Fisheries and Oceans Canada | Pêches et Océans Canada
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National Capital Region

Canadian Science Advisory Secretariat
Science Advisory Report 2017/032

A FRAMEWORK FOR ASSESSING VULNERABILITY OF BIOLOGICAL COMPONENTS TO SHIP-SOURCE OIL SPILLS

Figure 1. Department of Fisheries and Oceans' (DFO) six administrative regions. Stars depict pilot locations for Area Response Planning.

Context:

The Department of Fisheries and Oceans (DFO) is committed to ensuring sustainable aquatic ecosystems. The development of a framework to assess vulnerability of biological components to ship-source oil spills in the marine environment represents an important contribution toward meeting this commitment. The proposed framework addresses the need for a rapid assessment of vulnerability to ship-source oil spills for marine biological components under DFO mandate and contributes to the ecological aspects of the 'Resources at Risk' component of the overall model of oil spill planning and response. The framework is intended to be: nationally consistent; regionally flexible; grounded in science; and rapid and simple to implement, with the primary outcome being a concise list of biological components most vulnerable to oil. Currently, the assessment has been limited to components within DFO's mandate, however the hope is that this framework may be more broadly applicable.

This Science Advisory Report is from the March 1-3, 2016 National Peer Review meeting on a framework for assessing vulnerability of aquatic ecosystems to ship-source oil spills. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Canada

SUMMARY

- This Science Advisory Report (SAR) provides a framework for assessing and screening vulnerability of biological components to ship-source oil spills. This is a National framework, which now needs to be applied in the regions in order to assess effectiveness and any required changes.
- The scope of this framework is to address direct effects associated with immediate as well as potentially long term exposure resulting from a single ship-sourced oil spill event. This framework is not meant to assess indirect or secondary effects from oil exposure, or cumulative effects from multiple stressors.
- The application of this framework has the potential to streamline the provision of expert advice on those biological components that are vulnerable to ship-source oil spills.
- This framework was designed for application within the jurisdiction of DFO but could also be potentially applicable or of interest to other jurisdictions.
- Marine biological components were divided into groups and sub-groups in order to better enable vulnerability assessment for an oil spill.
- Criteria were developed to identify species sub-groups with higher vulnerabilities to oil spills. Criteria were grouped into three types: exposure, sensitivity, and recovery potential.
- A sequential screening system was developed to rapidly identify sub-groups that are exposed and sensitive to oil. Identified sub-groups are subject to further evaluation of recovery potential at the population level. Criteria are broad and aim to be adaptable to all species sub-groupings across Canada.
- Components of this framework (eg. species sub-groups, additional criteria) may not be entirely applicable to unique environments, especially in the Arctic.
- The framework allows for identification of knowledge and data gaps that could be used to improve the application of the framework.
- The framework process/structure may be suitable for assessing vulnerability of biological components to other types of spills (eg. Hazardous Noxious Substances). It may also be suitable to assess the impact of other marine activities.

BACKGROUND

The Department of Fisheries and Oceans (DFO) is committed to ensuring sustainable aquatic ecosystems. The development of a framework to assess vulnerability of biological components to ship-source oil spills in the marine environment represents an important contribution toward meeting this commitment. The proposed framework addresses the need for a rapid assessment of vulnerability to ship-source oil spills for marine biological components under DFO mandate, and contributes to the ecological aspects of the ‘Resources at Risk’ component of the overall model of oil spill planning and response (Figure 2). The framework is intended to be: nationally consistent; regionally flexible; grounded in science; and rapid and simple to implement, with the primary outcome being a concise list of biological components most vulnerable to oil. Currently, the assessment has been limited to components within DFO’s mandate, however the hope is that this framework may be more broadly applicable.

In this structured approach, biological components most affected by a ship-source oil spill are identified utilizing a suite of criteria to assess vulnerability. The term ‘vulnerability’ is an

increasingly used concept in many disciplines; while often used interchangeably with 'sensitivity', it is generally accepted that vulnerability is the degree to which a system is susceptible to, and unable to cope with, injury, damage, or harm (De Lange et al. 2010). As such, sensitivity is nested as a factor of vulnerability, where vulnerability is a function of: exposure to a stressor; sensitivity, and recovery potential. Following this approach, the proposed framework divides criteria into three categories: exposure, sensitivity, and recovery, each encompassing a number of criteria which are envisaged to be consistent and broad enough to be applicable in a variety of aquatic environments. It is anticipated that this approach will be useful for identification of biological components most affected by ship-source oil spills in any aquatic environment.

