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**Pacific Region**

# Proceedings of the Pacific regional peer review on the Evaluation of Pacific Region application of a National Framework to assess the vulnerability of biological components to ship-source oil spills in the marine environment

**September 14-15, 2016**
**Nanaimo, B.C.**

**Chairperson: Gilles Olivier**
**Editor: Candice St. Germain**

Fisheries and Oceans Canada
Science Branch
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

June 2017

Canada

**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 from September 14-15, 2016 at the Pacific Biological Station in Nanaimo, B.C. One working paper focusing on a Pacific Region pilot application of a National Framework to assess the vulnerability of biological components to ship-source oil spills in the marine environment was presented for peer review

In-person and web-based participation included representatives from Fisheries and Oceans Canada (DFO) Science and Oceans branches and external participation included representatives from the Ministry of the Environment for the Province of B.C, the National Oceanic and Atmospheric Administration (NOAA), the Vancouver Aquarium, and the Royal B.C. Museum.

The conclusions and advice resulting from this review will be provided in the form of one Science Advisory Report providing advice to DFO Oceans Branch to inform oil spill response planning for areas of interest within the Pacific Region (such as pilot areas for the World Class Tanker Safety System (WCTSS) initiative), and assist in identifying priority response-relevant spatial data for those marine biological subgroups identified as being most vulnerable to spilled oil.

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

## Compte rendu de l'examen par les pairs sur l’Évaluation de la demande de la Région du Pacifique pour un Cadre national d'évaluation de la vulnérabilité des composantes biologiques du milieu marin aux déversements d'hydrocarbures provenant de navires


### SOMMAIRE

Le présent compte rendu résume les discussions et les principales conclusions de la réunion régionale d'examen par les pairs de Pêches et Océans Canada (MPO) et du Secrétariat canadien de consultation scientifique (SCCS) qui a eu lieu du 14 au 15 décembre 2016 à la Station biologique du Pacifique de Nanaimo, en Colombie-Britannique. Un document de travail portant sur un projet pilote d'application d'un Cadre national d'évaluation de la vulnérabilité des composantes biologiques du milieu marin aux déversements d'hydrocarbures provenant de navires, mené dans la Région du Pacifique, a été présenté aux fins d'examen par les pairs.

Les participants en personne et en ligne comprenaient des représentants de Pêches et Océans Canada (MPO) et de la Direction des océans, ainsi que des représentants du ministère de l'Environnement de la Colombie-Britannique, de la National Oceanic and Atmospheric Administration (NOAA), de l'Aquarium de Vancouver et du Royal BC Museum.

Les conclusions et avis découlant de cet examen seront présentés sous la forme d'un avis scientifique fournissant des conseils à la Direction des océans du MPO afin d'orienter la planification des interventions en cas de déversement d’hydrocarbures dans les zones d'intérêt de la Région du Pacifique (telles que les zones pilotes de l'initiative du Système de sécurité de classe mondiale pour les navires-citernes [SSCMNC]), et d'aider à déterminer quelles sont les données prioritaires pertinentes concernant les sous-groupes jugés les plus vulnérables aux hydrocarbures déversés.

L'avis scientifique et le document de recherche à l'appui seront rendus publics sur le site Web du Secrétariat canadien de consultation scientifique (SCCS).

## INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS), Regional Peer Review (RPR) meeting was held on September 14-15, 2016 at the Pacific Biological Station in Nanaimo to evaluate the Pacific Region application of a National Framework to assess the vulnerability of biological components to ship-source oil spills in the marine environment.

The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from DFO Oceans. Notifications of the science review and conditions for participation were sent to representatives with relevant expertise from DFO Science and Oceans branches, the Ministry of the Environment for the Province of B.C, the National Oceanic and Atmospheric Administration (NOAA), the Vancouver Aquarium, and the Royal B.C. Museum.

The following working paper (WP) was prepared and made available to meeting participants prior to the meeting (working paper abstract provided in Appendix E):

Evaluation of Pacific Region application of a National Framework to assess the vulnerability of biological components to ship-source oil spills in the marine environment by Lucy Hannah, Candice St. Germain, Sharon Jeffery, Sarah Patton, and Miriam O. (CSAP WP2016OCN06)

The meeting Chair, Gilles Olivier, 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 Document), 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 and working papers.

The Chair reviewed the Agenda (Appendix C) and the Terms of Reference for the meeting, highlighting the objectives and identifying the Rapporteur for each review. The Chair then reviewed the ground rules and process for exchange, reminding participants that the meeting was a science review and not a consultation. The room was equipped with microphones to allow remote participation by web-based attendees, and in-person attendees were reminded to address comments and questions so they could be heard by those online.

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, 24 people participated in the RPR (Appendix D). Ben Grupe was identified as the Rapporteur for the meeting.

Participants were informed that Jerome Marty and Stephen Lehmann had been asked before the meeting to provide detailed written reviews for the working paper to assist everyone attending the peer-review meeting. Similarly, Jerome Marty and Stephen Lehmann provided written reviews of the working paper. Participants were provided with copies of the written reviews.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report to DFO Oceans to inform oil spill response planning for areas of interest within the Pacific Region (such as pilot areas for the World Class Tanker Safety System (WCTSS) initiative), and assist in identifying priority response-relevant spatial data for those marine biological subgroups identified as being most vulnerable to spilled oil. The Science Advisory

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

## REVIEW

| | |
|---|---|
| Working Paper: | Evaluation of Pacific Region application of a National Framework to assess the vulnerability of biological components to ship-source oil spills in the marine environment. WP2016OCN06. |
| Rapporteur: | Ben Grupe |
| Presenter(s): | Lucy Hannah, Candice St. Germain, Sharon Jeffery, Sarah Patton |

## DAY 1

## PRESENTATION: OVERVIEW OF THE WORKING PAPER

**Presenters: Sarah Patton, Sharon Jeffery, Lucie Hannah, Candice St. Germain**

An overview was provided by Sarah Patton to introduce the Pacific Regional Framework including context, sub-groups, criteria for scoring, and final results. In the Area Response Plan, potential oil spill scenarios will be created based on typical patterns of marine traffic and the resources at risk, including ecological resources that are considered in this regional peer-review (RPR). The National Framework was developed through a national CSAS in March 2016, and it establishes a process by which biological components should be organized, scored, and identified for level of vulnerability. It was acknowledged at the national level that regional adaptations of the sub-groups would be necessary for the framework to be applicable for regional spill scenarios. The primary outcome of the regional application of the framework is a ranked list of sub-groups most vulnerable to potential ship-source oil spills. Considerations of the scope of this process include the fact that the focus is only on biological components and does not consider shoreline type, socio-economic or cultural values, indirect effects of oil, marine protected areas, or types of oil.

Some changes were made to the sub-groups from the national framework, as presented by Lucie Hannah, to improve the differentiation of scoring among groups. The most significant changes were the inclusion of location and habitat descriptors (including in sub-group level 1 for invertebrates and fishes), adding missing sub-groups (31 total), and reorganizing some sub-groups. Changes were highlighted within each of the five major groups.

The vulnerability criteria and scoring for sub-groups was presented by Sharon Jeffery. Since all biological components in the marine environment could potentially be exposed in the event of an oil spill, three main categories were considered to assess vulnerability: Exposure, Sensitivity, and Recovery. Changes to the criteria within each vulnerability category were covered. Under the Exposure category, changes included moving site fidelity from the aggregation criterion to the mobility criterion, specifying the definition of “sea surface interacting” as occurring within the top 1 meter of the water column, and changing “sediment interacting” to “seafloor and/or vegetation interacting”. Changes were not made to criteria in the Sensitivity category, which involved both mechanical and chemical sensitivities. However, since oil is believe to be toxic to all organisms at some level, all sub-groups were scored as 1 for the criterion “impairment due to toxicity”, meaning that chemical toxicity cannot be used to distinguish between sub-group vulnerabilities. Some additional details and justifications were provided for the changes to criteria in the Recovery category. These included expanded definitions for “reproductive capacity” (which now included delayed maturity, semelparity, and infrequent reproductive

success) and “close association with sediments” (now specified as “unconsolidated” to include sand and smaller-grained sediments).

The scoring and screening process was presented by Candice St. Germain. The national method did not screen out many sub-groups, as only 3 of 119 sub-groups were screened out based on Exposure, and none screened out for Sensitivity (due to lack of scientific information and a precautionary approach). Eight other screening methods were tested, altering the number of fulfilled criteria required at each step, and the ranking procedure for the final screened list of sub-groups. Some of these methods resulted in biases, such as the final ranked list being weighted toward those species with low recovery potential when using total recovery score to rank sub-groups, or the final ranked list being weighted toward one criteria category when it was required that sub-groups fulfill two or more criteria within that criteria category. The screening method chosen was similar to the national method in that sub-groups needed to fulfill at least one Exposure and one Sensitivity criterion, but the final list is ranked by the total score instead of the Recovery score. The most vulnerable biological sub-groups included the intertidal vascular plants in low energy unconsolidated shoreline habitats (sea grasses, salt marsh grasses, succulents), sea otters, low mobility arthropods in sediments, sea grasses in high energy rocky shore habitats, transient salmon, and discrete baleen whales. The least vulnerable groups include many fishes (estuarine and subtidal) and certain high mobility invertebrates (crabs and squid). There were several notable cases where scoring results seemed to conflict with scientific literature or common perceptions. These included phytoplankton (a mid-level score despite some literature findings that phytoplankton are highly affected by oil), high mobility arthropods (low vulnerability score but there is anecdotal evidence of massive die-offs after oil spills), sea turtles (sometimes thought to be at high risk of oil spills, but movement patterns in BC makes them less vulnerable), and killer whales (moderate-low vulnerability score, despite some thoughts in the literature that they are at great risk to oil spills). Generally, the ranked vulnerability of sub-groups aligned well with scientific information in the literature.

