Fisheries and Oceans Canada
Ecosystems and Oceans Science

Pêches et Océans Canada
Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2017/057

Pacific Region

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

Lucie Hannah[1], Candice St. Germain[1], Sharon Jeffery[1], Sarah Patton[1], and Miriam O[1]

[1] Institute of Ocean Sciences
Fisheries and Oceans Canada
9860 West Saanich Road
P.O. Box 6000
Sidney, B.C. V8L 4B2

August 2017

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044

Correct citation for this publication:

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

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1 ABSTRACT

This paper examines the effectiveness of a framework to assess the vulnerability of biological components to ship-source oil spills in the marine environment (hereafter termed the “framework”) developed by Fisheries and Oceans Canada (DFO) (Thornborough et al. 2017) through a pilot application in the Pacific region. This pilot application of the framework is intended to be relevant to all biota in the (on-shelf) Pacific region. The functionality of the components of the framework method was assessed in this pilot application, and modifications made were deemed necessary with the support of regional subject matter experts. The 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.

Knowledge gaps were identified at each stage in the framework to highlight areas for prioritised research activities. The primary outcome of the pilot application is a list of ranked sub-groups identified as being most vulnerable to a ship-source oil spill in the Pacific region. 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 oil vulnerability. The outputs of the pilot application of the adapted framework will 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 will assist in identifying priority reponse-relevant spatial data for those marine biological sub-groups identified as being most vulnerable to spilled oil. This work contributes towards meeting the Department of Fisheries and Oceans (DFO) commitment to ensuring sustainable aquatic ecosystems.

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

2 RÉSUMÉ

Le présent document examine l'efficacité d'un cadre d'évaluation de la vulnérabilité des composantes biologiques du milieu marin aux déversements d'hydrocarbures provenant de navires (ci-après appelé le « cadre ») élaboré par Pêches et Océans Canada (MPO) (Thornborough et coll. 2017) au moyen d'une application pilote dans la Région du Pacifique. Cette application pilote du Cadre devrait s'appliquer à tout le biote de la Région du Pacifique (sur le plateau). La fonctionnalité des composantes de la méthode du cadre a été évaluée dans le cadre de cette application pilote et les modifications apportées ont été jugées nécessaires avec le soutien d’experts régionaux en la matière. Les objectifs de cette application pilote étaient les suivants :

1. Évaluer les sous-groupes (représentant le biote marin) et les adapter au besoin de manière à ce qu’ils conviennent au biote de la Région du Pacifique et qu'ils soient structurés de façon à ce que leur vulnérabilité aux hydrocarbures puisse être définie au moyen des critères de notation (en fonction de leurs caractéristiques biologiques et écologiques);
2. Évaluer et, au besoin, adapter les critères et les définitions pendant la mise à l'essai du Cadre;
3. Dresser une liste des sous-groupes les plus vulnérables à un déversement d'hydrocarbures provenant de navires dans la Région du Pacifique selon des sous-groupes adaptés aux pointages établis en fonction des critères de vulnérabilité et en appliquant un processus d’examen préalable et de classement.

Des lacunes en matière de connaissances ont été relevées à chaque étape du cadre afin de mettre en lumière les secteurs d'activités de recherche prioritaires. Le résultat principal de l’application pilote est une liste des sous-groupes recensés et classés en ordre de vulnérabilité à un déversement d’hydrocarbures provenant de navires dans la Région du Pacifique. Dans l'ensemble, les classements obtenus en fonction de la vulnérabilité déterminés par la méthode adaptée cadrent bien avec les résultats de diverses études et de la documentation portant sur les déversements d'hydrocarbures et confirment que le cadre constitue bel et bien une méthode simple et rapide permettant d’évaluer la vulnérabilité aux hydrocarbures. Les résultats de l’application pilote du cadre adapté orienteront 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 aideront à déterminer quelles sont les données prioritaires pertinentes concernant les sous-groupes jugés les plus vulnérables aux hydrocarbures déversés. Ce travail contribue à respecter l’engagement du ministère des Pêches et des Océans (MPO) visant à assurer la durabilité des écosystèmes aquatiques.

3 INTRODUCTION

CONTEXT

A framework to assess the vulnerability of biological components to ship-source oil spills in the marine environment (hereafter termed the “framework”) was developed by Fisheries and Oceans Canada (DFO) and reviewed in March 2016 through a Canadian Science Advisory Secretariat (CSAS) National Peer Review (Thornborough et al. 2017). The framework is a structured method to identify the biological components most vulnerable to a ship-source oil spill by utilizing a suite of vulnerability criteria. The CSAS peer review determined that the framework was appropriate to use in all Canadian regions with an allowance for regional flexibility; for example, biological sub-groups were anticipated to require tailoring to reflect regional biota.

The outputs of the framework contribute towards the development of a timely and informed response to ship-source oil spills and focused data collection for spill response planning. In terms of overall oil spill planning and response, the outputs of the vulnerability framework guide the contribution of DFO Science to the ‘ecological’ component of “Resources at Risk” (Figure 1).

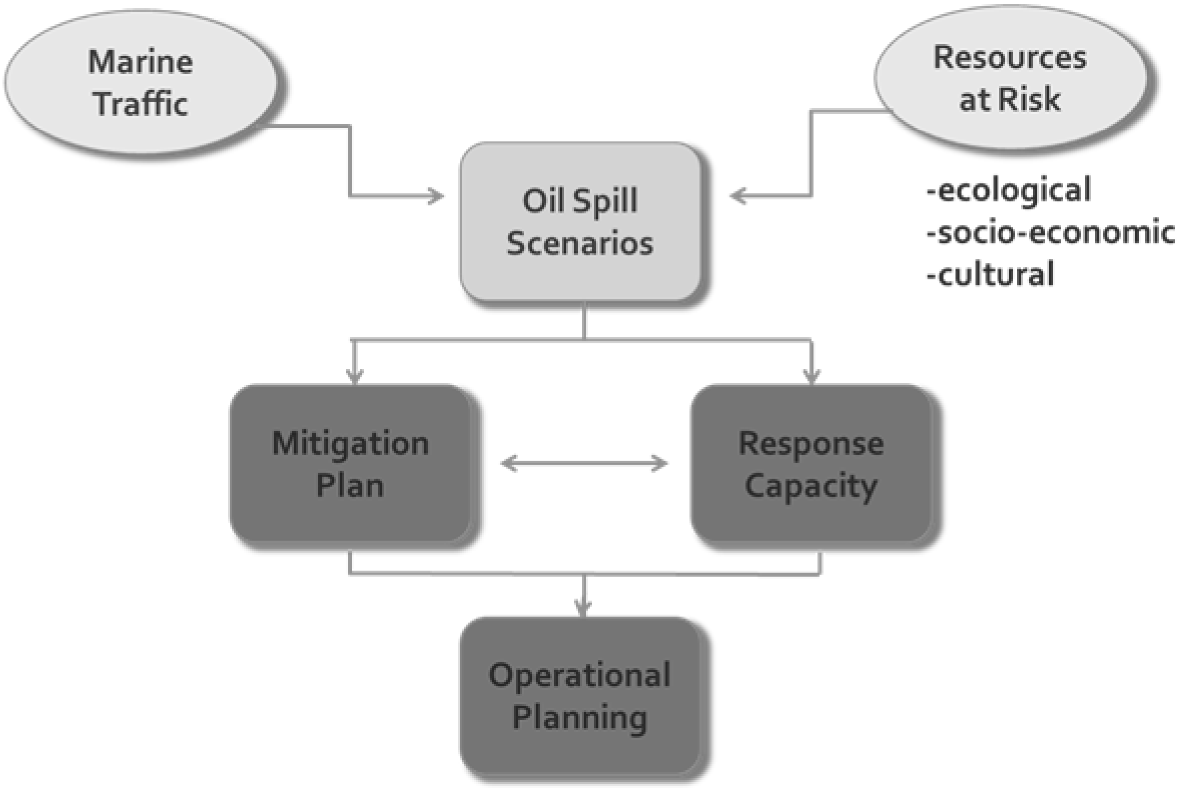

Figure 1. Overview of how the vulnerability framework fits in with the overall model for oil spill planning and response (“ecological” Resources at Risk)

Vulnerability is considered to be the degree to which a system is susceptible to, and unable to cope with, injury, damage, or harm (De Lange et al. 2010); however, the term ‘vulnerability’ has been used interchangeably with ‘sensitivity’. In the framework, sensitivity is nested as a factor of vulnerability, where vulnerability is a function of exposure to a stressor; sensitivity (also termed effect or potential impact), and recovery potential (also termed adaptive capacity or resilience) (De Lange et al. 2010). Following this approach, the framework divides criteria into three categories: exposure, sensitivity, and recovery. Each category encompasses a number of criteria used to assess aspects of vulnerability in sub-groups. The most vulnerable biological components are identified through the scoring, screening and ranking of sub-groups.

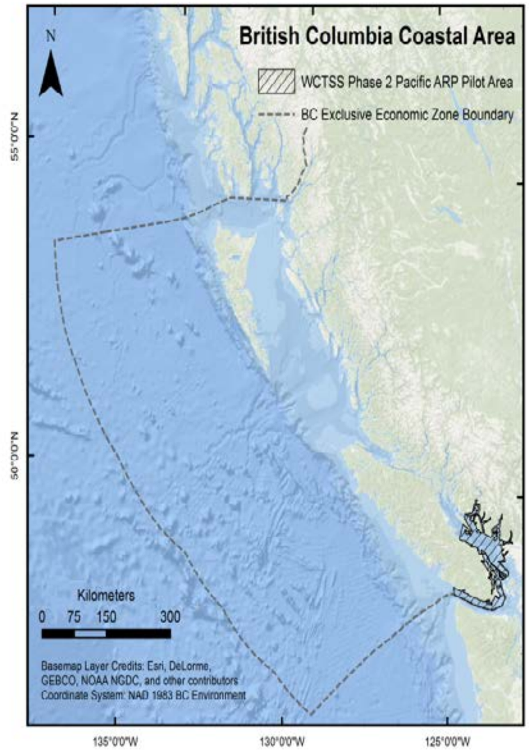

Figure 2. The British Columbia Pacific coastal region. The hatched area indicates the World Class Tanker Safety System (WCTSS) Area Response Plan (ARP) pilot area for Western Canada.

The framework was designed to be flexible enough to be applicable to all Canadian regions, and several of these regions are currently adapting and applying the framework. Comparisons among regional pilot applications will determine the effectiveness of the framework for identifying biological components most vulnerable to ship-source oil spills. As the framework was designed to be a flexible template, it is critical that if any regional adaptations are made, they are clearly stated to enable comparable re-assessments.

At the request of DFO's Oceans Branch, DFO Science Branch conducted a pilot adaptation and application of the framework to the Pacific region. The outputs of the pilot application of the adapted framework will 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) (Figure 2), and will assist in identifying priority reponse-relevant spatial data for those marine biological sub-groups identified as being most vulnerable to spilled oil.

This paper describes a pilot application of the framework to the Pacific region, the first test of the framework in a specific region.

The specific objectives of this Pacific region pilot application are to:

1. Assess, and where necessary, adapt sub-groups 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.

Examination of the framework application and outputs will determine the effectiveness of the framework to identify biological components most vulnerable to a ship-source oil spill in the Pacific region.

3.1 OIL TRANSPORTATION AND SPILLS ON THE PACIFIC COAST OF CANADA

Each year, 80 million tonnes of oil are shipped off Canada's east and west coasts, ranging from ultra-light condensates and light oils, to heavy oils and bitumens (John 2015, Lee et al. 2015). Because each type of oil can be a complex mixture of compounds, the chemical composition of any spilled oil is critical for understanding its physical properties, behaviour and impacts to biota (Lee et al. 2015; WSP 2014). In addition, the chemical properties of the initial surface slick of spilled oil can change due to physical, chemical and biological processes (weathering) that can result in components of the oil dissolving in the water, evaporating, or sinking (Lee et al. 2015). Condensates and light oils (e.g. gasoline and light crude oils) contain more volatile compounds that are acutely toxic to marine organisms, but they typically break down quickly and disappear. Heavier oils (e.g. bitumen and heavy fuel oils) contain more polycyclic aromatic hydrocarbons (PAHs), which persist in the environment, and cause chronic health effects (Lee et al. 2015). Crude oil is a mixture of very light to heavy compounds. Because the fate and behaviour of spilled oil in a marine environment can be so complex, the scope of the framework (Thornborough et al. 2017) was based on the possibility of a worst case scenario oil spill, including all types of oil and assuming oil would reach the seabed.

This study focuses on the Pacific west coast of Canada. British Columbia (BC), a region with a complex coastline of inlets, bays and fjords extending for over 27,000 km (National Geospatial Intelligence Agency, 2011), is a major shipping corridor between Asia and North America (BC Ministry of Environment, 2013). There are three major ports in B.C.: Port Metro Vancouver (PMV), Prince Rupert, and Kitimat, though most vessel transits occur in Southern B.C. through the Juan de Fuca Strait (BC Ministry of Environment, 2013). Approximately 2.2 million tonnes of oil were shipped from PMV (Southern BC) in 2011 (John 2015). There have been a number of oil spill incidents that have impacted B.C. waters in the past. For example:

- In 1988, the barge *Nestucca* collided in Washington (USA) waters spilling 874,000 litres of heavy fuel oil, much of which drifted onto the west coast of Vancouver Island (BC) (BC Ministry of Environment, 2016);
- In 2006, the *Queen of the North* ferry collided and sank with 220,000 litres of diesel fuel and 23,000 litres of lubricating oil on board (BC Ministry of Enviornment, 2016);
- In 2007, a LeRoy trucking barge, containing a tanker truck, sank with 10,000 litres of diesel fuel in Robson Bight in 2007 (BC Ministry of Enviornment 2016);
- In 2015, the *M/V Marathassa* discharged ~2,700 litres of bunker C fuel oil into English Bay, in Vancouver (Canadian Coast Guard 2015); and
- In 2016, the tug *Nathan E Stewart*, towing a fuel barge ran aground on the central Pacific coast, near Bella Bella spilling 100,000 litres of diesel fuel and 3,700 litres of lube oil, hydraulic oil, gear oil, and spent lubricants (Hunter, 2016, November 4)

Research on the impacts of these spills on marine biota in B.C. waters is limited to a few studies, mostly on the *Nestucca* spill (Davis 1989; Duval et al. 1989; Strand et al. 1992). However, there is more published research available on the impacts of major spills in other areas, the most relevant being the many published studies of the impacts of the *Exxon Valdez* oil spill which occurred in Alaska, and studies of the impacts of the *Deepwater Horizon* blowout oil spill in the Gulf of Mexico.

3.2 CURRENT RESEARCH ON OIL SPILL IMPACTS ON MARINE ORGANISMS

There is much research on the impacts of oil spills on marine organisms, and several literature reviews summarise major findings (e.g. Dupuis and Ucan-Marin 2015). Overall, marine mammals and fish have been the focus of most studies; with fewer studies covering marine plants, invertebrates, and reptiles. Sea otters, harbour seals, cetaceans, salmonids, bivalves, and intertidal macroalgae and invertebrates have been highlighted in the literature as being highly impacted, but there is uncertainty about the degree of impact to many of these organisms due to a general lack of pre-spill baseline data, and due to unstandardised sampling methods and experimental design (e.g. Garshelis and Johnson 2013). Available studies examine myriad oil types, and fractions of each oil type, as well as different doses and exposure times; making comparisons difficult both across studies and across taxa. Also, the impact of an oil spill on marine organisms may not be fully realised for many years, if ever (e.g. Matkin et al. 2008). In the framework, it is assumed that all organisms experience some degree of toxic effect when they encounter oil; thus criteria are used to highlight behaviours, physiology, and life history traits, that may make certain organisms more vulnerable to ship-source oil spills.

Indirect effects, such as trophic cascades and impacts to offspring; as well as compounding effects, such as multiple stressors acting synergistically, add to the complexity of determining toxic impacts. While these are important considerations for assessing the impacts of oil spills on marine organisms, there is currently not enough information to assess them properly, and they are not included in the scope of the framework.

3.3 SCOPE

The framework (as outlined in Thornborough et al. 2017):

- Is limited to considering only the direct effects of oil and was not designed to incorporate potentially significant indirect and food web effects such as consumption of contaminated food sources (e.g. contaminated plankton impacts on baleen whales), or cumulative effects from multiple stressors;
- This application is limited to marine biological components within DFO's jurisdiction in the Pacific region. However, it serves as an example of a method that could be applicable to biological components in other jurisdictions (e.g. marine birds);
- Does not assess species based on their socio-economic status (fishery and conservation status) or cultural value (other branches of DFO are responsible for this);
- Does not directly assess habitats, but includes them as important areas associated with vulnerable biological components, such as areas of aggregation for species within a sub-group. Biogenic habitats (e.g. eelgrass beds, glass sponge reefs) are assessed on a sub-group level, rather than as separate habitats (e.g. eelgrasses, Porifera);
- Does not consider shoreline type due to the existence of a well-established shoreline classification system that ranks the physical shoreline types by sensitivity to spilled oil and potential mitigation measures;

- Does not assess spatial planning areas such as Ecologically or Biologically Significant Marine Areas (EBSAs) and Marine Protected Areas (MPAs); and
- Is not limited to spills of a specific oil type, but rather focuses on generalised impacts from initial stages of large ship based spill.

4 FRAMEWORK

4.1 OVERVIEW

This paper applies a vulnerability framework (Thornborough et al. 2017) to the Pacific region to identify the marine biological components most vulnerable to oil. Other components of the framework (steps 4, 5 and 6 in Figure 3) are outside the scope of this document and will be implemented using the outputs of this application.

Vulnerable biological components are identified following three key phases in the framework (steps 1, 2 and 3 in Figure 3):

1. Grouping of biological components into sub-groups based on similar characteristics related to oil vulnerability;
2. Binary scoring of sub-groups against vulnerability criteria (under categories of exposure, sensitivity, and recovery); and
3. Applying a screening and ranking process to identify the most vulnerable sub-groups based on their scores.

The framework is designed to be: nationally consistent but regionally flexible; grounded in science; and rapid and simple to implement. The process is considered rapid because biological sub-groups are used rather than extensive species lists; the scoring system is simple; and a screening and ranking process is used to ensure that only the most vulnerable sub-groups are populated with species in future steps (see below). The framework utilises a top-down approach, whereby at the start of the process, all sub-groups (not species) present in an area are included regardless of data availability. This approach allows for the identification of knowledge gaps to inform future development of this framework. These knowledge gaps are identified at every phase of the framework to inform a gap analysis.

The flow chart developed for the framework (Thornborough et al. 2017) has been adapted to reflect more clearly how the framework was applied in practice (Figure 3). An iterative loop was included between steps 1 and 2 (the grouping of biological components and scoring of sub-groups) to reflect the fact that, though sub-group assessment and modification is the first step in the application of the framework, in practice it occurs in an iterative way with the scoring process; in many cases it was not evident that sub-groups required further modification until attempting to score the sub-groups for vulnerability criteria.

This assessment, followed by data collection and mapping of the most vulnerable components, is intended to be completed in advance of an oil spill, rather than in response to it. This pilot application of the framework is intended to be relevant to all biota in the (on-shelf) Pacific region. Subsequent steps of the Pacific region application will focus on specific areas within this broader region, namely the Pacific Area Response Plan (ARP) pilot area (Figure 2). These steps will involve populating the sub-groups identified as most vulnerable with species, and providing associated spatial data from within this area to guide oil spill planning efforts.

The Pacific region pilot application of the framework involved testing steps 1, 2 and 3 as outlined in Figure 3.

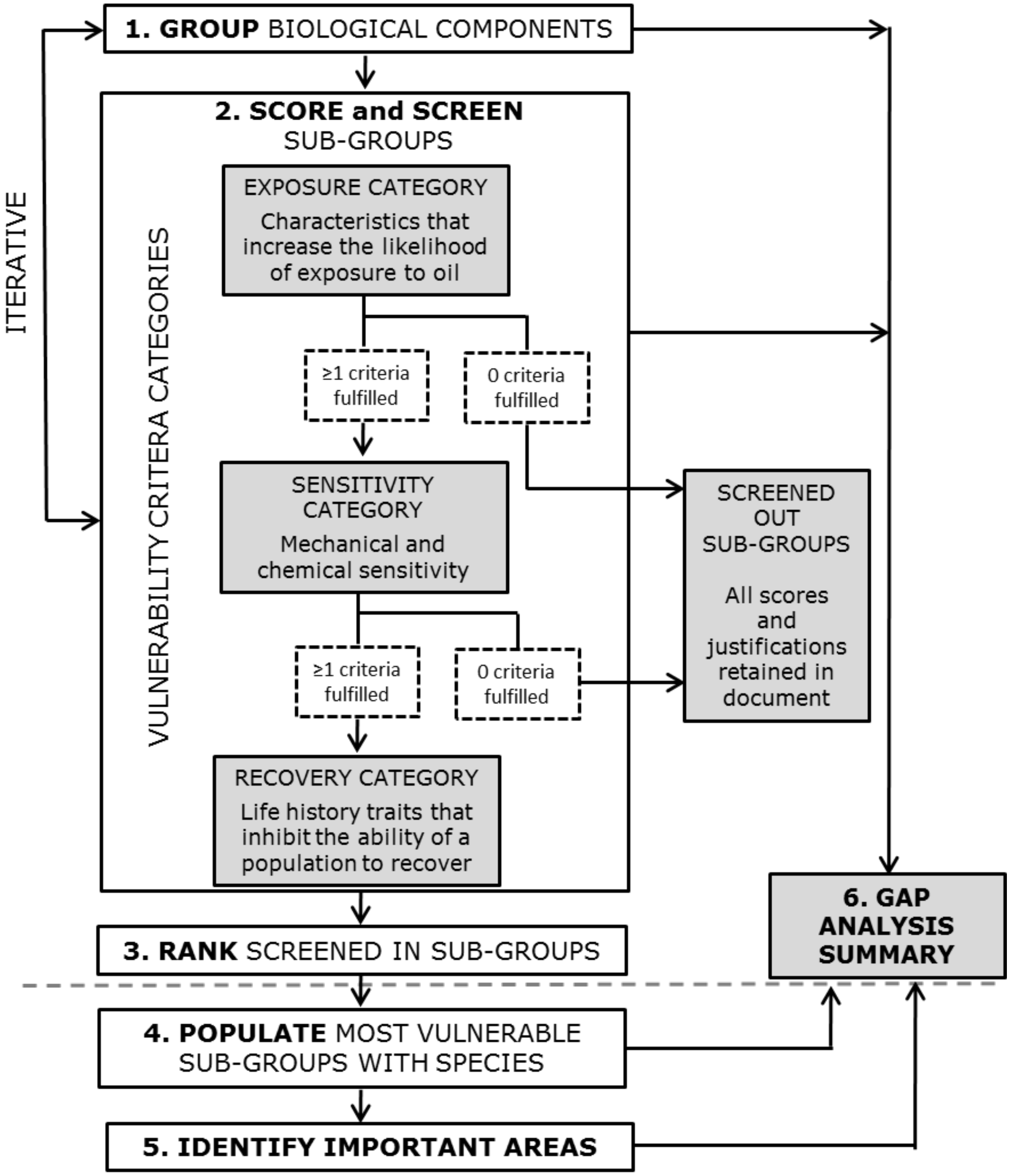

Figure 3. Overview of framework to identify vulnerable biological components (adapted from Figure 2.1 in Thornborough et al. 2017)

This framework is not an all-inclusive approach for oil spill response; rather it is a template that can be adapted for different needs, 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. Within Canada’s overall model of oil spill planning and response (Figure 1), the outputs of the vulnerability framework are used to guide the process of data prioritization and collection necessary to fulfill DFO Science’s contribution to the ecological component of “Resources at Risk” for oil spill planning.

4.2 GROUPING BIOLOGICAL COMPONENTS

The sub-groups outlined in the framework represent biota within five high-level biological groups:

1. Marine algae/plants;
2. Marine invertebrates;
3. Marine fishes;
4. Marine reptiles; and
5. Marine mammals.

Sub-groups in the high-level groupings above were created based on biological and ecological traits. Sub-groups under each of the high-level biological groups are structured with increasing levels of specificity, with a corresponding increase in the number of sub-groups, such that level 1 sub-groups have fewer, high level divisions (e.g. intertidal/subtidal), and subsequent sub-groups have a higher number of divisions at a finer level of detail (e.g. Mollusca). The number of sub-groups that are scored using the framework may be dictated by the availability of resources; where resources are limited, biological components could be scored at a broader sub-group level (e.g. at sub-group level 2 rather than level 4). In this pilot application, sub-groups are assessed at the finest level of detail available (sub-group level 3 or 4).

For the Pacific region application, it was necessary to adapt the framework sub-groups in some cases to ensure that sub-groups were not only representative of the suite of on-shelf biota in the Pacific region, but also that they were divided in a way that allowed their vulnerability to oil to be discerned by the criteria (based on their biological and ecological traits). Most sub-group modifications addressed difficulties discerning between sub-groups when criteria were scored. In some cases, substantive changes were required to the sub-group organization (marine plants/algae and marine fishes); whereas, in other cases, very few changes were necessary (marine mammals). In total, there were 52 additional sub-groups in the Pacific region application, and a total of 118 sub-groups were assessed.

4.2.1 Grouping modifications

It was necessary to modify sub-groups for most biological groups. Modifications were developed with the guidance of regional subject matter experts to ensure that the adapted sub-groups were both relevant to the on-shelf biota in the Pacific region, and were divided so that differences in vulnerability between sub-groups could be discerned when scored by vulnerability criteria.

Changes made to sub-groups were of three major types:

- Inclusion of location/habitat descriptors – to improve consistency across sub-groups by including descriptors for intertidal/ subtidal and benthic/ non-benthic/pelagic. Marine plants/algae had additional descriptors;
- Addition of missing sub-groups – Inclusion of sub-groups identified as missing by reviewers, and juvenile stages/pelagic larvae that did not fit the sub-group descriptions for adults (31 additional sub-groups overall); and
- Reorganisation - In many cases, sub-groups required restructuring to allow for clearer differentiation for scoring criteria once scoring began. This was an iterative process that occurred in parallel with scoring.

The following sections describe how sub-groups within each biological group were adapted. A total of 118 sub-groups are proposed for this pilot application at the highest level of detail (sub-group level 3 or 4). For reference, the original sub-groups proposed in the framework are provided in Appendix A.

4.2.2 Marine Algae/Plant Groupings

Substantive changes were made to the marine algae/plant sub-groups with the guidance of regional subject matter experts (see Appendices J and K).

4.2.2.1 Summary of changes made to the marine algae/plant sub-groups

Modifications to sub-groups, as well as justifications for each change, are described in Table 1. In most cases, the sub-groups were modified to ensure that species were divided in a way that resulted in better differentiation of criteria between the sub-groups (i.e. not all sub-groups received the same scores). The sub-groups were also modified to facilitate mapping wherever possible. For instance, subtidal canopy algae were divided into two sub-groups based on wave exposure to separate bull kelp (*Nereocystis luetkeana*) from giant kelp (*Macrocystis integrifolia*) as these species grow in distinct, mappable beds.

Table 1. Summary of changes to marine algae/plant sub-groups in the framework for the Pacific Region application

Sub-group level affected	Modification	Justification
Sub-group level 1	Changed from 'Pelagic and Benthic' to 'Epi-pelagic, Intertidal and Subtidal'.	To address tidal exposure and provide separation for sea surface interacting criterion.
Sub-group level 2	Removed 'Vascular' and 'Non-vascular' sub-groups, and instead divided 'Intertidal' and 'Subtidal' groups into 'vascular, canopy, turf & understory, and encrusting' and 'canopy, turf, understory, and encrusting' respectively.	The new sub-group headings were taken from level 2 and 3 headings in the framework. They were combined to avoid repetition of species between sub-groups, and to allow the incorporation of a habitat criterion as a level 3 division.
Sub-group level 3	Added habitat features such as substrate (unconsolidated versus consolidated) and wave exposure.	To provide a more meaningful separation of species within the sub-groups that could be mapped more easily. Habitat features also provided better separation for the 'population status' and 'reduction of photosynthesis' criteria.
Sub-group level 4	Included modifications of groupings that had previously been at level 3 (seagrasses, salt marsh grasses and succulents) for vascular plants. Also added morphological features (woody stipes or floats) under 'Subtidal, understory, rocky habitat'.	The vascular plant sub-groups are adaptations of grouping names from the framework that had also been grouped under the category 'vascular' and were retained because they provided separation for 'close association with unconsolidated substrate' and 'population status' criteria. The presence or absence of tall, woody stipes or floats was assessed for subtidal, understory algae in order to identify subtidal algae species that will remain erect in the water column and avoid contact with oil on the substrate.

4.2.2.2 Description of the sub-group breakdown used for marine algae/plants

An additional 8 sub-groups are proposed for marine plants/algae for the pilot application to the Pacific region (Table 2), making a total of 15 sub-groups.

Sub-group level 1 separates intertidal, subtidal and epi-pelagic types, the latter to distinguish phytoplankton, in order to address exposure considerations. The level 2 sub-group separates two of these groups into four groupings based on growth forms (Intertidal: vascular, canopy, turf & understory, and encrusting; subtidal; canopy, turf, understory, and encrusting). Level 3 sub-groups are divided based on habitat features (substrate type and wave exposure) to provide differentiation in the scores for a number of criteria including population status, association with unconsolidated substrates and, potentially, reduction in photosynthesis (by smothering). Level 4 sub-groups were only created under two of the level 3 sub-groups. The unconsolidated habitat division of the vascular plant sub-group is further separated into seagrasses, saltmarsh grasses and saltmarsh succulents, due to their differing morphologies and tidal elevations. The subtidal, understory rocky habitat sub-group is also further divided into 2 groups based on morphology; species that are erect in the water column due to tall, woody stipes or floats, and those that are not. This division was made to differentiate between species that would interact with the seafloor, and those that would not.

Phytoplankton was left as one sub-group covering all species. While it may be possible to record or predict phytoplankton blooms for given areas and respond to them in an oil spill situation, there are many species of phytoplankton in the pilot area, and breaking them out into sub-groups would have made this analysis unwieldy. This resolution is not sufficient to assist decision making, however it may be possible to further develop the integration of this group in future iterations of the framework.