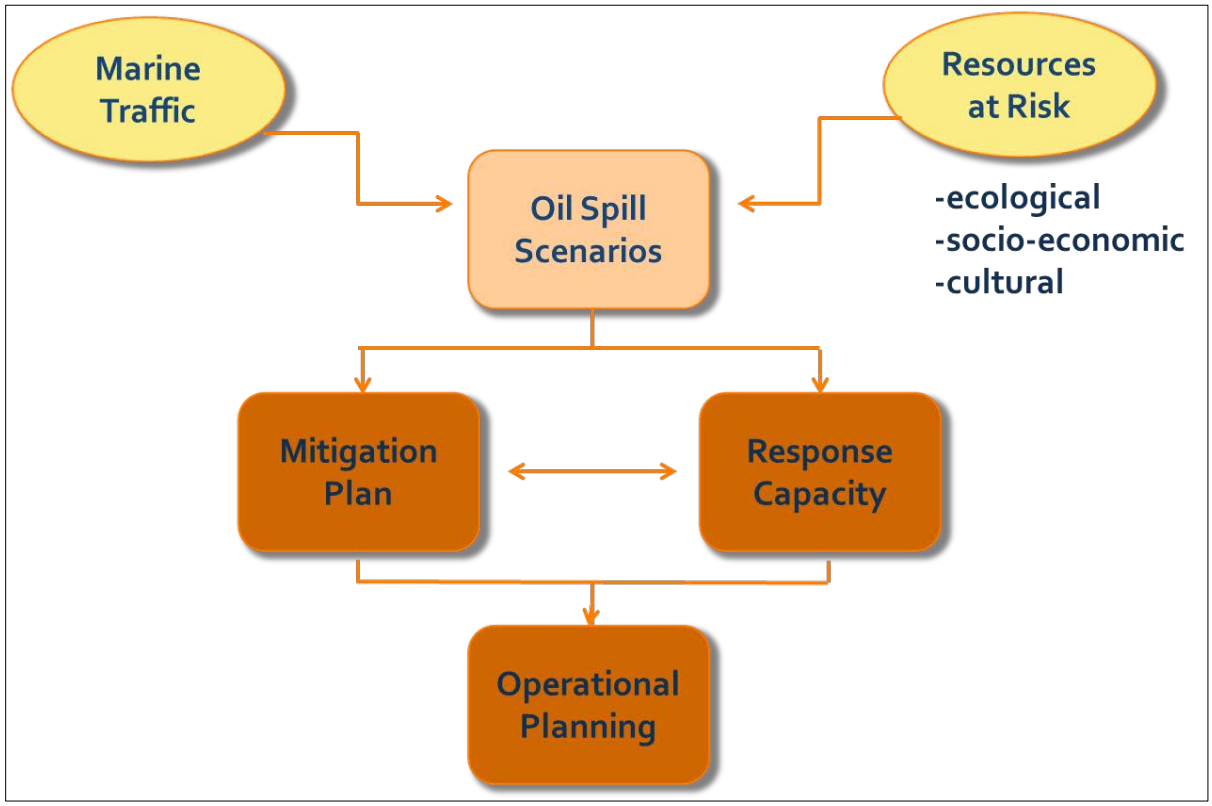

Figure 2. Overview of how the vulnerability framework fits in with the overall model for oil spill planning and response ("ecological" Resources at Risk).

Objectives

This project aimed to develop a structured, national framework to identify biological components most vulnerable to ship-source oil spills based on elements from sensitivity, vulnerability, and risk assessments. The framework should not be limited by data availability or heavily influenced by, or dependent on, expert opinion at the onset, and should be adaptable for application to any aquatic environment in Canada. The specific objectives are to:

1. Organise biological components into groups and sub-groups based upon similar characteristics with respect to factors important for vulnerability to oil;

2. Develop nationally consistent criteria for selection of vulnerable biological components for input into oil spill response plans that are flexible, yet general enough to be applied across Canada.