Gaps identified during the scoring process included knowledge gaps of some taxa, unknown persistence of oil in the environment, and almost no knowledge of the toxicity of oil to most marine animals. Future work that may benefit the framework includes comparisons with outcomes from other regions, adapting the framework to assess spills of specific oil types, consideration of higher level trophic impacts (indirect and trophic effects are not currently considered in vulnerability scores), and the incorporation of uncertainty into the scoring rubric (for example, scoring each subgroup 0-4 instead of a binary 0 or 1). The next steps will include populating sub-groups and finding geospatial information that will be useful to managers.

## PRESENTATION OF WRITTEN REVIEW(S)

### Reviewer Name: Jerome Marty

The first reviewer, Jerome Marty, noted the authors had done a good job handling the large amounts of data and difficulty of the task at hand. He strongly suggested the authors redefine the context of their analysis in a way that would assist responders (e.g. perhaps reframe the introduction, or else structure the conclusions based on the specific types of application). He said that it might be useful to consider how the information would be used for future risk assessment-based analyses or for other ecosystem stressors. He agreed with the authors’ decision to remove toxicity to oil as a consideration in distinguishing among sub-groups because of the large number of unknowns in this area of research while noting such an analysis would require knowledge of the biological effects of specific types of oil.

**Reviewer Name: Stephen Lehmann**

The second reviewer, Stephen Lehmann, agreed with many of Jerome's points and critiques. Coming from an applied science perspective, he acknowledged that DFO is trying to accomplish a very complicated task in creating this framework as a tool for oil spill responders. He noted that the entire process seems to be skipping over an initial step, which would be an analysis of the locations most at risk. Like the first reviewer, he stated a need (perhaps in the introduction) to envision where this information is most likely to be used, and by whom. Possible examples given were for future risk assessments for shoreline or marine construction or possible needs for mitigation or restoration priorities. Lehmann said he believes toxicity is important, and though one might need to extrapolate from few data, it is an important enough issue that the "impairment due to toxicity" criterion should not be completely left out of consideration.

## GENERAL DISCUSSION: OVERVIEW OF THE WORKING PAPER

As the discussion began, the chair noted that we want to think about the big picture and stay at a high level for now, but would get further into the details as the meeting progresses. Several participants wanted to discuss the overall context and purpose of the working paper, but it was decided that this would be best saved until the second day of the meeting. Initially, the focus remained on the current paper and whether the authors' work was sound and appropriate.

Several key issues involve the exclusion or modification of specific criteria. As an example, one participant gave an example using respiration for fishes, where oiled gills would contribute to a "mechanical sensitivity" in fish that use gills for filter-feeding, but not for all fish subgroups, even though they obviously are using gills for breathing. The participant suggested that it might be a mistake to exclude aspects of organismal performance that would be affected by oil. The authors' goal was to create a scoring system that would lead to differentiation among sub-groups, and so they decided it was not valuable to include criteria such as respiration, in which all fishes would presumably be sensitive at some level. Another participant suggested that at some point, it might be wise of the authors to identify the traits they considered not useful for differentiating among sub-groups.

There was discussion regarding the meaning of a "rapid response" and whether it was realistic. One author responded to the question and clarified that the process of scoring species or sub-groups was not intended to be rapid. Rather, the ranking of the scored sub-groups will hopefully allow managers to do their jobs and make decisions rapidly in the event of an oil spill, when critical decisions must be made in the initial hours of a response. Another author stated that one goal of this assessment was to be able to screen sub-groups out, and create a more concise list of groupings that would be provided to responders. Upon completion of this document, the aim is to give responders an objective list of particularly sensitive sub-groups (most vulnerable) that will allow them to make the best possible decisions in the field and not have to rely on intuition, and that should be seen as a step forward in making a rapid response possible.

## PRESENTATION: CHANGES TO SUB-GROUPS

**Presenter: Lucie Hannah**

More detail was presented by Lucie Hannah regarding the breakdown of the sub-groups, which had to be modified iteratively to make sure the criteria were appropriately separating sub-groups. Within Marine Plants/Algae, the most significant change was to incorporate wave exposure and substrata type, which provided separation of sub-groups based on several criteria including population status and photosynthetic mode. Sub-group level 1 (the highest level of distinction) classified plants/algae as living in the epi-pelagic, intertidal, or subtidal zone (National Framework used pelagic and benthic only). Level 2 distinguished sub-groups based

on morphology (vascular plants) and ecological function (canopy, turf & understory, encrusting). Level 3 incorporated habitat features that were not in the National Framework: distinguishing between unconsolidated and consolidated sediments, and allowing for different levels of wave exposure. Level 4 was used to further divide some sub-groups (intertidal vascular plants and subtidal understory algae) based on morphology.

Marine Invertebrate groups did not require many changes from the national framework. A sub-grouping for pelagic larvae was included in level 2, and lophophorates was included as a grouping of phyla for level 4.

The greatest number of changes to the national framework sub-groups occurred for Marine Fishes. Level 1 headings were simplified to estuarine, intertidal, and subtidal, instead of on-shelf and off-shelf (as the fishes pertinent for the Pacific region are entirely on-shelf species). The estuarine fish groups were divided into resident and transient, based on life histories (level 2). Other groups were split into benthic and non-benthic. Level 3 sub-groups were based on whether benthic fish are associated with consolidated or non-consolidated substrates, as only stating whether fish are associated with sediments is inappropriately broad (e.g. boulders, cobbles, sand and clay are all “sediments”). Finally, sub-groups distinguished at Level 4 were based on taxonomy (usually by Family).

For marine mammals and reptiles, few changes were made, but sub-group Level 3 (discrete vs dispersed) was removed for Pinnipeds that have fur, since there is only one species in the Pacific Region. Additionally, Hannah noted the terms “discrete” and “dispersed” needed to be more clearly defined for the authors to be able to make clear distinctions among sub-groups. They proposed to use “discrete” to refer to “sub-groups containing species that use habitat in coastal BC that is constrained to a limited number of focal areas for feeding, resting or socialising, as well as sub-groups that occur in large aggregations in the region”; essentially these are species that aggregate, while dispersed sub-groups do not aggregate.

## DISCUSSION: CHANGES TO SUB-GROUPS

The group discussed whether the authors’ work in modifying sub-groups was scientifically valid, or whether they had missed anything important. In general, reviewers and participants were supportive of most of the sub-group modifications as valid. The reviewers felt defining the classification of sub-group Level 1 as “estuarine”, “intertidal”, or “subtidal” made much more sense for the Pacific region than on-shelf and off-shelf. One reviewer asked whether values would match the classification for Environment Canada’s descriptors in the littoral zone. The authors were not sure, but agreed that it would be a good idea to compare with their classification system.

One participant mentioned several sub-groups they felt were lacking or under-represented. Phytoplankton are taxonomically diverse, and possibly overly broad to be considered a single sub-group. Another example of a broad group was zooplankton, and the authors noted that zooplankton currently fall into one of several sub-groups: pelagic larvae of various invertebrates, or non-larval zooplankton (holoplankton) in the pelagic, low mobility group. The authors felt it would be difficult to begin breaking these into different sub-groups and mapping would be very difficult, though one reviewer supposed that there may be cases where particular types of zooplankton (e.g. seasonal abundances of copepods or euphausiids or certain larvae) are individually mapable. One author responded that if they felt different types of zooplankton were likely to end up with different vulnerability scores, it might have been worth separating them into more sub-groups, but the authors felt this was not the case. A participant noted there is not currently a sub-group for larval fish that distinguishes them from invertebrates. A separation between neustonic and deeper-dwelling larval fish would presumably be associated with

different vulnerability scores, and there may be local experts who could assist with classification of fish larvae into these sub-groups. Another participant also mentioned that it was curious seabirds did not appear in the report, and if this is because they are not part of DFO's mandate this should be described clearly in the introduction. (Presently, oiled birds are referred to as an example of impacts from previous oil spills.)

One participant noted that certain terms ("canopy", "understory", "turf") are well-defined for algal surveys, and the authors should make sure they are following these definitions. The participant said the definition of "canopy algae" (a subtidal species extending to the surface) did not work for intertidal species, and suggested the authors use another term – perhaps "erect" or "stiff-stiped" – to refer to intertidal sub-groups that are presently called "canopy".