Table 2. Pacific region sub-group breakdown for marine plants/algae with species examples

Sub-group level 1	**Sub-group level 2**	**Sub-group level 3**	**Sub-group level 4**	**Examples of Pacific species within the sub-group**
Intertidal	Vascular	High energy, rocky habitat	Seagrasses	E.g. *Phyllospadix scouleri, P. torreyi, P. serrulatus*
		Moderate to low energy unconsolidated habitat	Seagrasses	E.g. *Zostera marina, Z. japonica, Ruppia maritima*
			Saltmarsh grasses	E.g. *Carex lyngbyei, Leymus mollis*
			Saltmarsh succulents	E.g. *Sarcocornia pacifica, Glaux maritima, Plantago maritima*
	Canopy	N/A	N/A	E.g. *Egregia menziesii*
	Understory and Turf	High energy, rocky habitat	N/A	E.g. *Cymathere triplicata, Pelvetiopsis limitata, Corallina vancouveriensis, Alaria nana, Palmaria hecatensis*
		Moderate to low energy rocky habitat	N/A	E.g. *Fucus gardneri, Neorhodomela larix, Codium fragile, Desmarestia* sp., *Laminaria saccharina*
	Encrusting	Rocky habitat	N/A	E.g. Coralline algae, *Codium setchellii, Hildenbrandia* sp., *Mastocarpus* (crust form)*, Ralfsia pacifica*
Subtidal	Canopy	High energy, rocky habitat	N/A	E.g. *Nereocystis leutkeana,Egregia menziesii, Pterygophora californica*
		Moderate to low energy rocky habitat	N/A	E.g. *Macrocystis integrifolia*
	Understory	Rocky habitat	With tall, woody stipes or floats	E.g. *Pterygophera californica, Sargassum muticum, Lessoniopsis littoralis*
			Without tall, woody stipes	E.g. *Desmarestia* sp., *Agarum fimbriatum, Laminaria* sp., *Prionitis lyallii*

Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4	Examples of Pacific species within the sub-group
			or floats	
	Turf	Rocky habitat	N/A	*E.g. Callophyllis sp; Dictyota binghamiae, Sarcodiotheca furcata, Fauchea laciniata, Rhodymenia pacifica*
	Encrusting	Rocky habitat	N/A	E.g. Coralline algal crusts, *Hildenbrandia* sp., *Codium setchellii*
Epi-pelagic	Phyto-plankton	N/A	N/A	

4.2.3 Marine Invertebrate Groupings

Only relatively minor changes to the marine invertebrate sub-groupings were necessary for application to the Pacific region with regional subject matter expert guidance (see Appendices J and K).

4.2.3.1 Summary of changes to the marine invertebrate sub-groups

Modifications to sub-groups, as well as justifications for each change, are described in Table 3, and primarily consist of the addition of several phyla to the level 4 sub-groups, as well as the addition of a pelagic larval invertebrate category to the level 2 sub-groups.

Table 3. Summary of changes made to marine invertebrate sub-groups for the Pacific region application

Sub-group level affected	Modification	Justification
Sub-group level 2	A sub-group for pelagic larvae was added at this level	To incorporate differences in scoring between benthic adult and pelagic larval life stages
Sub-group level 4	Sub-groups for five phyla and a grouping of phyla (Lophophorates) were added at this level	To account for species that were not otherwise captured in the groupings already outlined

4.2.3.2 Description of sub-group breakdown used for marine invertebrates

Fifty four marine invertebrate sub-groups are proposed for the pilot application to the Pacific region, (Table 4), 17 more than in the framework (Appendix A).

Sub-group level 1 separates marine invertebrates by location (intertidal/subtidal/pelagic) in order to address exposure. Sub-group level 2 separates species by a substrate factor (e.g. sediment in-fauna, sediment epifauna), to differentiate species based on likelihood of exposure and recovery. Sub-group level 3 addresses mobility (sessile/low mobility/high mobility) to identify sub-groups lacking the ability to move away from spilled oil. For example, within the pelagic invertebrates, zooplankton and jellyfish are considered low mobility as they have limited ability to move against the currents in comparison to squid, which is a more mobile group. Level 4 sub-groups are based upon taxonomic divisions, usually at the phylum level, to facilitate a relatively rapid assessment and to simplify comparisons to published toxicity studies.

Non-larval zooplankton was left as one sub-group covering all species. While it may be possible to record or predict areas of high concentration and respond to them in an oil spill situation, there are many species of zooplankton in the pilot area, and breaking them out into sub-groups would have made this analysis unwieldy. The resolution chosen here is not sufficient to assist decision making, however it may be possible to further develop the integration of this group in future iterations of the framework.

In sub-group level 4, worms include the phyla Platyhelminthes, Nemertea, Nemata, Nematomorpha, Acanthocephala, Gnathostomulida, Priapula, Sipuncula, Echiura, Annelida, and Onychophora. Also, in sub-group level 4, lophophorates include the phyla Entoprocta, Ectoprocta, Brachiopoda, and Phoronida.

Table 4. Pacific region sub-group breakdown for marine invertebrates with species examples

Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4	Pacific examples within the sub-group
Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Arthropoda	e.g. barnacles [Cirripedia]
			Mollusca	e.g. oysters [Bivalvia]
			Cnidaria	e.g. coral
			Porifera	e.g. demosponges
			Worms	e.g. tube worms [Polychaeta: Sedentaria]
			Urochordata	e.g. sea squirts
			Lophophorates	e.g. bryozoans [Ectoprocta]; lampshells [Brachiopoda]
		Low mobility	Worms	e.g. polychaetes [Errantia]; nemerteans
			Arthropoda	e.g. isopods [Isopoda]
			Cnidaria	e.g. sea anemones
			Mollusca	e.g. chitons [Polyplacopora]; snails [Gastropoda]
			Echinodermata	e.g. sea urchins [Echinoidea];sea cucumbers [Holothuroidea];sea stars [Asteroidea]
		High mobility	Arthropoda	e.g. crabs [Decapoda]
			Arthropoda (filter feeders)	e.g. porcelain crabs
			Mollusca	e.g. octopus
	Sediment infauna	Low mobility	Mollusca	e.g. clams [Bivalvia]; snails [Gastropoda]
			Worms	e.g. burrowers
			Arthropoda	e.g. sand crabs [Emerita]
			Lophophorates	e.g. horseshoe worms [Phoronida]; lampshells [Brachiopoda]
	Sediment epifauna	Low mobility	Gastropoda	e.g. predators
			Cnidaria	e.g. sea pens
			Echinodermata	e.g. sea stars
		High mobility	Arthropoda	e.g. crabs
Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Arthropoda	e.g. barnacles [Cirripedia]
			Mollusca	e.g. rock scallops [Bivalvia]
			Cnidaria	e.g. coral
			Porifera	e.g. glass sponges
			Worms	e.g. tube worms [Polychaeta: Sedentaria]
			Urochordata	e.g. sea squirts
			Lophophorates	e.g. bryozoans [Ectoprocta]; lampshells [Brachiopoda]

Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4	Pacific examples within the sub-group
		Low mobility	Worms	e.g. annelids
			Cnidaria	e.g. sea anemones
			Echinodermata	e.g. sea urchins, sea stars
			Gastropoda	e.g. snails [Cl. Gastropoda]
		High mobility	Arthropoda	e.g. crabs
			Mollusca	e.g. octopus
	Sediment infauna	Low mobility	Mollusca	e.g. clams
			Worms	e.g. annelids
			Lophophorates	e.g. horseshoe worms [Phoronida]; lampshells [Brachiopoda]
	Sediment epifauna	Low mobility	Mollusca	e.g. snails [Gastropoda]
			Cnidaria	e.g. sea pens
			Echinodermata	e.g. sea stars
		High mobility	Arthropoda	e.g. crabs
Pelagic	N/A	Low mobility	Zooplankton	(other than larvae) e.g. copepods, mysids
			Cnidaria	e.g. jellyfish
		High mobility	Mollusca	e.g. squid
	Larvae		Porifera	Porifera larvae
			Cnidaria	Cnidaria larvae
			Worms	Worm larvae
			Urochordata	Chordata (Urochordata) larvae
			Crustacea	Arthropoda larvae
			Mollusca	Mollusca larvae
			Echinodermata	Echinodermata larvae
			Lophophorates	Phoronida; Ectoprocta; Brachiopoda larvae

4.2.4 Marine Fishes Groupings

Substantial changes were made to the marine fishes sub-groups following a Pacific focused literature review; test scoring; and guidance of regional subject matter experts (see Appendices J and K).

4.2.4.1 Summary of changes to the marine fishes sub-groups

Substantive changes to the sub-group organization were necessary (Table 5) primarily because the structure of the sub-groups in the framework made it difficult to discern differences in several of the vulnerability criteria and because the sub-groups were not inclusive of the diversity of fishes found in the Pacific on-shelf region.

Table 5. Summary of changes made to marine fishes sub-groups for the Pacific region pilot application

Sub-group level affected	Modification	Justification
Sub-group level 1	Off shelf group removed	The Pacific region assessment only incorporates on-shelf sub-groups
	On shelf group renamed 'subtidal'	So that species could be divided into intertidal and subtidal to address different exposure potentials in the intertidal and subtidal
	Moved diadromous sub-group into estuarine and other relevant locations	Due to species overlap with estuarine, and so that different life stages could be separated if necessary
Sub-group level 2	Estuarine fishes divided into resident and transient	Split due to different life history characteristics of these two groups. Transient fishes include anadromous fishes which are all considered to be sea surface interacting
	Intertidal fishes divided into benthic and non-benthic	To address different exposure potentials for sea surface interaction and seafloor interaction criteria. For example, non-benthic fish species reside in the water column and would move out of the intertidal as the tide drops, which has implications for exposure
	Removed small and large pelagic fish divisions	Extra categories did not provide improved separation of sub-groups based on any criteria
Sub-group level 3	Added sub-group level 3 to address habitat for benthic sub-groups (associated with consolidated vs unconsolidated substrates)	To provide better differentiation of groups for the 'close association with unconsolidated substrates' criterion
	Included eelgrass associated fishes in benthic intertidal category	To capture their association with eelgrass which may be fouled by oil
Sub-group level 4	Moved some rockfish example species from intertidal benthic to subtidal benthic (quillback, yelloweye and canary rockfishes)	These species are not intertidal
	Elasmobranchs removed from intertidal	Elasmobranch species are rarely found in the intertidal.
	Elasmobranchs removed from estuarine	Only tolerate freshwater for short periods. No mention of them being in estuaries at any life stage in literature
	Salmonids moved to estuarine	Reorganisation of diadromous group which was removed and incorporated into estuarine sub-groups
	Removed juvenile rockfishes from intertidal sub-group	They are primarily subtidal except when in eelgrass beds
	Rockfish removed from Estuarine	Estuaries are not a major habitat for rockfishes
	Herring removed from Estuarine	Estuaries are not a major habitat for most herring
	Added Dolly Varden and steelhead to examples of estuarine salmonids	Estuaries are an important habitat adult Dolly Varden and Steelhead
	Added a sub-group for anchovy (in subtidal/non-benthic sub-group)	They represent one of only a few filter feeding fishes
	Included additional groups of subtidal and intertidal fish families (e.g. snailfish, clingfish, pipefish)	In order to be more inclusive of all fish groups
	Replaced references to Roundfish	Improves consistency

Sub-group level affected	Modification	Justification
	with specific family names wherever possible	
	Basking sharks separated into their own group	To reflect their uniqueness in the elasmobranch group and address exposure differences due to the fact that they are filter feeders

4.2.4.2 Description of sub-group breakdown used for marine fishes

The first level of sub-groups separates marine fishes by location (estuarine, intertidal and subtidal) to address exposure differences. Level 2 sub-groups separate estuarine fishes into ‘transient’ and ‘resident’ species to further address exposure criteria. For example, anadromous fish species in estuarine environments are defined as transient species, and are expected to interact with the sea surface as they pass from the ocean to rivers or streams. The intertidal and subtidal sub-groups were divided differently; they are separated into benthic and non-benthic species to provide separation for the ‘seafloor interacting’ criteria. Not all groups have a third level, but it was necessary to further separate the benthic groups to discern those associated with consolidated versus unconsolidated substrates, in order to provide separation for the ‘close association with unconsolidated substrates’ criterion. Level 4 sub-groups are based upon high level taxonomic divisions, usually families, to facilitate a relatively rapid assessment. Some families are repeated within the level 4 division due to the diversity of characteristics between life stages and species (for example, salmon are included in four sub-groups; as transient estuarine, resident estuarine, intertidal benthic and subtidal non-benthic species).

There are an additional 10 sub-groups proposed for marine fishes in the Pacific pilot application, (Table 6), for a total of 40 sub-groups.

Table 6. Pacific Region sub-group breakdown for marine fishes with species examples

Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4	Examples of Pacific species within the sub-group
Estuarine	Transient	N/A	Cod (Gadidae)	Pacific tomcod, walleye pollock (juveniles)
			Salmon (Salmonidae)	Salmon & steelhead
			Sturgeon (Acipenseridae)	Green sturgeon, white sturgeon
			Osmeridae	Eulachon
			Lampreys	River & Pacific lamprey
			Sculpins (Cottidae)	Prickly sculpin
			Sticklebacks (Gasterosteidae)	Threespine stickleback
			Flatfishes (Pleuronectiformes)	Starry flounder, juv English sole
	Resident	N/A	Surfperch (Embiotocidae)	Shiner perch
			Sculpins (Cottidae)	Staghorn sculpin
			Salmonidae	Cutthroat trout and Dolly Varden

Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4	Examples of Pacific species within the sub-group
Intertidal	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Snailfishes (Liparidae)	Tidepool snailfish
			Clingfishes (Gobiesocidae)	Northern clingfish
			Blennies (Stichaeidae & Pholidae)	Penpoint gunnel, crescent gunnel, high cockscomb
		Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass environments)	Salmonidae (juvenile)	Pink, chum, coho, chinook salmon
			Herring (Clupeidae)	Pacific herring
			Flatfishes- juvenile (Pleuronectidae)	English sole, starry flounder
			Pipefish (Sygnathidae)	Bay pipefish
			Ammodytidae & Osmeridae	Pacific sand lance, surf smelt
			Greenlings (Hexagrammidae)	Lingcod- juvenile
			Other species (e.g. Sculpins & Gobies)	Staghorn sculpin, plainfin midshipmen
	Non-benthic (pelagic & demersal)	N/A	Rockfishes (juvenile)	Black rockfish, copper rockfish
			Surfperches (Embiotocidae)	Shiner perch, striped perch, pile perch
Subtidal	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Wolf fish (Anarhichadidae)	Wolf-eel
			Greenlings (Hexagrammidae) & Sculpins (Cottidae)	Lingcod (adult), cabezon
			Rockfishes (Scorpaenidae)	Quillback, yelloweye, tiger & canary rockfishes
		Associated with unconsolidated substrate (silt/sand/gravel)	Flatfishes (Pleuronectidae)	Rock sole, starry flounder, halibut
			Elasmobranchs	Big skate, longnose skate
			Hagfishes (Myxinidae)	Pacific hagfish
			Rockfishes (Scorpaenidae)	Darkblotched rockfish, canary rockfish
	Non-benthic (pelagic, midwater and demersal)	N/A	Rockfishes (Scorpaenidae)	Yellowtail, blue, widow rockfishes, Bocaccio
			Cod (Gadidae)	Pacific cod, hake, Pacific tomcod, walleye pollock
			Misc. species	Sablefishes (Anoplopomatidae), salmon (Salmonidae), surfperches (Embiotocidae), herring (Clupeidae)
			Elasmobranchs	Spiny dogfish, Sixgill shark
			Elasmobranchs (filter feeders)	Basking shark
			Scombrids	Mackerel

Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4	Examples of Pacific species within the sub-group
			Molidae	Ocean sunfish
			Ammodytidae	Pacific sand lance
			Engraulidae	Northern anchovy
			Chimaeride	Spotted ratfish

4.2.5 Marine Reptile Groupings

As there is only a single sub-group for marine reptiles in Canada in the framework (Table 7), it was not necessary to adapt this group for the Pacific Region. Only some sea turtles, such as migratory leatherback sea turtles that are part of the Western Pacific population, use Canada's Pacific waters for foraging (Gregr et al. 2015).

Table 7. Pacific region sub-group breakdown for marine reptiles with Pacific species examples

Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4	Example of Pacific species within the sub-group
Sea Turtles	N/A	N/A	N/A	Leatherback sea turtle, green sea turtle, loggerhead sea turtle and olive Ridley sea turtle.

4.2.6 Marine Mammal Groupings

Only minor changes were required to the marine mammal sub-groups based on test scoring and guidance from regional subject matter experts (see Appendices J and K).

4.2.6.1 Summary of changes to the marine mammal sub-groups

The primary change made to the marine mammal sub-groups was the removal of sub-group level 3 (separation of discrete and dispersed) for “Pinnipeds>Thermoregulate with fur”, that was considered unnecessary as there is only one species in this sub-group in the Pacific region (i.e. the Northern fur seal) (Table 8).

Another change identified by reviewers, not affecting sub-group organisation, was to supplement the clarification text on the distinction between discrete and dispersed sub-groups, due to confusion on how this could be interpreted, e.g. use of habitat or seasonal distribution.

Table 8. Changes made to marine mammal sub-groups for application to the Pacific region

Sub-group level affected	Modification	Justification
Sub-group level 3	Removed sub-group level 3 (separation of discrete and dispersed) for “Pinnipeds> Thermoregulate with fur”	Due there being only one species of thermoregulating pinniped in B.C. (Northern fur seal)
Sub-group Level 3	Refined text describing the distinction between discrete and dispersed	Clear definition needed to minimise confusion when interpreting these terms in relation to scoring

4.2.6.2 Description of sub-group breakdown used for marine mammals

Level 1 sub-groups separate marine mammals into three major groups: cetaceans (whales and dolphins), pinnipeds (seals and sea lions) and mustelids (otters). Level 2 sub-groups are based on physical characteristics related to increased vulnerability to oil; baleen for whales and fur for mustelids/some pinnipeds (for those that rely on fur for thermoregulation - a crucial function that can be impaired by oil fouling). Level 3 sub-groups only apply to cetaceans and pinnipeds and were used to separate species/populations in a way that allows for clear scoring of the exposure criterion ‘aggregation/concentration’ by addressing whether a marine mammal sub-group is discrete or dispersed in the region. Species within sub-groups considered ‘discrete’ occur in concentrations/aggregations within the Pacific region, either as a general behavioural characteristic, or for a particular purpose (such as feeding aggregations of killer whales related to salmon concentrations); whereas species within sub-groups considered to be ‘dispersed’ do not tend to aggregate in the region. For example, Steller sea lions have year round residency in B.C. waters and aggregate at a small number of rookeries along the B.C. coastline so are considered ‘discrete’, whereas Northern elephant seals are considered ‘dispersed’ in the region as the majority of aggregations related to breeding and calving occurs outside of B.C. waters. Where both discrete and dispersed characteristics are present in one sub-group, a precautionary approach is taken and the sub-group is considered discrete.

There are eight sub-groups identified for marine mammals (Table 9), one fewer than in the framework.

Table 9. Pacific Region sub-group breakdown for marine mammals with species examples

Sub-group level 1	Sub-group level 2	Sub-group level 3	Examples of Pacific species within the sub-group
Cetaceans	Toothed	Discrete	Killer whales (resident and offshore populations; NE Pacific Northern & Southern residents & NE Pacific offshore); Pacific white sided dolphin
		Dispersed	Sperm whale, Killer whale (West coast transients); false killer whale; Baird's beaked whale; Hubbs' beaked whale; Stejneger's beaked whale; harbour porpoise
	Baleen	Discrete	Humpback whale; grey whale
		Dispersed	Sei whale; blue whale; fin whale; North Pacific right whale; common minke whale
Pinnipeds	Thermoregulate with fur		Northern fur Seal
	Other pinnipeds	Discrete	Steller sea lion, harbour seal; California sea lion
		Dispersed	Northern elephant seal;
Mustelids	N/A	N/A	Sea otter

4.3 ECOLOGICAL VULNERABILITY CRITERIA USED IN THE PACIFIC REGION PILOT APPLICATION

Criteria are used in the framework to assess different aspects of vulnerability in sub-groups, and a subsequent screening process is used to identify a list of the most vulnerable sub-groups based on the scores assigned to the criteria. The use of selection criteria and a straightforward screening process creates a structured and consistent approach allowing results from different areas to be comparable. Sub-groups are also comparable to one another, because they are scored in a relative manner with identical criteria across all groups. The outputs of the framework application are a list of ranked sub-groups indicating their relative vulnerability to spilled oil to one another within the framework.

Vulnerability criteria were divided into three categories: exposure, sensitivity, and recovery. Criteria in the exposure and sensitivity categories are scored at the sub-group level based on impacts from direct contact with spilled oil. Where possible, the general characteristics of members of a sub-group are used for scoring, but where this is not possible, an example species (the most vulnerable species) in the sub-group can be used as the basis for scoring. Recovery type criteria are scored at the species level, using the most vulnerable example species in the sub-group. Scores are assigned as either 0 (criterion not fulfilled) or 1 (criterion fulfilled). For species with distinct life stages, adult stages are scored first; if these score a zero, then juvenile stages are considered (this is more fully described in Section 0). Secondary (food web) impacts resulting from contact with oil are not addressed in the framework.

In the framework it was recommended that vulnerability criteria be used without modifications in order to facilitate comparisons (DFO 2017). However, challenges encountered during the pilot application of the framework in the Pacific region resulted in a number of modifications to the criteria and their definitions. Most of these proposed changes are recommended as improvements to the framework rather than specific changes required for the Pacific region exclusively.

4.3.1 Exposure Category Criteria

During a large ship-source oil spill, all marine biological components have the potential to be exposed to some degree. However, species that are more likely to encounter spilled oil are assumed to be more vulnerable (Reich et al. 2014). The four criteria in the exposure category identify characteristics that increase the likelihood of exposure to oil. As all criteria in this assessment are scored in a relative manner across all sub-groups, it was important to provide detailed scoring guidance for each sub-group to ensure that the criteria were applied consistently. This was particularly important for the mobility/site fidelity criterion due to the wide range of mobility types across sub-groups (from sessile barnacles to highly mobile killer whales) that were difficult to capture using the binary scoring method (see Table 11). The mobility criterion was not based on an assumption that mobile organisms would move away from spilled oil, rather it was recognised that mobile organisms have a lower chance of remaining in an oiled area and being impacted than species that do not move and are guaranteed to be impacted by oil if a spill occurs in their habitat.

Another aspect of low mobility that was considered in this application was site fidelity. For this application, organisms that exhibit limited movement throughout their lives (those with small home ranges) were considered to exhibit site fidelity. Site fidelity was moved from the aggregation/concentration criterion, to the mobility criterion, to capture mobile species that have limited home ranges and that would, therefore, be similarly impacted as a sessile species in the event of an oil spill. It is important to note that this definition of site fidelity is different to how the term is more commonly used in the literature, and so does not include marine mammals having site fidelity to areas such as haul outs or rubbing beaches. It also does not include sub-groups containing species that have associations with a range of areas of critical habitat (as in killer whales) that occur over a broader home range. However, marine mammals that have been demonstrated to have very restricted home ranges, such as sea otters that are unlikely to move far from the kelp forests they live in, were considered to have site fidelity.

Another exposure criterion requiring more detailed scoring guidance was the concentration/aggregation criterion. Many fish species exhibit schooling behavior for predator avoidance. As this behaviour is very common, scoring general schooling behavior for the aggregation criterion would not provide good separation between sub-groups. Therefore, only fish that aggregate or concentrate for a purpose such as feeding, rearing or breeding are considered to aggregate.This definition was chosen so that the risk of an oil spill affecting a large proportion of a population at once was appropriately addressed, while at the same time providing separation between groups.

4.3.1.1 Changes to criteria in the exposure category

For the Pacific region pilot framework application, the two most significant modifications made to criteria in the exposure category were:

1. Site fidelity was moved from the concentration/aggregation criterion to mobility criterion, so that the criterion became ‘‘mobility and/or site fidelity’, and the definition for site fidelity was refined;
2. The ‘sediment interaction’ criterion was expanded to include interactions with any seafloor substrate (‘seafloor and/or vegetation interacting’).

These, and all other proposed adjustments to the exposure criteria are summarised in Table 10.

The modification to the ‘sediment interacting criterion is considered a major change to the framework, and was made in order to address the fact that, although oil generally persists longer in unconsolidated substrates (silt/sand/gravel), it can also persist in larger substrates such as cobble, boulder, and bedrock for many months following a spill in areas with low wave exposure. Oil has been found to persist on rocks up to a year after a spill, remaining sticky for at least 7 months, and retaining its original toxicity for at least 5 weeks, with the potential to impact biota (Cretney et al. 1978). Oil from the *Exxon Valdez* spill has also been found to persist for over 12 years beneath the surface in beaches with boulder/cobble armouring (Irvine et al. 2006). Vegetation can also retain oil, impacting organisms that interact with it. For instance, marsh plants can retain oil and remain clumped together many months after a spill (Cretney et al. 1978). In these rocky or vegetated areas, new organisms would be exposed to oil from interactions with the vegetation and seafloor over a relatively long time frame. For this reason, the criterion was modified such that sub-groups that interact with any benthic substrate (e.g. fish in close contact with oiled plants/algae, or invertebrates that cling to oiled rocks) are scored as fulfilling the criterion, rather than just those interacting with unconsolidated substrates.

For a criterion to be effective in this framework it should be successful in screening sub-groups in and out. There was concern that the change to the ‘sediment interacting’ criterion would result in fewer sub-groups being screened out. To test the impact of this change on the effectiveness of the framework, the outcomes of using both the original criterion (sediment interacting), and the modified criterion (seafloor/vegetation interacting) were compared. The comparative assessment is outlined in Appendix H and showed that, when using the modified criterion, the scores for 49 out of 118 sub-groups changed from 0 to 1, bringing the total number of sub-groups scoring 1 for this criterion to 91 (out of 118). Given that 27 sub-groups still score 0, the modified criterion is still effective at screening sub-groups in and out.

Table 10. Summary of proposed changes to the exposure criteria from the framework

Exposure criterion	Modification	Justification
Aggregation and/or site fidelity	Site fidelity moved from this criterion to the Mobility criterion	Test scoring indicated it would be more appropriate in the mobility criterion, where it was particularly useful for scoring organisms that are capable of mobility, but that in practice, do not actually move (i.e. those with limited home ranges).
	Included word ‘discrete’ in the question ‘form discrete aggregations’	To emphasise that the criterion assesses discrete aggregations.
	Justification	Justification text improved to explain the reason the criterion is used rather than providing guidance.
Mobility	Justification changed	To reflect the addition of site fidelity.
Sea surface interacting	Specific depth of surface layer identified as -1m	The depth of the surface layer (e.g. sea-air interface) used in the application is a default of -10 cm but this could vary based on regional conditions (i.e. localised hydrodynamics). The sea surface is the layer of ocean water in direct contact with the atmosphere, or more broadly as the surface mixed layer, up to 50 m deep in the Pacific and the precise penetrative depth of oil depends on factors such as wind and wave conditions. Pacific region experts concurred that a shallow range of -1 m is appropriate to capture the intent of the “surface interacting” criterion (to assign higher vulnerability to organisms interacting with a surface oil slick). A depth of -1 m allows for some mixing at the surface, but discerns the higher exposure experienced by truly surface interacting organisms from those at depth (See Appendices J & K for reviewer details).
Sediment interacting	Changed from ‘Sediment interacting’ to ‘Seafloor and/or vegetation interacting’	Oil can persist for many months on rocks and vegetation, as well as in subsurface sediments, resulting in an increased likelihood of exposure to organisms that interact with them.

4.3.1.2 Exposure Category Criteria used in Pacific Region Pilot Application

Criteria within the exposure category identify characteristics that increase the likelihood of exposure to oil, including: concentration (aggregation); mobility; and surface and seafloor interaction. The exposure criteria used in the Pacific pilot application are described in Table 11 (the original criteria taken from the framework are described in Appendix B).

Table 11a. Concentration (aggregation) criterion within the exposure category and general scoring guidance for Pacific region pilot application

Concentration (aggregation)	
Question	Does the sub-group contain species that concentrate or form discrete aggregations in areas linked to fixed / transient habitat in the area of interest?
Justification	A large proportion of the population may be affected at once in the event of an oil spill if they live in high concentrations or aggregate in large numbers in specific locations.
Scoring guidance	Sub-groups containing species that concentrate for habitat, feeding, or breeding.

Table 11b. Mobility and/or exhibit site fidelity criterion within the exposure category and general scoring guidance for Pacific region pilot application

Mobility and/or exhibit site fidelity	
Question	Does the sub-group contain species with low or no mobility, or that exhibit site fidelity (i.e. have a limited home range)?
Justification	Organisms are likely to have higher exposure to spilled oil if they are unable to, or have limited ability to, move away from spilled oil; are known to be attracted to spilled oil; or exhibit site fidelity (have a limited home range).
Scoring guidance	Includes sub-groups containing sessile species or with sessile life-stages (e.g. sponges, corals, kelp, sea grass, etc.); sub-groups containing species with low mobility (e.g. echinoderms); sub-groups containing species with evidence of attraction to spilled oil; or sub-groups containing species that exhibit site fidelity (a limited home range).

Table 11c. Sea surface interacting criterion within the exposure category and general scoring guidance for Pacific region pilot application

Sea surface interacting	
Question	Does the sub-group contain species that are reliant on, or have regular interaction with, the air/near sea surface, including intertidal areas?
Justification	The sea surface is the first point of contact in a ship-source oil spill. Therefore, organisms reliant on, or that have regular interaction with, the sea surface have an increased likelihood of exposure to spilled oil. The intertidal zone is likely to experience significant exposure from floating oil spills as tidal movements bring species in direct contact with oil on the sea surface (Chang et al. 2014).
Scoring guidance	Sub-groups containing species reliant on, or that have regular interaction with, the near-surface of the ocean (e.g. marine mammals, basking sharks). This includes intertidal species, as intertidal areas regularly interact with the surface. The depth of the surface layer (e.g. sea-air interface) was defined as the top 1 m after regional expert consultation.

