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Proceedings of the Pacific Regional Peer Review on the Application of a Framework to Assess Vulnerability of Biological Components to Diesel and Gasoline; Bunker C; and Diluted Bitumen in the Marine Environment in the Pacific Region

December 12–15, 2022
Virtual Meeting

Chairperson: Erin Porszt
Editor: Yvonne Muirhead-Vert

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

These Proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting on December 12–15, 2022. The working papers presented for peer review focused on the application of a framework to assess vulnerability of biological components to three oil categories (diesel and gasoline, Bunker C, and diluted bitumen) in the marine environment in the Pacific Region.

Due to the COVID-19 pandemic, in-person gatherings have been restricted and a virtual format for this meeting was adopted. Participation included DFO Science, Fish and Fish Habitat Protection Program (FFHPP), and external participants from the University of Guelph, Toquaht Nation, Huntsman Marine Science Centre, Triox Environmental Emergencies, and Environment and Climate Change Canada.

The meeting participants agreed the working papers met all of the Terms of Reference objectives and were accepted with minor revisions. The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report (SAR) to inform emergency oil spill responses in the Pacific Region as well as recovery efforts and other marine spatial planning initiatives.

The Science Advisory Report and the supporting Research Documents will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) meeting entitled Application of a Framework to Assess Vulnerability of Biological Components to diesel and gasoline; Bunker C; and diluted bitumen in the marine environment in the Pacific Region, was held on December 12-15, 2022. Three working papers (listed below) were reviewed during the RPR meeting.

The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from DFO Fish and Fish Habitat Protection Program (FFHPP). Notifications of the science review and conditions for participation were sent to representatives with relevant expertise from DFO Science (Headquarters, National Capital, Maritimes, and Pacific Regions), Fish and Fish Habitat Protection Program (FFHPP) staff as well as representatives with relevant expertise from First Nations, Huntsman Marine Science Centre, academia, consultants, and other government organizations.

The working papers were prepared and made available to meeting participants prior to the meeting (the working paper abstracts are provided in Appendix B). Two of these papers will be developed into Research Documents and posted on the CSAS website.

St. Germain, C., Herborg, L.-M., Punt, M., Jeffery, S., Hannah, L., and Finney, J. Application of a framework to assess vulnerability of biological components to ship-source Diesel and Gasoline spills in the marine environment in the Pacific Region. 2022. CSAP Working Paper 2020FFHPP15a.

St. Germain, C., Herborg, L.-M., Punt, M., Jeffery, S., Hannah, L., and Finney, J. Application of a framework to assess vulnerability of biological components to ship-source Bunker C spills in the marine environment in the Pacific Region. 2022. CSAP Working Paper 2020FFHPP15b.[1]

St. Germain, C., Herborg, L.-M., Punt, M., Jeffery, S., Hannah, L., and Finney, J. Application of a framework to assess vulnerability of biological components to ship-source Diluted bitumen spills in the marine environment in the Pacific Region. 2022. CSAP Working Paper 2020FFHPP15c.

The meeting Chair, Erin Porszt, welcomed participants, reviewed the role of CSAS in the provision of peer-reviewed advice, and gave a general overview of the CSAS process. The Chair discussed the role of participants, the purpose of the various RPR publications (Science Advisory Report, Proceedings and Research Documents), and the definition and process around achieving consensus decisions and advice. Everyone was invited to participate fully in the discussion and to contribute knowledge to the process, with the goal of delivering scientifically defensible conclusions and advice. It was confirmed with participants that all had received copies of the Terms of Reference, working papers, written reviews, and the agenda.

The Chair reviewed the Agenda (Appendix D) and the Terms of Reference (Appendix A) for the meeting, highlighting the objectives and identifying Yvonne Muirhead-Vert as the Rapporteur for the meeting. Jessica Finney agreed to record the proposed revisions to the working papers for the authors. The Chair then reviewed the ground rules and process for exchange, reminding

[1] After the meeting, the authors determined that due to substantial overlap in content, working paper 2020FFHPP15b would be withdrawn, and the scope of working paper 2020FFHPP15c would be expanded to include both diluted bitumen and Bunker C.

participants that the meeting was a science review and not a consultation. Members were reminded that everyone at the meeting had equal standing as participants and that they were expected to contribute to the review process if they had information or questions relevant to the paper being discussed. In total, 23 people participated in the Regional Peer Review (RPR; Appendix D) over the four-day meeting.

Prior to the meeting, Aline Carrier (Toquaht Nation) and Brian Robinson (DFO Science, Maritimes Region) were asked to provide detailed written reviews of the working papers to assist everyone attending the peer review meeting. Participants were provided with copies of their written reviews ahead of the meeting.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report to inform emergency oil spill responses in the Pacific Region as well as recovery efforts and other marine spatial planning initiatives. The Science Advisory Report and supporting Research Documents will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

GENERAL DISCUSSION

Following a presentation by the authors, the two reviewers, Aline Carrier (Toquaht Nation) and Brian Robinson (DFO Science, Maritimes Region), shared their comments and questions on the working papers. The authors were given time to respond to the reviewers before the discussion was opened to all participants. This proceedings document summarizes the discussions that took place by topic, where points of clarification presented by the authors in their presentations and questions and comments raised by the reviewers and participants are captured within the appropriate topics. Both reviewers' formal submissions are located in Appendix C.

TERMS OF REFERENCE OBJECTIVE ONE

Identify any necessary adaptations to the vulnerability criteria, species subgroups, and scoring in the Pacific Application of the National Framework that are required to determine the relative vulnerability of species subgroups in the Pacific Region to the following three categories of oil: a) gasoline and diesel; b) Bunker C; and c) diluted bitumen.

Exposure criterion: One of the major scoring differences for diesel and gasoline, Bunker C, and diluted bitumen, as compared to the 2022 Update for all oil types (DFO 2023), was due to the exposure criterion "Seafloor interacting". These oil types float in the initial stages of a spill, so interacting with the seafloor does not increase the likelihood of exposure. This assumption was questioned by participants, and there was agreement to make the text clear that this analysis deals with fresh, floating oils only. Based on this assumption, only seafloor and vegetation in the intertidal would be fouled therefore the criterion name was updated to include "in intertidal areas".

The authors initially decided to use NA for the seafloor interacting criterion. The group recommended changing the scores for the seafloor interacting criterion from NA to zero if the subgroup is subtidal and 1 if the subgroup is intertidal and interacts with the seafloor or vegetation. This was done for all subgroups and keeps the values consistent with the National Framework (Thornborough et al. 2017).

Recovery criterion: Another scoring difference was due to the recovery criterion "Close association with unconsolidated substrates" because if oil floats, only substrates in the intertidal would be fouled. The criterion name was updated to include "in intertidal areas".

Sensitivity criterion: Scores were reviewed for the sensitivity criterion "mechanical sensitivity". In particular, scoring had to be adapted for diesel because a lighter oil would not cause mechanical impairment. This assumption was discussed at various times and in relation to specific species (e.g., barnacles, marine mammals).