The same participant also pointed out that "sediment" is a very specific term which includes everything except bedrock, and seems to be used incorrectly at some places in the report, as cobbles and boulders are unconsolidated forms of sediment in a sense. The response was that the authors intended to remove the term sediment from the document, and define particles the size of cobbles and smaller to be "unconsolidated substrates", while boulders and bedrock were in a separate habitat category.

Another participant wondered if it should be a concern that there is no means to flag species at risk (SAR) or habitats of concern, and at minimum suggested identifying species that may be globally rare. An author responded that the criteria within the Recovery potential category may capture these species if aspects of their population biology are related to their status as a SAR. Additionally, there will be a separate process that addresses these lists for managers.

Marine Mammals are the only group for which taxonomy is used in the first level of sub-groups, which one participant believed notable. This participant also suggested a clearer definition of "discrete" and "dispersed", which the authors agreed was important and planned to incorporate into the final paper. The participant warned to be careful with some groups that may be called "dispersed", but this could be due to insufficient information. They gave Baird's beaked whales as an example of a group thought to be wide-ranging, but more and more seems to live around (and perhaps aggregate) around submarine canyons. The authors responded that some of this spatial knowledge could be incorporated at the next mapping stages of the ARP process.

In general, participants felt it would be beneficial to provide more background on why changes were made to sub-groups (such as increasing the information in Table 5). This could be done within a paragraph describing the process of sub-groups being created in an iterative manner to end up with an organization that made sense. Finally, it was noted that one author (Sharon Jeffery) was also listed as an expert reviewer who gave feedback on sub-groups. These reviewing steps occurred before Jeffery had joined the team of authors, but to avoid any appearance of interest conflicts between authors and reviewers, it was suggested the authors include a table in the appendix listing reviewers and affiliations (at the time of reviewing).

## PRESENTATION: CHANGES TO CRITERIA

### Presenter: Sharon Jeffery

Sharon Jeffery presented the changes made to criteria, and reminded the group of the three aspects to assessing vulnerability: Exposure, Sensitivity, and Recovery potential. To avoid confusion, it was agreed that these should consistently be referred to as "categories", and subsequently, biological sub-groups would be scored for criteria within them. Changes the authors made to Exposure criteria were:

- removing site fidelity from the concentration (aggregation) criterion and adding it to the sessile/low mobility criterion.

- defining the surface depth as the top 1 meter of the water column, even though oil could impact the top 50 meters.
- Changing the criterion for “sediment interaction” to “seafloor and/or vegetation interacting” because species on rocky and consolidated substrates can also be exposed to oil.

No changes from the national framework were made to the criteria in the Sensitivity category, though the authors decided as a precaution to score all sub-groups as 1 in regards to impairment due to toxicity. They felt it was too difficult and time-consuming (and in many cases impossible) to find information in the literature with regards to oil’s toxicity for all sub-groups. An author remarked that given the binary scoring system, this criterion was not useful for screening; at some level of oil exposure, all organisms will be impacted negatively.

For the Recovery criteria, the authors expanded the definition of reproductive capacity to include traits that reduce the number of offspring over a lifetime. These included delayed maturity, semelparity, and infrequent reproductive success. Additionally, “close association with sediments” was changed to “close association with unconsolidated substrates”, as the intention of this criterion was to refer to sand and finer grained sediments, which are likely to remain oiled for a longer time than boulders and bedrock, leading to a longer recovery process for associated biological components.

## DISCUSSION: CHANGES TO CRITERIA

Oil toxicity was discussed at length. One participant commented, and reviewers agreed, that issues relating to organismal impairment due to toxicity are such an important issue, it is necessary for the authors to discuss clearly why it was not included as a factor in distinguishing among biological components. Another participant elaborated on the difficulty of judging organismal sensitivity to oil, offering information the authors could include in the final report. There are thousands of hydrocarbon compounds, and it is impossible to study them all individually or have a complete understanding of how they might affect all sub-groups. It might be good to generally state that oil spills create risks to all biota, and the taxon-specific effects will be based on the dose and the mixture of compounds. However, one could not develop an accurate scoring result that treats species sub-groups differently based on their individual sensitivities to oil – it is simply beyond the scope and ability of this document. This participant recommended a section in the paper with examples that refers to studies of effects of specific oil constituents, or controlled laboratory studies. Several participants discussed the usefulness of a literature review that includes information about known toxicity thresholds for certain compounds, possible positive effects of oil on some taxa, or known effects (or lack thereof) on particularly important regional sub-groups such as salmon (or their eggs). An additional suggestion was that for sub-groups known to be sensitive to oil (such as herring and salmonids, for example), scoring them as 1 instead of 1* will provide an indication of cases where we have specific evidence. Caveats might include that different oil compounds might have different biological effects, and any specific oil spill or incident is unlikely to replicate the same chemical constituents for which we have previous evidence or observations.

The authors responded that they would be able to include more text on the known toxic effects of oil on biological components, while also summarizing why it was impossible to perform this analysis on all sub-groups. However, they felt it would be too time consuming to decide where a 1* could be switched to a 1 on a group-by-group basis, given the literature review that would be involved.

Under the original loss of insulation criterion, organisms with fur that could become oiled would be scored as more vulnerable. One participant felt this created a bias toward marine mammals as being more likely to be listed as vulnerable, whereas the framework should treat all groups

equally. The authors responded that this is a sentiment that had previously been expressed, but it is still a characteristic that makes those particular taxa more vulnerable to oil. Eventually, this problem was solved when the loss of insulation criterion was combined with the fouling of feeding/photosynthetic structures under mechanical sensitivity.

Regarding Exposure criteria, one participant asked whether wave heights were considered when deciding that “sea surface interacting” would refer to just the top 1 meter of the water column. The participant suggested that with larger wave heights, even algae more than 1 meter below lower tide levels could potentially interact with the ocean’s surface and possible oil spills. The national recommendation was to decide regionally what should be considered “surface”, and the authors remarked they had consulted with experts, and decided that only considering the top 1 meter of the water column as “surface interacting” would appropriately discern between groups of taxa with significantly higher potential for exposure to surface conditions than those living in deeper waters.

There was some discussion regarding mobility and its effect on Exposure (invertebrates only are classified as having high or low mobility). The premise, from conversations at the national level, was that mobility potentially decreases exposure risk, since more mobile organisms may be able to move away from areas where toxic compounds are present, though this assumes organisms are able to leave a degraded habitat. Some thought it might be appropriate to disregard mobility, since scoring this criterion assumes animals will make the “right” decision to move away from oil (removing this criterion would have necessitated rescoring 23 of 54 invertebrate sub-groups). Moreover, “low” and “high” mobility are relative terms, making it unclear how to objectively distinguish between the two. One suggestion was to provide this definition of mobility at the level of the sub-group (similar to the current Table 12), if it wouldn’t create too much additional work. Another participant suggested including as vulnerable sessile invertebrates plus those showing site fidelity under this criterion, whereas any mobile sub-groups without site fidelity would not be scored as more vulnerable. The problem is that certain species may be mobile, but not to the extent they could escape an oil spill in their vicinity (e.g. worms).

One participant pointed out that “site fidelity” has a very specific definition in behavioral ecology, and if the authors are using a different definition that should be spelled out. Alternatively, the authors could refer to habitat preferences or associations instead of using the term fidelity. Depending on how it is defined for fish, there is the possibility some sub-groups would need to be rescored. This participant also suggested the authors include justification for why aggregations apart from breeding/feeding are not included in the concentration (aggregation) criterion.

Another participant, thinking from the perspective of a decision-maker working on a rapid response, brought up several questions they thought could be important to consider in this framework: Are there any SARA listed species or critical habitat within reach of a spill? Are there any first nation resources in spill zone? Are there any ephemeral habitats that are being missed by the rest of the framework? These were discussed as possibly meriting discussion in the paper, but the framework does not require altering on their behalf.

Under the Recovery category, the paper would benefit by including definitions of several terms, including “endemism or isolation”, “reproductive capacity”, and “reduced or declining populations”. Several participants were uncomfortable with the authors’ blanket statement within the scoring tables that fish “have high reproductive capacity compared to mammals”. Examples were given of some fish that, regardless of egg/larval production or reproductive age, only recruit rarely because of boom-or-bust reproductive strategies. These may have very low reproductive capacity. A participant pointed out some cases where knowing age at first

reproduction for a single species seemed to be applied to an entire sub-group, where it in fact might not be representative of other species in that sub-group.

The authors explained they sometimes scored groups relative to each other because it was important to apply criteria the same way across all sub-groups. While they acknowledged it may seem that definitions were tailored more within certain sub-groups, the aim was to find the best approach in ranking all sub-groups against each other. It is a compromise between having a great deal of information and possibly too many definitions in a sub-group, versus being able to maintain consistent comparisons between sub-groups.

A participant asked why semelparity should make a species more vulnerable, as they are actually thought to be more fecund than iteroparous species. The authors responded that they concluded if an oil spill were to impact a semelparous population about to reproduce, it could represent a particularly high risk to the entire population. After discussion, it was recommended the authors remove reference to semelparity in this regard, and simply talk about low reproductive capacity as a criterion.