Table 11d. Seafloor or vegetation interacting criterion within the exposure category and general scoring guidance for Pacific region pilot application

Seafloor or vegetation interacting	
Question	Does the sub-group contain species that interact regularly with the seafloor and/or marine plants and algae?
Justification	Direct exposure due to presence of oil on the seabed and/or vegetation. Contaminated seabed substrates can expose associated individuals in a population for as long as the oil persists. Persistent oil has the opportunity to impact a greater proportion of the population through direct contact over time.
Scoring guidance	Sub-groups containing species that inhabit substrate on the seafloor (e.g. clams) or who have regular interaction with the seafloor (e.g. grey whales feeding within unconsolidated substrates) and/or vegetation (such as eelgrass dwellers).

4.3.1.3 Specific Guidance for Scoring Exposure Category Criteria for each Biological Group

Though an overview of exposure category criteria descriptions is provided in Table 11, detailed supplemental scoring guidance is required for scoring criteria for each biological group. The guidance used in the Pacific region pilot application is outlined in Table 12 below.

Table 12. Detailed guidance used for scoring criteria within the exposure category for each biological group in the Pacific region application

Criterion	Group	Guidance
Concentration (aggregation)	Marine Algae/ Plants	Most marine plants/algae species are concentrated in areas where habitat conditions meet their specific needs (e.g. at certain tidal elevations). However, as these bands are not discrete, and the species are often ubiquitous across them, these are not considered to be aggregations here. For marine plants/algae, aggregations are considered to be large, discrete, mainly monospecific concentrations, such as eelgrass meadows, *Macrocystis* or *Nereocystis* beds and salt marshes.
	Marine Invertebrates	Sessile marine invertebrate species are concentrated in areas where habitat conditions meet their specific needs (e.g. at certain tidal elevations). However, as these bands are not discrete and the species are often ubiquitous across them, these are not considered to be aggregations. Sessile marine invertebrates are considered to be aggregating if they exhibit gregarious settlement (e.g. clams and mussels in discrete beds) and mobile marine invertebrates to be aggregating if they aggregate for a purpose such as feeding or breeding (e.g. breeding swarms of nereid worms).
	Reptiles	Species that aggregate for purposes such as nesting; however, this is not relevant here, as sea turtles are not known to aggregate in B.C. waters.
	Marine Fishes	Only fish that occur at high density for a purpose such as spawning, rearing, or feeding were considered to be aggregating. General schooling behavior was only considered if the schools were unusually large.
	Marine Mammals	Marine mammals that live in high concentrations or aggregate in specific locations (e.g. haul-outs).
Mobility / Site fidelity	Marine Algae/Plants	All sub-groups in the marine algae/plants group are considered to have low mobility). This includes phytoplankton that are carried with currents and have limited to no ability to move by themselves.
	Marine Invertebrates	Sub-groups containing species that are sessile (e.g. barnacles) or with low mobility (e.g. chitons), or mobile sub-groups that exhibit site fidelity (limited home range) such as den dwelling octopus. Zooplankton are also considered to fulfill this criterion because they are carried with currents and have limited to no ability to move by themselves.
	Reptiles	Sea turtles are highly mobile and would not fulfill this criterion.
	Marine Fishes	Fish sub-groups containing species that have limited movement throughout their lives/small home ranges.
	Marine Mammals	Marine mammals that would be considered low mobility in the framework would be those demonstrated to have very limited home ranges / limited movement throughout their lives. This would not include sub-groups containing species that have associations with a range of areas of critical habitat (as in killer whales) that occur within a broader home range.

Criterion	Group	Guidance
Sea surface/near surface interacting	Marine Algae/Plants	Sub-groups containing species that can extend from the seabed to the surface; those that occur primarily in the intertidal; and phytoplankton.
	Marine Invertebrates	Sub-groups containing intertidal and surface feeding marine invertebrates; pelagic groups that undergo vertical migrations; some cephalopods (i.e. jumping squid).
	Reptiles	Sea turtles fulfill this criterion as they must interact with the surface to breathe.
	Marine Fishes	Sub-groups containing species that live in intertidal areas, and fish that must pass through the intertidal to reach spawning grounds (anadromous), as they will have more interaction with the sea surface compared to subtidal benthic fishes.
	Marine Mammals	Marine mammals fulfill this criterion as they must regularly interact with the surface to breathe making them vulnerable to oil exposure (Peterson et al. 2003).
Seafloor or vegetation interacting	Marine Algae/Plants	With the exception of phytoplankton, marine algae/plants are all attached to the seafloor. Thus, all marine plants, with the exception of phytoplankton and those that have floats or woody stipes to hold the main portion of their thallus above the seafloor, fulfill this criterion.
	Marine Invertebrates	Sub-groups containing invertebrate species that live within the seafloor substrate (e.g., clams) or that regularly interact with the seafloor/vegetation for shelter/camouflage/ foraging.
	Reptiles	Sea turtles that would fulfill this criterion are those have been reported to frequently rest or forage on the seabed.
	Marine Fishes	Sub-groups containing fish species that forage in seafloor substrate, or that closely interact with the seafloor/vegetation for feeding, shelter or camouflage (e.g. those with benthic body morphologies such as flat fishes).
	Marine Mammals	Marine mammals that forage in below surface substrates for food (e.g. grey whales and sea otters) would fulfill this criterion.

4.3.2 Sensitivity Category Criteria

Criteria in the sensitivity category assess mechanical and chemical sensitivity based on physiological characteristics that can increase the magnitude of impact from exposure to oil (Thornborough et al. 2017). The mechanical sensitivity criterion identifies three physiological characteristics that are vulnerable to mechanical impairment by oil: reduction of feeding (e.g. oiled filter feeding structures); reduction of photosynthesis (from smothering); and reduction of insulation (oiled fur). The framework did not include impairment of respiration as a criterion since it is universally applicable to all sub-groups and, therefore, would not help discriminate between sub-groups. The chemical sensitivity (impairment due to toxicity) criterion 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 known pathways of exposure to oil are through adhesion, ingestion, absorption, and/or inhalation (Dupuis and Ucan-Marin 2015).

4.3.2.1 Changes to sensitivity category criteria

Two of the criteria in the sensitivity category were combined in the framework (Table 13).

Table 13. Summary of changes to sensitivity category criteria from the framework

Criterion	Modification	Justification
Loss of insulation	Merged with ‘reduction of feeding/photosynthesis’ criterion, changed criterion name to “Mechanical sensitivity (Reduction of feeding/photosynthesis/ insulation)	Both criteria capture mechanical impacts to energetics from fouled structures (e.g. fur, gills, blades)
Reduction of feeding/ photosynthesis	See above	See above
Impairment due to toxicity	Changed criterion name to “Chemical sensitivity (impairment due to toxicity)”	For clarity

4.3.2.2 Sensitivity Category Criteria used in Pacific Region Pilot Application

The adapted sensitivity category criteria used in the Pacific pilot application are described in Table 14. The original criteria taken from the framework are described in Appendix B.

Table 14a. Reduction of feeding/photosynthesis/insulation criterion within the sensitivity category criteria and general scoring guidance for Pacific region pilot application

MECHANICAL SENSITIVITY	
Reduction of feeding/photosynthesis/insulation	
Question	Does direct contact with oil result in the mechanical impairment of structures that can impact energetics of species in the sub-group?
Justification	Fouling of feeding structures by oil may reduce the ability of organisms to feed, reducing body condition and reproductive capacity, and increasing time spent feeding (Reich et al. 2014). Smothering can reduce photosynthesis, and oil causes a substantial decrease in the insulative value of fur, inhibiting the ability of affected organisms to thermoregulate (Reich et al. 2014).
Scoring guidance	Sub-groups that contain species that feed by filtering water through their systems and removing particles (filter feeders); sub-groups containing species that photosynthesize (smothering effects reducing photosynthesis). Sub-groups containing species reliant on fur as their primary means of thermoregulation.

Table 14b. Impairment due to toxicity criterion within the sensitivity category criteria and general scoring guidance for Pacific region pilot application

CHEMICAL SENSITIVITY	
Impairment due to toxicity	
Question	Does direct contact with oil result in severe, irreversible effects or death for species in the sub-group?
Justification	Organisms that are more sensitive to toxic effects of oil are more likely to experience irreversible effects or death.
Scoring guidance	Sub-groups containing species that display severe, irreversible effects or death due to oil toxicity. Acute effects from direct contact include: the inability of animals to digest and absorb foods; reproductive failure; respiratory failure; lesions; hemorrhaging; neurological impairment; and mortality.

4.3.2.3 Specific Guidance for Scoring Sensitivity Criteria for each Biological Group

Though the sensitivity criteria descriptions provided in Table 14 provide an overview, detailed supplemental scoring guidance is required for scoring sensitivity criteria for each biological group. The specific guidance used in the Pacific region pilot application is outlined in Table 15 below.

Table 15. Detailed guidance used for scoring criteria within the sensitivity category for each biological group in the Pacific region application

Criterion	Group	Guidance
Mechanical sensitivity (Reduction of feeding/ photosynthesis/ insulation)	Marine algae/plants	All marine plants/algae (except phytoplankton) can be smothered by oil and experience reduced photosynthesis.
	Marine Invertebrates	Sub-groups containing filter feeding marine invertebrates.
	Reptiles	Sea turtles do not filter feed, so their feeding structures are less vulnerable to clogging.
	Marine fishes	Sub-groups containing filter feeding fish (i.e. those with comb-like/tufted gill rakers) as these are presumed to be more easily clogged with oil, e.g. basking sharks, some bony fishes (e.g. sockeye salmon and herring).
	Marine mammals	Marine mammals with feeding structures vulnerable to clogging (e.g. baleen whales); marine mammals that depend on fur for thermoregulation (e.g. fur seals, sea otters).
Chemical sensitivity (Impairment due to toxicity)	Marine algae/plants	Sub-groups identified as experiencing severe toxic impacts in the literature.
	Marine Invertebrates	
	Reptiles	
	Marine fishes	
	Marine mammals	

4.3.3 Recovery Category Criteria

Criteria in the recovery category are used to assess the recovery potential from a single oil spill event by examining traits that impact the ability of a population to recover from exposure to oil (Thornborough et al. 2017). These criteria assess:

i. the current population status of species (‘population status’ criterion);

ii. how quickly they are likely to be able to replenish individuals lost due to an oil spill through reproduction (‘reproductive capacity’ criterion);

iii. whether species in a sub-group are endemic to the area of interest, or part of an population that is either genetically or physically isolated such that there is no access to outside organisms to replenish those lost due to an oil spill event (‘endemism/isolation’ criterion); and

iv. whether species in a sub-group live in close association with unconsolidated substrates where continuous exposure to oil retained in the substrate would hamper their recovery (‘close association with unconsolidated substrates’ criterion).

All criteria in this assessment are scored in a relative manner across all sub-groups, but the reproductive capacity criterion was challenging to score in a relative way because of the large variation in reproductive capacity across sub-groups (ranging from highly fecund broadcast spawners to sea otters that give birth to single pups), thus detailed guidance was provided to guide scoring of this criterion (Table 18).

Endemism was defined as ‘unique to a defined geographic location’, so that only sub-groups containing species that occurred within the area of interest, and not outside it, were considered to fulfill the criterion. The term ‘isolated population’ was used to describe sub-groups containing populations of species that have little or no genetic mixing with other populations of the same species (e.g. various stocks of salmon in British Columbia), or populations that occur in small geographically isolated areas.

4.3.3.1 Changes to Recovery Criteria

The overall changes proposed to the recovery criteria from those in the framework (Thornborough et al. 2017) described in Table 16 primarily involve the inclusion of more detail and justification for how criteria are defined and scored, following review of the literature and expert input.

Table 16. Summary of changes made to recovery criteria for the Pacific region pilot application

Criterion	Modification	Justification
Reduced / declining population	None	-
Reproductive capacity	Expanded definition from “Does the sub-group contain species with low reproductive capacity” to include “or have life history traits that can lead to low recovery potential?”	Increased clarity of the intention of this criterion; expanded definition to include any reproductive strategies that could result in lower reproductive potential
Endemism / Isolation	None	-
Close association with sediments	Changed to ‘Close association with unconsolidated substrates”, where unconsolidated substrates are defined as loose materials, ranging from clay to sand to gravel, with a range of porosity and permeability determining the degree to which water flows through spaces between grains (Spinelli et al. 2004). ‘Consolidated’ substrates are expected to be associated with an absence of subsurface oil.	Addresses a concern of Pacific reviewers as the term ‘sediment’ can be used to describe a number of substrate types including bedrock, whereas the intention of the criterion was to capture substrates that retain oil for very long periods such as silt,sand or gravel. The modification makes it clear what is meant by ‘unconsolidated substrates’ in this context (i.e. silt/sand/gravel) to distinguish from ‘consolidated’ substrates (cobble/ boulder/ bedrock)
	Modified ‘justification’ text	To better capture changes to criterion and include further information from literature on long term lingering subsurface oil studies following the *Exxon Valdez* oil spill

4.3.3.2 Recovery Criteria used in Pacific Region Pilot Application

The recovery criteria used in the Pacific pilot application and general scoring guidance are described in Table 17. The original criteria taken from the framework are described in Appendix B.

Table 17a. Population status criterion within the recovery category criteria and general guidance for scoring

Population status	
Question	Does the sub-group contain species with reduced or declining population levels?
Justification	Sub-groups containing species with greatly reduced or declining population numbers (in particular breeding population numbers) are compromised in their ability to recover from an impact, in contrast to those with healthy population levels which are most capable of recovering (Reich et al. 2014).
Scoring guidance	Sub-groups containing species with reduced or declining populations relative to historic (recent or long-term) levels. Sub-groups can fulfill this criterion in a number of ways: i. species in the sub-group have special conservation status (a proxy for a reduced population status), e.g. Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended, Species at Risk Act (SARA) listed, International Union for Conservation of Nature (IUCN) listed; Provincially listed; ii. stocks of species in the sub-group have been assessed as critical (commercially harvested species); and iii. evidence exists in the literature (including conservation status reports) that species within a sub-group have greatly reduced breeding population numbers relative to historic levels, or the population is known to be in decline.

Table 17b. Reproductive capacity criterion within the recovery category criteria and general guidance for scoring

Reproductive capacity	
Question	Does the sub-group contain species with relatively low reproductive capacity or other life history traits that can lead to low recovery potential?
Justification	Reproductive capacity of a species is a key contributor to population recovery. Sub-groups containing species with low reproductive capacity can be slow to recover from impact even with high population levels, whereas species with relatively high reproductive capacity are inherently more capable of population recovery from oil spill impacts (Reich et al. 2014). Other traits such as delayed maturity or infrequent reproductive success can also hinder population recovery.
Scoring guidance	Sub-groups that contain species with life history traits such as high parental investment (e.g. mammals), delayed maturity (e.g. geoduck), low fecundity (e.g. livebearers), and infrequent reproductive success (e.g. many rockfish species).

Table 17c. Endemism or isolation criterion within the recovery category criteria and general guidance for scoring

Endemism or isolation	
Question	Does the sub-group contain endemic species or species with populations that are spatially or genetically isolated within the region?
Justification	Sub-groups that contain species or populations endemic or isolated in the area are more likely to have a greater proportion of the population impacted by an oil spill, as well as lower potential for recolonization (Reich et al. 2014).
Scoring guidance	Sub-groups containing endemic species or isolated populations. For instance, species with populations that don’t interbreed (e.g. genetically isolated stocks of salmon) or species that occur in geographically isolated pockets within the area of interest. This criterion was assessed only for the period the species was present in the area of interest (e.g. seasonal abundances of species at certain times of the year).

Table 17d. Close association with unconsolidated substrate criterion within the recovery category criteria and general guidance for scoring

Close association with unconsolidated substrate	
Question	Does the sub-group contain species that are closely associated with unconsolidated substrates?
Justification	Significant amounts of spilled oil deposited in benthic substrates can persist sub-surface (5-18 cm deep) for over 20 years after a spill, and retain its original toxicity (*Exxon Valdez* Oil Spill Trustee Council 2009). This persistent oil will expose associated organisms for decades after a spill, and hinder their recovery (Gunster et al. 1993; Kennish 1996). Highest oil concentrations are found in fine-grained substrates (D'Ozouville et al. 1979).
Scoring guidance	Sub-groups containing species that live in unconsolidated substrates (e.g. eelgrass, clams, worms); sub-groups containing species which spend a significant proportion of time in close association with unconsolidated substrates, or that excavate into subsurface substrates (e.g. sea otters). Intertidal infauna and predators such as sea otters that excavate intertidal substrates are most likely to encounter lingering subsurface oil (Short et al. 2006).

4.3.3.3 Specific Guidance for Scoring Recovery Category Criteria for each Biological Group

Though the recovery criteria descriptions provided in Table 17 provide an overview, detailed supplemental scoring guidance is required for scoring recovery criteria for each biological group. The specific guidance used in the Pacific region pilot application is outlined in Table 18 below.

Table 18. Detailed guidance used for scoring criteria within the recovery category for each biological group in the Pacific region application

Criterion	Biological group	Specific Guidance
Population status	Marine algae/plants	Sub-groups containing species with reduced population levels as indicated by conservation status, or from other sources such as literature and subject matter experts (due to limited representation in conservation assessments for marine algae/plants).
	Marine Invertebrates	Sub-groups containing species with reduced population levels as indicated by conservation status, or from other sources such as literature and subject matter experts (where conservation assessments are limited).
	Reptiles	Sub-groups containing species with reduced population levels as indicated by conservation status.
	Marine fishes	Sub-groups containing species with reduced population levels as indicated by conservation status.
	Marine mammals	Sub-groups containing species with reduced population levels as indicated by conservation status.
Reproductive capacity	Marine algae/plants	Marine algae/plants with very low reproductive potential, e.g. long lived with delayed maturity, or a heavy reliance on vegetative growth.
	Marine Invertebrates	Sub-groups containing species with reproductive/life history characteristics that may delay recovery, such as those with delayed reproductive maturity (e.g. geoducks), high parental investment (e.g. giant Pacific octopus), those with infrequent reproductive success or low recruitment.
	Reptiles	Reptiles are long lived with slow development but

Criterion	Biological group	Specific Guidance
		produce many offspring.
	Marine fishes	Marine fishes with low reproductive capacity (e.g. livebearers), or life history traits that could limit recovery potential, such as those with delayed maturity (e.g. elasmobranchs), or infrequent reproductive success. (e.g. rockfishes).
	Marine mammals	Marine mammals have low reproductive capacity.
Endemism or Isolation	Marine algae/plants	Marine algae/plants endemic to the region or with isolated populations.
	Marine Invertebrates	Marine invertebrates endemic to the region or with isolated populations.
	Reptiles	None endemic to Canada or with isolated populations.
	Marine fishes	Fish endemic / with isolated populations in the region.
	Marine mammals	Marine mammals endemic to the region or with isolated populations.
Close association with unconsolidated substrate	Marine algae/plants	Marine algae/plants rooted in unconsolidated substrates (e.g. eelgrass).
	Marine Invertebrates	Marine invertebrates that live within unconsolidated substrate, particularly fine sediment (e.g., clams) or spend a large proportion of time in contact with it for shelter/camouflage/ foraging.
	Reptiles	Sea turtles that excavate unconsolidated substrates for foraging.
	Marine fishes	Fish that regularly rest on, bury into, or forage within unconsolidated substrates (usually with benthic body morphology (e.g. flatfishes, skates)).
	Marine mammals	Marine mammals that regularly forage in unconsolidated substrates.

4.4 SCORING PROCESS

The framework assesses vulnerability through a sequential scoring, screening, and ranking process, providing a rapid method to differentiate biological sub-groups that are relatively more vulnerable to oil spills (Figure 3).

4.4.1 Scoring

The framework uses a binary system to score sub-groups against vulnerability criteria as either (1) criterion fulfilled, or (0) criterion not fulfilled. All scores were assigned based on the assumption of direct contact with whole oil. Scoring decisions were aided by consulting general guidance tables (Table 11, Table 14, and Table 17) and supplemental guidance tables for each biological group (Table 12; Table 15; and Table 18), in addition to subject matter expertise (see Appendices J and K) and publications. Referenced publications were provided for each score where possible. In the framework, it was recommended as a best practice to provide three supporting references for each score, but this was not possible for most sub-groups due to the large numbers of scores assessed, as well as a lack of supporting publications. In addition, where a score was obvious or straightforward (e.g. surface interaction in marine mammals that must surface to breathe), a reference was not provided. A drawback of requiring three references per score is that it slows the assessment, which is designed to be rapid. To ensure the pilot application was scientifically valid and relevant to the Pacific region, the breakdown of sub-groups and all scores were subjected to peer-review by at least one subject matter expert for each of the major biological groups assessed.

Scoring was precautionary in a number of ways. For example, when assigning scores, a worst case scenario involving whole oil (rather than individual oil constituents) was assumed. Also, if at least one species within a sub-group was known to fulfill the criterion, then the whole sub-group was scored as fulfilling the criterion. The drawback to this approach is that the score for a whole sub-group may be driven by one species. However, further in the process, if resources are available, regions can populate identified sub-groups with species and score each species to identify the most vulnerable species within those groups. Furthermore, sub-groups were scored based on the life stages most sensitive to impacts from oil (e.g. juveniles vs. adults). This ensured that sub-groups containing species where the adults may be relatively unaffected while juveniles may be highly affected were screened into the assessment. This approach was challenging for marine fishes and invertebrates, and is discussed in more detail below.

The chemical sensitivity criterion (impairment due to toxicity) was difficult to assess accurately and rapidly for all sub-groups due to the breadth of literature review required to score the large number of sub-groups assessed (and in many cases, the inability to arrive at a clear score). Although there is a wealth of information for the toxic effects of oil on marine organisms, the lack of standardised experimentation makes experimental results difficult to compare. Also, in the case of post-spill impact studies, the lack of reliable baseline data render oil spill impacts difficult to quantify. Consequently, in this pilot application, most sub-groups were given a precautionary score of 1 (1*) for this criterion (for 3 sub-groups clear and convincing evidence of oil sensitivity was found, so the groups were scored as 1). This was considered valid, as all organisms will be sensitive to oil to some degree.

To ensure that final total scores were comparable across biological groups, it was important that scoring of sub-groups against criteria was done in a consistent and relative way. This was particularly relevant for the mobility and/or site fidelity criterion (exposure category) where it was important to consider spatial scale when scoring, particularly when scoring marine fish and marine invertebrate sub-groups. For this criterion, site fidelity was linked to spatial scale, and intended to capture those sub-groups that, although capable of swimming, have a very limited home range, and as such are functionally low mobility sub-groups. An example of a fish that would fulfill this criterion would be a den dwelling wolf eel or a small, intertidal fish such as a tidepool sculpin.

4.4.2 Incorporation of life stages

In the framework (Thornborough et al. 2017) it was recommended that sub-groups be scored based on the life stages most sensitive to impacts from oil (e.g. juveniles vs. adults), this precautionary approach aimed to ensure that sub-groups containing species where the adult population may be relatively unaffected while juveniles may be highly affected are included in the assessment. This was most relevant for the marine invertebrate and marine fishes groups. For marine fishes, in cases where it was suggested in the literature that juveniles would be more vulnerable than adults, separate sub-groups were created for each and placed within the most applicable groupings for scoring. For marine invertebrates, a pelagic larval invertebrate category was created in the level 2 sub-groups, and included sub-groups for each of the major phyla and groups to account for differences in scoring between the benthic adult and pelagic larval life stages.

4.4.3 Screening and ranking

The screening and ranking method outlined in the framework (Figure 3, Section 0), was tested in this Pacific region pilot application, whereby all sub-groups are first scored for exposure criteria, and only those sub-groups fulfilling one or more exposure criteria are retained to be scored for sensitivity criteria. Then only sub-groups which fulfilled at least 1 sensitivity criterion were retained and scored for recovery. The final list of screened sub-groups was then scored for recovery criteria and ranked based on cumulative recovery scores (0-4) to produce a list of vulnerable sub-groups ranked by recovery potential (sub-groups with the lowest potential for recovery ranked at the top of the list). Sub-groups high on this list are considered relatively more vulnerable to oil spills as they have a higher likelihood of exposure, a higher sensitivity to oil, and, a lower potential for recovery.

When applied to the Pacific region, the screening and ranking method in the framework was determined to be ineffective, as the ranked list it produced was not consistent with the scientific literature. In addition it resulted in only minimal screening of sub-groups at the exposure screening stage (2 of 118 sub-groups screened out), and no screening at the sensitivity screening stage, resulting in the need to fully score all but 2 sub-groups. All sub-groups scored at least 1 for sensitivity as every sub-group either scored 1 or a precautionary 1* for the "Chemical sensitivity (impairment due to toxicity)" criterion – justified in section 0), resulting in the need to fully score all but 2 sub-groups.

4.4.3.1 Screening and ranking methods tested

To identify a more effective screening and ranking method, eight alternative screening and ranking methods were explored (Table 19) each with a variation in the number of fulfilled criteria required at each screening step, as well as variation in the ranking procedure to assess the final screened list of sub-groups. For example, in screening and ranking method 1 (the framework method, Figure 3, Section 0), sub-groups must fulfill at least 1 criterion in the exposure category and 1 criterion in the sensitivity category and the final list of screened sub-groups is ranked by the recovery score (total for all recovery criteria). To be able to compare these methods it was necessary to score all biological sub-groups (118) for all criteria (10).

Table 19. Description of the 8 screening and ranking methods tested for the Pacific region framework application. Each method has a different combination of screening requirements and ranking procedure

Screening and ranking method	Screening requirements			**Ranking procedure** Final screened list ranked by:
	Exposure category: criteria fulfilled (minimum)	**Sensitivity category**: criteria fulfilled (minimum)	**Recovery category**: criteria fulfilled (minimum)	
1	1	1	N/A	Recovery score
2	1	1	N/A	Total score
3	1	1	1	Total score
4	1	1	N/A	Combined exposure and recovery scores
5	N/A	N/A	N/A	Total score
6	2	1	N/A	Recovery score
7	2	1	N/A	Total score
8	2	2	N/A	Recovery score
9	2	2	N/A	Total score

In all methods where the final screened list was ranked by recovery score (as in the framework), sub-groups with low recovery potential were ranked higher on the list. Many of these sub-groups had low exposure and sensitivity scores (e.g. Myxinidae – Pacific hagfish) or were transient in the area (e.g. sea turtles). Consequently, some resident, highly exposed, sensitive sub-groups, with moderate recovery potential were moved down the ranked vulnerability list. Ranking the final screened list of sub-groups using the total scores for all criteria appeared to remove this bias, producing a better representation of sub-groups scoring high for all three criteria types.

In screening and ranking method 5 (Table 19), where there were no screening requirements, and all sub-groups were ranked by the total score for all criteria, the final vulnerability list had good representation of sub-groups scoring high for all three criteria categories. This method offers a wealth of information, as all sub-groups are scored for all criteria, with justifications for each score. While the method is beneficial for a pilot application, allowing for multiple methods to be compared, scoring all sub-groups for all of the criteria with justifications can be time consuming. The sequential screening out of sub-groups at each step (as in other methods) is more functional for the “rapid approach” goal of the framework.

In four of the methods tested, there was a requirement for 2 or more criteria fulfilled in a given criteria category (Methods 6-9, Table 19). The outputs indicated that methods that required any more than 1 fulfilled criterion for a given category biased the results toward that category. For example, when 2 sensitivity criteria were required to be fulfilled for sub-groups to move through to recovery scoring, the final ranked vulnerability list contained only those sub-groups that fulfilled the “mechanical sensitivity (reduction in feeding/photosynthesis/insulation)” criterion. In another example, when 2 or more exposure criteria were required to be fulfilled for sub-groups to move through to sensitivity scoring, 17 of the 118 sub-groups were screened out at the first screening step. While this did seem to be functional for the “rapid approach” goal of the framework, some of the groups that were screened out were highly sensitive and/or had low recovery potential (e.g. dispersed baleen whales, pinnipeds that thermoregulate with fur, and basking sharks), which may be inappropriate.

To account for the fact that all sub-groups scored evenly for "Chemical sensitivity (impairment due to toxicity)" (explained in Section 0), removing sensitivity scores from the ranking process was tested, and ranking the final screened list using the total for exposure and recovery scores combined (screening method 4). In this scenario, valuable distinction was lost for those sub-groups that thermoregulate with fur, and those that either filter-feed or those that may experience a reduction in photosynthesis in the event of coating with oil. For these reasons, screening method 4 was not considered as a viable choice.

4.4.4 Proposed screening and ranking methodology for Pacific Region pilot application

Among the screening and ranking methods tested, method 2 (Table 19) was identified as the most appropriate to produce a final ranked vulnerability list of sub-groups for the Pacific region. This method used the same screening method as the framework, in that screening was sequential with the requirement of 1 criterion fulfilled in the exposure and sensitivity categories, but had a different ranking procedure. For the Pacific region pilot application, the final list of sub-groups was ranked using the total scores for all criteria (vulnerability scores), rather than by total recovery score (as in the framework). Though this method only screened out a limited number of sub-groups (2), the ranked complement of sub-groups it produced was the most consistent with the scientific literature.

While the goal of the framework was a “rapid approach” where, ideally, many sub-groups would be screened out, and not all sub-groups would need to be scored for all criteria, methods that allowed for greater screening (e.g. 2 criteria or more) introduced bias to the final list. Requiring 1 exposure category criterion and 1 sensitivity category criterion ensured that sub-groups were likely to be exposed, and sensitive to exposure, before moving on to be scored for recovery. This method allowed for the screening out of some sub-groups to decrease scoring effort, without biasing the final list toward any particular group of criteria. Since very few sub-groups were screened out, the method chosen was particularly appealing because it produced a ranked, but inclusive, list that gives flexibility to managers to choose a cut off that is appropriate for their area.

4.4.5 List of Most Vulnerable Sub-groups Identified for the Pacific Region

Table 20 summarises a ranked list of sub-groups identified as most vulnerable following the pilot application of the vulnerability framework. Of 118 sub-groups, 2 were screened out in the exposure screening stage, and these are highlighted in dark grey at the bottom of the table. No sub-groups were screened out in the sensitivity screening stage. Most major groups (e.g. marine invertebrates) were represented across the range of total scores from 1-9, and no sub-group had a total score greater than 9 (out of a possible 10).