Scope

This work focuses on providing guidance on assessing marine biological components that fall within DFO's mandate; those at and below mean high water springs (MHWS), including marine mammals, marine reptiles, marine fish, marine invertebrates, and marine plants/algae. Birds are not considered in this framework as they are under the mandate of Environment Canada and Climate Change (ECCC) and are being assessed by ECCC under the "ecological ECCC/DFO" component of the Resources at Risk (Figure 2).

Although socio-economic and cultural values have been identified as critical aspects of the 'Resources at Risk' component (Figure 2) and need to be considered in the development of oil spill plans, they were not included in this framework as they are outside the expertise of DFO's Science branch. However, these values will be provided by other sectors within our department. Fisheries species and species with conservation status are captured only when their sub-group is assessed as highly vulnerable.

Habitats are not directly assessed in this framework, but are included when associated with vulnerable biological components. Biogenic habitats (e.g. eelgrass beds, glass sponge reefs) are assessed on a species sub-group level rather than associated habitats (e.g. eelgrasses, Porifera).

Ecologically and Biologically Significant Areas (EBSAs), Marine Protected Areas (MPAs), and other spatial planning areas are not assessed in this framework, as this information is provided by other groups involved in oil spill planning and response.

The framework is not limited to spills of any specific oil type, but focuses on generalized impacts from a worst case scenario ship-based spill and does not consider mitigation measures such as the use of chemical dispersants.

ASSESSMENT

The framework to identify vulnerable marine biological components consists of two key phases:

1. Grouping of biological components based on similar characteristics related to oil vulnerability; and
2. Identification of most vulnerable biological sub-groups by scoring biological sub-groups against vulnerability criteria (exposure, sensitivity, and recovery).

Built into this framework at every phase is the identification of knowledge gaps to feed into a gap analysis. The proposed framework was developed as a top-down approach, whereby the start of the process includes all species groupings present in an area regardless of data availability. This approach allows for the identification of information gaps relating to vulnerable biological components, which will inform future development of this framework. The framework proposed here is designed for use by DFO to determine the provision of ecological data on the most vulnerable species groups under their mandate, for input to the development of oil spill response plans. The structure of the framework is outlined in Figure 3.