Some participants were not fond of the sub-groups, either because some sub-groups were overly broad, or because they were not created in a way that started from available data. The authors replied that the sub-group decisions were made at the national level and could not be revisited, and that data deficient sub-groups would reveal data gaps to help prioritize future work.

## PRESENTATION: CHANGES TO SCORING METHODOLOGY

**Presenter: Sharon Jeffery**

Sharon Jeffery reviewed the actual scoring of sub-groups (119 total) against the eleven criteria. She reiterated that scoring was binary, was based on direct contact with oil, and that the scoring system was reviewed by subject matter experts. The results of scoring sometimes revealed a need to revise sub-groupings. When not enough information regarding a particular sub-group against a criterion was available, the precautionary approach guided the authors to give a score of 1* and to consider that sub-group in the gap analysis. Sub-groups were scored based on the most sensitive member within the sub-group, but sometimes it made more sense to remove this member and rescore as multiple groups (ex: basking sharks as a filter-feeding elasmobranchs were removed from other elasmobranchs). Scoring based on life stages sometimes necessitated splitting juvenile and adult stages into different sub-groups (e.g. some rockfish switch habitats when they mature).

## DISCUSSION: CHANGES TO SCORING METHODOLOGY

Some scoring results had not yet been reviewed by experts (plants/algae and fish). For marine mammals, there was confusion about the meaning of “discrete” versus “dispersed” and one participant wanted clarification before completing the scoring. Another participant also stated they would like to take a closer look at the invertebrates scoring. Therefore, the reviewers told the authors that after they made recommended changes to criteria, it would be necessary for the scoring to be reviewed by various subject experts before finalizing the results.

Some discussion revolved around the idea that oil impacts on certain groups (e.g. zooplankton, fed on by many sub-groups including whales) would impact higher trophic levels, and that has not been incorporated into this analysis. The authors reminded the group that secondary effects had intentionally been omitted from the current scoring exercise. Participants and reviewers recommended including a section on how this report does or does not capture these secondary effects, and the authors responded that this could potentially be formalized in the gap analysis.

The chair asked the entire group if it would be acceptable to have the experts review the scoring, and have that be incorporated into the final document after the CSAS process. A CSAS representative said it would depend on the scale of the scoring changes and to what extent the ranking of sub-groups may be altered. Presuming the changes were not dramatic, another CSAS review would not be required.

It was agreed these new scoring reviews by subject experts would have to be done within one week and sent to the authors so that the final document could reflect the expert opinion on the authors' scoring. The subject experts would be Heidi Gartner (invertebrates), Joanne Lessard (plants/algae), Dana Haggarty (fish), and either Linda Nichol, Peter Ross, or John Ford (marine mammals). They would consider the revised definitions of some criteria and the discussions that occurred during this CSAS review. Then, after sending their scoring reviews to the authors, the authors would conduct any necessary re-scoring and would report the results back to the reviewers and participants.

## PRESENTATION: SCREENING PROCESS AND RESULTS

**Presenter: Candice St. Germain**

Candice St. Germain reviewed the screening and ranking methods the authors considered to determine which sub-groups were most vulnerable to oil spills. As mentioned before, they first considered the method developed through the national process, but it only screened out 3 of 119 sub-groups, so they also developed alternative methods, which altered the number of criteria that needed to be met at each step for a sub-group to be considered vulnerable. The alternative method the authors used for the Pacific region screened sub-groups in the same way as the national method, but ranked the final list of sub-groups by total score instead of Recovery score. The authors felt this resulted in a list more representative of the groups most vulnerable based on cumulative risk of exposure, sensitivity, and recovery following a spill.

The most vulnerable sub-groups were mostly plants and algae (scoring an 8 or 9, where 11 was the highest possible score) while no invertebrates scored higher than 7. High mobility invertebrate sub-groups and low mobility rock/rubble sub-groups tended to receive low vulnerability scores. The mammals scoring as most vulnerable were sea otters, discrete baleen whales, and discrete pinnipeds (including stellar sea lion and harbour seals). No mammals scored less than 4 (moderately low). St. Germain also went into detail discussing sub-groups whose scores did not necessarily align with the literature: these were phytoplankton, high mobility arthropods, sea turtles, and killer whales.

## DISCUSSION: SCREENING PROCESS AND RESULTS

Several participants were concerned about the results of scoring for Sensitivity (Figure 5). The loss of insulation criterion could only be fulfilled by mammals with fur, and the authors were asked whether it was appropriate to have criteria that could only apply to a restricted number of sub-groups. Additionally, since every species is scored a precautionary 1* for toxicity, then almost every sub-group receives a 1 or a 2, based on whether feeding is affected by oil. A maximum score of 3 was not possible, since mammals with fur do not have feeding structures that can be fouled by oil. This means the Sensitivity category is playing a minimal role in distinguishing among the vulnerability of sub-groups, where it seems it should be much more critical. The authors understood this, but they did not have a method that could increase the importance of Sensitivity, given the general lack of available toxicity information for sub-groups, and that removing Sensitivity completely would alter the results in a way that did not seem appropriate. In the end, the authors and participants decided the best way to handle Sensitivity would be to combine loss of insulation and the reduction of feeding/photosynthetic capacity into

a single criterion. This would not affect the scoring and rankings, and could be justified based on falling under “mechanical” sensitivities (whereas toxicity, the other criterion is a chemical sensitivity). This would result in a maximum score of 2 for the Sensitivity category, compared to 4 for Exposure and Recovery criteria.

One reviewer questioned whether certain plants should really score so high. They referred to some salt marsh grasses and seagrasses that actually did very well when affected by the Persian Gulf oil spill in the 1990s, and there is a fair bit of literature showing they are not seriously damaged by heavy crude oil. This may be due to regrowth from roots or rhizomes, the persistence of which may allow fast recovery of some eelgrass species. A participant pointed out that in some cases, the oil spills have killed seagrasses to the point where they have not recovered (e.g. Gulf of Mexico, Exxon Valdes).

A participant asked why so few sub-groups were screened out. The authors responded that this varied based on the screening methodology (9 different ones were tried). Their goal was not to try and screen out few sub-groups, but rather to create good resolution between sub-groups. The final screening method achieved this goal, while also making the most sense biologically. A participant asked whether it would be worth screening out any sub-groups that scored 0 for Recovery (with the idea that even if these groups were heavily impacted, there would be no reason to doubt their populations could recover over time). The authors responded that this was one of the 9 methods they tested, but it was not the best one.

Because recovery scores may not be feasible, or accurate based on lack of appropriate information, one participant commented, and others agreed, that they liked the idea of using a final ranking based on total score instead of recovery score alone.

## DAY 2

### IDENTIFICATION OF KEY ISSUES FOR DAY 2 DISCUSSION, CHECK-IN ON THE PROCESS, AND CONFIRMATION OF TOPICS THAT NEED TO BE ADDRESSED

The chair began the morning by recapping what had been discussed and achieved on the first day. He reminded the group that within the larger process of creating an Area Response Plan for oil spills, what this working paper intends is to do is identify the particular biological sub-groups in the Pacific region that might be particularly vulnerable to oil spills. During the first day, the group worked through the steps of the process and decided that a bit more text and explanation was necessary in regards to how the criteria were applied to sub-groups and to how scoring was determined. There were no major omissions or issues in discussing the sub-groups, other than some concern about lumping certain planktonic taxa together (phytoplankton as a single sub-group, non-larval zooplankton as a single sub-group, lack of larval fish as a sub-group(s)). After a long discussion on the criteria, the main issues involved mobility, reproductive capacity, loss of insulation, and toxicity. It was recommended the final report include a table in the appendix with reviewer names along with affiliations at the time. It was recommended that the final document refer to Exposure, Sensitivity, and Recovery as **categories** and not as **criteria**. The sub-elements of the categories are the criteria upon which vulnerability is based, and care to use this terminology avoids confusion for the reader.

### REVISITING THE CONCERNS REGARDING CRITERIA

The chair moderated additional discussion regarding the criteria that most concerned reviewers and subject experts.

**Reproductive capacity** seemed to be unevenly applied (and possibly confused) between different sub-groups, such as fishes. One participant stated that we do not know enough about how various life history traits in fishes are manifested in population dynamics, let alone the ability to recover from an event such as an oil spill. Participants agreed that for the criteria in the Recovery category, the authors should work with Dana Haggarty to write a paragraph about the issues and uncertainties with reproductive capacity specifically in application to fishes and invertebrates. This is especially important in light of reproductive capacity for many sub-groups being compared to marine mammals in a seemingly arbitrary way.

**Loss of insulation** will be combined with the criterion for oil physically coating feeding structures or photosynthetic apparatus; the resulting single criterion will relate to biological components having a mechanical sensitivity to oil, with the results being an impact on organismal energy budgets or metabolic requirements.