Marine plant and algae vulnerability scores ranged from 4 to 9. The highest vulnerability scores for this group included three sub-groups that scored 9, two that scored 8, and one that scored 7. The lowest vulnerability scores for this group included four sub-groups with vulnerability scores of 4.

Marine invertebrate vulnerability scores ranged from 3 to 8. The highest vulnerability scores for this group included three sub-groups that scored 8, and eleven sub-groups that scored 7. The lowest vulnerability scores included two marine invertebrate sub-groups with scores of 3.

Marine fish vulnerability scores ranged from 1-8. The highest vulnerability scores for this group included one sub-group with a score of 8 and two sub-groups with scores of 7. The lowest vulnerability scores included ten fish sub-groups that scored 3, one that scored 2, and two that scored 1, both of which were screened out at the exposure screening step.

The marine reptiles group comprised only one sub-group, sea turtles, which received a moderate to low score of 4.

Marine mammal vulnerability scores ranged from 4 to 9. The highest vulnerability scores for this group included two sub-groups that scored 9 and one that scored 7. The lowest vulnerability scores for this group included two sub-groups with scores of 4.

Table 20. Final ranked list of screened sub-groups for the Pacific regional application of the vulnerability framework produced by ranking sub-groups based on total vulnerability score (method 4 in Table 19).Separations between vulnerability scores (e.g. between those sub-groups scoring 9 and those scoring 8) are highlighted using alternating light grey shading. Sub-groups that were screened out are highlighted in dark grey shading at the bottom of the table.

Biological group	**Sub-groups**				**Pacific example species**	**Vulnerability score (0-10)**
	Sub-group level 1	**Sub-group level 2**	**Sub-group level 3**	**Sub-group level 4**		
MARINE PLANTS & ALGAE	Intertidal	Vascular Plants	Moderate to low energy unconsolidated habitat	Seagrasses	e.g. *Zostera marina, Z. japonica, Ruppia maritima*	9
				Salt marsh grasses	e.g. *Carex lyngbyei, Leymus mollis*	
				Salt marsh succulents	e.g. *Sarcocornia pacifica, Glaux maritima, Plantago maritima*	
MARINE MAMMALS	Mustelids	N/A	N/A	N/A	e.g. sea otter	
	Cetaceans	Baleen	Discrete	N/A	e.g. humpback whales; grey whales	
MARINE PLANTS & ALGAE	Intertidal	Vascular Plants	High energy, rocky habitat	Seagrasses	*e.g. Phyllospadix scouleri, P. torreyi, P. serrulatus*	8
MARINE INVERTEBRATES	Intertidal	Sediment epifauna	Low mobility	Mollusca	e.g. snails [Cl. Gastropoda]	
				Cnidaria	e.g. sea pens	
				Echinodermata	e.g. sea stars	
MARINE FISHES	Estuarine	Transient	N/A	Salmon (Salmonidae)	e.g. juvenile and adult salmon & steelhead	
	Intertidal	Benthic	Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass environments)	Salmonidae (juvenile)	e.g. pink, chum, coho, chinook salmon	

Biological group	Sub-groups				Pacific example species	Vulnerability score (0-10)
	Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4		
MARINE PLANTS & ALGAE	Intertidal	Understory / Turf Algae	High energy, rocky habitat	N/A	e.g. *Pelvetiopsis limitata, Cymathere triplicata, Postelsia palmaeformis, Corallina vancouveriensis, Alaria fistulosa*	7
	Subtidal	Canopy Algae	Moderate to low energy rocky habitat	N/A	e.g. *Macrocystis integrifolia*	
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Mollusca	e.g. oysters [Bivalvia]	
			Low mobility	Echinodermata	e.g. sea urchins [Echinoidea];sea cucumbers [Holothuroidea];sea stars [Asteroidea]	
MARINE INVERTEBRATES	Intertidal	Sediment infauna	Low mobility	Mollusca	e.g. clams [Bivalvia]; snails [Gastropoda]	
				Worms	e.g. burrowers	
				Arthropoda	e.g. sand crabs [Emerita]	
				Lophophorates	e.g. horseshoe worms [Phoronida]	
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard	Porifera	e.g. glass sponges	
			Low mobility	Echinodermata	e.g. sea urchins, sea stars	
		Sediment infauna	Low mobility	Mollusca	e.g. clams	
		Sediment epifauna	Low mobility	Cnidaria	e.g. sea pens	
				Echinodermata	e.g. sea stars	
MARINE FISHES	Estuarine	Transient	N/A	Sturgeon (Acipenseridae)	e.g. green sturgeon, white sturgeon	
	Intertidal	Benthic	Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass environments)	Herring (Clupeidae)	e.g. Pacific herring	
MARINE MAMMALS	Cetaceans	Toothed	Discrete	N/A	e.g. killer whales: residents (Northern and Southern), and offshore populations; Pacific white sided dolphin	

Biological group	Sub-groups				Pacific example species	Vulnerability score (0-10)
	Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4		
MARINE PLANTS AND ALGAE	Intertidal	Understory / Turf Algae	Moderate to low energy rocky habitat	N/A	e.g. *Fucus gardneri, Neorhodomela larix, Desmarestia sp., Laminaria saccharina, Calliarthron* spp.	6
	Subtidal	Canopy Algae	High energy, rocky habitat	N/A	e.g. *Nereocystis leutkeana, Egregia menziesii*	
		Understory Algae	Rocky habitat	With tall, woody stipes or floats	e.g. *Pterygophera californica, Sargassum muticum, Lessoniopsis littoralis*	
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Arthropoda	e.g. barnacles [Cirripedia]	
				Cnidaria	e.g. coral	
				Porifera	e.g. demosponges	
				Worms	e.g. tube worms [Polychaeta: Sedentaria]	
				Urochordata	e.g. sea squirts	
				Lophophorates	e.g.bryozoans [Ectoprocta]; lampshells [Brachiopoda]	
			Low mobility	Arthropoda	e.g. isopods [Isopoda]	
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Low mobility	Cnidaria	e.g. sea anemones	
	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Cnidaria	e.g. coral	
		Sediment infauna	Low mobility	Worms	e.g. annelids	
				Lophophorates	e.g. horseshoe worms [Phoronida]; lampshells [Brachiopoda]	
		Sediment epifauna	Low mobility	Mollusca	e.g. snails [Cl. Gastropoda]	
MARINE INVERTEBRATES	Pelagic	Larvae	N/A	Mollusca	N/A	
				Echinodermata	N/A	
MARINE FISHES	Subtidal	Benthic	Associated with unconsolidated substrate (silt/sand/gravel)	Elasmobranchs	e.g. big skate	

Biological group	**Sub-groups**				**Pacific example species**	**Vulnerability score (0-10)**
	Sub-group level 1	**Sub-group level 2**	**Sub-group level 3**	**Sub-group level 4**		
MARINE PLANTS & ALGAE	Intertidal	Canopy Algae	N/A	N/A	e.g. *Egregia menziesii*	5
		Encrusting Algae	Rocky habitat	N/A	e.g. Coralline algae, *Codium setchellii, Hildenbrandia* sp., *Mastocarpus* (crust form), *Ralfsia pacifica*	
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Low mobility	Worms	e.g. polychaetes [Errantia]; nemerteans	
				Mollusca	e.g. chitons [Cl. Polyplacopora]; snails [Cl. Gastropoda]	
			High mobility	Arthropoda (filter feeders)	e.g. porcelain crabs	
				Mollusca	e.g. octopuses	
		Sediment epifauna	High mobility	Arthropoda	e.g. crabs	
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Arthropoda	e.g. barnacles [Cirripedia]	
				Mollusca	e.g. rock scallops [Bivalvia]	
				Worms	e.g. tube worms [Polychaeta: Sedentaria]	
				Urochordata	e.g. sea squirts	
				Lophophorates	e.g.bryozoans [Ectoprocta]; lampshells [Brachiopoda]	
			Low mobility	Worms	e.g. annelids	
				Cnidaria	e.g. sea anemones	
	Pelagic	N/A	Low mobility	Zooplankton (other than larvae)	N/A	
MARINE INVERTEBRATES	Pelagic	N/A	Low mobility	Cnidaria	e.g. jellyfish	
		Larvae	N/A	Cnidaria	N/A	
				Worms	N/A	
				Arthropoda	N/A	
				Lophophorates	N/A	

Biological group	Sub-groups				Pacific example species	Vulnerability score (0-10)
	Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4		
MARINE FISHES	Estuarine	Resident	N/A	Surfperches (Embiotocidae)	e.g. shiner perch	5
		Transient	N/A	Osmeridae	e.g. eulachon	
	Intertidal	Benthic	Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass environments)	Ammodytidae & Osmeridae	e.g. Pacific sand lance, surf smelt	
				Other species (e.g. sculpins , gobies)	e.g. staghorn sculpin, plainfin midshipmen	
	Subtidal	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Rockfishes (Scorpaenidae)	e.g. quillback, yelloweye, tiger & china rockfish	
			Associated with unconsolidated substrate (silt/sand/gravel)	Rockfishes (Scorpaenidae)	e.g. dark-blotched rockfish, canary rockfish	
MARINE FISHES	Subtidal	Non-benthic (pelagic, midwater and demersal)	N/A	Rockfishes (Scorpaenidae)	e.g. yellowtail, blue, widow rockfishes, bocaccio	
				Elasmobranchs	e.g. spiny dogfish, sixgill sharks	
				Chimaeridae	e.g. spotted ratfish	
				Elasmobranchs filter feeder	e.g. basking shark	
MARINE MAMMALS	Cetaceans	Baleen	Dispersed	N/A	e.g. sei whale; blue whale; fin whale; North Pacific right whale; common minke whale	
	Pinnipeds	Thermoregulate with fur	N/A	N/A	e.g. Northern fur seal	
		Other pinnipeds	Discrete	N/A	e.g. Steller sea lion, harbour seal; California sea lion	
MARINE PLANTS & ALGAE	Pelagic	Phytoplankton	N/A	N/A	N/A	4
	Subtidal	Understory Algae	Rocky habitat	Without tall, woody stipes or floats	e.g. *Desmarestia* sp, *Agarum fimbriatum, Laminaria* sp., *Prionitis lyallii*	
		Turf Algae	Rocky habitat	N/A	e.g. *Callophyllis* sp.; *Dictyota binghamiae, Sarcodiotheca furcata, Rhodymenia pacifica*	
		Encrusting Algae	Rocky habitat	N/A	e.g. Coralline algal crusts, *Hildenbrandia* sp.	

Biological group	Sub-groups				Pacific example species	Vulnerability score (0-10)
	Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4		
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	High mobility	Arthropoda	e.g. crabs [Decapoda]	4
	Subtidal benthic	Rock and rubble dwellers	Low mobility	Mollusca	e.g. snails [Cl. Gastropoda]	
			High mobility	Mollusca	e.g. octopuses	
		Sediment epifauna	High mobility	Arthropoda	e.g. crabs	
	Pelagic	Larvae	N/A	Porifera	N/A	
				Chordata	N/A	
MARINE FISHES	Estuarine	Transient	N/A	Sticklebacks (Gasterosteidae)	e.g. threespine stickleback	
	Intertidal	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Snailfishes (Liparidae)	e.g. tidepool snailfish	
				Clingfishes (Gobiesocidae)	e.g. Northern clingfish	
				Blennies (Stichaeidae & Pholidae)	e.g. penpoint gunnel, crescent gunnel, high cockscomb	
			Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass	Pipefish (Sygnathidae)	e.g. bay pipefish	
				Greenlings (Hexagrammidae)	e.g. lingcod- juvenile	
		Non-benthic (pelagic and demersal)	N/A	Surfperch (Embiotocidae)	e.g. shiner perch, striped perch, pile perch	
				Rockfishes (juvenile)	e.g. black rockfish	
MARINE FISHES	Subtidal	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Wolf fish (Anarhichadidae)	e.g. wolf-eel	
				Greenlings (Hexagrammidae) & Sculpins (Cottidae)	e.g. lingcod (adult), cabezon	
			Associated with unconsolidated substrate (silt/sand/gravel)	Flatfishes (Pleuronectidae)	e.g. English sole, starry flounder, Pacific halibut	
		Non-benthic (pelagic, midwater and demersal)	N/A	Ammodytidae	e.g. Pacific sand lance	
				Engraulidae	e.g. Northern anchovy	
MARINE MAMMALS	Pinnipeds	Other pinnipeds	Dispersed	N/A	e.g. Northern elephant seal	
	Cetaceans	Toothed	Dispersed	N/A	e.g. sperm whales, killer whales (W.Coast transients); false killer whale; beaked whales (Baird's, Hubbs' and Stejneger's) harbour porpoise; Dall's porpoise	
MARINE REPTILES	Sea turtles	N/A	N/A	N/A	e.g. leatherback sea turtle; green sea turtle; olive ridley	

Biological group	**Sub-groups**				**Pacific example species**	**Vulnerability score (0-10)**
	Sub-group level 1	**Sub-group level 2**	**Sub-group level 3**	**Sub-group level 4**		
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	High mobility	Arthropoda	e.g. crabs	3
	Pelagic	N/A	High mobility	Mollusca	e.g. squid	
MARINE FISHES	Estuarine	Transient	N/A	Lampreys	e.g. river & Pacific lamprey	
				Sculpins (Cottidae)	e.g. prickly sculpin	
MARINE FISHES	Estuarine	Transient	N/A	Flatfishes (Pleuronectiformes)	e.g. starry flounder, juvenile English sole	
		Resident	N/A	Salmonidae	e.g. cutthroat trout and Dolly Varden	
				Sculpins (Cottidae)	e.g. staghorn sculpin	
	Intertidal	Benthic	Associated with unconsolidated substrates (silt/sand/gravel)	Flatfishes- juvenile (Pleuronectidae)	e.g. English sole, starry flounder	
	Subtidal	Benthic	Associated with unconsolidated substrate (silt/sand/gravel)	Hagfishes (Myxinidae)	e.g. Pacific hagfish	
		Non-benthic (pelagic, midwater and demersal)	N/A	Molidae	e.g. ocean sunfish	
				Cod (Gadidae)	e.g. Pacific cod, hake, Pacific tomcod, walleye pollock	
		Non-benthic (pelagic, midwater and demersal)	N/A	Misc species	e.g. sablefish (Anaplopomatidae), salmon (Salmonidae), surfperch (Embiotocidae), herring (Clupeidae)	
MARINE FISHES	Estuarine	Transient	N/A	Cod (Gadidae)	e.g. Pacific tomcod, walleye pollock *(juveniles)*	1
MARINE FISHES	Subtidal	Non-benthic (pelagic, midwater and demersal)	N/A	Scombrids	e.g. mackerel	

4.4.6 Distribution of Vulnerable Sub-group scores

The distributions of scores are outlined in histograms (Figure 4), showing: a. the frequency of total vulnerability score; b. total exposure score; c. total sensitivity score, and d. total recovery score. Total vulnerability scores had a normal distribution, indicating that scores for most sub-groups were in the mid-range, with fewer groups scoring very low and very high. The distribution of total exposure scores was skewed to the right, indicating that more sub-groups scored in the upper range of exposure scores. Total sensitivity scores were also skewed to the right, with no sub-groups scoring 0. Conversely, recovery scores were strongly skewed to the left, indicating that more sub-groups scored in the lower ranges of recovery scores. Only one sub-group scored 4 out of 4 for recovery criteria, and only 8 out of 118 sub-groups scored 3 out of 4.

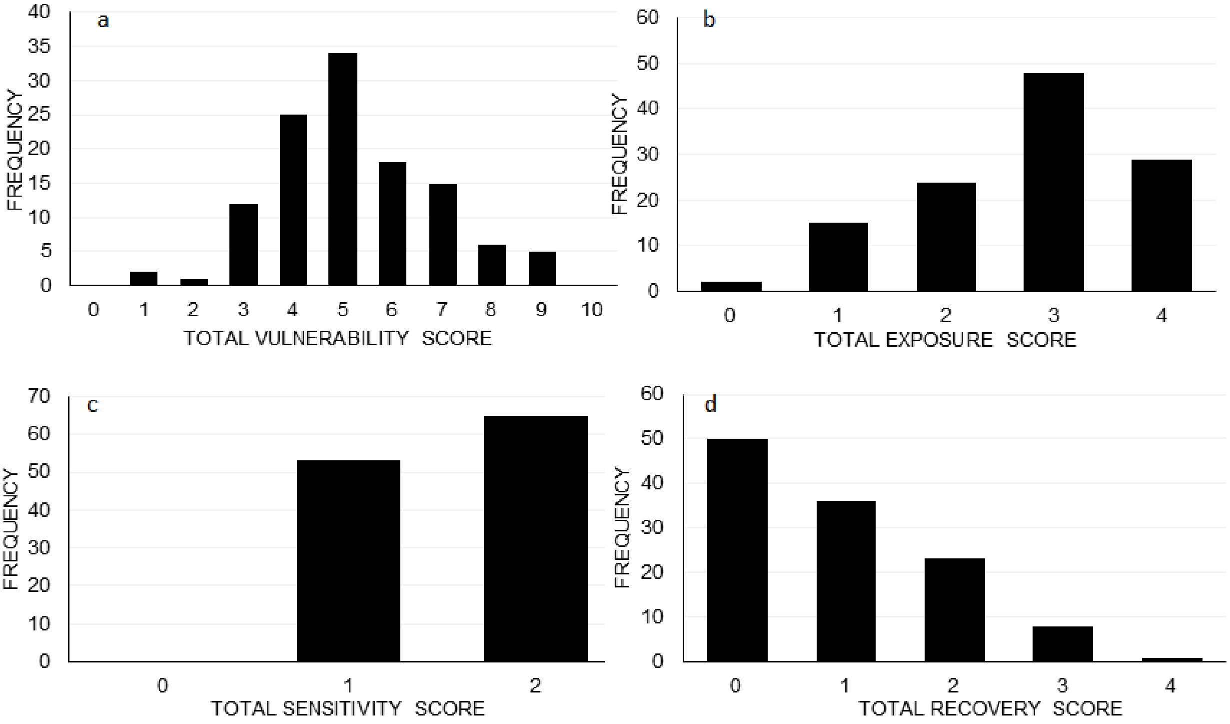

Figure 4. Histograms of the frequency of vulnerability scores for all scored sub-groups (118) a. Frequency of total vulnerability scores (range of possible scores 0-10); b. Frequency of total exposure scores (range of possible scores (0-4); c. Frequency of total sensitivity scores (range of possible scores 0-2); and d. Frequency of total recovery scores (range of possible scores 0-4).

5 DISCUSSION

The suitability of the framework (Thornborough et al. 2017) as a simple and rapid method to assess the vulnerability of marine biological components in the Pacific region to ship-source oil spills was assessed in this pilot application. The framework was adapted to fit the biological communities and conditions in the Pacific region by adapting the sub-groups and the assessment criteria. The relative vulnerability of these sub-groups to spilled oil was then assessed through a scoring, screening and ranking process. Regional subject matter experts were involved throughout the process to provide input, but focused on the adapted sub-groups and scoring. The functionality of the framework method was assessed at each step in this first pilot application, and modifications made where deemed necessary. Overall, the relative vulnerability rankings determined by the adapted method aligned well with the outputs from similar studies and oil spill literature.

5.1 SUITABILITY OF THE LIST OF MOST VULNERABLE SUB-GROUPS IDENTIFIED BY THE PACIFIC REGION FRAMEWORK APPLICATION

The list of most vulnerable sub-groups identified for the Pacific region contained 116 sub-groups screened for vulnerability to oil (exposure and sensitivity), and ranked by their total vulnerability score. The ranked list was compared to other studies examining the impacts of oil spills on marine organisms to assess its validity. Specifically, comparisons were made to studies on the impacts to biota following the *Exxon Valdez* oil spill (Alaska in 1989); the *Deepwater Horizon* well blowout (Gulf of Mexico in 2010); and the *Nestucca* oil spill (Washington in 1988 - impacting BC waters). It is important to note that, though the *Deepwater Horizon* spill was a well blowout, and not a ship-source spill, the findings on impacts are still relevant for making comparisons to this application.

5.1.1 Marine Plants and Algae

The plant and algae sub-groups that ranked highest for relative vulnerability to oil were the intertidal vascular plants (including all seagrasses and salt marsh plants) from low energy unconsolidated shore habitat (all scoring 9), and the intertidal vascular plant seagrasses from high energy rocky shore habitat (with a score of 8). These results align with several *Deepwater Horizon* oil spill studies that found large-scale destruction of seagrass beds (Beyer et al. 2016), reduced standing crop of marsh vegetation (Hester et al. 2016), and increased erosion following vegetation loss that will hinder recovery (Silliman et al. 2012). The *Nestucca* oil spill, which impacted the west coast of Vancouver Island in B.C., also resulted in mortality and damage to intertidal plants, particularly in rocky and sandy habitats (Duval et al. 1989). A recent review paper indicates that, though there are many oiling events where impacts to seagrass has been observed, there are also others where no discernible effects were reported (Fonseca et al. 2016). The impacts to vascular plants likely depend on the severity of fouling, and long-term impacts will depend on whether below-ground roots and rhizomes are affected.

Phytoplankton received a relatively low total vulnerability score. Findings for phytoplankton in the literature are variable, with some studies reporting local short term decreases in abundance and productivity of phytoplankton, while others report increases in primary productivity (Duval et al. 1989). A main driver for the low vulnerability score in this analysis was recovery, as phytoplankton are expected to have high recovery regardless of their exposure or sensitivity.

Other algal sub-groups that had low vulnerability scores include many groups in subtidal, rocky habitat. These groups have moderate likelihood of exposure and sensitivity, but high recovery potential, which makes them relatively less vulnerable. These results are in keeping with many studies on the effects of oil spills on subtidal algae, which have found either rapid recovery of algal communities, or very little impact of the spill (Pecko et al. 1990; Dean et al. 1996).

5.1.2 Marine Invertebrates

For marine invertebrates, intertidal, epifaunal, low mobility sub-groups including Mollusca, Cnidaria, and Echinodermata (all with scores of 8) ranked highest for relative vulnerability to oil. This aligns with findings that clam, mussel, and intertidal communities were still recovering from the *Exxon Valdez* oil spill 20 years later (*Exxon Valdez* Oil Spill Trustee Council 2009). Intertidal marine invertebrates are often one of the most visibly affected biological resources following oil spills (Duval et al. 1989). In the *Deepwater Horizon* spill, shallow water species that were identified as most affected included Cnidarians such as gorgonian corals (Etnoyer et al. 2015, 2016) and stony coral larvae (Goodbody-Gringley et al. 2013), aligning with the outputs of this pilot assessment. Impacts to mollusc groups appear to vary, with some groups appearing to be sensitive, while others were not (Washburn et al. 2016). Bivalves are particularly sensitive to crude oil, as they can consume oil droplets while filter-feeding and their low mobility stops them from moving away from contaminated waters (Dupuis and Ucan-Marin 2015). In this pilot vulnerability assessment, most sub-groups containing oysters and mussels were ranked as highly vulnerable, while one was ranked as moderately vulnerable.

In the *Deepwater Horizon* spill, offshore deep-water groups, including sea pens, glass sponges, and colonial tunicates (Valentine and Benfield 2013) as well as deep water corals (Hsing et al. 2013; White et al. 2012), were among those groups most affected, likely because the source of the oil spill was at depth. Other *Deepwater Horizon* reports state that echinoderms and crustaceans tended to be more sensitive to contaminants than many members of the phylum Annelida (reviewed in Washburn et al. 2016). The vulnerability of the echinoderm groups in this application aligns with these observations (no echinoderm group received a total score below 6); however, crustacean arthropod and worm sub-groups were represented throughout the range of scoring. These differences may be driven by different study species and habitats.

Most high mobility invertebrate sub-groups (including arthropods) received relatively low vulnerability scores (scores of 5, 4, 3). This is in contrast with findings following the *Nestucca* oil spill, where crabs (mobile arthropods) appeared to be highly impacted; large numbers of dead crabs were reported, with oil adhering to the carapaces of Dungeness crabs (Duval et al. 1989). However, these results were based on observations following within months of a spill and did not take into account recovery. Given their life history characteristics, arthropods are expected to have high recovery potential which could justify their relatively low vulnerability rating in this assessment.

5.1.3 Marine Fishes

The marine fish sub-groups ranking highest for relative vulnerability to oil included salmon, sturgeon, and herring. These findings align well with the literature that has examined the impacts on fish from the *Exxon Valdez* spill. For instance, the growth of Dolly Varden, cutthroat trout and pink salmon was reduced in the years following the *Exxon Valdez* oil spill (Hepler et al. 1996; Wertheimer & Celewycz 1996; Willette 1996), sockeye salmon smolt mortality was higher, and herring stocks were severely depleted following the *Exxon Valdez* oil spill. In the years after the oil spill, some salmon species were seen to recover, but this was not the case for herring that had not recovered after 20 years, although there are conflicting opinions over whether this can be solely attributed to the spill (*Exxon Valdez* Oil Spill Trustee Council 2009; Marty 2008).

Fish sub-groups with the lowest relative vulnerability scores include subtidal non-benthic scombrids and estuarine transient cod, both of which were screened out in the exposure screening step. These results align well with findings from studies following the *Exxon Valdez* oil spill that found higher numbers of Pacific cod in shallow subtidal habitats that had been oiled, compared to those that were not oiled, as well as higher stomach content volumes at oiled sites (Laur & Haldorson 1996). Other fish sub-groups with low scores that were not screened out include many non-benthic, benthic, and estuarine sub-groups including subtidal, non-benthic cod, and ocean sunfish. The abundance of non-benthic (pelagic, mid-water, and demersal) fish sub-groups in the lower range of vulnerability scores aligns with information reviewed in Beyer et al. (2016) which summarised that pelagic fishes appear to be relatively unharmed by exposure to oil. In this assessment, fish sub-groups with low vulnerability scores have life history traits that cause them to have a low likelihood of exposure, low sensitivity, and a high potential for recovery.

5.1.4 Marine Reptiles

Sea turtles, the sole group for marine reptiles, had a relatively low vulnerability score (4) that is in contrast to the low recovery potential of this group. This can be explained by the fact that although areas outside of the Pacific region are important for critical life functions, such as breeding (Gregr et al. 2015), sea turtles in the Pacific region are transient and usually seen swimming and foraging individually. Their score in this assessment is understandable given that sea turtle sightings are infrequent in the Pacific region of Canada (B.C.) making it difficult to draw conclusions about the distribution and habitat use of sea turtles in B.C. waters.

5.1.5 Marine Mammals

Marine mammal sub-groups that ranked the highest for relative oil vulnerability were the mustelids (sea otters; score of 9), discrete baleen whales (e.g. grey whales; score of 9), and discrete toothed whales (e.g. resident killer whales; score of 7). The high vulnerability ranking for sea otters (Mustelids) corresponds with reports of extensive sea otter deaths following the *Exxon Valdez* oil spill indicating population level injuries (Garshelis and Johnson 2013; Marty 2008), and at least one sea otter reported dead due to oil from the smaller *Nestucca* spill, which impacted the west coast of Vancouver island (Waldichuck 1988; Duval et al. 1989). High vulnerability for resident killer whales (discrete toothed whales) also aligns with findings of severe impacts following the *Exxon Valdez* spill, where 14 of the 36 killer whales in the resident Price William Sound pod disappeared in 1989-90 (*Exxon Valdez* Oil Spill Trustee Council 2009).

These findings are also comparable to recent findings of a marine mammal focused risk-based framework that took into account oil exposure routes, behavioural ecology, and physiological characteristics to assess hypothetical impacts of oil exposure in BC (Jarvela-Rosenberger et al. *2017*). The study identified resident killer whales (discrete toothed whales) and sea otters (mustelids) to be at greatest risk from an oil spill, followed by bigg's (transient) killer whales, humpback whales and steller sea lions. These findings were comparable to this pilot assessment with two exceptions: steller sea lions (Pinnipeds> Discrete) and transient killer whales (Cetaceans>Toothed>Dispersed) were deemed at high risk, whereas in this pilot assessment they recived moderate scores (5 and 4 respectively). Steller sea lions ranked high in the Jarvela-Rosenberger et al. (*submitted*) study as they were considered to have a high likelihood of population-level effects due to year-round residency in BC waters and a reliance on a small number of rookeries along the BC coastline. In this pilot application, although discrete pinnipeds (including the steller sea lion) did score high for exposure (3 out of 4 exposure criteria fulfilled), they did not score highly for recovery (1 out of 4 recovery criteria fulfilled). The population in BC is not in decline and has recovered to similar levels to before harvesting and predator-control programs began in the 1900s (COSEWIC 2013). Similarly, harbour seals, another species of discrete pinniped highly affected by the *Exxon Valdez* oil spill, also appear to have recovered, according to a study 20 years later (*Exxon Valdez* Oil Spill Trustee Council 2009).

Some of these differences can be attributed to the broader range of more detailed marine mammal specific factors considered in the Jarvela-Rosenberger et al. (*submitted*) report, such as social structure and level of dietary specialization, as well as secondary effects that aren't considered here. This level of detail is not functional for the current assessment, which is broader in scope and is a relative approach across biological groups, rather than within the marine mammals. However, it may be possible to incorporate some of these factors in future iterations of the framework if they are more focused in scope.

Marine mammal sub-groups that had a lower relative vulnerability ranking include the dispersed toothed whales (e.g. transient killer whales) and the dispersed "other" pinnipeds (e.g. Northern elephant seal). For both of these sub-groups, life history traits cause them to have a lower likelihood of exposure, lower sensitivity, and a higher potential for recovery than other marine mammals. That said, both of these groups had total scores of 4, which is higher than the minimum score of other groups. This relatively high minimum score for marine mammals indicates that, as a group, marine mammals have a number of traits and behaviours that make them more vulnerable to spilled oil than other major groups.

5.2 CHALLENGES AND LIMITATIONS

A number of challenges and limitations were encountered during the adaptation and application of the framework to the Pacific region; they are described below, along with details on how they were resolved.

