawning areas after the Exxon Valdez oil spill

Journal: Transactions of the American Fisheries Society

Hyperlink: http://www.tandfonline.com/doi/full/10.1577/1548-8659(1999)128%3C0909:ROPSSA%3E2.0.CO;2

Abstract: Up to 70% of wild pink salmon Oncorhynchus gorbuscha in Prince William Sound, Alaska, spawn in

intertidal stream areas, many of which were contaminated by the 1989 Exxon Valdez oil spill. To assess recovery of salmon habitat after the spill, we analyzed sediment samples from stream deltas throughout Prince William Sound from 1989 to 1991 and 1995. In 1989, petroleum hydrocarbon concentration at 172 stream deltas (1-8 samples each) was bimodally distributed: 85 deltas had no detectable petroleum hydrocarbons (detection limit, 2 mu g/g), whereas 87 deltas had a concentration of 2-90,000 mu g/g. In 1995, petroleum hydrocarbons were still detected at eight of nine oiled streams that we resampled, with mean concentration up to 242 mu g/g. The polynuclear aromatic hydrocarbon (PAH) fraction was also analyzed in 1995 to determine its origin, state of weathering, and toxic potential of the residual oil. The PAH fraction consisted mostly of the more toxic compounds with high molecular weight (e.g., phenanthrenes and chrysenes), and PAH composition was consistent with weathered Exxon Valdez oil. Total PAH concentration in 1995 averaged 0-1,300 ng/g, which was below the minimum sediment concentration (3,800 ng/g) shown to reduce salmon embryo survival in the laboratory. Interpolation between 1989 and 1995 indicated that residual PAH concentration exceeded 3,800 ng/g at some stream deltas through 1993, but all streams were below this level by 1994. We conclude that tidal leaching of PAH from weathered oil into incubation substrate could explain persistent elevated embryo mortality observed in pink salmon through 1993, and that spawning habitat had recovered to below lethal threshold by 1994.

RefID: 497

Author: Nakayama, K., Kitamura, S., Murakami, Y., Song, J.Y., Jung, S.J., Oh, M.J., Iwata, H. and Tanabe, S.

Year: 2008

Title: Toxicogenomic analysis of immune system-related genes in Japanese flounder (Paralichthys olivaceus) exposed to heavy oil

Journal: Marine Pollution Bulletin

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/18381219

Abstract: Heavy oil contamination is one of the most important environmental issues. Toxicities of polycyclic aromatic hydrocarbons (PAHs), including immune toxicities, are well characterized, however, the immune toxic effects of heavy oil, as a complex mixture of PAHs, have not been investigated. In the present study, we selected Japanese flounder (Paralichthys olivaceus) as a model organism, and observed alteration of immune function by the exposure to heavy oil. To analyze the expression profiles of immune system-related genes, we selected 309 cDNAs from our flounder EST library, and spotted them on a glass slide. Using this cDNA array, alteration of gene expression profiles was analyzed in the kidneys of flounders exposed to heavy oil. Six Japanese flounders (mean body weight: 197 g) were acclimated to laboratory conditions at 19-20 degrees C. Three fish were exposed to heavy oil C (bunker C) at a concentration of 3.8 g/L for 3 days, and the others were kept in seawater without heavy oil and used as the control. After the exposure period, the fish were transferred into control seawater and maintained for 4 days, and then they were dissected and their kidneys were removed. Total RNA was extracted from the kidney samples to use in gene expression analyses. The microarray detected alteration of immune system-related genes in the kidneys of heavy oil-exposed flounders, including down-regulation of immunoglobulin light chain, CD45, major histocompatibility complex class II antigens and macrophage colony-stimulating factor precursor, and up-regulation of interleukin-8 and lysozyme. These results suggest that pathogen resistance may be weakened in heavy oil-exposed fish, causing a subsequent bacterial infection, and then proinflammatory genes may be induced as a defensive response against the infection. Additionally, we found candidate genes for use as biomarkers of heavy oil exposure, such as N-myc downstream regulated gene 1 and heat shock cognate 71 kDa proteins. (c) 2008 Elsevier Ltd. All rights reserved.

RefID: 498

Author: National Research Council (NRC)

Year: 2013

Title: An Ecosystem Services Approach to Assessing the Impacts of the Deepwater Horizon Oil Spill in the Gulf of Mexico

Journal: Book

Hyperlink: http://www.nap.edu/catalog/18387/an-ecosystem-services-approach-to-assessing-the-impacts-of-the-deepwater-horizon-oil-spill-in-the-gulf-of-mexico

Abstract: As the Gulf of Mexico recovers from the Deepwater Horizon oil spill, natural resource managers face the challenge of understanding the impacts of the spill and setting priorities for restoration work. The full value of losses resulting from the spill cannot be captured, however, without consideration of changes in ecosystem services--the benefits delivered to society through natural processes. An Ecosystem Services Approach to Assessing the Impacts of the Deepwater Horizon Oil Spill in the Gulf of Mexico discusses the benefits and challenges associated with using an ecosystem services approach to damage assessment, describing potential impacts of response technologies, exploring the role of resilience, and offering suggestions for areas of future research. This report illustrates how this approach might be applied to coastal wetlands, fisheries, marine mammals, and the deep sea -- each of which provide key ecosystem services in the Gulf -- and identifies substantial differences among these case studies. The report also discusses the suite of technologies used in the spill response, including burning, skimming, and chemical dispersants, and their possible long-term impacts on ecosystem services.

RefID: 499

Author: Nayar, S., Goh, B.P.L. and Chou, L.M.

Year: 2005

Title: Environmental impacts of diesel fuel on bacteria and phytoplankton in a tropical estuary assessed using in situ mesocosms

Journal: Ecotoxicology

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/15943112

Abstract: Dissolved or dispersed petroleum hydrocarbon concentrations (DDPH) were monitored in Ponggol estuary, Singapore, fortnightly from July 1999 to June 2000. DDPH concentrations ranged from 4.4 to 248.9 mu g l(-1) and 0.4 to 1099.7 mu g l(-1) for surface and subsurface waters, respectively and with mean concentrations of 41.01 mu gl(-1) in the water column. Absorbed or adsorbed petroleum hydrocarbon (AAPH) concentrations measured in sediments ranged from 20.6 to 541.0 mg kg(-1), with mean concentrations of 148.23 mg kg(-1). In situ mesocosm studies of bacteria and phytoplankton were based on field monitoring of environmentally measured concentrations of petroleum hydrocarbons, using diesel fuel as the source of contaminant. The mesocosm comprised of 25 L clear polycarbonate carboys incubated in situ for 6 days. Water and sediments from a clean site with undetectable levels of petroleum hydrocarbons were used in controls. The treatment mesocosms comprised of mean and highest concentrations of DDPH and AAPH. The study revealed signs of acute toxicity to autotrophs viz., phytoplankton and autotrophic bacteria in treatments simulating concentrations of diesel fuel found in the sediments. A stimulatory effect was seen at lower concentrations. Bacterial heterotrophs responded positively to all concentrations of diesel fuel because of the abundance of a carbon source, reduced grazing pressure and reduced competition for nutrients from phytoplankton.

RefID: 500

Author: Nayar, S., Goh, B.P.L. and Chou, L.M.

Year: 2004

Title: The impact of petroleum hydrocarbons (diesel) on periphyton in an impacted tropical estuary based on in situ microcosms

Journal: Journal of Experimental Marine Biology and Ecology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0022098103005252

Abstract: The distribution of petroleum hydrocarbons and their effects on the periphytic algal biomass using in situ microcosms were investigated in Ponggol estuary located on the northeastern coast of Singapore. Dissolved or dispersed petroleum hydrocarbon (DDPH) concentrations in the surface and bottom waters and absorbed or adsorbed petroleum hydrocarbon (AAPH) concentrations in sediments were monitored from July 1999 to June 2000. Results showed concentrations ranging from 4.42 to 248.94 mug l(-1), from 0.35 to 1099.65 mug l(-1), and from 20.55 to 541.01 mg kg(-1) for DDPH in surface and bottom waters and AAPH in sediments, respectively. Accidental spillages of fuel from dredgers operating in the estuary, fuel and engine oil from recreational boats, shipping operations in the adjacent strait, and runoff monsoon drains in the vicinity were some of the possible sources of petroleum hydrocarbons in the estuary. An assessment of environmentally realistic concentrations of petroleum hydrocarbons on periphytic algal biomass using in situ microcosms revealed signs of acute toxicity. A reduction in periphytic algal biomass (with respect to controls) of 68-93% was observed for various treatments exposed to diesel. (C) 2003 Elsevier B.V. All rights reserved.

RefID: 501

Author: Neff, J.M. and Burns, W.A.

Year: 1996

Title: Estimation of polycyclic aromatic hydrocarbon concentrations in the water column based on tissue residues in mussels and salmon: An equilibrium partitioning approach

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620151218/abstract;jsessionid=89FAA56B8F505BE8097676A742AD00D0.f02t03

Abstract: Equilibrium partitioning was used to estimate concentrations of dissolved polycyclic aromatic hydrocarbons (PAHs) in the water column from PAH residues in tissues of mussels and juvenile pink salmon collected from coastal marine waters affected by the Exxon Valdez oil spill. Estimated concentrations were within factors of 2 to 5 for fish and 5 to 10 for mussels of average total dissolved and particulate PAHs measured in concurrent water samples. Temporal trends of estimated and measured water-column PAH concentrations were comparable. Water-column PAH concentrations estimated from residues in tissues of mussels (Mytilus trossulus) were higher than estimates based on residues in tissues of juvenile pink salmon (Oncorhynchus gorbuscha). Possible reasons for this difference include seasonal variations in mussel lipid content, differences in PAH uptake and depuration rates between fish and mussels, differences in how fish and mussels interact with particulate oil, and possible short exposure times for juvenile pink salmon. All of these factors may play a role. In any event, estimates of dissolved PAHs in the water column, based on PAH residues in either fish or mussel tissue, confirm that PAH concentrations generally did not exceed water quality standards for protection of marine life.

RefID: 502

Author: Neff, J.M. and Stubblefield, W.A.

Year: 1995

Title: Chemical and toxicological evaluation of water quality following the Exxon Valdez oil spill

Journal: Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters

Hyperlink: http://www.valdezsciences.com/dspArticle.cfm?catID=13&artID=1083&artSecID=1125

Abstract: As part of a comprehensive water-quality assessment program performed in Prince William Sound and the western Gulf of Alaska following the Exxon Valdez oil spill of March 24, 1989, water samples were collected from 417 locations, most of them in areas through which the oil drifted, to assess the distribution and concentrations of petroleum hydrocarbons in the water column. Over 5,000 water samples were analyzed for individual and total petroleum alkanes and for aromatic hydrocarbons by very sensitive gas chromatographic techniques. A total of 2,461 of these samples were analyzed for polycyclic aromatic hydrocarbons (PAHs). Concurrent with some of these samples, an additional 123 water samples were collected in April 1989 (a week to a month after the spill) at 32 offshore locations and in June 1989 at 7 nearshore sites in Prince William Sound to determine the toxicity of the water to representative species of marine organisms. The toxicity of Prince William Sound water was assessed with standard Environmental Protection Agency (EPA) and American Society for Testing and Materials (ASTM) marine toxicity tests with representative species of three taxonomic groups: (1) Skeletonema costatum (a marine diatom), (2) Mysidopsis bahia (a crustacean), and (3) larval/juvenile Cyprinodon variegalus (a fish, the sheepshead minnow). Highest concentrations of total PAHs, the best indicator of the potential toxicity of the spilled oil to water-column organisms, were observed in the water column of Prince William Sound in the first two months after the spill. Measured PAH levels were below the state of Alaska's water quality standard of 10 ppb total aromatic hydrocarbons. This finding is consistent with National Oceanic and Atmospheric Administration (NOAA) water samples collected during the same time period. PAH concentrations in the water column of the sound declined rapidly with time after the spill to essentially background concentrations of 0.01 to 0.1 ppb by mid to late summer of 1989. No water samples from spill path areas of the western Gulf of Alaska contained more than 1.0 ppb total PAHs These concentrations are well below concentrations reported in the scientific literature to be toxic to marine plants and animals. Eight of 329 samples (2.4%) of the water surface contained between 10 and 29.3 ppb total PAHs; these samples probably contained oil sheen material. Toxicity tests with full strength Prince William Sound water showed no acute or chronic toxicity to three representative species of marine organisms. There was no dose-response relationship for any species or seawater sample, and there was no relationship between the concentration of total PAHs in the undiluted seawater samples and percentage of survival or relative growth rates in the test organisms. These studies show that the traces of petroleum hydrocarbons present in the water column of Prince William Sound and the western Gulf of Alaska shortly after the spill were well below concentrations capable of producing harmful effects in populations of sensitive species and life stages of marine organisms.

RefID: 503

Author: Neff, J.M., Bence, A.E., Parker, K.R., Page, D.S., Brown, J.S. and Boehm, P.D.

Year: 2006

Title: Bioavailability of polycyclic aromatic hydrocarbons from buried shoreline oil residues thirteen years after the Exxon valdez oil spill: A multispecies assessment

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/05-339R.1/abstract

Abstract: Seven taxa of intertidal plants and animals were sampled at 17 shoreline sites in Prince William Sound ([PWS]; AK, USA), that were heavily oiled in 1989 by the Exxon Valdez oil spill (EVOS) to determine if polycyclic aromatic hydrocarbons (PAH) from buried oil in intertidal sediments are sufficiently bioavailable to intertidal prey organisms that they might pose a health risk to populations of birds and wildlife that forage on the shore. Buried residues of EVOS oil are present in upper and middle intertidal sediments at 16 sites. Lower intertidal (0 in) sediments contain little oil. Much of the PAH in lower intertidal sediments are from combustion sources. Mean tissue total PAH (TPAH) concentrations in intertidal clams, mussels, and worms from oiled sites range from 24 to 36 ng/g (parts per billion) dry weight; sea lettuce, whelks, hermit crabs, and intertidal fish contain lower concentrations. Concentrations of TPAH are similar or slightly lower in biota from unoiled reference sites. The low EVOS PAH concentrations detected in intertidal biota at oiled shoreline sites indicate that the PAH from EVOS oil buried in intertidal sediments at these sites have a low bioavailability to intertidal plants and animals. Individual sea otters or shorebirds that consumed a diet of intertidal clams and mussels exclusively from the 17 oiled shores in 2002 were at low risk of significant health problems. The low concentrations of EVOS PAH found in some intertidal organisms at some oiled shoreline sites in PWS do not represent a health risk to populations of marine birds and mammals that forage in the interfidal zone.

RefID: 504

Author: Neff, J.M., Ostazeski, S., Gardiner, W. and Stejskal, I.

Year: 2000

Title: Effects of weathering on the toxicity of three offshore Australian crude oils and a diesel fuel to marine animals

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620190715/abstract

Abstract: The evaporative weathering properties, chemical composition, and toxicity of three Australian Northwest Shelf crude oils and an Australian diesel fuel were evaluated. The crude oils include one each of a condensate, a light, and a medium crude oil. Between 23 and 100% of the mass of the oils is lost during evaporative weathering equivalent to about 1 week on the sea surface. During weathering, the oils lose most of their monocyclic aromatic hydrocarbons (MAHs) and phenols; concentrations increase of less volatile phenols and polycyclic aromatic hydrocarbons (PAHs). The acute toxicity of water-accommodated fractions (WAFs) of the fresh and weathered oils to six species of temperate and tropical marine animals ranges from > 100% to about 11% WAF The MAHs are the most important contributors to the acute toxicity of the WAFs of the fresh oils. The contribution of PAHs to WAF toxicity increases with weathering. About 58% of the hazard indices (HI: exposure concentratiocutely toxic concentration) for the WAFs of the two light oils weathered for the equivalent of 1 d are attributable to PAHs. The toxicity of the WAFs of the condensate and light crude oil can be accounted for by MAHs, PAHs, and phenols; WAFs of the middle-weight crude oil and diesel fuel are higher than predicted based on their concentrations of total MAHs, PAHs, and phenols, indicating that othercomponents of the WAFs are contributing to their toxicity. These components may include the unresolved complex mixture and polar compounds (resins).

RefID: 505

Author: Neff, J.M., Owens, E.H., Stoker, S.W. and McCormick, D.M.

Year: 1995

Title: Shoreline Oiling Conditions in Prince William Sound Following the Exxon Valdez Oil Spill

Journal: Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters

Hyperlink: http://www.valdezsciences.com/dspArticle.cfm?catID=1&artID=1029&artSecID=1006

Abstract: Following the Exxon Valdez oil spill of March 24, 1989, in Prince William Sound, Alaska, Exxon conducted comprehensive, systematic shoreline surveys in cooperation with federal and state authorities to obtain information on the distribution and magnitude of shoreline oiling and to identify natural and cultural resources requiring special protection. Similar joint surveys were performed during the springs of 1990, 1991, and 1992 on all Prince William Sound and Gulf of Alaska shorelines that were suspected of having remnants of weathered oil and that would benefit from further cleanup. The extent of oiling declined substantially between 1989 and 1992: in 1989, survey teams found oil on about 16% (783 km) of the approximately 5 000 km of shoreline in Prince William Sound; in the spring of 1991, they found oil on about 96 km; and, in May 1992, on only about 10 km of shoreline in the sound. During this period, most of the oil was located in the biologically least productive upper intertidal and supratidal zones. In the springs of 1990, 1991, and 1992, isolated pockets of subsurface oil were found, chiefly in small scattered zones in coarse cobble/boulder sediments in the upper intertidal or supratidal zones. In 1991, about one-third of the subdivisions in Prince William Sound with surface oil also contained some subsurface oil. The areal extent of this subsurface oil declined by nearly 70% between 1991 and 1992, from about 37 000m2 to about 12 000m2. Moreover, where subsurface oil remained in 1992, it was present in lesser amounts. Rates of oil removal were greatest on coastal sections treated early in the spring and summer of 1989. Where shoreline treatment was delayed, the subsequent rate of removal of oil from the shore by natural processes was slower.

RefID: 506

Author: Neff, J.M., Page, D.S. and Boehm, P.D.

Year: 2011

Title: Exposure of sea otters and harlequin ducks in Prince William Sound, Alaska, USA, to shoreline oil residues 20 years after the Exxon Valdez oil spill.

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.415/abstract

Abstract: We assessed whether sea otters and harlequin ducks in an area of western Prince William Sound, Alaska, USA (PWS), oiled by the 1989 Exxon Valdez oil spill (EVOS), are exposed to polycyclic aromatic hydrocarbons (PAH) from oil residues 20 years after the spill. Spilled oil has persisted in PWS for two decades as surface oil residues (SOR) and subsurface oil residues (SSOR) on the shore. The rare SOR are located primarily on the upper shore as inert, nonhazardous asphaltic deposits, and SSOR are confined to widely scattered locations as small patches under a boulder/cobble veneer, primarily on the middle and upper shore, in forms and locations that preclude physical contact by wildlife and diminish bioavailability. Sea otters and harlequin ducks consume benthic invertebrates that they collect by diving to the bottom in the intertidal and subtidal zones. Sea otters also dig intertidal and subtidal pits in search of clams. The three plausible exposure pathways are through the water, in oil-contaminated prey, or by direct contact with SSOR during foraging. Concentrations of PAH in near-shore water off oiled shores in 2002 to 2005 were at background levels (< 0.05 ng/L). Median concentrations of PAH in five intertidal prey species on oiled shores in 2002 to 2008 range from 4.0 to 34 ng/g dry weight, indistinguishable from background concentrations. Subsurface oil residues are restricted to locations on the shore and substrate types, where large clams do not occur and where sea otters do not dig foraging pits. Therefore, that sea otters and harlequin ducks continue to be exposed to environmentally significant amounts of PAH from EVOS 20 years after the spill is not plausible. Environ. Toxicol. Chem. 2011;30:659-672. (C) 2011 SETAC

RefID: 507

Author: Neff, J.M., Page, D.S., Landrum, P.F. and Chapman, P.M.

Year: 2013

Title: The importance of both potency and mechanism in dose-response analysis: An example from exposure of Pacific herring (Clupea pallasi) embryos to low concentrations of weathered crude oil

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X1200598X

Abstract: This paper reanalyzes data from an earlier study that used effluents from oiled-gravel columns to assess the toxicity of aqueous fractions of weathered crude oil to Pacific herring embryos and larvae. This reanalysis has implications for future similar investigations, including the observance of two distinct dose-response curves for lethal and sublethal endpoints for different exposures in the same experiment, and the need to consider both potency and slope of dose-response curves for components of a toxicant mixture that shows potentially different toxicity mechanisms/causation. Contrary to conclusions of the original study, the aqueous concentration data cannot support the hypothesis that polycyclic aromatic hydrocarbons (PAHs) were the sole cause of toxicity and that oil toxicity increased with weathering. Confounding issues associated with the oiled gravel columns include changes in the concentration and composition of chemicals in exposure water, which interfere with the production of reliable and reproducible results relevant to the field. (c) 2012 Elsevier Ltd. All rights reserved.

RefID: 508

Author: Nelson, B.

Year: 2009

Title: The Exxon Valdez Trustee Hydrocarbon Database

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/index.cfm?FA=searchResults.projectInfo&Project_ID=2140

Abstract: This is an on-going service project that provides data and sample archiving services for all samples collected for hydrocarbon analysis in support of Exxon Valdez Oil Spill Trustee Council projects. These data represent samples collected since the oil spill in 1989 to the present and include National Resource Damage Assessment (NRDA) studies (environmental and laboratory) and Restoration and Recovery data. This project serves as an archive for chemical analyses and sample data and storage of physical samples that have not been analyzed and provides copies of the ACCESS database to interested parties. The project also responds to several Freedom of Information Act (FOIA) requests each year for information associated with these data. Interpretative services for these data are available.

RefID: 509

Author: Nelson, T.R., DeVries, D.R., Wright, R.A. and Gagnon, J.E.

Year: 2015

Title: Fundulus grandis Otolith Microchemistry as a a Metric of Estuarine Discrimination and Oil Exposure

Journal: Estuaries and Coasts

Hyperlink: http://link.springer.com/article/10.1007%2Fs12237-014-9934-y

Abstract: The Gulf killifish, Fundulus grandis, is a vital component of saltmarsh ecosystems and an indicator species for environmental impacts, because of strong site fidelity. Also, their otoliths can provide a record of environmental conditions because they are metabolically inert, grow continuously with the fish, and incorporate trace elements from the environment. We used laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) to determine chemical composition differences in Gulf killifish otoliths across the northern Gulf of Mexico. Fish collections started in fall 2012 and continued through summer 2013. Concentrations of Mn, Sr, and Ba varied among sites and allowed for discrimination of fish between estuaries in Louisiana (elevated Ba concentrations) and the west side of Mobile Bay, Alabama (elevated Mn concentrations). However, elemental signatures of otoliths from Mississippi, Florida, and the east side of Alabama could not be discriminated from one another. Regional differences in otolith elemental signatures in Louisiana and west Alabama appear to provide unique chemical tags for these waters and, thus, may have utility for nursery habitat determination for species with estuarine-dependent juveniles. Otoliths of F. grandis that had been exposed to oil (either from the 2010 Deepwater Horizon oil spill or because of close proximity to an oil refinery) did not differ in elemental signature between paired oiled and non-oiled sites. Therefore, the otoliths did not contain trace metals associated with oil. Also, the relative condition of F. grandis did not differ between paired sites. The presence of F. grandis at all sites, the lack of effect of oiling on relative condition, and no signal of oil-related elements in the otoliths suggest minimal long-term impact of the Deepwater Horizon oil spill on F. grandis.

RefID: 510

Author: Nero, V., Farwell, A., Lee, L.E.J., Van Meer, T., MacKinnon, M.D. and Dixon, D.G.

Year: 2006

Title: The effects of salinity on naphthenic acid toxicity to yellow perch: Gill and liver histopathology

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651305001764

Abstract: Naphthenic acids (NAs) are naturally occurring saturated linear and cyclic carboxylic acids found in petroleum, including the bitumen contained in the Athabasca Oil Sands deposit in Alberta, Canada. The processing of these oil sands leads to elevated concentrations of NAs, as well as increased salinity from produced waters as a result of ions leaching from the ores, the process aids, and the water associated with the deeper aquifers. These changes can result in waters that challenge reclamation of impacted waters associated with oil sands development. Laboratory tests examined the effects of salinity on NA toxicity using local young-of-the-year yellow perch exposed to a commercially available mixture of NAs (CNA) and an NA mixture that was extracted from oil sands process-affected water (ENA), with and without the addition of sodium sulfate (Na2SO4). Gill and liver histopathological changes were evaluated in the surviving fish after 3 weeks of exposure. At 6.8 mg/L ENA and 3.6 mg/L CNA, 100% mortality was observed, both with and without the addition of salt. Exposure of yellow perch to 25% of the NA required to give an LC100 (0.9 mg/L CNA; 1.7 mg/L ENA) resulted in high levels of gill proliferative (epithelial, mucous, and chloride cell) changes, a response that was increased with the addition of 1 g/L salt (Na2SO4) for the ENA. The significance of these changes was a reduced gill surface area, which likely caused a reduction in both the transport of NAs within the fish and the exchange of vital respiratory gases. While the gills were affected, no liver alterations were identified following NA or NA+salt exposures. Differences in the chemical composition of the NAs tested may explain the differences in the lethality and histopathology of yellow perch.

RefID: 511

Author: Nero, V., Farwell, A., Lister, A., Van der Kraak, G., Lee, L.E.J., Van Meer, T., MacKinnon, M.D. and Dixon, D.G.

Year: 2006

Title: Gill and liver histopathological changes in yellow perch (Perca flavescens) and goldfish (Carassius auratus) exposed to oil sands process-affected water

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651305001181

Abstract: The extraction of bitumen from the Athabasca oil sands (Alberta, Canada) produces significant volumes of process-affected water containing elevated levels of naphthenic acids (NAs), ions, and polycyclic aromatic hydrocarbons (PAHs). The sublethal response of aquatic organisms exposed to oil sands constituents in experimental aquatic environments that represent possible reclamation options has been studied. In this study, the effects of process-affected waters on gill and liver tissues in yellow perch (Perca flavescens) and caged goldfish (Carassius auratus) held in several reclamation ponds at Syncrude's Mildred Lake site have been assessed. Following a 3-week exposure, significant gill (epithelial cell necrosis, mucous cell proliferation) and liver (hepatocellular degeneration, inflammatory cell infiltration) histopathological changes were noted in fish held in waters containing high levels of oil sands process-affected water. In addition, measurements of gill dimensions (gill morphometrical indices) proved sensitive and provided evidence of a physiological disturbance (gas exchange) with exposure to oil sands materials. Due to the complexity of oil sands process-affected water, the cause of the alterations could not be attributed to specific oil sands constituents. However, the histopathological parameters were strong indicators of exposure to oil sands process-affected water and morphometrical data were sensitive indicators of pathological response, which can be used to identify the interactive effects of ionic content, NAs, and PAHs in future laboratory studies. (c) 2005 Elsevier Inc. All rights reserved.

RefID: 512

Author: Neto, A.G. and Costa, C.S.B.

Year: 2009

Title: SURVIVAL AND GROWTH OF THE DOMINANT SALT MARSH GRASS SPARTINA ALTERNIFLORA IN AN OIL INDUSTRY SALINE WASTEWATER

Journal: International Journal of Phytoremediation

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/15226510902861727

Abstract: Saline oil produced water (PW) is the largest wastewater stream in the oil exploration and production processes. Although eventual disposal of PW into shallow coastal waters occurs nearby coastal wetlands, no studies regarding its toxicity to higher plants were found in our literature review. To fill this knowledge gap and evaluate the potential use of this halophyte for PW phytoremediation the salt marsh grass Spartina alterniflora was grown in five PW concentrations and no PW treatment control for seven weeks. The oil & grease, NaCl, and ammonium (N-NH4(+)) concentrations in the PW were 120 mg L(-1), 30 g L(-1), and 381 mg L(-1), respectively. Plants grown in 30% PW and 10% PW achieved survival rates (75%) significantly higher than plants grown in 100% PW (35% survival). LT50 of S. alterniflora to raw PW with 120 mg L(-1) of oil & grease (100% PW) was estimated at 30 days. Root and sprout biomass were significantly stimulated by PW; plants grown in 10% to 50% PW concentrations were 70-300% more productive than those in control, 80% PW and 100% PW, respectively. No significant inhibitory effects on survival or growth were detected for concentrations of PW less than 80% when compared to control. Our results pointed out that S. alterniflora grows in saline oil PW and its potential use to phytoremediate this effluent should be evaluated.

RefID: 513

Author: Neuparth, T., Capela, R., Pereira, S.P.P., Moreira, S.M., Santos, M.M. and Reis-Henriques, M.A.

Year: 2014

Title: TOXICITY EFFECTS OF HAZARDOUS AND NOXIOUS SUBSTANCES (HNS) TO MARINE ORGANISMS: ACUTE AND CHRONIC TOXICITY OF p-XYLENE TO THE AMPHIPOD Gammarus locusta

Journal: Journal of Toxicology and Environmental Health

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/15287394.2014.921867

Abstract: Despite the recent focus on hazardous and noxious substances (HNS) spills preparedness and responses, much remains to be done regarding the threat posed by HNS spills on marine biota. Among the identified priority HNS, p-xylene was selected to conduct ecotoxicological assays. The aim of this study was to assess the performance of the amphipod Gammarus locusta under acute and chronic exposure to p-xylene simulating conditions of a spill incident. In the acute exposure (96 h) the p-xylene LC50 was estimated. In the chronic bioassay (36 d), an integration of organism-level endpoints (survival, growth rate, and sex ratio) with biochemical markers indicative of oxidative stress including catalase (CAT), glutathione S-transferase (GST), and superoxide dismutase (SOD) activities and lipid peroxidation (LPO) levels was determined. The aim was to increase the xylene ecotoxicological database and better predict its impact in aquatic environments. p-Xylene induced several chronic toxicity effects in G. locusta. Significant alterations in antioxidant enzymes and lipid peroxidation levels as well as growth rate and biased sex-ratio were observed. p-Xylene significantly affected the activities of CAT, SOD, and GST in G. locusta and produced oxidative damage by increasing levels of LPO in males. Further, impacts in key ecological endpoints, that is, growth and sex ratio, were noted that might be indicative of potential effects at the population level in a spill scenario. The present data may be useful to assist relevant bodies in preparedness and response to HNS spills.

RefID: 514

Author: Niu, H., Li, Z., Lee, K., Kepkay, P. and Mullin, J.

Year: 2010

Title: A Method for Assessing Environmental Risks of Oil-Mineral-Aggregate to Benthic Organisms

Journal: Human and Ecological Risk Assessment

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/10807039.2010.501240

Abstract: Previous studies have shown that Oil-Mineral-Aggregate (OMA) formation enhances the dispersion of marine oil spills, but the potential impacts of settled OMAs on benthic organisms are not well known. A comprehensive numerical approach is proposed here to model the transport of OMAs and assesses their potential risks. The predicted environmental concentrations (PEC) of settled oil in OMAs was calculated using a random walk particle tracking model and the benchmark concentrations (BCs) of individual hydrocarbon groups were computed based on a equilibrium partitioning (EqP) approach. The likely of risks in terms of Hazard Quotient (HQ) were then determined using a Monte Carlo simulation method. HQ for both aliphatic and aromatic hydrocarbon groups were calculated for OMAs formed with two sediments, Mississippi River Delta (MRD) and Standard Reference Material (SRM). Mean total HQs were also determined by a simple sum of individual HQ. The predicted results from a case study based on a spill of 1000 tons of South Louisiana crude oil in the Gulf of St. Lawrence with a water depth of 80 m show that the SRM is unlikely to cause adverse impacts but this may not be the case for MRD. Furthermore, it has been found that the application of chemical dispersant (CD) increased the risks of MRD but it had little effects on SRM.

RefID: 515

Author: Norcross, B.L. and Frandsen, M.

Year: 1998

Title: Injury to larval fish in Prince William Sound

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/41571036.pdf

Abstract: Field studies were conducted in 1989 to determine spatial and temporal variation of finfish larvae in Prince William Sound in the months following the Exxon Valdez oil spill. This study contributes basic larval fish occurrence information for Prince William Sound. Unfortunately, it is biased as a baseline because it represents the ecosystem following an oil spill. The patterns of distribution are interpreted in the context of oceanographic patterns affecting transport of oil and larvae. Temporal and spatial distribution and abundance patterns are shown for the six most dominant taxa of larval fishes captured: walleye pollock Theragra chalcogramma, northern smoothtongue Leuroglossus schmidti, Pacific herring Clupeapallasi, capelin Mallotus villosus, rockfishes Sebastes spp., and flathead sole Hippoglossoides elassodon. Most larval fishes were in the upper 50 m of the water column and either concentrated in the oiled western portions of Prince William Sound or were transported through those areas by the same processes that moved the oil. Appendices provide temporal, spatial and geographic distribution and abundance of all fishes collected (44 species or species groups) on a gross scale including all of Prince William Sound and Resurrection Bay.

RefID: 516

Author: Norcross, B.L. and Frandsen, M.

Year: 1996

Title: Distribution and abundance of larval fishes in Prince William Sound, Alaska, during 1989 after the Exxon Valdez oil spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: Field studies were conducted in 1989 to determine spatial and temporal variation of finfish larvae in Prince William Sound in the months following the Exxon Valdez oil spill. This study contributes basic larval fish occurrence information for Prince William Sound. Unfortunately, it is biased as a baseline because it represents the ecosystem following an oil spill. The patterns of distribution are interpreted in the context of oceanographic patterns affecting transport of oil and larvae. Temporal and spatial distribution and abundance patterns arc shown for the six most dominant taxa of larval fishes captured: walleye polluck Theragra chalcogramma, northern smoothtongue Leuroglossus schmidtii, Pacific herring Clupea pallasi, capelin Mallotus villosus, rockfishes Sebastes spp., and flathead sole Hippoglossoides elassodon. Most larval fishes were in the upper 50 m of the water column and either concentrated in the oiled western portions of Prince William Sound or were transported through those areas by the same processes that moved the oil.

RefID: 517

Author: Norcross, B.L., Frandsen, M., Hose, J. and Biggs, E.

Year: 1995

Title: Larval herring distribution, abundance and sublethal assessment in Prince William Sound, Alaska during 1989 following the Exxon Valdez oil spill

Journal: Canadian Technical Report of Fisheries and Aquatic Sciences

Hyperlink: http://waves-vagues.dfo-mpo.gc.ca/waves-vagues/search-recherche/display-afficher/191554

Abstract: Pacific herring (Clupea pallasi) larvae were collected throughout Prince William Sound in May, June and July following the Exxon Valdez oil spill of March 1989. Herring may have been exposed as embryos in contaminated spawning grounds and as larvae encountering the oil trajectory. Although it was impossible to estimate individual exposure to Exxon Valdez oil, many larvae exhibited conditions previously associated with oil exposure. These included morphologicmal formations, genetic damage and small size. Growth between May and June was the least ever reported for larval herring. Genetic damage was highest in May and was elevated through the western area of the sound, which overlapped the oil trajectory. Deformed larvae were found both inside and outside of areas considered to be oiled. As movement of herring larvae is related tocurrent patterns within the sound, it is thus likely that the oil affected more areas of Prince William Sound than the oil spill trajectory maps may indicate.

RefID: 518

Author: Norcross, B.L., Hose, J.E., Frandsen, M. and Brown, E.D.

Year: 1996

Title: Distribution, abundance, morphological condition, and cytogenetic abnormalities of larval herring in Prince William Sound, Alaska, following the Exxon Valdez oil spill

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f96-212

Abstract: Pacific herring (Clupea pallasi) larvae were collected throughout Prince William Sound in May, June, and July following the Exxon Valdez oil spill of March 1989. Movement of herring larvae is related to current patterns within the sound, and deformed larvae were found both inside and outside of areas considered to be oiled. Herring may have been exposed to oil as embryos in contaminated spawning areas and as larvae encountering the oil trajectory. Although it was impossible to estimate the effects of exposure to Exxon Valdez oil, many larvae exhibited symptoms associated with oil exposure in laboratory experiments and other oil spills. These included morphological malformations, genetic damage, and small size. Growth between May and June 1989 was the lowest ever reported for field-caught larval herring. Jaw malformations and genetic damage were highest in May and were elevated through the western area of Prince William Sound, which overlapped the oil trajectory. In June 1989,jaw development was normal, but genetic damage persisted. In contrast, in May 1995, jaw and cytogenetic development were normal and significantly different from those in larvae in 1989.

RefID: 519

Author: Notini, M.

Year: 1978

Title: Long-Term Effects of an Oil Spill on Fucus Macrofauna in a Small Baltic Bay

Journal: Journal of the Fisheries Research Board of Canada

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f78-124

Abstract: On October 6, 1970, the small tanker Irini ran aground in the southern part of the stockholm archipelago, releasing about 1000 t of medium and heavy fuel oil. Approximately 400 t drifted into a small bay, Giistviken, wiping out nearly the entire littoral fauna. Most of the oil was collected mechanically during the winter, and by May 1971 cleanup operations were completed. The recruitment of the bladder wrack (Fucus vesiculosus) community in the bay was observed at intervals over a 5-yr period. Significantly increased macrofauna population densities were found for a number of species in the 1974 and 1976 samples compared to those of 1971 and 1972. From June-July l97l to June 1976, the mean numbers of individuals for all species rose from about 280 to 1000/100 g of Fucus dry weight. The bivalve Mytilus edulis increased in number from 0 to about 45, the gastropod Theodoxus fluviatilis from 0 to about 160, the amphipod Gamntarus spp. from about 40 to 580, the isopods Idotea spp. from about 5 to 35, and laera spp. from almost 0 to about 10/100 g Fucus. Larvae of Chirononridae were the only group found with a decreased density between the first and sixth summers after the spill, with 240 and 145 individuals, respectively. The data obtained are discussed in relation to conditions in a nearby unpolluted bay and to normally occurring cyclic variations.

RefID: 520

Author: Nunes, P. and Benville, P.E. Jr.

Year: 1978

Title: ACUTE TOXICITY OF THE WATER-SOLUBLE FRACTION OF COOK INLET CRUDE-OIL TO THE MANILA CLAM

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/0025326X78902424

Abstract:

RefID: 521

Author: O'Clair, C.E., Short, J.W. and Rice, S.D.

Year: 1996

Title: Petroleum hydrocarbon-induced injury to subtidal marine sediment resources

Journal: EVOS Trustee Council

Hyperlink: http://jlc-web.uaa.alaska.edu/client/arlis/search/detailnonmodal/ent:$002f$002fSD_ILS$002f265$002fSD_ILS:265143/ada?qu=Petroleum+hydrocarbon-induced+injury+to+subtidal+marine+sediment+resources&te=ILS

Abstract: This study was designed to assess the possible injury by petroleum, derived from the Exxon Valdez oil spill to benthic infaunal resources within Prince William Sound in waterdeeper than 20 m. The sampling plan was developed to coordinate with several other concurrent programs within Prince William Sound. Analyses of benthic biological datacollected from 14 bays in Prince William Sound in 1990 at 40, 100 and > 100 m, byunivariate and multivariate techniques, demonstrated no obvious disturbance effects on the benthic biota 16 months after the oil spill. In all multivariate analyses, the major environmental variables related to the composition of benthic assemblages were sedimentparameters such as percent silt, clay, mud, percent water and amount of nitrogen and carboni n sediment. Although limited amounts of petroleum hydrocarbons and presence of hydrocarbon degrading bacteria were detected at some sites at 40 and 100 m in 1989 and1990, minor or no impact was sustained by benthic fauna of the deep benthos within theSound. It is apparent that the current speed within Prince William Sound during the oil spillwas sufficient to flush out toxic fractions of the oil spill before they could damage the faunawithin the deep benthos.

RefID: 522

Author: O'Clair, C.E., Short, J.W. and Rice, S.D.

Year: 1996

Title: Recovery of sediments in the lower intertidal and subtidal environment

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/35840762.pdf

Abstract: Sediments were collected at ten locations in Prince William Sound in July 1993 to determine the geographical and bathymetric distribution of oil from the Exxon Valdez oil spill in the low intertidal zone and subtidal region. We sampled sediments at mean lower low water (0 m) and at five subtidal depths from 3 to 100 m. No Exxon Valdez oil was found in sediments at 0 m where the greatest mean intertidal concentration of total polynuclear aromatic hydrocarbons excluding perylene (54 ng/g) was observed at Moose Lips Bay. Subtidal sediments showed polynuclear aromatic hydrocarbon composition patternsimilar to Exxon Valdez oil at three sites, Herring Bay, Northwest Bay and Sleepy Bay. Contamination of sediments by Exxon Valdez oil reached a depth of 20 m at Northwest Bay and Sleepy Bay. The greatest mean concentration of total polynuclear aromatic hydrocarbons excluding perylene inbenthic sediments (423 1 ng/g) occurred at 20 m at Northwest Bay. In deep sediments (240 m) we found no evidence of weathered Exxon Valdez oil. The hydrocarbon concentrations in sediments at these depths were similar at reference and assessment locations. Petroleum hydrocarbons at the 100 m depth were chiefly from the Katalla source.

RefID: 523

Author: O'Brien, P.Y. and Dixon, P.S.

Year: 1976

Title: The effects of oils and oil components on algae: A review

Journal: Book

Hyperlink: http://www.tandfonline.com/doi/pdf/10.1080/00071617600650161

Abstract:

RefID: 524

Author: O'brien, W.J.

Year: 1978

Title: TOXICITY OF PRUDHOE BAY CRUDE-OIL TO ALASKAN ARCTIC ZOOPLANKTON

Journal: Arctic

Hyperlink: http://www.jstor.org/stable/40508900

Abstract: Bioassay experiments were conducted to determine the relative susceptibilities of three arctic zooplankton species to oil pollution, and the results were compared with the effects of an actual oil spill on a pond near Barrow. In both the bioassay s and the pond, the addition of Prudhoe Bay crude oil was toxic to fairy shrimp (Branchionecta paludosa O. F. Müller), which seemed most sensitive, Daphnia middendorffiana Fischer, which was next most susceptible and Heterocope septentrionalis Juday and Muttkowski, which appeared somewhat resistant to the effects of oil. Cyclopoid copepods were the only common zooplankters able to survive the pond oil spill, and these were still present two and one half weeks after the spill. The rapid deaths of the other species, especially the branchiopods, suggest that zooplankton may be the most susceptible of all arctic freshwater organisms to oil pollution.

RefID: 525

Author: O'Clair, C.E., Trowbridge, C. and Ackley, D.

Year: 1990

Title: Injury to Prince William Sound crabs. Exxon Valdez Oil Spill StatelFederal Natural Resource Damage Assessment Annual Report (Fish/Shellfish Study Number 14)

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/index.cfm?FA=searchResults.projectInfo&Project_ID=1257

Abstract: To determine the effects of exposure to oil from the Exxon Valdez on reproductive condition, incidence of limb loss and shell abnormalities, and histopathological responses of Dungeness and brown king crabs, we sampled crab populations using crab pots and divers. Dungeness crabs were sampled in Orca Bay (unoiled) in eastern Prince William Sound and at 12 locations in western Prince William Sound (oiled) in April/May 1989. A total of 188 crab pot pulls and 39 dives were made in search of Dungeness crabs. Brown king crabs were sampled with pots in Knight Island Passage (oiled) and outer Port Nellie Juan (unoiled) in early September 1989. Probably because of sea otter predation western Prince William Sound harbored very few Dungeness crabs, therefore precluding an assessment of the effects of the Exxon Valdez oil spill on Dungeness crab populations there. Approximately one-third of the brown king crabs captured in the oiled area exhibited injury with the majority of injuries to females. No oil was observed on pots, bait jars, lines, or crabs captured. Too few brown king crabs were caught in the control area to compare oiled and unoiled areas for reproductive condition, limb loss and abnormalities in new crab shells.

RefID: 526

Author: Olsen, A.J., Nordtug, T., Altin, D., Lervik, M. and Hansen, B.H.

Year: 2013

Title: Effects of dispersed oil on reproduction in the cold water copepod Calanus finmarchicus (Gunnerus)

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.2273/abstract

Abstract: Following a 120-h exposure period to 3 concentrations of oil dispersions (0.022 mg L-1, 1.8 mg L-1, and 16.5 mg L-1, plus controls) generated from a North Sea crude oil and a subsequent 21-d recovery, mortality, and several reproduction endpoints (egg production rates, egg hatching success, and fraction of females participating in reproduction) in Calanus finmarchicus were studied. Concentration-dependent mortality was found during exposure, averaging to 6%, 3%, 15%, and 42% for the controls and 3 exposure levels, respectively. At the start of the recovery period, mean egg production rates of surviving females from the highest concentrations were very low, but reproduction subsequently improved. In a 4-d single female reproduction test starting 13 d postexposure, no significant differences in egg production rates or hatching success were found between reproducing control and exposed copepods. However, a significantly lower portion of the surviving females from the highest exposure participated in egg production. The results indicate that although short-term exposure to oil-polluted water after an oil spill can induce severe mortality and temporarily suspend reproduction, copepods may recover and produce viable offspring soon after exposure. The results might imply that for C. finmarchicus populations, the impact from short-term exposure to an oil spill might be predicted from acute mortality and that delayed effects make only a limited contribution to population decrease. Environ Toxicol Chem 2013;32:2045-2055. (C) 2013 The Authors. Environmental Toxicology and Chemistry Published by Wiley Periodicals, Inc., on behalf of SETAC. This is an open access article under the terms of the Creative Commons Attribution-Non-Commercial License, which permits use, distribution, and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

RefID: 527

Author: Olsvik, P.A., Hansen, B.H., Nordtug, T., Moren, M., Holen, E. and Lie, K.K.

Year: 2011

Title: Transcriptional evidence for low contribution of oil droplets to acute toxicity from dispersed oil in first feeding Atlantic cod (Gadus morhua) larvae

Journal: Comparative Biochemistry and Physiology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S153204561100127X

Abstract: We evaluated the potential contribution of oil droplets to the toxicity of dispersed oil to first feeding fish larvae. Atlantic cod larvae were exposed to five concentrations of either artificially weathered (200 degrees C residue) dispersed oil (D1-D5) containing oil droplets [medium size 11-13 mu m based on volume] and water-soluble fraction [WSF] or the filtered dispersions containing only the corresponding equilibrium WSFs only (W1-W5). The larvae were exposed for 4 days and harvested for transcriptional analysis at 13 days post hatching. The most significant differently expressed genes were observed in cod larvae exposed to the highest concentration of the dispersed oil (containing 10.41 +/- 0.46 mu g Sigma PAH/L), with CYP1A showing the strongest response. Functional analysis further showed that the top scored network as analyzed with Ingenuity Pathway Analysis was "Drug Metabolism, Endocrine System Development and Function, Lipid Metabolism". Oil exposure also increased the expression of genes involved in bone resorption and decreased the expression of genes related to bone formation. In conclusion, oil exposure affects drug metabolism, endocrine regulation, cell differentiation and proliferation, apoptosis, fatty acid biosynthesis and tissue development in Atlantic cod larvae. The altered gene transcription was dominated by the WSF and the corresponding oil droplet fraction only had a moderate contribution to the observed changes. (C) 2011 Elsevier Inc. All rights reserved.

RefID: 528

Author: Olsvik, P.A., Lie, K.K., Nordtug, T. and Hansen, B.H.

Year: 2012

Title: Is chemically dispersed oil more toxic to Atlantic cod (Gadus morhua) larvae than mechanically dispersed oil? A transcriptional evaluation

Journal: BMC Genomics

Hyperlink: http://www.biomedcentral.com/1471-2164/13/702

Abstract: Background: The use of dispersants can be an effective way to deal with acute oil spills to limit environmental damage, however very little is known about whether chemically dispersed oil have the same toxic effect on marine organisms as mechanically dispersed oil. We exposed Atlantic cod larvae to chemically and mechanically dispersed oil for four days during the first-feeding stage of development, and collected larvae at 14 days post hatch for transcriptional analysis. A genome-wide microarray was used to screen for effects and to assess whether molecular responses to chemically and mechanically dispersed oil were similar, given the same exposure to oil (droplet distribution and concentration) with and without the addition of a chemical dispersant (Dasic NS). Results: Mechanically dispersed oil induced expression changes in almost three times as many transcripts compared to chemically dispersed oil (fold change >+/-1.5). Functional analyses suggest that chemically dispersed oil affects partly different pathways than mechanically dispersed oil. By comparing the alteration in gene transcription in cod larvae exposed to the highest concentrations of either chemically or mechanically dispersed oil directly, the chemically dispersed oil affected transcription of genes involved nucleosome regulation, i.e. genes encoding proteins participating in DNA replication and chromatin formation and regulation of cell proliferation, whereas the mechanically dispersed oil most strongly affected genes encoding proteins involved in proteasome-mediated protein degradation. Cyp1a was the transcript that was most strongly affected in both exposure groups, with a 60-fold induction in the two high-exposure groups according to the RT-qPCR data, but no significant difference in transcriptional levels was observed between the two treatments. Conclusions: In summary, dispersants do not appear to add to the magnitude of transcriptional responses of oil compounds but rather appear to lower or modify the transcriptional effect on cod larvae.

RefID: 529

Author: Orbea, A., Garmendia, L., Marigómez, I. and Cajaraville, M.P.