Chemical sensitivity and reliability screening: When scoring the chemical sensitivity criterion for these oil types the authors noted that they summarized the information found in the literature but that all groups received a precautionary score of 1* [1* (precautionary)] due to the unresolved challenge of using this criterion. The authors noted that it was challenging to find oil type-specific papers using comparable methods and that future iterations of the assessment could use reliability screening of the literature before it is incorporated into the framework. One participant recommended using toxicity studies to inform the scoring of chemical sensitivity criterion. The best practice would be to use reliability screening and a scoring metric to support decisions about including or excluding data found during the literature review for the scoring process. A reviewer shared some examples of reliability screening options to the group: Assessing the reliability of ecotoxicological studies: An overview of current needs and approaches and A Critical Review of the Availability, Reliability, and Ecological Relevance of Arctic Species Toxicity Tests for Use in Environmental Risk Assessment that could be reviewed and used in future updates to the framework.

Incorporating clearer guidance on toxicity endpoints in the literature into the framework in the future would allow for a score of zero for the chemical sensitivity criterion. A recommendation was made to include a quantitative assessment of the studies that will be used as references within the framework. An author suggested an alternative recommendation to remove toxicity and have the assessment completed by an agency with contaminant expertise and incorporate the assessment in another way. To effectively score chemical sensitivity requires detailed knowledge, a structured literature review, and interpretation on contaminants.

TERMS OF REFERENCE OBJECTIVE TWO

Identify and discuss the relative vulnerability of subgroups in the Pacific Region to the three categories of oil by applying the adapted framework.

Mechanical sensitivity criterion: For invertebrates and algae, the original mechanical sensitivity scoring was a precautionary one since adhered oil could limit gas exchange in algae and could potentially clog filter feeding structures in invertebrates. However, it was discussed that diesel/gasoline would likely disperse on the surface of the water and the level of particulates would be so low that the chance of mechanical impairment may be small. The group recommended that mechanical sensitivity score for diesel and gasoline should be zero for these subgroups. A participant recommended looking at the literature regarding barnacles, as these filter feeders have hairs and may not be able to handle any type of fouling. After review of the literature and re-scoring to show the group the implications on all scores, the group decided that invertebrates and algae subgroups should receive a score of 0 for mechanical impairment for diesel and gasoline.

Another question was raised regarding the difference between an emulsion compared to raw oil on the surface. The emulsion would be more viscous. The light oil would be more volatile and quickly break down through evaporation and dissolution in the water column compared to thicker oils. The authors provided some information on the physical adhesion to shoreline materials, such as marsh and peat scarp. The authors noted that the scores were reviewed by a consulting company and their review and comments were included in the working papers.

Birds and mechanical sensitivity: A participant noted that there is a lot of literature on diesel and gasoline and how it interacts with birds. They noted oil products affect birds by sticking to the feathers and can affect the microstructure within the feathers that creates insulation for the bird. Birds have the ability to preen their feathers and remove small amounts of diesel from them so they are able to modify their structure. These impacts may be similar to otters since they are able to preen their fur and ingest the oil. An author said that they had focused on relevant references on fur bearing animals.

Specific species: The group asked if the authors would be able to review the scoring and justifications for the following species: Eelgrass; Juvenile/adult Steelhead; Red Rock Crab; herring; and Razor Clam, and report back to the group.

Eelgrass: A participant was surprised with the scoring of Eelgrass being considered to be "most vulnerable" when they felt that oil would have little to no toxic effect on it based on the studies cited in the working papers. The authors emphasized that toxic effects only represented one criterion and indicated that many life history traits of Eelgrass contributed to its high score. Eelgrass also scored a one for all the exposure category criteria which explains why it is highly vulnerable.

The scores for Eelgrass were reviewed, and exposure scores (i.e., concentration/aggregation, low mobility, sea surface interacting, and seafloor interacting) remained the same. For the sensitivity criteria, a score of zero was given for all plants for mechanical sensitivity for diesel and gasoline and score of 1* for chemical sensitivity. A participant noted that the scoring for sensitivity for diluted bitumen is based on a laboratory study with high concentrations for 28 days. However, in field studies they were not aware of long-term impairment to Eelgrass.

There was concern that the Eelgrass would be prioritized over other species such as herring given its high scoring. There was a lengthy discussion regarding the scoring of Eelgrass and it was decided that the scoring would be kept as 1* for chemical sensitivity. The authors have agreed to add text in the table regarding the limitations of scoring of this species. A participant recommended that the next update critically review the literature underlying the chemical sensitivity for Eelgrass.

Juvenile/adult Steelhead: For salmonids and estuarine fish, the choice of endpoints could be reviewed to determine which endpoints should be selected in future iterations of the framework. Endpoints for reduced osmoregulation and ion function may need to be reconsidered against quality screening criteria for endpoints. The authors have agreed to add a star to the chemical sensitivity score to indicate the score is precautionary.

Red Rock Crab: A question was asked regarding how the information would be used in the report since Red Rock Crab is included in both the intertidal and subtidal groupings. They were wondering if there is some way to make it easier for species found in multiple places and if the most conservative score would be used. The authors responded that a database table will be used in the field when responding to an oil spill. In Appendix A, when multiple species are found within the table, text will be added to the metadata so the information can be captured when the tables are exported from Open Data.

Herring: In this framework, herring are included within two different subgroups (1. Intertidal species that associate with unconsolidated substrates or Eelgrass; and 2. Subtidal pelagic) that were scored differently for the vulnerability criteria. Herring are part of the first subgroup when they are nearshore during spawning in the spring and as juveniles, and part of the second subgroup as feeding adults. Herring that occur in intertidal areas have a higher vulnerability to oil due to their higher risk of exposure. This is reflected in the different scores for the two subgroups. A reviewer suggested that it would be easier for the reader if examples of the kind of life history characteristics that place marine fishes at a lower risk of exposure for oil were included in the text.

There was a reduction in the ranking of herring and it may need to be prioritized using other methods. The low ranking could cause concerns among Indigenous peoples since herring is of high cultural value for food, social and ceremonial (FSC) purposes. The authors noted that this framework only considers the ecological vulnerability of species to oil, but that other considerations such as cultural and socio-economic importance are included in other ways during a spill. Other response partners including Indigenous communities would provide guidance and advice to Environmental Incident Coordinators (EICs) on these subject areas.

Razor Clams: In the original framework application, Razor Clams received a total vulnerability score of seven. In this framework for specific oil types, the subgroup containing razor clams received a total score of six since it did not score for seafloor interaction as the oil is assumed to be floating.

Marine invertebrates: A reviewer recommended more details be included in the Marine Invertebrates section since there are ten fewer subgroups having a high vulnerability score for diluted bitumen compared to the 2022 Update for all oil types (DFO 2023). To the reviewer, it seemed counterintuitive since mussels, Pacific oysters, and Razor Clams are filter feeders and they suggested having more text on the life history traits that make them less vulnerable to fresh floating oil.