Firstly, some challenges were encountered when applying the framework criteria, resulting in adjustments to the criteria and their definitions, as well as clarifications to the specific scoring guidance for each major species group. For instance, the concentration/aggregation criterion was difficult to score for fishes; as many fish species school for predator avoidance, the criterion would not be useful for discerning between sub-groups if all species that lived in schools were scored as 1. To address this challenge, it was decided that unless fish lived in exceptionally large schools, only fish that aggregated or concentrated for a purpose such as feeding, rearing or breeding were scored for the aggregation/concentration criterion. This definition was chosen so that the risk of an oil spill affecting a large proportion of a population at once was appropriately addressed. Similarly, plants and algae were difficult to score for aggregation as many species aggregate inconsistently; sometimes occurring in dense, monospecific stands, and other times occurring in mixed species beds. For these species, the precautionary approach was taken, and sub-groups were scored as 1 if they frequently occurred in aggregations.

Another criterion that was particularly challenging to score within the framework was the chemical sensitivity (impairment due to toxicity) criterion. Difficulties arose when scoring this criterion due to the breadth of literature review required to determine a clear binary score for the large number of sub-groups assessed, and the difficulty of assigning scores based on conflicting results from studies on multiple oil types. Consequently, all sub-groups are scored a precautionary 1 (1*) for this criterion (except three groups for which sufficient evidence was found to give them a score of 1). This was considered acceptable for the pilot application because assessing the toxicity of different oil types to each sub-group was beyond the scope of this paper, and consensus of the results among studies of different oil types (of which there are hundreds) for a given sub-group was usually not evident in the literature. As a result of this precautionary scoring, vulnerability to chemical impacts of oil was not effective at differentiating between sub-groups as all groups received the same score in this pilot application.

Relative vulnerability rankings of sub-groups were based on total additive scores across the three vulnerability criteria categories (exposure, sensitivity, and recovery). It is important to note that the unequal number of criteria in each of the vulnerability categories may result in unequal weighting of those categories in the total score (vulnerability score). One way to minimise this bias is to standardise all scores before adding them together. Standardisation was investigated in Appendix L, but standardisation is not appropriate for binary scores. Instead, scores were adjusted so that all criteria categories were on the same scale (all had a maximum possible score of 4) and the adjusted list was compared with the list presented in Section 2.4.5. Using adjusted vulnerability scores, the rankings at the top and bottom of the list were very similar to those in the list produce by non-adjusted scores, while rankings in the middle of the list varied. Regardless, when bins were assigned for high (vulnerability scores 7-9, adjusted scores 9-12), medium (vulnerability scores 4-6, adjusted scores 5-8), and low (vulnerability scores 1-3, adjusted scores 1-4), only two sub-groups changed bins: estuarine > transient > sturgeon and cetaceans > toothed > discreet both changed from high to medium. This adjustment was not applied to the final ranked list reported in the main document, but may be considered for future applications of the framework.

As outlined in Thornborough et al. (2017), the framework provides guidance to score sub-groups based on the life stages most vulnerable to impacts from oil (e.g. juveniles vs. adults) to ensure that sub-groups containing species where the adult population may be relatively unaffected, while juveniles may be highly affected (based on differing vulnerabilities and distributions), are appropriately addressed. In practice, this approach was challenging to apply for the marine invertebrates and fishes, as both groups have complex life histories with sensitive juvenile stages, which result in many criteria being fulfilled. If all sub-groups fulfill a criterion, it becomes ineffective in the screening process, and so it was challenging to adequately capture the vulnerability of the juvenile stages, while effectively discerning between sub-groups. To address this challenge for the fish sub-groups, where there was evidence that juveniles were more vulnerable than adults, separate sub-groups were created for each. This worked well for fishes, and resulted in a more inclusive analysis. The approach was less effective when tested for the marine invertebrates as it resulted in an unmanageable number of invertebrate sub-groups. As an alternative, a pelagic larval invertebrate category was created at the level 2 grouping, which included level 4 sub-groups for each of the major phyla and groups. This helped to account for differences in scoring between the benthic adult and pelagic larval life stages, and resulted in a more inclusive analysis. This solution will also be beneficial for the next steps in the evaluation process (as outlined in Section 0), as it separates marine pelagic larval stages, which tend to be ubiquitous and may not be suitable for mapping.

Where challenges were encountered due to a lack of, or conflicting, information (knowledge gaps) the challenges were flagged for inclusion in a gap analysis to summarise where there were limitations and uncertainty in the framework adaptation and application. The gap analysis, summarised in Appendix I, is an important output of this pilot application, and allows recommendations to be made as to how to address these gaps, and provide direction and focus for future research and literature reviews.

A final challenge in the application of the framework to the Pacific region concerned the binary scoring method used. This ‘all or none’ approach doesn’t reflect the gradient of variability inherent in many of the ecological features that were assessed. A scoring rubric with more than one level to accommodate this gradient would provide clearer, more accurate scoring, and more discrimination of the outputs. For instance, when scoring the sea surface interacting criterion, it became evident from the literature that surface oil can penetrate the water column to depths of at least 30 m. However, to assign a score of 1 for surface interacting to every sub-group that contained species occurring to depths of 30 m would result in scoring almost every sub-group as 1, thus rendering the criterion useless for differentiating sub-group vulnerability. Because of this, sub-groups only fulfilled this criterion if they contained species that interact with the top 1 m of the sea surface, so that only sub-groups exposed to the highest concentrations of surface oil would be considered vulnerable to the criterion. This cutoff would not have been necessary with a multi-level scoring rubric such as that proposed in Jarvela-Rosenberger et al. (*submitted*). Their framework was developed specifically for marine mammals, and scored the likelihood of exposure for each species as either 'high, medium or low'. For example, the exposure criterion of adhesion was scored as 'low' for marine mammals with smooth skin, 'medium' for those with rough skin or short fur, and 'high' for those with true fur. The option for, and consequences of, using alternate scoring rubrics are discussed in Section 0.

Some limitations exist in the framework that cannot yet be addressed due to the current state of scientific knowledge. For instance, indirect effects or food web impacts were not considered due to lacking or inconsistent information on ecosystem/food web dynamics and the effects of oil. It may be possible to incorporate some of these factors in future iterations of this application using recent research that has focused on indirect effects (e.g. Clarke-Murray et al. 2016). Also, there were limitations in the knowledge of life histories, particularly for groups other than marine mammals, that may have impacted the scoring of criteria for those sub-groups. To address these limitations, the most relevant literature that could be found was used when scoring, experts were consulted to review the scores, and a precautionary score of 1 (1*) was applied wherever necessary to acknowledge the uncertaintly.

Also not considered in this assessment are increased vulnerabilities due to impacts from multiple stressors (i.e. cumulative effects), nor compounding impacts, including source-sink dynamics. Although these are important considerations for a comprehensive assessment of impacts to a system, it was not practical to include them in the framework, as assessing them can be very complicated and time consuming, and the intent of the framework is to provide a rapid scoring and selection process. That is not to say that understanding food web impacts, cascading trophic effects, and ecosystem dynamics are not critical to the evaluation of potential effects, only that it was beyond the scope of this work.

6 NEXT STEPS AND FUTURE WORK

A ranked and relative list of most vulnerable sub-groups for the Pacific region was produced by applying the framework to the region. The next steps in the evaluation process, as outlined in the framework overview (Figure 3), are to populate the vulnerable sub-groups with species for a specific area of interest, and identify important areas for these species. The final step in the process is the provision of appropriate geospatial data for each of the identified vulnerable species for planning and response purposes.

To this end, sub-groups identified as most vulnerable in the framework application will be populated with species known to inhabit a specific area of interest in the Pacific region (step 4 in the framework overview). Species will be identified from available literature, experts and species databases. If no examples of species are found for a sub-group in the area of interest, the sub-group will be removed from the analysis. For each species, important areas identified in the available literature will be recorded (step 5 in the framework overview). These important areas will be used to guide the subsequent search for geospatial datasets containing response relevant data for mapping purposes. Examples of important areas will include (migration routes, spawning sites, aggregation areas, etc). Where no explicit examples of important areas are identified in the literature, location information for areas of concentration for the species will be collected and provided for response purposes. The focus on important areas (including areas of concentration) while searching for geospatial datasets is critical to ensuring that only response relevant data are provided; the entire distribution of a species, or presence/absence data, would not appropriately inform responders setting protection priorities in the event of an oil spill.

It is expected that datasets for all species within a vulnerable sub-group will be rolled up into a single sub-group representation, consisting of multiple layers of datasets to be represented in a GIS and used in response planning. Ideally, aspects such as seasonal abundances and breeding can be incorporated, which would align with the NOAA ESI data table format (National Oceanic and Atmospheric Administration, 2002). An assessment of data gaps will be carried out at this stage to identify data that is lacking and required for oil spill response preparedness.

It is important to note that the ranked list of vulnerable sub-groups that is the product of this framework application is intended to be just one component of response preparedness (Figure 1). Oil spill response scenarios will depend not only on the most vulnerable sub-groups outlined by the application, but also on factors such as social and economic values, available resources, and whether mitigation measures are possible for each sub-group.

This application of the framework was designed to provide the basic building blocks for assessing vulnerability to oil spills that can be built on in the future. The following is a compilation of suggestions for work that could be addressed in the future to complement the current application. Some of the suggestions address limitations in the scope of this application, while others were identified when addressing challenges associated with this application of the framework.

- Comparisons with framework applications in other regions: Comparisons of the findings of the Pacific region pilot application with those of the two other pilot applications of the framework underway in the Maritimes and Quebec Regions of Canada will be valuable. The challenges and solutions adopted through framework adaptation by each region will provide insight that can reinforce and improve functionality of, not only the framework, but also the regional applications of the framework. It is expected that the regional application outcomes will reveal a number of shared problems with different proposed solutions, in particular in relation to the use of criteria, scoring and screening methods. The lessons learned from the regional applications will be important for strengthening and improving the framework and future applications.
- Adapting the framework to assess spills of different oil types: the current framework assesses vulnerability based on a worst case scenario spill of whole oil, and does not consider any specific type of oil, despite the fact that the behaviour and toxicity of spilled oil varies depending on the composition of the oil constituents. Future work could involve developing a series of vulnerability frameworks to assess the vulnerability of sub-groups to individual oil types transported by sea in the Pacific region. For each application, the framework components (sub-groups, criteria, screening) could be added to, or adapted, where necessary, based on the characteristics and behaviour of each oil type. The development of a series of Pathways of Effects (PoE) models would elucidate these characteristics and the ways that each type of oil interacts and impacts biological components. This work would result in the development of a suite of vulnerable sub-group lists for each type of oil, valuable for response, but also for planning of different spill scenarios.
- Higher level trophic impacts: The framework does not assess higher level trophic impacts, rather it evaluates vulnerability based on acute effects from direct contact with oil; chronic impacts are only considered in some of the recovery criteria in the current framework. A significant amount of knowledge is required to be able to assess such impacts that may not be available for all sub-groups. However, future work could begin to address this by incorporating higher level trophic impacts for a well studied biological group with a wealth of

research and knowledge, and a relatively simple and studied food web structure, such as marine mammals. The use of criteria to assess important parts of the food web such as diet and prey, as done in Jarvela-Rosenberger et al. (*submitted*), may allow the incorporation of some of these factors.

- Scoring Rubric and Incorporation of Uncertainty: Scoring solely using a binary scoring method (0 or 1) presented a number of challenges during framework application (discussed in Section 0). Rather than using binary scoring, a more detailed scoring rubric, with a range of 0-4 for example, may produce a higher degree of differentiation between sub-groups, and was proposed as future work in Thornborough et al. (2017). More detailed scoring rubrics have been used successfully in Reich et al. (2014) and in ecological risk assessments in the Pacific region (O et al. 2015). The incorporation of a more complex scoring rubric could provide accurate and flexible sub-group assessments with the ability to discern differences more clearly, and may also require less emphasis on detailed scoring guidance. As mentioned in Thornborough et al. (2017), the challenge of a multi-level rubric is the requirement of a method to standardise the scores on a relative scale between criteria for equal weighting.
- Expansion of plankton categories: planktonic organisms such as zooplankton (invertebrates and fishes) and phytoplankton were not assessed at a high resolution in this application of the framework because it was felt that this would result in an unmanageable number of sub-groups for which there would be insufficient scoring information to provide discrimination between sub-groups. In future iterations of this framework, the existing categories of phytoplankton, zooplankton and larval invertebrates could be broken down further; especially where evidence existed that data was available to map and respond to a group.

7 CONCLUSIONS/RECOMMENDATIONS

- 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.
- At present, the chemical sensitivity (impairment due to toxicity) criterion was not effective at differentiating between sub-groups based on vulnerability 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 characterise chemical vulnerability of sub-groups, or that the criterion be scored using multiple levels, rather than binary scoring.
- The screening method used in the framework (requiring sub-groups to fulfill1 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

framework 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 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 necessary 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.

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9 APPENDIX A: LIST OF NATIONAL FRAMEWORK SUB-GROUPS

The original sub-group breakdowns outlined in the framework (Thornborough et al., 2016) for reference to changes made to the Pacific pilot application.

Table A-1. Sub-group breakdown for marine plants/algae from Thornborough et al., 2016

Sub-group breakdown		
Sub-group 1	**Sub-group 2**	**Sub-group 3**
Pelagic	N/A	Phytoplankton
5Benthic	Vascular	Eelgrasses
		Surf grasses
		Saltmarsh grasses
	Non-vascular	Canopy forming kelps
		Understory
		Turf
		Encrusting

Table A-2. Sub-group breakdown for marine invertebrates from Thornborough et al., 2016

Sub-group breakdown			
Sub-group 1	**Sub-group 2**	**Sub-group 3**	**Sub-group 4**
Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Crustacea (*e.g. barnacles*)
			Mollusca (*e.g. oysters*)
			Cnidaria (*e.g. sea anemones*)
			Porifera (e.g. *demosponges*)
			Worms (*e.g. tube worms*)
			Ascidia (*e.g. sea squirts*)
		Low mobility	Worms (*e.g. annelids*)
			Echinoderms (*e.g. sea urchins*)
			Mollusca (*e.g. gastropods*)
		High mobility	Crustacea (*e.g. crabs*)
			Mollusca (*e.g. octopus*)
	Sediment infauna	Low mobility	Mollusca (*e.g. clams*)
			Worms (*e.g. annelids*)
	Sediment epifauna	Low mobility	Mollusca (*e.g. gastropods*)
			Cnidaria (*e.g. sea pens*)
			Echinoderms (*e.g. sea stars*)
		High mobility	Crustacea (*e.g. crabs*)
Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Crustacea (*e.g. barnacles*)
			Mollusca (*e.g. mussels*)
			Cnidaria (*e.g. coral*)
			Porifera (*e.g. glass sponges*)
			Worms (*e.g. tube worms*)
			Ascidia (*e.g. sea squirts*)
		Low mobility	Worms (*e.g. annelids*)
			Echinoderms (*e.g. sea urchins*)
			Mollusca (*e.g. gastropods*)
		High mobility	Crustacea (*e.g. crabs*)
			Mollusca (*e.g. octopus*)
	Sediment infauna	Low mobility	Mollusca (*e.g. clams*)
			Worms (*e.g. annelids*)

Sub-group breakdown			
Sub-group 1	**Sub-group 2**	**Sub-group 3**	**Sub-group 4**
	Sediment epifauna	Low mobility	Mollusca (*e.g. gastropods*)
			Cnidaria (e.*g. sea pens*)
			Echinoderms (*e.g. sea stars*)
		High mobility	Crustacea (*e.g. crabs*)
Pelagic	N/A	Low mobility	Zooplankton
			Cnidaria (*e.g. jellyfish*)
		High mobility	Mollusca (*e.g. squid*)

Table A-3. Sub-group breakdown for marine fish from Thornborough et al., 2016.

Sub-group breakdown		
Sub-group 1	**Sub-group 2**	**Sub-group 3**
Diadromous	Anadromous	Lampreys
		Acipenseridae
		Clupeidae
		Osmeridae
		Salmonidae
	Catadromous	Anguillidae
Estuarine (*excluding migrating groups*)	Demersal/ Semi-demersal	Roundfish
		Rockfish/Redfish
		Flatfish
		Elasmobranchs
Intertidal	Demersal/ Semi-demersal	Roundfish
		Rockfish/Redfish
		Flatfish
		Elasmobranchs
On shelf	Demersal/ Semi-demersal	Roundfish
		Rockfish/Redfish
		Flatfish
		Elasmobranchs
	Small pelagics/ Forage fish	Ammodytidae (*e.g. sandlance*)
		Embiotocidae (*e.g. Surfperch*)
		Clupeidae (*e.g. herring*)
		Osmeridae (*e.g. smelt, eulachon*)
	Large pelagics	Elasmobranchs
		Scombrids
Off shelf	Demersal/ Semi-demersal	Roundfish
		Rockfish/Redfish
		Flatfish
		Elasmobranchs
	Small pelagics/ Forage fish	Clupeidae (*e.g. sardines*)
	Large pelagics	Elasmobranchs

Table A-4. Sub-group breakdown for marine mammals from Thornborough et al., 2016.

Sub-group breakdown		
Sub-group 1	**Sub-group 2**	**Sub-group 3**
Cetaceans	Toothed	Discrete
		Dispersed
	Baleen	Discrete
		Dispersed
Pinnipeds	Thermoregulate with fur	Discrete
		Dispersed
	Other pinnipeds	Discrete
		Dispersed
Mustelids	N/A	N/A

Table A-5. Sub-group breakdown for marine mammals from Thornborough et al., 2016.

Sub-group breakdown		
Sub-group 1	**Sub-group 2**	**Sub-group 3**
Sea Turtles	N/A	N/A

Note: for marine reptiles, only one sub-group was identified – sea turtles.

10 APPENDIX B: FRAMEWORK CRITERIA (THORNBOROUGH ET AL., 2016)

Table B-1a. Proposed concentration (aggregation) and/or site fidelity criterion within the exposure category criteria and guidance for scoring in the framework

Concentration (aggregation) and/or site fidelity	
Question	Does the sub-group contain species that concentrate or aggregate in areas linked to fixed/transient habitat within the study area and/or exhibit site fidelity?
Justification	Organisms that live in high concentrations or aggregate in large numbers in fixed/transient locations. Organisms exhibiting site fidelity may try to remain in, or return to a specific area, even if they were to become oiled.
Scoring guidance	Sub-groups containing species that concentrate in fixed/transient locations for habitat, feeding, or breeding; Sub-groups containing species that exhibit site fidelity.

Table B-1b. Proposed mobility criterion within the exposure category criteria and guidance for scoring in the framework

Mobility	
Question	Does the sub-group contain species with low or no mobility?
Justification	Organisms that are unable to, or have limited ability to move away from spilled oil, or are known to be attracted to spilled oil are likely to have higher exposure to spilled oil.
Scoring guidance	Sub-groups containing species with sessile life-stages (e.g. sponges, corals, kelp, sea grass, etc.); sub-groups containing species with low mobility (e.g. echinoderms); sub-groups containing species with evidence of attraction to spilled oil.

Table B-1c. Proposed sea surface interacting criterion within the exposure category criteria and guidance for scoring in the framework

Sea surface interacting	
Question	Does the sub-group contain species that are reliant on or have regular interaction with the air/near sea surface, including intertidal areas?
Justification	The sea surface is the first point of contact in a ship-sourced spill. Therefore, organisms reliant on or with regular interaction with the sea surface have an increased likelihood of exposure to spilled oil. The intertidal zone is likely to experience significant exposure from floating oil spills as tidal movements bring species in direct contact with oil (Chang et al., 2014).
Scoring guidance	Sub-groups containing species that are reliant on or have regular interaction with the near-surface of the ocean (e.g. marine mammals, basking sharks). This includes intertidal species as intertidal areas regularly interact with the surface. The depth of the surface layer (e.g. sea-air interface or -10 m) should be defined by regional conditions (i.e. localised hydrodynamics).

Table B-1d. Proposed sediment interacting criterion within the exposure category criteria and guidance for scoring in the framework

Sediment interacting	
Question	Does the sub-group contain species closely associated with types of sediment that can retain oil for long periods?
Justification	Reoccurring direct exposure due to persistence of oil in sediments. Contaminated sediments can expose associated individuals in a population repeatedly. This is still considered an acute impact since it is not due to chronic (or multiple exposures) to a single individual. Rather this type of reoccurring exposure impacts a greater proportion of the population through direct contact.
Scoring guidance	Sub-groups containing species that inhabit sediment such as eelgrass and other sediment dwellers such as clams; Sub-groups containing species which spend a significant proportion of time in close association with sediment (e.g. grey whales feeding within sediments).

Table B-2a. Proposed sensitivity criteria and guidance for scoring

MECHANICAL SENSITIVITY	
Loss of insulation	
Question	Does contact with oil result in a loss of insulation/ability to thermoregulate for species in the sub-group?
Justification	Oil causes a substantial decrease in the insulative value of fur, inhibiting the ability of affected organisms to thermoregulate (Reich et al. 2014).
Scoring guidance	Sub-groups containing species reliant on fur as their primary means of thermoregulation.
Reduction of feeding/photosynthesis	
Question	Does direct contact with oil result in the mechanical impairment of feeding structures for species in the sub-group?
Justification	Fouling of feeding structures by oil may reduce the ability of organisms to feed, reducing their condition and reproductive capacity and increasing time spent feeding (Reich et al. 2014).
Scoring guidance	Sub-groups that contain species that feed by filtering water through their systems and removing particles (filter-feeders); sub-groups containing species that photosynthesize (smothering effects reducing photosynthesis).

Table B-2b. Proposed impairment due to toxicity criterion within the sensitivity category criteria and guidance for scoring

CHEMICAL SENSITIVITY	
Impairment due to toxicity	
Question	Does direct contact with oil result in severe, irreversible effects or death for species in the sub-group?
Justification	Organisms that are more sensitive to toxic effects of oil are more likely to experience irreversible effects or death.
Scoring guidance	Sub-groups containing species that display severe, irreversible effects or death due to oil toxicity. Acute effects from direct contact include: the inability of animals to digest and absorb foods; reproductive failure; respiratory failure; lesions; hemorrhaging; neurological impairment; and mortality.

Table B-3a. Proposed population status criterion within the recovery category criteria and guidance for scoring

Population status	
Question	Does the sub-group contain species with reduced or declining population levels?
Justification	Sub-groups containing species with greatly reduced or declining population numbers (in particular breeding population numbers) are compromised in their ability to recover from an impact, in contrast to those with healthy population levels which are most capable of recovering (Reich et al. 2014). Conservation status can be used as a proxy for reduced or declining population levels.
Scoring guidance	Sub-groups containing species with: low population levels relative to historic (incorporates groups underrepresented/not assessed in conservation indices) (e.g. stock assessment zones – healthy/cautious/critical); greatly reduced breeding population numbers relative to historic; special conservation status (a proxy for a low population status), e.g. Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended, Species at Risk Act (SARA) listed, International Union for Conservation of Nature (IUCN) listed; Provincially listed.

Table B-3b. Proposed reproductive capacity criterion within the recovery category criteria and guidance for scoring

Reproductive capacity	
Question	Does the sub-group contain species with low reproductive capacity?
Justification	Reproductive capacity of a species is a key contributor to population recovery. Sub-groups containing species with low reproductive capacity can be slow to recover from impact even with high population levels, whereas species with relatively high reproductive capacity are inherently more capable of population recovery from oil spill impacts (Reich et al. 2014).
Scoring guidance	Sub-groups that contain K-strategist species (i.e. have a longer life expectancy, grow and mature more slowly, and have fewer progeny with higher reproductive investment); Sub-groups that contain species with sporadic, infrequent, or density dependent recruitment success.

Table B-3c. Proposed endemism or isolation criterion within the recovery category criteria and guidance for scoring

Endemism or isolation	
Question	Does the sub-group contain endemic species or isolated populations that have limited distribution within the region?
Justification	Sub-groups that contain species or populations endemic or isolated in the area are more likely to have a greater proportion of the population impacted by an oil spill, as well as decreased ability of the population to recolonise an area (Reich et al. 2014).
Scoring guidance	Sub-groups containing endemic or isolated populations with limited distribution within the region. Assessed only for the period the species was present in the area of interest (e.g. seasonal abundances of species at certain times of the year).

Table B-3d. Proposed close association with sediments criterion within the recovery category criteria and guidance for scoring

Close association with sediments	
Question	Does the sub-group contain species that are closely associated with sediments types that can retain oil for long periods of time?
Justification	Sediments retaining oil can expose associated organisms for decades after a spill hindering their recovery. Aliphatic and polycylic aromatic hydrocarbon fractions of dissolved petroleum accumulate in sediments and can affect benthic organisms long after spill events (Gunster et al. 1993; Kennish 1996).
Scoring guidance	Sub-groups containing species that inhabit sediment such as eelgrass and other sediment dwellers such as clams, worms; sub-groups containing species which spend a significant proportion of time in close association with sediment (e.g. grey whales feeding within sediments).

11 APPENDIX C: DETAILED SCORING TABLES WITH JUSTIFICATIONS FOR MARINE PLANTS/ALGAE

*Table C-1. Marine plant and algae scores for EXPOSURE criteria, the column labelled "S" indicates the score assigned (note: Species lists are not exhaustive; scores with a * indicate a precautionary score due to lack of knowledge)*

SUB-GROUP LEVEL				**Pacific example species**	**EXPOSURE Criteria**							
					Concentration (aggregation)		**Mobility and/or exhibit site fidelity**		**Sea surface interacting**		**Seafloor or vegetation interacting**	
1	**2**	**3**	**4**		**S**	**Justification**	**S**	**Justification**	**S**	**Justification**	**S**	**Justification**
Intertidal	Vascular Plants	High energy, rocky habitat	Sea grasses	E.g. *Phyllospadix scouleri, P. torreyi, P. serrulatus*	1*	*Phyllospadix* plants can grow in large single species aggregations, or occur in smaller patches	1	All plants are immobile	1	Primary habitat for surfgrasses ranges from the upper intertidal to shallow subtidal- plants would interact with the surface from either location (Green & Short 2003)	1	*Phyllospadix* roots are in close association with a thin layer of sediment trapped between the rhizomes and directly attached to rocks (O'Brien & Dixon 1976)
		Moderate to low energy unconsolidated habitat	Sea grasses	E.g. *Zostera marina, Z. japonica, Ruppia maritima*	1	Both native and non-native *Zostera* species frequently grow in large single species stands (Phillips et al. 1983)	1	All plants are immobile	1	Primary habitat for eelgrasses is mid-low intertidal and shallow subtidal; intertidal and some subtidal plants would interact with the surface (Green & Short 2003)	1	Vascular plants are rooted in unconsolidated substrates
			Salt marsh grasses	E.g. *Carex lyngbyei, Leymus mollis*	1	Low species diversity is typical; *Carex lyngbyei* often occurs in dense, monospecific stands (Mackenzie & Moran 2004)	1	All plants are immobile	1	Primary habitat for saltmarsh grasses is mid intertidal to supratidal; all plants would interact with the surface (Mackenzie & Moran 2004)	1	Vascular plants are rooted in soft substrates
			Salt marsh succulents	E.g. *Sarcocornia virginica, S. pacifica, Glaux maritima, Plantago maritima*	1	*Sarcocornia* and *Glaux maritima* often occur in dense, pure stands (Mackenzie & Moran 2004)	1	All plants are immobile	1	Primary habitat for saltmarsh succulents is mid intertidal to supratidal; all plants would interact with the surface (Mackenzie & Moran 2004)	1	Vascular plants are rooted in unconsolidated substrates
	Canopy Algae	High energy, rocky habitat	N/A	E.g. *Egregia menziesii, Laminaria setchellii, Mazzaella splendens, Lessioniopsis littoralis, Postelsia palmaeformis*	0	Species in this sub-group are concentrated in areas where habitat conditions meet their specific needs; in particular at certain tidal elevations; but, as these bands are not discrete, and the species are often ubiquitous across them, it is not considered to aggregate	1	All algae are immobile	1	*Egregia* grows in the low intertidal and shallow subtidal; given their length, plants at any tidal elevation could interact with the surface (Mondragon & Mondragon 2003)	1*	Species in the intertidal will interact with the seafloor when they are exposed on a low tide, although it is possible this habitat would not retain oil for long periods
	Understory / Turf Algae	High energy, rocky habitat	N/A	E.g. *Pelvetiopsis limitata, Cymathere triplicata, , Palmaria hecatensis, Corallina vancouveriensis, Alaria fistulosa*	0	See explanation for 'High energy, intertidal, rocky habitat canopies (*Egregia*)' above	1	All algae are immobile	1	By definition, intertidal species will interact with the surface on a low tide	1*	Species in the intertidal will interact with the seafloor when they are exposed on a low tide, although it is possible this habitat would not retain oil for long periods