Year: 2006

Title: Effects of the 'Prestige' oil spill on cellular biomarkers in intertidal mussels: results of the first year of studies

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v306/p177-189/

Abstract: In November 2002 the tanker 'Prestige' sunk in front of the Galician coast (NW Iberian Peninsula). As a result, > 60000 t of heavy fuel oil leaked into the sea, affecting > 1000 km of coastline. In order to assess the effects of the oil spill on coastal ecosystems, mussels Mytilus galloprovincialis were sampled (April, July and September 2003) in 17 locations along the Galician and Bay of Biscay coasts. In this study, 3 biomarkers were assessed: lysosomal responses as changes in the lysosomal structure and in the lysosomal membrane stability, accumulation of intracellular neutral lipids and peroxisome proliferation as induction of acyl-CoA oxidase (AOX) activity. Mussel flesh condition index and gonad developmental stages were assessed as supporting parameters. Lysosomal membrane stability was reduced in mussels from all locations, indicating disturbed health, especially in mussels from all Galician locations. Similarly, lysosomal enlargement was observed in most locations, as shown by relatively low values of the surface-to-volume ratio, although the volume density of lysosomes was low due to decreased lysosomal numbers. Overall, intracellular accumulation of neutral lipids was conspicuous in digestive tubules of mussels collected in July and was increased further in September. AOX induction was detectable in mussels sampled in April, except for those collected in Galicia. In July mussels from the most impacted stations in Galicia, Caldebarcos and Camelle, showed the highest AOX values. In conclusion, the biomarkers employed detected exposure to toxic chemicals and a disturbed status of health in mussels from the northern Iberian Peninsula after the 'Prestige' oil spill and will allow assessment of the long-term effects of the spill on the coastal ecosystems.

RefID: 530

Author: Oris, J.T. and Roberts, A.P.

Year: 2013

Title: Cytochrome P450 1A (CYP1A) as a biomarker in oil spill assessments

Journal: Oil in the Environment: Legacies and Lessons of the Exxon Valdez Spill

Hyperlink:

Abstract: Book Chapter (no abstract)

RefID: 531

Author: Ormseth, O.A. and Ben-David, M.

Year: 2000

Title: Ingestion of crude oil: effects on digesta retention times and nutrient uptake in captive river otters

Journal: Journal of Comparative Physiology

Hyperlink: http://link.springer.com/article/10.1007%2Fs003600000119

Abstract: Studies following the Exxon Valdez oil spill in Prince William Sound, Alaska indicated that river otters (Lontra canadensis) from oiled regions displayed symptoms of degraded health, including reduced body weight. We examined the fate of ingested oil in the digestive tract and its effects on gut function in captive river otters. Fifteen wild-caught males were assigned to three groups, two of which were given weathered crude oil in food (i.e., control, 5 ppm day(-1), and 50 ppm day(-1)) under controlled conditions at the Alaska Sealife Center. Using glass beads as non-specific digesta markers and stable isotope analysis, we determined the effects of ingested oil on retention time and nutrient uptake. Our data indicated that oil ingestion reduced marker retention time when we controlled for activity and meal size. Fecal isotope ratios suggested that absorption of lipids in the oiled otters might have been affected by reduced retention time of food. In addition, a dilution model indicated that as much as 80% of ingested oil was not absorbed in high-dose animals. Thus, while the ingestion of large quantities of weathered crude oil appears to reduce absorption of oil hydrocarbons and may alleviate systemic effects, it may concurrently affect body condition by impacting digestive function.

RefID: 532

Author: Otitoloju, A.A.

Year: 2005

Title: Crude oil plus dispersant: always a boon or bane?

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651303002483

Abstract: The toxicities of a Nigerian brand of crude oil (Forcados Light), a newly approved dispersant for use in Nigerian ecosystems (Biosolve), and their mixtures, based on ratios 9:1, 6:1 and 4:1 (v/v), were evaluated against the juvenile stage of prawn, Macrobrachium vollenhovenii, in laboratory bioassays. On the basis of the derived toxicity indices, crude oil with 96-h LC(50) value of 0.28ml/L was found to be about six times more toxic than the dispersant (96-h LC(50) 1.9ml/L) when acting alone against M. vollenhovenii. Toxicity evaluations of the mixtures of crude oil and dispersant meant to simulate the environmental control settings of crude oil spillages in aquatic ecosystems revealed that effects of the crude oil/dispersant mixtures varied, depending largely upon the proportion of addition of the mixture components. The interactions between mixture of crude oil and dispersant at the test ratios of 9:1 and 4:1 were found to conform with the model of synergism (RTU = 1.2 and 2. 1, respectively), while the interactions between the mixture prepared based on ratio 6:1 conformed with the model of antagonism (RTU=0.16), based on the concentrationaddition model. Furthermore, the mixtures prepared based on ratios 9:1 and 6:1 were found to be less toxic than crude oil when acting singly against M. vollenhovenii while the mixture prepared based on ratio 4:1 was found to have similar toxicity with crude oil when acting singly, based on the derived synergistic ratio values. The importance of results obtained from the joint-action tests in setting effective and environmentally safe dispersal ratios is discussed.

RefID: 533

Author: Owens, E.H., Taylor, E. and Humphrey, B.

Year: 2008

Title: The persistence and character of stranded oil on coarse-sediment beaches

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X07003098

Abstract: Small amounts of oil that can persist for decades in the intertidal zone of coarse-sediment beaches have been documented in a few well-studied cases. Oil that survives attenuation over the short-term (weeks to months) will persist until there is a change in the environmental conditions, as might occur where there is a seasonal storm-wave climate or as a beach undergoes long-term (erosional) changes. Oil residues can persist on the beach surface as tar mats, asphalt-like pavements, or as veneers on sediment particles or hard surfaces. Subsurface oil residues can persist in similar forms or as fill or partial fill of the pore spaces between coarse-sediment particles. Oil penetrates until it reaches fine-grained sediment, the water table, bedrock, or other penetration-limiting layers. Amounts of persistent oil are very small fractions of the volumes that were originally stranded and these protected residues can continue to biodegrade as they become thinner and more discontinuous.

RefID: 534

Author: Ozhan, K. and Bargu, S.

Year: 2014

Title: Can Crude Oil Toxicity on Phytoplankton Be Predicted Based on Toxicity Data on Benzo(a)Pyrene and Naphthalene?

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs00128-013-1181-6

Abstract: Polycyclic aromatic hydrocarbons (PAHs), which are major components of crude oil, are responsible in large part for the toxicity of crude oil to phytoplankton. This study addressed the following question. Can reliable predictions of the aquatic toxicity of crude oil, a multi-component mixture, be described from toxicity data on individual PAH compounds? Naphthalene, the most abundant PAH compound, and benzo(a)pyrene, a highly toxic PAH compound, were selected as model compounds to quantify toxicity of crude oil on two phytoplankton species, Ditylum brightwellii and Heterocapsa triquetra, by analyzing the effects of different concentrations of these PAHs on growth rate. EC50 values suggested that the diatom D. brightwellii was more vulnerable to both toxicants than the dinoflagellate H. triquetra. However, a previous study, which investigated the impact of crude oil on the same two species, had opposite results. The differences in response from these phytoplankton species to naphthalene and benzo(a)pyrene toxicity compared to their response to crude oil suggest that they may not be solely used as surrogates to assess crude oil toxicity on phytoplankton.

RefID: 535

Author: Özhan, K. and Bargu, S.

Year: 2014

Title: Responses of sympatric Karenia brevis, Prorocentrum minimum, and Heterosigma akashiwo to the exposure of crude oil

Journal: Ecotoxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs10646-014-1281-z

Abstract: Impacts of the Deepwater Horizon oil spill on phytoplankton, particularly, the tolerability and changes to the toxin profiles of harmful toxic algal species remain unknown. The degree to which oil-affected sympatric Karenia brevis, Prorocentrum minimum, and Heterosigma akashiwo, all of which are ecologically important species in the Gulf of Mexico, was investigated. Comparison of their tolerability to that of non-toxic species showed that the toxin-production potential of harmful species does not provide a selective advantage. Investigated toxin profiles for K. brevis and P. minimum demonstrated an increase in toxin productivity at the lowest crude oil concentration (0.66 mg L-1) tested in this study. Higher crude oil concentrations led to significant growth inhibition and a decrease in toxin production. Findings from this study could assist in the assessment of shellfish bed closures due to high risk of increased toxin potential of these phytoplankton species, especially during times of stressed conditions.

RefID: 536

Author: Özhan, K., Miles, S.M., Gao, H. and Bargu, S.

Year: 2014

Title: Relative Phytoplankton growth responses to physically and chemically dispersed South Louisiana sweet crude oil

Journal: Environmental Monitoring and Assessment

Hyperlink: http://link.springer.com/article/10.1007%2Fs10661-014-3670-4

Abstract: We conducted controlled laboratory exposure experiments to assess the toxic effects of water-accommodated fractions (WAFs) of South Louisiana sweet crude oil on five phytoplankton species isolated from the Gulf of Mexico. Experiments were conducted with individual and combinations of the five phytoplankton species to determine growth inhibitions to eight total petroleum hydrocarbon (TPH) equivalent concentrations ranging from 461 to 7,205 ppb. The composition and concentration of crude oil were altered by physical and chemical processes and used to help evaluate crude oil toxicity. The impact of crude oil exposure on phytoplankton growth varied with the concentration of crude oil, species of microalgae, and their community composition. At a concentration of TPH < 1,200 ppb, dinoflagellate species showed significantly better tolerance, while diatom species showed a higher tolerance to crude oil at higher concentrations of TPH. For both groups, the larger species were more tolerant to crude oil than smaller ones. The toxicity potential of crude oil seems to be strongly influenced by the concentration of polycyclic aromatic hydrocarbons (PAHs). The addition of the dispersant, CorexitA (R) EC9500A, increased the amount of crude oil up to 50-fold in the water column, while the physical enhancement (vigorous mixing of water column) did not significantly increase the amount of TPH concentration in the water column. The species response to crude oil was also examined in the five-species community. Each phytoplankton species showed considerably less tolerance to crude oil in the five-species community compared to their individual responses. This study provides baseline information about individual phytoplankton responses to crude oil and dispersed crude oil for subsequent research efforts seeking to understand the impacts of oil on the phytoplankton in the bigger picture.

RefID: 537

Author: Ozhan, K., Parsons, M.L. and Bargu, S.

Year: 2014

Title: How Were Phytoplankton Affected by the Deepwater Horizon Oil Spill?

Journal: Bioscience

Hyperlink: http://bioscience.oxfordjournals.org/content/64/9/829

Abstract: A literature review demonstrates that crude oil spills can affect phytoplankton, favoring the growth of some while inhibiting the growth of others. Subsequently, the phytoplankton assemblage can change as a result of exposure to crude oil. Studies of phytoplankton responses to the Macondo (Deepwater Horizon) oil spill indicate that the phytoplankton may have been stimulated by the oil spill, although the presence of low-salinity water in the region makes it difficult to discount the importance of riverine-borne nutrients as a factor. A few studies suggest that the oil spill was toxic to some phytoplankton species, whereas others indicate that the degree of tolerance to the oil or to dispersants differs among species. These results generally comply with findings of previous studies, but a lack of published field data analyses prevents further assessment of the impacts of the Deepwater Horizon oil spill on phytoplankton population dynamics in the northern Gulf of Mexico.

RefID: 538

Author: Page, D.S., Boehm, P.D. and Neff, J.M.

Year: 2010

Title: Comment on "Unlike PAHs from Exxon Valdez Crude Oil, PAHs from Gulf of Alaska Coals are not Readily Bioavailable"

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es903508h

Abstract: Refers to T0035

RefID: 539

Author: Page, D.S., Boehm, P.D., Brown, J.S., Neff, J.M., Burns, W.A. and Bence, A.E.

Year: 2005

Title: Mussels document loss of bioavailable polycyclic aromatic hydrocarbons and the return to baseline conditions for oiled shorelines in Prince William Sound, Alaska

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0141113605000097

Abstract: Polycyclic aromatic hydrocarbons (PAH) were measured in mussels (Mytilus trossulus) collected between 1990 and 2002 from I I sites on the shores of Prince William Sound (PWS), Alaska, that were heavily oiled by the 1989 Exxon Valdez oil spill (EVOS). This study, utilizing the methods of the NOAA Status and Trends Mussel Watch Program, found that concentrations of PAH released from spill remnants have decreased dramatically with time and by 2002 were at or near the range of total PAH (TPAH) of 3-355 ng/g dry weight obtained for mussels from unoiled reference sites in PWS. Time-series TPAH data indicate a mean TPAH half-life in mussel tissues of 2.4 years with a range from 1.4 to 5.3, yielding an annual mean loss of bioaccumulated TPAH of 25%. The petroleum-derived TPAH fraction in mussel tissues has decreased with time, reflecting the decreasing release of EVOS residues in shoreline sediments. These results show that PAH from EVOS residues that remain buried in shoreline sediments after the early 1990s are in a form and at locations that have a low accessibility to mussels living in the intertidal zone. (c) 2005 Elsevier Ltd. All rights reserved.

RefID: 540

Author: Page, D.S., Boehm, P.D., Stubblefield, W.A., Parker, K.R., Gilfillan, E.S., Neff, J.M. and Maki, A.W.

Year: 2002

Title: Hydrocarbon composition and toxicity of sediments following the Exxon valdez oil spill in Prince William Sound, Alaska, USA

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620210715/abstract

Abstract: An 11-year study of the 1989 Exxon Valdez oil spill found that spill residues on the oiled shorelines rapidly lost toxicity through weathering. After 1990, toxicity of sediments remained at only a few heavily oiled, isolated locations in Prince William Sound (AK, USA), as measured by a standard amphipod bioassay using Rhepoxynius abronius. Data from 648 sediment samples taken during the 1990 to 1993 period were statistically analyzed to determine the relationship between the total concentration of 39 parent and methyl-substituted polycyclic aromatic hydrocarbons (defined as total polycyclic aromatic hydrocarbons [TPAH]) and amphipod mortality and the effect of oil weathering on toxicity. A logistic regression model yielded estimates of the lower threshold. LC10 (lethal concentration to 10% of the population), and LC50 (median lethal concentration) values of 2,600, 4,100, and 10,750 ng/g TPAH (dry wt), respectively. Estimates of the threshold and LC50 values in this field study relate well to corresponding sediment quality guideline (SQG) values reported in the literature. For sediment TPAH concentrations >2,600 ng/g. samples with high mortality values (>90%) had relatively high fractions of naphthalenes and those with low mortality (<20%) had relatively high fractions of chrysenes. By 1999, the median sediment TPAH concentration of 117 ng/g for the post-1989 worst-case sites studied were well below the 2,600 ng/g toxicity threshold value. confirming the lack of potential for long-term toxic effects. Analysis of biological community structure parameters for sediment samples taken concurrently found that species richness and Shannon diversity decreased with increasing TPAH above the 2,600 ng/g threshold, demonstrating a correspondence between sediment bioassay results and biological community effects in the field. The low probability of exposure to toxic concentrations of weathered spill residues at the worst-case sites sampled in this study is consistent with the rapid overall recovery of shoreline biota observed in 1990 to 1991.

RefID: 541

Author: Page, D.S., Chapman, P.M., Landrum, P.F., Neff, J. and Elston, R.

Year: 2012

Title: A Perspective on the Toxicity of Low Concentrations of Petroleum-Derived Polycyclic Aromatic Hydrocarbons to Early Life Stages of Herring and Salmon

Journal: Human and Ecological Risk Assessment

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/10807039.2012.650569

Abstract: This article presents a critical review of two groups of studies that reported adverse effects to salmon and herring eggs and fry from exposure to 1 mu g/L or less of aqueous total polycyclic aromatic hydrocarbons (TPAH), as weathered oil, and a more toxic aqueous extract of "very weathered oil." Exposure media were prepared by continuously flowing water up through vertical columns containing gravel oiled at different concentrations of Prudhoe Bay crude oil. Uncontrolled variables associated with the use of the oiled gravel columns included time-and treatment-dependent variations in the PAH concentration and composition in the exposure water, unexplored toxicity from other oil constituents/degradation products, potential toxicity from bacterial and fungal activity, oil droplets as a potential contaminant source, inherent differences between control and exposed embryo populations, and water flow rate differences. Based on a review of the evidence from published project reports, peer-reviewed publications, chemistry data in a public database, and unpublished reports and laboratory records, the reviewed studies did not establish consistent dose (concentration) response or causality and thus do not demonstrate that dissolved PAH alone from the weathered oil resulted in the claimed effects on fish embryos at low mu g/L TPAH concentrations. Accordingly, these studies should not be relied on for management decision-making, when assessing the risk of very low-level PAH exposures to early life stages of fish.

RefID: 542

Author: Page, D.S., Gilfillan, E.S., Boehm, P.D. and Harner, E.J.

Year: 1995

Title: Shoreline Ecology Program for Prince William Sound, Alaska, Following the Exxon Valdez Oil Spill: Part I - Study Design and Methods

Journal: Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters

Hyperlink: http://www.valdezsciences.com/dspArticle.cfm?catID=7&artID=1062&artSecID=1096

Abstract: Part I of a three-part series, this paper describes the design and analysis of 3 large field and laboratory program to assess shoreline recovery in Prince William Sound following the Exxon Valdez oil spill. The study was designed so that results could be generalized arcs-wide (biology, chemistry) or habitat-wide (toxicology) and projected forward in time (chemistry). It made use of the "sediment quality triad" approach, combining biological, chemical, and toxicological measurements to assess shoreline recovery. Key aspects of the study include the following: • Coordinated field sampling for chemical, toxicological, and biological studies • Stratified random sampling (SRS) as a basis for spatial generalization • Periodic sampling to assess trends, including sites with worst-case conditions • Analysis of oil-spill effects on hundreds of species • Statistical methods based on normal and non-normal theory, consistent with the structure of the data, including generalized linear models and multivariate correspondence analysis Prince William Sound shorelines were stratified into four types of habitat (exposed bedrock/rubble, sheltered bedrock/rubble, boulder/cobble, and pebble/gravel) and four different levels of oiling (unoiled, light, moderate, and heavy) Sixty-four SRS sites were randomly selected with an average of four replicates in each combination of habitat type and oiling level. The SRS sites were sampled in 1990 to assess the state of recovery in the sound. Twelve additional non-random sites, including some of the most heavily oiled locations in the sound, were monitored annually to assess trends from 1989 to 1991 At sedimentary sites, sediment samples were taken for hydrocarbon analysis, sediment toxicology, and biological (infaunal) analysis At bedrock/rubble sites, filter wipes and surface scrape samples were taken to assess chemistry and epibiota. Where present, mussel samples were taken to determine the bioavailability of any petroleum residues. Spill-affected shorelines are judged to have recovered when the biological communities are statistically indistinguishable from those at unoiled reference sites. Given the large natural variability observed among sites, this study provides a more accurate and comprehensive picture of shoreline recovery than approaches that focus on only a few species at subjectively chosen locations.

RefID: 543

Author: Page, D.S., Gilfillan, E.S., Boehm, P.D., Stubblefield, W.A., Parker, K.R., Neff, J.M. and Maki, A.W.

Year: 2003

Title: Comment on "hydrocarbon composition and toxicity of sediments following the Exxon valdez oil spill in Prince William Sound, Alaska, USA' - Reply

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/03-311/abstract

Abstract: Refers to W0068

RefID: 544

Author: Page, D.S., Huggettt, R.J., Stegeman, J.J., Parker, K.R., Woodin, B., Brown, J.S. and Bence, A.E.

Year: 2004

Title: Polycyclic aromatic hydrocarbon sources related to biomarker levels in fish from Prince William sound and the Gulf of Alaska

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es0403209

Abstract: Seafloor sediments in Prince William Sound (PWS) and the eastern Gulf of Alaska (GOA) have a substantial regional hydrocarbon background from natural sources including oil seeps and eroding sedimentary rocks along the eastern GOA coast. Polycyclic aromatic hydrocarbons (PAH) from that background appear to be bioavailable to fish. Fish collected from PWS and the GOA in a 1999-2000 biomarker study (bile fluorescent aromatic contaminants and liver ethoxyresorufin 0-deethylase) show evidence of exposure to low levels of PAH at all categories of sites sampled. Seafloor sediments at fish sampling sites in the GOA east of PWS and at three PWS site categories (nonspill path, spill path oiled, and spill path not oiled) contain hydrocarbons from four principal sources: regional background, combustion products, residues from the 1989 Exxon Valdez oil spill (EVOS), and Monterey (CA) petroleum residues. GOA sediments between PWS and Yakutat Bay, similar to350 km to the east, are dominated by regional petrogenic background hydrocarbons (total PAH (TPAH) range similar to60-3400 ng/g) that are the probable cause of low biomarker levels measured in halibut from this area. PWS sediments contain varying proportions of regional background, combustion products, Monterey residues, and EVOS residues at some spill path sites. Rockfish caught in PWS embayments in 1999 have liver EROD activities that correlate positively with the pyrogenic PAH indicator ratio (Fl+Py)/C24Ph. Although traces (< 5-100 ng/g TPAH) of EVOS residues were detected in seafloor sediments at some nearshore spill path sites, biomarker levels in fish from those sites are not elevated relative to other sites in PWS.

RefID: 545

Author: Page, D.S., Neff, J.M., Landrum, P.F. and Chapman, P.M.

Year: 2012

Title: SENSITIVITY OF PINK SALMON (ONCORHYNCHUS GORBUSCHA) EMBRYOS TO WEATHERED CRUDE OIL

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.694/full

Abstract: Letter to the editor - refers to Ref S0173

RefID: 546

Author: Page, D.S., Neff, J.M., Landrum, P.F. and Chapman, P.M.

Year: 2012

Title: SENSITIVITY OF PINK SALMON (ONCORHYNCHUS GORBUSCHA) EMBRYOS TO WEATHERED CRUDE OIL

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.1742/full

Abstract: Letter to the editor - refers to Ref S0173

RefID: 547

Author: Page, D.S., Neff, J.M., Landrum, P.F. and Chapman, P.M.

Year: 2012

Title: SENSITIVITY OF PINK SALMON (ONCORHYNCHUS GORBUSCHA) EMBRYOS TO WEATHERED CRUDE OIL

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.694/abstract

Abstract: An analysis of Heintz et al. [1] demonstrates that their datado not support the conclusion that polycyclic aromatic hydrocarbons(PAHs) in aqueous extracts of a very weathered crudeoil are toxic to early fish life stages at 1mg/L total PAH (TPAH)levels. Our review was undertaken because of the far-reachingwater quality regulatory implications of this conclusion. Heintz et al. based this conclusion on the results of a single, unreplicated toxicity test treatment with a very weathered oil (VWO) and pink salmon (Oncorhynchus gorbuscha) embryosand alevins.

RefID: 548

Author: Paine, M.D., Leggett, W.C., McRuer, J.K. and Frank, K.T.

Year: 1992

Title: EFFECTS OF HIBERNIA CRUDE-OIL ON CAPELIN (MALLOTUS-VILLOSUS) EMBRYOS AND LARVAE

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/014111369290147E

Abstract: Capelin (Mallotus villosus) embryos and larvae were exposed to the water-soluble fraction (WSF) of Hibernia crude oil in four different experiments. The WSF consisted primarily of aromatic compounds, whereas the parent oil consisted primarily of aliphatic compounds. Hydrocarbon concentrations, as measured by ultraviolet spectrophotometry, decreased in test beakers over time. Therefore, exposures were expressed as toxicity indexes (concentration x time) to account for differences in exposure conditions between experiments. Lethal effects on embryos were observed only at high concentrations over long exposures (27-37 mg/litre x days). Lethal effects on larvae were observed at lower concentrations and/or shorter exposures (1.3-7.1 mg/litre x days), indicating that larvae were more sensitive. Sublethal effects on growth, pigmentation, developmental rate, time to hatch, and vertical position of embryos or larvae were observed at concentrations < 10-50% of lethal concentrations.

Concentrations causing lethal effects on embryos are unlikely to occur or persist, except after spills or other accidents near spawning beaches. Concentrations causing lethal effects on larvae or sublethal effects on embryos or larvae are much more likely to occur and persist through the developmental period, and should be the major concern where potential conflicts exist between offshore oil developments and the inshore capelin fishery.

RefID: 549

Author: Paine, R.T., Ruesink, J.L., Sun, A., Soulanille, E.L., Wonham, M.J., Harley, C.D.G., Brumbaugh, D.R. and Secord, D.L.

Year: 1996

Title: Trouble on oiled waters: lessons from the Exxon Valdez oil spill

Journal: Annual Review of Ecology and Systematics

Hyperlink: http://www.annualreviews.org/doi/abs/10.1146%2Fannurev.ecolsys.27.1.197

Abstract:

RefID: 550

Author: Parab, S.R., Pandit, R.A., Kadam, A.N.,and Indap, M.M.

Year: 2008

Title: Effect of Bombay high crude oil and its water-soluble fraction on growth and metabolism of diatom Thalassiosira sp

Journal: Indian Journal of Geo-Marine Sciences

Hyperlink: http://nopr.niscair.res.in/handle/123456789/2046

Abstract: Effect of Bombay high crude oil (BHC) and its water-soluble fraction (WSF) on growth and metabolism of the phytoplankton, Thalassiosira sp. was assessed. The study revealed the signs of acute toxicity at higher concentrations of crude oil (0.5%) and WSF (40%), while stimulatory effect was observed at lower concentrations (0.01 and 0.1% of BHC and 5, 10% of WSF). WSF at higher concentrations (20 and 40%) caused reduction in DNA and RNA of the diatom. At lower concentrations it caused increase in protein and RNA content indicating increased metabolism. High concentrations of oil and its fraction had inhibitory effect on growth, protein content and nucleic acid content. This indicates that biosynthesis of these molecules may be probable targets for toxicity of oil.

RefID: 551

Author: Parker, K.R., Wiens, J.A., Day, R.H. and Murphy, S.H.

Year: 2013

Title: Assessing Effects and Recovery from Environmental Accidents

Journal: Oil in the Environment: Legacies and Lessons of the Exxon Valdez Spill

Hyperlink:

Abstract: Book Chapter (no abstract)

RefID: 552

Author: Parsons, T.R., Harrison, P.J., Acreman, J.C., Dovey, H.M., Thompson, P.A., Lalli, C.M., Lee, K., Guanguo, L., and Xiaolin, C.

Year: 1984

Title: An experimental marine ecosystem response to crude oil and Corexit 9527: Part 2—Biological effects

Journal: Marine Environmental Research

Hyperlink:

Abstract: Three experimental ecosystems were employed to test the effect of Corexit 9527, with and without Prudhoe Bay crude oil, on the ecology of a temperate pelagic ecosystem. The results indicated that Corexit 9527 alone enhanced biological productivity without changing the structure of the ecosystem. The mixture of Corexit and crude oil caused a major change in the ecology of the ecosystem which resulted in large numbers of bacteria and zooflagellates, but a depression of all other zooplankton phyla.

RefID: 553

Author: Pauka, L.M., Maceno, M., Rossi, S.C. and de Assis, H.C.S.

Year: 2011

Title: Embryotoxicity and Biotransformation Responses in Zebrafish Exposed to Water-Soluble Fraction of Crude Oil

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs00128-011-0235-x

Abstract: The toxic effects of water-soluble fraction (WSF) of crude oil (API27, Petrobras Campos Basin, Brazil) were evaluated during the early life stages of zebrafish, as well as its biotransformation in juvenile fish. Embryonic development was studied during 96 h. Reduced heartbeat rate, weak pigmentation, tail defects, and embryo mortality were observed for all of the tested concentrations of the WSF. Activities of the biotransformation enzymes were induced at the highest concentrations, showing that these enzymes played a role in its elimination. As shown in this study the crude oil WSF altered the normal embryonic development of fish.

RefID: 554

Author: Paul, J.H., Hollander, D., Coble, P., Daly, K.L., Murasko, S., English, D., Basso, J., Delaney, J., McDaniel, L. and Kovach, C.W.

Year: 2013

Title: Toxicity and Mutagenicity of Gulf of Mexico Waters During and After the Deepwater Horizon Oil Spill

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es401761h

Abstract: The Deepwater Horizon oil spill is unparalleled among environmental hydrocarbon releases, because of the tremendous volume of oil, the additional contamination by dispersant, and the oceanic depth at which this release occurred. Here, we present data on general toxicity and mutagenicity of upper water column waters and, to a lesser degree, sediment porewater of the Northeastern Gulf of Mexico (NEGOM) and west Florida shelf (WFS) at the time of the Deepwater Horizon oil spill in 2010 and thereafter. During a research cruise in August 2010, analysis of water collected in the NEGOM indicated that samples of 3 of 14 (21%) stations were toxic to bacteria based on the Microtox assay, 4 of 13 (34%) were toxic to phytoplankton via the QwikLite assay, and 6 of 14 (43%) showed DNA damaging activity using the lambda-Microscreen Prophage induction assay. The Microtox and Microscreen assays indicated that the degree of toxicity was correlated to total petroleum hydrocarbon concentration. Long-term monitoring of stations on the NEGOM and the WFS was undertaken by 8 and 6 cruises to these areas, respectively. Microtox toxicity was nearly totally absent by December 2010 in the Northeastern Gulf of Mexico (3 of 8 cruises with one positive station). In contrast, QwikLite toxicity assay yielded positives at each cruise, often at multiple stations or depths, indicating the greater sensitivity of the QwikLite assay to environmental factors. The Microscreen mutagenicity assays indicated that certain water column samples overlying the WFS were mutagenic at least 1.5 years after capping the Macondo well. Similarly, sediment porewater samples taken from 1000, 1200, and 1400 m from the slope off the WFS in June 2011 were also highly genotoxic. Our observations are consistent with a portion of the dispersed oil from the Macondo well area advecting to the southeast and upwelling onto the WFS, although other explanations exist. Organisms in contact with these waters might experience DNA damage that could lead to mutation and heritable alterations to the community pangenome. Such mutagenic interactions might not become apparent in higher organisms for years.

RefID: 555

Author: Payne, J.R., Driskell, W.B. and Short, J.W.

Year: 2003

Title: PWSRCAC-EVOS Long-term environmental monitoring program: 2002-2003 LTEMP monitoring report, Exxon Valdez Oil Spill Gulf Ecosystem Monitoring and Research Project Final Report (GEM Project 030623)

Journal: EVOS Trustee Council

Hyperlink: http://jlc-web.uaa.alaska.edu/client/arlis/search/detailnonmodal/ent:$002f$002fSD_ILS$002f1760$002fSD_ILS:1760878/one?qu=GEM+Project+030623

Abstract: After reviewing the LTEMP 2002-2003 results, we have concluded that the intertidal sites monitored by the LTEMP program are currently extremely clean. With the exception of the Alyeska Marine Terminal site and, to a lesser extent, the Gold Creek site in Port Valdez, the regional sites do not show elevated concentrations of hydrocarbons from either Alyeska Marine Terminal operations and discharges, or oil transportation activities within Prince William Sound. A large part of this report covers two main topics: 1) reevaluating historic trends and analytic issues and 2) the intercalibration of laboratory analyses (since the program has now changed from GERG to Auke Bay Lab for chemical analyses). With the possible exception of the 1997-1998 timeframe, the LTEMP program appears to be on-track with high-quality, high-sensitivity data with a good record of detected events. These are the hallmarks of a good monitoring program. The LTEMP data have also proven invaluable as a corroborating data set in acquiring a much more in-depth perspective of the trends and behavior of oil contaminants in the region.

RefID: 556

Author: Payne, J.R., Driskell, W.B., Short, J.W. and Larsen, M.L.

Year: 2008

Title: Long term monitoring for oil in the Exxon Valdez spill region

Journal: Marine Pollution Bulletin

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/18835610

Abstract: In the aftermath of the 1989 Exxon Valdez oil spill, a Long Term Environmental Monitoring Program (LTEMP) has been regularly sampling mussels (and some sediments) for polycyclic aromatic and saturated hydrocarbons (PAH and SHC) at sites in Port Valdez, Prince William Sound, and the nearby Gulf of Alaska region. After 1999, a decreasing trend appears in total PAH (TPAH) in tissues at all sites with current values below 100 ng/g dry weight (many below 50 ng/g). Currently, most samples reflect a predominantly dissolved-phase signal. This new low in TPAH likely represents ambient background levels. Synchrony in TPAH time-series and similarities in the hydrocarbon signatures portray regional-scale dynamics. The five inner Prince William Sound sites show similar composition and fluctuations that are different from the three Gulf of Alaska sites. The two Port Valdez sites represent a unique third region primarily influenced by the treated ballast water discharge from the Alyeska Marine Terminal. Prince William Sound has reverted to a stable environment of extremely low level contamination in which local perturbations are easily detected. (C) 2008 Elsevier Ltd. All rights reserved.

RefID: 557

Author: Payne, S.J., King, C.K., Zamora, L.M. and Virtue, P.

Year: 2014

Title: Temporal changes in the sensitivity of coastal Antarctic zooplankton communities to diesel fuel: A comparison between single- and multi-species toxicity tests

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/24590679

Abstract: Despite increasing human activity and risk of fuel spills in Antarctica, little is known about the impact of fuel on Antarctic marine fauna. The authors performed both single- and multi-species (whole community) acute toxicity tests to assess the sensitivity of an Antarctic coastal zooplankton community to the water-accommodated fraction of Special Antarctic Blend diesel. Single-species tests using abundant copepods Oncaea curvata, Oithona similis, and Stephos longipes allowed comparisons of sensitivity of key taxa and of sensitivity estimates obtained from traditional single-species and more novel multi-species tests. Special Antarctic Blend diesel caused significant mortality and species compositional change in the zooplankton community within 4 d to 7 d. The sensitivity of the community also increased across the summer sampling period, with decreasing 7-d median lethal concentration (LC50) values for total petroleum hydrocarbons (TPH): 1091 mu g TPH/L in early January 2011, 353 mu g TPH/L in mid January 2011, and 186 mu g TPH/L in early February 2011. Copepods showed similar sensitivities to Special Antarctic Blend diesel in single-species tests (7-d LC50s: O. curvata, 158 mu g TPH/L; O. similis, 176 mu g TPH/L; S. longipes, 188 mu g TPH/L). The combined use of single- and multi-species toxicity tests is a holistic approach to assessing the sensitivity of key species and the interactions and interdependence between species, enabling a broader understanding of the effects of fuel exposure on the whole zooplankton community. Environ Toxicol Chem 2014;33:882-890. (c) 2014 SETAC

RefID: 558

Author: Pearson, W.H., Bienert, R.W., Moksness, E. and Skalski, J.R.

Year: 1995

Title: Potential effects of the Exxon Valdez oil spill on Pacific herring in Prince William Sound

Journal: Canadian Technical Report of Fisheries and Aquatic Sciences

Hyperlink: http://waves-vagues.dfo-mpo.gc.ca/waves-vagues/search-recherche/display-afficher/191554

Abstract: In Prince William Sound (PWS), Alaska, Pacific herring, Clupea pallasi, spawn along hundreds of kilometres of shoreline and support several important commercial fisheries. In early April, large schools of pre-spawning adult herring aggregate in the nearshore waters of PWS. Spawning herring deposit and fertilize eggs on seaweed and kelp in the intertidal and shallowsubtidal zones. There the attached eggs incubate for about 3 weeks before hatching. The occurrence of the Exxon Valdez oil spill (EVOS) in March 1989 just before herring spawning, raised concerns about potential effects on Pacific herring for several reasons.

RefID: 559

Author: Pearson, W.H., Elston, R.A., Bienert, R.W., Drum, A.S. and Antrim, L.D.

Year: 1999

Title: Why did the Prince William Sound, Alaska, Pacific herring (Clupea pallasi)fisheries collapse in 1993 and 1994? Review of hypotheses

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f98-207

Abstract: Following record harvests of Pacific herring (Clupea pallasi) in Prince William Sound, Alaska, in the 3 years after the Exxon Valdez oil spill, the fishery failed in 1993. The hypotheses advanced to explain this dramatic 1993 decline occur in three categories: (i) effects associated with the 1989 oil spill, (ii) harvesting effects, and (iii) natural phenomena. Based on our review, we are convinced that a combination of increasing Prince William Sound herring biomass and decreasing food supply led to poor condition of Prince William Sound herring, which resulted in the 1993 decline. Other natural causes could have contributed to the decline, including disease, cold water temperatures, increased predation, and other natural stochastic processes. No evidence supports hypotheses that the decline resulted solely from overharvesting or underharvesting. The record high population levels and harvests of Prince William Sound herring in the years after the 1989 oil spill, the lack of change from the expected age-class distribution, and the low level of oil exposure documented for herring in 1989 and the following years all indicate that the 1989 oil spill did not contribute to the 1993 decline. Poor nutritional status, either alone or in combination with disease or other natural factors, was most likely responsible for the 1993 collapse.

RefID: 560

Author: Pearson, W.H., Elston, R.A., Humphrey, K. and Deriso, R.B.

Year: 2013

Title: Pacific Herring

Journal: Oil in the Environment: Legacies and Lessons of the Exxon Valdez Spill

Hyperlink:

Abstract: Book Chapter (no abstract)

RefID: 561

Author: Pearson, W.H., Moksness, E. and Skalski, J.R.

Year: 1995

Title: A field and laboratory assessment of oil spill effects on survival and reproduction of Pacific herring following the Exxon Valdez spill

Journal: Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters

Hyperlink: http://www.valdezsciences.com/dspArticle.cfm?catID=2&artID=1040&artSecID=1039

Abstract: Pacific herring, Clupea pallasi, spawn along hundreds of kilometres of shoreline in Prince William Sound. Herring eggs incubate in intertidal and shallow subtidal areas attached to kelp and eelgrass. In April 1989, following the Exxon Valdez oil spill, there was potential in Prince William Sound for localized effects on spawning herring, their eggs, and the hatching larvae. Field and laboratory investigations in 1989 and 1990 were designed to assess potential injury to Prince William Sound herring by testing for differences between oiled regions and unoiled reference areas and by relating biological response variables to the concentrations of polycyclic aromatic hydrocarbons (PAH) in eggs-on-kelp samples. Hydrocarbon analyses and laboratory incubation were conducted on eggs-on-kelp samples from Prince William Sound and Sitka Sound. The eggs and hatching larvae were examined to evaluate several response variables: egg development, hatch, larval survival, abnormal development of larvae, larval length, and larval yolk-sac volume. Analysis of 1989 shoreline surveys indicate that about 96% of the total spawn length (158 km) in Prince William Sound occurred along shorelines with no oiling, and less than 1% of the 1989 total spawn length occurred along shorelines with moderate to heavy oiling. Analysis of shoreline oiling in both 1989 and 1990 from all surveys indicates that about 90 to 91% of the total 1989 spawn length occurred along unoiled shorelines. Effects on herring eggs were minor in 1989 even in oiled areas. No significant relationship was found between 1989 PAH burdens in eggs-on-kelp samples and 9 out of 10 biological response variables. In 1989, significantly lower proportions of developed eggs were observed for Cabin Bay samples visibly contaminated with tarry deposits. The location where these effects were seen represented less than 2% of total 1989 spawn length. No effects of the spill on herring were evident in 1990. No significant relationship was found between 1990 PAH burdens and the seven biological response variables studied. Biological response variables from Sitka Sound were either not significantly different from or significantly lower (more adverse) than those from Prince William Sound. Our 1989 and 1990 results are consistent with the low exposure of herring to oil and do not indicate an extent of injury that would be significant to the Prince William Sound herring population. The biomass and harvests of Prince William Sound herring had reached record high levels in the three years immediately following the spill so that the minor effects observed in 1989 did not translate into decreases in the population level.

RefID: 562

Author: Peckol, P., Levings, S.C. and Garrity, S.D.

Year: 1990

Title: Kelp response following the World Prodigy oil spill

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/0025326X9090066H

Abstract: Associated with the June 1989 grounding of the tanker World Prodigy on brenton Reef, Rhode Island, approximately 922 t of No. 2 fuel oil were released into surrounding coastal waters. We investigated effects of oiling on the subtidal kelps, Laminaria saccharina and L. digitata. Kelp condition, growth rates with depth, and pigment acclimation were compared with pre-spill measurements of kelp performance at the same site in 1984–1987. There was no evidence that kelps were detrimentally affected by oiling; we observed no necrotic or bleached tissue on any kelps in an oiled cove. Growth rates of both species were within the range of our previous years' data and pigment acclimation was similar for all years. Lowest growth rates occurred in 1985 during a severe brown tide. This study and other data suggest that Narragansett Bay was spared potential disaster because little fuel oil mixed into the water column and contacted subtidal organisms.

RefID: 563

Author: Pelletier, M.C., Burgess, R.M., Ho, K.T., Kuhn, A., Mckinney, R.A. and Ryba, S.A.

Year: 1997

Title: Phototoxicity of individual polycyclic aromatic hydrocarbons and petroleum to marine invertebrate larvae and juveniles

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620161029/abstract

Abstract: Phototoxicity resulting from photoactivated polycyclic aromatic hydrocarbons (PAHs) has been reported in the literature for a variety of freshwater organisms. The magnitude of increase in PAH toxicity often exceeds a factor of 100. In the marine environment phototoxicity to marine organisms has not been reported for individual or complex mixtures of PAHs. In this study, larvae and juveniles of the bivalve, Mulinia lateralis, and juveniles of the mysid shrimp, Mysidopsis bahia, were exposed to individual known phototoxic PAHs (anthracene, fluoranthene, pyrene), as well as the water-accommodated fractions of several petroleum products (Fuel Oil #2, Arabian Light Crude, Prudhoe Bay Crude, Fuel Oil #6) containing PAHs. Phototoxicity of individual PAHs was 12 to >50,000 times that of conventional toxicity. Three of the petroleum products demonstrated phototoxicity while the lightest product, Fuel Oil #2, was not phototoxic at the concentrations tested. The phototoxicity of petroleum products appears to be dependent on the composition and concentrations of phototoxic PAHs present: lighter oils have fewer multiple aromatic ring, phototoxic compounds while heavier oils have higher levels of these types of molecules. This study shows that phototoxicity can occur in marine waters to marine species. Further, the occurrence of oil in marine waters presents the additional risk of phototoxicity not routinely assessed for during oil spills.

RefID: 564

Author: Perez, P., Fernandez, E. and Beiras, R.

Year: 2010

Title: Fuel toxicity on Isochrysis galbana and a coastal phytoplankton assemblage: Growth rate vs. variable fluorescence

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/20060589

Abstract: Laboratory cultures of the flagellate Isochrysis galbana and a coastal phytoplankton assemblage were used to assess the feasibility of variable fluorescence (F(v)), measured by means of fast repetition rate fluorometry, as endpoint to monitor the effect of fuel on microalgae as compared to phytoplankton growth rate. Parallel changes in cell size of I. galbana and taxonomic composition of the natural assemblage were recorded. The results presented in this investigation indicate that F(v) is a suitable endpoint to this aim, due to the ease and rapidity of the measurement, ecological relevance and sensitivity. The derived effective concentrations provided toxicity thresholds similar to, or even lower than concentrations derived from embryo-larval bioassays with marine organisms. The lowest calculated EC(10) corresponded to that of the natural assemblage, 2.5 mu g eq chrysene L(-1), concentration easily exceeded in high maritime traffic areas subjected to frequent spillages.

RefID: 565

Author: Perkins, R.A., Rhoton, S. and Behr-Andres, C.

Year: 2003

Title: Toxicity of dispersed and undispersed, fresh and weathered oil to larvae of a cold-water species, Tanner, crab (C-bairdi), and standard warm-water test species

Journal: Cold Regions Science and Technology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0165232X03000041

Abstract: There are many methods in current use for testing the toxicity of discharges to marine waters. Standard tests and species established by the Environmental Protection Agency and other regulators are commonly used.. None of these commonly used test procedures are conducted with cold seawater or species typical of northern latitudes. This paper reports on the toxicity testing of oil and dispersed oil, both fresh and weathered, to larvae of a cold-water species, the Tanner crab (Chionocetes bairdi), and compares these results to those observed with a standard warm-water test species, the saltwater mysid (Mysidopsis bahia). The method of reporting the exposure dose is based on: loading rate (LR). concentrations of volatile organic analytes (VOA, C6-C9), total petroleum hydrocarbon (TPH, C10-06), or on total hydrocarbon, content (THC, C6-C36). Different conclusions result, depending on the reporting method. These differences are chiefly due to the greater accommodation of VOA in the colder water and the paucity of TPH in undispersed cold-water solutions. (C) 2003 Elsevier Science B.V. All rights reserved.

RefID: 566

Author: Perkins, R.A., Rhoton, S. and Behr-Andres, C.

Year: 2005

Title: Comparative marine toxicity testing: A cold-water species and standard warm-water test species exposed to crude oiland dispersant

Journal: Cold Regions Science and Technology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0165232X05000273

Abstract: There are many methods in current use for testing the toxicity of discharges to marine waters, For practical purposes, standard tests and species are commonly used. None of these standard test procedures or species are done with the cold seawater and species typical of northern latitudes. This paper reports the toxicity testing of oil and dispersed oil to a cold-water species, the Tanner crab (Chionocetes bairdi) larvae, and compares the result to two standard warm-water test species. the saltwater mysid (Mysisidopsis bahia) and fish (Menidia beryllina) larvae. The method of reporting the exposure dose: loading rate, volatile organic analytes (VOA, C6-C9), total petroleum hydrocarbons (TPH C10 C36), or their summation, total hydrocarbon concentrations (THC C6-C36) would result in different conclusions, These differences are especially important with the water-accommodated fraction (WAF) in cold water, but may as well be significant when reporting the chemically enhanced-water accommodated fraction (CE-WAF), i.e., dispersed oil. The differences are chiefly due to the greater accommodation of VOA in the colder water. (c) 2005 Elsevier B.V. All rights reserved.

RefID: 567

Author: Peters, L.E., MacKinnon, M., Van Meer, T., van den Heuvel, M.R. and Dixon, D.G.

Year: 2007

Title: Effects of oil sands process-affected waters and naphthenic acids on yellow perch (Perca flavescens) and Japanese medaka (Orizias latipes) embryonic development

Journal: Chemosphere

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0045653506017826

Abstract: Syncrude Canada Ltd. is currently developing environmentally acceptable oil sands process-affected water management methods as part of their land reclamation strategy. Surface waters of the "wet landscape" reclamation option characteristically have elevated concentrations of sodium sulphate and naphthenic acids (NAs), with low levels of PAHs. The following experiment compared early-life stage responses of yellow perch (Perca flavesecens) to those of Japanese medaka (Oryzias latipes) when exposed to Mildred Lake settling basin (MLSB) surface water and a commercial sodium naphthenate (Na-NA) standard. Perch eggs were fertilized and incubated in: 100%, 50%, 20%, 4%, 0.8%, and 0.16% dilutions of MLSB water, as well as 20, 10, 5, 2.5, and 1.25 mg/l solutions of the commercial standard. Medaka embryos were exposed to the same treatments, post-fertilization. Both species demonstrated an increase in the incidence of deformity, and a decrease in length at hatch as NA concentrations increased. MLSB surface water contained higher levels of NAs than the commercial standard, however, showed consistently higher NA threshold effect concentrations for both species. Significant differences between the MLSB water and the Na-NA standard suggest that they contain NA congeners with different toxicity, or other compounds such as PAHs. Species differences in thresholds could be explained by the difference in developmental stage in which the exposures were initiated. (c) 2007 Elsevier Ltd. All rights reserved.

RefID: 568

Author: Peterson, C.H.

Year: 2001

Title: The “Exxon Valdez” oil spill in Alaska: acute, indirect and chronic effects on the ecosystem

Journal: Advances in Marine Biology

Hyperlink: http://www.sciencedirect.com/science/bookseries/00652881/39

Abstract: Following the oil spill in Prince William Sound, Alaska, in 1989, effects were observed across a wide range of habitats and species. The data allow us to evaluate direct and indirect links between shoreline habitats and the coastal ecosystem in general. The intertidal zone sufferred from direct oiling and clean-up treatments such as pressurized hot water, resulting in freeing of bare space on rocks and reductions in fucoid algal cover. Grazing limpets, periwinkles, mussels and barnacles were killed or removed. Subsequent indirect effects included colonization of the upper shore by ephemeral algae and an opportunistic barnacle and, in some regions, spread of Fucus gardneri into the lower shore where it inhibited return of red algae. The loss of habitat provided by the Fucus canopy slowed recovery on high shores, and lowered abundance of associated invertebrates. Abundance of sediment infauna declined and densities of clams were reduced directly. Their recovery was still incomplete by 1997 on oiled and treated shores where fine sediments had been washed down slope during treatment. Impacts in subtidal habitats were less intense than in the intertidal zone. Kelps were reduced in 1989 but recovered rapidly through re-colonization by 1990. Abundances of a dominant crab and seastar were reduced greatly, with recovery of the more mobile species, the crab, occurring by 1991. For about 4 years, there was reduced eelgrass density and hence less habitat for associated animals. Abundance of several toxin-sensitive amphipods declined dramatically and had not recovered by 1995. In general, how ever, many subtidal infaunal invertebrates increased in abundance, especially oligochaetes and surface deposit-feeding polychaetes. This may have resulted from increases in sediment hydrocarbon-degrading bacteria, but may also reflect reduction of predators. Along northern Knight Island, where sea otter populations had not recovered by 1997, green sea-urchins were larger, compared with those in un-oiled parts of Montague Island. This initial response from reduced predation by sea otters, if sustained, could lead to additional indirect effects of the spill. Scavenging terrstrial birds, such as bald eagles and northwestern crows, sufferred direct mortality as adults and reproductive losses, although eagles recovered rapidly. Numbers of intertidal benthic fishes were 40% lower on oiled than on un-oiled shores in 1990, but recovery was underway by 1991. Small benthic fishes living in eelgrass showed sensitivity to hydrocarbon contamination until at least 1996, as evidenced by hemosiderosis in liver tissues and P450 1A enzyme induction. Oiling of intertidal spawning habitats affected breeding of herring and pink salmon. Pink salmon, and possibly Dolly Varden char and cut-throat trout, showed slower growth when foraging on oiled shorelines as older juveniles and adults, which for pink salmon implies lower survival. The

pigeon guillemots that suffered from the oil spill showed reduced feeding on sand eels and capelin, which may also have been affected by the spill, and this may have contributed to failure of guillemot recovery. There was an analogous failure of harbor seals to recover. Sea otters declined by approximately 50%, and juvenile survival was depressed on oiled shores for at least four winters. Both black oystercatchers, shorebirds that feed on intertidal invertebrates, and also harlequin ducks showed reduced abundance on oiled shores that persisted for years after the spill. Oystercatchers consumed oiled mussels from beds where contamination by only partially weathered oil persisted until at least 1994, with a resulting impact on productivity of chicks. A high over-winter mortality of adult harlequin ducks continued in 1995–1996, 1996–1997 and 1997–1998. Delays in the recovery of avian and mammalian predators of fishes and invertebrates through chronic and indirect effects occurred long after the iniatial impacts of the spill. Such delayed effects are not usually incorporated into ecotoxicity risk assessments which thus substantially understimate impacts of a spill. Detection of delayed impacts requires rigorous long-term field sampling, so as to observe the dynamics of recovery processes.