It was also noted that there was conflicting information on how oil impacts crabs. The authors indicated there is a difference between the subspecies of crabs since they have different tolerances to the oil which would result in a different scoring within the framework. Highly mobile crabs would likely be impacted less compared to infaunal species of crabs since they could move away from the oil.

Marine mammals: There was a scoring difference between the three oils for baleen whales. The total vulnerability score was one lower value for diesel and gasoline than the other two oil types. The lower value was because diesel and gasoline are assumed not to clog baleen. A reviewer suggested the inclusion of life history characteristic examples in the text to explain why marine mammals could be at a lower risk of exposure to oil. The authors have agreed to add more detail in this section.

Echinoderms and *Pycnopodia*: These species have a reduced population status due to sea star wasting disease. A participant recommended scoring them as a one for the recovery criterion 'Endemism/Isolation' since there is unpublished research that refers to isolated populations remaining after a large population decline. The scoring guidance for the Endemism/Isolation criterion in this application of the vulnerability framework was to keep all scores the same as the 2022 update document (DFO 2023) since the criterion reflects the status of the subgroup and is not specific to an oil type. The authors agreed to review all tables for *Pycnopodia* and consider including this new information.

TERMS OF REFERENCE OBJECTIVE THREE

Develop scenarios of fate and behaviour for each of the three categories of oil over time and under different environmental conditions relevant in the Pacific Region using the National Oceanic and Atmospheric Administration's Automated Data Inquiry for Oil Spills (ADIOS) oil weathering model.

Automated Data Inquiry for Oil Spills (ADIOS): The Automated Data Inquiry for Oil Spills (ADIOS) is a weathering model used to predict the fate and behaviour of oil. A participant suggested that the time scales should be consistent in the figures since some of the figures in the working papers have a timescale of 120 hrs while others have timescale of 48 hrs. One of the authors indicated that the timescales in the figures are based on the evaporation data, and that the model does not provide density once the majority of the oil has evaporated. The authors will look in the database again for the timelines for diesel and Bunker C. If the timeline is a limitation of the ADIOS database then it should be clearly stated in the report. The longer time period is preferred to cutting the figures at the 48 hr mark to make the figures consistent. The participant then suggested that different format figures (example below) could be included in the working papers for ease of the reader. The figures show the percent lost due to weathering over time, broken down into dispersion in the water column, and through evaporation.

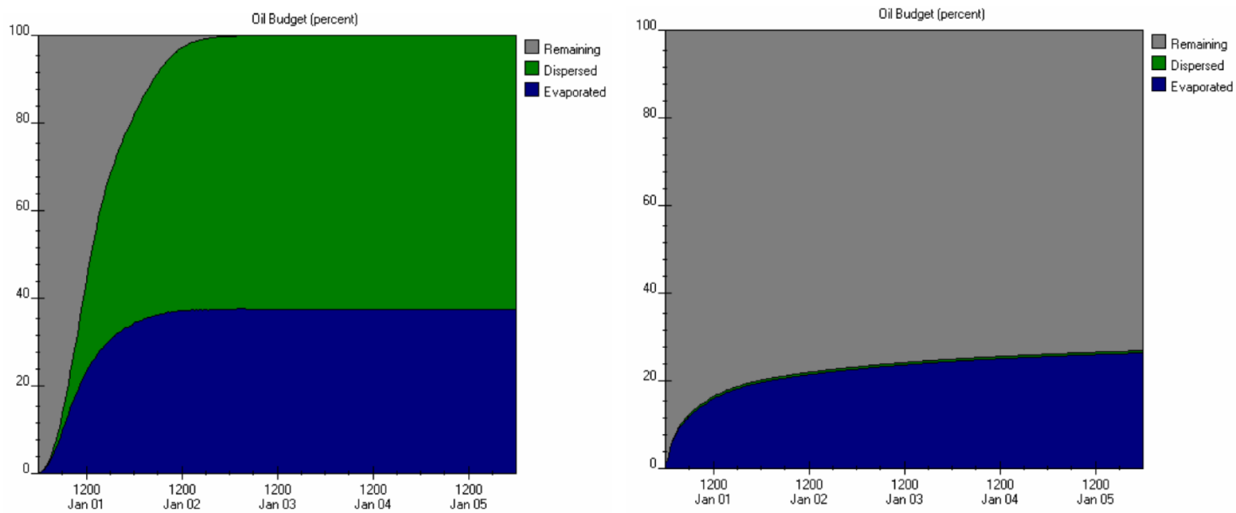

Figure 1. Example figures from Ryan et al. (2019) showing oil budget for a spill of diesel (left) and for a spill of intermediate fuel oil (IFO180) (right).

ADIOS model parameters: A member of the group indicated that the temperatures looked higher in the ADIOS model than what is typical for the Pacific Northwest. They wondered if the ADIOS model considered other variables (i.e., temperature, wind, salinity, stratification of the water column) since conditions of the oil would change depending on the environmental conditions. The authors noted that they had consulted with regional oceanographers to determine the values of the parameters that would feed the model. They agreed that they could add more text in the working papers on how environmental variables would change with latitude as one moves further north up the coast.

Scenarios: There is a suggestion that more models of the environmental conditions could be included in the papers to address the different behaviour of the oil. At this time, the papers presented the four major scenarios (i.e., summer versus winter water temperatures, calm versus rough water, and windier conditions).

A reviewer noted that a lot of fresh water enters the ocean in the winter and recommended a new scenario be generated to take this into account. In the winter, there may be more impacts due to fresh water than roughness. They also suggested that different salinities would change the model outputs for the fate and behaviour of the oil. The authors agreed to include more detail about modelling in the future work section and suggest more models on different salinities with the increased amounts of fresh water entering the ocean during the winter.

Weathering: A participant noted that the percent weathering in the oil fate behavior graphs should be defined as the percent of oil lost due to weathering. The person noted that it would be helpful in the papers to discuss where the remaining oil goes (i.e., remaining on the water's surface, in the water column, or interacting with sediments).

Another participant suggested that the section on the weathering and sinking of the oil could have some more detail. The sinking process could be different than what is presented in the papers since the density of the oil changes once it is exposed to weathering (i.e., oil products that have lighter composition would degrade more quickly than heavier oil products).

There was a question about whether or not the weathering scores are reflective of the initial spill. The greatest changes to the oil in the weathering profile occur in the first six to eighteen hours after a diesel spill, the first hour after a gasoline spill, the first two to five days after a Bunker C spill, and the first two to twelve hours after a diluted bitumen spill. After these timelines of weathering, Environmental Incident Coordinators (EICs) would revert back to using the 2022 Update for all oil types (DFO 2023). The authors agreed to make this section more clear within the papers.

Holding capacity: A participant asked what the holding capacity for the three oil products would be when the oil interacts with different substrates. Gasoline/diesel is thin so it would have a lower holding capacity compared to thick oil types which would stick longer on different substrates. Penetration of the oil is also a factor impacting how long the oil will stick to the substrate. They suggested that text on holding capacity could be included in the working papers.