SUB-GROUP LEVEL				Pacific example species	EXPOSURE Criteria							
					Concentration (aggregation)		Mobility and/or exhibit site fidelity		Sea surface interacting		Seafloor or vegetation interacting	
1	**2**	**3**	**4**		**S**	**Justification**	**S**	**Justification**	**S**	**Justification**	**S**	**Justification**
		Moderate to low energy rocky habitat	N/A	E.g. *Neorhodomela larix, Desmarestia* sp., *Laminaria saccharina, Calliarthron* spp.	0	See explanation for 'High energy, intertidal, rocky habitat canopies (*Egregia*)' above	1	All algae are immobile	1	By definition, intertidal species will interact with the surface on a low tide	1	Species in the intertidal will interact with the seafloor when they are exposed on a low tide
	Encrusting Algae	Rocky habitat	N/A	E.g. *Coralline algae, Codium setchellii, Hildenbrandia* sp, *Mastocarpus (crust form), Ralfsia pacifica*	0	Some species are found in isolated patches (*Codium setchelli*), while others are very widespread (coralline algae); none should be considered aggregating (Mondragon & Mondragon 2003)	1	All algae are immobile	1	By definition, intertidal species will interact with the surface on a low tide	1	Species in the intertidal will interact with the seafloor when they are exposed on a low tide
Subtidal	Canopy Algae	High energy, rocky habitat	N/A	E.g. *Nereocystis leutkeana, Egregia menziesii, Pterygophora californica*	1	*Nereocystis* forms extensive beds in the shallow subtidal (Mondragon & Mondragon 2003)	1	All algae are immobile	1	Due to their height and presence of floats, these species interact with the surface from the subtidal zone	0	Species in this sub-group have floats that keep their fronds above the seafloor and out of contact with unconsolidated substrates
		Moderate to low energy rocky habitat	N/A	E.g. *Macrocystis integrifolia*	1	*Macrocystis* forms extensive beds in the shallow subtidal (Mondragon & Mondragon 2003)	1	All algae are immobile	1	Given their height, and presence of floats/woody stipe, canopy species often reach the sea surface from the subtidal zone	0	Species in this sub-group have floats or woody stipes that keep their fronds above the seafloor and out of contact with unconsolidated substrates
	Understory Algae	Rocky habitat	With tall, woody stipes or floats	*E.g. Pterygophera californica, Sargassum muticum, Lessoniopsis littoralis*	0	See explanation for 'High energy, intertidal, rocky habitat canopies (*Egregia*)' above	1	All algae are immobile	1	Some woody stipe species, or those with floats, in this sub-group may be tall enough to reach the sea surface from the shallow subtidal environment	0	Species in this sub-group may be held out of contact with the seafloor by their stiff stipes or floats
			Without tall, woody stipes or floats	E.g. *Desmarestia sp, Agarum fimbriatum, Laminaria* sp.*, Prionitis lyallii*	0	See explanation for 'High energy, intertidal, rocky habitat canopies (*Egregia*)' above	1	All algae are immobile	0	Species in this sub-group lack stiff stipes or floats that would allow them to reach the sea surface from the subtidal environment	1	Species in this sub-group do not have a stiff stipe or floats to hold them away from the seafloor and so will be in contact with it
	Turf Algae	Rocky habitat	N/A	E.g. *Callophyllis* sp; *Dictyota binghamiae, Sarcodiotheca furcata, Rhodymenia pacifica*	0	See explanation for 'High energy, intertidal, rocky habitat canopies (*Egregia*)' above	1	All algae are immobile	0	The species in this sub-group are not expected to be tall enough to reach the sea surface from the subtidal environment	1	Algae in this sub-group are not tall, and will be in contact with the substrate to which they are anchored
	Encrusting Algae	Rocky habitat	N/A	E.g. Coralline algal crusts, *Hildenbrandia* sp	0	Coralline algae crusts are widespread in many areas	1	All algae are immobile	0	An encrusting seaweed in the subtidal would not interact with the sea surface	1	Encrusting algae grow directly over rocks, thereby interacting with the substrate

SUB-GROUP LEVEL				Pacific example species	EXPOSURE Criteria							
					Concentration (aggregation)		Mobility and/or exhibit site fidelity		Sea surface interacting		Seafloor or vegetation interacting	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
Pelagic	Phytoplankton	N/A	N/A	-	1*	Phytoplankton are ubiquitous, but can also occur in discrete, single species blooms that could be considered an aggregation	1	All algae are immobile	1	Phytoplankton are found throughout the water column and many would interact with the surface	0	This sub-group is pelagic and not expected to interact with the seafloor

*Table C-2. Marine plants and algae scores for SENSITIVITY criteria, the column labelled "S" indicates the score assigned (note: Species lists are not exhaustive; and scores with a * indicate a precautionary score due to lack of knowledge)*

SUB-GROUP LEVEL				**Pacific example species**	**SENSITIVITY Criteria**			
					Mechanical sensitivity (reduction in feeding/photosynthesis/insulation)		**Mechanical sensitivity (reduction in feeding/photosynthesis/insulation)**	
1	**2**	**3**	**4**		**S**	**Justification**	**S**	**Justification**
Intertidal	Vascular Plants	High energy, rocky habitat	Sea grasses	E.g. *Phyllospadix scouleri, P. torreyi, P. serrulatus*	1	*Phyllospadix* plants have been documented to trap oil between their blades (Foster et al. 1971)	1*	Soluble oil compounds are hydrophobic and are concentrated in the thylakoid membrane where they impair the photosynthetic ability of the plant (Runcie et al. 2004), but a lack of baseline data and standardised methods make results difficult to compare
		Moderate to low energy unconsolidated habitat	Sea grasses	E.g. *Zostera marina, Z. japonica, Ruppia maritima*	1	-	1*	Soluble oil compounds are hydrophobic and are concentrated in the thylakoid membrane where they impair the photosynthetic ability of the plant (Runcie et al. 2004), but a lack of baseline data and standardised methods make results difficult to compare
			Salt marsh grasses	E.g. *Carex lyngbyei, Leymus mollis*	1*	Tall, reedy or stiff grassy stems are more likely to stand above the oil, so photosynthetic impairment may not occur for some species in this sub-group (Morris & Harper 2006). Plants that are coated do experience photosynthetic impairment (Pezeshki et al. 2000)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Salt marsh succulents	E.g. *Sarcocornia virginica, S. pacifica, Glaux maritima, Plantago maritima*	1	Marsh plants coated in oil experience photosynthetic impairment (Pezeshki et al. 2000)	1*	Succulent type plants may be particularly sensitive to oil (Davy et al. 2001), but a lack of baseline data and standardised methods make results difficult to compare
	Canopy Algae	High energy, rocky habitat	N/A	E.g. *Egregia menziesii, Laminaria setchellii, Mazzaella splendens, Lessioniopsis littoralis, Postelsia palmaeformis*	1*	High energy environments do not retain oil for as long as low energy environments (Pecko et al. 1990), so photosynthetic impairment maybe less than in wave sheltered environments	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
	Understory / Turf Algae	High energy, rocky habitat	N/A	E.g. *Pelvetiopsis limitata, Cymathere triplicata, , Palmaria hecatensis, Corallina vancouveriensis, Alaria fistulosa*	1*	High energy environments do not retain oil for as long as low energy environments (Pecko et al. 1990), so photosynthetic impairment may be less than in wave sheltered environments. Futhermore, algae that grow directly beneath fronds of taller species may avoid smothering by oil in the same fashion that the inner portion of a profusely branched algae can remain uncoated (O'Brien & Dixon 1976)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
		Moderate to low energy rocky habitat	N/A	E.g. *Neorhodomela larix, Desmarestia* sp., *Laminaria saccharina, Calliarthron* spp.	1*	Algae that grow directly beneath fronds of taller species may avoid smothering by oil in the same fashion that the inner portion of a profusely branched algae can remain uncoated (O'Brien & Dixon 1976)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
	Encrusting Algae	Rocky habitat	N/A	E.g. *Coralline algae, Codium setchellii, Hildenbrandia* sp, *Mastocarpus (crust form), Ralfsia pacifica*	1	Photosynthetic impairment due to smothering is documented in marine algae, and is related to thickness of oil (O'Brien & Dixon 1976)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group

SUB-GROUP LEVEL				**Pacific example species**	**SENSITIVITY Criteria**			
					Mechanical sensitivity (reduction in feeding/photosynthesis/insulation)		**Mechanical sensitivity (reduction in feeding/photosynthesis/insulation)**	
1	**2**	**3**	**4**		**S**	**Justification**	**S**	**Justification**
Subtidal	Canopy Algae	High energy, rocky habitat	N/A	E.g. *Nereocystis leutkeana, Egregia menziesii, Pterygophora californica*	1*	High energy environments do not retain oil for as long as low energy environments (Pecko et al. 1990, so photosynthetic impairment may be less than in wave sheltered environments	1*	Impairment of photosynthesis has been documented for *Nereocystis* after exposure to oil for 4 and 24 hrs (Antrim et al. 1995), but a lack of baseline data and standardised methods make results difficult to compare
		Moderate to low energy rocky habitat	N/A	E.g. *Macrocystis integrifolia*	1	Photosynthetic impairment due to smothering is documented in marine algae, and is related to thickness of oil (O'Brien & Dixon 1976)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
	Understory Algae	Rocky habitat	With tall, woody stipes or floats	*E.g. Pterygophera californica, Sargassum muticum, Lessoniopsis littoralis*	1	Photosynthetic impairment due to smothering is documented in marine algae, and is related to thickness of oil (O'Brien & Dixon 1976)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Without tall, woody stipes or floats	E.g. *Desmarestia sp, Agarum fimbriatum, Laminaria* sp., *Prionitis lyallii*	1	Photosynthetic impairment due to smothering is documented in marine algae, and is related to thickness of oil (O'Brien & Dixon 1976)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
	Turf Algae	Rocky habitat	N/A	E.g. *Callophyllis* sp; *Dictyota binghamiae, Sarcodiotheca furcata, Rhodymenia pacifica*	1	Photosynthetic impairment due to smothering is documented in marine algae, and is related to thickness of oil (O'Brien & Dixon 1976)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
	Encrusting Algae	Rocky habitat	N/A	E.g. Coralline algal crusts, *Hildenbrandia* sp	1	Photosynthetic impairment due to smothering is documented in marine algae, and is related to thickness of oil (O'Brien & Dixon 1976)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
Pelagic	Phytoplankton	N/A	N/A	-	0	Phytoplankton are unlikely to be smothered by oil due to their small size and the fact that they are pelagic	1*	At low concentrations, exposure to oil can actually stimulate growth of some species (< 1.0 mg/L), but at higher concentrations causes growth inhibition (Ozhan et al. 2014)

*Table C-3. Marine plants and algae scores for RECOVERY criteria, the column labelled "S" indicates the score assigned (note: Species lists are not exhaustive; and scores with a * indicate a precautionary score due to lack of knowledge)*

SUB-GROUP LEVEL				**Pacific examples**	**RECOVERY criteria**							
					Population status		**Reproductive capacity**		**Endemism or Isolation**		**Close association with unconsolidated substrates**	
1	2	3	4		**S**	**Justification**	**S**	**Justification**	**S**	**Justification**	**S**	**Justification**
Intertidal	Vascular Plants	High energy, rocky habitat	Sea grasses	E.g. *Phyllospadix scouleri, P. torreyi, P. serrulatus*	0	-	1*	-	0	No evidence of endemic/isolated populations	1	*Phyllospadix* roots are in close association with the thin layer of sediment trapped around the rhizomes, but the amount of sediment is minimal compared to *Zostera* roots (O'Brien & Dixon 1976).
		Moderate to low energy unconsolidated habitat	Sea grasses	E.g. *Zostera marina, Z. japonica, Ruppia maritima*	1	Eelgrass has been documented to be in decline in many areas of the Salish Sea (Thom et al. 2011)	1*	*Zostera* marina beds rely on asexual rhizome expansion rather than seeds for bed expansion and persistence in British Columbia (Phillips et al. 1983). Eelgrass beds have been documented to recover quickly after damage from oils spills when only leaves are damaged (Dean et al. 1998), but recovery is predicted to be slow if damage to rhizomes occurs (Zieman et al. 1984)	0	No evidence of endemic/isolated populations	1	The roots and rhizomes of *Zostera* grow within unconsolidated substrates
			Salt marsh grasses	E.g. *Carex lyngbyei, Leymus mollis*	1*	-	1*	Perennial plants are generally faster to recover than annuals (Hampson & Moul 1978)	0	No evidence of endemic/isolated populations	1	The roots of all vascular marsh plants are in close association with unconsolidated substrates. Oil can persist in marshes for decades and hinder recovery (Culbertson et al. 2008)
			Salt marsh succulents	E.g. *Sarcocornia virginica, S. pacifica, Glaux maritima, Plantago maritima*	1*	-	1*	-	0	No evidence of endemic/isolated populations	1	The roots of all vascular marsh plants are in close association with unconsolidated substrates. Oil can persist in marshes for decades and hinder recovery (Culbertson et al. 2008)
	Canopy Algae	High energy, rocky habitat	N/A	E.g. *Egregia menziesii, Laminaria setchellii, Mazzaella splendens, Lessioniopsis littoralis, Postelsia palmaeformis*	0	-	0	Algae species can have either opportunistic or late successional life history strategies, but most are classified as having a relatively high reproductive capacity when compared to other ecosystem components (such as whales) (Lobban & Harrison 1994)		No evidence of endemic/isolated populations	0	Algae have no roots and grow on rocks; therefore, not in close association with unconsolidated substrates
	Understory / Turf Algae	High energy, rocky habitat	N/A	E.g. *Pelvetiopsis limitata, Cymathere triplicata, , Palmaria hecatensis, Corallina vancouveriensis, Alaria fistulosa*	0	-	1	*Laminaria setchelli* does not become reproductive until 3-5 years after establishment and can live for up to 25 years (Lobban & Harrison 1994)	0	No evidence of endemic/isolated populations	0	Algae have no roots and grow on rocks; therefore, not in close association with unconsolidated substrates
		Moderate to low energy rocky habitat	N/A	E.g. *Neorhodomela larix, Desmarestia* sp., *Laminaria saccharina, Calliarthron* spp.	0	-	0	See explanation for 'intertidal, canopy, high energy rocky shore' (*Egregia*) (Lobban & Harrison 1994)	0	No evidence of endemic/isolated populations	0	Algae have no roots and grow on rocks; therefore, not in close association with unconsolidated substrates
	s ti n g	Rocky habitat	N/A	E.g. *Coralline algae, Codium setchellii,*	0	-	0	See explanation for 'intertidal, canopy, high energy rocky shore'	0	No evidence of endemic/isolated	0	Algae have no roots and grow on rocks; therefore, not in close

				Hildenbrandia sp, *Mastocarpus (crust form), Ralfsia pacifica*				(*Egregia*) (Lobban & Harrison 1994)		populations		association with unconsolidated substrates
Subtidal	Canopy Algae	High energy, rocky habitat	N/A	E.g. *Nereocystis leutkeana, Egregia menziesii, Pterygophora californica*	1*	There have been increasing reports of canopy kelp decline in past few years (*Nereocystis* and *Macrocystis*). Most recent kelp report from DNR in Wash showed declines (Ecoscan Resource Data 2015), and many local community groups in B.C. are reporting declines (eg Help the Kelp)	0	See explanation for ‘intertidal, canopy, high energy rocky shore’ (*Egregia*) (Lobban & Harrison 1994)	0	No evidence of endemic/isolated populations	0	Algae have no roots and grow on rocks; therefore, not in close association with unconsolidated substrates
		Moderate to low energy rocky habitat	N/A	E.g. *Macrocystis integrifolia*	1*	See explanation for ‘subtidal, canopy, high energy rocky shore’ (*Nereocystis*)	1	*Pterygophera* does not become reproductive until 3-5 years after establishment and can live for up to 25 years (Lobban & Harrison 1994)	0	No evidence of endemic/isolated populations	0	Algae have no roots and grow on rocks; therefore, not in close association with unconsolidated substrates
	Understory Algae	Rocky habitat	With tall, woody stipes or floats	*E.g. Pterygophera californica, Sargassum muticum, Lessoniopsis littoralis*	0	-	0	See explanation for ‘intertidal, canopy, high energy rocky shore’ (*Egregia*) (Lobban & Harrison 1994)	0	No evidence of endemic/isolated populations	0	Algae have no roots and grow on rocks; therefore, not in close association with unconsolidated substrates
			Without tall, woody stipes or floats	E.g. *Desmarestia* sp*, Agarum fimbriatum, Laminaria* sp.*, Prionitis lyallii*	0	-	0	See explanation for ‘intertidal, canopy, high energy rocky shore’ (*Egregia*) (Lobban & Harrison 1994)	0	No evidence of endemic/isolated populations	0	Algae have no roots and grow on rocks; therefore, not in close association with unconsolidated substrates
	Turf Algae	Rocky habitat	N/A	E.g. *Callophyllis* sp; *Dictyota binghamiae, Sarcodiotheca furcata, Rhodymenia pacifica*	0	-	0	See explanation for ‘intertidal, canopy, high energy rocky shore’ (*Egregia*) (Lobban & Harrison 1994)	0	No evidence of endemic/isolated populations	0	Algae have no roots and grow on rocks; therefore, not in close association with unconsolidated substrates
	Encrusting Algae	Rocky habitat	N/A	E.g. Coralline algal crusts, *Hildenbrandia* sp	0	-	0	See explanation for ‘intertidal, canopy, high energy rocky shore’ (*Egregia*) (Lobban & Harrison 1994)	0	No evidence of endemic/isolated populations	0	Algae have no roots and grow on rocks; therefore, not in close association with unconsolidated substrates
Pelagic	Phytoplankton	N/A	N/A	-	0	-	0	See explanation for ‘intertidal, canopy, high energy rocky shore’ (*Egregia*)	0	No evidence of endemic/isolated populations	0	This sub-group is pelagic and not expected to interact with unconsolidated substrates

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12 APPENDIX D: DETAILED SCORING TABLES WITH JUSTIFICATIONS FOR MARINE INVERTEBRATES

Table D-1. Marine invertebrates scores for EXPOSURE criteria, *the column labelled "S" indicates the score assigned* (note: Species list is not exhaustive, and scores with a * next to them indicate a precautionary score due to lack of knowledge)

SUB-GROUP LEVEL				**Pacific example species**	**EXPOSURE Criteria**							
					Concentration (aggregation)		**Mobility and/or exhibit site fidelity**		**Sea surface interacting**		**Seafloor or vegetation interacting**	
1	**2**	**3**	**4**		**S**	**Justification**	**S**	**Justification**	**S**	**Justification**	**S**	**Justification**
Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Arthro-poda	*e.g. barnacles [Cirripedia]*	1	Several barnacles have gregarious recruitment (e.g. *Balanus nubilus*)(Burke 1986; Rudy and Rudy 1983)	1	Sessile sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Mollusca	*e.g. oysters [Bivalvia]*	1	*Crassostrea gigas* oysters have gregarious recruitment (Vasquez et al. 2013)	1	Sessile sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Cnidaria	*e.g. coral*	1	Gregarious recruitment (Shanks 2001)	1	Sessile sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Porifera	e.g. *demosponges*	1	Gregarious recruitment (Shanks 2001)	1	Sessile sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Worms	*e.g. tube worms [Polychaeta: Sedentaria]*	1	*Eudistylia vancouveri* have gregarious recruitment (Rudy and Rudy 1983)	1	Sessile sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Urochor-data	*e.g. sea squirts*	1	Gregarious recruitment (Shanks 2001)	1	Sessile sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Lopho-phorates	*e.g.bryozoans [Ectoprocta]; lampshells [Brachiopoda]*	1	Gregarious recruitment (Shanks 2001)	1	Sessile sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
		Low mobility	Worms	*e.g. polychaetes [Errantia]; nemerteans*	1	Spawning aggregations (Blake 1975)	1	Low mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Arthro-poda	*e.g. isopods [Isopoda]*	1	Isopods aggregate for social and reproductive reasons (Heip 1976)	1	Low mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Cnidaria	*e.g. sea anemones*	1	*Anthopleura elegantissima* displays gregarious settlement (Ford 1964)	1	Low mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Mollusca	*e.g. chitons [Cl. Polyplacopora]; snails [Cl. Gastropoda]*	1	Breeding aggregations (Heip 1976)	1	Low mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Echinode rmata	*e.g. sea urchins [Echinoidea];sea cucumbers [Holothuroidea]; sea stars [Asteroidea]*	1	Sea urchins aggregate for defense and feeding (Vadas et al. 1986)	1	Low mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation

SUB-GROUP LEVEL				Pacific example species	EXPOSURE Criteria							
					Concentration (aggregation)		Mobility and/or exhibit site fidelity		Sea surface interacting		Seafloor or vegetation interacting	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
		High mobility	Arthro-poda	*e.g. crabs [Decapoda]*	1	Several crabs form breeding aggregations (Stevens et al. 1994; Stevens et al. 1992)	0	High mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Arthro-poda (filter feeders)	*porcelain crabs*	1	Porcelain crabs have gregarious recruitment behaviour (Jensen 1989)	0	High mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Mollusca	*e.g. octopuses*	0	Giant Pacific octopus is solitary (Kubodera 1991)	1	High mobility sub-group, but exhibits site fidelity (Kubodera 1991)	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
	Sediment infauna	Low mobility	Mollusca	*e.g. clams [Bivalvia]; snails [Gastropoda]*	1	Conspecific aggregation is common for many bivalve species and is important for spawning synchronization and fertilization success (Sastry 1979)	1	Low mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Sediment infauna live within the seafloor substrate, so have regular interaction
			Worms	*e.g. burrowers*	1	Gregarious recruitment (Shanks 2001)	1	Low mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Sediment infauna live within the seafloor substrate, so have regular interaction
			Arthro-poda	*e.g. sand crabs [Emerita]*	1	More highly aggregated during breeding season (Perry 1980)	1	Low mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Sediment infauna live within the seafloor substrate, so have regular interaction
			Lopho-phorates	*e.g. horseshoe worms [Phoronida]; lampshells [Brachiopoda]*	1	Gregarious recruitment (Shanks 2001)	1	Low mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Sediment infauna live within the seafloor substrate, so have regular interaction
	Sediment epifauna	Low mobility	Mollusca	*e.g. snails [Cl. Gastropoda]*	1	Can be highly aggregated, particularly during breeding; e.g. Nucella lamellosa (was Thais lamellosa) (Spight 1974)	1	Low mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Sediment epifauna live in close contact with the seafloor, so have regular interaction
			Cnidaria	*e.g. sea pens*	1	Gregarious recruitment (Shanks 2001); Sea whips aggregate as well (Lindholm et al. 2008)	1	Low mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Sediment epifauna live in close contact with the seafloor, so have regular interaction
			Echino-dermata	*e.g. sea stars*	1	Feeding aggregations; e.g.Pisaster ochraceus feeding on mussel beds (Mcclintock and Robnett 1986)	1	Low mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Sediment epifauna live in close contact with the seafloor, so have regular interaction
		High mobility	Arthro-poda	*e.g. crabs*	1	Several crabs form breeding aggregations (Stevens et al. 1994; Stevens et al. 1992)	0	High mobility sub-group	1	Primary habitat is the intertidal, which is in regular contact with the sea surface	1	Sediment epifauna live in close contact with the seafloor, so have regular interaction

SUB-GROUP LEVEL				Pacific example species	EXPOSURE Criteria							
					Concentration (aggregation)		Mobility and/or exhibit site fidelity		Sea surface interacting		Seafloor or vegetation interacting	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Arthro-poda	*e.g. barnacles [Cirripedia]*	1	Gregarious recruitment (Shanks 2001)	1	Sessile sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Mollusca	*e.g. rock scallops [Bivalvia]*	1	Conspecific aggregation is common for many bivalve species and is important for spawning synchronization and fertilization success (Sastry 1979)	1	Sessile sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Cnidaria	*e.g. coral*	1	Gregarious recruitment (Shanks 2001)	1	Sessile sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Porifera	*e.g. glass sponges*	1	Gregarious recruitment (Shanks 2001)	1	Sessile sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Worms	*e.g. tube worms [Polychaeta: Sedentaria]*	1	Gregarious recruitment (Shanks 2001)	1	Sessile sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Urochordata	*e.g. sea squirts*	1	Gregarious recruitment (Shanks 2001)	1	Sessile sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Lopho-phorates	*e.g.bryozoans [Ectoprocta]; lampshells [Brachiopoda]*	1	Gregarious recruitment (Shanks 2001)	1	Sessile sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
		Low mobility	Worms	*e.g. annelids*	1	Breeding aggregations (Blake 1975)	1	Low mobility sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Cnidaria	*e.g. sea anemones*	1	Anemones display gregarious settlement (Ford 1964)	1	Low mobility sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Echino-dermata	*e.g. sea urchins, sea stars*	1	Sea urchins aggregate for defense and feeding (Vadas et al. 1986)	1	Low mobility sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Mollusca	*e.g. snails [Cl. Gastropoda]*	1	Can be highly aggregated, particularly during breeding; e.g. *Nucella lamellosa* (was *Thais lamellosa*) (Spight 1974)	1	Low mobility sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation

SUB-GROUP LEVEL				Pacific example species	EXPOSURE Criteria							
					Concentration (aggregation)		Mobility and/or exhibit site fidelity		Sea surface interacting		Seafloor or vegetation interacting	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
		High mobility	Arthropoda	*e.g. crabs*	1	Several crabs form breeding aggregations (Stevens et al. 1994; Stevens et al. 1992)	0	High mobility sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
			Mollusca	*e.g. octopuses*	0	Giant Pacific octopus is solitary (Kubodera 1991)	1	Giant Pacific octopus exhibits site fidelity (Kubodera 1991)	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Rock and rubble dwellers live in contact with the seafloor and/or vegetation
	Sediment infauna	Low mobility	Mollusca	*e.g. clams*	1	Conspecific aggregation is common for many bivalve species and is important for spawning synchronization and fertilization success (Sastry 1979)	1	Low mobility sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Sediment infauna live within the seafloor substrate, so have regular interaction
			Worms	*e.g. annelids*	1	Spawning aggregations (Blake 1975)	1	Low mobility sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Sediment infauna live within the seafloor substrate, so have regular interaction
			Lophophorates	*e.g. horseshoe worms [Phoronida]; lampshells [Brachiopoda]*	1	Gregarious recruitment (Shanks 2001)	1	Low mobility sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Sediment infauna live within the seafloor substrate, so have regular interaction
	Sediment epifauna	Low mobility	Mollusca	*e.g. snails [Cl. Gastropoda]*	1	Some groups/species are almost always found in at least small aggregations eg *Bittium* (Reviewer comment: Heidi Gartner)	1	Low mobility sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Sediment epifauna live in close contact with the seafloor, so have regular interaction
			Cnidaria	e.g. sea pens	1	*Ptilosarcus guerneyi* and several other hydrozoans have gregarious recruitment (Burke 1986)	1	Low mobility sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Sediment epifauna live in close contact with the seafloor, so have regular interaction
			Echinodermata	e.g. sea stars	1	Feeding aggregations; e.g.*Pisaster ochraceus* feeding on mussel beds (Mcclintock and Robnett 1986)	1	Low mobility sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Sediment epifauna live in close contact with the seafloor, so have regular interaction
		High mobility	Arthropoda	e.g. crabs	1	Several crabs form breeding aggregations (Stevens et al. 1994; Stevens et al. 1992)	0	High mobility sub-group	0	Primary habitat is subtidal, so are not expected to be in regular contact with the sea surface	1	Sediment epifauna live in close contact with the seafloor, so have regular interaction
Pelagic		Low mobility	Zooplankton (other than larvae)	e.g. krill	1*	There may be patchiness or aggregations where a large number of individuals would be affected at once	1	Low mobility sub-group	1	Several pelagic zooplankton have regular interaction with surface waters	0	Pelagic larvae and adults are not expected to have regular contact with the seafloor and/or vegetation
			Cnidaria	e.g. jellyfish	1	Jellyfish form large spawning aggregations (e.g. *Aurelia aurita*)(Hamner et al. 1994)	1	Low mobility sub-group	1	Several pelagic jellyfish have regular interaction with surface waters	0	Pelagic larvae and adults are not expected to have regular contact with the seafloor and/or vegetation

SUB-GROUP LEVEL				Pacific example species	EXPOSURE Criteria							
					Concentration (aggregation)		Mobility and/or exhibit site fidelity		Sea surface interacting		Seafloor or vegetation interacting	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
		High mobility	Mollusca	e.g. squid	1	Squid form spawning aggregations (Forsythe et al. 2004)	0	High mobility sub-group	1	Pelagic squid perform regular migrations to surface waters for feeding and spawning	0	Pelagic larvae and adults are not expected to have regular contact with the seafloor and/or vegetation
	Larvae		Porifera	-	1*	There may be patchiness or aggregations where a large number of larvae would be affected at once	1	Larvae have low mobility	1	Pelagic larvae likely to have regular interaction with the sea surface	0	Pelagic larvae and adults are not expected to have regular contact with the seafloor and/or vegetation
			Cnidaria	-	1*	There may be patchiness or aggregations where a large number of larvae would be affected at once	1	Larvae have low mobility	1	Pelagic larvae likely to have regular interaction with the sea surface	0	Pelagic larvae and adults are not expected to have regular contact with the seafloor and/or vegetation
			Worms	-	1*	There may be patchiness or aggregations where a large number of larvae would be affected at once	1	Larvae have low mobility	1	Pelagic larvae likely to have regular interaction with the sea surface	0	Pelagic larvae and adults are not expected to have regular contact with the seafloor and/or vegetation
			Chordata	-	1*	There may be patchiness or aggregations where a large number of larvae would be affected at once	1	Larvae have low mobility	1	Pelagic larvae likely to have regular interaction with the sea surface	0	Pelagic larvae and adults are not expected to have regular contact with the seafloor and/or vegetation
			Arthropoda	-	1*	There may be patchiness or aggregations where a large number of larvae would be affected at once	1	Larvae have low mobility	1	Pelagic larvae likely to have regular interaction with the sea surface	0	Pelagic larvae and adults are not expected to have regular contact with the seafloor and/or vegetation
			Mollusca	-	1*	There may be patchiness or aggregations where a large number of larvae would be affected at once	1	Larvae have low mobility	1	Pelagic larvae likely to have regular interaction with the sea surface	0	Pelagic larvae and adults are not expected to have regular contact with the seafloor and/or vegetation
			Echino-dermata	-	1*	There may be patchiness or aggregations where a large number of larvae would be affected at once	1	Larvae have low mobility	1	Pelagic larvae likely to have regular interaction with the sea surface	0	Pelagic larvae and adults are not expected to have regular contact with the seafloor and/or vegetation
			Lopho-phorates	-	1*	There may be patchiness or aggregations where a large number of larvae would be affected at once	1	Larvae have low mobility	1	Pelagic larvae likely to have regular interaction with the sea surface	0	Pelagic larvae and adults are not expected to have regular contact with the seafloor and/or vegetation

*Table D-2. Marine invertebrates scores for SENSITIVITY criteria, the column labelled "S" indicates the score assigned (note: Species list is not exhaustive, and scores (S) with a * next to them indicate a precautionary score due to lack of knowledge)*