RefID: 569

Author: Peterson, C.H., McDonald, L.L., Green, R.H. and Erickson, W.P.

Year: 2001

Title: Sampling design begets conclusions: the statistical basis for detection of injury to and recovery of shoreline communities after the 'Exxon Valdez' oil spill

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v210/p255-283/

Abstract: The joint effect of multiple initial decisions made about sampling design in evaluation of environmental impacts using observational field assessments influences the ability to detect and accurately estimate responses. The design can dictate in advance whether the study can identify even large impacts that truly exist. Following the 'Exxon Valdez' oil spill in 1989, 4 separate studies of effects of the spill on the intertidal biota were conducted. Studies overlapped sufficiently in geographic area, shoreline habitat, and biological response variables to permit contrasts showing how the aggregate of multiple design decisions led to differences in conclusions. The SEP (ShoreLine Ecology Program) supported by Exxon and the CHIA (Coastal Habitat Injury Assessment) funded by the Exxon Valdez Oil Spill Trustee Council shared a core approach of establishing a stratified random design of site selection. The Exxon-supported GOA (Gulf of Alaska) study and the NOAA (National Oceanographic and Atmospheric Administration) Hazmat (Hazardous Materials) study both chose to employ subjective choices of fixed sites. Despite many common goals, these 4 studies differed greatly in: (1) sampling effort (area covered per sample quadrat, sample replication within sites, numbers of study sites per category, numbers of samplings, and total areas sampled) and sampling design (philosophy of targeting sampling effort, complete randomization versus matched pair designs, sampling frame, treatment of habitat heterogeneity within sites, interspersion of sites, and control of shoreline treatment and oiling intensity); (2) analytical methodology (analysis of covariance versus paired designs, treatment of subsamples as replicates in F-ratios, logic of inferring recovery, and power calculations); and (3) choice of biological response variables (taxonomic level of analysis. aggregating versus spitting separate communities, and scope of communities and habitats examined). The CHIA and NOAA Hazmat studies of epibiotic responses in sheltered rocky shores of Prince William Sound made several decisions to enhance detection power and produced similar conclusions about large reductions in total biotic cover of intertidal space, Fucus cover, mussel abundance, abundance of the Limpet Tectura persona and a balanoid barnacle, and increases in open space and abundance of an opportunistic barnacle, Chthamalus dalli. In contrast, the SEP study of this same habitat and geographic region adopted design choices resulting in lower power of detection in 12 (vs CHIA and vs NOAA Hazmat) of 15 separate decisions (with one tie in each contrast). Accordingly, the SEP study was able to detect declines only in Fucus cover and occasionally in total Limpet abundance but not in total epifaunal or mussel or balanoid barnacle abundance and, unlike the results of the other 2 studies, most of the taxa analyzed showed apparent increases rather than decreases from oiling and shoreline treatment. The more powerful GOA and CHIA studies of impacts of oiling in the Gulf of Alaska, where oil grounded 1 to 8 wk later and in more weathered condition than in Prince William Sound, showed more consistent and larger reductions in intertidal biota in the sheltered rocky habitat than did the SEP study of Prince William Sound. Thus, the combined effects of many design decisions that reduced power to detect impacts in the SEP study led to failure to demonstrate large impacts of the spill documented by other studies of the same habitat in the same and the more remote region.

RefID: 570

Author: Peterson, C.H., Rice, S.D., Short, J.W., Esler, D., Bodkin, J.L., Ballachey, B.E. and Irons, D.B.

Year: 2003

Title: Long-term ecosystem response to the Exxon Valdez oil spill

Journal: Science

Hyperlink: http://www.sciencemag.org/content/302/5653/2082

Abstract: The ecosystem response to the 1989 spill of oil from the Exxon Valdez into Prince William Sound, Alaska, shows that current practices for assessing ecological risks of oil in the oceans and, by extension, other toxic sources should be changed. Previously, it was assumed that impacts to populations derive almost exclusively from acute mortality. However, in the Alaskan coastal ecosystem, unexpected persistence of toxic subsurface oil and chronic exposures, even at sublethal levels, have continued to affect wildlife. Delayed population reductions and cascades of indirect effects postponed recovery. Development of ecosystem-based toxicology is required to understand and ultimately predict chronic, delayed, and indirect long-term risks and impacts.

RefID: 571

Author: Pezeshki, S.R., Delaune, R.D. and Jugsujinda, A.

Year: 2001

Title: The effects of crude oil and the effectiveness of cleaner application following oiling on US Gulf of Mexico coastal marsh plants

Journal: Environmental Pollution

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/11291454

Abstract: Field studies were conducted in two different marsh habitats in Louisiana coastal wetlands to evaluate the effects of oiling (using South Louisiana Crude oil, SLC) and the effectiveness of a shoreline cleaner (COREXIT 9580) in removing oil from plant canopies. The study sites represented two major marsh habitats; the brackish marsh site was covered by Spartina patens and the freshwater marsh was covered by Sagittaria lancifolia. Field studies were conducted in each habitat using replicated 5.8 m(2) plots that were subjected to three treatments; oiled only, oiled + cleaner (cleaner was used 2 days after oiling), and a control. Plant gas exchange responses, survival, growth, and biomass accumulation were measured. Results indicated that oiling led to rapid reductions in leaf gas exchange rates in both species. However, both species in 'oiled + cleaned' plots displayed improved leaf conductance and CO? fixation rates. Twelve weeks after treatment initiation, photosynthetic carbon fixation in both species had recovered to normal levels. Over the short-term? S. patens showed more sensitivity to oiling with SLC than S. lancifolia as was evident from the data of the number of live shoots and above-ground biomass. Above-ground biomass remained significantly lower than control in S. patens under 'oiled' and 'oiled + cleaned' treatments while it was comparable to controls in S. lancifolia. These studies indicated that the cleaner removed oil from marsh grasses and alleviated the short-term impact of oil on gas exchange function of the study plants. However, use of cleaner had no detectable effects on above-ground biomass production or regeneration at the end of the first growing season in S. patens. Similarly, no beneficial effects of cleaner on carbon fixation and number of live shoots were apparent beyond 12 weeks in S. lancifolia. (C) 2001 Elsevier Science Ltd. All rights reserved.

RefID: 572

Author: Pezeshki, S.R., Jugsujinda, A. and Delaune, R.D.

Year: 1998

Title: Responses of selected US Gulf coast marsh macrophyte species to oiling and commercial cleaners

Journal: Water Air and Soil Pollution

Hyperlink: http://download.springer.com/static/pdf/512/art%3A10.1023%2FA%3A1004927732642.pdf?auth66=1422999436_4b4785c7fdbb3e801b908b3914e01e03&ext=.pdf

Abstract: A shoreline cleaner was tested to determine its effectiveness in removing different types of oil from selected US Gulf coastal marsh macrophytes. Bulltongue (Sagittaria lancifolia L.), three cornered grass (Scirpus olneyi E. & G.) and broadleaf cattail (Typha latifolia L.) were subjected to oil application and cleaning in a greenhouse and the subsequent effects on plant functions were evaluated during the period immediately after treatment initiation. Plant stomatal functioning, photosynthesis, respiration, regeneration, growth and biomass were monitored. Two types of oil, South Louisiana Crude (SLC) or Arabian Medium Crude (AMC) were used. The treatments included: control (no oil or cleaner), cleaner only (COREXIT 9580 only, no oil), oiled with SLC or AMC only (no cleaner), and oiled using SLC or AMC and cleaned with COREXIT 9580 after two days. The existing leaves on the macrophytes at the time of treatment application directly subjected to oiling (but not cleaned) did not recover from the effects of oiling in all of the study species. However, leaves under oil+cleaner treatments or leaves developed during the post-oiling period (new leaves) showed a different pattern of response. For instance, in bulltongue plants, new leaves had stomatal conductances at or close to the Values recorded for control plants. However, new leaves and leaves subjected to oil+cleaner treatment in cattail and three-cornered plants, had stomatal conductances significantly lower than their respective control plants. However, photosynthetic and respiration data indicated no overall significant differences within each species across treatments. Thus, the physiological functions of the study species had apparently recovered from the initial adverse effects of oiling within the experimental period. Based on photosynthetic and respiration data, the study species sensitivity ranking is similar. Furthermore, there were no significant differences in physiological responses of the study species to oil types. In addition, above-ground biomass was not affected significantly by the treatments in bulltongue or cattail but was reduced significantly in three-corner plants. Based on the overall physiological and biomass data, bulltongue was the least sensitive of the three species to SLC and AMC oil types than the other species while cattail appeared to be the most sensitive. Any beneficial effects of the cleaner may be more pronounced in plant species highly sensitive to specific oil types than the species studied.

RefID: 573

Author: Pfeiffer, C.J., Sharova, L.V. and Gray, L.

Year: 2000

Title: Functional and ultrastructural cell pathology induced by fuel oil in cultured dolphin renal cells

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/11023700

Abstract: Investigations mere undertaken to elucidate in a marine mammal renal cell culture system the toxicity and some of the mechanisms of cytopathology in a standardized preparation following exposure to No. 1 fuel oil. Cell survivability of a cultured SP1K renal cell line from the Atlantic spotted dolphin Stenella plagiodon was reduced in a dose-dependent manner after a 12-h exposure to fuel oil. Early morphologic changes reflecting cytotoxicity, as revealed by transmission electron microscopy, included enlarged rough endoplasmic reticula, cytoplasmic vacuolization, and degenerative cytoplasmic inclusions, but mitochondria remained resistant. Assessment of extracellular proton loss by microphysiometry of cultured cells revealed fuel oil-induced enhancement of proton loss that was dependent upon both protein kinase C and renal epithelial Na+/H+ countertransport functioning, as the specific inhibitors H-7 and amiloride reduced this stimulatory petroleum effect. Cell cycle progression and apoptosis (programmed cell death) were studied in dolphin renal cells exposed to fuel oil for 12, 24, and 48 hours. The toxicant increased the percentage of cells in GO/GI phase and decreased the percentage of cells in S phase starting after 24 hours. The number of cells undergoing early apoptosis was also increased after 24 hours. (C) 2000 Academic Press.

RefID: 574

Author: Phalen, L.J., Koellner, B., Leclair, L.A., Hogan, N.S. and van den Heuvel, M.R.

Year: 2014

Title: The effects of benzo a pyrene on leucocyte distribution and antibody response in rainbow trout (Oncorhynchus mykiss)

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X13003585

Abstract: Polycyclic aromatic hydrocarbons (PAHs) are a group of compounds with immunotoxic and carcinogenic potential that may pose a threat to fish populations. This study aims to utilize a newly developed fish immunotoxicology model to determine the immune tissue/cell population level effects of PAHs on rainbow trout, using benzo[a]pyrene (BaP) as a representative immunotoxic PAH. Intraperitoneal injection of 25 or 100 mg/kg BaP resulted in sustained exposure as indicated by biliary fluorescence at BaP wavelengths for up to 42 days. A new flow cytometry method for absolute counts of differential leucocyte distributions in spleen, blood, and head kidney was developed by combining absolute quantitative counts of total leukocytes in the tissue (3,3'-dihexyloxacarbocyanine iodide (DiOC(6)) dye) with relative differential counts using monoclonal antibodies for B cells, T cells, myeloid cells, and thrombocytes. Experiments indicated dose- and time-dependent decreases in the absolute number of B cells, myeloid cells, or T cells in blood, spleen, or head kidney after 7, 14 or 21 d of exposure. There was no change in the absolute numbers of erythrocytes or thrombocytes in any tissue. When rainbow trout were exposed to inactivated Aeromonas salmonicida after a 21 d exposure to 100 mg/kg BaP, circulating antibody concentrations were decreased by 56%. It was concluded that BaP has a cell lineage-specific toxic effect on some immune cells of rainbow trout, and causes a decrease in circulating antibody levels. (C) 2013 Elsevier B.V. All rights reserved.

RefID: 575

Author: Pham, P.H., Huang, Y.J., Chen, C. and Bols, N.C.

Year: 2014

Title: Corexit 9500 Inactivates Two Enveloped Viruses of Aquatic Animals but Enhances the Infectivity of a Nonenveloped Fish Virus

Journal: Applied and Environmental Microbiology

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/24271186

Abstract: The effects of Corexit 9500, a dispersant used to clean up oil spills, on invertebrates, lower vertebrates, birds, and human health have been examined, but there is a significant lack of study of the effect of this dispersant on aquatic viruses. In this study, the effects of Corexit 9500 on four aquatic viruses of differing structural composition were examined. Corexit 9500 reduced the titer of the enveloped viral hemorrhagic septicemia virus (VHSV) at all concentrations (10% to 0.001%) examined. The titer of frog virus 3 (FV3), a virus with both enveloped and nonenveloped virions, was reduced only at the high Corexit 9500 concentrations (10% to 0.1%). Corexit 9500 was unable to reduce the titer of nonenveloped infectious pancreatic necrosis virus (IPNV) but enhanced the titer of chum salmon reovirus (CSV) by 2 to 4 logs. With the ability to inactivate enveloped viruses and possibly enhance some nonenveloped viruses, Corexit 9500 has the potential to alter the aquatic virosphere.

RefID: 576

Author: Pilcher, W., Miles, S., Tang, S., Mayer, G. and Whitehead, A.

Year: 2014

Title: Genomic and Genotoxic Responses to Controlled Weathered-Oil Exposures Confirm and Extend Field Studies on Impacts of the Deepwater Horizon Oil Spill on Native Killifish

Journal: Plos One

Hyperlink: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0106351

Abstract: To understand the ecotoxicological impacts of the Deepwater Horizon oil spill, field studies provide a context for ecological realism but laboratory-based studies offer power for connecting biological effects with specific causes. As a complement to field studies, we characterized genome-wide gene expression responses of Gulf killifish (Fundulus grandis) to oil-contaminated waters in controlled laboratory exposures. Transcriptional responses to the highest concentrations of oiled water in the laboratory were predictive of field-observed responses that coincided with the timing and location of major oiling. The transcriptional response to the low concentration (similar to 10-fold lower than the high concentration) was distinct from the high concentration and was not predictive of major oiling in the field. The high concentration response was characterized by activation of the molecular signaling pathway that facilitates oil metabolism and oil toxicity. The high concentration also induced DNA damage. The low concentration invoked expression of genes that may support a compensatory response, including genes associated with regulation of transcription, cell cycle progression, RNA processing, DNA damage, and apoptosis. We conclude that the gene expression response detected in the field was a robust indicator of exposure to the toxic components of contaminating oil, that animals in the field were exposed to relatively high concentrations that are especially damaging to early life stages, and that such exposures can damage DNA.

RefID: 577

Author: Piñeiro, M.E.A., Yusty, M.A.L., González-Barros, S.T.C. and Lozano, J.S.

Year: 1996

Title: Aliphatic hydrocarbon levels in turbot and salmon farmed close to the site of the Aegean Sea oil spill

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs001289900261

Abstract:

RefID: 578

Author: Pollino, C.A. and Holdway, D.A.

Year: 2002

Title: Toxicity testing of crude oil and related compounds using early life stages of the crimson-spotted rainbowfish (Melanotaenia fluviatilis)

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651302921901

Abstract: The toxicity of petroleum hydrocarbons to marine aquatic organisms has been widely investigated; however, the effects on freshwater environments have largely been ignored. In the Australian freshwater environment, the potential impacts of petroleum hydrocarbons are virtually unknown. The toxicity of crude oil and related compounds were measured in the sensitive early life stages of the crimson-spotted rainbowfish (Melanotaenia fluviatilis). Waterborne petroleum hydrocarbons crossed the chorion of embryonic rainbowfish, reducing survival and hatchability. Acute exposures resulted in developmental abnormalities at and above 0.5 mg/L total petroleum hydrocarbons (TPH). Deformities included pericardial edema, disturbed axis formation, and abnormal jaw development. When assessing the acute toxicities of the water-accommodated fraction (WAF) of crude oil, dispersants, dispersant-oil mixtures, and naphthalene to larval rainbowfish, the lowest to highest 96-h median lethal concentrations for day of hatch larvae were naphthalene (0.51 mg/L), dispersed crude oil WAF (DCWAF)-9527 (0.74 mg/L TPH), WAF (1.28 mg/L TPH), DCSWAF-9500 (1.37 mg/l, TPH), Corexit 9500 (14.5 mg/L TPH), and Corexit 9527 (20.1 mg/L). Using naphthalene as a reference toxicant, no differences were found between the sensitivities of larval rainbowfish collected from adults exposed to petroleum hydrocarbons during embryonic development and those collected from unexposed adults. (C) 2002 Elsoier Science (USA).

RefID: 579

Author: Pollino, C.A., Georgiades, E. and Holdway, D.A.

Year: 2009

Title: Physiological changes in reproductively active rainbowfish (Melanotaenia fluviatilis) following exposure to naphthalene

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651309000232

Abstract: Naphthalene makes up a substantial fraction of polycyclic aromatic hydrocarbons (PAHs) in crude oil and is an important by-product of industry; however, few studies have investigated the toxicity of naphthalene to aquatic organisms. We examined the toxicity of increasing concentrations (0, carrier control, 130, 200 and 400 mu g/l) of naphthalene to adult rainbowfish (Melanotaenia fluviatilis) for 3 and 14 days to determine its potential to act as an endocrine disruptor. After exposure for 3 days, no changes in sex steroids were measured. After 14 days, a decrease of serum estradiol in females and an increase in serum testosterone in males was observed. These results suggest that naphthalene has the potential to act as an endocrine disruptor, although since no changes in plasma vitellogenin concentrations were observed in either sex, it is unlikely that naphthalene is acting as a xenoestrogen. There was a positive correlation between the incidences of deformities in larval offspring with increasing naphthalene concentrations, suggesting parental transfer of the toxicant. Egg production, hatchability and larval lengths remained unaltered, whilst few changes were measured in gamma-glutamyltranspeptidase (GTP), an enzymatic indicator of spermatogenesis. Contrary to other PAHs, hepatic ethoxyresorufin-O-deethylase (EROD) activities declined with increasing exposure concentration, suggesting that naphthalene was either having a cytotoxic effect or disrupting enzyme synthesis. (c) 2009 Elsevier Inc. All rights reserved.

RefID: 580

Author: Power, H.

Year: 2013

Title: Risk of Enbridge Northern Gateway Pipeline Project to Eulachon (Thaleichthys pacificus)

Journal: Thesis, Queens University

Hyperlink: http://qspace.library.queensu.ca/handle/1974/7978

Abstract: Eulachon, (Thaleichthys pacificus), is an anadromous species that spawns in the Kitimat River, British Columbia. The proposed Enbridge Northern Gateway Pipeline travels alongside this waterway and will put this species at risk. Eulachon are a unique species, and are important to freshwater and riparian ecosystems. Spawning runs occur at the end of winter, and they provide marine-derived nutrients that are essential to the functioning of these ecosystems. Species such as bears, gulls, eagles, and piscivorous fish all rely on eulachon for sustenance. The status of the central BC population of eulachon is “critically endangered”, with Kitimat River populations being “virtually extirpated” with fewer than 1000 members per run. Since 1992, eulachon runs of the Kitimat River have dropped substantially, and an oil spill at the most inopportune time could potentially eliminate this population. Haisla First Nations rely on eulachon runs for food, social, and ceremonial purposes. The elimination of these populations would have devastating effects on their way of life. The pipeline project puts eulachon at risk during all life stages; eulachon may be exposed as embryos incubating in the Kitimat River, as juveniles in the Kitimat Arm of the Douglas Channel, or as spawning adults running up the Douglas Channel. Should there be a tanker spill in the ocean, adult eulachon may also be exposed. There has been no research into the toxicological effects of crude oil or bitumen on eulachon during any life stage. Pink salmon (Oncorhynchus gorbuscha), Pacific herring (Clupea pallasii), and rainbow trout (Oncorhynchus mykiss) are three species that are most similar to eulachon. Toxicity of crude oil to pink salmon and Pacific herring embryos is observed at concentrations as low as 18 μg/L and 0.4 μg/L respectively. Liver lesions are observed in pink salmon juveniles exposed to ≥ 25 μg/L crude oil. Adult Pacific herring exposed to crude oil exhibit immunosuppression. Eulachon may have similar effects upon exposure to diluted bitumen.

RefID: 581

Author: Puttaswamy, N. and Liber, K.

Year: 2011

Title: IDENTIFYING THE CAUSES OF OIL SANDS COKE LEACHATE TOXICITY TO AQUATIC Invertebrates

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.653/abstract;jsessionid=9E1E0D0BAF12A869EAF9522D34D2164B.f04t03

Abstract: A previous study found that coke leachates (CL) collected from oil sands field sites were acutely toxic to Ceriodaphnia dubia; however, the cause of toxicity was not known. Therefore, the purpose of this study was to generate CL in the laboratory to evaluate the toxicity response of C. dubia and perform chronic toxicity identification evaluation (TIE) tests to identify the causes of CL toxicity. Coke was subjected to a 15-d batch leaching process at pH 5.5 and 9.5. Leachates were filtered on day 15 and used for chemical and toxicological characterization. The 7-d median lethal concentration (LC50) was 6.3 and 28.7% (v/v) for pH 5.5 and 9.5 CLs, respectively. Trace element characterization of the CLs showed Ni and V levels to be well above their respective 7-d LC50s for C. dubia. Addition of ethylenediaminetetraacetic acid significantly ($p \le 0.05$) improved survival and reproduction in pH 5.5 CL, but not in pH 9.5 CL. Cationic and anionic resins removed toxicity of pH 5.5 CL only. Conversely, the toxicity of pH 9.5 CL was completely removed with an anion resin alone, suggesting that the pH 9.5 CL contained metals that formed oxyanions. Toxicity reappeared when Ni and V were added back to anion resin-treated CLs. The TIE results combined with the trace element chemistry suggest that both Ni and V are the cause of toxicity in pH 5.5 CL, whereas V appears to be the primary cause of toxicity in pH 9.5 CL. Environmental monitoring and risk assessments should therefore focus on the fate and toxicity of metals, especially Ni and V, in coke-amended oil sands reclamation landscapes. Environ. Toxicol. Chem. 2011;30:2576-2585. (C) 2011 SETAC

RefID: 582

Author: Quagraine, E.K., Peterson, H.G. and Headley, J.V.

Year: 2005

Title: In situ bioremediation of naphthenic acids contaminated tailing pond waters in the Athabasca oil sands region-demonstrated field studies and plausible options: A review

Journal: Journal of Environmental Science and Health

Hyperlink: http://www.tandfonline.com/doi/abs/10.1081/ESE-200046649

Abstract: Currently, there are three industrial plants that recover oil from the lower Athabasca oil sands area, and there are plans in the future for several additional mines. The extraction procedures produce large volumes of slurry wastes contaminated with naphthenic acids (NAs). Because of a "zero discharge" policy the oil sands companies do not release any extraction wastes from their leases. The process-affected waters and fluid tailings contaminated with NAs are contained on-site primarily in large settling ponds. These fluid wastes from the tailing ponds can be acutely and chronically toxic to aquatic organisms, and NAs have been associated with this toxicity. The huge tailings containment area must ultimately be reclaimed, and this is of major concern to the oil sands industry. Some reclamation options have been investigated by both pioneering industries (Syncrude Energy Inc. and Suncor Inc.) with mixed results. The bioremediation techniques have limited success to date in biodegrading NAs to levels below 19 mg/L. Some tailing pond waters have been stored for more than 10 years, and it appears that the remaining high molecular weight NAs are refractory to the natural biodegradation process in the ponds. Some plausible options to further degrade the NAs in the tailings pond water include: bioaugmentation with bacteria selected to degrade the more refractory classes of NAs; the use of attachment materials such as clays to concentrate both the NA and the NA-degrading bacteria in their surfaces and/or pores; synergistic association between algae and bacteria consortia to promote efficient aerobic degradation; and biostimulation with nutrients to promote the growth and activity of the microorganisms.

RefID: 583

Author: Quesnel, D.M., Bhaskar, I.M., Gieg, L.M. and Chua, G.

Year: 2011

Title: Naphthenic acid biodegradation by the unicellular alga Dunaliella tertiolecta

Journal: Chemosphere

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0045653511002815

Abstract: Naphthenic acids (NAs) are a major contributor to toxicity in tailings waste generated from bitumen production in the Athabasca Oil Sands region. While investigations have shown that bacteria can biodegrade NAs and reduce tailings toxicity, the potential of algae to biodegrade NAs and the biochemical mechanisms involved remain poorly understood. Here, we discovered that the marine alga Dunaliella tertiolecta is able to tolerate five model NAs (cyclohexanecarboxylic acid, cyclohexaneacetic acid, cyclohexanepropionic acid, cyclohexanebutyric acid and 1,2,3,4-tetrahydro-2-naphthoic acid) at 300 mg L(-1), a level which exceeds that of any single or combination of NAs typically found in tailings ponds. Moreover, we show that D. tertiolecta can metabolize four of the model NAs. Analysis of NA-amended cultures of D. tertiolecta via low resolution gas chromatography-mass spectrometry allowed us to quantify decreasing NA levels, identify metabolites, and formulate putative mechanisms of biodegradation. Degradation of cyclohexanebutyric acid and cyclohexanepropionic acid proceeded via beta-oxidation and resulted in the transient accumulation of cyclohexaneacetic acid and cyclohexanecarboxylic acid, respectively. Cyclohexanecarboxylic acid was metabolized via 1-cyclohexenecarboxylic acid suggesting that further degradation may occur by step-wise beta-oxidation. When D. tertiolecta was inoculated in the presence of oil sands tailings water from the Athabasca region, biodegradation of single-ring NAs was observed relative to controls. This result corroborates the trend we observed with the single-ring model NAs. Crown Copyright (C) 2011 Published by Elsevier Ltd. All rights reserved.

RefID: 584

Author: Quinterno, P.J. and Carkin, B.A.

Year: 1991

Title: Benthic foraminifers from Prince William Sound, Alaska -- One year after the Exxon Valdez Oil Spill

Journal: In: Carlson, PR (Ed.) "Sediment of Prince William Sound, beach to deep fjord floor, a year after the Exxon Valdez oil spill." U.S. Geological Survey Open-File Report 91-631, 101 p.

Hyperlink:

Abstract: On March 24, 1989 the oil tanker EXXON VALDEZ struck Bligh Reef in upper Prince William Sound and spilled approximately 240,000 barrels of crude oil into the estuary. About 50 days later the U.S. Geological Survey conducted a cruise aboard the R/V FARNELLA to determine what effect, if any, the spill had on the bottom sediment (Carlson and Reimnitz, 1990). During a subsequent cruise, 13 box core samples were collected at 11 sites (9 were reoccupation sites) during the May-June 1990 NOAA cruise aboard the R/V DAVIDSON. In August, 1990 fifty-two samples (anchor, beach, grab and gravity core samples) from 41 shallow, nearshore sites were collected during a U.S.G.S. cruise aboard the R/V KARLUK. This report discusses the benthic foraminifers collected during the 1990 cruises and compares them with those from the 1989 cruise. The distribution of benthic foraminifers in Prince William Sound was not known before the oil spill; therefore, it is not possible to know if the spill affected the benthic foraminiferal population. However, live (stained) foraminifers are present in samples from both the 1989 and 1990 cruises.

RefID: 585

Author: Radniecki, T.S., Schneider, M.C. and Semprini, L.

Year: 2013

Title: The influence of Corexit 9500A and weathering on Alaska North Slope crude oil toxicity to the ammonia oxidizing bacterium, Nitrosomonas europaea

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X12006236

Abstract: The toxicity of the water associated fraction (WAF) of Alaska North Slope Crude oil (ANSC), Corexit 9500A and the dispersant enhanced WAF (DEWAF) of ANSC:Corexit 9500A mixtures were examined on the model ammonia oxidizing bacterium, Nitrosomonas europaea. Corexit 9500A was not toxic at environmentally relevant concentrations. Corexit 9500A greatly increased the toxicity of ANSC by increasing the chemical oxygen demand (COD) of the DEWAF. However, a majority of the DEWAF compounds were not toxic to N. europaea. Weathered WAF and DEWAF were not toxic to N. europaea even though their COD did not change compared to non-weathered controls, suggesting that toxicity was due to a small volatile fraction of the ANSC. The over-expression of the NE1545 gene, a marker for aromatic hydrocarbon exposure, in N. europaea cells exposed to WAF and DEWAF suggests that aromatic hydrocarbons are bioavailable to the cells and may play a role in the observed toxicity. Published by Elsevier Ltd.

RefID: 586

Author: Raimondo, S., Jackson, C.R., Krzykwa, J., Hemmer, B.L., Awkerman, J.A. and Barron, M.G.

Year: 2014

Title: Developmental toxicity of Louisiana crude oil-spiked sediment to zebrafish

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651314003194

Abstract: Embryonic exposures to the components of petroleum, including polycyclic aromatic hydrocarbons (PAHs), cause a characteristic suite of developmental defects and cardiotoxicity in a variety of fish species. We exposed zebrafish embryos to reference sediment mixed with laboratory weathered South Louisiana crude oil and to sediment collected from an oiled site in Barataria Bay, Louisiana in December 2010. Laboratory oiled sediment exposures caused a reproducible set of developmental malformations in zebrafish embryos including yolk sac and pericardial edema, craniofacial and spinal defects, and tissue degeneration. Dose-response studies with spiked sediment showed that total polycyclic aromatic hydrocarbons (tPAH) concentrations of 27 mg tPAH/kg (dry weight normalized to 1 percent organic carbon [1 percent OC]) caused a significant increase in defects, and concentrations above 78 mg tPAH/kg 1 percent OC caused nearly complete embryo mortality. No toxicity was observed in Barataria sediment with 2 mg tPAH/kg 1 percent OC. Laboratory aging of spiked sediment at 4 degrees C resulted in a nearly 10-fold decrease in sensitivity over a 40-day period. This study demonstrates oiled sediment as an exposure pathway to fish with dose-dependent effects on embryogenesis that are consistent with PAH mechanisms of developmental toxicity. The results have implications for effects on estuarine fish from oiled coastal areas during the Deepwater Horizon spill. Published by Elsevier Inc.

RefID: 587

Author: Raingeard, D., Bilbao, E., Sáez-Morquecho, C., de Cerio, O.D., Orbea, A., Cancio, I. and Cajaraville, M.P.

Year: 2009

Title: Cloning and transcription of nuclear receptors and other toxicologically relevant genes, and exposure biomarkers in European hake (Merluccius merluccius) after the Prestige oil spill

Journal: Marine Genomics

Hyperlink: http://www.sciencedirect.com/science/article/pii/S1874778709000750

Abstract: In November 2002 the tanker Prestige released more than 60,000 t of a heavy fuel oil which spread over Galician waters and the Biscay Bay, affecting coastal ecosystems. Polycyclic aromatic hydrocarbons are the main components of the Prestige fuel oil and induce biotransformation metabolism and peroxisome proliferation in marine organisms. In vertebrates, this later response involves peroxisome proliferator-activated receptors (PPARs), transcription factors belonging to the nuclear receptor superfamily, that act upon hetero-dimerization with the retinoid X receptor (RXR). In order to assess the possible biological effects of the Prestige oil spill in the Biscay Bay, male and female juvenile and adult European hakes Merluccius merluccius were sampled in June and December 2004 and 2005. PCR screening of hake liver cDNA with degenerate primers resulted in cloning and sequencing of cDNA fragments of PPAR alpha (1011 bp), PPAR gamma (812 bp), RXR (270 bp) and of the PPARa target gene palmitoyl-CoA oxidase (AOX1, 792 bp). Fragments of another 9 toxicologically relevant genes were also cloned and sequenced. PPAR alpha mRNA expression was not significantly different among groups. In juvenile females transcription of PPAR gamma, RXR and AOX1 significantly increased in June 2005 when compared to June 2004. In adult males levels of AOX1 decreased in the same period. AOX1 and 7-ethoxyresorufin O-deethylase (EROD) activities, measured as exposure biomarkers, differed between years only in males sampled in June. EROD activity was higher in 2004 than in 2005 in adults, whereas both juvenile and adults showed higher AOX1 activity in 2005. The lack of historical data previous to the accident or in areas not affected by the accident did not allow to relate observed variations in gene transcription levels and enzyme activities to the Prestige oil spill. Reported data could be useful for comparison purposes for future studies in European hake and contributes gene sequence information relevant for future toxicological studies. (C) 2009 Elsevier B.V. All rights reserved.

RefID: 588

Author: Ramachandran, S.D., Hodson, P.V., Khan, C.W. and Lee, K.

Year: 2004

Title: Oil dispersant increases PAH uptake by fish exposed to crude oil

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651303001684

Abstract: The use of oil dispersants is a controversial countermeasure in the effort to minimize the impact of oil spills. The risk of ecological effects will depend on whether oil dispersion increases or decreases the exposure of aquatic species to the toxic components of oil. To evaluate whether fish would be exposed to more polycyclic aromatic hydrocarbon (PAH) in dispersed oil relative to equivalent amounts of the water-accommodated fraction (WAF), measurements were made of CYP1A induction in trout exposed to the dispersant (Corexit 9500), WAFs, and the chemically enhanced WAF (dispersant; CEWAF) of three crude oils. The crude oils comprised the higher viscosity Mesa and Terra Nova and the less viscous Scotian Light. Total petroleum hydrocarbon and PAH concentrations in the test media were determined to relate the observed CYP1A induction in trout to dissolved fractions of the crude oil. CYP1A induction was 6- to 1100-fold higher in CEWAF treatments than in WAF treatments, with Terra Nova having the greatest increase, followed by Mesa and Scotian Light. Mesa had the highest induction potential with the lowest EC50 values for both WAF and CEWAF. The dispersant Corexit was not an inducer and it did not appear to affect the permeability of the gill surface to known inducers such as beta-napthoflavone. These experiments suggest that the use of oil dispersants will increase the exposure of fish to hydrocarbons in crude oil. (C) 2003 Published by Elsevier Inc.

RefID: 589

Author: Ramachandran, S.D., Sweezey, M.J., Hodson, P.V., Boudreau, M., Courtenay, S.C., Lee, K., King, T. and Dixon, J.A.

Year: 2006

Title: Influence of salinity and fish species on PAH uptake from dispersed crude oil

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X06000634

Abstract: The use of chemical oil dispersants to minimize spill impacts causes a transient increase in hydrocarbon concentrations in water, which increases the risk to aquatic species if toxic components become more bioavailable. The risk of effects depends on the extent to which dispersants enhance the exposure to toxic components, such as polycyclic aromatic hydrocarbons (PAH). Increased salinities can reduce the solubility of PAH and the efficiency of oil dispersants. This study measured changes in the induction of CYP1A enzymes of fish to demonstrate the effect of salinity on PAH availability. Freshwater rainbow trout and euryhaline mummichog were exposed to water accommodated fractions (WAF), and chemically-enhanced water accommodated fractions (CEWAF) at 0 parts per thousand, 15 parts per thousand, and 30 parts per thousand salinity. For both species, PAH exposure decreased as salinity increased whereas dispersant effectiveness decreased only at the highest salinity. Hence, risks to fish of PAH from dispersed oil will be greatest in coastal waters where salinities are low. (c) 2006 Elsevier Ltd. All rights reserved.

RefID: 590

Author: Rebar, A.H., Ballachey, B.E., Bruden, D.K. and Kloecker, K.A.

Year: 1996

Title: Hematology and clinical chemistry of sea otters captured in Prince William Sound, Alaska following the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/35756426.pdf

Abstract: Hematologic and serum chemical analyses were performed on sea otter blood samples collected from 31 adult males, 63 adult females, and 42 pups captured in western Prince William Sound (oiled area), and 12 adult males, 40 adult females, and 15 pups captured in eastern Prince William Sound (unoiled area) in 1989 and 1990. Hematologic differences between eastern and western adult males were minimal. Both hematocrits and hemoglobins were higher in western than eastern otters but the biological significance of this is equivocal. Western males had higher absolute eosinophil counts, suggesting possible systemic hypersensitivity reactions. Western males had higher serum protein and serum globulin levels than eastern males, suggesting greater antigenic stimulation (more inflammatory and/or infectious conditions). There were no differences in hematologic parameters between eastern and western female otters. Some chemistry changes were present, but the degree of difference was small. Total protein and serum globulin levels were slightly higher in western females, a finding also seen in adult males. Mean levels of liver enzymes for western females were somewhat higher than for the eastern otters, suggesting the possibility of subclinical liver disease. As a group, western pup hematocrits, hemoglobins, and red cell counts were significantly lower than those of eastern pups. From a biological perspective, these reductions were minimal but supported by individual animal data. The red cell data suggest a mild anemia in western pups; however, the degree of anemia was minimal, so that biological significance was equivocal. Other hematologic and clinical chemical differences between eastern and western pups were not striking and were also of equivocal biological significance. Key Words: carcasses, Enhydra lutris, Exxon Valdez, mortality, oil

RefID: 591

Author: Redman, A.D., McGrath, J.A., Stubblefield, W.A., Maki, A.W. and Di Toro, D.M.

Year: 2012

Title: Quantifying the concentration of crude oil microdroplets in oil-water preparations

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.1882/abstract;jsessionid=3F0C8EE447417385E54FE536D873BE2C.f03t02

Abstract: Dissolved constituents of crude oil, particularly polycyclic aromatic hydrocarbons (PAHs), can contribute substantially to the toxicity of aquatic organisms. Measured aqueous concentrations of highmolecular weight PAHs (e.g., chrysenes, benzo[a]pyrene) as well as long-chain aliphatic hydrocarbons can exceed the theoretical solubility of these sparingly soluble compounds. This is attributed to the presence of a microdroplet or colloidal oil phase. It is important to be able to quantify the dissolved fraction of these compounds in oil-in-water preparations that are commonly used in toxicity assays because the interpretation of test results often assumes that the compounds are dissolved. A method is presented to determine the microdroplet contribution in crude oil-in-water preparations using a comparison of predicted and measured aqueous concentrations. Measured concentrations are reproduced in the model by including both microdroplets and dissolved constituents of petroleum hydrocarbons. Microdroplets were found in all oilwater preparation data sets analyzed. Estimated microdroplet oil concentrations typically ranged from 10 to 700?mu g oil/L water. The fraction of dissolved individual petroleum hydrocarbons ranges from 1.0 for highly soluble compounds (e.g., benzene, toluene, ethylbenzene, and xylene) to far less than 0.1 for sparingly soluble compounds (e.g., chrysenes) depending on the microdroplet oil concentration. The presence of these microdroplets complicates the interpretation of toxicity test data because they may exert an additional toxic effect due to a change in the exposure profile. The implications of the droplet model on toxicity are also discussed in terms of both dissolved hydrocarbons and microdroplets. Environ. Toxicol. Chem. 2012; 31: 18141822. (c) 2012 SETAC

RefID: 592

Author: Redman, A.D., Parkerton, T.F., Letinski, D.J., Manning, R.G., Adams, J.E. and Hodson, P.V.

Year: 2014

Title: EVALUATING TOXICITY OF HEAVY FUEL OIL FRACTIONS USING COMPLEMENTARY MODELING AND BIOMIMETIC EXTRACTION METHODS

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.1882/abstract;jsessionid=3F0C8EE447417385E54FE536D873BE2C.f03t02

Abstract: The toxicity of chemically dispersed heavy fuel oil (HFO) and 3 distillate fractions to rainbow trout (Oncorhynchus mykiss) embryos was evaluated using the PETROTOX model and a biomimetic extraction technique that involved passive sampling of oil-contaminated test media with solid-phase microextraction (SPME) fibers. Test solutions for toxicity testing were generated using a combination of dispersant and high-energy mixing. The resulting water accommodated fractions (WAF) provided complex exposure regimens that included both dissolved hydrocarbons and oil droplets. The toxicity of the various fractions differed by approximately 3 orders of magnitude when expressed on the basis of WAF dilution. Using detailed compositional data, the PETROTOX model predicted the speciation of hydrocarbons between dissolved and oil droplet phases and explained observed toxicity based on computed dissolved phase toxic units (TUs). A key finding from model calculations was that dissolved hydrocarbon exposures and associated TUs were a nonlinear function of WAF dilution, because dissolved hydrocarbons were largely controlled by the dissolution of oil droplets that were transferred in WAF dilutions. Hence, oil droplets served to "buffer" dissolved concentrations in WAF dilutions at loadings greater than 1 mg/L, resulting in higher dissolved concentrations and TUs than expected based on dilution. The TUs computed at each WAF dilution explained the observed toxicity among the HFO and fractions to within a factor of 3. Dissolved material measured by SPME showed a consistent relationship with model-predicted TUs, confirming the utility of this approach for providing an integrated measure of exposure to bioavailable hydrocarbons. These 2 approaches provide complementary tools for better defining bioavailability of complex petroleum substance. (c) 2014 SETAC

RefID: 593

Author: Reynolds, J.H. and Braman, N.

Year: 2009

Title: Using tolerance intervals to assess recovery of mussel beds impacted by the Exxon Valdez oil spill

Journal: Marine Pollution Bulletin

Hyperlink: http://www.pubfacts.com/detail/19596365/Using-tolerance-intervals-to-assess-recovery-of-mussel-beds-impacted-by-the-Exxon-Valdez-oil-spill.

Abstract: Polycyclic aromatic hydrocarbons (PAH) have been measured in mussel tissues in early spring and summer since 1993 throughout Prince William Sound (PWS) and the Gulf of Alaska (GOA). Season-specific thresholds were established at reference sites to identify' above background' total PAH levels. Thresholds were estimated using one-sided 99% tolerance limits. Thresholds were similar across reference sites but differed by an order of magnitude across seasons. Trends in total PAH since 1998 were assessed for sites impacted by the 1989 Exxon Valdez oil spill or the Alyeska Marine Terminal. Summer samples exhibited no trends; early spring samples declined. In early spring, all sites were judged 'recovered' by 2004; in summer, one site in western Prince William Sound and two in the western GOA exceeded thresholds by 11 ng/g dry weight or less. Robust estimation methods prevented bias from observations affected by unknown releases or laboratory errors. (C) 2009 Elsevier Ltd. All rights

RefID: 594

Author: Rial, D., Beiras, R., Vázquez, J.A. and Murado, M.A.

Year: 2010

Title: Acute Toxicity of a Shoreline Cleaner, CytoSol, Mixed With Oil and Ecological Risk Assessment of its Use on the Galician Coast

Journal: Archives of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs00244-010-9492-7

Abstract: The application of embryo-larval bioassay with the purple sea urchin Paracentrotus lividus and the mussel Mytilus galloprovincialis at 48 hours, and with neonates of the mysid Siriella armata at 96 hours, was used to evaluate the acute toxicities of the following preparations: (1) the shoreline cleaning agent CytoSol; (2) the water-accommodated fraction of CytoSol plus a light crude oil; and (3) the runoff from a pilot-scale treatment with CytoSol of a rocky coastal substrate impregnated with residues from the Prestige oil spill (which occurred on November 19, 2002). The mussel was the most sensitive organism to CytoSol and runoff effects (EC(50) = 8.0 mu L/L and 64.3 mL/L, respectively), and the mysid was the least sensitive to the runoff (EC(50) > 200 mL/L). The predicted no-effect environmental concentration (PNEC) was calculated from the no observed-effect concentration of the species most sensitive to the runoff. The predicted environmental concentration (PEC) was estimated from a simple and reasonable dilution model, and the PEC/PNEC ratio was calculated according to the area treated and the values of the variables considered in the model. Implications for the management of the treatment operations are discussed.

RefID: 595

Author: Rial, D., Murado, M.A., Menduiña, A., Fuciños, P., González, P., Mirón, J. and Vázquez, J.A.

Year: 2013

Title: Effects of spill-treating agents on growth kinetics of marine microalgae

Journal: Journal of Hazardous Materials

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0304389413004883

Abstract: The effects of four spill-treating agents (STAs) (CytoSol, Finasol (R) OSR 51, Agma OSD 569 and OD4000) on the growth kinetics of three marine microalgae (Isochrysis galbana, Chaetoceros gracilis, Phaeodactylum tricornutum) were studied. Chlorophyll a concentration and optical density at 700 nm were assessed to describe the logistic growth of algae in batch cultures. The optical density data were initially analyzed as described for standard algal growth inhibition tests and subsequently modelled by a bivariate model, as a function of time and dose, to assess the toxic effects on growth parameters. Increasing trends in EC50 and EC10 values with time were found with the standard approach. In 8 of the 11 tests, the lag phase (lambda) or the time required to achieve half the maximum biomass (tau) was significantly dependent on the STA concentration. A global parameter (EC50,tau) was calculated to summarize the effects of STAs on growth parameters in the bivariate model. The ranking of sensitivity as EC50,tau. values was I. galbana > C gracilis > P. tricornutum. For all species tested, the least toxic agent was Agma OSD 569, followed by CytoSol. The mathematical model allowed successful ecotoxicological evaluation of chemicals on microalgal growth. (C) 2013 Elsevier B.V. All rights reserved.

RefID: 596

Author: Rial, D., Radović, J.R., Bayona, J.M., Macrae, K., Thomas, K.V. and Beiras, R.

Year: 2013

Title: Effects of simulated weathering on the toxicity of selected crude oils and their components to sea urchin embryos

Journal: Journal of Hazardous Materials

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0304389413003208

Abstract: Artificial weathering of Angolan crude and a Heavy Fuel Oil (HFO) was performed by evaporation and photooxidation. The aliphatic, aromatic, polar and asphaltene fractions of the fresh and weathered oils were isolated. The toxicity of the water accommodated fraction or an oil/fraction dissolved in DMSO was assessed using the sea urchin embryo test. Photooxidation was observed to decrease the aromatics content and increase polar compounds. A slight reduction in the toxicity of Angolan crude was observed following weathering for the water-accommodated fraction and the extract in DMSO, but no effect was seen for the Heavy Fuel Oil. For aliphatic compounds, the toxicity decreased in the order fresh > evaporated > photooxidated for both Angolan crude and HFO. Weathering slightly increased the toxicity of the aromatic and polar fractions of the oil. The aromatic fractions were responsible for most of the toxicity and the polar compounds were the second most important toxic components, despite having less or similar abundance than the aliphatic fraction. The toxic contribution of the aromatic compounds was higher for the HFO than for the Angolan crude. A decrease in the toxicity of Angolan crude following weathering correlated with a reduction in the toxicity of the aliphatic fraction. (C) 2013 Elsevier B.V. All rights reserved.

RefID: 597

Author: Rial, D., Vázquez, J.A. and Murado, M.A.

Year: 2014

Title: Toxicity of spill-treating agents and oil to sea urchin embryos

Journal: Science of the Total Environment

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0048969713013119

Abstract: The aim of this study was to assess the joint toxicity of a Maya crude oil and four spill-treating agents (STAs) (CytoSol, Finasol OSR51, Agma OSD569 and OD4000). The acute toxicity of the binary mixtures of the water accommodated fractions (WAFs) obtained independently for the oil and each STA was assessed. The toxicity of the chemically enhanced WAF (CEWAF) of oil and Finasol OSR51 at several dispersant to oil ratios (1:2, 1:10 and 1:100) was also evaluated. The toxicity (EC50) obtained for the WAFs of the STAs was: CytoSol (15.1 mL/L) < Agma OSD 569 (9.8 mL/L) < OD4000 (2.6 mL/L) < and Finasol OSR 51 (1.8 mL/L). An accurate description of the toxicity of binary mixtures was obtained by the following models: Concentration Addition (Agma OSD569 and CytoSol), Independent Action (Finasol OSR51) and extended Concentration Addition model to describe antagonistic effects (004000). The CEWAFs showed an intermediate position between the more moderate effects of the WAF of oil and the higher toxicity of the WAFs of Finasol OSR51, which suggested the high sensitivity of the sea urchin embryo toward the dispersant. (C) 2013 Elsevier B.V. All rights reserved.

RefID: 598

Author: Rial, D., Vázquez, J.A., Menduiña, A., García, A.M., González, M.P., Mirón, J., Murado, M.A.

Year: 2013

Title: Toxicity of binary mixtures of oil fractions to sea urchin embryos

Journal: Journal of Hazardous Materials

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0304389413007036

Abstract: The assumption of additive toxicity for oil compounds is related to a narcotic mode of action. However, the joint toxicity of oil fractions has not been fully investigated. A fractionation of Maya crude oil into aliphatics, aromatics and polars was performed, fractions were dissolved in dimethyl sulfoxide (DMSO) and subsequently toxicity of single fractions and binary mixtures was assessed using the sea urchin embryo test. The descriptive ability of Concentration Addition (CA), Independent Action (IA) and modifications of both models for describing the joint toxicity of mixtures has also been evaluated. The hydrocarbon content extractable with dichloromethane of the fractions dissolved in DMSO was: 12.0 +/- 1.8 mg mL(-1), 39.0 +/- 0.5 mg mL(-1) and 20.5 +/- 2.5 mg mL(-1) for aliphatics, aromatics and polars, respectively. The toxicity of the extracts in DMSO of the fractions as EC50 (mu LL-1) was: aliphatics

(165.8-242.3) < polars (87.1-115.7) < aromatics (20.5-34.6). The goodness of fit of the CA model was in most binary mixtures (aliphatics-aromatics, aromatics-polars) greater than the IA (aliphatics-polars) according to the Akaike Information Criterion, so CA was considered a better option than IA to explain the joint toxicity of oil fractions. In addition, synergistic or antagonistic effects were not observed. (C) 2013 Elsevier B.V. All rights reserved.

RefID: 599

Author: Rice, S.D. and Carls, M.G.