Framework timelines: The application of the vulnerability framework is for the initial spill when the oil is fresh and still floating. After the first 72 hrs of a spill, EICs would incorporate field observations (i.e., people on the ground and in boats, fly-bys, etc.) to inform their recommendations to support decision-making. The vulnerability frameworks for specific oil types and the 2022 Update for all oil types (DFO 2023) would be used as references for the duration of the response.

TERMS OF REFERENCE OBJECTIVE FOUR

Discuss in general how the relative vulnerability of subgroups, as identified in objective 2, may change when considering the fate and behaviour of the three categories of oil over time and under different environmental conditions.

Timing of framework: The fate and behaviour of oil over time and under different environmental conditions in relation to changes in oil vulnerability scores was discussed so that EICs use the correct vulnerability scores. In this framework, this primarily relates to when the oil weathers and potentially moves from the water surface to other compartments of the environment (e.g., water column, ocean floor). Participants recommended making the time to transition under various conditions clear in the advice so end users know when to switch from the oil specific scoring to the all oils scoring.

General fate and behaviour information on oil toxicity: A reviewer suggested that additional background information on the fate and behavior of oil toxicity could be included. It would be beneficial to have discussion regarding the bioavailability and the dissolution of low molecular weight components between the three oil products. It is important for EICs to understand the potential acute, chronic, and indirect effects of polycyclic aromatic hydrocarbons (PAHs) entering the environment as well as their exposure pathways at environmentally relevant concentrations.

Behaviour on water: It was suggested that more information could be included in Section 2.2.3 to address how other aggregates such as oil-particle aggregates (OPAs), oil-sediment aggregates (OSAs), oil-mineral aggregates (OMAs), and other biological particulate interactions would likely form in the environment. They suggested that text could be included on suspended particulate matter (SPM) concentrations that promote the formation of OPAs for a given oil type, and how the framework would apply to the West coast. There are threshold concentrations of SPMs needed to start the formation of OPAs, so if these minimum SPM concentrations are known, then a review of the areas could be conducted to determine which area would be vulnerable to OPA formation. There is evidence that oil and site-specific OPAs can form in high energy environments and sink to the ocean floor. A reviewer asked if the paragraph discussing Bunker C and diluted bitumen not sinking in high energy environments could be revised to indicate the possibility of OPAs forming and sinking.

Oiled marine snow: Oiled marine snow is created when oil droplets combine with organisms, organic matter, and minerals to form aggregates that sink to the bottom of the ocean. This was a major driver of oil droplets reaching the bottom sediments during the Gulf of Mexico spill in 2010. It was mentioned that marine oil snow may violate the assumption of floating oil types underlying this assessment.

Chemical properties: PAHs are the main driver of oil toxicity contamination. A participant suggested that more text regarding low molecular weight (LMW) and high molecular weight (HMW) PAHs could be included showing a significant difference in the PAH profiles of the three different oil products. High level information on the PAH chemistry could be included as well as additional information on their characteristics (i.e, petrogenic versus pyrogenic hydrocarbons, parent versus alkylated compounds) since the characteristics will influence the toxicity and fate of the oil in the environment. Environmental samples (water, sediment, biota) are taken and analyzed for PAH contamination during a spill response.

TERMS OF REFERENCE OBJECTIVE FIVE

Examine and identify uncertainties in the data and methods.

Screening of subgroups: The authors mentioned that they used the same process for screening of the scores as the National Framework (Thornborough et al. 2017) and applied it to the Pacific application. This process only screened out two subgroups that did not score at least one for the exposure criteria. Clarification was sought for subgroups that scored a zero for exposure and if they should be removed from the subsequent analysis. It was suggested that the subgroup should be kept on the list but use a weight of evidence approach so the overall score is not at the top of the list if there is limited exposure. The authors suggested that they could highlight subgroups that scored zero or one (out of four) for the exposure criteria to distinguish them from the other subgroups.

Weighting of criteria category scores: There was extensive discussion about the use of weighting the scores for the three categories of criteria; there are four criteria for both the exposure and recovery categories and only two criteria for sensitivity. The score for the exposure category could take a step-wise approach for weighting depending on whether or not the organism will actually be exposed to the oil. A reviewer suggested that the vulnerability framework could consider the weighting of criteria similar to other frameworks such as spill impact mitigation assessment (SIMA) and net environmental benefit analysis (NEBA). A participant suggested weighting equally across exposure, sensitivity, and recovery.

One of the authors mentioned that weighting had been discussed extensively during the CSAS meeting for the original framework application in 2016 and that it had not been considered appropriate. Additionally, the authors emphasized that the objectives of this meeting were not to examine framework methods, which have already been reviewed in previous processes and this was out of scope for this work.

Scoring of seafloor or vegetation interacting criterion: The seafloor or vegetation interacting criterion was initially scored as NA for all subgroups because the oil floats and the total vulnerability score was out of 9. After discussion it was decided that subtidal subgroups will be scored a zero for the seafloor or vegetation interacting criterion and intertidal groups that interact with the seafloor or vegetation will have a score of one. There will be an update to the criterion name for intertidal areas only. Six out of 13 groups would now increase to a total vulnerability score of 7 and fall into the high vulnerability category. In the full application, the intertidal species are counted for both sea surface and seafloor interactions. The overall score for the vulnerability framework would be out of 10 to make it consistent with the all oils framework application.

Chemical sensitivity: For the chemical sensitivity criterion, all subgroups received a precautionary score of 1* unless the authors found evidence of adverse effects to the species, in which case they removed the precautionary *. For scoring of the three oil types no subgroups received a score of zero. Future work was suggested to allow for a zero score in this criterion.

Editorial: A participant suggested that the definitions for each criterion have slight differences in each oil type document. The authors will review all the tables to make sure the naming convention is consistent.

TERMS OF REFERENCE OBJECTIVE SIX

Provide recommendations for next steps including comments on research needs to address gaps, limitations in the advice, and any issues regarding implementation.

Fresh oil assumption: A major assumption of the papers is that fresh oil floats. A member of the group wondered why that assumption was made. In winter, an oil spill response may not be mounted within the timelines provided and the oil would be sinking into the water column, so why not include oil in the substrate. The authors responded that the fate and effect of all oils was covered within the National Framework (Thornborough et al. 2017) and Pacific Application for all oil types (DFO 2017). This research refines the guidance for the initial stages of a spill when the oil floats and generates a targeted response. It was suggested that there should be more emphasis placed on this assumption in the paper and SAR.

Scoring chemical sensitivity: All organisms started with a precautionary score of 1*, and then were given a score of one when there was an impact to the organism. A score of zero was not assigned. Additional information could be included in the WPs to note that there is no clear guidance to derive a score of zero for chemical sensitivity.

Selection of endpoints: Discussions occurred about the importance of defining the endpoints with a reference so future readers can look up the paper and evaluate it themselves. At times, the information found in the literature was conflicting and/or there was uncertainty in the end points required to justify a particular toxicity score. Typically, endpoints are selected on growth, reproduction function, and survival instead of using endpoints such as enzyme induction. The authors have agreed to include a discussion on the hierarchy of endpoints on the weighting of criteria within the context of future work.