SUB-GROUP LEVEL				**Pacific example species**	**SENSITIVITY criteria**			
					Mechanical sensitivity (reduction in feeding/photosynthesis/insulation)		**Chemical sensitivity (impairment due to toxicity)**	
1	**2**	**3**	**4**		**S**	**Justification**	**S**	**Justification**
Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Arthropoda	*e.g. barnacles [Cirripedia]*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	A few studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Mollusca	*e.g. oysters [Bivalvia]*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Several studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Cnidaria	*e.g. coral*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Porifera	e.g. *demosponges*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Worms	*e.g. tube worms [Polychaeta: Sedentaria]*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	A few studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Urochordata	*e.g. sea squirts*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Lophophorates	*e.g.bryozoans [Ectoprocta]; lampshells [Brachiopoda]*	1	Lophophorates filter feed using the lophophore (Pechenik 2005) which can become clogged with oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
		Low mobility	Worms	*e.g. polychaetes [Errantia]; nemerteans*	0	Most feed by eversion of muscular pharynx (Pechenik 2005)	1*	A few studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Arthropoda	*e.g. isopods [Isopoda]*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Cnidaria	*e.g. sea anemones*	1	Some species suspension feed (Pechenik 2005)	1*	A few studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Mollusca	*e.g. chitons [Cl. Polyplacopora]; snails [Cl. Gastropoda]*	0	Don't filter or suspension feed (Pechenik 2005)	1*	A few studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Echinodermata	*e.g. sea urchins [Echinoidea];sea cucumbers [Holothuroidea];sea stars [Asteroidea]*	1	Some sea cucumbers suspension feed (Pechenik 2005)	1*	Several studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
		High mobility	Arthropoda	*e.g. crabs [Decapoda]*	0	Don't filter or suspension feed (Pechenik 2005)	1*	Several studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare

SUB-GROUP LEVEL				Pacific example species	SENSITIVITY criteria			
					Mechanical sensitivity (reduction in feeding/photosynthesis/insulation)		Chemical sensitivity (impairment due to toxicity)	
1	**2**	**3**	**4**		**S**	**Justification**	**S**	**Justification**
			Arthropoda (filter feeders)	*porcelain crabs*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Mollusca	*e.g. octopuses*	0	Don't filter or suspension feed (Pechenik 2005)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
	Sediment infauna	Low mobility	Mollusca	*e.g. clams [Bivalvia]; snails [Gastropoda]*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Several studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Worms	*e.g. burrowers*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	A few studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Arthropoda	*e.g. sand crabs [Emerita]*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Lophophorates	*e.g. horseshoe worms [Phoronida]; lampshells [Brachiopoda]*	1	Lophophorates filter feed using the lophophore (Pechenik 2005) which can become clogged with oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
	Sediment epifauna	Low mobility	Mollusca	*e.g. snails [Cl. Gastropoda]*	1	Some species suspension feed (Pechenik 2005)	1*	A few studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Cnidaria	*e.g. sea pens*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Echinodermata	*e.g. sea stars*	1	Some species suspension feed (Pechenik 2005)	1*	Several studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
		High mobility	Arthropoda	*e.g. crabs*	0	Don't filter or suspension feed (Pechenik 2005)	1*	Several studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Arthropoda	*e.g. barnacles [Cirripedia]*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	A few studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Mollusca	*e.g. rock scallops [Bivalvia]*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Cnidaria	*e.g. coral*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Porifera	*e.g. glass sponges*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Worms	*e.g. tube worms [Polychaeta: Sedentaria]*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	A few studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Urochordata	*e.g. sea squirts*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Lophophorates	*e.g.bryozoans [Ectoprocta]; lampshells [Brachiopoda]*	1	Lophophorates filter feed using the lophophore (Pechenik 2005) which can become clogged with oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
		Low mobility	Worms	*e.g. annelids*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	A few studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Cnidaria	*e.g. sea anemones*	1	Some species filter or suspension feed (Pechenik 2005)	1*	A few studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare

SUB-GROUP LEVEL				Pacific example species	SENSITIVITY criteria			
					Mechanical sensitivity (reduction in feeding/photosynthesis/insulation)		Chemical sensitivity (impairment due to toxicity)	
1	2	3	4		S	Justification	S	Justification
			Echinodermata	*e.g. sea urchins, sea stars*	1	Some species filter or suspension feed (Pechenik 2005)	1*	Several studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Mollusca	*e.g. snails [Cl. Gastropoda]*	0	Don't filter or suspension feed (Pechenik 2005)	1*	A few studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
		High mobility	Arthropoda	*e.g. crabs*	0	Don't filter or suspension feed (Pechenik 2005)	1*	Several studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Mollusca	*e.g. octopuses*	0	Don't filter or suspension feed (Pechenik 2005)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
	Sediment infauna	Low mobility	Mollusca	*e.g. clams*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Several studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Worms	*e.g. annelids*	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	A few studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Lophophorates	*e.g. horseshoe worms [Phoronida]; lampshells [Brachiopoda]*	1	Lophophorates filter feed using the lophophore (Pechenik 2005) which can become clogged with oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
	Sediment epifauna	Low mobility	Mollusca	*e.g. snails [Cl. Gastropoda]*	1	Some species filter or suspension feed (Pechenik 2005)	1*	A few studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
			Cnidaria	e.g. sea pens	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Echinodermata	e.g. sea stars	1	Feather stars suspension feed (Pechenik 2005)	1*	Several studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
		High mobility	Arthropoda	e.g. crabs	0	Don't filter or suspension feed (Pechenik 2005)	1*	Several studies have investigated the toxic effects of oil on this group, but a lack of baseline data and standardised methods make results difficult to compare
Pelagic		Low mobility	Zooplankton (other than larvae)	e.g. krill	1	Filter or suspension feeders (Pechenik 2005) with feeding appendages that can become clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Cnidaria	e.g. jellyfish	1	Fine tentacles may become clumped by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
		High mobility	Mollusca	e.g. squid	0	Don't filter or suspension feed (Pechenik 2005)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
	Larvae		Porifera	-	0	Larvae don't feed in the plankton (Shanks 2001)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Cnidaria	-	1	Some species filter or suspension feed (e.g. Metriduim larvae) (Shanks 2001)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Worms	-	1	Many larvae in this sub-group have cilia for capturing food particles (Shanks 2001)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Chordata	-	0	All ascidian larvae are lecithotrophic (Shanks 2001)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group

SUB-GROUP LEVEL				Pacific example species	SENSITIVITY criteria			
					Mechanical sensitivity (reduction in feeding/photosynthesis/insulation)		Chemical sensitivity (impairment due to toxicity)	
1	**2**	**3**	**4**		**S**	**Justification**	**S**	**Justification**
			Arthropoda	-	1	Many crustacean larvae feed using setae to gather particles (Shanks 2001)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Mollusca	-	1	Many mollusc larvae feed using cilia to gather particles (Shanks 2001)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Echinodermata	-	1	Planktotrophic echinoderm larvae use ciliated arms to gather food particles (Shanks 2001)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group
			Lophophorates	-	1	Lophophorate larvae use cilia to gather food particles (Shanks 2001)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on this group

*Table D-3. Marine invertebrates scores for RECOVERY criteria, the column labelled "S" indicates the score assigned (note: Species list is not exhaustive, and scores (S) with a * next to them indicate a precautionary score due to lack of knowledge)*

SUB-GROUP LEVEL				**Pacific example species**	**Recovery Criteria**							
					Population status		**Reproductive capacity**		**Endemism or Isolation**		**Close association with unconsolidated substrates**	
1	2	3	4		**S**	Justification	**S**	Justification	**S**	Justification	**S**	Justification
Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Arthropoda	*e.g. barnacles [Cirripedia]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Mollusca	*e.g. oysters [Bivalvia]*	1	Northern abalone (Endangered - COSEWIC 2016); Olympia oyster (Special Concern - COSEWIC 2016)	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Cnidaria	*e.g. coral*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Porifera	*e.g. demosponges*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Worms	*e.g. tube worms [Polychaeta: Sedentaria]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Urochordata	*e.g. sea squirts*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Lophophorates	*e.g.bryozoans [Ectoprocta]; lampshells [Brachiopoda]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
		Low mobility	Worms	*e.g. polychaetes [Errantia]; nemerteans*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Arthropoda	*e.g. isopods [Isopoda]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Cnidaria	*e.g. sea anemones*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion

SUB-GROUP LEVEL				Pacific example species	Recovery Criteria							
					Population status		Reproductive capacity		Endemism or Isolation		Close association with unconsolidated substrates	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
			Mollusca	*e.g. chitons [Cl. Polyplacopora]; snails [Cl. Gastropoda]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Echinodermata	*e.g. sea urchins [Echinoidea];sea cucumbers [Holothuroidea];sea stars [Asteroidea]*	1	Seastar wasting disease has caused population declines (Hewson et al. 2014)	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
		High mobility	Arthropoda	*e.g. crabs [Decapoda]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Arthropoda filter feeders)	*porcelain crabs*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Mollusca	*e.g. octopuses*	0	-	1	Giant Pacific octopus females reach sexual maturity at 3-5 years and die after spawning and tending eggs (Kubodera 1991) - this gives a much lower reproductive capacity and is as low as some marine mammals	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
	Sediment infauna	Low mobility	Mollusca	*e.g. clams [Bivalvia]; snails [Gastropoda]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	1	Sediment infauna live within unconsolidated substrates, so have a high degree of interaction
			Worms	*e.g. burrowers*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	1	Sediment infauna live within unconsolidated substrates, so have a high degree of interaction
			Arthropoda	*e.g. sand crabs [Emerita]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	1	Sediment infauna live within unconsolidated substrates, so have a high degree of interaction
			Lophophorates	*e.g. horseshoe worms [Phoronida]; lampshells [Brachiopoda]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	1	Sediment infauna live within unconsolidated substrates, so have a high degree of interaction
	Sediment epifauna	Low mobility	Mollusca	*e.g. snails [Cl. Gastropoda]*	1	Newcomb Periwinkle (*Algamorda subrotundata*) is listed as a species of concern under the US Federal Endangered Species Act (Gaydos and Gilardi 2003)	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	1	Sediment epifauna live in close contact with unconsolidated substrates and may forage within them

SUB-GROUP LEVEL				Pacific example species	Recovery Criteria							
					Population status		Reproductive capacity		Endemism or Isolation		Close association with unconsolidated substrates	
1	2	3	4		**S**	Justification	**S**	Justification	**S**	Justification	**S**	Justification
			Cnidaria	*e.g. sea pens*	0	-	1	Some sea pens take over 5 years to mature (Reviewer comment: Anya Dunham)	0	-	1	Sediment epifauna live in close contact with unconsolidated substrates and may forage within them
			Echinodermata	*e.g. sea stars*	1	Seastar wasting disease has caused population declines (Hewson et al. 2014)	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	1	Sediment epifauna live in close contact with unconsolidated substrates and may forage within them
		High mobility	Arthropoda	*e.g. crabs*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	1	Sediment epifauna live in close contact with unconsolidated substrates and may forage within them
Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Arthropoda	*e.g. barnacles [Cirripedia]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Mollusca	*e.g. rock scallops [Bivalvia]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Cnidaria	*e.g. coral*	0	-	1	Some coral species are slow to reach maturity (e.g. gorgonian corals) (Reviewer comment: Anya Dunham)	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Porifera	*e.g. glass sponges*	0	-	1	Some sponge species are slow to reach maturity and glass sponges are data limited (Reviewer comment: Anya Dunham)	1	While glass sponges are not endemic to the area, the glass sponge reefs are a unique feature (Austin 1999)	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Worms	*e.g. tube worms [Polychaeta: Sedentaria]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Urochordata	*e.g. sea squirts*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Lophophorates	*e.g.bryozoans [Ectoprocta]; lampshells [Brachiopoda]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
		Low mobility	Worms	*e.g. annelids*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion

SUB-GROUP LEVEL				Pacific example species	Recovery Criteria							
					Population status		Reproductive capacity		Endemism or Isolation		Close association with unconsolidated substrates	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
			Cnidaria	*e.g. sea anemones*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Echinodermata	*e.g. sea urchins, sea stars*	1	Seastar wasting disease has caused population declines (Hewson et al. 2014)	0	Relative to other biological groups, most invertebrates have high reproductive capacity	1	Brittle star, Ophioplocus esmarki, has isolated populations in B.C. and California and no records of sightings in middle of range. This is a live-bearer, so migration in the plankton unlikely (Austin 1999)	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Mollusca	*e.g. snails [Cl. Gastropoda]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
		High mobility	Arthropoda	*e.g. crabs*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Mollusca	*e.g. octopuses*	0	-	1	Giant Pacific octopus females reach sexual maturity at 3-5 years and die after spawning and tending eggs (Kubodera 1991) - this gives a much lower reproductive capacity and is as low as some marine mammals	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
	Sediment infauna	Low mobility	Mollusca	*e.g. clams*	0	-	1	Geoducks are slow to mature (7+) years and experience low recruitment and high egg, larval, and juvenile mortality rates (reviewed in Willner 2006). The average recovery time for a harvested geoduck population is predicted to be 39 years (Palazzi *et al*. 2001).	0	-	1	Sediment infauna live within unconsolidated substrates, so have a high degree of interaction
			Worms	*e.g. annelids*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	1	Sediment infauna live within unconsolidated substrates, so have a high degree of interaction
			Lophophorates	*e.g. horseshoe worms [Phoronida]; lampshells [Brachiopoda]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	1	Sediment infauna live within unconsolidated substrates, so have a high degree of interaction
	Sediment epifauna	Low mobility	Mollusca	*e.g. snails [Cl. Gastropoda]*	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	1	Sediment epifauna live in close contact with unconsolidated substrates and may forage within them
			Cnidaria	e.g. sea pens	0	-	1	Some sea pens take 5+ years to mature (Reviewer comment: Anya Dunham)	0	-	1	Sediment epifauna live in close contact with unconsolidated substrates and may forage within them

SUB-GROUP LEVEL				Pacific example species	Recovery Criteria							
					Population status		Reproductive capacity		Endemism or Isolation		Close association with unconsolidated substrates	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
			Echinodermata	e.g. sea stars	1	Seastar wasting disease has caused population declines (Hewson et al. 2014)	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	1	Sediment epifauna live in close contact with unconsolidated substrates and may forage within them
		High mobility	Arthro-poda	e.g. crabs	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	1	Sediment epifauna live in close contact with unconsolidated substrates and may forage within them
Pelagic		Low mobility	Zooplankton (other than larvae)	N/A	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Cnidaria	e.g. jellyfish	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
		High mobility	Mollusca	e.g. squid	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
	Larvae		Porifera	N/A	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Cnidaria	N/A	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Worms	N/A	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Chordata	N/A	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Arthro-poda	N/A	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Mollusca	N/A	1	Northern abalone (Endangered - COSEWIC 2016); Olympia oyster (Special Concern - COSEWIC 2016); Newcomb Periwinkle	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion

SUB-GROUP LEVEL				**Pacific example species**	**Recovery Criteria**							
					Population status		**Reproductive capacity**		**Endemism or Isolation**		**Close association with unconsolidated substrates**	
1	2	3	4		**S**	Justification	**S**	Justification	**S**	Justification	**S**	Justification
						(*Algamorda subrotundata*)(Species of concern - US Federal Endangered Species Act (Gaydos & Gilardi 2003)						
			Echinodermata	N/A	1	Seastar wasting disease has caused population declines (Hewson et al. 2014)	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion
			Lophophorates	N/A	0	-	0	Relative to other biological groups, most invertebrates have high reproductive capacity	0	-	0	Only infaunal sub-groups and those that spend a significant portion of time in contact with unconsolidated substrate fulfill this criterion

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13 APPENDIX E: DETAILED SCORING TABLES WITH JUSTIFICATIONS FOR MARINE FISHES

*Table E-1. Marine fish scores for EXPOSURE criteria, the column labelled "S" indicates the score assigned (note: Species list is not exhaustive, and scores with a * next to them indicate a precautionary score due to lack of knowledge)*

SUB-GROUP LEVEL				Pacific example species	EXPOSURE Criteria							
					Concentration (aggregation)		Mobility and/or exhibit site fidelity		Sea surface interacting		Seafloor or vegetation interacting	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
Estuarine	Transient	N/A	Cod (Gadidae)	Pacific tomcod, walleye pollock *(juveniles)*	0	Aggregations in this group are not documented to occur in estuaries, though do elsewhere, e.g. walleye pollock spawn in aggregations and form very large schools (Love 2011); Pacific Cod aggregate in deep water for breeding (shelf break) (Neidetcher et al. 2014)	0	Most fish species are considered highly mobile relative to an oil spill	0	Adult cod are a deeper water species that live in the mid-water column or demersally and would not be expected to interact with the surface regularly (Love 2011)	0	Not expected to have regular interaction with the seabed in the estuary
			Salmon (Salmonidae)	Juvenile and adult salmon & steelhead	1	Adult salmon aggregate in estuaries in preparation for river spawning runs, schools of juveniles transit through estuaries in schools as they leave the rivers (Love 2011)	1	When adult salmon are in estuaries they exhibit high site fidelity as they prepare for migration up rivers	1	In estuaries, fishes in this sub-group are scored for regular surface interaction as they mill in dense aggregations at all depths in the water column in prep for seasonal spawning migrations	1	Juveniles use eelgrass and other vegetation as rearing and feeding habitat, and adults dig redds in gravel. Eggs developing within gravel can suffer increased mortality in oiled areas (Bue et al. 1996)
			Sturgeon (Acipenseridae)	Green sturgeon, white sturgeon	1	Green sturgeon have seasonal feeding aggregations in estuaries in B.C. in non-natal estuaries and coastal bays - they do not spawn in B.C. rivers but further south in Oregon (Love 2011). They also aggregate near the Brooks Peninsula likely for overwintering (Lindley et al. 2008)	0	Most fish species are considered highly mobile relative to an oil spill	1	Green Sturgeon do not spawn in B.C. rivers and are, therefore, not expected to have regular surface interaction in estuaries. White sturgeon are expected to interact with the surface occasionally, as they spend time in estuaries as juveniles and many migrate in and out of rivers throughout their life	1	White Sturgeon use their barbels in soft sediment in estuaries while feeding
			Osmeridae	Eulachon	1	Eulachon aggregate in estuaries/river mouths, for example in the Fraser River there is a bottleneck which aggregates both seaward bound and river bound fish / juveniles (Jamieson & Levesque 2014)	0	Most fish species are considered highly mobile relative to an oil spill	1	Fishes in this sub-group will have regular surface interaction as they aggregate in shallow estuarine waters for seasonal spawning migrations	0	Not expected to have regular interaction with the seabed in the estuary
			Lampreys	River lamprey, Pacific lamprey	1	Lampreys are *thought* to aggregate in estuaries (for feeding) to coincide with salmon aggregating in estuaries (preparing head up river for spawning) as high lamprey attacks have been reported in some cases (Beamish 1980)	0	Most fish species are considered highly mobile relative to an oil spill	0	Not expected to have regular surface interaction in estuaries	1	Lamprey are poor swimmers and rely on sucking onto rocks in a current (Love 1996)
			Sculpins (Cottidae)	Prickly sculpin	0	Not documented to aggregate in estuaries, e.g. the mainly freshwater Prickly Sculpin travels to estuaries for breeding (catadromous), but do not aggregate for spawning, they aggregate up river and move back and forth into the estuary for spawning (Morrow 1980)	0	Most fish species are considered highly mobile relative to an oil spill	0	Sculpins are not expected to have regular surface interaction, but larvae can occur in near surface waters (Love 2011)	1	Prickly sculpin often rest on bottoms of fine materials, predominantly sand (Lee et al. 1980)

SUB-GROUP LEVEL				Pacific example species	EXPOSURE Criteria							
					Concentration (aggregation)		Mobility and/or exhibit site fidelity		Sea surface interacting		Seafloor or vegetation interacting	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
			Sticklebacks (Gasterosteidae)	Threespine stickleback	1	Some populations are anadromous, spawning in rivers, but not in aggregations (Love 2011). Spend most of their lives in schools (Love 2011), and can form feeding aggregations, outside of estuaries (Froese and Pauly 2016)	1	Sticklebacks have limited mobility due to their small size	0	Threespine sticklebacks can rise into surface waters at night (Love 2011) but this is not considered a regular interaction.	1	Excavate soft substrates to build nests (Love 2011)
			Flatfishes (Pleuronecti-formes)	Starry flounder, juv english sole	0	Seasonal abundances have been observed in the Starry Flounder in the Fraser River Estuary (Birtwell et al. 1993) but not enough info to know if this is a spawning/feeding aggregation (Love 2011)	0	Most fish species are considered highly mobile relative to an oil spill	0	Not expected to interact with the surface regularly as they are benthic fish	1	Flatfishes have a close interaction with the seafloor as they are bottom dwelling fish whose bodies are in frequently contact with the seabed (Love 2011)
	Resident	N/A	Surfperch (Embiotocidae)	Shiner perch	1	Surfperch species are schooling types, sometimes in large schools of many thousands (such as the shiner perch) (Love 2011). They form large aggregations for mating and giving birth during the spring and summer (Lane et al. 2002)	0	Most fish species are considered highly mobile relative to an oil spill	1	Surf perch are present in the intertidal, and are expected to have regular interaction with the surface (Love 2011)	1	Surfperch don't interact with the seafloor regularly as they are continuously swimming in the water column. However, they are found in vegetated habitats where they interact with vegetation by picking food off fronds (Love 1996)
			Sculpins (Cottidae)	Staghorn sculpin	0	Do not aggregate for spawning in estuaries (Morrow 1980)	0	Most fish species are considered highly mobile relative to an oil spill	0	Sculpins are a benthic species and not expected to have regular surface interaction (Love 2011)	1	Staghorn sculpins are most common in the sand or mud of bays and estuaries (Love 1996). They are frequently found buried in soft substrates
			Salmonidae	Cutthroat trout, Dolly Varden	0	Dolly Varden tend to remain in estuaries unlike other salmonids. Aggregative behaviour observed when overwintering, but this is when fish have moved back into the river so not in the estuary (Reynolds 1997; Levy & Levings 1978)	0	Most fish species are considered highly mobile relative to an oil spill	1	In estuaries, fishes in this sub-group would have regular surface interactions as they aggregate in shallow estuarine waters for seasonal spawning migrations	1*	Dolly Varden build nests for spawning in gravel, but this usually occurs in freshwater and likely not be impacted by a marine oil spill
Intertidal	Non-benthic (pelagic & demersal)	N/A	Rockfish (juvenile)	Black rockfish, copper rockfish	0	Juveniles school in the intertidal where many species rear, but usually do not occur at high enough densities to be considered aggregating	0	Most fish species are considered highly mobile relative to an oil spill	0	Resident intertidal organisms are assumed to have regular surface interaction due to tidal movements. However, fish species in this group move in and out with the tides and so are less likely to have regular surface interaction	1	These non-benthic species are generally not expected to have regular interaction with the seafloor, but do rest against and feed off vegetation
			Surfperch (Embiotocidae)	Shiner perch	1	Surfperch species are schooling types, sometimes in large schools of many thousands (such as the shiner perch) (Love 2011). Shiner perch form large aggregations for mating and giving birth during the spring and summer (Lane et al. 2002). Many species aggregate under docks and pilings for shelter	0	Most fish species are considered highly mobile relative to an oil spill	0	Resident intertidal organisms are assumed to have regular surface interaction due to tidal movements. However, fish species in this sub-group are less likely to interact with the surface regularly as they move in and out of intertidal areas with the tides	1	Surfperch don’t interact with the seafloor regularly as they are continuously swimming in the water column. However, they are found in vegetated habitats where they interact with vegetation by picking food off fronds

SUB-GROUP LEVEL				Pacific example species	EXPOSURE Criteria							
					Concentration (aggregation)		Mobility and/or exhibit site fidelity		Sea surface interacting		Seafloor or vegetation interacting	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Snailfishes (Liparidae)	Tidepool snailfish	0	Not expected to aggregate in the benthic intertidal for a specific purpose or in significantly large numbers	1	These small species that live in close association with rocks likely have a relatively limited home range	1	Intertidal organisms are assumed to have regular surface interaction due to tidal movements. Surface interaction is very likely in this group because they will remain in the intertidal as the tide drops (Lamb & Edgell 2010)	1	Species in this sub-group have regular interactions with the seafloor
			Clingfishes (Gobiesocidae)	Northern clingfish	0	Not expected to aggregate in the benthic intertidal for a specific purpose or in significantly large numbers	1	These small species that live in close association with rocks likely have a relatively limited home range	1	Intertidal organisms are assumed to have regular surface interaction due to tidal movements. Regular surface interaction is likely in this group because they remain in the intertidal as the tide drops (Lamb & Edgell 2010)	1	Species in this sub-group have regular interactions with the seafloor
			Blennies (Stichaeidae & Pholidae)	Penpoint gunnel, crescent gunnel, high cockscomb	0	Not expected to aggregate in the benthic intertidal for a specific purpose or in significantly large numbers	1	These small species that live in close association with rocks likely have a relatively limited home range	1	Resident intertidal organisms are assumed to have regular surface interaction due to tidal movements. Surface interaction is likely in this group because they remain in the intertidal as the tide drops (Lamb & Edgell 2010)	1	Species in this sub-group have regular interactions with the seafloor (*Exxon Valdez* Oil Spill Trustee Council 2009)
		Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass environments)	Salmonidae (juvenile)	Pink, coho, chinook salmon	1	Juveniles occur in high densities in intertidal areas including eelgrass beds (Love 2011; Groot & Margolis 1991)	0	Most fish species are considered highly mobile relative to an oil spill	1	Intertidal organisms are assumed to have regular surface interaction due to tidal movements. This is accurate in this group as juvenile salmon can school close to the surface and pick insects from the water/air interface (COSEWIC 2016)	1	Juvenile salmon will not have regular interaction with the seafloor, but do seek shelter and food in vegetated habitats
			Herring (Clupeidae)	Pacific herring	1	Pacific Herring aggregate in significant numbers to spawn, there are multiple spawning locations that occur in B.C., one of the most prominent being in the Southern Gulf Islands (Jamieson & Levesque 2014). Juveniles occur in dense schools in rearing habitats such as eelgrass beds	1	Most fish species are considered highly mobile relative to an oil spill; however, spawning adults will exhibit site fidelity at intertidal spawning grounds	1	Intertidal organisms are assumed to have regular surface interaction due to tidal movements. For this sub-group, adults interact with the surface when spawning, and eggs would also interact with the surface when deposited in the intertidal (COSEWIC 2016)	1	Eggs deposited on vegetation and rocks will be in close association with the seafloor until they hatch, adult fish will be in close association while they are spawning
			Flatfishes-juvenile (Pleuronectidae)	English sole, starry flounder	0	Not expected to aggregate in the benthic intertidal	0	Most fish species are considered highly mobile relative to an oil spill	0	Intertidal organisms are assumed to have regular surface interaction due to tidal movements. However, fish species in this sub-group are less likely to interact with the surface regularly as they move in and out of intertidal areas with the tides	1	Flatfishes have a close interaction with unconsolidated substrates as they are bottom dwelling species whose bodies are in frequently contact with the seabed
			Pipefish (Sygnathidae)	Bay pipefish	0	No large aggregations for reproduction expected	1	Pipefish are not considered highly mobile as evidenced by low genetic connectivity between populations (DeGraaf 2006)	0	Intertidal organisms are assumed to have regular surface interaction due to tidal movements. However, species in this sub-group (pipefish) move in and out of the intertidal with the tides. Pipefish may interact with the surface if oiled eelgrass leaves prevent them from leaving the intertidal as the tide drops (COSEWIC 2016)	1	Not expected to have regular interaction with the seafloor, but will be in close association with eelgrass

SUB-GROUP LEVEL				Pacific example species	EXPOSURE Criteria							
					Concentration (aggregation)		Mobility and/or exhibit site fidelity		Sea surface interacting		Seafloor or vegetation interacting	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
			Ammodytidae & Osmeridae	Pacific sand lance, surf smelt	1	Pacific sand lance (*Ammodytes hexapterus*) aggregate to spawn in the intertidal - adults migrate to sandy-gravel spawning beaches and wriggle into the sand to deposit eggs near the top of the beach on high tides (Hart 1973; Robards et al. 1999). Female smelt deposit eggs on coarse sand beaches near the high tide line (Love 2011)	0	Most fish species are considered highly mobile relative to an oil spill	1	Intertidal organisms are assumed to have regular surface interaction due to tidal movements. Species in this sub-group would interact with the surface while spawning on the beach	1	The eggs and spawning adults will interact closely with the seafloor
			Greenlings (Hexagramm-idae)	Lingcod-juvenile	0	Juveniles rear in sandy intertidal and eelgrass areas, often at high densities (Love 2011), but these are not large enough to be considered aggregating	0	Most fish species are considered highly mobile relative to an oil spill	0	Intertidal organisms are assumed to have regular surface interaction due to tidal movements. However, fish species in this sub-group are less likely to interact with the surface regularly as they move in and out of intertidal areas with the tides	1	All greenlings, including lingcod live in association with the seafloor and vegetation as juveniles. Juvenile lingcod typically associate with sandy bottoms (Love 2011)
			Other species (e.g. Sculpins & Gobies)	Buffalo sculpin, staghorn sculpin, plainfin midshipmen	0	No reports found to demonstrate that they aggregate	1	These species are not highly mobile, and nest site fidelity has been observed for midshipmen during breeding season as males guard clutches of eggs	1	Resident intertidal organisms are assumed to have regular surface interaction due to tidal movements. Surface interaction is likely for some species in this group because they can remain in the intertidal as the tide drops	1	Staghorn sculpins bury themselves in soft substrates, as do plainfin midshipmen who spawn, guard eggs and rear young in soft substrates (Lamb & Edgell 2010)
Subtidal	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Wolf fish (Anarhichadidae)	Wolf-eel	0	Do not aggregate	1	Expected to exhibit site fidelity (as they live in rocky dens)(Parra et al. 2001)	0	Benthic organisms in the subtidal are generally considered not to have regular surface interaction. In this sub-group wolf-eels tend to stay close to their benthic dens, and would not be expected to regularly interact with the surface	1	Wolf eels will regularly interact with rocky seafloors
			Greenlings (Hexagrammidae)	Lingcod-adult	0	Lingcod can be found in very high densities where habitat conditions are good and fishing pressure is low, especially during spawning season, but this is a habitat preference rather than a breeding aggregation. Adults are mostly found in the subtidal, but can be found in the low intertidal during spawning season (Love 2011)	1	Nest site fidelity has been reported during breeding season as males guard clutches of eggs laid amongst rocks and often return to the same site in subsequent years (King & Withler 2005)	0	Benthic organisms in the subtidal are generally considered not to have regular surface interaction (COSEWIC 2016)	1	All greenlings, including lingcod live in association with the seafloor and vegetation as juveniles. Juvenile lingcod typically associate with sandy bottoms and adults with rocky relief and boulders (Love 2011)