Some participants felt **impairment due to toxicity** should be removed as a criterion, arguing we lack information on which organisms experience toxicity at different levels of exposure. As a precautionary approach, other participants and the authors felt that by leaving toxicity in place and giving all sub-groups a 1*, it acts as a placeholder and a symbol of an area where more research is needed. This is not a satisfactory approach in the long run, but it would take a great deal of time to do a full literature review to determine for which sub-groups evidence exists for physiological toxicity (in those cases the * *could* be removed). Regardless, reviewers and participants agreed that the vulnerability scores would not change, as all organisms are thought to be susceptible to oil at some level (so no sub-groups can change from 1 to 0). The authors will make an effort to consider where a * can be removed (changing some sub-groups scores from 1* to 1) before submitting the final document. Toxicology will also be flagged for the gap analysis and future work.

Regarding the **mobility/site fidelity** criterion, an author explained the authors' current state of thought. For marine invertebrates, the national document suggested distinguishing between high mobility, low mobility, and sessile organisms. This document specifically noted that this is not meant to address whether organisms will move toward or away from oil (a continued concern in the mind of several participants). Therefore, the authors decided to score a 1 for mobility unless they had reason to believe sub-groups had high mobility, with the exception of mobile species showing site fidelity. It turns out that octopods are the only group fulfilling this site fidelity exception. One participant maintained that they would rather this criterion separate sessile taxa from mobile taxa and not discuss low and high mobility, but that they were willing to accept the authors' resolution since it follows directly from the national process.

In the current approach, marine fish were scored 0 for the mobility criterion unless the authors found evidence to the contrary. Examples included fish with clear site fidelity (e.g. lingcod), fish with seasonally-specific spatial limitations (e.g. salmon at river mouths in spring), cases where reproduction alters mobility (e.g. herring spawning), and those with particularly limited home ranges (e.g. some rockfish, wolf eels, some intertidal benthic fish, bay pipefish). It was recommended that these examples and justifications be clearly explained in the text. Still, participants were concerned about the mobility criterion and how meaningful it is. A paragraph in the document should capture the current discussion regarding spatial scale of potential events, the difference between site fidelity and habitat affinity, and cases where physiological constraints may prevent an otherwise mobile organism from leaving a habitat (such as Dolly Varden in an estuary).

A suggestion was made that the authors attempt to identify the level of uncertainty for each category and to address in the gap analysis where not enough information exists to score the sub-groups accurately.

## CONCERNS REGARDING THE RANKING OF SUB-GROUPS

In terms of the overall sub-groups flagged to be most vulnerable to oil, reviewers and experts were largely satisfied with the rankings. Seagrasses did come out ranked as being very vulnerable to oil, and one reviewer again pointed out anecdotal cases where seagrass has been quite resilient to oil contamination. This reviewer stated that typically it is highly refined oil (e.g. diesel or gasoline) that has the greatest mortality effects on vascular plants, and a ship-source contamination event involving crude oil may not have the same effects. This will need to be acknowledged in the final paper, and if there is a high degree of uncertainty authors should make sure those sub-groups receive 1* in the scoring for particular criteria.

A major discussion point, brought up by one participant, was the fact that final rankings are currently calculated based on adding up the scores for each individual criterion. This participant noted that this ranking was based on a total possible score of 10 (4 from each of the Exposure and Recovery categories, and only 2 from the Sensitivity category). Therefore, the final ranking of sub-groups artificially down-weights Sensitivity criteria compared to the others, because this additive method considers each individual criterion equally. The participant said that if this is how the final document ranks species, the authors need to explain that Sensitivity has been down-weighted and why that is a valid methodology. Because of the importance in justifying how we arrive at a final ranking, the final document needs to discuss whether it is more important to rank species based on equal influence of Exposure, Sensitivity, and Recovery, or instead to rank sub-groups based on all of the individual elements within the three major criteria categories. This participant and others provided a solution, if the authors wanted to equally weight the three criteria, which would be to normalize the scores within each group. In other words, since there were fewer Sensitivity criteria, they would each receive extra weight so that as a category, Sensitivity would compare equally to Exposure and Recovery.

Over the lunch break, the authors went through one set of normalization procedures, effectively doubling the scoring for Sensitivity, since it contained two criteria, where Exposure and Recovery both contained four. They found that under this approach, the ranking of the most vulnerable species changed slightly; two of the highly vulnerable sub-groups moved down into the middle of the rankings. Many of the sub-groups in the middle of the list moved a fair amount within the middle of the rankings, and the rankings of the least vulnerable sub-groups did not change.

As a final decision, the entire group decided that because of the weight placed on categories in the working document and in the literature, the alterative rankings under normalization procedures should be calculated and included in an appendix. Given the lack of appreciable changes using normalization ranking methods, it was recommended that rather than adopt this as a preferred method in the final report, the authors instead clearly explain the technical aspects of considering either criteria equal to each other, or categories equal to each other. A section in the text (a sensitivity analysis of sorts) could describe differences between the two forms of ranking and the outcomes of normalization among categories. One possible justification the authors could use for adding unweighted scores (considering criteria equal) could be to clarify that they do not intend to consider qualitative differences between the elements; the criteria are considered iterative, each one contributes to the vulnerability of a sub-group, and therefore they should contribute equally to the final ranking.

This discussion and the related statistical methods were flagged as a recommended point to focus on during future processes, which could take a closer look at how rankings might be influenced by different ways of weighting or normalizing the three major categories and their criteria. Participants agreed that regardless of the method used, the process needs to be well

described so as to be repeatable. The authors should consider whether the process gets to the right place for the right or the wrong reasons.

## THE NEXT STEPS

The chair asked the group to think about next steps. Participants and reviewers considered who the users of this working document are going to be, and how it would be used in the future. There is an evolving role of responsibility in terms of oil spill response, but eventually this document would likely be used by the environmental unit the Canadian Coast Guard would establish in the event of an oil spill. One reviewer pointed out that the information in this document will need to be ranked against other layers before it can become useful to responders (for example birds, terrestrial mammals, cultural and socioeconomic resources, etc.). This document represents a foundation for some marine ecological element of a resource prioritization map that will contain many layers from many groups, from algae and whales to sacred sites for First Nations. Initially, managers may only take a cursory look at such a map, but in the case of a major oil spill, each data layer will become important as decision-makers look into why different sub-groups were ranked as particularly vulnerable (or not). Following on this use, the reviewer notes this report could also be important in future court proceedings if DFO Science must justify why it ranked one biological resource as being more or less important than others.

Through the ARP process, this working document will help identify a proper plan for DFO Science to move forward. There may come a next step where we need to address gaps (features or sub-groups for which the analysis did not have enough information). The current framework will help DFO Science to recognize important scientific gaps. A DFO participant noted that some may be able to use the results of this report to consider whether a GIS data-gathering and data-assessment exercise is needed to address data gaps. It was noted that some spatial data in the PMECS database are not yet in a usable format. The geospatial element that follows from this process will result in a strong tool for use in future spatial management and MPA planning exercises for BC within DFO Science.

DFO Oceans requested this information because there will be a point where Oceans needs to provide an agreed-upon prioritization of species that are susceptible to spills. This document helps identify the scientific priorities to allow DFO to give appropriate advice, as well as to direct research funds based on critical needs and resources. Possibly it could identify areas that have vulnerable sub-groups and are also difficult to access or respond to potential spills, and that may influence future tanker routes. In the event of a spill, this document could help inform where monitoring is most important as sub-groups begin to recover, and what the important ecological indicators to measure might be.

The group briefly discussed any research gaps or tool gaps that became apparent over the course of this meeting. The lack of a current geospatial framework combining all sub-groups was mentioned, but this is intended to be included in future work direct following from the regional process. One participant pointed out that because the sub-groupings were initiated at the national level and not the regional level, there may be data gaps where DFO does not have spatially-explicit data for certain sub-groups. Lastly, another participant suggested the authors look at the John Butler report after the Marathassa incident. He said it may describe the spill response, ecological monitoring, and the role of different agents, and so it might reveal important gaps in the current process. The Greater Vancouver Spill Response plan also goes over a lot of these items and would be valuable for the authors to consult.

## SCIENCE ADVISORY REPORT AND MEETING CONCLUSION

Finally, all participants and authors discussed the Science Advisory Report (SAR), spelling out the summary points that captured the essence of the meeting. As the chair explained, the SAR should convey the essence of the meeting and needed to include sources of uncertainty, results and conclusions of the CSAS review, and additional advice to management. While the SAR was written, there was an extended amount of discussion centered on toxicity. It was clear that future iterations of this process really need to take a closer look at how best to use toxicity (how it is defined or applied) as an indication of the sensitivity of different sub-groups. It will also be important in the future to consider specific toxic compounds or oil types, even if only as illustrative examples. There were different ideas for conclusions of the CSAS review, with some focusing on what this paper allows DFO to do now, and others focusing on what DFO should be expected to do moving forward. As it stands, this paper improves the ability of DFO to collaborate with managers and other agencies and partners in contributing to an emergency oil spill response. And in the future, there is an expectation that this paper will lead to data (from DFO and other jurisdictions) representing different sub-groups being presented in a geospatial context so that managers will have improved tools in coordinating responses to contamination events and spills.