Chemical toxicity: A limitation of the vulnerability framework is that it is not able to consider the impacts of chronic, cumulative, or indirect effects on organisms when using binary scoring, which can contribute to the overall effects of toxicity and long term impacts on individuals and populations. This vulnerability framework only considers acute effects and does not consider the effects of the oil when it weathers over time, therefore, it may underestimate the overall effects on species.

Laboratory study: A participant proposed that results from a Master's thesis cited within the working papers may not be representative of what happens in the field, or appropriate for inclusion as they have not been peer-reviewed (Banning 2010). The authors agreed to add more detail and requested that the participant send them references to be included.

Target lipid model: There are over 50 years of oil toxicity data in the literature but not all are useful for the purpose of this application. There are various methods that do rank species and are oil independent. For example, a target lipid model is where the critical target body burden is a way of normalizing comparisons across species so they can be ranked. This method takes into account the composition of the oil and how oil and its toxicity change over time. It was suggested that this compositional data could be brought into the framework.

Another participant asked if there was a way to use the relative toxicity or a representation of the PAH profile for each oil type to standardize the data so that it can be compared across species. The participant noted that there is an acute toxicity database with 97 distinct species (i.e., mollusks, algae, crustaceans) associated with the target lipid model. Some studies in the database are older but it shows the spread of the data and gives a ranking of what is most sensitive in this model for acute toxicity. The database ranks the species in terms of exposure and this method should be considered in future work as a way of comparing the data.

Timeline for the framework: The vulnerability framework is only applicable during the fresh, floating phase of the oil in calm weather conditions to deal with the acute effects in the early stages of an oil spill. This framework would not likely be applied in high energy environments when the oil is being driven into the water column. In high energy environments, EICs would revert back to using the Pacific application of the framework (DFO 2017) to respond to a spill. The results of all framework applications are used in conjunction with other decision-making tools including information from Indigenous communities and other response partners to inform and refine the development of a list of resources at risk during a spill. The addition of resource maps showing where vulnerable biota are located would be helpful to assist with the planning to prioritize specific areas and species for protection.

Limitations of the ADIOS model: A participant mentioned the working papers have a section on the limitations of the model since there are some uncertainties in the parameters (i.e., salinity, wind, temperature, etc.). The model may not be representative of the region of the spill and the parameters do not take into account seasonal variability. It is likely that the amount of fresh water outflow (i.e., near the Fraser River) entering the system for the weathering of oil would be different compared to other parts of BC. More information on the water column stratification could be added to the working papers.

This model also assumes a single point source release so the application may not apply to all scenarios. The model also does not take into account a long slow release over time (i.e., a continuous release). In a spill, both frameworks could apply when fresh and weathered oil are being released into the environment.

Main ports and shipping statistics: Only the Port of Vancouver was considered in Table 1 of the working papers where petroleum product shipments were summarized. The other ports such as the Port of Prince Rupert and Kitimat were not included. A participant wondered if there were data available for these other ports along the coast of BC. Transport Canada may have additional data for these other ports. The data in Table 1 are an underestimation of the volume of oil that is being moved up and down the coast. The table does not distinguish between the fuel onboard a vessel for its operation and the product on a vessel as cargo.

The authors will review the Port of Vancouver statistics to look at tanker transects by entrance and how to divide the oil types into chemical product categories such as oil and oil products. A participant cautioned that there might be a duplication of data between USA/Canada shipping lanes and port calls. The authors agreed that the text for Table 1 will clarify what fuel is being shipped as fuel or as cargo since there are risks coastwide. A recommendation could be made for a risk assessment to be conducted in the future on oils in shipping.

Diesel is typically transported on barges and is in ships that go everywhere along the coast. There have been spills over the last few winters that have released diesel into vulnerable areas and have been hard to respond to given the isolated locations. There is a likelihood that there are typical routes and distributions of where they could spill, whereas bitumen is on large ships and would come out of specific ports (i.e., Port of Vancouver and potentially Kitimat) and travel along shipping lanes. The authors have agreed to add some wording on this in the working papers.

Digital format or app: A participant suggested that it would be helpful to create an app or to have the vulnerability framework in an electronic/online document for ease of use as a reference. The framework could be tested in the field with oil spill exercises to find the strengths and weaknesses of it and how the application of the framework will be integrated into other spill response tools (i.e., resources at risk documents, sampling decision-making trees, conceptual site models). The scoring of the species could be updated as new data becomes available. The authors have agreed to upload the scoring tables into Open Data.

Updates to the framework: A reviewer suggested it would be beneficial for the next application of the framework (i.e., regional scoring) to occur in 5 years instead of 10 years. Vulnerability studies could be different and more data would be available which could change the scoring for some taxa.

CONCLUSIONS

The group was shown the revision table with all revisions agreed upon by the authors. Meeting participants agreed the working papers satisfied all Terms of Reference objectives and the papers were accepted with minor revisions.

RECOMMENDATIONS AND ADVICE

DRAFTING OF THE SCIENCE ADVISORY REPORT

Participants were provided with a draft Science Advisory Report (SAR) that was prepared in advance of the meeting. During the meeting, the authors used track changes on the draft SAR to document changes during discussions. The SAR was discussed and participants had the opportunity to contribute to key sections and identify the included tables and figures. At the end of the meeting, a draft SAR was completed. The meeting Chair will work with the authors to finalize the draft SAR. Once completed, the Centre for Science Advice Pacific (CSAP) office will circulate the draft SAR and draft Proceedings (PRO) to all participants for final review and input.

Use of the frameworks: It was asked what the consequences would be if the wrong framework (e.g. 2022 all oil update (DFO 2023), compared with a single oil type) is used for an oil spill. Participants indicated that both frameworks would be considered by EICs during the spill. Furthermore, the highest scoring groups are similar across frameworks. The users would use Canada-Wide Standards (CWS) as well as information from Environment and Climate Change Canada, Indigenous groups, and responder observations on the ground to inform the response. A participant mentioned that a consensus-based approach is used when multiple organizations, government departments, and First Nations collaborate during an incident. Information is documented as it is used during the incident and an evidence-based approach is used. The vulnerability framework is only one tool in the toolbox.

ACKNOWLEDGEMENTS

The Centre for Science Advice Pacific (CSAP) congratulates the authors on the successful papers and appreciates the contribution from all participants. We thank the formal reviewers, Aline Carrier (Toquaht Nation) and Brian Robinson, (DFO Science, Maritimes Region) for their time, expertise, and providing their formal reviews of the working papers. We would also like to thank Erin Porszt for her support throughout the process and as Chair of the meeting.

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Banning, J. 2010. The Effects of Diluted Bitumen on Marine Intertidal Vascular Plants. Master's thesis: Simon Fraser University, British Columbia, Canada.

DFO. 2009. A fishery decision-making framework incorporating the Precautionary Approach.

DFO. 2017. Application of a framework to assess vulnerability of biological components to ship-source oil spills in the marine environment in the Pacific Region. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/013.