Year: 2007

Title: Prince William Sound herring: an updated synthesis of population declines and lack of recovery

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/A/428827063.pdf

Abstract: The PWS herring population collapsed 4 years after the Exxon Valdez oil spill, igniting debate about the cause. Fishermen who once depended on this stock for income and some investigators are convinced that the spill was causal, others are not. Our re-examination of the data demonstrates that polynuclear aromatic hydrocarbons (PAH) are highly toxic and that the oil spill significantly damaged herring embryos in 1989. These effects were no longer detectable after 1990 and strong recruitment of the 1988 year-class (in 1991) marked population recovery from the direct toxic effects of the spill. No plausible oil-related mechanisms have been developed to explain a delayed response after intervening years of no response. By 1993, recruitment to an expanding population (plus an additional 1 to 2% because the stock was not fished in 1989) helped precipitate a catastrophic disease outbreak. Epidemiological analysis identifies three significant risk factors for the 1993 population crash: 1) relatively large biomass from 1988 to 1992 (i.e., a susceptible host); 2) relatively low zooplankton production in 1991 3 and 1992 (i.e., environmental conditions contributing to poor overwinter condition); and 3) the presence of disease (VHSV and filamentous bacteria). Timing of the population collapse was questioned by some, who extrapolated hydroacoustic data (a time series that began in the mid- 1990s) to dates earlier than sampled and suggested the collapse began in 1989, adding fuel to the controversy that the oil spill was linked to the collapse. However, this particular hindcast fails to explain the observation of lethargic survivors with external hemorrhages in 1993 and is inconsistent with a competing age-structured model. Although linkage of the 1993 collapse with the oil spill cannot be proved or disproved with certainty, reasons for poor recovery since the collapse remain perplexing. Natural factors, including climate, inter-species competition, suboptimal recruitment, condition prior to entering the winter starvation period, disease, and predation may be important. Disease measurements through 2002 continued to indicate the population was restricted by chronic disease; recruitment was negatively affected by VHSV and life spans were shortened by Ichthyophonus, although reasons why disease continues to cycle in the population are unresolved. Aside from limited measurement in a reference population (southeast Alaska), comparable disease measurements in other fish populations do not exist. The PWS herring population is not genetically discrete within the Gulf of Alaska. Thus, genetic diversity within the population and exchange with surrounding populations is adequate and does not explain the lack of population recovery, despite the sudden population collapse in 1993. Continued disease cycles may be the most parsimonious reason why the PWS herring population has failed to recover in the past 13 years but the root causes for this are unknown. The resulting lack of recovery is more than likely the contribution of several factors, not just one factor.

RefID: 600

Author: Rice, S.D., Babcock, M.M., Brodersen, C.C., Carls, M.G., Gharrett, J.A., Kern, S., Moles, A. and Short, J.W.

Year: 1986

Title: LETHAL AND SUBLETHAL EFFECTS OF THE WATER-SOLUBLE FRACTION OF COOK INLET CRUDE OIL ON PACIFIC HERRING (CLUPEA HARENGUS PALLASI) REPRODUCTION

Journal: NOAA Final Report: Outer Continental Shelf Environmental Assessment Program Research Unit 661

Hyperlink: http://jlc-web.uaa.alaska.edu/client/asl/search/detailnonmodal/ent:$002f$002fSD_ILS$002f1695$002fSD_ILS:1695719/ada;jsessionid=F2445EEAD94ADA96AA74B6C7C12FB29F?qu=Auke+Bay+Laboratory+%28Juneau%2C+Alaska%29&qf=SUBJECT%09Subject%09Pacific+herring+--+Effect+

Abstract: The results of our study are summarized:* Prespawn adult herring exposed to WSF had a 2- and 12-day LC50 (themedian concentration that killed 50% of the herring) of 2.3 parts per million (ppm) aromatic hydrocarbons. * Eggs of adults exposed 12 days to 1.6 ppm had normal hatching success.* Eggs exposed 2 days to 5.3 ppm had normal hatching success; eggs exposed 12 days had an LC50 of 1.5 ppm*Yolk-sac larvae exposed<6 hours to 6.0 ppm survived; yolk-sac larvaeexposed from 16 hours to 6 days had LC50'S of 2.8 to 2.3 ppm *Feeding larvae exposed 7 days had an LC50 of 1.8 ppm, and 21 days, 0.36 ppm. *Tissue (muscle, liver, testes, and mature and immature ovaries) uptake of hydrocarbons in adult herring was rapid, but equilibriumwas not reached in 10 days of exposure.*Muscle tissue generally accumulated the highest levels ofhydrocarbons; immature ovarian tissue accumulated almost two times the levels found in mature ovarian tissue. *In adults, initial deputation was rapid but slowed after 24 hours,and 10% of the hydrocarbons were still present after 7 days ofdeputation in clean water. Hydrocarbon levels after 14 days were not significantly higher than control levels. *Uptake in larvae was more rapid than in adults and reachedequilibrium within 4 hours. Retention was less in larvae thanadults, and after 24 hours, only 2% of the 14C-labeled naphthalener emained in larval
tissues.

*Growth of larvae was significantly reduced after 7 days of exposure to 0.3 ppm, and reductions were greater after longer exposures and higher concentrations. *Growth of larvae was not significantly reduced by a diet of oil-contaminated prey. We conclude that the life stage at which the reproductive successPacific herring is most likely to be impaired by oil is feedingl arvae: Larvae are killed by shorter exposures and lower concentrationst han are the eggs or the adult reproductive products or the adultst hemselves. We conclude also that even if oil is present at levels too low to threaten the survival of herring, the fisheries could be impactedbecause the rapid bioaccumulation of oil hydrocarbons in the edible muscle and ovarian tissues could make the herring unmarketable.

RefID: 601

Author: Rice, S.D., Carls, M.G., Heintz, R.A. and Short, J.W.

Year: 2003

Title: Comment on "hydrocarbon composition and toxicity of sediments following the Exxon valdez oil spill in Prince William Sound, Alaska, USA'

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/02-631/abstract

Abstract: Refers to W0068

RefID: 602

Author: Rice, S.D., Short, J.W., Carls, M.G., Moles, A. and Spies, R.B.

Year: 2006

Title: The Exxon Valdez Oil Spill

Journal: Long-term ecological change in the northern Gulf of Alaska

Hyperlink: http://jlc-web.uaa.alaska.edu/client/arlis/search/detailnonmodal/ent:$002f$002fSD_ILS$002f1772$002fSD_ILS:1772845/ada?qu=Long-term+ecological+change+in+the+northern+Gulf+of+Alaska&te=ILS

Abstract: Book chapter; no abstract

RefID: 603

Author: Rice, S.D., Thomas, R.E., Carls, M.G., Heintz, R.A., Wertheimer, A.C., Murphy, M.L., Short, J.W. and Moles, J.

Year: 2001

Title: Impacts to Pink Salmon Following the Exxon Valdez Oil Spill: Persistence, Toxicity, Sensitivity, and Controversy

Journal: Reviews in Fisheries Science

Hyperlink:

Abstract: Injury to a species resulting from long-term exposure to low concentrations of pollutants is seldom noted or even tested. One of the products of the Exxon Valdez oil spill was the first report of damage to eggs and larvae of pink salmon (Oncorhynchus gorbuscha) following long-term exposure to low concentrations of weathered crude oil. These life stages were previously thought to be highly resistant to injury from oil. Growth rate among migrating fry was depressed, and the population was reduced via size-dependent mortality. Elevated egg mortality in oiled streams continued for at least 4 years after the spill. Laboratory tests verified that embryos are sensitive to long-term exposure to weathered oil in the low parts per billion range. These results are compared with those of studies conducted by investigators funded by Exxon Corporation and, where controversy exists, we attempt to reconcile the studies. These findings are important to the pink salmon fisheries of Prince William Sound (PWS) and are also broadly applicable to toxicity and impact from nonpoint source pollution of urban estuaries.

RefID: 604

Author: Richmond, S.A., Lindstrom, J.E. and Braddock, J.F.

Year: 2001

Title: Effects of chitin on microbial emulsification, mineralization potential, and toxicity of bunker C fuel oil

Journal: Marine Pollution Bulletin

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/11585070

Abstract: Bunker C, one of the most frequently spilled petroleum products in the US, is difficult to remove from oiled surfaces and is relatively recalcitrant to biodegradation; therefore, emulsification and biodegradability must be optimized before bioremediation can be considered a viable treatment option. Sand from a freshly oiled beach near Dutch Harbor, Alaska, was incubated at 10 degreesC with nutrients (Bushnell-Haas (BH)) or nutrients with crab shell chitin (BH-C). BH-C amendment resulted in greater numbers of bunker C emulsifiers and greater mineralization potentials for hexadecane, phenanthrene, and fluorene than with BH only. Compared to BH alone, mineralization potentials for bunker C also were higher in BH-C, with an estimated 8% of fuel oil mineralized after 6 weeks. Microbially emulsified oil was more toxic than in uninoculated controls ($p < 0.05$) as measured by Microtox assays. However, toxicity was significantly lower in BH-C than BH after 4 and 6 weeks incubation ($p < 0.05$).

RefID: 605

Author: Rico-Martínez, R., Snell, T.W. and Shearer, T.L.

Year: 2013

Title: Synergistic toxicity of Macondo crude oil and dispersant Corexit 9500A (R) to the Brachionus plicatilis species complex(Rotifera)

Journal: Environmental Pollution

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0269749112004344

Abstract: Using the marine rotifer Brachionus plicatilis acute toxicity tests, we estimated the toxicity of Corexit 9500A (R), propylene glycol, and Macondo oil. Ratios of 1:10, 1:50 and 1:130 for Corexit 9500A (R):Macondo oil mixture represent: maximum exposure concentrations, recommended ratios for deploying Corexit (1:10-1:50), 1:130 the actual dispersant:oil ratio used in the Deep Water Horizon spill. Corexit 9500A (R) and oil are similar in their toxicity. However, when Corexit 9500A (R) and oil are mixed, toxicity to B. manjavacas increases up to 52-fold. Extrapolating these results to the oil released by the Macondo well, suggests underestimation of increased toxicity from Corexit application. We found small differences in sensitivity among species of the B. plicatilis species complex, likely reflecting phylogenetic similarity. Just 2.6% of the water-accommodated fraction of oil inhibited rotifer cyst hatching by 50%, an ecologically significant result because rotifer cyst in sediments are critical resources for the recolonization of populations each Spring. (C) 2012 Elsevier Ltd. All rights reserved.

RefID: 606

Author: Roberts, A.P., Oris, J.T. and Stubblefield, W.A.

Year: 2006

Title: Gene expression in caged juvenile Coho Salmon (Oncorhynchys kisutch) exposed to the waters of Prince William Sound, Alaska

Journal: Marine Pollution Bulletin

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/16854435

Abstract: The 1989 Exxon Valdez oil spill (EVOS) resulted in the release of 258,000 barrels of crude oil into the waters of Prince William Sound (PWS), Alaska. The current study, conducted in 2004, sought to use juvenile Coho salmon (Oncorhynchus kisutch) caged in situ to determine whether biomarker induction differed at sites where the adjacent shoreline contained buried residues from the 1989 oil spill compared to sites that were never oiled. Juvenile Coho salmon were caged at five sites; three oiled during the 1989 EVOS and two that were not oiled. Tissue samples were collected from organisms caged at each site as well as a control group housed onboard the research vessel. Analysis of CYP1A, superoxide dismutase (SOD), and glutathione peroxidase (GPO) gene expression was conducted using real time reverse transcriptase polymerase chain reaction (rtRT-PCR). Statistically significant levels of CYP1A expression were observed at some sites indicating increased hydrocarbon exposure. No patterns were observed regarding sites that were originally oiled or not oiled by the 1989 EVOS, indicating that sources of PAHs other than EVOS oil occur in PWS. (c) 2006 Elsevier Ltd. All rights reserved.

RefID: 607

Author: Roberts, P.O., Henry, C.B. Jr, Shigenaka, G. and Fukuyama, A.

Year: 1999

Title: Weathered Petroleum “Bioavailability” to Intertidal Bivalve Species After the T/V Exxon Valdez Incident

Journal: International Oil Spill Conference Proceedings

Hyperlink:

Abstract: Sediment and bivalve samples were collected annually to assess residual oil concentration, degradation and persistence after the T/V Exxon Valdez incident through NOAA's Prince William Sound Shoreline Monitoring Program. Detailed gas chromatography/mass spectroscopy (GC/MS) analyses of samples from various sites still contain residual oil. The residual oil from the 1989 spill shows a similar though altered aromatic hydrocarbon (AH) profile in the bivalve body burden. The residual oil profile of bivalves and sediments contain components not highly water soluble, therefore mechanisms other than dissolution are the primary mode of petroleum transport. The presence of altered whole oil within the mussel and clam tissues provides inferences into the oil transport and exposure mechanisms.

RefID: 608

Author: Rodrigues, R.V., Miranda-Filho, K.C., Gusmão, E.P., Moreira, C.B., Romano, L.A. and Sampaio, L.A.

Year: 2010

Title: Deleterious effects of water-soluble fraction of petroleum, diesel and gasoline on marine pejerrey Odontesthes argentinensis larvae

Journal: Science of the Total Environment

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0048969710000884

Abstract: Accidental discharges and oil spills are frequent around the world. Petroleum-derived hydrocarbons are considered one of the main pollutants of aquatic ecosystem. The importance of petroleum and refined fuels is notorious because today's society depends on them. Researches related to the toxic water-soluble fraction (WSF) of petroleum and derivatives to aquatic biota are scarce. For this reason, deleterious effects of WSF of Brazilian petroleum, automotive diesel and unleaded gasoline to marine pejerrey Odontesthes argentinensis larvae were studied employing toxicity tests and histopathological examination. Each WSF was generated in a laboratory by mixing four parts of seawater with one part of pollutant by approximately 22 h. Larvae were exposed during 96 h to different concentrations of WSF of petroleum, diesel, and gasoline, plus a control. After 96 h of exposure to the different WSFs, three larvae were sampled for histopathological studies. The median lethal concentration after 96 h (LC50) of exposure for WSF of petroleum was equal to 70.68%, it was significantly higher (P<0.05) than the values for WSF of diesel and gasoline, which were 13.46% and 5.48%, respectively. The histological examination of pejerrey larvae exposed to WSF of petroleum, diesel and gasoline after 96 h revealed a variety of lesions in the larvae. The gills, pseudobranchs and esophagus presented epithelial hyperplasia, and the liver presented dilatation of hepatic sinusoids, hepatocitomegaly, bi-nucleated and nuclear degeneration of hepatocytes, such as pyknotic nuclei. The acute toxicity of diesel and gasoline is at least fivefold higher than Brazilian petroleum. However, all toxicants induced histopathological abnormalities in pejerrey larvae. The results are of importance since much attention has been paid to large visible surfaces of petroleum spills instead of potential toxic effects of dissolved aromatic hydrocarbons, which are more available to marine biota. (C) 2010 Elsevier B.V. All rights reserved.

RefID: 609

Author: Rogowska, J., Wolska, L. and Namieśnik, J.

Year: 2010

Title: Impacts of pollution derived from ship wrecks on the marine environment on the basis of s/s "Stuttgart" (Polish coast, Europe)

Journal: Science of the Total Environment

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0048969710007254

Abstract: In 1943 the German hospital ship s/s Stuttgart (Lazaretschiff "C") was sunk close to the port of Gdynia (Gulf of Gdansk Polish coast) This and other actions (undertaken after the war to remove the wreck) led to pollution of the sea bottom with oil derivatives. During our studies (2009) 11 surface sediment and water samples were collected as well as sediment core samples at 4 locations in order to determine the concentration levels of priority pollutants belonging to polycyclic aromatic hydrocarbons (PAH) and polychlorinated biphenyls (PCB) The concentrations of 16 PAI-1 and 7 PCB were analysed with GC-MS Sigma PAH varied between 11.54 +/- 0.39 and 206 7 +/- 6.5 mg/kg dry weight in the surface sediments, and from 0 686 +/- 0.026 to 1291 +/- 53 mg/kg dry weight in the core samples Contamination in the core samples collected may reach a depth of at least 230-240 cm (deepest sample studied). The PAH-group profiles in all surface sediment samples suggest a pyrolytic source of PAH, while the results obtained for core samples indicate a mixed pattern of pyrolytic and petrogenic inputs of PAH. Results obtained may suggest also that fuel residues being present at sea bottom is not crude oil derived but results from coal processing (synthetic fuel) The sum of PCB in surface sediments ranged from 0 761 +/- 0 068 to 682 +/- 028 mu g/kg dry weight (except for sampling point W2, where Sigma PCB was 108 +/- 8 44 mu g/kg dry weight) The strong correlation between PAH and PCB levels, and the fact that PCB are present only in the surface sediments. suggest that the compounds in these sediments got there as a result of emission from urban areas, entering the aquatic environment via atmospheric deposition PCB levels in the sediment core samples were generally very low and in most cases did not exceed the method quantification limit (C) 2010 Elsevier BV All rights reserved.

RefID: 610

Author: Romero-Lopez, J., Lopez-Rodas, V. and Costas, E.

Year: 2012

Title: Estimating the capability of microalgae to physiological acclimatization and genetic adaptation to petroleum and diesel oil contamination

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X12002287

Abstract: There is increasing scientific interest in how phytoplankton reacts to petroleum contamination, since crude oil and its derivatives are generating extensive contamination of aquatic environments. However, toxic effects of short-term petroleum exposure are more widely known than the adaptation of phytoplankton to long-term petroleum exposure. An analysis of short-term and long-term effects of petroleum exposure was done using experimental populations of freshwater (Scenedesmus intermedius and Microcystis aeruginosa) and marine (Dunaliella tertiolecta) microalgae isolated from pristine sites without crude oil product contamination. These strains were exposed to increased levels of petroleum and diesel oil. Short-term exposure to petroleum or diesel oil revealed a rapid inhibition of photosynthetic performance and cell proliferation in freshwater and marine phytoplankton species. A broad degree of inter-specific variation in lethal contamination level was observed. When different strains were exposed to petroleum or diesel oil over the long-term, the cultures showed massive destruction of the sensitive cells. Nonetheless, after further incubation, some cultures were able to grow again due to cells that were resistant to the toxins. By means of a fluctuation analysis, discrimination between cells that had become resistant due to physiological acclimatization and resistant cells arising from rare spontaneous mutations was accomplished. In addition, an analysis was done as to the maximum capacity of adaptation to a gradual contamination process. An experimental ratchet protocol was used, which maintains a strong selection pressure in a temporal scale up to several months over very large experimental populations of microalgae. Microalgae are able to survive to petroleum contamination as a result of physiological acclimatization without genetic changes. However, when petroleum concentration exceeds the physiological limits, survival depends exclusively on the occurrence on mutations that confer resistance and subsequent selection of these mutants. Finally, it is certain that further mutations and selection will ultimately determine adaptation of microalgae to the environmental forcing. (C) 2012 Elsevier B.V. All rights reserved.

RefID: 611

Author: Roth, K., Whitmore, C. and Hansen, P.

Year: 1990

Title: Prince William Sound and Gulf of Alaska sport fishery harvest and effort, 1989, Exxon Valdez Oil Spill State/Federal Natural Resource Damage Assessment Report (Fish/Shellfish Study Number 6)

Journal: EVOS Trustee Council

Hyperlink: http://jlc-web.uaa.alaska.edu/client/arlis/search/detailnonmodal/ent:$002f$002fSD_ILS$002f281$002fSD_ILS:281542/ada?qu=TITLE%3D%22Prince+William+Sound+and+Gulf+of+Alaska+sport+fishery+harvest+and+effort%22&qu=AUTHOR%3DRoth

Abstract: The sport fisheries of Prince William Sound (PWS), Resurrection Bay, lower Kenai Peninsula, and Kodiak were studied in 1989 as part of a plan to assess potential injury due to the Exxon Valdez oil spill. These potential impacts were measured by examination of the sport harvest for oil contamination and estimation ofselected fishery parameters. In addition, this project provided the means by which information vital to other NRDA programs could be collected. No visibly discernable contamination was observed on any of the 12,597 salmon, halibut, and rockfish inspected at Valdez, Cordova, Kodiak, Seward, Whittier, and Homer. Demersal rockfish comprised up to 100% ofthe sport harvest ofrockfish in the sampled ports. Mortality and subsequent hydrocarbon contamination of demersal rockfish were documented in Fish/Shellfish Study Number 17 (Injury to Rockfish in Prince William Sound). An unprecedented decline in sport fishing effort during 1989 was documented for Seward, a major marine sport fishing port and base of a large charter fleet. Sport fishing effort was significantly (a = 0.05) lower than any recorded level of fishing effort dating back to 1968. Also, seven of eight Anchorage air charter operators reported reduced charter flights to PWS during 1989 compared to 1988.

RefID: 612

Author: Rotterman, L.M. and Monnett, C.

Year: 1995

Title: Mortality of sea otter weanlings in eastern and western Prince William Sound, Alaska, during the winter of 1990-91

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33944237.pdf

Abstract: Sixty-four dependent sea otters [Eastern prince William Sound (EPWS): n = 24; Western Prince William Sound (WPWS), the oil spill area: n = 401 were captured, examined, instrumented with radio-transmitters, and monitored in Prince William Sound between September 1990 and July 15, 1991. This study was one of several interrelated studies aimed at assessing the impact of the T/V Exxon Valdez oil spill on sea otters in Prince William Sound, Alaska. Peak periods for birth, weaning, and mortality of young of the year may occur a month or more later in the oil spill area than in the eastern portion of Prince William Sound. While the absolute timing of instrumentation was similar for pups in EPWS and the oil spill area, pups in the oil spill area weighed significantly less at the time of capture than their counterparts in EPWS. Most pups in EPWS became independent of their mothers in October, whereas mother-pup separation typically occurred in November and December in the oil spill area. Most mortality in EPWS occurred during November and December of 1990, whereas most mortality in the oil spill area occurred during January 1991. Survival rates of weanlings over their first winter (analyses consider data until May 1, 1991) were significantly higher in EPWS (the control) than in the oil spill region. This result was the same regardless of whether missing animals were assumed to be dead @ = 4.64, 1 D.F., p < 0.05) or were eliminated from the analyses @ = 4.70, 1 D.F., p < 0 05).

RefID: 613

Author: Rotterman, L.M. and Monnett, C.

Year: 2002

Title: Length-mass and total body length of adult female sea otters in Prince William Sound before and after the Exxon Valdez oil spill

Journal: Marine Mammal Science

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1111/j.1748-7692.2002.tb01086.x/abstract

Abstract: After the 1989 T/V Exxon Valdez oil spill (EVOS), the body condition of non-pregnant female sea otters (Enhydra lutris) ages 4 yr and older in the EVOS-affected region of western Prince William Sound, Alaska (WPWS), was significantly poorer than that of individuals captured in the same or adjacent habitat in WPWS approximately a decade earlier, and than that of individuals inhabiting unoiled habitat in eastern PWS (EPWS) between 1984 and 1990. However, the body condition of females of this age category captured in WPWS prior to EVOS was not significantly different from that of pre- and postspill EPWS females. The mean total body length (TBL) of non-pregnant females captured prespill in WPWS was significantly less than that of pre- and postspill EPWS and postspill WPWS females. Evidence from this and other studies suggests that the body condition of at least some classes of sea otters was negatively affected by one or more EVOS-related factors.

RefID: 614

Author: Roubal, W.T., Stranahan, S.I. and Malins, D.C.

Year: 1978

Title: ACCUMULATION OF LOW-MOLECULAR WEIGHT AROMATIC-HYDROCARBONS OF CRUDE-OIL BY COHO SALMON (ONCORHYNCHUS-KISUTCH) AND STARRY FLOUNDER (PLATICHTHYS-STELLATUS)

Journal: Archives of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2FBF02332052

Abstract: Coho salmon (Oncorhynchus kisutch) and starry flounder (Platichthysstellatus) were exposed to 0.9 _+ 0.1 ppm of a water-soluble fraction (WSF) of Prudhoe Bay crude oil in flowing sea water. Both species accumulateda complex spectrum of low molecular weight aromatic hydrocarbons.Bioconcentration factors (ppm hydrocarbon based on dry weight of tissue/ ppm hydrocarbon in flow-through water) for most hydrocarbons in starry flounder muscle were substantially higher than for coho salmon muscle. Aftertwo weeks of exposure, for example, there were 17 ppm (dry weight of tissue)of C,- and Cs-substituted benzenes in muscle of starry flounder (bioconcentrationf actor of 1,700) but only 1.5 ppm of these compounds occurred inmuscle of coho salmon (bioconcentration factor of 150). Generally, alkylated aromatic hydrocarbons accumulated in tissues to a greater degree than unsubstituted derivatives. In both species, accumulations of substituted benzenesand naphthalenes in muscle increased in relation to the degree ofalkylation. Complex mixtures of aromatic hydrocarbons were found in gillsand liver of starry flounder. Accumulated hydrocarbons in coho salmonexposed for six weeks fell below limits of detection within a week when fish were transferred to clean water. Starry flounder exposed for two weeksr etained substantial concentrations (7 to 26 ppm) of C2-C3-substituted naphthaleneand C4-Cs-substituted benzenes in muscle two weeks after the terminationof exposure. Substantial variations were found in bioconcentrationf actors for individual hydrocarbons in both species. Thus the data reflectdifficulties in relating specific sources of petroleum pollution to hydrocarbonprofiles in tissues.

RefID: 615

Author: Rougée, L., Downs, C.A., Richmond,R.H. and Ostrander, G.K.

Year: 2006

Title: Alteration of normal cellular profiles in the scleractinian coral (Pocillopora damicornis) following laboratory exposure to fuel oil

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/05-510R2.1/abstract

Abstract: Petroleum contamination from oil spills is a continuing threat to our ocean's fragile ecosystems. Herein, we explored the effects of the water-soluble fraction of crude oil on a stony coral, Pocillopora damicornis (Linneaeus 1758). We developed methods for exposing corals to various concentrations of crude oil and for assessing the potential molecular responses of the corals. Corals were exposed to water-accommodated fraction solutions, and appropriate cellular biomarkers were quantified. When compared to the "healthy" control specimens, exposed corals exhibited shifts in biomarker concentrations that were indicative of a shift from homeostasis. Significant changes were seen in cytochrome P450 1-class, cytochrome P450 2-class, glutathione-S-transferase-pi, and cnidarian multixenobiotic resistance protein-1 biomarkers, which are involved the cellular response to, and manipulation and excretion of, toxic compounds, including polycyclic aromatic hydrocarbons. A shift in biomarkers necessary for porphyrin production (e.g., protoporphyrinogen oxidase IX and ferrochelatase) and porphyrin destruction (e.g., heme oxygenase-1 and invertebrate neuroglobin homologue) illustrates only one of the cellular protective mechanisms. The response to oxidative stress was evaluated through measurements of copper/zinc superoxide dismutase-1 and DNA glycosylase MutY homologue-1 concentrations. Likewise, changes in heat shock protein 70 and small heat shock proteins indicated an adjustment in the cellular production of proteins. Finally, the results of this laboratory study were nearly identical to what we observed previously among corals of a different species, Porites lobata, exposed to an oil spill in the field after the grounding of the Merchant Vessel Kyowa Violet.

RefID: 616

Author: Roy, N.K., Stabile, J., Seeb, J.E., Habicht, C. and Wirgin, I.

Year: 1999

Title: High frequency of K-ras mutations in pink salmon embryos experimentally exposed to Exxon Valdez oil

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620180726/abstract

Abstract: Previous studies demonstrated reduced survivorship of pink salmon embryos from populations in Prince William Sound, Alaska, USA, that were exposed to Exxon Valdez-released oil compared with populations from matched nonoiled streams. Survivorship was also significantly decreased in embyros from lineages that were oiled in Prince William Sound and reared in clean water under controlled hatchery conditions compared with the descendants of nonoiled lineages. This suggests that the effect of oiling on pink salmon populations was persistent and could be transmitted intergenerationally. However, the ability of environmentally released oil to cause DNA sequence alterations in natural populations has vet to be demonstrated. We used polymerase chain reaction analysis to screen for alterations in the K-ras oncogene in DNA from pink salmon embryos that were exposed under controlled laboratory conditions to weathered Prudhoe Bay crude oil. Polymerase chain reaction and direct DNA sequence analyses were used to identify mutational hotspots within exons 1 and 2 of K-ras. and 3' primer mismatch analysis was used to determine the frequency of mutations in the 30 offspring of two families of pink salmon that were experimentally exposed to oiled or clean gravel. Mutations were only observed at codons 12, 13, and 61 of K-ras, sites that are frequently mutated in animal and human tumors. All mutations resulted in deduced amino acid substitutions. As expected, in all individuals exhibiting mutations, the copy number of the normal allele exceeded that of the mutated allele. The frequencies of mutations in oiled embryos at K-ras exons 1 and 2 were 68 and 41%, respectively. K-ras mutations were not observed in siblings that were exposed to clean gravel or in the parents of the two experimental matings. These results indicate that exposure of pink salmon embryos to weathered Prudhoe Bay crude oil under controlled laboratory conditions can elicit somatic cell mutations in high frequency at mutational hotspots in genes such as K-ras. However the frequency of these events in oiled natural populations of pink salmon and other vulnerable species in Prince William Sound and the heritability of these mutations within oiled lineages have yet to beevaluated.

RefID: 617

Author: Ruggerone, G.T. and Rogers, D.E.

Year: 1998

Title: Historical analysis of sockeye salmon growth among populations affected by the Exxon Valdez oil spill and large spawning escapements

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/42244045.pdf

Abstract: Adult sockeye salmon scales, which provide an index of annual salmon growth in fresh and marine waters during 1965-1997, were measured to examine the effects on growth and adult returns of large spawning escapements influenced by the Exxon Valdez oil spill. Scale growth in freshwater was significantly reduced by the large 1989 spawning escapements in the Kenai River system, Red Lake, and Akalura Lake, but not in Chignik Lake. In the Kenai River system, juvenile sockeye growth recovered to historical levels during the second year of low escapement after the spill, but growth significantly declined following the moderately-high escapement in 1992. Growth of Akalura sockeye reached average levels four years after the oil spill; growth of yearling salmon co-inhabiting the lake with the 1989 fry also was reduced. Red Lake sockeye growth recovered to historical levels three years after the spill, then growth declined following a moderate escapement in 1992. These data suggest that sockeye growth in freshwater may be less stable following the large escapement. Furthermore, the observations of large escapement adversely affecting growth of adjacent brood years of salmon has important implications for stock-recruitment modeling. In Prince William Sound, Coghill Lake sockeye salmon that migrated through oil-contaminated waters did not exhibit noticeably reduced marine growth, but a model was developed that might explain low adult returns in recent years

RefID: 618

Author: Ruggerone, G.T. and Rogers, D.E.

Year: 2003

Title: Multi-year effects of high densities of sockeye salmon spawners on juvenile salmon growth and survival: a case study from the Exxon Valdez oil spill

Journal: Fisheries Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0165783603000997

Abstract: Reduced fishing after the 1989 Exxon Valdez oil spill in Prince William Sound, Alaska, contributed to exceptionally large numbers of sockeye salmon spawners up to 860 km from the spill site. We measured annual scale growth of adult sockeye salmon from four affected populations, 1970-1997, in order to test the hypothesis that large spawner densities can have multi-year effects on juvenile size and subsequent adult abundances as a result of intraspecific competition among juveniles in the nursery lake. Sockeye salmon scale growth in fresh water was significantly reduced by the large 1989 spawner densities in the Kenai River system, Red Lake, Akalura Lake, but not Chignik Lake. Scale growth in the three affected systems recovered to previous levels 2-4 years after the oil spill, but subsequent moderately high spawner densities led to exceptionally low growth. Juvenile salmon growth was negatively related to parent spawners, spawners from the next brood year (second season in lake), and spawners from the previous brood year. Multi-variate time series analyses indicated adult sockeye salmon abundance increased with greater numbers of parent spawners, but decreased as a result of either large numbers of spawners in the previous year or small juvenile salmon size. These results indicate sockeye salmon spawners can affect juvenile growth and adult production of adjacent year classes. Implications for stock-recruitment modeling and spawner density management are discussed. (C) 2003 Elsevier Science B.V. All rights reserved.

RefID: 619

Author: Ruiz, P., Ortiz-Zarragoitia, M., Orbea, A., Theron, M., Le Floch, S. and Cajaraville, M.P.

Year: 2012

Title: Responses of conventional and molecular biomarkers in turbot Scophthalmus maximus exposed to heavy fuel oil no. 6 and styrene

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X12000549

Abstract: Several accidental spills in European coastal areas have resulted in the release of different toxic compounds into the marine environment, such as heavy fuel oil type no. 6 in the "Erika" and "Prestige" oil spills and the highly toxic styrene after the loss of the "Ievoli Sun". There is a clear need to develop tools that might allow assessing the biological impact of these accidental spills on aquatic organisms. The aim of the present study was to determine the short-term effects and recovery after exposure of juvenile fish (Scophthalmus maximus) to heavy fuel oil no. 6 and styrene by using a battery of molecular, cell and tissue level biomarkers. Turbots were exposed to styrene for 7 days and to the diluted soluble fraction of the oil (10%) for 14 days, and then allowed to recover in clean seawater for the same time periods. cyp1a1 transcript was overexpressed in turbots after 3 and 14 days of exposure to heavy fuel oil, whereas ahr transcription was not modulated after heavy fuel oil and styrene exposure. ppar alpha transcription level was significantly up-regulated after 3 days of treatment with styrene. Liver activity of peroxisomal acyl-CoA oxidase (AOX) was significantly induced after 14 days of oil exposure, but it was not affected by styrene. Hepatocyte lysosomal membrane stability (LMS) was significantly reduced after exposure to both treatments, indicating that the tested compounds significantly impaired fish health. Both AOX and LMS values returned to control levels after the recovery period. No differences in gamete development were observed between fuel- or styrene- exposed fish and control fish, and vitellogenin plasma levels were low, suggesting no xenoestrogenic effects of fuel oil or styrene. While styrene did not cause any increase in the prevalence of liver histopathological alterations, prevalence of extensive cell vacuolization increased after exposure to heavy fuel oil for 14 days. In conclusion, the suite of selected biomarkers proved to be useful to determine the early impact of and recovery from exposure to tested compounds in turbot. (C) 2012 Published by Elsevier B.V.

RefID: 620

Author: Ryder, K., Temara, A. and Holdway, D.A.

Year: 2004

Title: Avoidance of crude-oil contaminated sediment by the Australian seastar, Patiriella exigua (Echinodermata : Asteroidea)

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X04002346

Abstract: This study attempted to determine whether Patiriella exigua, an Australian seastar, could detect and/or avoid oiled sediment when given an equal choice of unoiled sediment. The sediment was spiked once to produce one of three concentrations of oiled sediment used in the test chambers versus unoiled sediment. Behavioral observations were repeated over a 32 day period to test the effects of aging the oiled sediment. Results show that Patiriella exigua was capable of detecting oiled sediment and/or an oiled environment. Seastars avoided oiled sediment, with significantly higher numbers choosing either to reside on the clean sediment ($p < 0.05$) or to travel up the glass sides of the tanks ($p < 0.001$). Avoidance of oiled sediment increased with increasing sediment oil concentrations. Aging the oiled sediment decreased the oil content of the sediment and increased the number of seastars able to inhabit it ($p < 0.001$). A potential narcotic effect of exposure to oiled sediment was observed. (C) 2004 Elsevier Ltd. All rights reserved.

RefID: 621

Author: Saco-Álvarez, L., Bellas, J., Nieto, Ó., Bayona, J.M., Albaigés, J. and Beiras, R.

Year: 2008

Title: Toxicity and phototoxicity of water-accommodated fraction obtained from Prestige fuel oil and marine fuel oil evaluated by marine bioassays

Journal: Science of the Total Environment

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0048969708000958

Abstract: Acute toxicity and phototoxicity of heavy fuel oil extracted directly from the sunken tanker Prestige in comparison to a standard Marine fuel oil were evaluated by obtaining the water-accommodated fraction (WAF) and using mussel Mytilus galloprovincialis and sea urchin Paracentrotus lividus embryogenesis bioassays, and copepod Acartia tonsa and fish Cyprinodon variegatus survival bioassays. Aromatic hydrocarbon (AH) levels in WAF were measured by gas chromatography. Prestige WAF was not phototoxic, its median effective concentrations (EC) w 13% d 10% WAF for mussel and sea urchin respectively, and maximum lethal threshold concentrations (MLTC) were 12% and 50% for copepod and fish respectively. Marine WAF resulted phototoxic for mussel bioassay. EC(50)s of Marine WAF were 50% for sea urchin in both treatments and 20% for mussel under illumination. Undiluted Marine WAF only caused a 20% decrease in mussel normal larvae. Similar sensitivities were found among sea urchins, mussels and copepods, whilst fish were less sensitive. Unlike Marine WAF, Prestige WAF showed EC50 values at dilutions below 20%, and its toxicity was independent of lighting conditions. The differences in toxicity between both kinds of fuel could not be explained on the basis of total AH content. (c) 2008 Elsevier B.V. All rights reserved.

RefID: 622

Author: Saeed, T., Al-mutairi, M., Ali, L.N., Al-obaid, T. and Beg, M.U.

Year: 1998

Title: The effect of temperature on the composition and relative toxicity of the water-soluble fraction of Kuwait crude oil (export) in the seawater

Journal: International Journal of Environmental Analytical Chemistry

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/03067319808035899

Abstract: The effect of temperature on the composition of the water-soluble fraction (WSF) of Kuwait crude oil was investigated. The results showed that the WSF consisted of mostly monoaromatic (BTEX) compounds. The total concentration of volatiles in the WSF was about 7.5 mg/l. The increase in the temperature from 15 degrees C to 25 degrees C caused an increase of about 10% and to 35 degrees C did not significantly affect the total concentration. GC-MS analysis of the concentrated extract of the WSF resulted in the identification of nine PAHs and six methylated PAHs. The total concentration of the PAHs ranged from 0.217 mg/l to 0.634 mg/l. The PAHs increased significantly with increasing temperature. Naphthalene and methylated naphthalenes constituted about 95% of the total PAHs. Microtox assay of the WSF showed that the relative toxicity increased when the temperature was increased from 15 degrees to 25 degrees C. Increasing temperature further to 35 degrees C did not effect the relative toxicity.

RefID: 623

Author: Salaberria, I., Brakstad, O.G., Olsen, A.J., Nordtug, T. and Hansen, B.H.

Year: 2014

Title: Endocrine and AhR-CYP1A Pathway Responses to the Water-Soluble Fraction of Oil in Zebrafish (Danio rerio Hamilton)

Journal: Journal of Toxicology and Environmental Health

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/15287394.2014.886983

Abstract: Crude oil is a complex mixture of compounds of which the water-soluble fraction (WSF) is considered to be bioavailable and potentially toxic to aquatic biota. Containing numerous compounds, WSF becomes a source of multiple chemical stressors to wildlife when introduced into the environment. To study the combined effects of WSF components on aquatic biota, the model species zebrafish (Danio rerio Hamilton) was exposed for 24 or 72 h to 10 or 50% WSF solution of known composition, generated from artificially weathered North Sea crude oil. Hepatic expression of genes involved in the aryl hydrocarbon receptor-cytochrome P-450 1A (AhR-CYP1A) pathway (AhR2, AhRR1, CYP1A1) and steroidogenesis (StAR, CYP11A, 3 beta-HSD, CYP19A, CYP19B) was measured, as well as estrogen receptors ER alpha and ER beta 1. Induction of CYP1A and particularly of AhRR1 was observed while ER alpha and steroidogenic enzymes CYP11A and 3 beta-HSD were downregulated. Regression analysis demonstrated a negative relationship between AhR-CYP1A pathway and endocrine transcript levels, although causality remains to be established. These findings indicate that exposure to WSF of oil disrupts steroidogenesis and may therefore constitute a potential risk for reproductive ability of aquatic organisms. In addition, it is proposed that hepatic gene expression of AhRR1 may serve as a novel biomarker of WSF exposure.

RefID: 624

Author: Salamanca, M.J., Jiménez-Tenorio, N., González de Canales, M.L. and Del Valls, T.A.

Year: 2008

Title: Evaluation of the toxicity of an oil spill conducted through bioassays using the fish Solea senegalensis

Journal: Ciencias Marinas

Hyperlink: http://digital.csic.es/handle/10261/48141

Abstract: The toxicity produced by fuel pollutants was evaluated through bioassays using the Senegalese sole Solea senegalensis. Juveniles were exposed for 21 days to different dilutions obtained by mixing fuel extracted from the Prestige oil tanker and sediment from a clean area of Cadiz Bay. After the exposure period, three biomarkers were analyzed (7-ethoxyresorufin-O-deethylase [EROD], glutathione S-transferase [GST], and glutathione reductase [GR] enzymatic activity), as well as the histopathology of two of the main target organs (gills and liver). Significant ($P < 0.05$) biomarker inductions were observed in the exposed fish analyzed on day 21 relative to the control group (day zero). Lesions were detected in both organs studied, but the liver was the most affected. The frequency of appearance of the lesions was greater in the samples containing higher concentrations of polycyclic aromatic hydrocarbons (PAHs) and metals. The results showed significant correlations between the total PAH concentrations and GST, GR, and EROD enzymatic activity, with correlation coefficients of $R = 0.96$ for GST, $R = 0.82$ for GR, and $R = 0.60$ for EROD.

RefID: 625

Author: Salazar, S.

Year: 2003

Title: Impacts of the Jessica oil spill on sea lion (Zalophus wollebaeki) populations

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X03001607

Abstract: Following the Jessica oil spill, a total of 79 oiled Galápagos sea lions (Zalophus wollebaeki) were recorded around the islands of San Cristóbal, Santa Fé, Isabela and Floreana. Almost half of these animals required washing and other treatment. One sea lion death and a high incidence of conjunctivitis and burns were detected during the period of the oil spill. Sea lion populations exhibited a tendency for decline in the first months following the spill at all three colonies monitored close to the grounding site on San Cristóbal. By comparison, declines of similar magnitude occurred at only one of six sea lion colonies monitored on islands more distant from the spill. However, no significant decreases in population numbers were detected for any colony in the year following the spill. Galápagos sea lion populations were partially recovering from the much more catastrophic impact of the 1997/98 El Niño.

RefID: 626

Author: Sale, D.M., Gibeaut, J.C. and Short, J.W.

Year: 1995

Title: Nearshore transport of hydrocarbons and sediments following the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33964084.pdf

Abstract: Following the Exxon Valdez oil spill, sediment traps were deployed in nearshore subtidal areas of Prince William Sound, Alaska (PWS) to monitor particulate chemistry and mineralogy. Complemented by benthic sediment chemistry and core sample stratigraphy at the study sites, results were compared to historical trends and data from other Exxon Valdez studies. These results clearly indicate the transport of oil-laden sediments from oiled shorelines to adjacent subtidal sediments. The composition of hydrocarbons adsorbed to settling particulates at sites adjacent to oiled shorelines matched the PAH pattern of weathered Exxon Valdez crude oil. The highest total PAH concentrations were found near more heavily oiled shorelines and exhibited a declining trend over time. Oil-laden sediments were only slightly incorporated into nearshore benthic sediments, except where uneven bathymetry impedes the transport of sediments from nearshore depositional areas. Hydrocarbon patterns and clay mineralogy show that hydrocarbon contributions from PAH-laden sediments carried into PWS through Hinchinbrook Entrance infrequently exceeded 400 ng/g in the shallow subtidal (< 20 m depth) at sites within or near the path of the spill.

RefID: 627

Author: Samiullah, Y.

Year: 1985

Title: Biological effects of marine oil pollution

Journal: Oil and Petrochemical Pollution

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0143712785902339

Abstract: Approximately 3.5 million tonnes of petroleum hydrocarbons enter the marine environment annually, either directly or indirectly from anthropogenic and natural, terrestrial, atmospheric and marine sources. This paper reviews available evidence on the biological consequences of such discharges and concludes that while effects are apparently not significant on a global scale, local catastrophes are a continuing reality. In areas affected by oil slicks, local populations of invertebrates, birds and mammals may be greatly reduced and badly oiled vegetation may die. Particularly around the coast of the British Isles, whole populations of diving and gregarious birds are at risk. Generally, worst-affected organisms are those which inhabit shallow water and the littoral zone and those, such as marine mammals, which are obliged to cross the air-sea interface. Special reference is made to vulnerable polar, salt-marsh, coral reef and mangrove habitats where biological effects of oil pollution may persist for decades. Effects on humans discussed range from dietary taste-tainting to theonomic costs of impaired recreational amenities. Possible risks from ingesting carcinogens in seafoods are outlined and a new research initiative in this area is recommended.

RefID: 628

Author: Sanders, S.M.

Year: 2005

Title: Immunotoxicology of Pacific herring: Determination of reference ranges and their application to assessing exposure to the water-soluble fraction of crude oil

Journal: Aquatic Toxicology

Hyperlink: http://summit.sfu.ca/item/10137

Abstract: Declines in Pacific herring returning to spawn in Prince William Sound four years after the 1989 Exxon Valdez oil spill, and isolation of pathogens, raised concern that crude oil exposure might alter immunocompetence and increase disease susceptibility. While adverse effects of sublethal crude oil exposure on eggs, embryos and larvae of Pacific herring and median lethal concentrations for juveniles and adults were known, little information existed on immunological consequences of sublethal exposure in juvenile and adult herring. Therefore, a suite of assays from the 3-tiered immunotoxicological approach examined if sublethal water soluble fraction of oil (WSFO) exposure of juvenile and adult herring affects their hematology, plasma biochemistry and immunological status. Wide intraspecific variance of several variables was identified in control fish, which was largely attributable to age, size, and holding time prior to experiments, as well as duration of experiments. Additionally, skin lesions were associated with elevation of plasma lysozyme and hematocrit in juveniles, while hematocrit, leucocrit, spleen-somatic index (SSI) and plasma cortisol varied with gender in adults. A significant captivity effect was observed in control and WSF fish alike. In a series of experiments using a pulse 16 to 28 day exposure to WSFO (26 to 321 ppb total polyaromatic hydrocarbons range), few statistically significant ($p<0.05$) changes occurred consistently in Tier 1 and 2 variables in either age class. Comparison with the 95'h percentile estimation and inter-quartile reference ranges (derived from baseline and control herring) and the literature aided interpretation of statistical changes. Only plasma lysozyme, lactate and phagocytosis varied in association with WSFO exposure in both age classes, but changes were not concentration-related. Despite transitory changes in plasma biochemistry, lysozyme and phagocytosis, no single variable was a consistent predictor of WSFO exposure. Viral Hemorrhagic Septicemia Virus (VHSV) challenges, in conjunction with WSFO exposures, could not induce clinical disease. Mortality was not altered in adults and overall they were resilient to WSFO exposure, under the experimental conditions described. Juveniles exposed to WSFO and VHSV showed increased cumulative mortality. It is recommended that age, size and captivity time be considered important modifying factors in future studies of this nature.

RefID: 629

Author: Sargian, P., Mas., S., Pelletier, É. and Demers, S.

Year: 2007

Title: Multiple stressors on an Antarctic microplankton assemblage: water soluble crude oil and enhanced UVBR level at Ushuaia (Argentina)

Journal: Polar Biology

Hyperlink: http://web.a.ebscohost.com/ehost/detail/detail?sid=8f818ed1-194a-41e0-9f5a-82db700c17b7%40sessionmgr4003&vid=0&hid=4207&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3d%3d

Abstract: Changes in phytoplankton pigment content, in vivo fluorescence as well as in abundance and cell characteristics of phyto- and bacterioplankton were investigated on a field-collected microplankton assemblage from Ushuaia Bay (Southern Argentina). Effects of different experimental treatments were examined: natural and enhanced ultraviolet-B radiation (UVBR: 280-320 nm) exposures, and water soluble fraction (WSF) of crude oil contamination under both UVBR exposures. After a 5-day exposure to experimental treatments in microcosms, significant UVBR-induced deleterious effects were observed with afternoon depression of the photochemical yield followed by night-time recovery. A significant increase in photoprotective pigments (PPCs) was also observed. Due to their smaller size, picophytoplankton cells appeared to be more impacted than nanophytoplankton cells as revealed by their increasing mean cell size and decreasing growth rate implying a perturbation of the cell cycle. On the other hand, the differential response between the two bacterial sub-populations identified (i.e., as sub-populations 1 and 2 according to their cellular characteristics) suggests a higher vulnerability for only one of these sub-populations to UVBR stress. WSF alone was also shown to induce deleterious effects on phytoplankton assemblage. Nevertheless, bacteria were positively affected, and particularly bacterial sub-population 2. The combination of WSF and enhanced UVBR exposure resulted in an exacerbation of these individual effects, demonstrating a synergistic effect of both stresses. Moreover, Cryptomonas sp. were observed to develop only under dual stresses in response to their capacity to switch between phototrophic and mixotrophic states following stressed conditions. In situ studies with natural communities provided a unique tool for determining the short-term biological response of microplankton assemblages exposed to multiple stressors.

RefID: 630

Author: Scarlett, A., Galloway, T.S. and Rowland, S.J.

Year: 2007

Title: Chronic toxicity of unresolved complex mixtures (UCM) of hydrocarbons in marine sediments

Journal: Journal of Soils and Sediments

Hyperlink: http://link.springer.com/article/10.1065%2Fjss2007.06.232

Abstract: Background, Aim and Scope. Unresolved complex mixtures (UCM) of hydrocarbons, containing many thousands of compounds which cannot be resolved by conventional gas chromatography (GC), are common contaminants of sediments but little is known of their potential to affect sediment-dwelling organisms. Evidence exists for reduced health status in mussels, arising from aqueous exposure to aromatic UCM components acting through a narcotic mode of action. However, UCM contaminants in sediments may not be sufficiently bioavailable to elicit toxic effects. The aim of our study was therefore to measure the sublethal effects of chronic exposure to model UCM-dominated oils at environmentally realistic concentrations and compare this to effects produced by a UCM containing weathered crude oil. A further aim was to determine which, if any, fractions of the oils were responsible for any observed toxicity. Materials and Methods. Whole oils were spiked into estuarine sediment to give nominal concentrations of 500 mu g g(-1) dry weight. juveniles of the estuarine amphipod Coropbium volutator were exposed to the contaminated sediment for 35 days and their survival, growth rate and reproductive success quantified. Using an effect-directed fractionation approach, the oils were fractionated into aliphatic and two aromatic fractions by open column chromatography and their toxicity assessed by further chronic exposures using juvenile C. volutator. Results. The growth rates of amphipods were reduced following exposure to the oils although this was only statistically significant for the weathered oil; reproductive success was reduced by all oil exposures. Sediment spiked with UCM fractions also caused reduced growth and reproduction but no particular fraction was found to be responsible for the observed toxicity. Survivorship was not affected by any oil or fraction. Discussion. The study showed that chronic exposure to sediments contaminated by UCM-dominated oils could have population level effects on amphipods. The observed effects could not be explained by hydrocarbons resolved by conventional GC and effects were similar for both UCM-dominated and weathered oils. All of the fractions appeared to contribute to the observed effects; this is in contrast to previous research which had shown that an aliphatic UCM did not cause adverse effects in mussels. Conclusions. To our knowledge, this is the first study to demonstrate population-level effects arising from exposure to sediments contaminated by realistic environmental concentrations of UCM hydrocarbons. The results are consistent with many compounds, at very low individual concentrations, contributing towards the overall observed toxicity. Recommendations. Risk assessments of contaminated sediments should take into account the contribution towards the potential for toxic effects from UCM hydrocarbons. Studies into sediment contamination should report both aliphatic and aromatic UCM concentrations to aid risk assessments.