The chair ended the meeting by surveying the group on what they liked about the meeting and what they would suggest changing. Those who were familiar with the national process on creating an ARP liked that as a follow-up, this meeting included people who had worked together before and shared common background knowledge. Many liked the use of microphones, which reduced interruptions and gave everyone a chance to feel heard. It was a collaborative process in which a large variety of expertise, suggestions, and opinions were shared, leading to a very robust peer review. Even topics that were more difficult were worked on together until the group got to a solution where all parties could agree on a path forward. In terms of changes, one recommendation was to keep a running list of what had been decided, or what revisions to the working paper had been suggested. Additionally, if an example Science Advisory Response were given to the rapporteur at the beginning of the meeting, it might be possible for him or her to take notes in a way that it could be completed more quickly at the end of the meeting.

Following are the recommendations and suggestions offered to the authors as they edited and prepared a final version of the working paper. They are generally listed chronologically, as they would come up in the paper, and not per the order in which they were discussed during the CSAS Review.

## RECOMMENDATIONS TO AUTHORS AS THEY REVISE THE WORKING PAPER:

- Upfront in the introduction, clarify the rationale and audience for whom this paper is intended.
- In the introduction, provide a nice, sharp, succinct explanation of where this document fits into the larger ARP process, clarifying linkages to other groups, and perhaps creating a flowchart.
- Clarify the scope of elements being considered (for example, authors should specifically mention that seabirds are not included in the sub-groupings because they do not fall within DFO’s mandate and are being looked at by another agency).
- Better define “rapid” so that it is clear what a rapid assessment refers to.

- Final document should refer to Exposure, Sensitivity, and Recovery as the vulnerability categories and not as criteria. It should only use “criteria” to refer to the individual criteria elements within the three categories.
- Check to see if the descriptors in the littoral zone will match the classification Environment Canada is using. Address this comparison in the text.
- Provide justifications for why the sub-groups include phytoplankton and non-larval zooplankton (these are very broad groups and perhaps could have been divided further into more sub-groups).
- There is no sub-grouping for larval fish that distinguishes them from invertebrates in the zooplankton, and authors should explain why they do not make this distinction or else incorporate the suggestion to create a new sub-grouping for larval fish (possibly neustonic versus epipelagic larval fish).
- In general, provide more background on why changes were made to sub-groups. This could be done within a paragraph describing the process of sub-groups being created in an iterative manner to end up with an organization that made sense. Additionally, it is recommended the authors include more information in Table 5 so readers have better background on why sub-grouping changes were made.
- The sub-group “Worms” needs to be defined because it refers to so many different phyla and classes.
- In regards to mobility, authors are recommended to carefully clarify the definition of mobility with respect to the different major groupings (similar to as in Table 12). They should include examples and justifications related to the fish that were scored as 1 for mobility for explicit reasons.
- Related to this recommendation, it would be useful if a paragraph in the document captures the essence of the discussion regarding spatial scale of potential events, the difference between site fidelity and habitat affinity, and cases where physiological constraints may prevent an otherwise mobile organism from leaving a habitat (such as Dolly Varden in an estuary).
- The recommendations for how to deal with impairment due to toxicity are:
    - In the text, better explain why discriminating between different sub-groups’ toxicological oil was beyond the scope of this paper (including the caveat for differing effects being based on specific oil compounds, of which there are 1000s)
    - Keep the scoring of 1* for each group
    - Given time, before the final paper is published, make effort to remove asterisk from sub-groups for which there is scientific evidence of toxicological impairment.
- For the mechanical sensitivity, authors should merge loss of insulation with fouling of filter-feeding or photosynthetic structures into a single criterion
- Authors should work with Dana Haggarty to write a paragraph that covers the issues and uncertainties dealing with reproductive capacity of fishes and invertebrates.
- When scoring for reproductive capacity, every sub-group should not be compared to marine mammals (unless justification is given in the text).
- The gap analysis should note that this report does not capture the interactions among sub-groups. The example given was between zooplankton and baleen whales, where the latter

may be affected trophically by an oil spill that decreases zooplankton populations or introduces toxins into the food chain.

- There are seeming typos in the scoring that need to be checked by authors. In general, the authors should check for consistency in their scoring, and make sure the tables reflect scoring accurately. An example was provided from Table 6 in which sand lances and non-benthic subtidal fish (salmonids, and surf perch) seem to be organized and scored differently than in the appendices.
- Experts will review the scoring again, respond to authors within a week, and then the authors will need to again total the scores for sub-groups and re-organize the rankings.
- The authors were recommended to calculate alternative rankings using normalization procedures that result in setting each category as equally contributing to the final score, and to include these rankings in an appendix.
- Appendix will need a table with the expert reviewers, including affiliation at the time of review

## ADDITIONAL SUGGESTIONS FOR IMPROVING WORKING PAPER CLARITY OR USEFULNESS:

- It would be useful if “discrete” and “dispersed” were clearly defined in the text (as they were during the presentation).
- There was a suggestion to avoid calling any intertidal algae “canopy”, but to use “erect” or “stiff-stiped”, since “canopy” is used by DFO surveys as a descriptor referring to specific types of subtidal algae.
- Authors are asked to provide justification for why aggregations apart from breeding and feeding are not included.
- It is suggested the authors remove “semelparous” as an example that represents low reproductive capacity unless they have specific justifications and references that show semelparity lowers reproductive capacity in fish populations.
- “Endemism or isolation” and “Reduced or declining populations” were examples of terms used by the authors that currently may not have clear definitions within the text; if that is true, those definitions should be included.
- Currently screening and ranking are combined in what the authors term “screening method”. Since recommendations were made to consider different rankings based on normalizing the vulnerability categories, the authors should take care to distinguish between screening methods and ranking methods in the final text.
- Discussion points suggested to include:
- Final document should include acknowledgement that research exists suggesting vascular plants are not necessarily as vulnerable to crude oil as this ranking suggests, and it likely depends on the severity of fouling and long-term effect may depend on whether it affects below-ground roots and rhizomes.
- Text should discuss the two forms of ranking, and the outcomes of normalization among the three categories. Potential future work could explore other ranking methodologies (this could also be mentioned in the gap analysis)

- One next step is to develop certain GIS data layers to make a response plan operational, as well as being able to state whether there are particular data needed that DFO Science does not currently have.
- In the appendix, there is a suggestion to create a table discussing the traits or criteria that were considered by the authors, but ended up not creating distinctions among sub-groups (e.g. respiration in fishes)

## CONCLUSIONS & ADVICE

A framework was applied to the Pacific region to assess vulnerability of biological components to ship-source oil spills in the marine environment. The structured method comprised three major components:

1. Grouping of biological components into sub-groups;
2. Scoring of sub-groups against criteria in three categories (exposure, sensitivity and recovery); and
3. Screening and ranking of scored sub-groups to produce a list of biological components ranked for vulnerability.

- The working paper was accepted with revisions
- The sub-groups proposed for the Pacific application of the framework represent the suite of on-shelf biota in the Pacific region, while also providing sufficient discrimination for effective scoring of vulnerability criteria.
- Some biological groups required considerable changes to sub-group breakdown for the regional application (i.e. marine fishes and marine algae/plants), whereas other biological groups required few to no changes (i.e. marine mammals, marine reptiles, marine invertebrates). Modifications to sub-groups were clearly stated and justified to facilitate comparable re-assessments in other regions.
- Scoring all sub-groups against all criteria in this pilot application allowed for a detailed evaluation of the outcomes of a range of different screening and ranking methods, and provided justification for recommending the chosen method. However, scoring all sub-groups for all criteria may not be feasible for future applications if resources are limited.
- At present, the chemical sensitivity (impairment due to toxicity) criterion was not effective at differentiating between sub-groups based on sensitivity to chemical impacts of oil due to the scoring methods used. If future iterations of this framework application include this criterion, it is recommended that further investigation is needed to better characterize chemical sensitivity of sub-groups.
- The screening method used in the framework (requiring sub-groups to fulfill 1 exposure and 1 sensitivity criteria) was retained in the Pacific application, but the ranking method was modified so that sub-groups were ranked based on vulnerability scores (total score over all criteria), rather than on recovery scores. With the incorporation of this modification, the proposed screening and ranking method appears to function effectively to identify a ranked list of vulnerable sub-groups for the Pacific region that is most consistent with the scientific literature on oil impacts to marine organisms.
- This application of the framework will result in more focused data collection and expert advice on those biological components identified as most vulnerable to ship-source oil spills in the Pacific region

- Throughout the framework application, knowledge gaps were documented and included in a gap analysis which can be used to guide future work to address these gaps.
- The importance of expert input throughout all phases of regional framework development is emphasised, and is an appropriate approach for quality control. It is recommended that expert input on scoring and sub-group modifications be considered for future iterations of the framework adaptation.
- The geospatial products that will be produced based on the outputs of this framework will provide a foundation for coordinated planning and response across various organizations

The overall recommendations from this pilot application are outlined below.