DFO. 2023. 2022 Update to the application of a framework to assess the vulnerability of biological components to ship-source oil spills in the marine environment in the Pacific region. DFO Can. Sci. Advis. Sec. Sci. Resp. 2023/016.

Ryan, S.A., Wohlgeschaffen, G., Jahan, N., Niu, H., Ortmann, A.C., Brown, T.N., King, T.L., and Clyburne, J. 2019. State of Knowledge on Fate and Behaviour of Ship-Source Petroleum Product Spills: Volume 3, Port Hawkesbury-Canso Strait, Nova Scotia. Can. Manuscr. Rep. Fish. Aquat. Sci. 3176: viii + 41 p.

Thornborough, K., Hannah, L., St. Germain, C., and O, M. 2017. A framework to assess vulnerability of biological components to ship-source oil spills in the marine environment. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/038. vi + 24 p.

APPENDIX A: TERMS OF REFERENCE

Application of a framework to assess vulnerability of biological components to diesel and gasoline; Bunker C; and diluted bitumen in the marine environment in the Pacific Region

Regional Peer Review – Pacific Region

December 12-15, 2022
Virtual Meeting

Chairperson: Erin Porszt

Context

Under Canada's World Class Tanker Safety System Initiative (WCTSS) a national framework was developed to identify marine biological organisms most vulnerable to ship-source oil (Thornborough et al. 2017) in the event of an oil spill. The Pacific regional application of this framework (Hannah et al. 2017) identified 27 highly vulnerable biological groups, with sea grasses, salt marsh grasses/succulents, Sea Otters, and baleen whales being most vulnerable. The Pacific regional application considered all oil types as one category, however it was recommended to further define impacts by assessing vulnerability for individual oil types or categories separately (DFO 2017).

Under the Fisheries and Oceans Canada (DFO) spill response program initiative, there is a need in the Pacific Region to build on the vulnerability to oil framework to better understand impacts of different products on vulnerable species. At present, the vulnerability framework is the best tool available for Government of Canada Environmental Incident Coordinators (EICs) to prioritize which species or species assemblages are most vulnerable to oil. EICs use the framework as the foundation to prioritize 'resources at risk' for ecological concerns and, consequently, to inform spill response planning processes, emergency response operations during spills and subsequently to inform recovery options for species impacted. The previous assessment in the Pacific Region considered all oil types as one category (Hannah et al. 2017), however, some species are expected to respond differently to different categories of oil. This work will refine assessments for species based on different oil categories to inform oil spill response relative to each oil category.

Fisheries and Oceans Canada (DFO) Fish and Fish Habitat Protection Program (FFHPP), Ecosystem Management Branch, has requested that Science Branch assess which groups of species are most vulnerable to three categories of oil (gasoline and diesel; Bunker C; and diluted bitumen) and whether vulnerability may change when considering the fate and behaviour of the three oil categories over time and under different environmental conditions. The assessment should focus on the acute effects of direct contact with oils. The assessment, and advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR), will be used to inform emergency oil spill responses in the Pacific Region as well as recovery efforts and other marine spatial planning initiatives.

Objectives

The following working papers will be reviewed and provide the basis for discussion and advice on the specific objectives outlined below.

St. Germain, C., Herborg, L.-M., Punt, M., Jeffery, S., Hannah, L., and Finney, J. Application of a framework to assess vulnerability of biological components to Diesel and gasoline in the marine environment in the Pacific Region. 2022. CSAP Working Paper 2020FFHPP15a.

St. Germain, C., Herborg, L.-M., Punt, M., Jeffery, S., Hannah, L., and Finney, J. Application of a framework to assess vulnerability of biological components to Bunker C in the marine environment in the Pacific Region. 2022. CSAP Working Paper 2020FFHPP15b.

St. Germain, C., Herborg, L.-M., Punt, M., Jeffery, S., Hannah, L., and Finney, J. Application of a framework to assess vulnerability of biological components to diluted bitumen in the marine environment in the Pacific Region. 2022. CSAP Working Paper 2020FFHPP15c.

The specific objectives of this review are to:

1. Identify any necessary adaptations to the vulnerability criteria, species subgroups, and scoring in the Pacific Application of the National Framework that are required to determine the relative vulnerability of species subgroups in the Pacific Region to the following three categories of oil: a) gasoline and Diesel; b) Bunker C; and c) diluted bitumen.
2. Identify and discuss the relative vulnerability of subgroups in the Pacific Region to the three categories of oil by applying the adapted framework.
3. Develop scenarios of fate and behaviour for each of the three categories of oil over time and under different environmental conditions relevant in the Pacific Region using the National Oceanic and Atmospheric Administration's Automated Data Inquiry for Oil Spills (ADIOS) oil weathering model.
4. Discuss in general how the relative vulnerability of subgroups, as identified in objective 2, may change when considering the fate and behaviour of the three categories of oil over time and under different environmental conditions.
5. Examine and identify uncertainties in the data and methods.
6. Provide recommendations for next steps including comments on research needs to address gaps, limitations in the advice, and any issues regarding implementation.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Documents (3)

Expected Participation

- Fisheries and Oceans Canada (DFO) (Science, Fish and Fish Habitat Protection Program, Centre for Offshore Oil, Gas and Energy Research, Multi-Partner Research Initiative)
- Other government jurisdictions (Province of BC, Environment and Climate Change Canada, National Oceanic and Atmospheric Administration)
- Indigenous communities/organizations (Nuu-Chah-Nulth Tribal Council)
- Industry (Western Canada Marine Response Corporation)
- Other invited experts (Huntsman Marine Science Centre)

References

DFO. 2017. Application of a framework to assess vulnerability of biological components to shipsource oil spills in the marine environment in the Pacific Region. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/013.

Hannah, L., St. Germain, C., Jeffery, S., Patton, S., and O, M. 2017. Application of a framework to assess vulnerability of biological components to ship-source oil spills in the marine environment in the Pacific Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/057. ix + 145 p.

Thornborough, K., Hannah, L., St. Germain, C., and O, M. 2017. A framework to assess vulnerability of biological components to ship-source oil spills in the marine environment. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/038. vi + 24 p.

APPENDIX B: WORKING PAPER ABSTRACTS

Diesel and Gasoline Application

In 2017 a National framework was developed to identify marine biological organisms most vulnerable to ship-source oil spills under the World Class Tanker Safety System Initiative (WCTSS). Environmental Incident Coordinators (EICs) use outputs from the vulnerability framework as a tool for prioritizing ecological 'resources at risk' during spills. A 2017 Pacific Regional Application of this framework considered all oil types together and identified 27 highly vulnerable biological groups, with sea grasses, salt marsh grasses/succulents, sea otters, and baleen whales at the top of the list. In 2022 we updated the Application in the Pacific Region with new information. The Application of the vulnerability framework is currently being expanded to assess the vulnerability of Pacific marine species to three different categories of oil: Diesel and Gasoline, diluted bitumen, and bunker C. This document presents the results of the Diesel and Gasoline Application. Overall, the largest differences from the results of the 2022 Update for all oil types were with subtidal benthic species groups. Many of these groups moved from high vulnerability (under the 2022 Update) to moderate vulnerability when only Diesel and Gasoline were considered. This is due to the fact that Diesel and Gasoline do not tend to sink when spilled on water, putting subtidal benthic areas at less risk initially. In addition to vulnerability scoring, we modeled oil fate and behaviour using NOAA's ADIOS oil weathering model to include considerations of changes in the Diesel and Gasoline over time, and under different environmental conditions. As oil spills are an ongoing challenge, better tools to indicate which species are vulnerable to specific types of oil, and how the oil will behave under various environmental conditions, improve the ability to provide advice in emergency situations.