RefID: 631

Author: Schein, A., Scott, J.A., Mos, L. and Hodson, P.V.

Year: 2009

Title: Oil dispersion increases the apparent bioavailability and toxicity of diesel to rainbow trout (Oncorhynchus mykiss)

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/08-315.1/abstract

Abstract: Diesel is a complex mixture containing polycyclic aromatic hydrocarbons, which persist after a spill, pass readily from water into tissues, and are toxic to early life stages of fish. The bioavailability and chronic toxicity of hydrocarbons dissolved into water from floating diesel (water-accommodated fraction) and chemically dispersed diesel (chemically enhanced water-accommodated fraction) were measured by the extent of ethoxyresorufin-O-deethylase (EROD) induction in juvenile rainbow trout (Oncorhynchus mykiss) and by the severity of blue sac disease in embryos. The water-accommodated fraction of floating diesel was virtually nontoxic to embryos at nominal concentrations up to 1,000 mg/L, causing only small weight changes. Liver EROD induction in juvenile trout was only observed at the highest nominal water-accommodated fraction concentration (10,000 mg/L). Chemical dispersion increased the bioavailability and toxicity of diesel to trout by 100-fold. Diesel chemically enhanced water-accommodated fraction induced EROD activity, caused blue sac disease, and impaired development and growth of embryonic trout at nominal concentrations as low as 10 mg/L; 88% mortality occurred at 100 mg/L. However, when total hydrocarbon concentrations were measured, differences between dispersed and undispersed diesel disappeared, with a median lethal concentration of 8 mg/L of total hydrocarbons and sublethal median effective concentrations ranging from 1.3 to 6.1 mg/L. Dispersion of diesel by high-energy mechanical mixing was recently reported to cause acute lethality to juvenile trout between 40 and 200 mg/L. Therefore, dispersion of oil by any means increases the bioavailability and apparent toxicity of diesel to fish embryos without changing the toxicity of its components. Nevertheless, in an actual spill, dispersion of diesel increases the effects of oil on fish populations.

RefID: 632

Author: Schmidt, D.C., Tarbox, K.E., King, B.E., Brannian, L.K., Kyle, G.B. and Carlson, S.R.

Year: 1996

Title: Kenai river sockeye salmon: An assessment of overescapements as a cause of the decline

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: In the Kenai River, the estimated number of smolts of sockeye salmon Oncorhynchus nerka decreased from 30 million in 1989 to less than 500,000 in 1992, while parent-year escapements were high. In 1989, an estimated 1.4 million sockeye salmon entered the Kenai River as a result of curtailed fishing because of oil on the fishing grounds from the Exxon Valdez oil spill. We examined the causes for declining smolt production and identified decreased winter survival of age-0 juvenile sockeye salmon rearing in Skilak and Kenai lakes as the major contributor to this decline. We compared smolt production in the Kenai system with that from Tustumena Lake, a nearby system that had an average escapement in 1989 that did not exhibit major changes in smolt production. Adult returns from years with extremely low smolt production in the Kenai system arc needed to verify smolt estimation methods. Preliminary examination of limnological data (chemical, physical, and zooplankton forage base) from Skilak and Kenai lakes provided no obvious explanation for the major decline in winter survival of juvenile sockeye salmon. Because diel vertical migration of zooplankton differed among Kenai Peninsula glacial lakes with different densities of planktivores, we hypothesize that behavioral changes in the zooplankton induced by predation was a major contributor to the decreased production of juvenile sockeye salmon in the Kenai River lakes.

RefID: 633

Author: Schwacke, L.H., Smith, C.R., Townsend, F.I., Wells, R.S., Hart, L.B., Balmer, B.C., Collier, T.K., De Guise, S., Fry, M.M., Guillette, L.J., Jr., Lamb, S.V., Lane, S.M., Mcfee, W.E., Place, N.J., Tumlin, M.C., Ylitalo, G.M., Zolman, E.S. and Rowles, T.K.

Year: 2014

Title: Health of Common Bottlenose Dolphins (Tursiops truncatus) in Barataria Bay, Louisiana, Following the Deepwater Horizon Oil Spill

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es403610f

Abstract: The oil spill resulting from the explosion of the Deepwater Horizon drilling platform initiated immediate concern for marine wildlife, including common bottlenose dolphins in sensitive coastal habitats. To evaluate potential sublethal effects on dolphins, health assessments were conducted in Barataria Bay, Louisiana, an area that received heavy and prolonged oiling, and in a reference site, Sarasota Bay, Florida, where oil was not observed. Dolphins were temporarily captured, received a veterinary examination, and were then released. Dolphins sampled in Barataria Bay showed evidence of hypoadrenocorticism, consistent with adrenal toxicity as previously reported for laboratory mammals exposed to oil. Barataria Bay dolphins were 5 times more likely to have moderate severe lung disease, generally characterized by significant alveolar interstitial syndrome, lung masses, and pulmonary consolidation. Of 29 dolphins evaluated from Barataria Bay, 48% were given a guarded or worse prognosis, and 17% were considered poor or grave, indicating that they were not expected to survive. Disease conditions in Barataria Bay dolphins were significantly greater in prevalence and severity than those in Sarasota Bay dolphins, as well as those previously reported in other wild dolphin populations. Many disease conditions observed in Barataria Bay dolphins are uncommon but consistent with petroleum hydrocarbon exposure and toxicity.

RefID: 634

Author: Schwartz, J.A., Aldridge, B.M., Lasley, B.L., Snyder, P.W., Stott, J.L. and Mohr, F.C.

Year: 2004

Title: Chronic fuel oil toxicity in American mink (Mustela vison): systemic and hematological effects of ingestion of a low-concentration of bunker C fuel oil

Journal: Toxicology and Applied Pharmacology

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/15476867

Abstract: Petroleum oil enters the coastal marine environment through various sources; marine mammals such as sea otters that inhabit this environment may be exposed to low concentrations of petroleum hydrocarbons through ingestion of contaminated prey. The inability to perform controlled studies in free-ranging animals hinders investigations of the effects of chronic petroleum oil exposure on sea otter morbidity and mortality, necessitating the development of a reliable laboratory model. We examined the effects of oral exposure to 500 ppm bunker C fuel oil over 113-118 days on American mink, a species phylogenetically related to the sea otter. Hematological parameters and organs were examined for fuel oil-associated changes. Hepatic cytochrome P4501A1 mRNA expression and fecal cortisol concentrations were also measured. Ingestion of fuel oil was associated with a decrease in erythrocyte count, hemoglobin concentration (Hgb), hematocrit (HCT), and an increase in mean corpuscular volume (MCV). Total leukocytes were elevated in the fuel oil group from increases in neutrophils, lymphocytes, and monocytes. Significant interactions between fuel oil and antigen challenge were found for erythrocyte parameters, monocyte and lymphocyte counts. Liver and adrenal weights were increased although mesenteric lymph node weights were decreased in the fuel oil group. Hepatic cytochrome P4501A1 mRNA was elevated in the fuel oil group. Fecal cortisol concentration did not vary between the two groups. Our findings show that fuel oil exposure alters circulating leukocyte numbers, erythrocyte homeostasis, hepatic metabolism and adrenal physiology and establish a framework to use mink as a model for sea otters in studying the systemic effects of marine contaminants. (C) 2004 Elsevier Inc. All rights reserved.

RefID: 635

Author: Scott, A.C., MacKinnon, M.D. and Fedorak, P.M.

Year: 2005

Title: Naphthenic acids in athabasca oil sands tailings waters are less biodegradable than commercial naphthenic acids

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es051003k

Abstract: Naphthenic acids (NAs) are natural constituents in many petroleum sources, including bitumen in the oil sands of Northern Alberta, Canada. Bitumen extraction processes produce tailings waters that cannot be discharged to the environment because NAs are acutely toxic to aquatic species. However, aerobic biodegradation reduces the toxic character of NAs. In this study, four commercial NAs and the NAs in two oil sands tailings waters were characterized by gas chromatography-mass spectrometry. These NAs were also incubated with microorganisms in the tailings waters under aerobic, laboratory conditions. The NAs in the commercial preparations had lower molecular masses than the NAs in the tailings waters. The commercial NAs were biodegraded within 14 days, but only about 25% of the NAs native to the tailings waters were removed after 40-49 days. These results show that low molecular mass NAs C <= 17) are more readily biodegraded than high molecular mass NAs (C >= 18). Moreover, the results indicate that biodegradation studies using commercial NAs alone will not accurately reflect the potential biodegradability of NAs in the oil sands tailings waters.

RefID: 636

Author: Scott, G.I., Fulton, M.H., DeLorenzo, M.E., Wirth, E.F., Key, P.B., Pennington, P.L., Kennedy, D.M., Porter, D., Chandler, G.T., Scott, C.H. and Ferry, J.L.

Year: 2013

Title: The Environmental Sensitivity Index and Oil and Hazardous Materials Impact Assessments: Linking Prespill Contingency Planning and Ecological Risk Assessment

Journal: Journal of Coastal Research

Hyperlink: http://www.bioone.org/doi/abs/10.2112/SI_69_8

Abstract: The oil spill Environmental Sensitivity Index (ESI) was developed by Miles O. Hayes and researchers at Research Planning Institute and at the University of South Carolina during the 1970s and has been used by the National Oceanic and Atmospheric Administration (NOAA) to assess, forecast, and mitigate oil spill impacts throughout coastal regions of the United States. The ESI delineates different habitats types within coastal ecosystems and prioritizes their vulnerability to oil spills based on the persistence of oil and the ecological sensitivity of marine animals and plants within each habitat type. More physically exposed habitats (e.g., rock headlands), have shorter oil spill persistence and are less vulnerable than more sheltered habitats (e.g., tidal flats and salt marshes), where oil persists longer. Salt marshes are generally the most vulnerable habitats identified in most coastal regions of the United States using the ESI. To further assess impacts of oil and hazardous materials on salt marsh ecosystems, NOAA has developed a salt marsh mesocosm testing system that uses a modular approach to predict pollution impacts in the different marsh subhabitats, which are useful in defining multiple species toxicity and sensitivity to petroleum hydrocarbons and other chemical contaminants among the different salt marsh faunal taxa. The modular approach allows taxa in different salt marsh subhabitats, including Spartina alterniflora, Salicornia bigelovii, and Juncus roemerianus marsh communities, to be both individually and simultaneously compared and assessed. These mesocosms are also useful in predicting fate and effects, food web bioaccumulation, acute or chronic toxicity, and sublethal bioeffects for a number of pollutants. Results from these mesocosm studies indicate the utility of this integrated risk assessment method for predicting the fate and bioeffects of chemical contaminants on the estuarine salt marsh community and provide a direct link with the ESI, thus connecting prespill contingency planning and predictive ecological risk assessment.

RefID: 637

Author: See, M.G.

Year: 2001

Title: Lessons learned: evaluating scientific sampling of effects from the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/70788605.pdf

Abstract: This pilot project reviewed scientific research conducted on the impacts of the Exxon Valdez oil spill, and developed recommendations regarding research effectiveness. Topics included herring, pink salmon, blue mussels, harlequin ducks, murres, sea otters, as well as recreation and archeology. Recommendations were also prepared for issues related to damage assessment including interagency coordination, ecosystem approach, post-spill studies, baseline data, and relationship to restoration. A workshop for resource scientists, managers, and authors of white papers provided the forum for examining results and developing recommendations. Participants evaluated the effectiveness of the project for assessing resource impacts associated with the spill.

RefID: 638

Author: Seeb, J.E. and Habicht, C.

Year: 1999

Title: Laboratory examination of oil-related embryo mortalities that persist in pink salmon populations in Prince William Sound

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/44141053.pdf

Abstract: We used an array of genetic detection methods to test the hypothesis that incubation of pink salmon embryos in an oiled substrate induces genetic damage. Mortality and abnormality rates were higher for embryos in oiled incubators than for those in unoiled incubators. Despite high statistical power, we found no relationship between exposure to oil and incidence of genetic damage detectable by flow cytometry. Androgens produced from males incubated in oil as embryos demonstrated no elevated mortality; however, this experiment lacked statistical power due to unanticipated male-to-male variability. We found unexpectedly little polymorphism and no differences in either cytochrome b or the region of tumor suppressor gene p53 reported to be hypervariable in other species. A pilot study of four microsatellite loci showed no change of allelic expression. However, a high frequency of K-rus mutations was observed in pink salmon embryos experimentally exposed to Exxon Valdez crude oil.

RefID: 639

Author: Seeb, L.W., Habicht, C., Templin, W.D., Tarbox, K.E., Davis, R.Z., Brannian, L.K. and Seeb, J.E.

Year: 2000

Title: Genetic diversity of sockeye salmon of Cook Inlet, Alaska, and its application to management of populations affected by the Exxon Valdez oil spill

Journal: Transactions of the American Fisheries Society

Hyperlink: http://www.tandfonline.com/doi/full/10.1577/1548-8659(2000)129%3C1223:GDOSSO%3E2.0.CO;2

Abstract: Genetic data from sockeye salmon Oncorhynchus nerka were collected from all major systems in upper Cook Inlet, Alaska, that produce sockeye salmon, including the Kenai River drainage, a major system that was affected by the Exxon Valdez oil spill. The products of 29 enzymes encoded by 67 protein-encoding loci resolved by allozyme analysis revealed a substantial amount of genetic diversity among populations distributed both within and among major drainages. The data support a model of population structure based on the nursery lake. A gene diversity analysis estimated that 0.4% of the total variability was attributable to the effect of sampling at different sites within nursery lakes, compared with 7.5% among nursery lakes within regions and 2.9% among regions. This diversity probably arises from isolation and genetic drift within nursery lakes and the tendency of sockeye salmon to home with great fidelity. Sockeye salmon from these drainages are commercially harvested in mixed-stock aggregations in upper Cook Inlet. Mixed-stock analyses using maximum likelihood methods with data from 27 loci were performed to estimate the proportion of source populations in upper Cook Inlet fisheries. Simulations indicated that six regional groups (Kenai River, Susitna and Yentna rivers, West Cook Inlet, Kasilof River, Northeast Cook Inlet, and Knik Arm) could be identified in mixtures at a level of precision and accuracy useful for fishery management. Samples from fisheries were analyzed both in-season (within 48 h) and postseason. Samples taken from within the rivers were also analyzed to evaluate the baseline and to estimate the contributions of individual spawning populations to the larger river systems.

RefID: 640

Author: Sellin Jeffries, M.K., Claytor, C., Stubblefield, W., Pearson, W.H. and Oris, J.T.

Year: 2013

Title: Quantitative Risk Model for Polycyclic Aromatic Hydrocarbon Photoinduced Toxicity in Pacific Herring Following the Exxon Valdez Oil Spill

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/full/10.1021/es400759y

Abstract: Phototoxicity occurs when exposure to ultraviolet radiation increases the toxicity of certain contaminants, including polycyclic aromatic hydrocarbons (PAHs). This study aimed to (1) develop a quantitative model to predict the risk of PAH phototoxicity to fish, (2) assess the predictive value of the model, and (3) estimate the risk of PAH phototoxicity to larval and young of year Pacific herring (Clupea pallasi) following the Exxon Valdez oil spill (EVOS) in Prince William Sound, Alaska. The model, in which median lethal times (LT50 values) are estimated from whole-body phototoxic PAH concentrations and ultraviolet A (UVA) exposure, was constructed from previously reported PAH phototoxicity data. The predictive value of this model was confirmed by the overlap of model-predicted and experimentally derived LT50 values. The model, along with UVA characterization data, was used to generate estimates for depths of de minimiz risk for PAH phototoxicity in young herring in 2003/2004 and immediately following the 1989 EVOS, assuming average and worst case conditions. Depths of de minimiz risk were estimated to be between 0 and 2 m deep when worst case UVA and PAH conditions were considered. A post hoc assessment determined that <1% of the young herring population would have been present at depths associated with significant risk of PAH phototoxicity in 2003/2004 and 1989.

RefID: 641

Author: Seuront, L.

Year: 2010

Title: Zooplankton avoidance behaviour as a response to point sources of hydrocarbon-contaminated water

Journal: Marine and Freshwater Research

Hyperlink: http://www.publish.csiro.au/?paper=MF09055

Abstract: Hydrocarbon contamination is a pernicious threat for marine ecosystems as non-lethal effects on the plankton propagate through the food chain and accumulate in the tissues of top predators, ultimately putting human health at risk. The swimming behaviour of the calanoid copepods Eurytemora affinis and Temora longicornis was investigated in relation to point-source contamination by five different-sized patches of the water-soluble fraction of diesel oil diluted at 1 : 100, 1 : 1000 and 1 : 10 000 in estuarine and coastal waters. Both species consistently showed avoidance of the contaminated patches, irrespective of their size and concentration. Specifically, E. affinis exhibited similar sensory abilities irrespective of contaminant concentrations. In contrast, T. longicornis more efficiently identified high-density contaminated patches than low-density ones, and exhibited a negative exponential density dependence of its sensing abilities to the intensity of the chemical cues. Although the conclusions from this experiment need to be generalised to a variety of hydrocarbon contaminants, the present work indicates that zooplankton organisms have the potential to avoid hydrocarbon-contaminated waters, and also suggests that zooplankton swimming behaviour could potentially be used as an endpoint for a toxicity bioassay to assess the presence of toxic chemicals in estuarine and coastal waters.

RefID: 642

Author: Shafir, S., van Rijn, J. and Rinkevich, B.

Year: 2007

Title: Short and long term toxicity of crude oil and oil dispersants to two representative coral species

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es0704582

Abstract: Oil dispersants, the tool of choice for treating oil spills in tropical marine environments, is potentially harmful to marine life, including reef corals. In a previous study, we found that dispersed oil and oil dispersants are harmful to soft and hard coral species at early life stages. In this broader study, we employed a "nubbin assay" on more than 10 000 coral fragments to evaluate the short- and long-term impacts of dispersed oil fractions (DOFs) from six commercial dispersants, the dispersants and water-soluble-fractions (WSFs) of Egyptian crude oil, on two Indo Pacific branching coral species, Stylophora pistillata and Pocillopora damicornis. Survivorship and growth of nubbins were recorded for up to 50 days following a single, short (24 h) exposure to toxicants in various concentrations. Manufacturer-recommended dispersant concentrations proved to be highly toxic and resulted in mortality for all nubbins. The dispersed oil and the dispersants were significantly more toxic than crude oil WSFs. As corals are particularly susceptible to oil detergents and dispersed oil, the results of these assays rules out the use of any oil dispersant in coral reefs and in their vicinity. The ecotoxicological impacts of the various dispersants on the corals could be rated on a scale from the least to the most harmful agent, as follows: Slickgone > Petrotech > Inipol = Biorieco > Emulgal > Dispolen.

RefID: 643

Author: Shane, S.H.

Year: 1990

Title: PROTECTING SEA OTTERS FROM OIL SPILLS RECOMMENDATIONS BASED ON THE ALASKA USA EXPERIENCE

Journal: U S Fish and Wildlife Service Biological Report

Hyperlink: https://openlibrary.org/books/OL24349175M/Sea_otter_symposium

Abstract: The 1989 Alaska oil spill provided valuable lessons about how to improve management of sea otters (Enhydra lutris) during a spill: The U.S. Fish and Wildlife Service, the Federal agency charged with responsibility for sea otters, must have clear authority and unlimited funds to respond immediately to otters affected or threatened by an oil spill. Decisions affecting otters cannot be left to the spiller. Once an oil spill occurs, the Service must direct protective booming efforts and preemptive captures to prevent sea otters from becoming oiled. To adequately treat oiled otters, sea otter rescue and holding facilities must be constructed and operational before an oil spill occurs. Trained staff and volunteers, otter care protocols, and record-keeping procedures must be in place before a spill occurs to ensure that otters receive the best care possible. Both short- and long-term research projects relating to the effects of oil spills on otters find their habitat should be designed in advance of an oil spill and implemented as soon as a spill occurs.

RefID: 644

Author: Shang, D., Buday, C., van Aggelen, G. and Colodey, A.

Year: 2012

Title: Toxicity Evaluation of the Oil Surface Washing Agent Corexit® 9580 and its Shoreline Application in Burrard Inlet, British Columbia

Journal: In: Proceedings of the 35th Arctic and Marine Oilspill Program (AMOP) Technical Seminar

Hyperlink:

Abstract: Corexit® 9580 surface washing agent and pressure washing treatments were applied to the Burrard

Inlet, British Columbia shoreline to facilitate clean-up afer an oil spill from an onshore pipeline break. Water samples from the foreshore were collected after the oil spill, before and after the shoreline treatments. The seawater samples were not acutely toxic to Microtox® bacteria (Vibrio fischeri), Coho salmon (Oncorhynchus kisutch) and echinoid fertilization (Dendraster excentricus). Elevated hydrocarbon concentrations were detected in the water samples taken after the shoreline treatments compared to the water samples taken before the shoreline treatments, indicating increased immobilization of hydrocarbon concentration in the water column.

RefID: 645

Author: Sharr, S., Bue, B.G., Moffitt, S.D., Craig, A. and Evans, D.G.

Year: 1994

Title: Injury to salmon eggs and preemergent fry in Prince William Sound

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/42725188.pdf

Abstract: Fish/Shellfish Study Number 1 was designed to document oil contamination ofintertidal spawning habitat and changes in the number and distribution of pink salmon spawning inintertidal and upstream areas relative to oil contamination resulting fiom the Exxon Valdez oil spill. Although the presence of oil was documented on intertidal substrate in anadromous streams bothvisually and through analysis of mussel Mytilus sp. samples, no obvious effects on adult pink salmon abundance, distribution, or histology were found. As other damage assessment studies established injury to pink salmon embryos and juveniles, adult pink salmon restoration studies were initiated to evaluate and improve escapement enumeration techniques to ensure that injuredpopulations were adequately protected. Restoration Studies 9 and 60B focused on the main sources of error affecting accuracy and precision of escapement estimates generated by area-under-thecurvecalculations, stream life and observer efficiency. Ground observer counts were found to tendto be more accurate than aerial observer counts, but both methods underestimated actual numbers of spawners. We obtained strong evidence that escapement estimates based onappropriate streamlifeand observer efficiency values were more accurate and always greater than those based on thecurrently used 17.5 day stream-life value and no observer efficiency adjustment.

RefID: 646

Author: Sharr, S., Seeb, J.E., Bue, B.G., Craig, A. and Miller, G.D.

Year: 1994

Title: Injury to salmon eggs and preemergent fry in Prince William Sound

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33088664.pdf

Abstract: We examined the possibility that the differences in pink salmon embryo mortality observed in the field in past years was due to traits carried by the parents. Gametes were collected from adults in spawning condition as they amassed on or near the spawning ground from eight oil contaminated and eight unimpacted streams. The resulting pink salmon embryos from oil contaminated streams showed elevated mortalities when compared to the embryos from unimpacted streams. No difference in embryo to preemergent fry survival for pink salmon incubating during the winter of 1992.1993 was detected between oil contaminated and unimpacted streams.

RefID: 647

Author: Shelton, M.E., Chapman, P.J., Foss, S.S. and Fisher, W.S.

Year: 1999

Title: Degradation of weathered oil by mixed marine bacteria and the toxicity of accumulated water-soluble material to two marine crustacea

Journal: Archives of Environmental Contamination and Toxicology

Hyperlink: http://download.springer.com/static/pdf/999/art%3A10.1007%2Fs002449900437.pdf?auth66=141936883
7_e6bed2b18442d1ea4bc0fa29976fa3cb&ext=.pdf

Abstract: Artificially weathered crude oil was degraded by four diverse cultures of mixed marine bacteria under optimized conditions for 7 and 14 days. Loss in total weight of starting oil (30 g) ranged from 6.8-17.3% in biologically active incubations compared with only 0.9-1.1% in sterile and nutrient-limited controls. In all incubations, both neutral and acidic water-soluble fractions (WSF) were accumulated. In biologically active systems, 50.9-249.0 mg neutral and 63.3-406.8 mg acidic WSF were accumulated whereas only 6.5-11.1 mg neutral and 1.7-2.2 mg acidic WSF were accumulated in control incubations. Analysis by gas chromatography demonstrated that accumulated WSF in biologically active systems contained compounds different from those washed from the starting crude oil. Exposure of grass shrimp (Palaemonetes pugio) embryos to neutral WSF from each of the biologically active cultures resulted in high embryo mortalities relative to sterile and nutrient-limited controls which exhibited >90% hatching success and larval survival. Toxicity of neutral WSF was also demonstrated on larvae of mysids (Mysidopsis bahia). In both cases, toxicity occurred only on exposure to neutral material accumulated by active, oil-degrading cultures and not with material washed from the weathered crude oil. These results imply that unique compounds were accumulated during degradation that may have been responsible for increased toxicity.

RefID: 648

Author: Shigenaka, G., Coats, D.A., Fukuyama, A.K. and Roberts, P.O.

Year: 1999

Title: Effects and Trends in Littleneck Clams (Protothaca Staminea) Impacted by the Exxon Valdez Oil Spill

Journal: International Oil Spill Conference Proceedings

Hyperlink:

Abstract: Littleneck clams, Protothaca staminea, are a common intertidal clam species in Prince William Sound. With several years of results from National Oceanic and Atmospheric Association/Hazardous Materials Response and Assessment Division (NOAA/HAZMAT) monitoring available, it is possible to infer some trends in clams affected by the Exxon Valdez incident: At oiled and washed sites, Protothaca staminea numbers reflect a different pattern of impact and recovery than other infaunal species, i.e., they do not show a depression in abundance followed by the dramatic population increase observed among many recovering species. Abundance differences between washed sites and unoiled sites may reflect lingering spill impacts. Extrapolation of the current trend suggests population abundance at oiled and washed sites could converge to that at unoiled sites by 2006. Chemistry results showed large declines in tissue aromatic hydrocarbon concentrations between 1990 and 1992. However, statistically significant differences between results for oiled sites and unoiled sited remained until 1997. Littleneck clams bioaccumulate oil to slightly higher concentrations than co-located mussels. Route of exposure has not been identified, but hydrocarbons adsorbed to particulates and food is a likely source. Subtle impacts to Protothaca staminea age structure and other population features may manifest themselves over the longer term. The authors' goal is to identify and characterize such effects. The overall task of impact and recovery assessment is complicated by factors such as sea otter predation, recovery from other major disruptions like the 1964 earthquake, and El Niño-Southern Oscillation shifts.

RefID: 649

Author: Short, J.W. and Babcock, M.M.

Year: 1996

Title: Prespill and Postspill Concentrations of Hydrocarbons in Mussels and Sediments in Prince William Sound

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: Hydrocarbon concentrations in intertidal mussels and sediments were compared before and after crude oil from the TV Exxon V aldez contaminated beaches in Prince William Sound. Comparison of

hydrocarbon concentrations in these samples at stations inside and outside the path of the oil and before tand after landfall of the spilled oil were used to (1) evaluate the significance of petroleum hydrocarbon contaminants found after the spill, (2) establish restoration criteria for affected beaches, and (3) determine natural recovery rates for these beaches. Concentrations of polynuclear aromatic hydrocarbons (PAHs) near or below detection limits in mussels outside the path of the spilled oil, or collected before oil became beached, indicate that other sources of PAHs were negligible and that seawater in the spill area generally was free of anthropogenic hydrocarbon pollution. Contamination of mussels by PAHs derived fr4om natural sources, such as marine oil seeps, was not detected. Contamination of mussels was highest during the first few weeks after th espill, followed by a consistent decline. Concentrations of hydrocarbons derived from Exon Valdez oil were highest and most persistent in mussels near or on heavily oiled beaches. Contamination of lower intertidal sediments by PAHs derived from Exxon Valdez oil was less than 1,000 ng/g (dry weight basis), even when concentrations in adjacent upper intertidal sediments were higher by factors exceeding 10. Concentrations of spill-derived PAHs in lower intertidal sediments consistently declined during the years after the spill. At stations unaffected by the spilled oil, total PAH (TPAH) concnetrations in lower intertidal mussels and sediments were usually less than 100 ng/g, except near Hinchinbrook Entrance. Analytical data on mussels and sediments for stations sampled before the spill and for unaffected stations can be used to establish restoration criteria for oiled beaches.

RefID: 650

Author: Short, J.W. and Harris, P.M.

Year: 1996

Title: Petroleum Hydrocarbons in Caged Mussels Deployed in Prince William Sound after the Exxon Valdez Oil Spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: Mussels Mytilus trossulus, initially free of hydrocarbons, were deployed in nearshore waters along the path of oil spilled from the Exxon Valdez to determine the biological availability and persistence of petroleum-derived hydrocarbons. Mussels were deployed at 22 locations inside Prince William Sound and 16 locations outside the sound at depths of 1, 5, and 25 m for 2-8 weeks. We conducted four successive deployments in 1989 after the spill and two in 1990 and 1991. Mussels were analyzed for 23 alkane and 43 polynuclear aromatic hydrocarbon (PAH) analytes. Concentrations of PAHs in mussels deployed along the oil's path decreased with depth, time, and distance from heavily oiled beaches. The highest concentration of total PAHs was 45,200 ng/g dry tissue weight at Herring Bay, 1-m depth, 1-2 months after the spill. Concentrations of nearly that high at north Smith Island and Snug Harbor. Lower concentrations with PAH composition similar to Exxon Valdez crude oil were detected at other locations inside Prince William Sound, except at the control site, Olsen Bay. Concentrations of PAHs in mussels deployed inside Prince William Sound declined by late summer 1989. In 1990 and 1991, PAHs could only be detected near heavily oiled beaches at concentrations that were usually below 500 ng/g. Alternative sources of petroleum hydrocarbons in the mussels were negligible compared with Exxon Valdez crude oil. Petroleum hydrocarbons similar to those of Exxon Valdez crude oil were detected only sporadically outside the sound in1989 and were generally below detection limits by 1990 and 1991. Accumulation of hydrocarbons were available to subsurface marine fauna, such as fish and invertebrates during the summer after the spill, especially in shallow wters near oiled beaches. Oil accumulated from seatater at these trophic levels would serve as a route of oil exposure through ingestion by fauna at higher trophic levels.

RefID: 651

Author: Short, J.W., Rice, S.D., Heintz, R.A., Carls, M.G. and Moles, A.

Year: 2003

Title: Long-term effects of crude oil on developing fish: Lessons from the Exxon Valdez oil spill

Journal: Energy Sources

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/00908310390195589

Abstract: Habitat damage resulting from oil contamination is underestimated by acute toxicity assays. Nearshore substrates oiled by spills may become persistent pollution sources of toxic polycyclic aromatic hydrocarbons (PAH). Recent findings resulting from research following the Exxon Valdez oil spill include: (1) PAHs are released from oil films and droplets at progressively slower rates with an increasing molecular weight, leading to greater persistence of larger PAHs; (2) eggs from demersally-spawning fish species accumulate dissolved PAHs released from oiled substrates, even when the oil is heavily weathered; and (3) PAHs accumulated by embryos from aqueous concentrations of < 1 μg/L can lead to adverse sequelae appearing at random over the lifespan of an exposed cohort, probably as a result of damage during early embryogenesis. Polycyclic Aromatic Hydrocarbons (PAH) can be a slow-acting poison, and toxic effects may not manifest until long after exposure. These considerations have important policy implications regarding protection of fish natal and rearing habitats.

RefID: 652

Author: Short, J.W., Springman, K.R., Lindeberg, M.R., Holland, L.G., Larsen, M.L., Sloan, C.A., Khan, C., Hodson, P.V. and Rice, S.D.

Year: 2008

Title: Semipermeable membrane devices link site-specific contaminants to effects: PART II - A comparison of lingering Exxon Valdez oil with other potential sources of CYP1A inducers in Prince William Sound, Alaska

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S014111360800202X

Abstract: We deployed semipermeable membrane devices (SPMDs) on beaches for 28 days at 53 sites in Prince William Sound (PWS), Alaska, to evaluate the induction potential from suspected sources of cytochrome P450 1A(CYP1A)-inducing contaminants. Sites were selected to assess known point sources, or were chosen randomly to evaluate the region-wide sources. After deployment, SPMD extracts were analyzed chemically for persistent organic pollutants (POPs) and polycyclic aromatic hydrocarbons (PAH). These results were compared with hepatic CYP1A enzyme activity of juvenile rainbow trout injected with the same extracts priorto clean-up for the chemical analyses. Increased CYP1A activity was strongly associated with PAH concentrations in extracts, especially chrysene homologues but was not associated with POPs. The only apparent sources of chrysene homologues were lingering oil from Exxon Valdez, asphalt and bunker fuels released from storage tanks during the 1964 Alaska earthquake, creosote leaching from numerous pilings at one site, and PAH-contaminated sediments at Cordova Harbor. Our results indicate that PWS is remarkably free of pollution from PAH when nearby sources are absent as well as from pesticides and PCBs generally. Published by Elsevier Ltd.

RefID: 653

Author: Shukla, P., Gopalani, M., Ramteke, D.S. and Wate, S.R.

Year: 2007

Title: Influence of salinity on PAH uptake from water soluble fraction of crude oil in Tilapia mossambica

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs00128-007-9272-x

Abstract: Accidents during marine transport and offshore production facilities often are responsible for oil spills in the open sea. In few cases, these oil slicks drift towards the shore and further into the estuaries, which serve as an important spawning and nursing grounds for many fish species. This study examined the role of salinity in the uptake and accumulation of toxic PAH from crude oil in select somatic and reproductive organs of Tilapia mossambica. Our results showed significantly (ANOVA, $p < 0.01$) lower PAH solubility in higher salinity waters and its uptake by fish. The differences were largest with the low molecular weight (LMW) two (naphthalenes) and three (phenanthrene) ring compounds as compared with higher molecular weight (HMW) compounds such as pyrene (four ringed).

RefID: 654

Author: Silliman, B.D.

Year: 2014

Title: Guidelines to Prepare for Oil Sands Product Spills in Varied Aquatic Environments

Journal: International Oil Spill Conference Proceedings

Hyperlink: http://ioscproceedings.org/doi/abs/10.7901/2169-3358-2014.1.426

Abstract: ABSTRACT On July 24, 2007, the Westridge Transfer Line in Burnaby, British Columbia, ruptured spilling 1,400 barrels of oil sands product into the area's storm water systems and eventually into the Burrard Inlet at Vancouver Harbor. The response to this spill was considered successful and there is no record of oil sinking. Several years later, in July of 2010, the Line 6B pipeline operated by Enbridge Energy Partners LLP ruptured spilling 20,082 barrels of oil sands product into the Kalamazoo River. In contrast to the Burnaby spill, this response was extremely difficult due to the sinking of large quantities of oil. The variance in fate and behavior of the oil sands products in these two spills demonstrates how environmental factors can result in different response challenges. Many environmental factors affect the fate of spilled oil sands products in aquatic environments because bitumen, a large component of oil sands products, has a density greater than freshwater. By analyzing specific factors in areas at risk, responders can better prepare for, and expect, submergence in oil sands product spills. Areas identified to have low salinity, rough sedimentation, high turbidity, strong sunlight exposure, high temperatures, and strong currents have a high risk of submergence. Response teams in these areas of high risk should have submerged oil recovery equipment readily available for rapid deployment.

RefID: 655

Author: Singer, M.M., George, S., Jacobson, S., Lee, I., Tjeerdema, R.S. and Sowby, M.L.

Year: 1994

Title: COMPARATIVE EFFECTS OF OIL DISPERSANTS TO THE EARLY-LIFE STAGES OF TOPSMELT (ATHERINOPS-AFFINIS) AND KELP (MACROCYSTIS-PYRIFERA)

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620130415/pdf

Abstract: The acute effects of two oilspill dispersants were compared using the early life stages of two common nearshore marine organisms the topsmelt (Atherinops affinis), a common fish in bays and estuaries, and the giant kelp (Macrocystis pyrrfera), a canopy forming brown alga. Testing was done under closed, flow through conditions, with spiked dispersant concentrations measured in real time using UV spectrophotometry Both dispersants were composed of complex mixtures of anionic and non-ionic surfactants and solvents Median effect concentration data showed Atherinops tests to be more sensitive to both dispersants than Macrocystis tests, with values ranging from 48 2 to 72 9 ppm (LCSO) and 73 0 to 79 4 ppm (IC50), respectively, for Nokomis@ 3, and from 43 7 to 45 8 ppm (LCSO) and 73 0 to 95 9 pprn (ICSO), respectively, for Slik-A-Way a different pattern was seen in NOECs, in which both species showed significantly higher sensitivity to Slik A Way than to Nokomis 3(a = 0 05) Comparison of the present data with those previously compiled for the same products with two other species the red abalone (Huhotis rufescens) and a mysid (Holmesimysis tostata), showed fairly consistent interspecific patterns among three of the four species, Holmesimysis tests were seen to be least sensitive to Nokomis 3 and second most sensitive to Slik A Way. In addition, Slik A Way was more toxic to all species except Macrocystis.

RefID: 656

Author: Singer, M.M., George, S., Jacobson, S., Lee, I., Weetman, L.L., Tjeerdema, R.S. and Sowby, M.L.

Year: 1995

Title: ACUTE TOXICITY OF THE OIL DISPERSANT COREXIT-9554 TO MARINE ORGANISMS

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/8565881

Abstract:

RefID: 657

Author: Singer, M.M., George, S., Jacobson, S., Lee, I., Weetman, L.L., Tjeerdema, R.S. and Sowby, M.L.

Year: 1996

Title: Comparison of acute aquatic effects of the oil dispersant Corexit 9500 with those of other Corexit series dispersants

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/8950541

Abstract: The acute aquatic toxicity of a new Corexit series dispersant, Corexit 9500, was evaluated and compared with that of others in the series using early life stages of two common nearshore marine organisms: the red abalone (Haliotis rufescens) and a kelp forest mysid (Holmesimysis costata), Spiked-concentration testing was performed under closed, flowthrough conditions, with dispersant concentrations measured in real time using UV spectrophotometry, Median-effect concentrations ranged from 12.8 to 19.7 initial ppm for Haliotis and from 158.0 to 245.4 initial ppm for Holmesimysis. The difference in sensitivity of the two types of tests was consistent with patterns seen with other oil dispersants, Also, these data indicate Corexit 9500 to be of similar toxicity to Corexit 9527 and 9554, Corexit 9500 represents a reformulation of a longtime industry "standard," Corexit 9527, to allow use on higher viscosity oils and emulsions. The present data suggest that acute aquatic toxicity concerns surrounding the use of this newer dispersant should not be significantly different from those associated with the use of Corexit 9527. (C) 1996 Academic Press, Inc.

RefID: 658

Author: Singer, M.M., George, S., Lee, I., Jacobson, S., Weetman, L.L., Blondina, G., Tjeerdema, R.S., Aurand, D. and Sowby, M.L.

Year: 1998

Title: Effects of dispersant treatment on the acute aquatic toxicity of petroleum hydrocarbons

Journal: Archives of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs002449900302

Abstract: The acute effects of both untreated and dispersant-treated Prudhoe Bay crude oil on the early life-stages of three marine species were investigated. Identification of which water-accommodated fraction (undispersed or chemically dispersed) was considered "more toxic" was dependent on species, time, and endpoint (and by inference, test protocol). Generally, the data showed that at roughly equivalent hydrocarbon concentrations untreated oil solutions resulted in higher initial effects (< 1 h) in mysid and topsmelt tests, whereas dispersed oil solutions elicited higher levels of larval abnormality in abalone tests and higher levels of mortality in mysid tests. While differences in test protocols existed among the species tested, topsmelt were the most sensitive species to untreated oil solutions, with mysids being most sensitive to dispersed oil solutions.

RefID: 659

Author: Singh, A.K. and Gaur, J.P.

Year: 1990

Title: EFFECTS OF PETROLEUM OILS AND THEIR PARAFFINIC, ASPHALTIC, AND AROMATIC FRACTIONS ON PHOTOSYNTHESIS AND RESPIRATION OF MICROALGAE

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/014765139090073E

Abstract:

RefID: 660

Author: Siron, R., Giusti, G., Berland, B., Morales-Loo, R. and Pelletier, E.

Year: 1991

Title: WATER-SOLUBLE PETROLEUM COMPOUNDS - CHEMICAL ASPECTS AND EFFECTS ON THE GROWTH OF MICROALGAE

Journal: Science of the Total Environment

Hyperlink: http://www.sciencedirect.com/science/article/pii/004896979190073N

Abstract: Fluorescence and high performance liquid chromatographic (HPLC) analyses revealed the relative enrichment of the water-soluble fraction (WSF) of crude oil with mono- and diaromatic hydrocarbons and with highly polar petroleum fractions, including phenolic components. Chemical changes of the WSF were recorded simultaneously with the growth of the diatom Phaeodactylum tricornutum and the chlorophyte Dunaliella tertiolecta in batch cultures. Results confirm the potential phytotoxicity of low-molecular-weight aromatic hydrocarbons and photooxidation by-products. Both stimulation and inhibition of growth were observed with the concentrations tested (from 0.02 to 29.3 mg l-1 WSF). Particularly noticeable was stimulation of the exponential growth phase following reduction of photosynthetic capacity during the lag phase when the chlorophyte was exposed to WSF ranging from 0.2 to 15.3 mg l-1. Significant linear relationships between WSF concentration and the difference in growth between control and test cultures were found for both microalgae during the exponential growth phase, demonstrating differences in their sensitivity to soluble petroleum compounds; the EC50 (growth reduction) for P. tricornutum and D. tertiolecta was 16.4 and 36.0 mg l-1 WSF, respectively. A significant linear relationship was again found for the most sensitive species, P. tricornutum, when considering only the hydrocarbon fraction of WSF; growth inhibition appeared from 0.04 mg l-1 and the EC50 was calculated at 0.36 mg l-1 hydrocarbons. The toxicity of the WSF was recorded with and without added phosphorus; no significant WSF-phosphorus interaction (ANOVA, P > 0.05) was observed.

RefID: 661

Author: Siwik, P.L., Van Meer, T., MacKinnon, M.D. and Paszkowski, C.A.

Year: 2000

Title: Growth of fathead minnows in oilsand-processed wastewater in laboratory and field

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620190718/abstract;jsessionid=F0BA2A90C6ADEE0F0A9A15A872A4503C.f02t01

Abstract: Two waste products of Syncrude Canada Ltd. (SCL) oilsands mine are mature fine tailings (MFT), a toxic aqueous suspension of particles, organic acids, bitumen, and metals, and tailings pond water (TPW), a saline solution containing organic and inorganic contaminants. The chemical profiles of MFT interstitial water and TPW are very similar. Syncrude Canada has proposed disposing of MFT in constructed lakes, which would be lined with MFT and capped with clean water. As the MFT consolidates, MET-associated water would be released into the overlying watercap. Prototype ponds support fathead minnows (Pimephales promelas), but the long-term viability of these populations is unknown. This study attempts to determine if exposure to MFT and TPW, a related waste product, affected growth of fathead minnow larvae in the laboratory and field. Laboratory larval growth bioassays (7 and 56 d) on whole effluent from numerous prototype ponds yielded no significant differences in dry weight, but one 7-d bioassay showed reduced survival in two SCL sites. A 56-d growth bioassay showed significant increases in length of fish exposed to SCL wastewater at 7 d but not at 28 or 56 d. Larvae exposed as embryos and then introduced into field mesocosms did display significant differences in dry weight. In this instance, fish exposed to wastewater were significantly larger during the laboratory portion of the test (initial), but after

21 d in a field mesocosm (final), they were similar in size or smaller than fish growing in nonprocessed water.

RefID: 662

Author: Sloan, N.A.

Year: 1999

Title: Oil impacts on cold water marine resources: a review relevant to Parks Canada's evolving marine mandate

Journal: Parks Canada Occasional Paper

Hyperlink:

Abstract: This review provides a brief current account of the effects of oil pollution relevant to the new stewardship mandate of Parks Canada for representative Canadian cold water ocean and estuarine ecosystems. It is timely because of recent contributions from the 1989 Exxon Valdez oil spill (EVOS), important long-term oil fate and effects studies and the commitment in Parks Canada to Geographic Information System (GIS)-based shoreline inventory and oil spill response planning where GIS information plays a key role. The acute, short-term effects of oil spills are reasonably well described. There remains, however, uncertainty and controversy over the chronic, long-term and sublethal effects of oil at population and ecosystem levels. The EVOS experience has shown, again, that spills can have sociopolitical dimensions that, in a crisis situation, will overwhelm science considerations. Each spill event is a unique blend of place, nature and human influences among which science is a facet. Effects on pelagic (open water) and deeper subtidal benthic (sea bottom) systems are relatively small. Effects at interfaces can be great, such as on groups contacting the sea surface (e.g., seabirds and marine mammals) and on intertidal ecosystems at the land -sea interface. Pelagic species, which complete part of their life cycle at interfaces by having floating eggs at the sea surface or by spawning intertidally, are also vulnerable to oil. Substrate and exposure to wave energy are the critical variables to impacts of intertidal oil. Sheltered and sedimentary habitats retain oil, while exposed rocky shores are more quickly cleaned by nature. The following key weaknesses in our understanding of the biology of oil impacts remain: • poor pre -oiling environmental baseline data for comparison with post -oiling status; • defining and quantifying exposure to oil hydrocarbons remains speculative; • few integrated population or ecosystem studies compared to single species studies; • inability to differentiate natural ecosystem changes from oil pollution effects; and • poor understanding of long-term, chronic sublethal impacts of oil pollution.Despite these problems, recent experiences such as lessons learned from the EVOS, will lead to a more prominent role for science. There now is a body of knowledge on oil fate and effects that can assist non -specialists to understand and anticipate likely impacts, cooperate in damage assessment and remediation, and predict recovery. The utility of this information is enhanced by Parks Canada's use of GIS for coastal inventory that provides a framework for meaningful cooperation in a spill situation.

RefID: 663

Author: Smith, E.E., Carr, J.A., Wages, M., Wang, J.F., Murali, S. and Kendall, R.

Year: 2012

Title: Response of larval frogs to Corexit 9500

Journal: Toxicological and Environmental Chemistry

Hyperlink: http://www.tandfonline.com/doi/full/10.1080/02772248.2012.692553

Abstract: The use of dispersants in the Gulf of Mexico has created a number of environmental and human health concerns, chief among them are questions regarding the potential impact of Corexit 9500 on the health and fitness of Gulf wildlife. These studies were designed to use a biological toxicity test during post-fertilization and early development to evaluate Corexit 9500A effect on The Frog Embryo Teratogenesis Assay-Xenopus (FETAX) assay. Frog embryos were exposed to concentrations ranging from 1000 to 1 uL L-1 for Corexit 9500 A. Various forms of malformations were recorded following exposure to Corexit 9500. These abnormalities included pharyngeal and thoracic edema, severe optic edema, and incomplete and reversed gut coiling. The percent of males was higher in the Corexit-treated groups, while control was closer to the expected 50: 50 males to females ratio. In addition, a statistically greater number of hypomelanistic animals were observed in the Corexit-treated animals versus controls. Exposure of early life stage frogs to dispersants may exert chronic effects on health status of adults and as such consideration and evaluation of Corexit exposure to vulnerable life stages needs to be given high priority in the determination of risk and long-term impact and recovery of the ecosystem.

RefID: 664

Author: Smith, R.L. and Cameron, J.A.

Year: 1979

Title: EFFECT OF WATER-SOLUBLE FRACTION OF PRUDHOE BAY CRUDE-OIL ON EMBRYONIC-DEVELOPMENT OF PACIFIC HERRING

Journal: Transactions of the American Fisheries Society

Hyperlink: http://www.tandfonline.com/doi/abs/10.1577/1548-8659%281979%29108%3C70%3AEOWSFO%3E2.0.CO%3B2

Abstract:

RefID: 665

Author: Sogbanmu, T.O. and Otitoloju, A.A.

Year: 2014

Title: Joint Action Toxicity and Biochemical effects of Binary Mixtures of Forcados Light Crude Oil and Three Dispersants against Clarias gariepinus

Journal: International Journal of Environmental Research

Hyperlink: http://web.a.ebscohost.com/ehost/detail/detail?sid=be66de70-0226-44ff-b34c-8ec2f563f3e2%40sessionmgr4002&vid=0&hid=4207&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3d%3d

Abstract: Laboratory-scale experiments were conducted to evaluate the joint action toxicity and biochemical effects of sublethal concentrations of Forcados light crude oil (FLCO) and three dispersants against Clarias gariepinus over a period of 28 days. The derived 96hrLC(50) values revealed that the dispersant, DS/TT/066 (0.03mL/L) was the most toxic, followed by dispersant, OC/TT/OSI (0.19mL/L), FLCO (5.06mL/L) and crystal clear oil dispersant (CCOD = 12.06mL/L) the least toxic when acting singly. Joint action toxicity evaluations of FLCO and dispersants showed that the interaction between FLCO : DS/TT/066 and FLCO : OC/TT/OSI was synergistic (synergistic ratio (SR) > I) with SR values of 10.5 and 3 respectively. However, for the mixture of FLCO : CCOD, the interaction was antagonistic (SR < I) with SR value of 0.97. The result of the biochemical effects study revealed that malondialdehyde (MDA) levels decreased significantly (P<0.05) in the exposed fishes, reduced gluthathione (GSH) and gluthathione-s-transferase (GST) activities increased significantly (P<0.05) in fishes exposed to FLCO : CCOD mixture alone while there was no significant difference (p>0.05) in superoxide dismutase (SOD) and catalase (CAT) activities in all the exposed fishes compared to control animals. The observed increase in GSH and GST levels in conjunction with a decrease in MDA concentration in the liver of test animals exposed to binary mixtures of FLCO and CCOD reveals the ability of the animals to overcome the effects of lipid peroxidation in this group. Further studies on the mechanism of toxicity of these dispersants in field and laboratory assays are recommended.