- It is recommended that further iterations of this approach look carefully at how the relative rankings are calculated to avoid unintentional bias in specific categories of vulnerability criteria (exposure, sensitivity and recovery).
- The development of accessible and comprehensive geospatial databases is recommended as a next step, incorporating collaboration among DFO programs and other agencies engaged in marine spatial planning and response initiatives to avoid duplication of efforts and ensure efficiencies.
- Future iterations could examine alternative scoring and ranking methodologies, for example, scoring methods that are non-binary to provide gradient, and methods that could illustrate confidence in the score based on the data/info used to score.
- Phytoplankton and non-larval zooplankton were not assessed at sufficient resolution to assist decision making. It is recommended that the development of these two groups be included in future iterations of the framework

## ACKNOWLEDGEMENTS

The authors wish to acknowledge the invaluable contributions of our meeting chair, Gilles Olivier, our two formal reviewers, Stephen Lehmann and Jerome Marty, our rapporteur, Ben Grupe, each of the pre-reviewers, Anya Dunham, Heidi Gartner, Joanne Lessard, John ford, Robert DeWreede, Dana Haggarty, Jacqueline King, Peter Ross, and Linda Nicholl, as well as each of the meeting participants. These people spent significant time reviewing the document, participating in the regional peer review process, and/or working with the authors to produce a robust final product.

## APPENDIX A: TERMS OF REFERENCE

**Evaluation of Pacific Region application of a National Framework to assess the vulnerability of biological components to ship-source oil spills in the marine environment**

**Regional Peer Review Process – Pacific Region**

**September 14-15, 2016**
**Nanaimo, British Columbia**

Chairperson: Gilles Olivier

### Context

A National Framework to Assess the Vulnerability of Biological Components to Ship-source Oil Spills in the Marine Environment (the Framework) was developed by Fisheries and Oceans Canada (DFO), and reviewed in March 2016 through a Canadian Science Advice Secretariat (CSAS) National Peer Review (Thornborough et al., unpublished[1]). The Framework contributes towards the development of a timely and informed response to ship-source oil spills by identifying which marine biological species sub-groups are most vulnerable to spilled oil, and focusing data collection for spill response planning.

The National CSAS review determined that the Framework was appropriate for use in all Canadian regions but with an allowance for regional flexibility given that regions have differing biota. To ensure a regionally meaningful application of the Framework, it was anticipated that biological sub-groups would require tailoring to reflect the habitat and species components of a particular region. As this is a first trial of the Framework, changes may also be necessary to criteria or filtering methods.

Fisheries and Ocean's Canada's (DFO) Oceans Branch has requested that Science Branch provide a Pacific regional adaptation and application of the National Framework, and provide advice as outlined within the objectives below. The assessment and advice obtained from this CSAS Regional Peer Review (RPR), and the application of the adapted Framework, will be used to inform oil spill response planning for areas of interest within the Pacific Region, (such as pilot areas for the World Class Tanker Safety System (WCTSS) initiative) and assist in identifying priority data relevant for those subgroups identified as being most vulnerable to oil. The scientific advice will primarily be used by DFO in the Pacific Region, but may inform similar processes in other Canadian regions, or be used as part of further National reviews under subsequent phases of the WCTSS initiative.

### Objectives

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

*Hannah, L.et al. Evaluation of Pacific Region application of a National Framework to assess the vulnerability of biological components to ship-source oil spills in the marine environment. CSAS Working Paper 2015OCN06*

The specific objectives of this review are to:

[1] Thornborough, K., Hannah, L., St. Germain, C., and M.O. (2016). A framework to assess vulnerability of biological components to ship-source oil spills in the marine environment. Unpublished manuscript to be submitted for publication as a CSAS Research Document.

1. Evaluate whether the National Framework was appropriately adapted to the Pacific Region:
    a. Assess whether the species subgroups are representative of the suite of on-shelf biota in the region.
    b. Assess if the species subgroups have been divided so that their vulnerabilities to oil can be discerned by the scoring criteria based on their biological and ecological traits
    c. Determine if the scoring criteria and the filtering methods effectively identified an appropriate list of subgroups most vulnerable to ship-source oil spill in the region.
2. Note that efforts will be made to seek expert input at each stage of the adaptation process to ensure that subgroups identified and scoring methods chosen are consistent with best available knowledge and information.

**Expected Publications**

- Science Advisory Report
- Proceedings
- Research Document

**Expected Participation**

- Fisheries and Oceans Canada (DFO) (Ecosystems and Oceans Science, Oceans Management, and Fisheries Protection Program)
- Transport Canada
- Canadian Coast Guard
- Environment and Climate Change Canada
- Government of BC
- Academia
- Industry
- Other invited experts

## APPENDIX B: WORKING PAPER REVIEWS

### Reviewer: Jerome Marty

Review of Working Paper: *Application of a national framework to assess vulnerability of biological components to ship-source oil spills in the marine environment in the Pacific Region*

**Overall comments**

The research document 'Application of a national framework to assess vulnerability of biological components to ship-source oil spills in the marine environment in the Pacific Region' from Hannah et al. is an important contribution in the field of ecosystem stressor studies because:

1. the analysis is generated from a large amount of data covering both large spatial and temporal scales and
2. it is applicable to one stressor of concern for Canadian aquatic ecosystems: oil exposure.

The analysis is following the structure presented earlier as a National framework and authors made adjustments to address some limitations and needed clarifications when applying the national tool to the pacific region data. The analysis is well structured, provides the reader with sufficient details on the rational to modify the national framework. The report benefited from expert consultations to refine some of the criteria used to select species sensitive to oil.

The value of the analysis is not only in the most appropriate list of selected species: the review includes key questions/recommendations that were raised by conducting a gap analysis, conducted at each steps of the analysis. I particularly find useful the evaluation of various methods to combine ranking values obtained at each steps of the analysis. Although no detailed analysis was conducted to evaluate the level of uncertainty for each level, the gap analysis is a first step as a surrogate of a more formal 'uncertainty' analysis. Among the next steps/recommendations, the authors are suggesting to not consider toxicity related ranking as it is very difficult to provide such assessment at the sub-group (or species) level. Clearly, more research is needed in this field, and unfortunately, such expertise now needed by DFO is no longer available internally. The limitation goes beyond the available scientific knowledge…

I have added specific comments in the document. I would encourage the authors to present better the analysis in the context of its use. Why do we need to conduct this analysis ? The report is indicating that it does support the development of future plans to respond to oil spills. I do not fully agree with this. When responding to an emergency (that is first to prioritized respond in the first hours following the spill), responders will evaluate 2 elements after trying to reduce the spill at the source:

1. what can be done at the surface and
2. how do we respond to shore exposure.

The other components of the ecosystem, although exposed to oil, will unfortunately not be prioritized, not because they are not important but because we do not have a response available for them. I think the analysis conducted for the report as a broader application: it does provide insight on areas of high sensitivity to oil exposure- areas where we could prioritize the deployment of equipment to stop/limit oil expansion, and maybe more importantly, provide advice for areas where limitation in oil transport should be considered. How would the result of this work feed current (and future) risk assessment for oil exposure ?

Another element raised by the author is the need to consider the various properties of oil. There is a need to join expertise from chemists and toxicologists with that from biologists. Oil is a

broad term and the same effort to describe biological features is needed to describe oil properties when spilled in the environment. This is needed to have a 'complete and accurate' picture of oil exposure. This is particularly important in BC where many oil product types are transported (huge volumes of crude via the Alaskan trade, large volumes of diluted bitumen and important traffic associated with fuel oils).

To end this review, I would like to thank the authors for inviting me to review and hopefully contribute to the analysis with my comments. I urge the authors to publish their work in a peer review journal as too little information on this topic exists in the scientific literature.

Best regards

Jerome Marty.

## Reviewer: Stephen Lehmann

NOAA
Sept. 8, 2016

Application of a national framework to assess vulnerability of biological components to ship-source oil spills in the marine environment in the Pacific Region

**Is the purpose of the working paper clearly stated?**

The intent of the paper is clear although where it will be used and how it will be used is less straight forward. A more specific vision on the works possible uses in the development of other products (policy, contingency plan, response guidance, etc.) might help the reader apply his or her personal perspectives on the work and, indeed, even broader the reach of the work by suggesting areas not thought of by the authors.

**Are the data and methods adequate to support the conclusions?**

The considerations of the groups and sub-groups (and often sub-sub-groups) appears quite thorough and well thought-out. As this is a synthesis of data rather than raw data itself, there is no foundation on which to comment, but the methods are explained well. As to whether they support the conclusions, the matrices of vulnerable resources largely fits my experience and intuition (low energy habitats, sessile organisms, high exposure conditions).

**Are the data and methods explained in sufficient detail to properly evaluate the conclusions?**

Yes, particularly with knowledge of the national program paper.