Diluted Bitumen Application

In 2017 a National framework was developed to identify marine biological organisms most vulnerable to ship-source oil spills under the World Class Tanker Safety System Initiative (WCTSS). Environmental Incident Coordinators (EICs) use outputs from the vulnerability framework as a tool for prioritizing ecological 'resources at risk' during spills. A 2017 Pacific Regional Application of this framework considered all oil types together and identified 27 highly vulnerable biological groups, with sea grasses, salt marsh grasses/succulents, sea otters, and baleen whales at the top of the list. In 2022 we updated the Application in the Pacific Region with new information. The Application of the vulnerability framework is currently being expanded to assess the vulnerability of Pacific marine species to three different categories of oil: Diesel and gasoline, bunker C, and Diluted Bitumen. This document presents the results of the Diluted Bitumen Application. Overall, the largest differences from the results of the 2022 Update for all oil types were with subtidal benthic species groups. Many of these groups moved from high vulnerability (under the 2022 Update), to moderate vulnerability when only Diluted Bitumen was considered. This is due to the fact that Diluted Bitumen does not tend to sink when spilled on water, putting subtidal benthic areas at less risk initially. In addition to vulnerability scoring, we modeled oil fate and behaviour using NOAA's ADIOS oil weathering model to include considerations of changes in the Diluted Bitumen over time, and under different environmental conditions. As oil spills are an ongoing challenge, better tools to indicate which species are vulnerable to specific types of oil, and how the oil will behave under various environmental conditions, improve the ability to provide advice in emergency situations.

Bunker C Application

In 2017 a National framework was developed to identify marine biological organisms most vulnerable to ship-source oil spills under the World Class Tanker Safety System Initiative (WCTSS). Environmental Incident Coordinators (EICs) use outputs from the vulnerability framework as a tool for prioritizing ecological 'resources at risk' during spills. A 2017 Pacific

Regional Application of this framework considered all oil types together and identified 27 highly vulnerable biological groups, with sea grasses, salt marsh grasses/succulents, sea otters, and baleen whales at the top of the list. In 2022 we updated the Application in the Pacific Region with new information. The Application of the vulnerability framework is currently being expanded to assess the vulnerability of Pacific marine species to three different categories of oil: Diesel and Gasoline, Diluted Bitumen, and Bunker C. This document presents the results of the Bunker C Application. Overall, the largest differences from the results of the 2022 Update for all oil types were with subtidal benthic species groups. Many of these groups moved from high vulnerability (under the 2022 Update), to moderate vulnerability when only Bunker C was considered. This is due to the fact that Bunker C does not tend to sink when spilled on water, putting subtidal benthic areas at less risk initially. In addition to vulnerability scoring, we modeled oil fate and behaviour using NOAA’s ADIOS oil weathering model to include considerations of changes in the Bunker C over time, and under different environmental conditions. As oil spills are an ongoing challenge, better tools to indicate which species are vulnerable to specific types of oil, and how the oil will behave under various environmental conditions, improve the ability to provide advice in emergency situations.

APPENDIX C: WORKING PAPER REVIEWS

WRITTEN REVIEW

Date: 2-Dec-2022

Reviewer: Brian Robinson, DFO (Science - Maritimes Region - Centre for Offshore Oil, Gas and Energy Research)

Working Paper Titles:

Application of a framework to assess vulnerability of biological components to Diesel and gasoline in the marine environment in the Pacific Region. 2022. 2020FFHPP15a.

Application of a framework to assess vulnerability of biological components to Bunker C in the marine environment in the Pacific Region. 2022. 2020FFHPP15b.

Application of a framework to assess vulnerability of biological components to diluted bitumen in the marine environment in the Pacific Region. 2022. 2020FFHPP15c.

GENERAL COMMENTS

The working papers have clearly outlined all the steps and justifications for how the authors applied the vulnerability framework for specific Pacific marine species exposed to three different oil types. By preparing three separate papers, the authors have clearly recognized that the fate and behaviour of these products differs once they are spilled in the marine environment and hence their impact on marine ecosystems will also vary. In addition, it was great to see the incorporation of oil weathering into the evaluation of vulnerability through the use of the ADIOS modelling. The resulting products that have been generated will be useful additions to the toolbox used by DFO EIC's during oil spill response. I would suggest that the framework be converted to an electronic/online document so that it could be more easily referenced and modified.

SPECIFIC COMMENTS

1. I would like to see more information on the chemical composition of the different oil products. Specifically, Section 2.2.1 (Chemical Properties) should mention the PAH composition of the oils. PAH's are the main drivers of oil toxicity, and there are significant differences in the PAH profiles of the three different products. This could be kept relatively simple by discussing their PAH composition in terms of low molecular weight (LMW) vs high molecular weight (HMW) compounds. It is important to discuss the PAH content of the oils since any sampling effort that is undertaken to support oil spill response will involve the analysis of environmental samples (water/sediment/biota) for PAH contamination.
2. Section 2.2 (General Fate and Behaviour Information) does not include any discussion on oil toxicity. While it would not be possible to summarize toxicity information for all the different biological components covered by the vulnerability framework, it would still be useful to discuss oil toxicity more broadly. This relates back to the PAH profiles and could include a discussion of acute effects (LMW PAH) vs chronic effects (HWM PAH), as well as exposure pathways and environmentally relevant concentrations.
3. It was good to see that Section 2.2.3 (Behaviour on Water) included a discussion on oil buoyancy and the formation of oil-sediment aggregates, however I would like to see a little more information in this section.
   a. Suggest referring to the aggregates as oil-particle aggregates (OPAs) to cover both sediment (OSA), mineral (OMA) and biological particulate interactions.

b. It might be useful to discuss what SPM concentrations promote the formation of OPAs for a given oil type (O'Laughlin et al 2017).

c. When discussing oil buoyancy, the authors should mention the potential for the formation of oiled marine snow (MOS) and how this can be a pathway for oil reaching the sediments (Quigg et al 2019).

d. The wording in this section seems to favour the idea that the oil (Bunker C and Diluted Bitumen) will not sink in high energy environments due to turbulence keeping oil droplets suspended in the water column. I would prefer to see the wording in this section be more neutral, since there are a number of factors here that could lead oil sinking in high energy environments (Government of Canada 2013; US EPA 2016).