RefID: 666

Author: Sol, S.Y., Johnson, L.L., Horness, B.H. and Collier, T.K.

Year: 2000

Title: Relationship between oil exposure and reproductive parameters in fish collected following the Exxon Valdez oil spill

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X00000746

Abstract: Following the Exxon Valdez oil spill (EVOS) in 1989, the effect of oil exposure on reproductive parameters was investigated in wild populations of female dolly varden, yellowfin sole, and pollock, Exposure to oil was the highest in the first year of sampling and decreased in the subsequent years of sampling, Both positive and negative correlations between reproductive parameters and indices of exposure were detected in varying degrees for all three species. Reproductive parameters were not measured in the first year of sampling. For those parameters found to be significantly correlated to oil exposure, an exponential regression function was used to project reproductive parameters of fish sampled in the first year of the spill. A higher proportion of dolly varden sampled in 1989 were projected to have depressed plasma estradiol-17 beta compared to the fish sampled in 1990, Published by Elsevier Science Ltd.

RefID: 667

Author: Solé, M., Buet, A., Ortiz, L., Maynou, F., Bayona, J.M. and Albaigés, J.

Year: 2007

Title: Bioaccumulation and biochemical responses in mussels exposed to the water-accommodated fraction of the Prestige fuel oil

Journal: Scientia Marina

Hyperlink: http://www.icm.csic.es/scimar/index.php/secId/6/IdArt/3524/

Abstract: The activity of the antioxidant defences catalase (CAT, EC 1.11.1.6), glutathione peroxidase (t-GPX, EC 1.11.1.9), glutathione reductase (GR, EC 1.6.4.2), phase II glutathione S-transferase (GST, EC 2.5.1.18) along with the NADPH-dependent cytochrome c (CYP) reductase (EC 1.6.2.4), NADH-dependent cytochrome c reductase (EC 1.6.2.2), and NADH-dependent ferricyanide (b(5)) reductase (EC 1.18.1.1) was determined in the digestive gland of mussels Mytilus galloprovincialis fed with Tetroselmis sp. pre-exposed to the water accommodated fraction of the Prestige oil. Mussel gills were also used for measuring acetylcholinesterase activity (AChE, EC 3.1.1.7) and lipid peroxidation (LP) as an indication of neurotoxicity and oxidative stress damage respectively. Bioaccumulation of the selected polycyclic aromatic hydrocarbons (2 to 6 rings PAHs) in mussels after 2, 4, 7 and 10 days of exposure did not show any significant trend; the 2-3 ring PAHs were best represented (51%). A significant ($p < 0.05$) bioaccumulation in exposed mussels was only observed for some alkylated 2-3 ring PAHs. Biochemical antioxidant responses (CAT, t-GPX and GR) significantly increased over time, regardless of exposure, whereas NADH-dependent reductases and LP were affected, regardless of the length of exposure. However, due to the low solubility of the Prestige crude, the PAH levels reached in exposed mussels were not sufficient to cause a clearly associated biochemical response.

RefID: 668

Author: Solé, M., Lima, D., Reis-Henriques, M.A. and Santos, M.M.

Year: 2008

Title: Stress biomarkers in juvenile senegal sole, Solea senegalensis, exposed to the water-accommodated fraction of the "Prestige" fuel oil

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs00128-007-9289-1

Abstract: NA

RefID: 669

Author: Spies, R.B., Rice, S.D., Wolfe, D.A. and Wright, B.A.

Year: 1996

Title: The effects of the Exxon Valdez oil spill on the Alaskan coastal environment

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: The 1989 Exxon Valdez oil spill had an immediate acute effect on seabirds, bald eagles Haliaeetus leucocephalus, marine mammals, and intertidal communities in Prince William Sound and portions of the northern Gulf of Alaska. Longer-term impacts, some lasting several years or more, were found on Pacific herring Clupea pallasi, pink salmon Oncorhynchus gorbuscha, Dolly Varden Salvelinus malma, cutthroat trout 0. clarki, and the intertidal and subtidal environments in Prince William Sound. The spill and the subsequent cleanup activity also had impacts on important coastal archaeological sites, the use of marine resources by subsistence communities, and the social structure of spill-area communities. The oil was distributed over hundreds of kilometers from Blight Reef in Prince William Sound well into the Gulf of Alaska. Beached oil penetrated deeply into cobbled beaches and still persists in some areas beneath the surface layer of rocks and under mussel beds 5 years after the surface cleanup. Dispersion, recovery, transformation, evaporation, photodegradation, and especially bacterial degradation have been the main processes removing the oil from the ecosystem. The determination of injury and recovery and the restoration program were undertaken by the United States and Alaska governments through the Exxon Valdez Oil Spill Trustee Council. Several sources of uncertainty, particularly the lack of prespill data on marine resources, have hampered a full determination of the spill's effects, leading to a variety of interpretations. However, numerous species sustained significant damage, especially sea surface dwellers such as seabirds and marine mammals. The intertidal communities were severely impacted, and early life history stages of intertidally spawning fish were affected. Recovery is occurring at different rates for different species. Constraints on recovery and the underlying causes of declines apparent in some species before the spill are the subject of several ecosystem-based studies. The practical legacy from the scientific studies of resource damage assessment and restoration are a greater understanding of how a rich subarctic marine ecosystem can be affected by a large petroleum spill, provision of new and improved tools for management of natural resources, and a better understanding of the marine ecosystem of Prince William Sound and the northern Gulf of Alaska.

RefID: 670

Author: Spraker, T.R.

Year: 1990

Title: HAZARDS OF RELEASING REHABILITATED ANIMALS WITH EMPHASIS ON SEA OTTERS AND THE T-V EXXON VALDEZ OIL SPILL

Journal: U S Fish and Wildlife Service Biological Report

Hyperlink: https://openlibrary.org/books/OL24349175M/Sea_otter_symposium

Abstract: When animals are removed from the wild for rehabilitation and then released into preexisting or new habitat, many problems can occur. Of particular concern is the transmission of disease to free-ranging animals from the released animals. These can be endemic diseases of the rehabilitated animals or diseases that were acquired during trapping, handling, and rehabilitation procedures. Numerous problems can result from such disease exposure, including death of an animal and the animal becoming a disease carrier, which could make the animal diseased in times of low nutrition or stress and allow it to transmit disease to its offspring or to other species. I discuss examples of these conditions as they relate to the sea otter (Enhydra lutrls) release program after the T/V Exxon Valdez oil spill. The potential exposure to disease for the rehabilitated sea otters was overwhelming. I believe the decision to release rehabilitated sea otters into Prince William Sound and the Kenai Peninsula was probably not wise.

RefID: 671

Author: Springman, K.R., Short, J.W., Lindeberg, M.R., Maselko, J.M., Khan, C., Hodson, P.V. and Rice, S.D.

Year: 2008

Title: Semipermeable membrane devices link site-specific contaminants to effects: Part 1 – Induction of CYP1A in rainbow trout from contaminants in Prince William Sound, Alaska

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0141113608001785

Abstract: Extracts from semi-permeable membrane devices (SPMDs) deployed on beaches in Prince William Sound (PWS), Alaska, were used to evaluate if complex contaminant mixtures from different sources can be distinguished by the resulting cytochrome P450 1A (CYP1A) activity in exposed test animals. Deployment sites included canneries, salmon hatcheries, and beaches where lingering oil remains from discharges during the 1964 earthquake or the 1989 Exxon Valdez oil spill. Other sites were selected at random to evaluate region-wide contaminant inputs or were located in salmon streams to evaluate contaminants carried and released by migrating salmon carcasses following reproduction. Following standard deployments of approximately 28 d, an aliquot of the accumulated contaminants was intraperitoneally injected without cleanup into juvenile rainbow trout (Oncorhynchus mykiss). After 2 d and 7 d, the activity of CYP1A was measured by the ethoxyresorufin-o-deethylase (EROD) assay. Exposure to extracts from the oiled sites and one hatchery site with numerous creosote pilings elicited strong EROD responses, whereas fish exposed to salmon stream extracts elicited weak but significant responses during late summer compared to late spring. Responses from the other sites were not significant, indicating contaminants from these sources are unlikely to cause CYP1A induction in resident biota. Rather than simply assessing extant contaminants, this method evaluates the potency of the different sites for bringing about aryl hydrocarbon receptor responses in resident biota.

RefID: 672

Author: Stagg, R.M., Robinson, C., McIntosh, A.M., Moffat, C.F. and Bruno, D.W.

Year: 1998

Title: The effects of the 'Braer' oil spill, Shetland Isles, Scotland, on P4501A in farmed Atlantic salmon (Salmo salar) and the common dab (Limanda limanda)

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0141113698000142

Abstract: This paper describes the response of two fish species, the Atlantic salmon (Salmo salar) and the common dab (Limanda limanda) to the oil spilled from the Braer tanker which grounded on the southern tip of Shetland, Scotland, on 5 January 1993. Both the immediate sublethal effects and the long-term response to the oil which accumulated in sediments around the Shetland Isles, Scotland, are examined. The primary, response measured was the induction of detoxification enzymes and the relationship of the levels or activities of these enzymes to the concentration and distribution of aromatic hydrocarbons measured in sediments, water and fish. The results show that, immediately following the spill, there was a marked induction of Cytochrome P4501A enzymes in salmon, indicative of exposure to bioavailable aromatics. In dab there was evidence of induction at some sites in January 1993 immediately following the spill brit, subsequently,, no induction has been observed in fish caught in the vicinity of Shetland despite the very high concentrations of oil measured in sediments at some locations. This would indicate that the polyaromatic hydrocarbons in these sediments are unlikely to be directly, bioavailable to fish. The effect of the oil spill on hepatic pathology in dab was investigated and shells that pathology, predictive of neoplasia, such as basophilic foci and vacuolation, were observed in fish from the most contaminated sites in 1994 but not in 1993. The incidence of this pathology appeared to correlate with the degree of contamination at the sites, but additional studies are required to establish whether this was a consequence of the initial impact and exposure from waterborne oil at the time of the spill or whether it was die to the continued exposure to oil from the sediments.

RefID: 673

Author: Stagg, R.M., Rusin, J., McPhail, M.E., McIntosh, A.D., Moffat, C.F. and Craft, J.A.

Year: 2000

Title: Effects of polycyclic aromatic hydrocarbons on expression of CYP1A in salmon (Salmo salar) following experimental exposure and after the Braer oil spill

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620191126/abstract;jsessionid=F4AD1FC02820A74CFC4

CF1E57E47C52F.f02t04

Abstract: The induction of hepatic CYP1A by selected polycyclic aromatic hydrocarbons (PAHs) was followed in Atlantic salmon (Salmo salar) by measurement of CYP1A messenger RNA (mRNA), CYP1A protein levels, and catalytically by the measurement of 7-ethoxyresorufin-O-deethylase activity. There was clear correspondence between all three methods of measurement both in terms of the specificity of response to five- and some four-ring PAHs and in terms of the dose-response relationship to methylcholanthrene. The level of induction was compared with that measured in salmon confined in sea pens around Shetland and exposed to crude oil spilled from the Braer in January 1993. This oil was rapidly dispersed by the extreme weather (turbulence) at the time of the spill. The time course of the hepatic CYP1A induction was followed and related to the levels of oil measured in water and the concentration of PAHs determined in the flesh of the fish. Again there was a good correspondence between the different methods of measuring CYP1A expression, and the results show a rapid induction response in fish at the most contaminated sites and small; insignificant changes occurring at the reference stations. There was a clear concentration response between CYP1A and catalytic activity and between the exposure observed.

RefID: 674

Author: Stantec

Year: 2012

Title: Summary of Clean up and Effects of the 2007 Spill of Oil from Trans Mountain Pipeline to Burrard Inlet

Journal: Stantec, 111 Dunsmuir St. #1100, Vancouver, BC V6B 6A3

Hyperlink: https://www.transmountain.com/westridge-2007-spill

Abstract: On July 24, 2007, third party contact with the Trans Mountain Pipeline operated by Kinder Morgan Canada resulted in the release of crude oil onto Inlet Drive in Burnaby BC. Oil travelled through the storm drain system into Burrard Inlet. Three general areas were affected: 1) the residential area; 2) the foreshore of Burrard Inlet; and 3) Kask Creek. This fact sheet summarizes the activities and environmental conditions associated with the spill for the foreshore area, which was the main marine area affected. Information is provided about: (1) The oil release, immediate spill responses and subsequent remediation activities; (2) Short-term effects of the spill; (3) Establishment of endpoints for recovery; (4) Long term monitoring as follow-up for the spill, and attainment of recovery endpoints; (5) A summary of response activities and effects on Kask Creek; (6) Recommendations for spill preparedness; and (7) A list of reports documenting the environmental impacts, endpoints for recovery and long-term monitoring. The emergency response and follow up remediation at the Westridge release site were effective in removing the released oil from the environment and limiting the short term and long term effects of the spill. By 2011, most of the recovery endpoints established for the spill had been met (water quality in 2007; intertidal sediment quality, PAH levels in crab and intertidal community structure in 2011). PAH levels in mussels collected at Westridge have not yet met the endpoint; however, results are confounded due to the influence of PAHs from unrelated, third party sources such as urban runoff and vessel traffic; monitoring of this component continues. Intertidal communities in two areas near the terminal were disturbed in 2007 by removal of oiled vegetation; although community structure (dominated by the seaweed Fucus, with associated benthic invertebrates) has recovered, monitoring will continue to assess variability in the affected areas.

RefID: 675

Author: Steadman, B.L., Farag, A.M. and Bergman, H.L.

Year: 1991

Title: EXPOSURE-RELATED PATTERNS OF BIOCHEMICAL INDICATORS IN RAINBOW-TROUT EXPOSED TO NO-2 FUEL-OIL

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620100309/abstract

Abstract: Several biochemical indicators were evaluated as monitoring techniques in rainbow trout (Oncorhynchus mykiss) exposed to No. 2 fuel oil (2FO) for their ability to predict the exposure concentration. The principal factor affecting the response of the ratio of liver weight to body weight, microsomal and cytosolic protein, reduced glutathione (GSH), 7-ethoxyresorufin O-deethylation (EROD) and metallothionein (MTN) was the length of exposure, not the exposure concentration. Two patterns of response were observed, depending on the length of exposure. In rainbow trout exposed for 3 d to 12 to 100 mg/L 2FO, cytoplasmic protein and EROD activity were elevated and GSH was depleted; in fish exposed for 21 d, liver size, microsomal and cytoplasmic protein, EROD activity, GSH and MTN were all increased. The appearance of an MTN response due to 2FO exposure causes us to question the use of this protein as a metal bioindicator. Furthermore, we did not observe a dose-dependent response in any of the biochemical responses and suggest that toxicity was responsible for the lack of concentration dependence. This lack of a concentration-dependent response will complicate the use of these biochemical indicators in a biomonitoring program.

RefID: 676

Author: Steadman, B.L., Stubblefield, W.A., LaPoint, T.W., Bergman, H.L. and Kaiser, M.S.

Year: 1991

Title: DECREASED SURVIVAL OF RAINBOW-TROUT EXPOSED TO NO-2 FUEL-OIL CAUSED BY SUBLETHAL PREEXPOSURE

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.v10:3/issuetoc

Abstract: Rainbow trout (Oncorhynchus mykiss) were exposed for 21 d to sublethal levels of No. 2 fuel oil (2FO). The four exposure concentrations ranged from 12 to 100 mg/L 2FO dispersed in water and resulted in 0 to 12% mortality. Following this exposure period (preexposure) the ability of preexposed trout to survive exposure to acutely lethal levels of 2FO was observed. Preexposure to either 50 or 100 mg/L 2FO consistently resulted in decreased survival and a lower LC50 for a given observation period. Unfortunately, because the LC50 determinations were not obtained independently, they could not be used to test statistically the effects of preexposure on survival. Therefore, two proportional hazard modeling techniques were applied to the data to test for effects due to preexposure. Both modeling techniques indicated that preexposure results in decreased survival of rainbow trout exposed to acutely toxic levels of 2FO. Thus, in contrast to preexposure to metals, which results in acclimation, preexposure to 2FO results in decreased survival.

RefID: 677

Author: Stekoll, M.S. and Deysher, L.

Year: 1996

Title: Recolonization and restoration of upper intertidal Fucus gardneri (Fucales, Phaeophyta) following the Exxon Valdez oil spill

Journal: Hydrobiologia

Hyperlink: ../../../../../C:/Users/toughbook/AppData/Roaming/Microsoft/Downloads/link.springer.com/article/10.1007/BF00047824

Abstract: The Exxon Valdez oil spill in March 1989 and subsequent cleanup caused injury to intertidal Fucus gardneri populations especially in the upper intertidal. A survey in 1994 in Prince William Sound, Alaska showed that the upper boundary of Fucus populations at oiled sites was still an average of 0.4 m lower than the upper boundary at unoiled sites. Restoration of severely damaged Fucus populations was started on a small-scale at a heavily oiled rocky site in Herring Bay, Prince William Sound. Experiments employed mats of biodegradable erosion control fabric to act as a substratum for Fucus germlings and to protect germlings from heat and desiccation stress. A series of plots was covered with mats made from a resilient coconut-fiber fabric in June 1993. Half of the mats were inoculated with Fucus zygotes. A series of uncovered control plots was also monitored. There was no enhancement of Fucus recruitment on the rock surfaces under the mats. Dense populations of Fucus developed on the surface of all of the mats by the summer of 1994. The natural rock surfaces in the control plots, both inoculated and not, were barren of macroscopic algal cover. By September 1994, the juvenile thalli on the mats were approximately 2 cm in length. Inoculating the mats had an effect only in the upper region of the intertidal. It is expected that the thalli will become fertile during the 1995 season. These thalli may serve as a source of embryos to enhance the recovery of new Fucus populations in this high intertidal area.

RefID: 678

Author: Stekoll, M.S. and Deysher, L.

Year: 2000

Title: Response of the Dominant Alga Fucus gardneri (Silva) (Phaeophyceae) to the Exxon Valdez Oil Spill and Clean-up

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X00000473

Abstract: The Coastal Habitat Injury Assessment Study was initiated to assess injury to and recovery of intertidal habitats affected by the Exxon Valdez oil spill, 1989, and subsequent clean-up. The spill area was divided into three major regions: Prince William Sound (PWS), Cook Inlet-Kenai (CIK) and Kodiak–Alaska Peninsula (KAP) and distinct habitat types within the area. The dominant intertidal macrophyte, Fucus gardneri, was impacted over the entire area of the spill, although observed differences varied across regions, habitats, and tidal heights. Generally F. gardneri biomass and percent cover were reduced in most habitats. However, at the low intertidal in CIK sheltered rocky habitat, the F. gardneri population was enhanced at the expense of annuals. Thalli of F. gardneri at oiled sites were not as reproductively competent as those at reference sites. Population structures were also altered. A greater proportion of adult F. gardneri thalli had attached epiphytes in oiled sites. Additional data collected during 1992–1994, indicate varying rates of recovery for F. gardneri populations.

RefID: 679

Author: Stekoll, M.S., Deysher, L., Highsmith, R..C, Saupe, S.M., Guo, Z.Y., Erickson, W.P., McDonald, L. and Strickland, D.

Year: 1996

Title: Coastal habitat injury assessment: Intertidal communities and the Exxon Valdez oil spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: This paper summarizes results of intertidal community studies from the Natural Resource Damage Assessment, Coastal Habitat Injury Assessment (CHIA) Project carried out from spring 1990 through summer 1991. Injuries to the intertidal plant and invertebrate populations by the Exxon Valdez oil spill and subsequent cleanup treatment activities were documented over the entire area of the spill, from Prince William Sound to the Alaska Peninsula. A stratified random sample of oiled sites was selected and populations on matching reference (control) sites were compared. Statistically significant differences between oiled-treated and reference sites are interpreted as injury resulting from the oil spill. These differences are summarized for algal and invertebrate variables, such as percent cover. biomass, and abundance. Results indicate that the oil spill and subsequent cleanup treatment had serious effects that were evident throughout the entire region, at least until 1991, when the study ended. The organisms most often showing differences between oiled-treated and reference sites included /rums, Limpets, mussels, barnacles, littorine gastropods, and oligochaetes. However, the responses of the intertidal biota to the oil spill and treatment varied depending on the tidal elevation, habitat, and region. As of 1991 recovery of the intertidal biota showed varying patterns for the oiled-treated sites depending on the tide level, habitat, and region. Additional monitoring is needed to determine complete recovery of these affected areas.

RefID: 680

Author: Stubblefield, W.A., Hancock, G.A., Ford, W.H., Prince, H.H. and Ringer, R.K.

Year: 1995

Title: Evaluation of the Toxic Properties of Naturally Weathered Exxon Valdez Crude Oil to Surrogate Wildlife Species

Journal: Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters

Hyperlink: http://www.valdezsciences.com/dspArticle.cfm?catID=8&artID=1071&artSecID=1111

Abstract: The toxic properties of naturally weathered Exxon Valdez crude oil (WEVC) to avian and mammalian wildlife species were evaluated using the surrogate species, mallard duck, Anas platyrhynchos, and European ferret, Mustela putorius. This study was conducted to evaluate the potential for toxic (rather than physical) injury to wildlife species that may have been exposed to WEVC, either through external contact or through dietary uptake. Previous studies have assessed the toxicity of unweathered crude oils, including Alaskan North Slope Crude, but little information exists regarding the toxicity of a naturally weathered crude oil, typical of that encountered following a spill.A battery of laboratory toxicity tests was conducted, in compliance with standard and published test procedures, to evaluate acute and subchronic toxicity of WEVC. These included tests of food avoidance, reproductive effects, and direct eggshell application toxicity. Naturally weathered EVC, recovered postspill from Prince William Sound, was used as the test material. No treatment-related mortalities or gross signs of toxicity were noted in ducks at oral doses of 5,000 mg/kg body weight or at dietary concentrations up to 100,000 ppm (mg WEVC/kg diet), or in ferrets at oral doses up to 5,000 mg/kg body weight. Test animals did not avoid oil-contaminated food. No significant adverse effects were noted in birds fed diets containing up to 2,000 mg WEVC/kg diet in the reproductive toxicity test. However, significant reductions in mean eggshell thickness and strength were observed in birds fed 20,000 mg WEVC/kg diets. Applications of up to 92 mg/egg of WEVC to developing eggs produced no toxic effects. Feeding weathered EVC to ducks and ferrets at oral doses or dietary concentrations exceeding those representing maximum likely field exposures from heavily affected spill areas did not significantly affect survival, growth, or reproduction. These results suggest that naturally weathered EVC posed little toxic risk to wildlife consuming oil or oiled food items following the Exxon Valdez spill, particularly considering the environmental exposure conditions that existed in the spill-affected area after 1989.

RefID: 681

Author: Stubblefield, W.A., McKee, R.H., Kapp, R.W. and Hinz, J.P.

Year: 1989

Title: An evaluation of the acute toxic properties of liquids derived from oil sands

Journal: Journal of Applied Toxicology

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/jat.2550090111/abstract

Abstract: The acute toxicity of three materials derived from Athabasca Oil Sands--(1) bitumen plus naphtha, (2) untreated naphtha (0-250°C) and (3) synthetic crude oil (0-500°C)-- was assessed in a battery of tests. In acute oral studies, all three test materials exhibited a low order of toxicity (LD50 > 5.0 g kg-1). The acute dermal LD50 was also low (> 3 g kg-1) for each test material. All three materials were judged to be 'slight' ocular irritants. Acute inhalation studies (6-h exposures at the maximum attainable concentrations) produced varied responses. Bitumen plus naphtha administered at a concentration of 1.46 mg l-1 did not cause mortality in exposed rats or mice. Lung discoloration was the only necropsy finding of note. Untreated naphtha administered at a concentration of 10.6 mg l-1 was lethal to essentially all of the mice; but only two rats died. Necropsy findings included elevated weights in the liver and kidneys of the exposed mice, elevated lung weights in male rats and elevated liver weights in female rats. Synthetic crude oil administered at a concentration of (4 mg l-1) was lethal to 5/10 mice, but none of the rats (0/10) died. Severe hair loss was noted in the surviving mice, and slight alopecia was also observed in rats. Both species exhibited elevated liver weight, and elevated lung weight was noted in female rats.

RefID: 682

Author: Sturdevant, M.V., Wertheimer, A.C. and Lum, J.L.

Year: 1996

Title: Diets of juvenile pink and chum salmon in oiled and non-oiled nearshore habitats in Prince William Sound, 1989 and 1990

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: The diets of juvenile pink salmon Oncorhynchus gorbuscha and chum salmon 0. keta were studied in nearshore habitats in oiled and non-oiled areas of Prince William Sound after the March 1989 Enron Valdez oil spill. Food consumption by pink and chum salmon did not decrease in the presence of oil. Stomach fullness and food quantity were similar in oiled and non-oiled areas in both 1989 and 1990. Oil globules or sheen were observed, however, in the stomachs of pink and chum salmon from oiled sites in 1989. Because no oil was observed in fish stomachs from non-oiled sites in 1989 or from any site in 1990, these observations suggest that ingested oil could be a route of hydrocarbon contamination. Zooplankton averaged 69% of pink and 56% of chum salmon diet biomass in the 2 years. Small and large calanoid copepods were the primary zooplankters consumed by pink and chum salmon, respectively. Diets in oiled and non-oiled areas changed from 1989 to 1990. Pink salmon fed more on zooplankton in oiled areas than in non-oiled areas in 1989. Both pink and chum salmon fed less on zooplankton in oiled areas than in non-oiled areas in 1990. Conversely, both species ate epibenthic prey less in oiled areas in 1989, and more in oiled areas in 1990. These interannual changes in diet between oiled and non-oiled areas could have been caused by differences in distribution of fish, by interannual variation in prey availability, or by effects of oil.

RefID: 683

Author: Suderman, K. and Thistle, D.

Year: 2004

Title: The relative impacts of spills of two alternative fuels on the microalgae of a sandy site: a microcosm study

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X0400089X

Abstract: Electric power generation in the United States uses substantial amounts of fuel oil #6. Orimulsion((R)), an emulsion of bitumen, water, and a surfactant, is an alternative. A portion of the information that managers need to compare the two fuels is their relative environmental impacts. Both fuels are shipped by sea, so the impact of spills on the marine benthos is a concern. We used microcosms to assess the relative impacts of simulated spills of these fuels on the microalgae of shallow subtidal sandy bottoms. Response variables included microalgal abundance, primary productivity, ratio of chlorophyll a to phaeophytin, and ratio of primary production to chlorophyll a. During our 88-day experiment, we found no significant differences between the fuels for any variable. We suggest that weathering before the spill reaches the shore removes the most toxic components, rendering the fuels essentially equal in their impact on benthic microalgae. (C) 2004 Elsevier Ltd. All rights reserved.

RefID: 684

Author: Sundberg, H., Ishaq, R., Tjärnlund, U., Åkerman, G., Grunder, K., Bandh, C., Broman, D. and Balk, L.

Year: 2006

Title: Contribution of commonly analyzed polycyclic aromatic hydrocarbons (PAHs) to potential toxicity in early life stages of rainbow trout (Oncorhynchus mykiss)

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f06-034

Abstract: In a series of bio-effect-directed fractionation experiments, we investigated the potential toxicity of sediment extracts from a contaminated bay. A previous study investigated abnormalities and hepatic ethoxyresorufin O-deethylase (EROD) activities in rainbow trout (Oncorhynchus mykiss) larvae by

exposing newly fertilized eggs to the total extract and to fractions separated by degree of aromaticity. A major part of the potential toxicity was isolated in a fraction containing polycyclic aromatic compounds (PACs). In this study, we prepared a synthetic PAC mixture with 17 commonly analyzed polycyclic aromatic hydrocarbons (PAHs) in amounts equimolar to those found in the sediment PAC fraction. The 17 PAHs, which included 11 of the 16 United States Environmental Protection Agency (US EPA) priority PAHs, were unable to account for the toxicopathic effects observed and could explain less than 4% of the total EROD induction. The lack of a clear relationship between toxicopathic effects and EROD induction underlines the need for a battery of biomarkers for estimating environmental risk. These results reveal the limits of our knowledge regarding compounds responsible for potential toxicity in field situations.

RefID: 685

Author: Svecevičius, G., Kazlauskienė, N. and Vosylienė, M.Z.

Year: 2003

Title: Toxic effects of orimulsion on rainbow trout Oncorhynchus mykiss

Journal: Environmental Science and Pollution Research

Hyperlink: http://link.springer.com/article/10.1065%2Fespr2003.06.157

Abstract: Goal, Scope and Background. Orimulsion (stable emulsion of natural bitumen and water) is a new imported industrial fuel in Lithuania. No data on its toxicity to fish is freely available. The aim of this study was to investigate sensitivity of rainbow trout (Oncorhynchus mykiss) to acute and chronic toxicity of orimulsion and to estimate the Maximum Acceptable Toxicant Concentration (MATC) of orimulsion to fish. Methods. Laboratory tests were conducted on rainbow trout in all stages of development (embryos, larvae, adults). Acute toxicity (96-hour duration) and long-term (28 or 60-day duration) tests evaluating the wide range spectrum of biological indices were performed under semi-static conditions. Results and Discussion. Median lethal concentration (96-hour LC50) values and their 95% confidence intervals derived from the tests were: 0.1 (0.09-0.12) to embryos, 0.06 (0.05-0.07) to larvae and 2.22 (2.02-2.43) to adult fish, and 28-day LC50 to adult fish was found to be 0.26 (0.21-0.32) g/l of total orimulsion respectively. The acute toxicity of orimulsion to rainbow trout can be characterised by a narrow zone of toxic effect and a sharp boundary between lethal and sublethal concentrations. The lowest 'safe' or 'no-effect' concentration values of total orimulsion obtained in long-term tests were equal to 0.09 g/l to adult fish, 0.019 g/l to embryos, and 0.0017 g/l to larvae. Proposed value of 'application factor' for orimulsion was found to be equal to 0.03. Since orimulsion has the property to disperse in all water volume, its toxic effect on fish can be characterised by the combined effects of dispersion and water-soluble-fraction. Conclusions. Maximum Acceptable Toxicant Concentration (MATC) of 0.0017 g/l of total orimulsion to fish was derived from long-term tests based on the most sensitive parameter of rainbow trout larvae (relative mass increase at the end of the test). According to substance toxicity classification accepted for Lithuanian inland waters, orimulsion can be referred to substances of 'moderate' toxicity to fish. Recommendations and Outlook. For prediction and evaluation of toxic impact of orimulsion accident spills on fish, some recommendations should be given. Since orimulsion has the property to disperse in all water volume during short time periods, the amounts of both spilled orimulsion and polluted water should be ascertained. Once both parameters are known, the real concentration of orimulsion in the water body must be determined. Then this concentration must be compared with 'safe' concentration to fish. By use of 'application factor' 0.03, approximate MATC for other fish species can be estimated when only acute toxicity data (96-hour LC50 value) is available.

RefID: 686

Author: Swannell, R.P.J., Mitchell, D., Lethbridge, G., Jones, D., Heath, D., Hagley, M., Jones, M., Petch, S., Milne, R., Croxford, R. and Lee, K.

Year: 1999

Title: A field demonstration of the efficacy of bioremediation to treat oiled shorelines following the Sea Empress incident

Journal: Environmental Technology

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/09593332008616881

Abstract: Bioremediation was investigated as a method of treating a mixture of Forties Crude Oil and Heavy Fuel Oil stranded on Bullwell Bay, Milford Haven, UK after the grounding of the Sea Empress in 1996. A randomised block design in triplicate was used to test the efficacy of two bioremediation treatments: a weekly application of mineral nutrients dissolved in seawater and a single application of a slow-release fertilizer. Each treatment supplied an equivalent amount of nitrogen and phosphorus. Concentrations of residual hydrocarbons normalised to the biomarker 17 alpha(H),21 beta(H)-hopane showed that after two months the oil was significantly ($p<0.001$) more biodegraded in the treated plots than in the controls. On average, the oil in the nutrient amended plots was 37% more: degraded than that found in the controls. There was no evidence that the bioremediation treatments increased the toxicity of the oiled sediment. The results confirm that bioremediation can be used to treat a mixture of crude and heavy fuel oil on a pebble beach. In particular, the data suggest that the application of a slow-release fertilizer alone may he a cost-effective method of treating low-energy, contaminated shorelines after a spill incident.

RefID: 687

Author: Swanton, C.O., Dalton, T.J., Barrett, B.M., Pengilly, D., Brennan, K.R. and Nelson, P.A.

Year: 1993

Title: Effects of pink salmon (Oncorhynchus gorbuscha) escapement level of egg retention, preemergent fry, and adult returns to the Kodiak and Chignik management areas caused by the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33088140.pdf

Abstract: Potential impacts of overescapement on several life history stages of pink salmon from streams located within the Kodiak and Chignik commercial salmon fishing areas were studied. The 1989 pink salmon escapement for Kodiak was 21.0 million (odd-year escapement goal 4.7 million) and for Chignik 1.4 million fish (odd-year escapement goal 0.7 million).Measurements of egg retention, fecundity, stream residence time (stream life), total available spawning habitat, and preemergent fry densities were obtained. Egg retention was found to bepositively related to spawner density; observed 1990 preemergent fry densities were significantlybelow predicted values for 23 Kodiak and 7 Chignik streams indicating reduced spawner successfor some streams. Return per spawner analyses for Kodiak showed a significant densitydependent response, however no such result was found for the Chignik data. Overall no conclusive evidence of reduced production of pink salmon adults from the 1989 escapement event was found.

RefID: 688

Author: Swigert, J.P., Lee, C., Wong, D.C.L. and Podhasky, P.

Year: 2014

Title: Aquatic hazard and biodegradability of light and middle atmospheric distillate petroleum streams

Journal: Chemosphere

Hyperlink: http://www.sciencedirect.com/science/article/pii/S004565351400232X

Abstract: Light and middle atmospheric distillate petroleum substances are blended to produce fuels used in transportation and heating. These substances represent the majority by volume of crude oil refined products in the United States. The goal of this research was to develop biodegradability and aquatic toxicity data for four substances; heavy, straight-run naphtha (HSRN), hydro-desulfurized kerosene (HDK), hydro-cracked gas oil (HCGO), and catalytic-cracked gas oil (CCGO). Ready biodegradability tests demonstrated rapid and extensive microbial oxidation of these test substances, indicating a lack of persistence in the aquatic environment. Differences in biodegradation patterns reflected compositional differences in the constituent hydrocarbons. Results of aquatic toxicity tests on alga, cladocera, and fish demonstrated that toxicity was greatest for catalytic-cracked gas oil, which contained a high proportion of aromatic hydrocarbons. Aromatic hydrocarbons are more soluble, and hence more bioavailable, resulting in higher toxicity. When expressed on the basis of loading rates, acute toxicity values (LL/EL50) ranged between 0.3 and 5.5 mg L-1 for all three species, while chronic no-observed-effect loading rates (NOELR) ranged between 0.05 and 0.64 mg L-1. PETROTOX estimates for acute and chronic toxicity ranged from 0.18 to 2.3 mg L-1 and 0.06 to 0.14 mg L-1. respectively, which were generally more conservative than experimental data. (C) 2014 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-SA license (http://creativecommons.org/licenses/by-nc-sa/3.0/).

RefID: 689

Author: Tarbox, K.E., Davis, R.Z., Brannian, L.K. and Fried, S.M.

Year: 1995

Title: Kenai River sockeye salmon restoration, Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project94255)

Journal: EVOS Trustee Council

Hyperlink: http://www.evostc.state.ak.us/index.cfm?FA=searchResults.projectInfo&Project_ID=854

Abstract: Greatly reduced fishing time in the Upper Cook Inlet (UCI) area due to EVOS caused sockeye salmon spawning escapement levels in the Kenai River system to exceed the desired amount by three times. Data collected by the Natural Resources Damage Assessment following the EVOS indicated greatly reduced survival of juvenile sockeye salmon during the winter-spring rearing period. Overpopulated rearing juvenile sockeye salmon may have exceeded the carrying capacity of salmon rearing lakes, affecting all trophic levels in the lakes. Limiting sockeye salmon fry production by closely regulating the number of spawning adults may be the only way to restore the productivity of these rearing areas. The goal of this project is to restore Kenai River sockeye salmon stocks injured by the EVOS through improved stock assessment capabilities, more accurate regulation of spawning levels, and modification of human use. Kenai River System sockeye salmon will be identified by Genetic Stock Identification (GSI) techniques. Abundance estimates will be made using hydroacoustic techniques developed in 1992 and 1993.

RefID: 690

Author: Taylor, C., Ben-David, M., Bowyer, R.T. and Duffy, L.K.

Year: 2001

Title: Response of river otters to experimental exposure of weathered crude oil: Fecal porphyrin profiles

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es001298w

Abstract: Profiles of porphyrins were characterized in fecal samples from river otters (Lontra canadensis) experimentally exposed to weathered crude oil to determine effects on heme synthesis. Fifteen male river otters were randomly assigned to th ree groups of five individuals each representing a control group, a low-dosage group that received 5 mg/ kg body mass of oil per day, and;a high-dosage group that received 50 mg/kg body mass of oil per day. Mean levers of coproporphyrin III (CoproIII) and protoporphyrin IX (ProtoIX) in fecal samples collected from all experimental river otters were higher throughout the experimental period than levels of CoproIII and ProtoIX in fecal samples collected previously at two field sites. No statistically significant differences in levels of CoproIII and ProtoIX were observed between treatment groups, although a trend of reduction in variability in CoproIII was observed in the low- and high-dose groups. We found no relation. between levels of CoproIII and ProtoIX, suggesting that the process of disruption that leads to oxidation of the precursors of porphyrins is probably nonlinear. Our results also indicate that the interaction between oiled induced reduction in hemoglobin levels and induction of CYP1A1 corresponded with significantly lower levels of ProtoIX in the fecal samples, possibly representing high demand for ProtoIX. Therefore, while this experiment does not support the use of porphyrin profiles as an individual biomarker, it does suggest that the latter may be valuable when a weight of evidence is used in an ecotoxicological risk assessment in which the interactions between several biomarkers are explored.

RefID: 691

Author: Taylor, C., Duffy, L.K., Bowyer, R.T. and Blundell, G.M.

Year: 2000

Title: Profiles of fecal porphyrins in river otters following the Exxon Valdez oil spill

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X00000734

Abstract: Median levels of Coproporphyrin III (Copro III) in fecal samples of river otters (Lontra canadensis) collected from an oiled area in Prince William Sound, Alaska, USA, during 1990 were significantly higher than in samples collected from the same oiled area during 1996 ($p = 0.011$, one way analysis of variance), a nonoiled reference area in Prince William Sound during 1996 ($p = 0.002$) and a reference area in southeast Alaska during 1998 ($p = 0.004$), An overall test of significance that combined probabilities from the statistical analysis of this porphyrin study with those from other biomarker studies revealed a significant difference in physiological response of river otters between oiled and nonoiled areas of the Sound for 1990 ($p < 0.01$), We demonstrated that changes in levels of fecal porphyrins may serve as a biomarker that may contribute to a health assessment of wild river otters. (C) 2000 Elsevier Science Ltd. All rights reserved.

RefID: 692

Author: Thomas, M.L.H.

Year: 1973

Title: Effects of Bunker C Oil on Intertidal and Lagoonal Biota in Chedabucto Bay, Nova Scotia

Journal: Journal of the Fisheries Research Board of Canada

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f73-011

Abstract: In February 1970, a large spill of Bunker C oil occurred in Chedabucto Bay, Nova Scotia.The incident was of particular interest since large spills of this type of oil had not previouslybeen studied. Further interest was added by the unusually cold temperatures and by the nonuseof detergents in cleanup. The effects of the oil on intertidal and lagoonal biota have been followed since the accident. Many rocky shores and lagoons were heavily oiled. On exposedshores, oil has decreased steadily since oi1 stopped coming ashore in mid-1970 and by August 1971 only small amounts remained. In sheltered areas, particularly lagoons, heavy oil contaminationr emains. The summer remobilisation and subsequent redeposition of oil added achronic aspect to the pollution. Initial etrects of oil involved minor smothering of fauna andtearing loose of algae. Longer term effects involved extensive mortalities of Fucus spiralison rocky shores and Mya arenaria and Spartina alterniflora in lagoons. Other biota were not visually affected. In all three affected species, mortalities took place either continuously oronly in the second year of potrlution. Causes of death are unknown. It is recommended that in all intertidal areas very heavy oil deposits should be mechanically removed and the remainder of the oil left to natural degradation.

RefID: 693

Author: Thomas, M.L.H.

Year: 1978

Title: Comparison of Oiled and Unoiled Intertidal Communities in Chedabucto Bay, Nova Scotia

Journal: Journal of the Fisheries Research Board of Canada

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f78-121

Abstract:

RefID: 694

Author: Thomas, R.E., Brodersen, C., Carls, M.G., Babcock, M. and Rice, S.D.

Year: 1999

Title: Lack of physiological responses to hydrocarbon accumulation by Mytilus trossulus after 3-4 years chronic exposure to spilled Exxon Valdez crude oil in Prince William Sound

Journal: Comparative Biochemistry and Physiology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0742841398100993

Abstract: Mussels, Mytilus trossulus, were sampled in 1992 and 1993 from beaches in Prince William Sound that had been oiled by the Exxon Valdez spill of March, 1989. At some of the oiled beaches, mussels were collected from beds overlying oiled sediments, and from bedrock adjacent to these beds. Mussels were also collected from beaches within the Sound that had not been impacted by the spill. Polynuclear aromatic hydrocarbon (PAH) concentrations in mussel tissue, physiological responses (byssal thread production, condition index, clearance rate, and glycogen content), were determined for each group of mussels. Total PAH concentrations in mussel tissue ranged from 0 to 6 mu g g(-1), and were significantly greater in mussels from oiled beds than those from reference beds. No significant differences were noted in byssal thread production, condition index, clearance rate, or glycogen content between oiled sample sites and reference sites. The lack of physiological response was surprising because mussels in this study were chronically exposed to PAH for 3-4 years, and none of the physiological responses measured appeared to be affected by that exposure. The lack of a physiological response suggests that chronically exposed mussels may develop a physiological tolerance to PAH, but we recognize that these measures may not have been sensitive enough to discriminate response from background noise. (C) 1999 Elsevier Science Inc. All rights reserved.

RefID: 695

Author: Thomas, R.E., Harris, P.M. and Rice, S.D.

Year: 1999

Title: Survival in air of Mytilus trossulus following long-term exposure to spilled Exxon Valdez crude oil in Prince William sound

Journal: Comparative Biochemistry and Physiology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0742841398100981

Abstract: Mussels, Mytilus trossulus, were sampled in 1996 from beaches in Prince William Sound (PWS) which contained residual oil resulting from the Exxon Valdez oil spill of March 1989, and from one beach which had been lightly oiled in 1989, but contained no residual oil in 1996. The latter mussels served as un-oiled references. Mussels were also collected from Tee Harbor, Southeast Alaska, to be used as an additional reference group. Where the size of the individuals in the resident population would permit, two size groups were sampled, 32-35 and 18-20 mm in length. Polynuclear aromatic hydrocarbon (PAH) concentrations in mussel tissue, and air survival time were determined for each group of mussels. Total PAH concentrations were significantly greater in tissue of mussels from oiled beds (0.6-2.0 mu g g(-1)) than from references (0.01-0.12 mu g g(-1)) ($P < 0.01$). Oil-exposed mussels had significantly lower LT50 values ($P < 0.05$) for air survival than reference groups. Tolerance of small mussels to air exposure was significantly greater ($P < 0.01$) than large mussels in both the unoiled reference and oil exposed groups. (C) 1999 Elsevier Science Inc. All rights reserved.

RefID: 696

Author: Thomas, R.E., Lindeberg, M., Harris, P.M. and Rice, S.D.

Year: 2007

Title: Induction of DNA strand breaks in the mussel (Mytilus trossulus) and clam (Protothaca staminea) following chronic field exposure to polycyclic aromatic hydrocarbons from the Exxon Valdez spill

Journal: Marine Pollution Bulletin

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/17328928

Abstract: In 2002, 13 years after the Exxon Valdez spill, mussels and clams were examined for lingering oil exposure and damage. Known oil patches were sampled at four locations, and compared to nearby reference areas (same bay), and were also compared to "hot reference" sites to verify the methods used (Cordova harbor and fresh diesel spill at Port Chalmers). Passive samplers deployed for a month at the sites, along with tissue samples, confirmed that the oiled sites were oiled (fingerprinting back to Exxon Valdez oil) and that reference sites were clean. The highest PAH loads were detected in sub-surface interstitial waters at oiled sites. Exposure at the surface was generally low level, and probably intermittent. DNA damage was assessed in blood cells using sensitive comet analyses. DNA strand breakage was detected in both mussels and clams, with the highest level of damage detected at "hot reference" sites of Cordova harbor and Port Chalmers. Bioavailability and DNA damage at the oiled sties was low, indicating there has been substantial progress in recovery from the spill 13 years before, yet low level bioavailability and damage were still detectable.

RefID: 697

Author: Thorne, R.E. and Thomas, G.L.

Year: 2014

Title: The Exxon Valdez Oil Spill and the Collapse of the Prince William Sound Herring Stock: A reexamination of Critical Biomass Estimaties

Journal: Impacts of Oil Spill Disasters on Marine Habitats and Fisheries in North America

Hyperlink: http://www.crcpress.com/product/isbn/9781466557208

Abstract: Book Chapter (no abstract)

RefID: 698

Author: Thorne, R.E. and Thomas, G.L.

Year: 2008

Title: Herring and the "Exxon Valdez" oil spill: an investigation into historical data conflicts

Journal: Ices Journal of Marine Science

Hyperlink: http://icesjms.oxfordjournals.org/content/65/1/44.abstract?sid=dd268b3a-94ef-4190-b408-091b5890f268

Abstract: It was generally believed that the 1989 "Exxon Valdez" oil spill did not cause the collapse of the Prince William Sound Pacific herring (Clupea pallasi) population because of a 4-year gap between the spill and the collapse. However, we noted in a previous paper that some data suggested an earlier timing for the herring decline. We examine historical patterns of herring spawn, anomalies in historical fisheries model predictions, changes in predation behaviour of Steller sea lions (Eumetopias jubatus), and a decadal database of acoustic measurements of herring biomass. Behaviour of adult herring makes them especially vulnerable to damage from oil spills, something that was either unknown or misunderstood at the time of the spill. We therefore argue that the start of the herring decline was coincident with the oil spill, and that the decline took place over a 5-year period, rather than the single-year collapse previously reported. Although a comprehensive management approach is now in use for herring, the tools were not in place at the time of the oil spill or the subsequent collapse.

RefID: 699

Author: Trowbridge, C., Baker, T.T. and Johnson, J.D.

Year: 2001

Title: Effects of hydrocarbons on bivalves following the Exxon Valdez oil spill

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/51589227.pd

Abstract: We examined the effects of hydrocarbons on bivalve populations in Prince William Sound, Kenai Peninsula, Kodiak Island, and the Alaska Peninsula following the Exxon Valdez oil spill. The majority of sampling sites were exposed to low levels of aromatic hydrocarbons. One designated control site (Simpson Bay) was also partially contaminated by refined petroleum hydrocarbons. Bivalve tissues at oiled sties were found to have high levels of aromatic hydrocarbons. However, clam tissues were not severely affected histopathologically either in 1989 or 1990. We were unable to determine mortality rates of bivalves during this study. Growth rates of littleneck clams decreased as the levels of aromatic hydrocarbons increased. Growth rates of littleneck clams also decreased as tide level increased. There were no significant differences in recruitment of young-of-the-year (YOY) littleneck clams between control and oiled sites in Prince William Sound. The initiation of future studies is recommended to study bivalve populations throughout Prince William Sound, Cook Inlet, Kodiak Island, and the Alaska Peninsula to provide baseline information in the event of another oil spill.

RefID: 700

Author: Tsaprailis, H.

Year: 2014

Title: Properties of Dilbit and Conventional Crude Oils

Journal: Alberta Innovates

Hyperlink: https://www.google.ca/webhp?sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8

Abstract:

RefID: 701

Author: Tsomides, H.J., Hughes, J.B., Thomas, J.M. and Ward, C.H.

Year: 1995

Title: EFFECT OF SURFACTANT ADDITION ON PHENANTHRENE BIODEGRADATION IN SEDIMENTS

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.5620140605/abstract

Abstract: A laboratory study was conducted to determine whether commercial surfactants enhance the bioremediation of PAH-contaminated sediments. Phenanthrene was chosen as a representative PAH; an inoculum of PAH-degrading microorganisms, enriched from an aquatic sediment, was used in sediment-water slurry microcosm biodegradation experiments. Of seven nonionic surfactants tested, only one (Triton X-100) did not inhibit phenanthrene mineralization at concentrations above the critical micelle concentration (CMC). Temporal studies on Triton X-100 revealed that while it initially inhibited mineralization in sediment-free microcosms, after 1 week Triton X-100 slightly improved phenanthrene biotransformation and mineralization in microcosms with and without sediment. For all treatments, phenanthrene disappearance was complete after 9 d, and mineralization reached 50 to 65% after 12 d. Sorption to the sediment appears to have reduced the free aqueous surfactant concentration, thereby reducing surfactant toxicity to the microorganisms. These results suggest that many surfactants are toxic to PAH-degrading microorganisms, and while surfactant addition may not always have adverse effects on biodegradation, the use of surfactants might not be desirable to achieve complete contaminant removal.