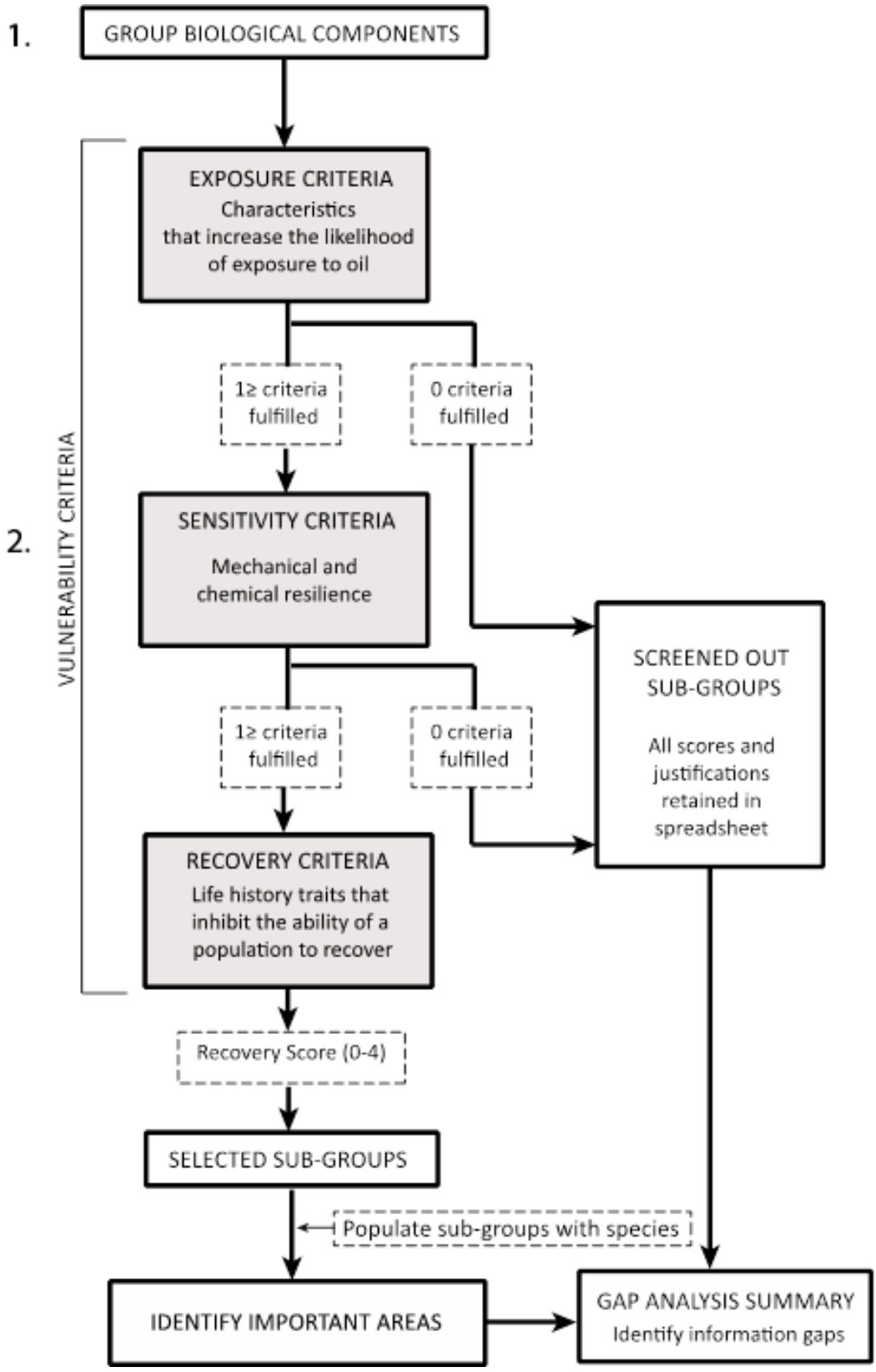

Figure 3. Overview of framework to identify vulnerable biological components.

This framework should not be considered an all-inclusive approach for oil spill response; rather it is a template that can be adapted for different needs, by regions and groups for identifying what to provide to larger oil spill planning and response efforts. It is also not a risk assessment, but could be a framework for identifying the biological groups which should be considered within such an assessment.

Grouping Biological Components

In the proposed framework (Figure 3), only sub-groups identified as most vulnerable are populated with species. Sub-groupings were developed for five high-level groups: marine algae/plants; marine invertebrates; marine reptiles; marine fish and marine mammals, based upon biological expertise and available literature. Sub-groups were structured to enable them to be distinguished from one another by their vulnerability to oil and so be effectively assessed by the criteria; it follows that members of a sub-group should share similar characteristics with respect to factors important for vulnerability to oil. The proposed sub-groups are listed in Table 1 of the research document. As this framework has a national scope, proposed groupings are general enough to be applicable across Canada but the framework allows for flexibility in the divisions of sub-groups to account for differences between regions. Sub-groups are likely to require adjustments for different regions, and particularly where freshwater or ice-influenced areas are being assessed.

Ecological Vulnerability Criteria

All marine biological components are assumed to be vulnerable to spilled petroleum products to some degree. In order to provide area response coordinators with guidance on only the most vulnerable biological components, criteria are used to determine the vulnerability of each sub-group. Selection criteria create a structured approach to a top-down selection process, making results comparable across regions.

Exposure Criteria

While it is possible that all marine biological components may be exposed to some degree during a large ship-source oil spill, species that are more likely to encounter spilled oil are assumed to be more vulnerable. Exposure criteria identify behavioural characteristics that increase the likelihood of exposure to oil, including:

- concentration (aggregation);
- sessile/low mobility; and,
- surface interaction.