4. The vulnerability scoring used information from Table 6 to determine oil penetration and retention on various shoreline material types. The data in this table is based on a laboratory study that used a limited exposure time and a single tidal flushing under uniform conditions. This may not be realistic of what would happen during an actual spill where oil could remain on a non-uniform shoreline for multiple tidal cycles. Since the results of this study likely underestimate oil penetration and retention, it would be worth discussing potential implications on the vulnerability scoring.

5. For the ADIOS modelling results in Section 4.2.1, why was the % weathering examined for 120 hrs but the changes in density and viscosity only shown for 48 hrs (Figure 6 & 7).

6. In Section 5.4, the authors discuss the challenges they faced when scoring the chemical sensitivity criterion. Although I appreciate the challenges involved and commend the authors for explaining their reasoning for why everything was scored a precautionary 1* when no data was available, the fact that every sub-group is scored the same makes me question the usefulness of including this criterion in the framework.

7. Related to the challenges associated with scoring the chemical sensitivity, the vulnerability framework does not allow for the weighting of criteria unlike other oil spill related evaluation processes (NEBA and SIMA). If the chemical sensitivity criteria were weighted in the scoring process, it might allow for the incorporation of dose-response relationships when evaluating the sensitivity of a specific species or sub-group. Without considering the concentration of oil that an organism is exposed to, all organisms would likely show some level of sensitivity to oil if the dose were great enough.

REFERENCES

Government of Canada. Properties, Composition and Marine Spill Behaviour, Fate and Transport of Two Diluted Bitumen Products from the Canadian Oil Sands. Federal Government Technical Report, November 30, 2013.

Casey M. O'Laughlin, Brent A. Law, Vanessa S. Zions, Thomas L. King, Brian Robinson, Yongsheng Wu. 2017. Settling of dilbit-derived oil-mineral aggregates (OMAs) & transport parameters for oil spill modelling. Marine Pollution Bulletin, 124:1, p292-302.

Quigg, Antonietta. Passow, Uta. Daly, Kendra. Burd, Adrian. Hollander, David. Schwing, Patrick; and Lee, Kenneth. (2019). Marine Oil Snow Sedimentation and Flocculent Accumulation (MOSSFA) Events: Learning from the Past to Predict the Future. In Deep Oil Spills, Springer, p196-220.

US EPA. FOSC Desk Report for the Enbridge Line 6b Oil Spill in Marshall Michigan. April 2016.

WRITTEN REVIEW

Date: 05 December 2022

Reviewer: Aline Carrier, Toquaht Nation

Working Paper Titles:

Application of a framework to assess vulnerability of biological components to Diesel and gasoline in the marine environment in the Pacific Region. 2022. 2020FFHPP15a.

Application of a framework to assess vulnerability of biological components to Bunker C in the marine environment in the Pacific Region. 2022. 2020FFHPP15b.

Application of a framework to assess vulnerability of biological components to diluted bitumen in the marine environment in the Pacific Region. 2022. 2020FFHPP15c.

1. Is the purpose of the working papers clearly stated?

The purpose is clearly stated and repeated many times. I think that the reason why choosing these three types of oil should be explain more clearly.

2. Has the working paper fulfilled the objectives written in the Terms of Reference?

Yes. However, objective 4 could be develop more for each paper. (see below)

3. Are the data and methods adequate to support the conclusions, and explained in sufficient detail?

In each Paper, in section 5.1, it would be great to have more details. When explaining which groups are not in the high vulnerability category anymore, it would be great to have more example about the species and developing about the life trait thats make them less vulnerable. It could help the reader to better understand something that could be counter intuitive.

4. If the document presents advice to decision-makers, are the recommendations provided in a useable form, and does the advice reflect the uncertainty in the data, analysis or process?

Yes, I believe it reflect the uncertainty and it’s clearly expressed in the papers.

5. Can you suggest additional areas of research that are needed to improve the analysis and advice presented in the working paper?

As it was stated in the paper, it would be great to explore more the oil fate and behaviour information and models. It could be great to include more variables such as water stratification and salinity to help having a better representativity of the conditions along the coast.

Also, more studies should be done regarding the toxicity of each oil types.

APPENDIX D: AGENDA

DAY 1 – Monday, December 12

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
0915	Review Terms of Reference	Chair
0930	Presentation of Working Papers	Authors
1030	**Break**	
1045	Overview Written Reviews	Reviewers & Authors
1145	Identification of Key Issues for Group Discussion	RPR Participants
1230	**Adjourn for the Day**	

DAY 2 – Tuesday, December 13

Time	Subject	Presenter
0900	Review Agenda & Housekeeping Review Status of Previous Day (*As Necessary*)	Chair
0915	Discussion & Resolution of Methods	RPR Participants
1030	**Break**	
1045	Discussion & Resolution of Results & Conclusions by Oil Type	RPR Participants
1130	Develop Consensus on 3 Papers Acceptability & Agreed upon Revisions (TOR objectives)	RPR Participants
1230	**Adjourn for the Day**	

DAY 3 – Wednesday, December 14

Time	Subject	Presenter
0900	Review Agenda & Housekeeping Review Status of Previous Day (*As Necessary*)	Chair
0915	Revisions Table Finalized	RPR Participants
1030	**Break**	

Time	Subject	Presenter
1045	*Science Advisory Report (SAR)* Develop consensus on the following for inclusion: • Summary Bullets • Sources of Uncertainty	RPR Participants
1230	**Adjourn for the Day**	

DAY 4 - Thursday, December 15

Time	Subject	Presenter
0900	Review Agenda & Housekeeping	Chair
0915	*Science Advisory Report (SAR)* Develop consensus on the following for inclusion: • Results & Conclusions • Figures/Tables • Additional advice to Management (as warranted)	RPR Participants
1030	**Break**	
1045	*Science Advisory Report (SAR) cont'd*	RPR Participants
1145	Next Steps – Chair to review • SAR review/approval process and timelines • Research Document & Proceedings timelines • Other follow-up or commitments (*as necessary)*	Chair
1230	**Adjourn meeting**	

APPENDIX E: PARTICIPANTS

Last Name	First Name	Affiliation
Anderson	Erika	DFO Centre for Science Advice Pacific
Black	Tyler	University of Guelph
Carrier	Aline	Toquaht Nation
de Jourdan	Benjamin	Huntsman Marine Science Centre
Dubetz	Cory	DFO Science
Finney	Jessica	DFO Science
Gartner	Heidi	DFO Science
Greig	Ryan	DFO Science
Hamer	Adrian	DFO Science
Hannah	Lucie	DFO Science
Hawryshyn	Jessica	DFO Fish and Fish Habitat Protection Program
Herborg	Matthias	DFO Science
Hunter	Karen	DFO Science
Jeffery	Sharon	DFO Science
Johnston	Cynthia	DFO Fish and Fish Habitat Protection Program
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Nichol	Linda	DFO Science
O	Miriam	DFO Science
Porszt	Erin	DFO Science
Prosser	Ryan	University of Guelph
Punt	Monique	Triox Environmental Emergencies
Robinson	Brian	DFO Science
St. Germain	Candice	DFO Science
Willie	Megan	Environment and Climate Change Canada