RefID: 702

Author: Turja, R., Guimarães, L., Nevala, A., Kankaanpää, H., Korpinen, S. and Lehtonen, K.K.

Year: 2014

Title: Cumulative effects of exposure to cyanobacteria bloom extracts and benzo a pyrene on antioxidant defence biomarkers in Gammarus oceanicus (Crustacea: Amphipoda)

Journal: Toxicon

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0041010113004479

Abstract: The Baltic Sea suffers from extensive blooms of the toxic cyanobacteria Nodularia spumigena that

produces nodularin toxin (NOD). Additionally, intensification of oil transportation and related activities in the area increase the risk of oil spills. The current experiment was designed to mimic a situation where an oil spill occurs during a cyanobacterial bloom by exposing the amphipod Gammarus oceanicus to a NOD-rich cyanobacterial extract and the polycyclic aromatic hydrocarbon compound benzo[a]pyrene (B[a]P), a common constituent of oil. The activity of the antioxidant enzymes glutathione S-transferase (GST), glutathione peroxidase (GPx), catalase (CAT) and superoxide dismutase (SOD) were examined after 48 and 96 h of exposure. Exposure to low and high levels of the NOD-rich extract produced a time-dependent activation of GST, GPx and SOD. CAT levels were elevated only by high NOD treatment. Also the toxicity of B[a]P was indicated by significantly elevated antioxidant response. In the combined exposures treatment-dependent additive increases in the activity of GPx and SOD were observed as well as inhibitory (antagonistic) effects on GST, CAT and GPx. Rapid concentration-dependent accumulation of NOD by G. oceanicus was observed. The addition of B[a]P reduced the accumulation of NOD and resulted in different biomarker response patterns compared to single exposures demonstrating the effects of mixture toxicity. (C) 2013 Elsevier Ltd. All rights reserved.

RefID: 703

Author: Upton, H.F.

Year: 2011

Title: The Deepwater Horizon Oil Spill and the Gulf of Mexico Fishing Industry

Journal: Report

Hyperlink: http://fpc.state.gov/documents/organization/159014.pdf

Abstract: The Deepwater Horizon oil spill has caused significant socioeconomic injuries to the Gulf of Mexico fishing industry. Immediate economic injuries occurred because large areas of federal and state waters in or adjacent to the spill area were closed to fishing as a precautionary measure to ensure the safety of seafood. Perhaps of greater concern are intermediate and long-term harm to Gulf of Mexico ecosystems. Seafood production is dependent on Gulf ecosystems for spawning areas, nurseries, and growth.

RefID: 704

Author: Urho, L.

Year: 1990

Title: IMPACT OF AN OIL-SPILL ON HERRING STOCK

Journal: Proceedings of the International Herring Symposium

Hyperlink: https://www.researchgate.net/publication/29723546_Impact_of_an_oil_spill_on_herring_stock

Abstract: In February 1987 the tanker Antonio Gramsci ran aground near the Söderskär Islands in the Gulf of Finland (Baltic Sea); 570 tons of oil spilled into the sea, remained between the ice two months before spreading, then "disappeared". Abnormal herring larvae were frequent near the Söderskär Islands in 1987 and 1988. The occurrence of herring larvae with curvature in posterior notochord revealed oil-affected areas. Prespawning herring were collected from commercial catches and the changes in gonadosomatic (GSI) and liversomatic (LSI) indices among herring from the affected area were compared with those from the control area. In the affected area the mean size of herring livers in 1987 was twice that in the control area, while almost the opposite was noted for the mean size of ovaries. In 1987 and 1988 the differences in the means between the areas were very significant, but decreased with time; in 1989 there was no significant difference. The absolute levels changed in both areas, partly due to dissimilar samples. However, the normal seasonal reduction of enlarged livers during gonad maturation did not occur in herring from the affected area, which resulted in smaller gonads. The results demonstrated that while the oil spill affected local herring population in the Gulf of Finland, its effect on stock as a whole is not clear.

RefID: 705

Author: van den Heuvel, M.R., Hogan, N.S., Roloson, S.D. and Van Der Kraak, G.J.

Year: 2012

Title: Reproductive development of yellow perch (Perca flavescens) exposed to oil sands-affected waters

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.1732/abstract;jsessionid=7EEDEA06E1A3601833CEB8D37553DB52.f04t03

Abstract: In similar experiments conducted in 1996 and 2009, yellow perch (Perca flavescens) were stocked into two experimental systems: a demonstration lake where oil sands fine tailings were capped with natural water and a lake in a watershed containing bitumen-bearing sodic clays. In both experiments, yellow perch were captured in May from a nearby reservoir and released into the experimental ponds. Perch were recaptured in the experimental systems, the source lake, and two reference lakes in late September and lethally sampled to examine reproductive parameters. In the 1996 experiment, gonad size and steroid hormones were not affected in either pond environment. In the 2009 experiment, male perch in the water-capped tailings pond showed a significant reduction in the testicular development and reductions in circulating testosterone and 11-ketotestosterone, while no reductions were seen in the second experimental pond. No changes were observed in ovarian size or circulating steroid levels in female perch. In the pond containing tailings, the release of water from underlying tailings caused approximately a twofold increase in salinity, alkalinity, and naphthenic acids, and a pH increase from 8.4 to 9.4 over the 13-year period of the study. In the pond influenced by unextracted oil sands materials, total dissolved solids, major ions, and pH did not change substantially. However, naphthenic acids in this system dropped more than twofold postwatershed reclamation. Because the selective reproductive effect observed in male perch in the experimental end-pit lake were accompanied by increases in naphthenic acids, alkalinity, and pH, a specific cause cannot be determined. The present study adds to the evidence, suggesting the presence of endocrine-disrupting substances in oil sands. Environ. Toxicol. Chem. 2012;31:654662. (C) 2011 SETAC

RefID: 706

Author: van den Heuvel, M.R., Power, M., Richards, J., MacKinnon, M. and Dixon, D.G.

Year: 2000

Title: Disease and gill lesions in yellow perch (Perca flavescens) exposed to oil sands mining-associated waters

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651399919127

Abstract: Adult yellow perch were stocked into experimental ponds designed to test the biological effects of aquatic reclamation alternatives currently being pursued bg the oil sands mining industry, Water-quality characteristics of oil sands-influenced water in the experimental ponds included increased salinity and elevated trace organics associated with ran, oil sands (bitumen), After 3 and 10 months of exposure to affected waters, perch gross pathologies including severe fin erosion and virally induced tumors were observed in exposed individuals. Gill histopathology revealed large aneurysms accompanied by a proliferation of chloride and epithelial cells in the interlamellar spaces. Gill pathologies were not paralleled by a decrease in plasma sodium, calcium, or chloride. The frequencies of gross pathologies and gill changes were correlated to the concentrations of the oil sands-related compounds. As inorganic and organic compounds associated dth oil sands activities are highly intercorrelated, and the observed lesions and changes are not diagnostic of particular toxicants, it was not possible to isolate the causative chemical factor(s) responsible. The incidence of observed lesions and gill pathologies could not be conclusively linked to increased mortality rates observed in the exposed populations. Evidence of recovery in the pathologies nas observed between 3 and 10 months of exposure, coincident with a stabilization in population numbers. (C) 2000 Academic Press.

RefID: 707

Author: Van Scoy, A.R., Lin, C.Y., Anderson, B.S., Philips, B.M., Martin, M.J., McCall, J., Todd, C.R., Crane, D., Sowby, M.L., Viant, M.R. and Tjeerdema, R.S.

Year: 2010

Title: Metabolic responses produced by crude versus dispersed oil in Chinook salmon pre-smolts via NMR-based metabolomics

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651310000564

Abstract: Crude oil spills from tankers remain a serious threat along coastal California. Resource managers require information on the acute toxicity of treated and untreated oil, and their sublethal effects on wildlife. This investigation compared the toxic actions of the water-accommodated fraction (WAF) and the chemically-enhanced WAF (CEWAF; Corexit 9500) of Prudhoe Bay crude oil in pre-smolt Chinook salmon (Oncorhynchus tshawytscha) via nuclear magnetic resonance (NMR)-based metabolomics. Metabolite profiles from muscle samples, after 96 h exposures, were measured using 1D (1)H NMR and compared via principal component analysis. It was determined that both WAF and CEWAF produced similar profiles in which amino acids, lactate and ATP comprised the highest intensity signals. Overall, metabolic substrates and growth measurements did not show residual effects of short-term exposure on long-term development. In conclusion, the 96 h LC(50)s indicate dispersant application significantly decreased hydrocarbon potency and identified metabolites may be bio-indicators of hydrocarbon stress from hydrocarbon exposure. (C) 2010 Elsevier Inc. All rights reserved.

RefID: 708

Author: van Tamelen, P.G. and Stekoll, M.S.

Year: 1996

Title: Population response of the brown alga Fucus gardneri and other algae in Herring Bay, Prince William Sound, to the Exxon Valdez oil spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: Disturbance of populations of the brown alga Fucus gardneri and other intertidal algae by the Exton Valdez oil spill and subsequent cleanup efforts was examined with an after-event, control–impact paired design study in Herring Bay, Prince William Sound. At oiled sites, both on rocky and coarse-textured shorelines, the larger size-classes of Fucus occurred in depressed numbers in 1990, but recovered to control levels by 1992. Populations in the upper intertidal zones recovered more slowly. In some areas a transient increase in ephemeral algae preceded Fucus repopulation. Fucus reproductive potential was significantly lower in plants from oiled areas in the upper intertidal zone. Reproductive capacity of the Herring Bay Fucus population had not recovered by the end of the field season in 1993. Populations in oiled areas that were cleaned with hot water and water under high pressure showed more damage and slower recovery.

RefID: 709

Author: van Tamelen, P.G., Stekoll, M.S. and Deysher, L.

Year: 1997

Title: Recovery processes of the brown alga Fucus gardneri following the 'Exxon Valdez' oil spill: settlement and recruitment

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v160/p265-277/

Abstract: The 1989 'Exxon Valdez' oil spill and subsequent cleanup efforts left many shorelines in Prince William Sound (Alaska, USA), especially in the higher tidal zones, mostly devoid of the dominant intertidal alga Fucus gardneri. Settlement and recruitment processes of F. gardneri were studied to determine the factors that can limit F. gardneri recolonization. Zygote settlement rates were initially lower at oiled sites relative to unoiled sites, but increased to values similar to those for unoiled sites in the lower intertidal zones after 3 yr. In the upper intertidal, settlement rates after 3 yr had not yet converged with those at

unoiled sites. The low settlement rates of F. gardneri at oiled sites were probably due to low densities of reproductive plants and limited egg dispersal. Settlement was also negatively correlated to net flow of water. The effect of substrate rugosity on settlement was investigated by using grooved ceramic tiles. We found that grooves enhance survival and recruitment of germlings in the high intertidal zone. Germlings survived best initially in deep, narrow grooves. After 2 yr there were more recruits in medium width, deep grooves. Manipulation of F. gardneri canopy over tiles revealed that F. gardneri canopy ameliorated heat and desiccation stress, but a whiplash effect dislodged small plants. Overall the positive effects of canopy were stronger than the negative effects. There were no significant herbivore effects on germling survival, but both recruitment and average thallus size were increased in the absence of herbivores.

RefID: 710

Author: Varanasi, U., Chan, S.L., MacLeod, W.D., Stein, J.E., Brown, D.W., Burrows, D.G., Tilbury, K.L., Landahl, J.T., Wigren, C.A., Hom, T. and Pierce, S.M.

Year: 1990

Title: Survey of subsistence fish and shellfish for exposure to oil spilled from the Exxon Valdez, First year: 1989

Journal: NOAA TechnicalMemorandum

Hyperlink:

Abstract: More than 500 fish and shellfish samples collected from native Alaskan fishing grounds were analyzed for aromatic contaminants (ACs) from petroleum (alkylated and unsubstituted aromatic hydrocarbons with 2-7 benzenoid rings and dibenzothiophenes). Intertidal molluscs (mussels, clams, chitons, and snails) from Windy Bay, Kodiak (City), Chenega Bay,and Old Harbor consistently had more than 100 parts-per-billion (ppb) ACs, with levels in mussels from Windy Bay and Kodiak as high as 12,000 to18,000 ppb. Levels of ACs in molluscs, crabs, and sea urchins from othervillages were less than 10 ppb, a level comparable to that measured inshellfish from the designated reference area in Southeast Alaska near Angoon. Nonparametric statistics on 147 samples of molluscs showed that levels of ACs in molluscs from Windy Bay, Kodiak, and Chenega Bay were significantly higher (p £ 0.05) than those in the Angoon molluscs sampled. Of the 210 samples of edible flesh of fish analyzed in 1989, only two samples of pink salmon (Onchorhynchus gorbuscha) from Kodiak had AC levels that neared or exceeded 100 ppb. Another 11 samples of pink and coho salmon (O. kisutch) from Kodiak, Chenega Bay, Tatitlek, and Larsen Bay exceeded 10 ppb of total ACs. The levels in the edible flesh of salmon from other subsistence fishing areas and in bottomfish from all areas weregenerally comparable (less than 10 ppb) to the levels detected in the same correlated species from the reference site, near Angoon. Two samples of smoked salmon, one from Old Harbor and one from Tatitlek, contained 8,200 and 22,000 ppb of ACs, respectively. In an unofficial advisory opinion, the Food and Drug Administration has indicated that little risk is involved in the consumption of the nonsmoked subsistence foods studied. The results to date provide important information on the level of contamination of subsistence fish and shellfish from fishing areas of native Alaskan villages in and near Prince William Sound and a reference database against which future temporal changes of petroleum derived ACs in the edible flesh of fish and shellfish can beevaluated.

RefID: 711

Author: Varanasi, U., Collier, T.K., Krone, C.A., Krahn, M.M., Johnson, L.L., Myers, M.S. and Chan, S.L.

Year: 1995

Title: Assessment of oil spill impacts on fishery resources: measurement of hydrocarbons and their metabolites, and their effects, in important species

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/34496952.pdf

Abstract: Studies were conducted from 1989 to 1991 to assess injury to fisheriesresources related to the Exxon Valdez oil spill. These studies were designed todetermine exposure of fish to petroleum-derived compounds, specifically aromatichydrocarbons, and assess possible effects. Over 4000 fish were collected from >50sites in Prince William Sound, Lower Cook Inlet, and embayments along the Kenaiand Alaska Peninsulas. Biliary fluorescent aromatic compounds (FACs) and hepaticaryl hydrocarbon hydroxylase (AHH) activities were measured, and used todetermine degree of exposure of fish to aromatic compounds. The results showed continuing exposure through 1991 of several benthic fish species, which suggestedpersistent petroleum contamination of subtidal sediments. Pollock were found to have increased exposure to petroleum hydrocarbons at sites up to 400 miles fromt he spill origin, more than one year after the spill, suggesting that the spilled oil affected either the water column or food supply of these fish at great distances fromt he spill, and for some time after the spill. While major histopathological andr eproductive effects were not documented, the potential impact on fishery resourcesof long-term exposure to petroleum, albeit at moderate to low levels, could not bedetermined from these studies.

RefID: 712

Author: Vieira, L.R. and Guilhermino, L.

Year: 2012

Title: Multiple stress effects on marine planktonic organisms: Influence of temperature on the toxicity of polycyclic aromatic hydrocarbons to Tetraselmis chuii

Journal: Journal of Sea Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/S1385110112000196

Abstract: In the present context of global warming and increasing long-range transport of oil and goods by sea potentially resulting in oil spills, more knowledge on the toxicological interactions between temperature and oil components on marine organisms is urgently needed. Therefore, the effects of temperature increase on the toxicity of three polycyclic aromatic hydrocarbons (PAH; anthracene, phenanthrene and naphthalene) to the marine planktonic algae Tetraselmis chuii were investigated under laboratory conditions. T. chuii cultures were exposed for 96 h to different concentrations of each of the test substances at both 20 and 25 degrees C. Effect criterion was the inhibition of culture growth assessed at 24 h intervals. All the PAHs significantly reduced T. chuii growth after 96 h of exposure with 20% inhibition concentrations between 0.052 and 1.124 mg L-1 at 20 degrees C, and between 0.048 and 0.831 mg L-1 at 25 degrees C. At both temperatures, the ranking, in order of decreasing toxicity based on the 50% inhibition concentration, was phenanthrene> naphthalene> anthracene. The increase of temperature by 5 degrees C significantly increased the toxicity of all the PAHs tested. These findings highlight the importance of considering temperature variation in the ecological risk assessment of oil and other chemical spills in the marine environment, and the need of more research on the toxic effects of multiple stressors on marine organisms. (C) 2012 Elsevier B.V. All rights reserved.

RefID: 713

Author: Vignier, V., Vandermeulen, J.H. and Fraser, A.J.

Year: 1992

Title: GROWTH AND FOOD CONVERSION BY ATLANTIC SALMON PARR DURING 40 DAYS EXPOSURE TO CRUDE-OIL

Journal: Transactions of the American Fisheries Society

Hyperlink: http://www.tandfonline.com/doi/abs/10.1577/1548-8659%281992%29121%3C0322%3AGAFCBA%3E2.3.CO%3B2

Abstract: Parr of Atlantic salmon Salmo salar were exposed to two sublethal flow-through concentrations (averaging 0.2 and 1.0 mg/L) of Hibernia oil-water mixture for up to 40 d to determine relative importance of loss of feeding and food conversion for this juvenile life stage. Oiled parr showed reduced growth for 14 d before growth rates approached those of controls. There were also more weight-losing parr in oiled groups than in control groups. Reduction in growth coincided with reduced food conversion efficiency rather than reduced food intake. Food conversion efficiency was lowest for parr experiencing the higher oil exposure. Net efficiencies in both oiled groups returned to control levels within 2 to 3 weeks, although overall efficiencies in oiled groups lagged behind the control group. Liver glycogen levels were generally lower in oil-exposed parr, whereas liver protein content and the liver-somatic index were higher in parr exposed to the highest concentration of oil. Energy reserves were lower in parr that lost weight during the experiment in comparison with weight-gaining parr. Results suggest that medium-term (2 weeks to 1 month) exposure to low concentrations of oil may have-transitory effects on Atlantic salmon parr, but that chronic oiling may impair growth and may influence the timing of length-dependent smoltification.

RefID: 714

Author: Vikebø, F.B., Rønningen, P., Lien, V.S., Meier, S., Reed, M., Ådlandsvik, B. and Kristiansen, T.

Year: 2014

Title: Spatio-temporal overlap of oil spills and early life stages of fish

Journal: Ices Journal of Marine Science

Hyperlink: http://icesjms.oxfordjournals.org/content/71/4/970

Abstract: Coupling an oil drift and fates model (Oscar) in an offline environment with an individual-based model (IBM) for Northeast Arctic cod (Gadus morhua) eggs and larvae enables us to quantify the exposure of eggs and larvae to oil from various oil spill scenarios. Oscar describes the spatio-temporal dispersal and fate of hydrocarbons, whereas the egg and larval IBM integrates the exposure of each individual. We can thus evaluate the effects of the time and location of an oil spill on the degree of exposure for individuals from different spawning grounds (SGs). In addition, we quantify how this effect is modified by the dynamic vertical positioning of eggs and the vertical behaviour of larvae. The principal findings of the study indicate that the mean egg and larval exposures for individuals from different SGs are highly dependent on the time and location of the spill and the vertical distribution of the offspring. Approximately 9.9, 4.7, 3.5, and 0.4% of the offspring would experience total polycyclic aromatic hydrocarbon (TPAH) concentrations above 1 A mu g l(-1) (parts per billion, ppb) for oil spill scenarios situated at Haltenbanken, Lofoten, and VesterAyenlen near the coast and near the shelf edge, respectively, based on the maximum TPAH concentrations in the water column along the individual offspring trajectories.

RefID: 715

Author: Villanueva, R.D., Montaño, M.N.E. and Yap, H.T.

Year: 2008

Title: Effects of natural gas condensate – water accommodated fraction on coral larvae

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0025326X08002658

Abstract: The toxic effects of the water accommodated fraction (WAF) of a natural gas condensate on the larvae of five brooding coral species of the Family Pocilloporidae were examined in short term (96 h) bioassays. Lethality was observed in some larvae of Seriatopora hystrix and Seriatopora guttatus upon exposure to high concentrations of the condensate WAF, while those of Stylophora pistillata, Pocillopora damicornis and Pocillopora verrucosa did not experience mortality. Furthermore, increasing concentrations of WAF produced either delayed or impeded metamorphosis for all species except P. damicornis. Growth of juveniles, exposed to different WAF treatments for 96 h during their larval/early juvenile stages, was measured after 30 d. Marked decrease in subsequent growth rate (polyp count) was observed for S. hystrix, S. guttatus and S. pistillata with increasing WAF concentration. The results showed differential susceptibility of larvae of closely related coral species to oil stress, with the following sensitivity ranking: S. guttatus > S. hystrix > S. pistillata > P. verrucosa > P. damicornis. Oil exposure during the planktonic, larval stage of susceptible corals can adversely affect survivorship, recruitment and/or subsequent colony growth, thereby having profound consequences for the abundance of these corals in space and time.

RefID: 716

Author: Villanueva, R.D., Yap, H.T. and Montaño, M.N.E.

Year: 2011

Title: Reproductive effects of the water-accommodated fraction of a natural gas condensate in the Indo-Pacific reef-building coral Pocillopora damicornis

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651311002466

Abstract: Toxic effects of the water-accommodated fraction (WAF) of a natural gas condensate on the reproduction of the brooding coral Pocillopora damicornis were studied in short-term (24 h) laboratory experiments. Coral fragments were exposed to varying concentrations of condensate WAF during different reproductive phases: gametogenesis, early embryogenesis, and late embryogenesis (when nighttime planulation occurs). During gametogenesis, exposure to condensate WAF did not inhibit subsequent production of larvae. On the other hand, exposure to >25% WAF of gravid corals, at early and late embryogenesis, resulted in abortion and early release of larvae, respectively, with higher percentages of larvae expelled in fragments treated with higher concentrations of condensate WAF at least 3 h after onset of exposure. Aborted larvae during early embryogenesis were 'premature', as they are of small size (0.06±0.03 mm3), low metamorphic competency (54%), and white in coloration, with a pale brown oral end (indicating low density of zooxanthellae). Those larvae released at the latter part of embryogenesis are bigger in size (0.22±0.08 mm3), possess 100% metamorphic competency, and are brown in coloration (high density of zooxanthellae). Aside from direct effects on reproduction, fragment mortality index was higher in samples exposed to higher concentrations of condensate WAF (>25%), hence lowering the number of potentially reproducing polyps. Altogether, exposure to >25% natural gas condensate WAF for at least 3 h can potentially disrupt the replenishment of coral populations due to negative effects on reproduction and early life processes.

RefID: 717

Author: Vosylienė, M.Z., Kazlauskienė, N. and Jokšas, K.

Year: 2005

Title: Toxic effects of crude oil combined with oil cleaner simple green on yolk-sac larvae and adult rainbow trout Oncorhynchus mykiss

Journal: Environmental Science and Pollution Research

Hyperlink: http://link.springer.com/article/10.1065%2Fespr2005.04.245

Abstract: Background, Goal and Scope. Cleaner CRYSTAL Simple Green (SG) was used for the cleanup of the oil spill in the Baltic Sea near Lithuania in 2001. No scientific data are available on the effects and consequences of its application for local aquatic life. The aim of this study was to determine and compare sublethal effects of a) solution SG; b) crude oil alone; c) SG in combination with oil on rainbow trout Oncorhynchus mykiss at different stages of its development in laboratory conditions. Methods. Laboratory studies were performed on adult rainbow trout (4-day duration) and on yolk-sac larvae (25-day duration) evaluating their biological parameters. Concentrations of water-soluble and thin-dispersed fractions of petroleum hydrocarbons were measured using gas chromatography. Results and Discussion. SG solution (0.5 mg/l) did not affect the survival of larvae and adult fish, and no significant changes were determined in respiratory parameters of the exposed larvae and adult fish. The most expressed alterations were found in morphological parameters (a decrease in the average body mass) of larvae and in haematological indices (a decrease in the leukocyte count) of adult fish at the end of the tests. Crude oil (1610 mg/l) did not affect the survival of adult fish during the 4-day exposure. An increase in larvae mortality rate (similar to 36%) was recorded at the end of the tests. A significant decrease in the average body mass and heart rate of larvae as well as in gill ventilation frequency of larvae and adult fish were determined. SG combined with oil induced an increase in larval mortality similar to 46% of individuals died at the end of the tests. No mortality was recorded in adult fish. The average body mass and heart rate of larvae were significantly decreased. Marked changes were also found in respiratory parameters (gill ventilation frequency of larvae and adult fish significantly decreased, while 'coughing' rate increased). A 1-day, 2-day exposure of fish to SG combined with oil induced a significant decrease in the leukocyte count of adult fish, which was also determined at the end of the tests. The augmentation of adverse impact could be explained by the data obtained from our studies. When SG was added into dilution water with crude oil the concentration of petroleum hydrocarbons in the mixture increased 3 similar to 4.5 times after 24 h and 96 h, respectively. Conclusions. The comparative study of the effects of crude oil alone, SG and SG combined with oil showed that their toxic effects on fish differed. Oil combined with SG was found to be more toxic to fish (larvae and adults) than SG alone and oil alone. Fish at early stages of development (yolk-sac larvae) were more sensitive to the effects of the compounds studied than adults. Recommendations and Outlook. To diminish the negative impact of oil spill cleanup using chemicals on aquatic ecosystems, it is recommended to carry out more comprehensive studies of their effects and after-effects in laboratory conditions using a wide scale of local aquatic organisms. The selected species of the most sensitive aquatic organisms should include those which are unable to escape the impact of combined action of oil and cleaners. Special attention should be directed to the research of effects of these pollutants on studied organisms at their most sensitive stages of life (reproduction, hatching, early stages of development), as after-effects of exposure to pollutants may be observed in future generations.

RefID: 718

Author: Vrabie, C.M., Jonker, M.T.O. and Murk, A.J.

Year: 2009

Title: SPECIFIC IN VITRO TOXICITY OF CRUDE AND REFINED PETROLEUM PRODUCTS. 1. ARYL HYDROCARBON RECEPTOR-MEDIATED RESPONSES

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/08-624.1/pdf

Abstract: The present study is the first in a series reporting on in vitro toxic potencies of oils. The objective was to determine whether 11 crude oils and refined products activate the aryl hydrocarbon receptor (AhR) in a dioxin receptor-mediated luciferase assay. Cells were exposed for 6 and 24 h to different oil concentrations to screen for polycyclic aromatic hydrocarbon-like or dioxin-like activity. Moreover, cytotoxicity of the oils was determined using rat hepatoma cells. Except for one crude oil, none of the oils appeared cytotoxic up to 100 mg/L, but all oils activated the AhR. Strong AhR induction was observed for most oils after 6 h, and responses decreased after 24 h, indicating the presence of metabolizable agonists. However, several oils still caused high responses after 24 h, also demonstrating the presence of persistent agonists. The potencies (calculated based on comparisons of concentrations at which 50% of the maximal effect was observed) of oils were found to be approximately 40 to 10(6) times lower than the potency of the assay's standards benzo[a] pyrene and 2,3,7,8-tetrachlorodibenzo-p-dioxin. However, considering that oils contain thousands of chemicals, the potencies of petrochemical agonists may be very high. Among the most potent oils were bunker and crude oils. Induction up to 200% as compared to the maximum induction caused by benzo[a] pyrene was observed for these oils. Such supermaximal responses suggest mixture effects that may not be receptor-mediated. Experiments in which oils were tested in combination with the standards demonstrated that oils acted via an antagonistic or additive mode. The results of the present study may help improve risk assessment of petroleum products and judge the necessity or priority of oil spill cleanup activities.

RefID: 719

Author: Waldichuk, M.

Year: 1990

Title: SEA OTTERS AND OIL POLLUTION

Journal: Marine Pollution Bulletin

Hyperlink: http://www.sciencedirect.com/science/article/pii/0025326X9090145X

Abstract:

RefID: 720

Author: Waldichuk, M.

Year: 1983

Title: Pollution in the Strait of Georgia: a Review

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f83-132

Abstract:

RefID: 721

Author: Wan, Y., Wang, B., Khim, J.S., Hong, S., Shim, W.J. and Hu, J.

Year: 2014

Title: Naphthenic Acids in Coastal Sediments after the Hebei Spirit Oil Spill: A Potential Indicator for Oil Contamination

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es405034y

Abstract: Naphthenic acids (NAs) as toxic components in most petroleum sources are suspected to be one of the major pollutants in the aquatic environment following oil spills, and the polarity and persistence of NAs make it a potential indicator for oil contamination. However, the contamination and potential effects of pollutants in oil spill affected areas remain unknown. To investigate NAs in oil spill affected areas, a sensitive method was first established for analysis of NAs, together with oxy-NAs in sediment samples by UPLC-QTOF-MS. Then the method was applied to determine the NA mixtures in crude oil, weathered oil, and sediments from the spilled sites after the Hebei Spirit oil spill, Taean, South Korea (Dec. 2007). Concentrations of NAs, O-3-NAs, and O-4-NAs were found to be 7.8-130, 3.6-44, and 0.8-20 mg kg(-1) dw in sediments from the Taean area, respectively, which were much greater than those measured in the reference sites of Manlipo and Anmyundo beaches. Concentrations of NAs were 50-100 times greater than those (0.077-2.5 mg kg(-1) dw) of PAHs in the same sediment samples, thus the ecological risk of NAs in oil spill affected areas deserves more attention. The sedimentary profiles of. oil-derived NAs and background NAs centered around compounds with 21-35 and 12-21 carbons, respectively, indicating that the crude-derived NA mixtures originating from the 2007 oil spill were persistent. Acyclic NAsn=5-20 were easily degraded compared to cyclic NAsn=21-41 during the oil weathering processes, and the ratio of oxy-NAsn=21-41 relative to NAsn=21-41, could be a novel index to estimate the degree of oil weathering in sediments. Altogether, the persistent oil-derived NAsn=21-41 could be used as a potential indicator for oil-specific contamination, as such compounds would not be much affected by the properties of coastal sediments possibly due to the high sorption of the negatively charged compounds (NAs) in sediment.

RefID: 722

Author: Wang, S.Y., Lum, J.L., Carls, M.G. and Rice, S.D.

Year: 1993

Title: RELATIONSHIP BETWEEN GROWTH AND TOTAL NUCLEIC-ACIDS IN JUVENILE PINK SALMON, ONCORHYNCHUS-GORBUSCHA, FED CRUDE-OIL CONTAMINATED FOOD

Journal: Canadian Journal of Fisheries and Aquatic Sciences

Hyperlink: http://www.nrcresearchpress.com/doi/abs/10.1139/f93-115

Abstract: Total nucleic acids of juvenile pink salmon, oncorhynchus gorbuscha, fed crude oil contaminated food were analyzed to determine if nucleic acid measurements can be used to evaluate growth of fish collected at oil spill sites. In general, the nucleic acid concentration (micrograms per milligram dry weight) of salmon fry fed food contaminated with either 0.37 or 2.78 mg crude oil/g food was not significantly affected. However, RNA concentration of fry fed food contaminated with 34.83 mg/g was reduced whereas DNA concentration increased. Results over 8 wk indicate decreased protein synthesis and cell content but maintenance of cell integrity in these fish. Growth was inversely related to the level of crude oil contamination in the food. The significant correlations between measured growth and RNA/DNA ratios and RNA contents (micrograms RNA per millimetre fork length) suggest that nucleic acid measurements can be used to compare growth of fish collected from the field.

RefID: 723

Author: Wang, X. and Wang, W.X.

Year: 2006

Title: Bioaccumulation and transfer of benzo(a)pyrene in a simplified marine food chain

Journal: Marine Ecology Progress Series

Hyperlink: http://www.int-res.com/abstracts/meps/v312/p101-111/

Abstract: We examined the toxicokinetics of benzo(a)pyrene (BaP) and the trophic transfer in a marine planktonic food chain comprising phytoplankton, copepods, and fish. Kinetic parameters including the uptake rate from the dissolved phase, the assimilation efficiency (AE) from the ingested food, and the elimination rate were quantified. Influences of food quality and quantity and different routes of exposure (aqueous and food) on the biokinetics were also examined. The uptake rate constants were 390 to 1090 ml mg(-1) h(-1) in different species of phytoplankton, 1.2 ml mg(-1) h(-1) in the copepods, and 0.157 ml mg(-1) h(-1) in the fish, respectively. The assimilation efficiencies were 2 to 24% in the copepods and 32 to 51% in the fish ingesting different prey types. Increasing food concentration significantly reduced the AEs, whereas the AEs varied little among the different food diets tested at the same biomass. The elimination rate constants by the copepods were 0.8 to 1.7 d(-1), and comparable following uptake from the aqueous phase and the dietary phase. A kinetic modeling calculation suggests that more BaP accumulated in the copepods originates from the dietary intake than the aqueous intake. For fish, both trophic transfer and aqueous uptake are important in BaP bioaccumulation. Feeding rates contribute to the differences in the relative proportion of accumulated BaP in the fish.

RefID: 724

Author: Wang, X., Zhang, J., Shi, X., Zhu, C., An, Y., Jun, S., Li, R., Zhu, M. and Chen, S.

Year: 2002

Title: Determination of toxicokinetic parameters for bioconcentration of water-soluble fraction of petroleum hydrocarbon associated with No. 0 diesel in Changjiang Estuary and Jiaozhou Bay: Model versus mesocosm experiments

Journal: Archives of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs00244-001-0025-2

Abstract: A method is proposed for determination of toxicokinetic parameters for bioconcentration by phytoplankton of the water-soluble fraction (WSF) of petroleum hydrocarbon (PH) associated with No. 0 diesel, in which WSF-PH concentration in phytoplankton cells, C-A(d) is estimated by subtracting concentration in water (S-bottle) containing a phytoplankton sample from that in a C-bottle without phytoplankton. It was demonstrated that C-A(d) agrees well with the concentration found by direct ultrasonication extraction of collected cells, C-A(ind) (r = 0.88, p < 0.0001), and its uncertainty was about 17.6%. Mesocosms in 25-m(3) ethylene vinyl acetate or 4-m(3) polyethylene bags were performed at two sites in China: Changjiang Estuary in spring/summer 1998 and Jiaozhou Bay in autumn 1999 and spring/summer 2000. The experiments were designed to determine toxicokinetic parameters, including specific rates of uptake and elimination. and bioconcentration factor (BCF), for bioconcentration of WSF-PH by phytoplankton. A modified kinetic two-compartment model for bioconcentration of WSF-PH by phytoplankton was developed to estimate the toxicokinetic parameters. In the model. the influence of phytoplankton growth on bioconcentration and WSF-PH decline due to biotic and abiotic processes other than bioconcentration, such as volatilization, microbial degradation, phytolysis, and sorption expressed as an exponential-decay equation, are taken into account. Size-dependent BCF was observed in the laboratory experiment. BCFs were 1.0 X 10(4) in summer in ChangJiang Estuary, 1.6 X 10(4) in summer, and 1.1 X 10(4) in autumn in Jiaozhou Bay. The difference in BCF may be interpreted by its size dependence.

RefID: 725

Author: Wang, Z.D. and Fingas, M.

Year: 1996

Title: Separation and characterization of petroleum hydrocarbons and surfactant in Orimulsion dispersion samples

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es960248h

Abstract: Orimulsion is an oil-in-water emulsion into which a nonionic surfactant has been added in order to stabilize the emulsion. Many countries have shown great interest in this new bitumen-based fuel because of its competitive price, guaranteed long-term supply, and no need for major infrastructure changes for use in existing power stations. In view of the increasing importance of Orimulsion as an alternative fuel, it becomes necessary to have a better understanding of its physical properties, chemical composition, and toxicity to aquatic organisms. This paper reports detailed separation and characterization results of petroleum hydrocarbons and surfactant in Orimulsion dispersions. A reliable and effective combined method of using membrane filtration, capillary GC, and HPLC techniques has been developed and applied for separation, characterization, and quantitation of petroleum hydrocarbons and nonionic surfactant in complicated oil-in-water dispersion samples used for fish toxicity tests. The GC analysis results demonstrate that (1) the saturates in Orimulsion are dominantly composed of GC-unresolvable aliphatic hydrocarbons; (2) Orimulsion does not contain BTEX (the collective name of benzene, toluene, ethylbenzene, and the xylene isomers) and lighter alkylbenzenes, and concentrations of alkylated PAHs are low relative to most crudes; (3) the concentrations of biomarker compounds are significantly higher than most oils. Identification of the surfactant in Orimulsion was achieved by (1) narrowing the searching range based on theoretical considerations and analysis and (2) comparing the chromatographic profiles, oligomer distribution patterns, and retention times of oligomer peaks with the known surfactants. The surfactant in Orimulsion was identified as polyethoxylated nonylphenol with oligomers having EO numbers ranging from 8 to 24 (average EO units around 20). The concentration of polyethoxylated nonylphenol in the source Orimulsion was estimated to be around 0.5.

RefID: 726

Author: Wells, P.G., Butler, J.N. and Hughes, J.S.

Year: 1995

Title: Exxon Valdez oil spill: Fate and effects in Alaskan waters - Introduction, overview, issues

Journal: Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters

Hyperlink: https://books.google.ca/books?id=7zCV2kAAgT4C&pg=PA3&lpg=PA3&dq=Exxon+Valdez+oil+spill:+Fate+and+effects+in+Alaskan+waters+-+Introduction,+overview,+issues&source=bl&ots=5hrsCb3Uzj&sig=bq-XEHuouR_PkCVBFaZEsGIdqhg&hl=en&sa=X&ei=WSPIVLyZL5TIsATwsYBA&ved=0CB

Abstract: The Exxon Valdez oil spill in Prince William Sound, Alaska, in March 1989, was the largest crude spill to date in US waters. It prompted many studies on the fate, transport and effects of the oil on biota in Alaskan waters, as well as on archaeological sites. This book consists of 25 research papers presented at an ASTM Symposium in April 1993. This introductory chapter summarizes topics and highlights of those papers, covering chemistry and fate, shoreline impacts, effects on fish, fisheries and wildlife, and impacts an archaeological sites, and discusses some of the issues arising from the study of this spill. Some lessons learned from this research included: • The need for accurate identification of the spilled oil-derived hydrocarbons in all samples, • The extensive movement of the oil down the Alaskan coast, with its unique fate characteristics, • The strong chemical basis required for interpreting the biological significance of sedimented hydrocarbons, • The difficulty of separating oil effects on biological populations from changes due to other variables (biotic and abiotic), • The need for sensitive hydrocarbon biomarkers, and • The need to have established definitions and criteria to determine whether biological recovery had occurred. To provide a context for the papers in this volume, other published literature and symposia on this spill arc discussed. Some of the more important remaining

issues include: • The duration of effects of the residual oil, • The extent of intertidal impact and recovery, • The extent and duration of impacts of the spill on fisheries and wildlife populations, including seabirds and sea otters. Additional issues, of considerable importance, but not concerned primarily with the fate and effects of the spilled oil, include: • The need for the oil spill community as a whole to agree ahead of time on how to study such accidental spills, and select appropriate monitoring tools.• The effect of impending litigation on the type and extent of the research conducted, This volume provides the reader with detailed insights into the ecological impacts of such accidents in cold sub-arctic waters, and some of the outstanding scientific issues on the effects and recovery patterns after such spill events.

RefID: 727

Author: Wertheimer, A.C. and Celewycz, A.G.

Year: 1996

Title: Abundance and Growth of Juvenile Pink Salmon in Oiled and Non-oiled Locations of Western Prince William Sound after the Exxon Valdez Oil Spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: Juvenile pink salmon Oncorhynchus gorbuscha were sampled in oiled and non-oiled locations during their initial residancey in the nearshore waters of Prince William Sound in 1989 and 1990. Pink Salmon moved rapiedly from sheltered bays to more exposed and steep beaches in migration corridors. Pink salmon were less abundant in oiled than in non-oiled locations in both 1989 and 1990; only 18% (1989) and 14% (1990) of pink salmon captured in systematic sampling were from oiled locations. Because othe pattern of abundance did not change between years as oil contamination dinimished, we atrribute these differences to geographic variation in local production of pink salmon fry and in their migration pathways to the Gulf of Alaska, raather than to exposure to oil. Juvenile pink salmon were significantly smaller and had significantly lower apparent growth in oiled than in non-oiled locations in 1989, but not in 1990. In 1989, when growth was lower in oiled locations, hydrocarbon contamination of the environment was greatest, and direct contamination of juvenle pink salmon was observed. In 1990, when growth was similar between oiled and non-oiled locations, hydrocarbon contamination of the environment was greatly diminished, and no direct contamination of juvenile pink salmon was observed. For these reasons, we attribute the lower growth in oiled locations in 1989 to exposure to Exxon Valdez oil.

RefID: 728

Author: Wertheimer, A.C., Bax, N.J., Celeqycz, A.G., Carls, M.G. and Landingham, J.H.

Year: 1996

Title: Harpacticoid Copepod Abundance and Population Structure in Prince William Sound, One Year after the Exxon Valdez Oil Spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: Density and population structure of epibenthic harpacticoid copepods were compared between lightly oiled and heavily oiled beaches in two bays, Herring Bay and Bay of Isles, in Prince William Sound in 1990, 1 year after the Exxon Valdez oil spill. Level of oiling was categorized according to shoreline surveys in fall 1989. Mean densities of total epibenthic harpacticoid copepods in both bays and of Harpacticus spp. in Herring Bay were higher on heavily oiled beaches than on lightly oiled beaches. Proportions of copepodites and egg-bearing female copepods were similar at lightly oiled beaches. Level of oiling in 1989 explained more of the variance in copepod densities in 1990 than did substrate composition, macrophyte coverage, total organic carbon in the sediments, or polycyclic aromatic hydrocarbons in the sediments. Amount of oil in sediments was not significantly correlated with the 1989 oiling level; however, interpretation of the hydrocarbon data was complicated by cleanup activity and possible secondary contamination of the sites. The results of this study suggest that epibenthic harpacticoids, which are common prey for salmon fry, maintained or increased their abundance in response to direct and indirect impacts of the Exxon Valdez oil spill on their intertidal habitats during the year after the spill.

RefID: 729

Author: Wertheimer, A.C., Celewycz, A.G., Carls, M.G. and Sturdevant, M.V.

Year: 1994

Title: Impact of the oil spill on juvenile pink and chum salmon and their prey in critical nearshore habitats

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33088516.pdf

Abstract: The objective of this study was to determine the impact of the Exxon Valdez oil spill on juvenile pink and chum salmon during their initial period of residency in nearshore marine habitats of western Prince William Sound. In oiled locations, both pink and chum salmon fry in the nearshore marine environment were contaminated by hydrocarbons in 1989, but not in 1990. Field observations and laboratory experiments indicated that ingestion of whole oil or oil-contaminated prey was an important route of contamination. In 1989, juvenile pink salmon grew significantly slower and were significantly smaller in oiled locations than non-oiled locations, although neither their feeding nor availability of their prey was reduced in oiled locations. In 1990, size and growth of juvenile pink salmon were similar in oiled and non-oiled locations. We concluded that oil contamination from the Exxon Valdez reduced the growth of juvenile pink salmon in western Prince William in 1989. Because survival of pink salmon is directly related to growth during their early marine residency, survival and productivity of affected salmon populations were probably also reduc

RefID: 730

Author: Wertheimer, A.C., Celewycz, A.G., Carls, M.G. and Sturdevant, M.V.

Year: 1994

Title: THE IMPACT OF THE EXXON-VALDEZ OIL SPILL ON JUVENILE PINK AND CHUM SALMON AND THEIR PREY IN NEARSHORE MARINE HABITATS

Journal: Proceedings of the 16th Northeast Pacific Pink and Chum Salmon Workshop

Hyperlink: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.376.2049&rep=rep1&type=pdf

Abstract:

RefID: 731

Author: Wertheimer, A.C., Heintz, R.A., Thedinga, J.F., Maselko, J.M. and Rice, S.D.

Year: 2000

Title: Straying of adult pink salmon from their natal stream following embryonic exposure to weathered Exxon Valdez crude oil

Journal: Transactions of the American Fisheries Society

Hyperlink: http://www.tandfonline.com/doi/abs/10.1577/1548-8659%282000%29129%3C0989%3ASOAPSF%3E2.3.CO%3B2

Abstract: Numbers of strays (adult salmon returning to a nonnatal stream:), straying rates, and distribution of strays were estimated for pink salmon incubated in oil-contaminated gravel and for an unexposed control group. The treatment groups were incubated in oiled gravel, which resulted in initial aqueous exposures for total polynuclear aromatic hydrocarbons (TPAHs) of 5 and 19 mu g/L for a low and high dose, respectively; the control group was incubated in gravel without oil. Fry from each treatment group were marked with coded wire tags (CWTs). The numbers of tagged fish released were 65,409 from the control; 69,441 from the low-dose group; and 70,414 from the high-dose group. A total of 288,492 pink salmon were sampled for CWTs when returning to spawn in the natal stream of the experimental fish, when returning to streams within 60 km of the natal stream, and when returning to two hatcheries within 100 km of the natal stream. The frequencies of observed strays were 0.023, 0.030, and 0.025 for the control, low-dose, and high-dose groups, respectively. Although the frequency of observed strays was 30% and 9% (respectively) higher than the controls for the low- and high-dose groups, the differences among treatments were not statistically significant, and the rates did not increase with TPAH dose. Estimates of the adult straying rates (with 95% confidence intervals) within a 35-km radius of the natal watershed were as follows: 5.3% (3.4-7.1%) for the control group; 9.2% (5.1-13.2%) for the low-dose group; and 5.7% (2.8-8.5%) for the high-dose group. Most (90%) strays were recovered within 10 km of the natal watershed. Exposed fish tended to be recovered at a greater distance from the natal stream than were control fish. The estimated percentage of strays recovered within 10 km was higher for the control group (95%) than for either the low-dose (81%) or high-dose (83%) groups, and only fish from oiled groups were recovered in distant fishing areas. However, these differences were also not statistically significant. Our results do not support the hypothesis that oil exposure of embryos in intertidal spawning grounds was responsible for the high rates of straying of wildstock pink salmon that were observed in Prince William Sound after the Exxon Valdez oil spill.

RefID: 732

Author: Wertheimer, A.C., Heintz, R.A., Thedinga, J.F., Maselko, J.M., Celewycz, A.G., Bradshaw, R.F. and Rice, S.D.

Year: 1999

Title: Effects of oiled incubation substrate on survival and straying of wild pink salmon

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/48114406.pdf

Abstract: The objectives of this project were to determine the effect of exposure of pink salmon embryos to weathered crude oil on subsequent marine growth and survival, and to examine theeffect of oil exposure and other factors on the straying behavior of pink salmon. The projectrelied on extensive marking of pink salmon fry from controlled exposure groups and from wildstocks: a total of 478,749 fry were marked and released at the tagging sites in 1996. Treatmentgroups were incubated in oiled gravel simulating conditions in contaminated streams in Prince William Sound after the Exxon Valdez oil spill, resulting in initial aqueous exposures for totalpolynuclear aromatic hydrocarbons of <5.2 and <19.4 parts per billion (ppb) for a low and highdose, respectively. Control fish were incubated in gravel without oil. Superficially healthy frywere marked by removing the adipose fin and inserting coded-wire tags after volitionallyemigrating from the incubators. Pink salmon from two wild stocks, an intertidal and an upstreamspawning stock, were also marked by removing the adipose fin and inserting coded-wire tags as they emigrated to seawater. To examine the effect of coded-wire tags on survival and straying, some pink salmon fry from the control incubators and from the upstream spawning stock were marked by removing the adipose fin and a pelvic fin. Marks were recovered from fisheries, natal streams, and streams up to 60 km of the natal streams, to provide the statistical power todiscriminate long-term effects of oil exposure and to quantify straying and the precision ofstraying estimates.Embryonic exposure to oil produced sublethal effects in pink salmon that led to reducedgrowth and marine survival at concentrations in the low ppb. Oil exposure as embryos resulted in significant reductions in juvenile marine growth and in survival to adults at exposures <5.2ppb. Marine survival was reduced by 15% for fish exposed to <5.2 ppb, and 38% for fish exposed at <19.4 ppb. These data demonstrate that the contributions of delayed mortality are asignificant component to total mortality resulting from exposure to oil, and indicate the potential for much greater population level effects to pink salmon from the Exxon Valdez oil spill than previous estimates. Overall straying of returning pink salmon that were not exposed to oil, adjusted forsampling effort, was 5.1% within a 45 km radius of the natal watershed. The proportion of adultfish observed to have strayed was higher for the exposed than the control groups, but the differences among treatments were not statistically significant, and the proportion did noti ncrease with dose. Estimated straying of tagged fish was 9.2% for the intertidal stock, morethan double the 3.7% rate estimated for tagged fish from the upstream-spawning stock. Coded-ivwire tags did have a significant effect on observed straying; estimated straying rates averaged2.6% higher for CWT fish than for their fin-clipped siblings. Although tagging and oil may influence straying to some degree, the magnitude of straying associated with these factors does not explain the high straying rates (average 25%, range 9 to 53%) observed in Prince WilliamSound following the oil spill. Incubation environment and natal watershed characteristics appearto be major determinants of the natural straying of pink salmon, and of the regional differencesobserved in straying rates between southeastern Alaska and Prince William Sound.

RefID: 733

Author: West, J.E., O'Neill, S.M., Ylitalo, G.M., Incardona, J.P., Doty, D.C. and Dutch, M.E.