**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?**

The document presents a methodology rather than advice, per se. As such, to answer this question the term "decision-maker" must be better defined. Oil spill planning can be seen as a three-legged stool where prevention, response and restoration represent the three legs. The term "decision-maker" can easily apply to each of the legs. If I presume that the goal is to inform regulation (part of the prevention leg), then once it is in a geographic context it could help define traffic routes, lightering and anchorage locations, pipeline easements and so on. Likewise, if the decision-maker is involved in the assessment of an injury or the restoration of an injured resource, understanding species vulnerabilities is important and the justifications for ranking in the paper might be very helpful. However, if the decisions in question are meant for the response community, where brevity, geographic relevance and simplicity are critical, then the paper is less helpful. In order to be relevant to the response community, these data must be

further digested and available in a geo-spatial format, preferably searchable and seasonally adjusted.

There is brief discussion of the ESI maps produced by NOAA. Here is an example of a tool specifically designed for the response decision-maker. The data displayed can be read quickly and easily. However, the ESI only services one of the three legs. It does not have the detail necessary for injury assessment and controversial regulation development. I think once the rankings are applied in a geographic context, there will be a multiplier effect that might be very useful. For example, low energy coastal environments will combine sensitive plants species with sessile organisms and early life stage organisms rendering a map useful to planner, regulators and responders.

**Can you suggest additional areas of research that are needed to improve our assessment abilities?**

The document is clear about its scope and in particular elements it is not examining. This narrow focus is most understandable given the limitations driven by DFO's purview and the time and resources dedicated to the project. However, oil spills are, if nothing else, multi-dimensional and require considerations driven by response and treatment methods, competing resources-at-risk, including commercial and qualitative trade-off decisions made by impacted stakeholders. The good work being displayed in this document must, at some future point, be compared to similar work on vulnerable resources and operational parameters. I view this as a single piece a larger, more holistic effort.

As a result of the Deepwater Horizon oil spill in the US Gulf of Mexico, a great deal of research that pertains to this document is being conducted both at the government and academic levels. I particularly suggest that DFO stay current with Gulf of Mexico Research Initiative (GOMRI), a $500 million dollar research grant program targeting oil spill related issues. Likewise, most of the government studies conducted for the purpose of assessing injury following the DWH event are now available due to the advent of a legal settlement with the responsible parties. These studies may yield some important new findings in the areas of marine life impact.

**Other Considerations**

**The decision to exclude "Impairment due to toxicity criterion"**

It is understandable that this criterion is difficult to use due the "lack of standardized experimentation" and "reliable baseline data." However, the exclusion of this category means possibly discounting effects for which we have strong, albeit no conclusive, evidence. In doing so, decision-makers may put less value on certain habitat and/or organisms. A good example are salmon. While they rank comparatively high because of other factors, there are many credible studies suggesting an impact to young salmon from oil persisting in their habitat after the EVOS event. How the investigators rationalize the inconsistencies among experiments, the lack of data for all species and the lack of baseline data is open for debate, but the some consideration should be made for this criterion.

"The impairment due to toxicity criterion was difficult to score with any rapidity due to the breadth of literature required to consult to arrive at a clear score for a sub-group. Consequently, in this pilot application all sub-groups are scored a precautionary 1 (1*) for this criterion until further work on reviewing literature on all groups can be completed." 4.3.2.1 Changes to Sensitivity Criteria

Giving a precautionary score of 1 indicates, to me, an uncertainty level that is greater than deserved. This is implying "toxic until proven otherwise" (including those sub-groups for which no data exist) and creates a false equivalency between those with no data and those with some,

but less than perfect data. Finding a way score those organisms for which some data exists is important.

## APPENDIX C: AGENDA

### Centre for Science Advice Pacific

### Regional Peer Review Meeting (RPR)

### Evaluation of Pacific Region application of a National Framework to assess the vulnerability of biological components to ship-source oil spills in the marine environment

September 14-15, 2016
Nanaimo, British Columbia

Chair: Gilles Olivier

**DAY 1 – Wednesday, September 14**

| Time | Subject | Presenter |
|---|---|---|
| 0900 | Introductions<br>Review Agenda & Housekeeping<br>CSAS Overview and Procedures | Chair |
| 0915 | Review Terms of Reference | Chair |
| 0930 | Presentation of Working Paper: overview | Sarah, Lucie, Sharon, Candice |
| 1015 | Reviewer comments: overview | Chair + Reviewers & Authors |
| 1030 | ***Break*** | |
| 1050 | Discussion and Identification of key issues | RPR Participants |
| 1200 | ***Lunch Break*** | |
| 1300 | Presentation of Working Paper: Part 1 changes to sub-groups | Lucie |
| 1315 | Reviewer comments: sub-groups | Chair + Reviewers & Authors |
| 1330 | Discussion and Identification of key issues | RPR Participants |
| 1445 | ***Break*** | |
| 1500 | Presentation of Working Paper: Part 2: changes to criteria and scoring | Sharon |
| 1510 | Reviewers comments: criteria and scoring | Chair + Reviewers & Authors |

| Time | Subject | Presenter |
|---|---|---|
| 1525 | Discussion and Identification of key issues | RPR Participants |
| 1600 | Presentation of Working Paper: Part 3: screening process and results | Candice |
| 1610 | Reviewer comments : screening process and results | Chair + Reviewers & Authors |
| 1625 | Identification of key issues for day 2 discussion | RPR Participants |
| 1645 | Check in on progress and confirmation of topics for discussion on Day 2 | Chair |
| 1700 | Adjourn for the Day | |

**DAY 2 – Thursday, September 15**

| Time | Subject | Presenter |
|---|---|---|
| 0900 | Introductions<br>Review Agenda & Housekeeping<br>Review Status of Day 1 | Chair |
| 0915 | Discussion and Identification of key issues<br>(Continued from Day 1) | RPR Participants |
| 1030 | ***Break*** | |
| 1045 | Discussion (continued) | RPR Participants |
| 1200 | ***Lunch Break*** | |
| 1300 | *Science Advisory Report (SAR)*<br>Develop consensus on the following for inclusion:<br>• Sources of Uncertainty<br>• Results & Conclusions<br>• Additional advice to Management (as warranted) | RPR Participants |
| 1430 | ***Break*** | |
| 1445 | *Science Advisory Report (SAR) (*Continued) | RPR Participants |
| 1630 | Next Steps – Chair to review<br>• SAR review/approval process and timelines<br>• Research Document & Proceedings timelines<br>• Other follow-up or commitments (*as necessary)* | Chair |
| 1645 | Other Business arising from the review | Chair & Participants |
| 1700 | ***Adjourn meeting*** | |

## APPENDIX D: PARTICIPANTS

| Last Name | First Name | Affiliation |
|---|---|---|
| Desjardins | Christine | DFO Science |
| Dunham | Anya | DFO Science |
| Fu | Caihong | DFO Science |
| Gale | Katie | DFO Science |
| Gartner | Heidi | Royal BC Museum |
| Grupe | Ben | DFO Science |
| Haggarty | Dana | DFO Science |
| Hannah | Lucie | DFO Science |
| Holmes | John | DFO Science |
| Jeffery | Sharon | DFO Science |
| Jerome | Marty | DFO Science |
| Lehmann | Stephen | NOAA |
| Lessard | Joanne | DFO Science |
| MacDougall | Lesley | DFO Science |
| Nichol | Linda | DFO Science |
| O | Miriam | DFO Science |
| Odense | Remi | Province of BC |
| Olivier | Gilles | DFO Science |
| Patton | Sarah | DFO Science |
| Perry | Ian | DFO Science |
| Ross | Peter | Vancouver Aquarium |
| St. Germain | Candice | DFO Science |
| Thornborough | Kate | Independent |
| Van der Slagt | Graham | DFO Science |

## APPENDIX E: ABSTRACT OF WORKING PAPER

This paper examines the effectiveness of a framework to assess vulnerability of marine biological components to a ship-source oil spill (Thornborough et al. 2017, in press) through a pilot application to the Pacific region. The functionality of the framework method was assessed at each step in this pilot application, and modifications made where deemed necessary with the support of regional subject matter experts throughout the process. The main objectives of this pilot application were to:

1. Assess, and where necessary, adapt sub-groups (representing marine biota) so that they are appropriate to Pacific Region biota and structured so that their vulnerabilities to oil can be discerned by the scoring criteria (based on their biological and ecological traits);
2. Assess, and where necessary, adapt criteria and definitions through testing of the framework; and
3. Identify a list of sub-groups most vulnerable to a ship-source oil spill in the Pacific region by scoring adapted sub-groups for vulnerability criteria and applying a screening and ranking process.

Overall, the relative vulnerability rankings determined by the adapted method aligned well with the outputs from studies and oil spill literature and support the framework as a simple and rapid method to assess vulnerability to oil. Knowledge gaps are identified at each stage in the framework to highlight areas for prioritized research activities. The outcomes of the pilot application are primarily a list of ranked sub-groups identified as being most vulnerable to a ship-source oil spill in the Pacific region. This pilot application of the framework is intended to be relevant to all biota in the (on-shelf) Pacific region but subsequent steps of this Pacific region application will focus on specific areas within this broader region, namely the Pacific Area Response Plan (ARP) pilot area. This work contributes towards meeting the Department of Fisheries and Oceans (DFO) commitment to ensuring sustainable aquatic ecosystems.

### REFERENCES: APPENDIX E

Thornborough, K., Hannah, L., St. Germain, C., 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.