Sensitivity Criteria

This suite of criteria examines both mechanical and chemical sensitivity based on physiological characteristics that may influence the magnitude of impact from exposure to oil:

- Mechanical sensitivity identifies physiological characteristics more vulnerable to mechanical impairment by oil (e.g. loss of insulation when fur becomes oiled and reduction of feeding when feeding structures become oiled).
- Chemical sensitivity identifies physiological characteristics more vulnerable to chemical impairment by the oil (e.g. pathologies developed as a result of contact with the toxic components of oil).

The pathways of exposure to oil are through adhesion, ingestion, absorption, and/or inhalation.

Recovery Criteria

Recovery (often referred to as adaptive capacity or resilience) criteria examine the life history traits that impact the ability of a population to recover, including:

- population status;
- reproductive capacity;
- geographic range within the region;
- ability to metabolise, excrete or otherwise remove hydrocarbons; and,
- close association with sediments.

Scoring and Screening Process

The scoring and screening process is outlined in Figure 3. The current framework proposes to assess biological sub-groups by scoring them against three categories of criteria (exposure, sensitivity, and recovery) in a sequential manner. This sequential application of criteria is intended to provide a rapid and efficient guided scoring process to differentiate those sub-groups that are relatively more vulnerable to oil spills.

A binary system is employed to score biological sub-groups against criteria as either (1) criterion fulfilled, or (0) criterion not fulfilled. These scores are explored in detail by consulting publications and subject matter experts and providing referenced justifications for each score, maintaining scoring consistency. Exposure criteria are scored first, as these criteria are straightforward and rapid to score using the biological expertise of the scorers. While each exposure criterion is scored per sub-group, only those sub-groups that fulfill at least one exposure criterion move on to be scored against sensitivity criteria. Sensitivity criteria require the biological expertise of the scorers, literature review, and consultation with experts; and are more time consuming to score. As with the exposure criteria, all sensitivity criteria are scored, but only those sub-groups that fulfil at least one sensitivity criterion move on to be scored against recovery criteria. Those sub-groups that did not fulfill any exposure and/or sensitivity criteria are included in a spreadsheet with justifications for removal, and to revisit periodically when additional information may change the outcome of this assessment. Each remaining sub-group is scored against all recovery criteria and is ranked based on the cumulative score for all four recovery criteria (i.e. from 0-4).

The final list of vulnerable sub-groups will include those that fulfil a minimum of one criterion for both exposure and sensitivity criteria. The end result of the sequential application is a list of species sub-groups that are relatively more vulnerable to oil spills (have the highest likelihood of exposure, the highest sensitivity to oil, and the lowest potential for recovery).

Each criterion is scored against the lowest level of species sub-group, with each criterion and criteria type having equal weighting. Recovery criteria are scored on a species level. Where possible, each criterion should be scored based on the life stage most likely to be impacted. However, this approach may be difficult to apply consistently across all species groups. This is particularly the case for invertebrates, where the most sensitive life stage is often their planktonic form. This may lead to little differentiation in scores between sub-groups, and may elevate the vulnerabilities of invertebrates higher than other species groups. In cases where this precautionary scoring may not be feasible, this challenge should be highlighted in the gap analysis. A potential solution to this problem would be to separate all life stages for each species sub-group and score each separately. While this approach is not feasible for a rapid assessment of vulnerabilities, this may be incorporated into more detailed assessments for other purposes.

Populating Sub-Groups and Geospatial Representation

Once the most vulnerable species sub-groups are selected, each sub-group must be populated with area-specific species lists, which are represented geospatially by areas of high concentrations and/or those important for the most sensitive life stages identified. Species lists should be compiled from available databases, literature, and expert opinion, in that order of preference. Where no species is found for a sub-group in a region, it is assumed that no species under that sub-group is currently in the focus area, and the sub-group is removed from the analysis.

The entire distribution of multiple biological components would not appropriately inform responders setting protection priorities in the event of a spill, particularly for transient or relatively evenly distributed organisms. Instead, only areas of high concentrations and those important for the most sensitive life-stages should be included in this process. A list of suggested areas to be mapped for each species group is provided in Table 2.6 of the research document (Thornborough et al. 2016). Once the areas to be mapped have been identified for each of the species within a sub-group, these areas are rolled up into a single sub-group representation. These areas should represent the distribution of vulnerable sub-groups and associated important habitats. Further collaboration (between all data holders and providers) is recommended to identify the tools available for geospatial representation.