Year: 2014

Title: An evaluation of background levels and sources of polycyclic aromatic hydrocarbons in naturally spawned embryos of Pacific herring (Clupea pallasii) from Puget Sound, Washington, USA

Journal: Science of the Total Environment

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/25181043

Abstract: Pacific herring embryos spawned in nearshore habitats may be exposed to toxic contaminants as they develop, from exogenous sources in spawning habitats and from maternal transfer. Determining baseline concentrations of these toxic contaminants is important for evaluating the health of this species, especially during this sensitive life stage. In this study we compared concentrations of polycyclic aromatic hydrocarbons, or PAHs, in naturally spawned herring embryos from five spawning areas across Puget Sound. The summed values of 31 PAH analytes (Sigma(31)PAH) in early- to late-stage development embryos ranged from 1.1 to 140 ng/g, wet weight. Sigma(31)PAH concentrations increased with development time in embryos from one spawning area where the greatest concentrations were observed, and the relative abundance of PAH chemicals in late-stage embryos was similar to those in nearby sediments, suggesting accumulation from local environmental sources. PAHs in both sediments and late-stage embryos appeared to exhibit a pyrogenic pattern. Although maternal transfer of PAHs appeared to be a negligible source to embryos in spawning areas with the greatest embryo PAH concentrations, maternal transfer may have been the dominant source in embryos from spawning areas where the lowest levels of embryo-PAHs occurred. Chronic embryo mortality has been reported in spawning habitats where we observed the greatest concentration of PAHs in embryos, and necrotic tissue in herring embryos from one such location was similar in description to phototoxic PAH necrosis reported elsewhere for embryonic zebrafish. (C) 2014 Elsevier B.V. All rights reserved.

RefID: 734

Author: Whitehead, A.

Year: 2013

Title: Interactions between Oil-Spill Pollutants and Natural Stressors Can Compound Ecotoxicological Effects

Journal: Integrative and Comparative Biology

Hyperlink: http://icb.oxfordjournals.org/content/53/4/635

Abstract: Coastal estuaries are among the most biologically productive habitats on earth, yet are at risk from human activities including marine oil spills. The 2010 Deepwater Horizon oil spill contaminated hundreds of kilometers of coastal habitat, particularly in Louisiana's delta. Coastal estuaries are naturally dynamic habitats where periodic and stochastic fluctuations, for example in temperature, salinity, nutrients, and hypoxia, are common. Such environmental variability regularly imposes suboptimal conditions for which resident species must continually compensate by drawing on diverse physiological abilities. However, exposures to oil, in addition to their direct toxic effects, may interfere with functions that normally enable physiological compensation for suboptimal conditions. This review summarizes the panoply of naturally-encountered stressors that may interact with oil, including salinity, hypoxia, pathogens, and competition, and the mechanisms that may underlie these interactions. Combined effects of these stressors can amplify the costs of oil-exposures to organisms in the real world, and contribute to impacts on fitness, populations, and communities, that may not have been predicted from direct toxicity of hydrocarbons alone. These interactions pose challenges for accurate and realistic assessment of risks and of actual damage. To meet these challenges, environmental scientists and managers must capitalize on the latest understanding of the complexities of chemical effects of natural stressors on organisms, and adopt integrative and holistic measures of effect from the molecular to whole-animal levels, in order to anticipate, characterize, diagnose, and solve, ecotoxicological problems.

RefID: 735

Author: Whitehead, A., Dubansky, B., Bodinier, C., Garcia, T.I., Miles, S., Pilley, C., Raghunathan, V., Roach, J.L., Walker, N., Walter, R.B., Rice, C.D. and Galvez, F.

Year: 2012

Title: Genomic and physiological footprint of the Deepwater Horizon oil spill on resident marsh fishes

Journal: Proceedings of the National Academy of Sciences of the United States of America

Hyperlink: http://www.pnas.org/content/109/50/20298.full

Abstract: The biological consequences of the Deepwater Horizon oil spill are unknown, especially for resident organisms. Here, we report results from a field study tracking the effects of contaminating oil across space and time in resident killifish during the first 4 mo of the spill event. Remote sensing and analytical chemistry identified exposures, which were linked to effects in fish characterized by genome expression and associated gill immunohisto-chemistry, despite very low concentrations of hydrocarbons remaining in water and tissues. Divergence in genome expression coincides with contaminating oil and is consistent with genome responses that are predictive of exposure to hydrocarbon-like chemicals and indicative of physiological and reproductive impairment. Oil-contaminated waters are also associated with aberrant protein expression in gill tissues of larval and adult fish. These data suggest that heavily weathered crude oil from the spill imparts significant biological impacts in sensitive Louisiana marshes, some of which remain for over 2 mo following initial exposures.

RefID: 736

Author: Wiedmer, M., Fink, M.J., Stegeman, J.J., Smolowitz, R., Marty, G.D. and Hinton, D.E.

Year: 1996

Title: Cytochrome P-450 Induction and Histopathology in Preemergent Pink Salmon from Oiled Spawning Sites in Prince William Sound

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: The March 1989 Exxon Valdez oil spill contaminated intertidal pink salmon Oncorhynchus gorbuscha spawning areas in Prince William Sound and the Gulf of Alaska. To determine if 8- to 26-month old oil remaining in some spawning areas produced physiological responses in developing pink salmon eggs and alevins, we conducted an initial assessment of cytochrome P-4501A induction and histopathologic lesion occurrence in preemergent pink salmon collected from oiled spawning substrates. Egg and alevin samples were collected from four oiled and five reference sites in Prince William Sound, Alaska, between December 1989 and May 1991. Immunohistochemical staining for cytochrome P-4501A was increased in alevins from 13 of 16 samples from oiled sites, but was not increased in any of the 7 samples from the reference sites. Cytochrome P-4501A induction was not detected in egg samples from either oiled or control sites. Persistent P-4501A staining through the end of the study was evidence for chronic exposure of two year-classes of pink salmon to hydrocarbon contamination. Histopathologic lesions were more frequent in alevins from oiled sites, but differences were not statistically significant, and lesion occurrence seemed dependent on developmental stage. These results provide evidence that pink salmon alevins developing in heavily oiled sites were exposed to hydrocarbons more than 2 years after the initial spill and that the hydrocarbons induced detectable physiological changes. Results of this study were used to develop appropriate treatments for oiled anadromous fish streams.

RefID: 737

Author: Willette, M.

Year: 1996

Title: Impacts of the Exxon Valdez oil spill on the migration, growth, and survival of juvenile pink salmon in Prince William Sound

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink: https://fisheries.org/shop/x54018xm

Abstract: This study investigated the effects of the Exxon Valdez oil spill on the migration, growth, and survival of juvenile pink salmon Oncorhynchus gorbuscha during the first 2 months of their marine residence in Prince William Sound, Alaska. Coded-wire-lagged juvenile salmon released from hatcheries in the sound in 1989, 1990, and 1991 were the principal sources of data. The growth of juvenile pink salmon in Prince William Sound appeared to be reduced by oil contamination from the bacon Valdez oil spill in 1989. Growth rates of juveniles released from Armin F. Koernig (AFK) Hatchery in 1989 were significantly lower (P = 0.034) in the moderately oiled area near the hatchery than along the lightly oiled southern coast of Knight Island. In 1990 and 1991, growth rates of juvenile pink salmon released from AFK Hatchery were again lower in the moderately oiled area compared with the lightly oiled southern coast of Knight Island. However, the growth difference was not significant in 1990 (P = 0.103), and was only marginally significant in 1991 (P = 0.085). The magnitude of the growth difference in 1990 and 1991 was also one half of the growth difference in 1989. Growth rates of juveniles released from Wally H. Noerenberg (WHN) Hatchery in 1989 were significantly lower (P = 0.019) in the moderately oiled area near Main Bay than in the non-oiled area near WHN Hatchery. Growth rates of juveniles released from WHN Hatchery were not significantly different between oiled and non-oiled areas in 1990 (P = 0.767) and 1991 (P = 0.883). Exposure to hydrocarbons from the Exxon Valdez oil spill appeared to reduce the growth rate of juvenile pink salmon by 0.76-0.94% body weight/day in 1989. The observed differences in growth rate did not appear to have been caused by measurement or sampling error or by differences in food consumption rate, prey composition, or water temperature. The observed reduction in growth rate was associated with a significantly greater (P < 0.05) frequency of cytochrome P-4501A enzyme induction in moderately oiled areas compared with non-oiled and lightly oiled areas in 1989. The greater frequency of P-4501A enzyme induction in moderately oiled areas indicates that fish in oil-contaminated habitats expended energy to metabolize and depurate hydrocarbons, leaving less energy available for somatic growth. Sufficient data were not available to determine if the level of hydrocarbon exposure was great enough to cause the estimated reduction in growth rate attributed to oil contamination. The growth of juvenile pink salmon in 1989 was significantly related (P = 0.016) to survival to the adult stage. The reduction in juvenile growth rate attributed to oil contamination in 1989 probably caused a 1.7-2.2% reduction in survival to the adult stage among fish that reared in oiled areas. The adult pink salmon return to Prince William Sound in 1990 was thus lower than if the Exton Valdez oil spill had not occurred.

RefID: 738

Author: Willette, T.M., Carpenter, G., Shields, P. and Carlson, S.R.

Year: 1994

Title: Early marine salmon injury assessment in Prince William Sound

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/33949944.pdf

Abstract: We investigated the effects of the Exxon Valdez oil spill and evaluated naturalenvironmental effects on the migration, growth, and survival of juvenile pink salmon during the first two months of marine residence in Prince William Sound using coded-wire taggedj uveniles released from hatcheries in 1989-1991. Juveniles from Koernig Hatchery migratedf rom the nearby moderately-oiled area to the lightly-oiled southern coast of Knight Island in1989; similar migration was not observed in 1990 and 1991. Growth rates of juvenilesreleased from Koernig Hatchery in 1989 were significantly lower (P=.O34) near the hatcherythan along Knight Island's southern coast, and although lower, not significantly different in1990 (P=.103), and marginally significant in 1991 (P=.085). Growth rates of juvenilesreleased from Noerenberg Hatchery in 1989 were significantly lower (P= ,019) in themoderately-oiled area near Main Bay than near the non-oiled hatchery, but not significantlydifferent in 1990 (P=.767) and 1991 (P=.883). Exposure to hydrocarbons appeared toreduce the juvenile growth rate by 0.76 to 0.94% body weight day-' in 1989, and wasassociated with a significantly greater (P< .05) frequency of cytochrome P4501A enzymeinduction in moderately-oiled areas. Growth rate reduction likely caused a 1.7 to 2.2%reduction in survival to the adult stage among fish reared in oiled areas.

RefID: 739

Author: Williams, J., Roderick, C. and Alexander, R.

Year: 2003

Title: Sublethal effects of Orimulsion-400((R)) on eggs and larvae of Atlantic herring (Clupea harengus L.)

Journal: Environmental Toxicology and Chemistry

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1897/02-404/abstract

Abstract: Orimulsion-400(R) is a novel bitumen-emulsion power plant fuel. We exposed Atlantic herring (Chipea harengus L.) eggs to 0, 0.1. 1.0, 10, 100, and 1,000 mg/L concentrations of an oil-in-water dispersion of Orimulsion-400 for a 24-h period. No significant differences were found in daily mortality or percent hatch. The 1,000 mg/L exposure resulted in a significantly higher incidence of premature hatch, indicated by significantly shorter incubation time, significantly smaller total length and notochord length, and significantly greater yolk sac depth. The larvae exposed to the 1,000 mg/L treatment also had a significantly higher incidence of abnormalities than all other treatments.

RefID: 740

Author: Williams, R., Gero, S., Bejder, L., Calambokidis, J., Kraus, S.D., Lusseau, D., Read, A.J. and Robbins, J.

Year: 2011

Title: Underestimating the damage: interpreting cetacean carcass recoveries in the context of the Deepwater Horizon/BP incident

Journal: Conservation Letters

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1111/j.1755-263X.2011.00168.x/abstract

Abstract: Evaluating impacts of human activities on marine ecosystems is difficult when effects occur out of plain sight. Oil spill severity is often measured by the number of marine birds and mammals killed, but only a small fraction of carcasses are recovered. The Deepwater Horizon/BP oil spill in the Gulf of Mexico was the largest in the U.S. history, but some reports implied modest environmental impacts, in part because of a relatively low number (101) of observed marine mammal mortalities. We estimate historical carcass-detection rates for 14 cetacean species in the northern Gulf of Mexico that have estimates of abundance, survival rates, and stranding records. This preliminary analysis suggests that carcasses are recovered, on an average, from only 2% (range: 0-6.2%) of cetacean deaths. Thus, the true death toll could be 50 times the number of carcasses recovered, given no additional information. We discuss caveats to this estimate, but present it as a counterpoint to illustrate the magnitude of misrepresentation implicit in presenting observed carcass counts without similar qualification. We urge methodological development to develop appropriate multipliers. Analytical methods are required to account explicitly for low probability of carcass recovery from cryptic mortality events (e.g., oil spills, ship strikes, bycatch in unmonitored fisheries and acoustic trauma).

RefID: 741

Author: Wise, C.F., Wise, J.T.F., Wise, S.S., Thompson, W.D., Wise, J.P., Jr. and Wise, J.P., Sr.

Year: 2014

Title: Chemical dispersants used in the Gulf of Mexico oil crisis are cytotoxic and genotoxic to sperm whale skin cells

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X14001490

Abstract: The 2010 Deepwater Horizon oil rig explosion in the Gulf of Mexico drew attention to the need for toxicological studies of chemical dispersants. We are still learning the effects these spills had on wildlife. Little is known about the toxicity of these substances in marine mammals. The objective of this study was to determine the toxicity of the two dispersants (Corexit 9500 and 9527). Corexit 9500 and 9527 were both cytotoxic to sperm whale skin fibroblasts. Corexit 9527 was less cytotoxic than 9500. S9 mediated metabolism did not alter cytotoxicity of either dispersant. Both dispersants were genotoxic to sperm whale skin fibroblasts; S9 mediated metabolism increased Corexit 9527 genotoxicity.

RefID: 742

Author: Wiseman, S.B., Anderson, J.C., Liber, K. and Giesy, J.P.

Year: 2013

Title: Endocrine disruption and oxidative stress in larvae of Chironomus dilutus following short-term exposure to fresh or aged oil sands process-affected water

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X13002300

Abstract: Understanding the toxicity of oil sands process-affected water (OSPW) is a significant issue associated with the production of oil from the Alberta oil sands. OSPW is acutely and chronically toxic to organisms, including larvae of Chironomus dilutus. In this study, fresh OSPW ('WIP-OSPW') was collected from the West In-Pit settling pond and aged OSPW ('FE5-OSPW') was collected from the FE5 experimental reclamation pond, both of which are located on the Syncrude Canada Ltd. lease site near Fort McMurray, Alberta, Canada. Larvae of C. dilutus were exposed to a freshwater control, WIP-OSPW, or FE5-OSPW for 4 or 7 days and survival, growth, and markers of oxidative stress and endocrine disruption were assessed. Survival was not significantly different among treatment groups. Compared to masses of larvae exposed to freshwater, masses of larvae exposed to WIP-OSPW were 49% lesser on day 4 and 62% lesser on day 7. However, organisms exposed to FE5-OSPW did not have significantly lesser masses than controls. Abundances of transcripts of glutathione-s-transferase (gst), catalase (cat), and glutathione peroxidase (gpx), which are important for the response to oxidative stress, were significantly altered in larvae exposed to WIP-OSPW, but not FE5-OSPW, relative to controls. Peroxidation of lipids was greater in larvae exposed to WIP-OSPW, but not FE5-OSPW. Exposure to fresh OSPW might have caused endocrine disruption because abundances of transcripts of the steroid hormone receptors, ultraspiricle protein (usp), ecysteroid receptor (esr), and estrogen related receptor (err) were greater in larvae exposed to WIP-OSPW for 7 days, but not FE5-OSPW. These results suggest that lesser growth of larvae of C. dilutus exposed to fresh OSPW might be due to oxidative stress and disruption of endocrine processes, and that aging of OSPW attenuates these adverse effects.

RefID: 743

Author: Wiseman, S.B., He, Y., Gamal-El Din, M., Martin, J.W., Jones, P.D., Hecker, M. and Giesy, J.P.

Year: 2013

Title: Transcriptional responses of male fathead minnows exposed to oil sands process-affected water

Journal: Comparative Biochemistry and Physiology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S1532045612001421

Abstract: Oil sands process-affected water (OSPW) is produced by the oil sands industry in Alberta, Canada. OSPW has acute and chronic effects on aquatic organisms, but the suite of effects of OSPW, and mechanisms of effects, are not understood. The goal of this study was to use RNA sequencing (RNAseq) to quantify abundances of transcripts in livers of male fathead minnows exposed to untreated OSPW and ozone-treated OSPW to investigate sublethal effects of untreated OSPW and to determine whether ozonation imparts toxicity upon OSPW. A reference transcriptome of 25,342 contigs was constructed from RNA from livers of fathead minnows exposed to various experimental conditions. Exposure to untreated OSPW resulted in greater abundances of 104 transcripts and lesser abundances of 91 transcripts. Oxidative metabolism, oxidative stress, apoptosis, and immune function were identified as processes affected by OSPW. Exposure to ozone-treated OSPW resulted in greater abundances of 57 transcripts and lesser abundances of 75 transcripts. However, in general, putative pathways for effects of OSPW in fathead minnows exposed to untreated OSPW were not identified in minnows exposed to ozone-treated OSPW, and pathways by which ozone-treated OSPW might have effects were not identified.

RefID: 744

Author: Wolf, D.A.

Year: 1996

Title: Fate and toxicity of spilled oil from the Exxon Valdez

Journal: EVOS Trustee Council

Hyperlink: http://www.arlis.org/docs/vol1/35903258.pdf

Abstract: Three separate papers are represented in this final report; Toxicity of intertidal and subtidal sediments contaminated by the Exxon Valdez oil spill; Comparative toxicities of polar and non-polar organic fractions from sediments affected by the Exxon Valdez oil spill in Prince William Sound, Alaska; and Fate of the oil spilled from the Exxon Valdez in Prince William Sound, Alaska.

RefID: 745

Author: Wolfe, D.A., Krahn, M.M., Casillas, E., Sol, S., Thompson, T.A., Lunz, J. and Scott, K.J.

Year: 1996

Title: Toxicity of intertidal and subtidal sediments contaminated by the Exxon Valdez oil spill

Journal: Proceedings of the Exxon Valdez Oil Spill Symposium

Hyperlink:

Abstract: To estimate the toxicity potential of sediments oiled by the Exxon Valdez spill, standardized toxicity tests were applied to intertidal (0 m) and subtidal (three to five depths ranging from 3 to 100 m) sediment samples from Prince William Sound and the nearby Gulf of Alaska during 1989-1991. In 1989, toxicity measured by Microtox® in shallow subtidal (0-6 m) sediments showed a generally decreasing trend with increasing distance from the spill center. At the Prince William Sound sites, however, where the ranges of total hydrocarbon concentrations were greatest (at 0 and 3 m) and where those concentrations were related most certainly to Exxon Valdez oil, the Microtox® test did not show clear dose-response relations to ultraviolet fluorescence signal. Laboratory tests confirmed the non-responsiveness of the Microtox® test to Exxon Valdez oil, and the test was not used further. In 1990 and 1991, sediment toxicities at oiled and non-oiled sites were compared using a sediment elutriate test with larval Pacific oysters Crassostrea gigas and a whole sediment test with amphipods Ampelisca abdita. The 1990 amphipod results indicated that (1) mortality was correlated with hydrocarbon concentrations in intertidal sediments, (2) intertidal toxicity was substantially higher than subtidal toxicity, and (3) mean toxicity of intertidal sediments at exposed sites was significantly higher than at reference sites. Mean mortalities in subtidal sediments (at 6, 20, and 40 m) were not significantly different between exposed and reference sites. although concentrations of total hydrocarbons were generally higher at the exposed sites down to 20 m. In 1991, toxicity was generally low at all depths at all sites. Although some 1991 sediment samples (from 0, 6, and 20 m) caused mortalities of test organisms that were significantly greater than in controls, no difference in mean toxicity was demonstrated between oiled and reference sites with amphipods or oyster larvae. Between 1990 and 1991. the relative toxicity of sediments from exposed sites (compared to reference sites) decreased for intertidal lu rn) sediments and may have increased slightly for shallow subtidal (6 m) sediments. These results suggest that residual toxicity was still present during summer 1990 in intertidal sediments from some sites that were heavily oiled in 1989. By 1991, the toxicity of these sediments had diminished to background levels. These studies demonstrated no significant toxicity to test amphipods or oyster larvae that was clearly associated with Faxon Valdez oil in subtidal sediments (6-40 m) during 1990-1991.

RefID: 746

Author: Wolfe, M.F., Schlosser, J.A., Schwartz, G.J.B., Singaram, S., Mielbrecht, E.E., Tjeerdema, R.S. and Sowby, M.L.

Year: 1998

Title: Influence of dispersants on the bioavailability and trophic transfer of petroleum hydrocarbons to primary levels of a marine food chain

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X97000969

Abstract: Use of chemical dispersants as oil spill clean-up agents, alters normal behavior of petroleum hydrocarbons (PH) by increasing functional water solubility. The bioavailable fraction may be increased through higher PH concentrations in the water column and altered interactions between dispersant, oil, and biological membranes. The objective of this research was to determine the impact of dispersing agents on PH bioavailability and trophic transfer. Uptake, bioaccumulation, depuration, and metabolic transformation of a model PH, [C-14]naphthalene, were measured and compared for Prudhoe Bay crude oil (PBCO) dispersed with Corexit(R) 9527 (DO) and undispersed preparations of the water-accommodated fraction (WAF) of PBCO. The model food chain consisted of Isochrysis galbana, a primary producer, and Brachionus plicatilis, a primary consumer. Direct aqueous (AQ) exposure was compared with combined aqueous and dietary (AQ and D) exposure. Results showed uptake of naphthalene by rotifers was not increased significantly ($P > 0.05$) in the presence of dispersant. A significant ($P < 0.01$) increase in depuration of naphthalene was observed in rotifers during DO exposures. Uptake of naphthalene increased by up to 45% via trophic transfer in both WAF and DO exposures. An unidentified metabolite was found associated with algae and rotifer tissue samples but not detected in controls or exposure media. This metabolite constituted an increasing percentage of [C-14] recovered in AQ and D exposures and remained associated with the organism during depuration. Characterization of WAF and DO media showed aqueous concentrations of naphthalene were not significantly different. This research has demonstrated that dispersants altered uptake and depuration processes of naphthalene, independent of concentration, in representative species of primary trophic levels of the marine food chain which may in turn modify bioavailability and bioaccumulation at higher trophic levels.

RefID: 747

Author: Wolfe, M.F., Schwartz, G.J.B., Singaram, S., Mielbrecht, E.E., Tjeerdema, R.S. and Sowby, M.L.

Year: 1998

Title: Influence of dispersants on the bioavailability of naphthalene from the water-accommodated fraction crude oil to the golden-brown algae, Isochrysis galbana

Journal: Archives of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs002449900376

Abstract: The golden-brown algae Isochrysis galbana, a primary producer, was used to determine the influence of the chemical dispersing agent, Corexit 9527(R), on the bioavailability of naphthalene. Cells were exposed to laboratory preparations of either the water-accommodated fraction (WAF) of Prudhoe Bay crude oil (PBCO) or a dispersed oil (DO) mixture of PBCO and Corexit 9527 spiked with [(UC)-C-14]naphthalene. Uptake was determined by the amount of algae-associated [C-14]. High-pressure liquid chromatography ((HPLC) co-chromatography was used to fractionate and identify metabolic products. A 24-h bioaccumulation factor (BAF) was calculated in the absence of steady state. The presence of Corexit 9527, had significant influence ($p = 0.001$) on the uptake of naphthalene, but no significant effect on the 24-h BAF (BAF: 168 and 180 from WAF and DO, respectively), or metabolic fate of naphthalene in I. galbana. Results of this research indicate that dispersants have the potential to increase organismal exposure to certain petroleum hydrocarbons without increasing their aqueous concentration.

RefID: 748

Author: Wolfe, M.F., Schwartz, G.J.B., Singaram, S., Mielbrecht, E.E., Tjeerdema, R.S. and Sowby, M.L.

Year: 2001

Title: Influence of dispersants on the bioavailability and trophic transfer of petroleum hydrocarbons to larval topsmelt (Atherinops affinis)

Journal: Aquatic Toxicology

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0166445X00001314

Abstract: Use of chemical dispersants as oil spill clean-up agents may alter the normal behavior of petroleum hydrocarbons (PH) by increasing their functional water solubility, resulting in increased bioavailability and altered interactions between dispersant, oil, and biological membranes. The objective of this research was to determine the impact of dispersing agents on PH bioavailability and trophic transfer to larval fish from primary levels of a marine food chain. Uptake, bioaccumulation, depuration, and metabolic transformation of a model PH, [C-14]naphthalene, were measured and compared for Prudhoe Bay crude oil (PBCO) dispersed with Corexit 9527(R) (DO) and undispersed preparations of the water-accommodated fraction (WAF) of PBCO. The model food chain consisted of a primary producer, Isochrysis galbana; and a primary consumer, the rotifer, Brachionus plicatilis; and larval topsmelt, Atherinops affinis. Direct aqueous (AQ) exposure was compared with combined aqueous and dietary (AQ&D) exposure. Dispersants altered the uptake and depuration processes of naphthalene, independent of aqueous concentrations, in primary trophic species of a marine food chain. The amount of naphthalene taken up by topsmelt was initially significantly (P less than or equal to 0.05) enhanced in the presence of dispersant, reaching a maximum more quickly than undispersed samples. Dispersion treatment significantly increased naphthalene dispension in topsmelt (P less than or equal to 0.05) from both AQ and AQ&D exposures. No significant change in naphthalene uptake by fish was observed with the addition of contaminated food for either WAF or DO medium; however, both uptake and depuration rate constants Varied significantly with route of exposure consistent with greater naphthalene turnover. The majority (greater than or equal to 72%) of naphthalene-derived radioactivity from fish tissue following all exposures was in the parent form, with smaller quantities of alpha- and beta -naphthols, alpha- and beta -naphthyl sulfates, and an unidentified derivative. (C) 2001 Elsevier Science B.V. All rights reserved.

RefID: 749

Author: Woodin, B.R. and Stegeman, J.J.

Year: 1993

Title: Elevated P4501A protein in intertidal fish in Prince William Sound associated with the Exxon Valdez oil spill

Journal: Marine Environmental Research

Hyperlink: http://www.sciencedirect.com/science/article/pii/0141113693900452

Abstract: Induction of CYP1A genes is a sensitive and specific adaptive response in fish exposed to a wide variety of xenobiotics, including aromatic hydrocarbon components of crude oil. The present studies examined such induction in fish from sites affected by the Exxon Valdez oil spill in Prince William Sound. Four species of intertidal fish (Anoplarchus purpurescens, Pholis laeta, Phytichthus chirus, and Xiphister atropurpureus) were collected 14 months after the spill, from reference sites and from sites oiled to varying degrees. The most abundant species (A. purpurescens) were also collected from a reference site (Hinchinbrook Island) and subsequently caged at that site and at two oiled sites (Knight and Ingot Islands). Liver-microsomal preparations from the various field and caged animals were analyzed by immunoblot using monoclonal antibody 1-12-3 to the P4501A1 of scup. P4501A protein was induced in all fish sampled from or caged at oiled sites, when compared with fish from reference sites. Fish of all species exhibited the greatest P4501A content at Disk Island. P4501A specific contents in A. purpurescens and P. laeta from Disk Island were elevated 6- and 16-fold, respectively, over fish collected at the reference site. The A. purpurescens caged at Knight and Ingot Islands had a content of P4501A equivalent to that in the fish captured at those sites. Our results indicate that the sedimententrained and weathered oil present 14 months after the spill is capable of altering P4501A levels in intertidal fish. The degree of response seen in fish from the field relative to that possible in these fish is under investigation. However, the rapid and sensitive nature of the induction response allows relatively simple determinations of biochemical effects of residual oil and may serve as a good indicator of when an oil-impacted area is 'clean' by a standard more stringent than superficial visual examination. The relationship between the induction of P4501A and the health of these intertidal fish has not been established. Supported by the Oil Spill Response Center of the Alaska Department of Environmental Conservation.

RefID: 750

Author: Woodin, B.R., Smolowitz, R.M. and Stegeman, J.J.

Year: 1997

Title: Induction of Cytochrome P4501A in the Intertidal Fish Anoplarchus purpurescens by Prudhoe Bay Crude Oil and Environmental Induction in Fish from Prince William Sound

Journal: Environmental Science & Technology

Hyperlink: http://pubs.acs.org/doi/abs/10.1021/es9607190

Abstract: Cytochrome P4501A (CYP1A) induction is a sensitive and specific adaptive response in fish exposed to xenobiotics including petroleum hydrocarbons. CYP1A expression was examined in the intertidal fish Anoplarchus purpurescens collected from or caged at reference sites and sites oiled by the Exxon Valdez spill in Prince William Sound. Immunoblotting of hepatic microsomes showed that the content of CYP1A in fish at oiled sites was up to 6-fold greater than that in reference site fish. Fish injected with the CYP1A inducer β-naphthoflavone showed a 70-fold induction of CYP1A, to levels six times the highest level seen in the field. To model the field exposure, fish were maintained over oiled sediments and/or fed amphipods collected from an oiled site. Hepatic microsomal CYP1A was induced 49-fold in fish exposed to oiled sediments but rapidly returned to control levels after fish were removed from oil exposure. Immunohistochemistry showed CYP1A induction in multiple organs. CYP1A staining in hepatic and some extrahepatic cells was highly correlated ($r^2 \geq 0.95$) with the hepatic CYP1A content detected by immunoblot. Oiled food induced CYP1A most strongly in intestinal mucosal epithelial and endothelial cells. Relatively low levels of CYP1A were observed in liver, gill, and gonad of fish exposed to oil through the diet, consistent with the metabolism of dietary hydrocarbons by intestinal CYP1A. Exposure to oiled sediment alone strongly induced CYP1A in endothelial cells in all organs examined. Thus, oil present in Prince William Sound sediments more than 1 year after the spill was able to induce CYP1A in intertidal fish. The caging and laboratory experiments indicate that the induction of CYP1A observed in field specimens of A. purpurescens from oiled sites was due primarily to persistent spill-derived hydrocarbons.

RefID: 751

Author: Wright, M.E.

Year: 1994

Title: Nestucca project : inventory for Department of Fisheries and Oceans biological resource datasets

Journal: Canadian manuscript report of fisheries and aquatic sciences

Hyperlink:

Abstract: Fifty-two biological resource datasets held within the Department of Fisheries and Oceans, Pacific region are described in terms of their data; parameters, form of collection, geographic extent, georeference, collection dates and frequency, confidentially and quality. The applicability of the data to oil spill response is stated. The electronic and hardcopy format, operating system and software are described along with the dataset status, frequency of update and access protocol. Dataset manager names, office location and telephone numbers are provided. Biological resources include marine fish (salmon, herring and groundfish), shellfish (crustaceans, mollusks and echinoderms), vegetation and marine mammals.

RefID: 752

Author: Wu, D.M., Wang, Z., Hollebone, B., McIntosh, S., King, T. and Hodson, P.V.

Year: 2012

Title: Comparative toxicity of four chemically dispersed and undispersed crude oils to rainbow trout embryos

Journal: Ecotoxicology

Hyperlink: http://onlinelibrary.wiley.com/doi/10.1002/etc.1739/abstract

Abstract: The chronic toxicity of crude oil to fish embryos depends on the chemical constituents of the test oil and on factors that control the exposure of embryos to those constituents. The partitioning of chemicals from oil to water depends on the surface area of oil exposed to water and thus on the susceptibility of oil to be dispersed into droplets. The chronic toxicity of four different crude oils to embryos of rainbow trout (Oncorhynchus mykiss) was measured by exposure to the water-accommodated fraction (WAF; no droplet formation) and to the chemically enhanced WAF (CEWAF) of each oil. When effects were compared with the amount of WAF or CEWAF added to test solutions, chemical dispersion increased toxicity dramatically, by >35 to >300-fold, with the smallest difference measured for the lightest and least viscous oil. When effects were compared with measured concentrations of oil in test solutions, there were no differences in toxicity between WAF and CEWAF treatments, indicating that chemical dispersion promoted droplet formation and the partitioning of hydrocarbons from oil to water. On a dilution basis, the differences in toxicity among the four oils were correlated with the concentrations in oil of polynuclear aromatic hydrocarbons (PAH), particularly those with three to five rings, and with their viscosity, an index of dispersibility. However, when PAH concentrations were measured in solution, toxicity did not vary substantially among the four oils, suggesting that the PAH of each oil had equivalent toxicities and that differences in toxicity represented differences in dispersability. Environ. Toxicol. Chem. 2012;31:754765. (c) 2011 SETAC

RefID: 753

Author: Yang, C., Wang, Z., Yang, Z., Hollebone, B., Brown, C.E., Landriault, M. and Fieldhouse, B.

Year: 2011

Title: Chemical Fingerprints of Alberta Oil Sands and Related Petroleum Products

Journal: Environmental Forensics

Hyperlink: http://www.tandfonline.com/doi/abs/10.1080/15275922.2011.574312

Abstract: Alberta oil sands are known to contain the world's largest reserves of bitumen. The rapid growth in their production could result in a significant environmental impact. Fingerprinting bitumen and petroleum products from the Alberta oil sands is essential in order to better understand the chemical compositions of oil sands, prepare for potential oil spills, and address the associated environmental problems. This study presents an integrated quantitative chemical characterization of Alberta oil sands bitumen and other related Alberta oils using gas chromatography-flame ionization detection (GC-FID) and gas chromatography-mass spectrometry (GC-MS). The characterized target hydrocarbons include n-alkanes, unsubstituted polycyclic aromatic hydrocarbons (PAHs) and their alkylated homologues (APAHs), biomarker terpanes and steranes, bicyclic sesquiterpanes, and diamondoids. The chemical features of bitumen in oil sands are clearly distinguishable from those of most other conventional crude oils. The chemical fingerprints of diluted oil sands bitumen and Albian Heavy Synthetic crude were significantly altered by either the diluent blended with the former or the upgrading processing of crude bitumen in the latter. A chromatographic hump of unresolved complex mixtures (UCMs) eluting between n-C10 to n-C40 is pronounced and n-alkanes are nearly absent in bitumen extracted from oil sands. Alkylated naphthalenes account for only a small proportion of the total APAHs in Alberta oil sands extracts. The PAH compounds in oil sands extracts and diluted bitumen are dominated by alkylated homologues with the relative distribution of C0- < C1- < C2- < C3- for all five APAH series. Biomarker terpanes and cage-like adamantanes were determined in almost identical abundance and distribution profile in oil sands extracts and diluted crude bitumen, while biomarker steranes and bicyclic sesquiterpanes were removed to varying degrees by physical weathering or biodegradation. [PUBLICATION ABSTRACT]

RefID: 754

Author: Young, R.F., Michel, L.M. and Fedorak, P.M.

Year: 2011

Title: Distribution of naphthenic acids in tissues of laboratory-exposed fish and in wild fishes from near the Athabasca oil sands in Alberta, Canada

Journal: Ecotoxicology and Environmental Safety

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0147651310003921

Abstract: Naphthenic acids, which have a variety of commercial applications, occur naturally in conventional crude oil and in highly biodegraded petroleum such as that found in the Athabasca oil sands in Alberta, Canada. Oil sands extraction is done using a caustic aqueous extraction process. The alkaline pH releases the naphthenic acids from the oil sands and dissolves them into water as their soluble naphthenate forms, which are anionic surfactants. These aqueous extracts contain concentrations of naphthenates that are acutely lethal to fishes and other aquatic organisms. Previous research has shown that naphthenic acids can be taken up by fish, but the distribution of these acids in various tissues of the fish has not been determined. In this study, rainbow trout (Oncorhynchus mykiss) were exposed to commercial (Merichem) naphthenic acids in the laboratory. After a 10-d exposure to approximately 3 mg naphthenic acids/L, the fish were dissected and samples of gills, heart, liver, kidney, muscle, and eggs were extracted and analyzed for free (unconjugated) naphthenic acids by a gas chromatography-mass spectrometry method. Each of the tissues contained naphthenic acids and non-parametric statistical analyses showed that gills and livers contained higher concentrations than the muscles and that the livers had higher concentrations than the hearts. Four different species of fish (two fish of each species) were collected from the Athabasca River near two oil sands mining and extraction operations. No free naphthenic acids were detected in the muscle or liver of these fish. (C) 2010 Elsevier Inc. All rights reserved.

RefID: 755

Author: Young, R.F., Orr, E.A., Goss, G.G. and Fedorak, P.M.

Year: 2007

Title: Detection of naphthenic acids in fish exposed to commercial naphthenic acids and oil sands process-affected water

Journal: Chemosphere

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0045653506018108

Abstract: Naphthenic acids are a complex mixture of carboxylic acids that occur naturally in petroleum. During the extraction of bitumen from the oil sands in northeastern Alberta, Canada, naphthenic acids are released into the aqueous phase and these acids become the most toxic components in the process-affected water. Although previous studies have exposed fish to naphthenic acids or oil sands process-affected waters, there has been no analytical method to specifically detect naphthenic acids in fish. Here, we describe a qualitative method to specifically detect these acids. In 96-h static renewal tests, rainbow trout (Oncorhynchus mykiss) fingerlings were exposed to three different treatments: (1) fed pellets that contained commercial naphthenic acids (1.5 mg g(-1) of food), (2) kept in tap water that contained commercial naphthenic acids (3 mg l(-1)) and (3) kept in an oil sands process-affected water that contained 15 mg naphthenic acids l(-1). Five-gram samples of fish were homogenized and extracted, then the mixture of free fatty acids and naphthenic acids was isolated from the extract using strong anion exchange chromatography. The mixture was derivatized and analyzed by gas chromatography-mass spectrometry. Reconstructed ion chromatograms (m/z = 267) selectively detected naphthenic acids. These acids were present in each fish that was exposed to naphthenic acids, but absent in fish that were not exposed to naphthenic acids. The minimum detectable concentration was about 1 mu g naphthenic acids g-1 of fish. (c) 2006 Elsevier Ltd. All rights reserved.

RefID: 756

Author: Young, R.F., Wismer, W.V. and Fedorak, P.M.

Year: 2008

Title: Estimating naphthenic acids concentrations in laboratory-exposed fish and in fish from the wild

Journal: Chemosphere

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0045653508008229

Abstract: Naphthenic acids (NAs) are the most water-soluble organic components found in the Athabasca oil sands in Alberta, Canada, and these acids are released into aqueous tailing waters as a result of bitumen extraction. Although the toxicity of NAs to fish is well known, there has been no method available to estimate NAs concentrations in fish. This paper describes a newly developed analytical method using single ion monitoring gas chromatography-mass spectrometry (GC-MS) to measure NAs in fish, down to concentrations of similar to 0.1 mg kg(-1) of fish flesh. This method was used to measure the uptake and depuration of commercial NAs in laboratory experiments. Exposure of rainbow trout (Oncorhynchus mykiss) to 3 mg NAs l(-1) for 9 d gave a bioconcentration factor of similar to 2 at pH 8.2. Within 1 d after the fish were transferred to NAs-free water, about 95% of the NAs were depurated. In addition, the analytical method was used to determine if NAs were present in four species of wild fish - northern pike (Esox lucius), lake whitefish (Coregonus clupeaformis), white sucker (Catostomus commersoni), walleye (Sander vitreus) - collected from near the oil sands. Flesh samples from 23 wild fish were analyzed, and 18 of these had no detectable NAs. Four fish (one of each species) contained NAs at concentrations from 0.2 to 2.8 mg kg(-1). The GC-MS results from one wild fish presented a unique problem. However, with additional work it was concluded that the NAs concentration in this fish was <0.1 mg kg(-1). (C) 2008 Elsevier Ltd. All rights reserved.

RefID: 757

Author: Zachleder, V. and Tukaj, Z.

Year: 1993

Title: EFFECT OF FUEL-OIL AND DISPERSANT ON CELL-CYCLE AND MACROMOLECULAR-SYNTHESIS IN THE CHLOROCOCCAL ALGA SCENEDESMUS-ARMATUS

Journal: Marine Biology

Hyperlink: http://link.springer.com/article/10.1007%2FBF00345680

Abstract: Growth and reproductive processes in synchronous cultures of the alga Scenedesmus armatus (isolated from Baltic phytoplankton) were followed in the presence of various concentrations of dispersant DP-105, oil, and mixtures of oil and dispersant. The inhibition of protoplast fission was the most prominent effect of oil. Nuclear division was inhibited to a lesser extent. With an increasing concentration of oil, dispersant, or a mixture of both, the inhibitory effects were expressed earlier. The presence of oil compounds did not effect the timing of DNA replication, but it did reduce the number of replication rounds in a concentration dependent manner. The inhibition of DNA synthesis was accompanied by slightly delayed cessation of RNA and protein synthesis. Starch synthesis was always inhibited to a lesser extent, and at a later time, than other macromolecular syntheses. Pigment synthesis continued almost to the end of the cell cycle. Thereafter, a rapid degradation of all pigments began and the cells became bleached. No inhibitory effect on reproductive processes was found if oil or dispersant were added to cultures transferred into darkness. Furthermore, recovery from inhibition of reproductive processes caused by oil in continuously illuminated cultures was observed in darkened cells. Chemically dispersed fuel oil was only slightly more toxic than mechanically dispersed fuel oil; an additive, rather than synergistic, effect of oil/dispersant mixture was found.

RefID: 758

Author: Zanette, J., de Almeida, E.A., da Silva, A.Z., Guzenski, J., Ferreira, J.F., Di Mascio, P., Marques, M.R.F. and Bainy, A.C.D.

Year: 2011

Title: Salinity influences glutathione S-transferase activity and lipid peroxidation responses in the Crassostrea gigas oyster exposed to diesel oil

Journal: Science of the Total Environment

Hyperlink: http://www.ncbi.nlm.nih.gov/pubmed/21349572

Abstract: Biochemical responses in bivalve mollusks are commonly employed in environmental studies as biomarkers of aquatic contamination. The present study evaluated the possible influence of salinity (35, 25,15 and 9 ppt) in the biomarker responses of Crassostrea gigas oysters exposed to diesel at different nominal concentrations (0.01, 0.1 and 1 mLL(-1)) using a semi-static exposure system. Salinity alone did not resulted in major changes in the gill's catalase activity (CAT), glutathione S-transferase activity (GST) and lipid peroxidation levels (measured as malondialdehyde. MDA), but influenced diesel related responses. At 25 ppt salinity, but not at the other salinity levels, oysters exposed to diesel showed a strikingly positive concentration-dependent GST response. At 25 ppt and 1 mLL(-1) diesel, the GST activity in the gills remained elevated, even after one week of depuration in clean water. The increased MDA levels in the oysters exposed to diesel comparing to control groups at 9, 15 and 35 ppt salinities suggest the occurrence of lipid peroxidation in those salinities, but not at 25 ppt salinity. The MDA quickly returned to basal levels after 24 h of depuration. CAT activity was unaltered by the treatments employed. High toxicity for 1 mLL(-1) diesel was observed only at 35 ppt salinity, but not in the other salinities. Results from this study strongly suggest that salinity influences the diesel related biomarker responses and toxicity in C. gigas, and that some of those responses remain altered even after depuration. (C) 2011 Elsevier B.V. All rights reserved.

RefID: 759

Author: Zhang, J.F., Shen, H., Xu, T.L., Wang, X.R., Li, W.M. and Gu, Y.F.

Year: 2003

Title: Effects of long-term exposure of low-level diesel oil on the antioxidant defense system of fish

Journal: Bulletin of Environmental Contamination and Toxicology

Hyperlink: http://link.springer.com/article/10.1007%2Fs00128-003-0155-5

Abstract:

RefID: 760

Author: Zheng, M.Y., Ahuja, M., Bhattacharya, D., Clement, T.P., Hayworth, J.S. and Dhanasekaran, M.

Year: 2014

Title: Evaluation of differential cytotoxic effects of the oil spill dispersant Corexit 9500

Journal: Life Sciences

Hyperlink: http://www.sciencedirect.com/science/article/pii/S0024320513007571

Abstract: Aims: The British Petroleum (BP) oil spill has raised several ecological and health concerns. As the first response, BP used a chemical dispersant, Corexit-9500, to disperse the crude oil in the Gulf of Mexico to limit shoreline contamination problems. Nevertheless, portions of this oil/Corexit mixture reached the shoreline and still remain in various Gulf shore environments. The use of Corexit itself has become a significant concern since its impacts on human health and environment is unclear. Main methods: In this study, in vitro cytotoxic effects of Corexit were evaluated using different mammalian cells. Key findings: Under serum free conditions, the LC50 value for Corexit in BL16/BL6 cell was 16 ppm, in 1321N1 cell was 33 ppm, in H19-7 cell was 70 ppm, in HEK293 was 93 ppm, and in HK-2 cell was 95 ppm. With regard to the mechanisms of cytotoxicity, we hypothesize that Corexit can possibly induce cytotoxicity in mammalian cells by altering the intracellular oxidative balance and inhibiting mitochondrial functions. Corexit induced increased reactive oxygen species and lipid peroxide levels; also, it depleted glutathione content and altered catalase activity in H19-7 cells. In addition, there was mitochondrial complex-I inhibition and increase in the pro-apoptotic factors including caspase-3 and BAX expression. Significance: The experimental results show changes in intracellular oxidative radicals leading to mitochondrial dysfunctions and apoptosis in Corexit treatments, possibly contributing to cell death. Our findings raise concerns about using large volumes of Corexit, a potential environmental toxin, in sensitive ocean environments. (C) 2013 Elsevier Inc All rights reserved.

RefID: 761

Author: Zhou, S., Heras, H. and Ackman, R.G.

Year: 1997

Title: Role of adipocytes in the muscle tissue of Atlantic salmon (Salmo salar) in the uptake, release and retention of water-soluble fraction of crude oil hydrocarbons

Journal: Marine Biology

Hyperlink: http://link.springer.com/article/10.1007%2Fs002270050044

Abstract: The uptake and depuration of the water-soluble fraction (WSF) of hydrocarbons of crude petroleum by Atlantic salmon (Salmo salar) has previously been examined in terms of whole muscle. The hypothesis that the tainting WSF in the muscle was retained primarily by adipocytes has been investigated by the isolation of adipocytes and the subsequent analysis for hydrocarbons in adipocytes. After 96 h exposure of market-sized Atlantic salmon to 0.2 ppm WSF, adipocytes isolated from the belly flap region of the muscle tissue accumulated 14.3 times more WSF (59.4 ppm) than the dorsal white muscle (4.2 ppm), while 54% of the tainting WSF in the dorsal white muscle was found to be stored in associated adipocytes. When returned to clean seawater, WSF accumulated in the dorsal white muscle was released much faster than that in the adipocytes. These results indicated that the loose association of WSF with the nonlipid portion of white muscle, mainly muscle cells and intercellular fluid, is responsible for the rapid discharge of WSF from the dorsal muscle tissue in the early stages of depuration. After 4 d of depuration, the adipocytes became the principal storage site of residual WSF in white muscle and the depuration of WSF from muscle tissue then reflected the release of WSF from adipocytes in the muscle tissue. After 20 d of depuration, 10.7 ppm of tainting WSF in the form of high molecular weight aromatic hydrocarbons (mainly C-4-benzenes, naphthalene and alkylated naphthalenes) were still present in adipocytes, while in the dorsal white muscle only a trace of total WSF was detected. Increases in the number of aromatic rings and the alkylations on the rings enhanced the accumulation and retention of individual hydrocarbons in both adipocytes and white muscle. From these studies we conclude that it is the adipocytes in the muscle tissue which control the actual accumulation and release of hydrocarbons in the whole muscle tissue of Atlantic salmon.

RefID: 762

Author: Ziolkowska, A. and Wyszkowski, M.

Year: 2010

Title: TOXICITY OF PETROLEUM SUBSTANCES TO MICROORGANISMS AND PLANTS

Journal: Ecological Chemistry and Engineering

Hyperlink: http://tchie.uni.opole.pl/freeECE/S_17_1/ZiolkowskaWyszkowski_17%28S1%29.pdf

Abstract: The paper discusses sources of petroleum substances in environment and threats caused by petroleum contamination of water and soil. The physicochemical and biological properties of petroleum substances have been determined along with their toxicity, particularly that of aromatic hydrocarbons, including the so-called BTEX group (benzene, toluene, ethyl benzene and xylenes) to microorganisms and plants. Much emphasis has been laid on the properties which shape toxicity. The effect (typically degrading one) on live organisms present in water and soil environment, including biological equilibrium of soil (abundance of microorganisms, enzymatic activity), has been discussed as well as the growth and development of plants growing on soil polluted with these substances. In addition, factors (soil or water properties and condition, C:N ratio, pH reaction, soil moisture, content of organic substance, fertilization, type and species of aquatic or land organisms) which influence the effect produced by petroleum substances on live organisms in environment have been mentioned.

RefID: 763

Author: Zuijdgeest, A. and Huettel, M.

Year: 2012

Title: Dispersants as Used in Response to the MC252-Spill Lead to Higher Mobility of Polycyclic Aromatic Hydrocarbons in Oil-Contaminated Gulf of Mexico Sand

Journal: Plos One

Hyperlink: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0050549

Abstract: After the explosion of the Deepwater Horizon oil rig, large volumes of crude oil were washed onto and embedded in the sandy beaches and sublittoral sands of the Northern Gulf of Mexico. Some of this oil was mechanically or chemically dispersed before reaching the shore. With a set of laboratory-column experiments we show that the addition of chemical dispersants (Corexit 9500A) increases the mobility of polycyclic aromatic hydrocarbons (PAHs) in saturated permeable sediments by up to two orders of magnitude. Distribution and concentrations of PAHs, measured in the solid phase and effluent water of the columns using GC/MS, revealed that the mobility of the PAHs depended on their hydrophobicity and was species specific also in the presence of dispersant. Deepest penetration was observed for acenaphthylene and phenanthrene. Flushing of the columns with seawater after percolation of the oiled water resulted in enhanced movement by remobilization of retained PAHs. An in-situ benthic chamber experiment demonstrated that aromatic hydrocarbons are transported into permeable sublittoral sediment, emphasizing the relevance of our laboratory column experiments in natural settings. We conclude that the addition of dispersants permits crude oil components to penetrate faster and deeper into permeable saturated sands, where anaerobic conditions may slow degradation of these compounds, thus extending the persistence of potentially harmful PAHs in the marine environment. Application of dispersants in nearshore oil spills should take into account enhanced penetration depths into saturated sands as this may entail potential threats to the groundwater.