Sources of Uncertainty

A key output of the framework is the identification of knowledge and data gaps, which may prove useful to identify and prioritize research moving forward. Knowledge gaps are related to the known vulnerabilities, sensitivities, and recovery potential of biological components in relation to ship-source oil spills. Often there is either little information or conflicting opinion as to the impact of oil on biological components. Data gaps relate to the lack of available data or the limitations associated with the available data. These can include: a lack of data on areas of species concentration; low spatiotemporal resolution of the data; a lack of current data; and, data availability or access.

Once the scoring and filtering steps have been applied, selected sub-groups have been populated with species, and available data compiled, all components that were flagged for inclusion in the gap analysis should be compiled into a gap analysis summary. Identifying gaps at every step in the process allows us to understand what is driving these gaps, so that recommendations can be made as to how these gaps can be addressed (e.g., targeted research versus data management).

CONCLUSIONS AND ADVICE

- Marine biological components were divided into groups and sub-groups by taxonomy and similar responses to spilled petroleum products. These groupings seem to be applicable across Canada, but may be altered or further divided to accommodate any regional differences.
- Criteria were developed to identify species sub-groups with higher vulnerabilities to ship-sourced spills. Criteria were grouped into three types: exposure, sensitivity, and recovery. A sequential application of these criteria types allows for a more rapid assessment and filtering of sub-groups that may not fulfill a particular criteria type. Criteria are broad and aim to be adaptable to all species sub-groupings across Canada. There is flexibility in the

framework to include extra criteria if appropriate, or introduce a more complex scoring rubric if sub-groups are not being appropriately differentiated.

- The selection of species to populate the selected/highlighted species sub-groups is regionally specific. Species lists should be compiled from available databases, literature, and expert opinion, in that order of preference.
- Once the scoring and filtering steps have been applied, selected sub-groups have been populated with species, and required data have been compiled, all components that were flagged for inclusion in the gap analysis should be compiled into a gap analysis summary. Identifying gaps at every step in the process allows us to understand what is driving these gaps and make recommendations as to how these gaps can be addressed.
- The flexibility that is provided by this framework makes it critical that chosen methods and options are clearly stated in the application of this framework, resulting in comparable re-assessments.
- The effectiveness of the proposed framework will not be fully realized until after sub-groups and criteria have been fully applied to multiple areas across Canada.
- It is recommended that this framework be applied and evaluated at the regional level to assess its suitability to multiple aquatic environments.
- It is recommended that an evaluation of Arctic knowledge be completed before this framework is applied to the Arctic.
- It is recommended that an evaluation of knowledge, both internal and external to DFO, be completed after regional applications to determine knowledge and data gaps.
- It is recommended that this framework be expanded to incorporate secondary exposure and associated impacts, and impacts from multiple stressors (i.e. cumulative effects).

OTHER CONSIDERATIONS

The framework has been designed to be as flexible as possible in order to be applicable across a range of aquatic environments and situations. However, there are some limitations in the current framework that cannot be addressed due to the current state of knowledge. Vulnerability is assessed based on acute effects from direct contact with oil as secondary impacts (higher level trophic) are difficult to assess without knowledge of food webs and the impacts of oil on all biological components. Increased vulnerabilities due to impacts from multiple stressors are not considered in this framework, nor are compounding impacts, including sink-source dynamics. Again, although these are important considerations for a comprehensive assessment of impacts to a system, it is not practical to include these at this stage in our understanding of impacts from an oil spill.

The intent of the proposed framework is that it provides a rapid scoring and selection process, whereas assessing factors such as those mentioned above can be very complicated and time consuming. That is not to say that understanding food web impacts, cascading trophic effects, and ecosystem dynamics are not critical to our evaluation of potential effects, only that it is beyond the scope of this proposed framework. The hope is that this framework provides the basic building blocks upon which more criteria can be added to include considerations such as indirect impact, freshwater species, and species beyond DFO’s mandate (e.g. sea birds).

SOURCES OF INFORMATION

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