SUB-GROUP LEVEL				Pacific example species	EXPOSURE Criteria							
					Concentration (aggregation)		Mobility and/or exhibit site fidelity		Sea surface interacting		Seafloor or vegetation interacting	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
			Rockfishes (Scorpaenidae)	Quillback rockfish, yelloweye rockfish, canary rockfish	0	Benthic rockfish species in the subtidal sometimes occur in schools, but are most often solitary (Love et al. 2002)	1	Some adult rockfish species are reported to have very limited home ranges (black rockfish, china rockfish)(Marliave et al. 2013; Love et al. 2002)	0	Benthic organisms in the subtidal are generally considered not to have regular surface interaction (COSEWIC 2016)	1	Rockfish species in rocky subtidal habitats often rest on the seafloor and hide in rocky crevices (Lamb & Edgell 2010)
		Associated with unconsolidated substrate (silt/sand/gravel)	Flatfishes (Pleuronectidae)	English sole, starry flounder, Pacific halibut	1	Some flatfishes aggregate to spawn in B.C. locations. For example, Dover sole and Petrale sole aggregate for spawning off the West Coast of Vancouver Island (Fargo 1998, 1999)	0	Most fish species are considered highly mobile relative to an oil spill	0	Benthic organisms in the subtidal are generally considered not to have regular surface interaction (COSEWIC 2016)	1	Expected to have regular interaction with the seafloor, as they are placed in this sub-group due to their association with unconsolidated substrate (silt/sand/gravel).
			Elasmobranchs	Big skate	1	Egg cases of some species are deposited in aggregations (Love et al. 2008, Hoff 2016)	0	Most fish species are considered highly mobile relative to an oil spill	0	Benthic organisms in the subtidal are generally considered not to have regular surface interaction (COSEWIC 2016)	1	Expected to have regular interaction with seafloor, as they are placed in this category due to their association with unconsolidated substrate (silt/sand/gravel)
			Hagfishes (Myxinidae)	Pacific hagfish	0	There are no documented aggregations (Love 1996), it is unknown whether there is a discrete spawning season, or whether spawning migrations occur, but these are unlikely	0	Most fish species are considered highly mobile relative to an oil spill	0	Benthic organisms in the subtidal are generally considered not to have regular surface interaction (COSEWIC 2016)	1	Expected to have regular interaction with the seafloor based on their known preference for mud habitats (Love 1996)
			Rockfishes (Scorpaenidae)	Darkblotched rockfish	0	No mention of darkblotch rockfish aggregations in reference books (Love et al. 2002). When canary rockfish are found associated with the seafloor, they are not in aggregations	0	Most fish species are considered highly mobile relative to an oil spill	0	Benthic organisms in the subtidal are generally considered not to have regular surface interaction (COSEWIC 2016)	1	Darkblotched rockfish are typically found on mud near cobble or boulders (Love et al. 2002)
	Non-benthic (pelagic, midwater and demersal)	N/A	Rockfishes (Scorpaenidae)	Yellowtail, blue, widow rockfishes, Bocaccio	1*	Widow rockfish live in aggregations of 1000s -10,000s (Love 1996, 2011) as do many other species including blue rockfish and yellowtail rockfish. No indications of aggregation for a specific purpose such as spawning of feeding though	0	Most fish species are considered highly mobile relative to an oil spill	1	Some species in this sub-group interact with the surface, as they have been observed feeding and tail flicking at the surface (Love et al. 2002)	0	Not expected to have regular interaction with the seafloor, as they are placed in the mid water/pelagic category (Levesque & Jamieson 2014)
			Cod (Gadidae)	Pacific cod, hake, Pacific tomcod, walleye pollock	1	Hake aggregate in the Juan de Fuca eddy area, presumably for feeding (Jamieson & Levesque 2014), and Pacific cod are known to aggregate in deeper water for breeding (on the shelf break)(Neidetcher et al. 2014)	0	Most fish species are considered highly mobile relative to an oil spill	0	Species in this sub-group are not reported to interact with the surface regularly (COSEWIC 2016)	1	Most cod species will live in close association with the seafloor in addition to schooling in the midwater

SUB-GROUP LEVEL				Pacific example species	EXPOSURE Criteria							
					Concentration (aggregation)		Mobility and/or exhibit site fidelity		Sea surface interacting		Seafloor or vegetation interacting	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
			Misc species	Sablefish (Anaplopomatidae), Salmon (Salmonidae), Surfperch (Embiotocidae), Herring (Clupeidae)	0	Have not found evidence of sablefish aggregating for a purpose or in significantly large numbers. Salmon and herring often occur in large schools, but not for feeding or breeding in this habitat	0	Most fish species are considered highly mobile relative to an oil spill	1	Not all species in this sub-group interact with the surface regularly, although salmon, herring and perch can be observed in surface waters in the subtidal environment (Lamb & Edgell 2010)	0	Not expected to have regular interaction with the seafloor, as they are placed in the mid water/pelagic category
			Elasmobranchs	Basking shark	0	Basking sharks used to be found in large aggregations in some parts of the province, but no longer due to severely depleted populations (Wallace & Gisborne 2006)	0	Most fish species are considered highly mobile relative to an oil spill	1	Expected to have regular surface interaction as they feed close to the surface (COSEWIC 2016)	0	Not expected to have regular interaction with the seafloor, as they are placed in the mid water/pelagic category
			Elasmobranchs	Spiny dogfish, sixgill sharks	1	Spiny dogfish form very large aggregations (Love 2011). They are scored a 1 as they likely aggregate this way for feeding, and due to the particularly large extent of the schools, it is also expected that aggregations are related to reproduction, as pregnant females are found together (Tribuzio & Kruse 2012)	0	Most fish species are considered highly mobile relative to an oil spill	1	Satellite tagging indicates that sixgill sharks do occupy surface waters in summer; Spiny dogfish have been observed at surface waters and smaller individuals can form nomadic schools at the surface (Love 2011); however, it is unclear if this is a 'regular' interaction	0	Note expected to have regular interaction with the seafloor, as they are placed in the mid water/pelagic category
			Scombrids	Mackerel	0	Form large schools, but not expected that these are for spawning/feeding (Froese and Pauly 2016)	0	Most fish species are considered highly mobile relative to an oil spill	0	No evidence of regular surface interaction	0	Not expected to have regular interaction with the seafloor, as they are placed in the mid water/pelagic category
			Molidae	Ocean sunfish	0	Found singly or in small groups off western North America (Love 1996)	0	Most fish species are considered highly mobile relative to an oil spill	1	Ocean sunfish are expected to have regular surface interaction as they bask at the surface (Love 2011)	0	Not expected to have regular interaction with the seafloor, as they are placed in the mid water/pelagic category
			Ammodytidae	Pacific sand lance	0	Pacific sand lance (*Ammodytes hexapterus)* can form large schools in the subtidal but spawning aggregations occur in the intertidal, where they spawn on sandy beaches depositing eggs in the upper intertidal zone (Hart 1973; Love 2011)	0	Most fish species are considered highly mobile relative to an oil spill	1	Pacific sand lance are expected to have regular surface interaction, as they have been reported to occur close to the surface regularly (COSEWIC 2016; Love 2011)	1	Although sand lance are a midwater schooling species, they also regularly spend time buried in sand and fine gravel (Love 2011)
			Engraulidae	Northern anchovy	1	Anchovy form large schools in the pelagic environment, presumably for feeding and spawning. They can also be found aggregated around docks and pilings (Love 2011)	0	Most fish species are considered highly mobile relative to an oil spill	1	Anchovy migrate to the surface at night, and are more commonly found in shallow, inshore water waters during the spring (Kucas 1986)	0	Not expected to have regular interaction with the seafloor, as they are placed in the mid water/pelagic category
			Chimaeridae	Spotted ratfish	0	Can occur in very large schools (King & McPhie 2015) but not reported to aggregate for reproduction or feeding	0	Most fish species are considered highly mobile relative to an oil spill	1	They have been observed to undergo diel vertical migrations occupying surface waters at night (COSEWIC 2016)	1	Ratfish mostly swim above the seafloor, but do interact with unconsolidated substrates in order to feed

*Table E-2. Marine fish scores for SENSITIVITY criteria, the column labelled "S" indicates the score assigned (note: Species list is not exhaustive, and scores with a * next to them indicate a precautionary score due to lack of knowledge)*

SUB-GROUP LEVEL				**Pacific example species**	**SENSITIVITY Criteria**			
					Mechanical sensitivity (reduction in feeding/photosynthesis/insulation)		**Chemical sensitivity (impairment due to toxicity)**	
1	2	3	4		**S**	**Justification**	**S**	**Justification**
Estuarine	Transient	N/A	Cod (Gadidae)	Pacific tomcod, walleye pollock *(in estuaries when young, Love 2011)*	0	Do not contain filter feeding structures that could be clogged by oil	1*	Documented evidence of exposure to petroleum hydrocarbons following EVOS, effects evidence is inconclusive (Varanasi et al. 1995)
			Salmon (Salmonidae)	Juvenile and adult salmon & steelhead	1	Sockeye salmon use gill rakers for feeding (Tyler et al. 2001)	1*	Several studies have documented toxic effects of oil on salmonids (e.g. decreased growth and protein synthesis, elevated mortality, lesions) (e.g. Ballachey et al. 2014; Marty et al. 2000; Wang et al. 1993).
			Sturgeon (Acipenseridae)	Green sturgeon, white sturgeon	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on sturgeon
			Osmeridae	Eulachon	0	Do not contain filter feeding structures that could be clogged by oil	1*	A few studies have investigated the toxic effects of oil on the Osmeridae (e.g. Power 2013 - eulachon), but a lack of baseline data and standardised methods make results difficult to compare
			Lampreys	River lamprey, Pacific lamprey	0	Do not contain filter feeding structures that could be clogged by oil	1*	A few studies have investigated the toxic effects of oil on lampreys (e.g. Andersen et al. 2010), but a lack of baseline data and standardised methods make results difficult to compare
			Sculpins (Cottidae)	Prickly sculpin	0	Do not contain filter feeding structures that could be clogged by oil	1*	A handful of studies have investigated the toxic effects of oil on sculpins (e.g. de Hoop et al. 2011), but a lack of baseline data and standardised methods make results difficult to compare
			Sticklebacks (Gasterosteidae)	Threespine stickleback	0	Do not contain filter feeding structures that could be clogged by oil	1*	A few studies have investigated the toxic effects of oil on sticklebacks (e.g. Geoghagen et al. 2008), but a lack of baseline data and standardised methods make results difficult to compare
			Flatfishes (Pleuronectiformes)	Starry flounder, juv english sole	0	Do not contain filter feeding structures that could be clogged by oil	1*	Documented evidence of exposure to petroleum hydrocarbons following EVOS, effects evidence is inconclusive (Varanasi et al. 1995)
	Resident	N/A	Surfperch (Embiotocidae)	Shiner perch	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on surfperch
			Sculpins (Cottidae)	Staghorn sculpin	0	Do not contain filter feeding structures that could be clogged by oil	1*	A handful of studies have investigated the toxic effects of oil on sculpins (e.g. de Hoop et al. 2011), but a lack of baseline data and standardised methods make results difficult to compare
			Salmonidae	Cutthroat trout, Dolly Varden	0	Do not contain filter feeding structures that could be clogged by oil	1*	Several studies have documented toxic effects of oil on salmonids (e.g. decreased growth and protein synthesis, elevated mortality, lesions) (e.g. Ballachey et al. 2014; Marty et al. 2000; Wang et al. 1993).
Intertidal	Non-benthic (pelagic and demersal)	N/A	Rockfish (juvenile)	Black rockfish, copper rockfish	0	Do not contain filter feeding structures that could be clogged by oil	1*	A handful of studies have investigated the toxic effects of oil on rockfish (e.g. Marty et al. 2003), but a lack of baseline data and standardised methods make results difficult to compare
			Surfperch (Embiotocidae)	Shiner perch	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on surfperch

SUB-GROUP LEVEL				Pacific example species	SENSITIVITY Criteria			
					Mechanical sensitivity (reduction in feeding/photosynthesis/insulation)		Chemical sensitivity (impairment due to toxicity)	
1	2	3	4		**S**	**Justification**	**S**	**Justification**
	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Snailfishes (Liparidae)	Tidepool snailfish	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on snailfishes
			Clingfishes (Gobiesocidae)	Northern clingfish	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on clingfishes
			Blennies (Stichaeidae & Pholidae)	Penpoint gunnel, crescent gunnel, high cockscomb	0	Do not contain filter feeding structures that could be clogged by oil	1*	A handful of studies have investigated the toxic effects of oil on gunnels (e.g. Jewett et al. 2002), but a lack of baseline data and standardised methods make results difficult to compare
		Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass environments)	Salmonidae (juvenile)	Pink, coho, chinook salmon	1	Sockeye salmon use gill rakers for feeding	1*	Several studies have documented toxic effects of oil on salmonids (e.g. decreased growth and protein synthesis, elevated mortality, lesions) (e.g. Ballachey et al. 2014; Marty et al. 2000; Wang et al. 1993).
			Herring (Clupeidae)	Pacific herring	1	Herring use gill rakers for feeding (Sanderson et al. 2001)	1*	Herring were about to spawn when EVOS occurred - lethal and sub-lethal effects were documented, and adult returns from this year class was low (Brown & Baker 1998, Hose et al. 1996, Johnson et al. 1997, Marty et al. 1997, McGurk & Brown 1996, Kocan et al. 1996, Marty et al. 1999, Thorne & Thomas 2008, 2014)
			Flatfishes- juvenile (Pleuronectidae)	English sole, starry flounder	0	Do not contain filter feeding structures that could be clogged by oil	1*	Documented evidence of exposure to petroleum hydrocarbons following EVOS, effects evidence is inconclusive (Varanasi et al. 1995)
			Pipefish (Sygnathidae)	Bay pipefish	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on pipefish
			Ammodytidae & Osmeridae	Pacific sand lance, surf smelt	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on these fishes
			Greenlings (Hexagrammidae)	Lingcod- juvenile	0	Do not contain filter feeding structures that could be clogged by oil	1*	Research is lacking for the toxic effects of oil on lingcod specifically, and effects information is inconclusive for other cod species (e.g. Varanasi et al. 1995)
			Other species (e.g. Sculpins & Gobies)	Buffalo sculpin, staghorn sculpin, plainfin midshipmen	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on these fishes
Subtidal	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Wolf fish (Anarhichadidae)	Wolf-eel	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on wolf fish
			Greenlings (Hexagrammidae)	Lingcod- adult	0	Do not contain filter feeding structures that could be clogged by oil	1*	Research is lacking for the toxic effects of oil on lingcod specifically, and effects information is inconclusive for other cod species (e.g. Varanasi et al. 1995)
			Rockfishes (Scorpaenidae)	Quillback rockfish, yelloweye rockfish, canary rockfish	0	Do not contain filter feeding structures that could be clogged by oil	1*	A handful of studies have investigated the toxic effects of oil on rockfish (e.g. Marty et al. 2003), but a lack of baseline data and standardised methods make results difficult to compare

SUB-GROUP LEVEL				Pacific example species	SENSITIVITY Criteria			
					Mechanical sensitivity (reduction in feeding/photosynthesis/insulation)		Chemical sensitivity (impairment due to toxicity)	
1	2	3	4		S	Justification	S	Justification
		Associated with unconsolidated substrate (silt/sand/gravel)	Flatfishes (Pleuronectidae)	English sole, starry flounder, Pacific halibut	0	Do not contain filter feeding structures that could be clogged by oil	1*	Documented evidence of exposure to petroleum hydrocarbons following EVOS, effects evidence is inconclusive (Varanasi et al. 1995)
			Elasmobranchs	Big skate	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on elasmobranchs
			Hagfishes (Myxinidae)	Pacific hagfish	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on hagfishes
			Rockfishes (Scorpaenidae)	Darkblotched rockfish	0	Do not contain filter feeding structures that could be clogged by oil	1*	A handful of studies have investigated the toxic effects of oil on rockfish (e.g. Marty et al. 2003), but a lack of baseline data and standardised methods make results difficult to compare
	Non-benthic (pelagic, midwater and demersal)	N/A	Rockfishes (Scorpaenidae)	Yellowtail, blue, widow rockfishes, Bocaccio	0	Do not contain filter feeding structures that could be clogged by oil	1*	A handful of studies have investigated the toxic effects of oil on rockfish (e.g. Marty et al. 2003), but a lack of baseline data and standardised methods make results difficult to compare
			Cod (Gadidae)	Pacific cod, hake, Pacific tomcod, walleye pollock	0	Do not contain filter feeding structures that could be clogged by oil	1*	Documented evidence of exposure to petroleum hydrocarbons following EVOS, effects evidence is inconclusive (Varanasi et al. 1995)
			Misc species	Sablefish (Anaplopomatidae), Salmon (Salmonidae), Surfperch (Embiotocidae), Herring (Clupeidae)	0	Do not contain filter feeding structures that could be clogged by oil	1*	Several studies have documented the toxic effects of oil on salmonids (e.g. Ballachey et al. 2014; Marty et al. 2000; Wang et al. 1993), but results are inconclusive or research is lacking for other fishes in this group (e.g. herring, surfperch)
			Elasmobranchs	Basking shark	1	Basking sharks feed using gill rakers that may become clogged by oil and inhibit filter feeding	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on elasmobranchs
				Spiny dogfish, sixgill sharks	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on elasmobranchs
			Scombrids	Mackerel	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on scombrids
			Molidae	Ocean sunfish	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on Molidae
			Ammodytidae	Pacific sand lance	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on Ammodytidae
			Engraulidae	Northern anchovy	1	Anchovy filter feed using gill rakers (Lamb & Edgell 2010)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on Engraulidae
			Chimaeridae	Spotted ratfish	0	Do not contain filter feeding structures that could be clogged by oil	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on Chimaeridae

*Table E-3. Marine fish scores for RECOVERY criteria (note: Species list is not exhaustive, and scores with a * next to them indicate a precautionary score due to lack of knowledge)*

SUB-GROUP LEVEL				**Pacific example species**	**RECOVERY Criteria**							
					Population status		**Reproductive capacity**		**Endemism or Isolation**		**Close association with unconsolidated substrates**	
1	2	3	4		**S**	**Justification**	**S**	**Justification**	**S**	**Justification**	**S**	**Justification**
Estuarine	Transient	N/A	Cod (Gadidae)	Pacific tomcod, walleye pollock *(in estuaries when young, Love, 2011)*	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	0	Not expected to have regular and close interaction with unconsolidated substrates in the estuary
			Salmon (Salmonidae)	Juvenile and adult salmon & steelhead	1	Coho salmon (Endangered (Interior Fraser River population) - COSEWIC); Sockeye salmon (Endangered (Cultus and Sakinaw populations) - COSEWIC); Chinook salmon (Threatened (Okanagan population) - COSEWIC)	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	1	Many populations of salmon in B.C. are endemic (DFO 2005)	0	Not expected to have regular and close interaction with unconsolidated substrates in the estuary
			Sturgeon (Acipenseridae)	Green sturgeon, white sturgeon	1	Green sturgeon (Schedule 1 - Special Concern – SARA 2016); white sturgeon have experienced severe population decline in B.C. (Lamb & Edgell 2010)	1	High fecundity, but late reproductive maturity. White sturgeon reach sexual maturity at a minimum of 11 years (males) and 26 year (females) and spawning interval in the Fraser River population is every 4-11 years (DFO 2014b)	0	No endemism or isolation	1*	Sturgeon live over sand and silt substrates. Their mouth is benthically oriented and their diet consists of benthic fishes and molluscs. Extensive association with unconsolidated substrates for feeding is likely
			Osmeridae	Eulachon	1	Eulachon have been reported to have declined dramatically in the last two decades (Hay et al. 1997). Eulachon (*Thaleichthys pacificus*), SARA Status: Under consideration for listing. COSEWIC Status: Nass/Skeena Rivers population (Special Concern); Central Pacific Coast population (Endangered); Fraser River Population (Endangered)	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	1	There are several genetically isolated populations of eulachon in B.C. (COSEWIC 2013)	0	Not expected to have regular and close interaction with unconsolidated substrates in the estuary
			Lampreys	River lamprey, Pacific lamprey	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	0	Lamprey are poor swimmers and rely on sucking onto rocks in a current, so association with unconsolidated substrates is unlikely (Love 1996)
			Sculpins (Cottidae)	Prickly sculpin	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	1	Prickly sculpin regularly rest on bottoms of fine materials, predominantly sand (Lee et al. 1980)
			Sticklebacks (Gasterostei-dae)	Threespine stickleback	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	0	Build nests in soft substrates, but don't spend the majority of their time closely associated with unconsolidated substrates (Love 2011)

SUB-GROUP LEVEL				Pacific example species	RECOVERY Criteria							
					Population status		Reproductive capacity		Endemism or Isolation		Close association with unconsolidated substrates	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
			Flatfishes (Pleuronecti-formes)	Starry flounder, juv english sole	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	1	Flat fishes have a close interaction with unconsolidated substrates as they are bottom dwelling fish whose bodies are in frequently contact with the seabed (Love 2011)
	Resident	N/A	Surfperch (Embiotocidae)	Shiner perch	0	-	1	Embiotocids exhibit viviparity and produce few young each year compared to other fish groups. This has the potential to limit their recovery potential (Lane et al. 2002)	0	No endemism or isolation	0	Surfperch are mainly found over unconsolidated substrates in estuaries, such as in eelgrass beds (Love 1996). However, they don't interact with the seafloor regularly as they are continuously swimming in the water column
			Sculpins (Cottidae)	Staghorn sculpin	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	1	Staghorn sculpins are commonly found in the sand or mud of bays and estuaries (Love 1996). They are frequently found buried in soft substrates
			Salmonidae	Cutthroat trout, Dolly Varden	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	0	Though Dolly Varden build nests for spawning, this is in fresh water rather than marine habitats
Intertidal	Non-benthic (pelagic and demersal)	N/A	Rockfish (juvenile)	Black rockfish, copper rockfish	0	-	1	Although fecundity can be high, only 50% of copper rockfish are mature by 4-6 years and reproductive success is infrequent (Love 1996)	0	No endemism or isolation	0	These non-benthic groups are generally not expected to have regular interaction with unconsolidated substrates
			Surfperch (Embiotoci-dae)	Shiner perch	0	-	1	Embiotocids exhibit viviparity and produce few young each year compared to other fish groups. This has the potential to limit their recovery potential (Lane et al. 2002)	0	No endemism or isolation	0	These non-benthic groups are generally not expected to have regular interaction with unconsolidated substrates
	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Snailfishes (Liparidae)	Tidepool snailfish	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	0	Not expected to have regular interaction with unconsolidated substrates
			Clingfishes (Gobiesocidae)	Northern clingfish	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	0	Not expected to have regular interaction with unconsolidated substrates

SUB-GROUP LEVEL				Pacific example species	RECOVERY Criteria							
					Population status		Reproductive capacity		Endemism or Isolation		Close association with unconsolidated substrates	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
			Blennies (Stichaeidae & Pholidae)	Penpoint gunnel, crescent gunnel, high cockscomb	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	0	Not expected to have regular interaction with unconsolidated substrates
		Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass environments)	Salmonidae (juvenile)	Pink, coho, chinook salmon	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	1	Many populations of salmon in B.C. are endemic (DFO 2005)	1	The young of intertidal spawning populations of pink and chum salmon would be in close, regular association with unconsolidated substrates
			Herring (Clupeidae)	Pacific herring	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation (Ware & Schweigert 2001)	0	The eggs are deposited on rocks and vegetation, not on unconsolidated substrates
			Flatfishes- juvenile (Pleuronectidae)	English sole, starry flounder	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups (e.g. marine mammals)	0	No endemism or isolation	1	Flat fishes have a close interaction with unconsolidated substrates as they are bottom dwelling fish whose bodies are in frequent contact with the seabed
			Pipefish (Sygnathidae)	Bay pipefish	0	-	1	Pipefish have lower fecundity due to male brooding behavior	0	No endemism or isolation	0	Not expected to have regular interaction unconsolidated substrates
			Ammodytidae & Osmeridae	Pacific sand lance, surf smelt	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	1	The eggs and spawning adults will interact heavily with unconsolidated substrates. Pacific sand lance are generally in the water column by day and buried in sand at night and generally spend day and night buried in sand over the winter (Love 2011)
			Greenlings (Hexagramm-idae)	Lingcod- juvenile	1*	Lingcod are not listed by COSEWIC or SARA, but their abundance in the Strait of Georgia is low enough to warrant conservation concern (DFO 2014a)	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	1	All greenlings, including lingcod live in association with the seafloor. Juvenile lingcod associate with sandy bottoms (Love 2011)

SUB-GROUP LEVEL				Pacific example species	RECOVERY Criteria							
					Population status		Reproductive capacity		Endemism or Isolation		Close association with unconsolidated substrates	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
			Other species (e.g. Sculpins & Gobies)	Buffalo sculpin, staghorn sculpin, plainfin midshipmen	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	1	Staghorn sculpins bury themselves in soft substrates (Lamb & Edgell 2010)
Subtidal	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Wolf fish (Anarhichidae)	Wolf-eel	0	-	1	Reproductive maturity at 7 years (Love 1996)	0	No endemism or isolation	0	Wolf eels will regularly interact with rocky seafloors but not often with unconsolidated seafloors
			Greenlings (Hexagrammidae)	Lingcod- adult	1*	Lingcod are not listed by COSEWIC or SARA, but their abundance in the Strait of Georgia is low enough to warrant conservation concern (DFO 2014a)	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	0	All greenlings, including lingcod live in association with the seafloor, but adults live mostly associated with rocky relief and boulders(Love 2011)
			Rockfishes (Scorpaenidae)	Quillback, yelloweye, tiger & china rockfishes	1	Quillback rockfish (Threatened - COSEWIC); Yelloweye rockfish (Special Concern - COSEWIC); Canary rockfish (Threatened – COWEWIC); Rougheye rockfish (Special Concern - COSEWIC)	1	Only 50% of yellow-eye rockfish are mature at 19-22 years and for quillback rockfish, 50% are mature by 11 years. Also, many rockfish species have infrequent reproductive success (Love et al. 2002)	0	No endemism or isolation	0	-
		Associated with unconsolidated substrate (silt/sand/gravel)	Flatfishes (Pleuronectidae)	English sole, starry flounder, Pacific halibut	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	1	Flat fishes have a close interaction with unconsolidated substrate as they are bottom dwelling fish whose bodies are in frequent contact with the seafloor
			Elasmobranchs	Big skate	1	Big Skate (near threatened – IUCN 2016); Longnose skate (Least concern – IUCN 2016)	1	Big skate reaches maturity at 6-8 years; longnose skate reaches maturity at 7-10 years (McFarlane & King 2006)	0	No endemism or isolation	1	Have a close interaction with sediment, as they are bottom dwelling fish whose bodies are in frequent contact with unconsolidated substrate types (silt/sand/gravel) likely to retain oil

SUB-GROUP LEVEL				Pacific example species	RECOVERY Criteria							
					Population status		Reproductive capacity		Endemism or Isolation		Close association with unconsolidated substrates	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
			Hagfishes (Myxinidae)	Pacific hagfish	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	1	Have a close interaction with unconsolidated substrates, as they are bottom dwelling fish whose bodies are in frequent contact with unconsolidated substrate types (silt/sand/gravel) likely to retain oil. Also, likely preference for mud mentioned in Love 1996
			Rockfishes (Scorpaenidae)	Darkblotched & canary rockfishes	1	Darkblotched rockfish (Special Concern - COSEWIC)	1	Darkblotched rockfish mature from 4-8 years and many rockfish species have infrequent reproductive success (Love et al. 2002)	0	No endemism or isolation	1	Darkblotched rockfish are typically found on mud near cobble or boulders (Love et al. 2002)
	Non-benthic (pelagic, midwater and demersal)	N/A	Rockfishes (Scorpaenidae)	Yellowtail, blue, widow rockfishes, Bocaccio	1	Bocaccio rockfish (Endangered COSEWIC); Yellowmouth rockfish (Threatened - COSEWIC);	1	50% of Yellowtail rockfish are mature between 6 and 15 years (Love et al. 2002); Widow rockfish mature at 8-9 years. Also, many rockfish species have infrequent reproductive success (Love et al. 2002)	0	No endemism or isolation	0	Not expected to have regular, close interaction with unconsolidated substrates, as they are placed in the non-benthic category
			Cod (Gadidae)	Pacific cod, hake, Pacific tomcod, walleye pollock	0	-	0	Pacific cod mature at 2-4 years (Love 1996)	0	No endemism or isolation	0	Not expected to have regular, close interaction with unconsolidated substrates, as they are placed in the non-benthic category
			Misc species	Sablefish (Anaplopomatidae), Salmon (Salmonidae), Surfperch (Embiotocidae), Herring (Clupeidae)	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	0	Not expected to have regular, close interaction with unconsolidated substrates, as they are placed in the non-benthic category
			Elasmobranchs	Basking shark	1	Basking Shark (Endangered (Pacific population) – SARA 2016);	1*	No estimate for age at maturity (Love 1996)	0	No endemism or isolation	0	Not expected to have regular, close interaction with unconsolidated substrates, as they are placed in the non-benthic category

SUB-GROUP LEVEL				Pacific example species	RECOVERY Criteria							
					Population status		Reproductive capacity		Endemism or Isolation		Close association with unconsolidated substrates	
1	2	3	4		S	Justification	S	Justification	S	Justification	S	Justification
			Elasmobranchs	Spiny dogfish, sixgill sharks	1	Common Thresher Shark (Vulnerable (Eastern Central Pacific) – IUCN 2016); Bluntnose Sixgill Shark (Special Concern – SARA 2016); Broadnose Sevengill Shark (Data deficient – IUCN 2016); Blue Shark (Near Threatened – IUCN 2016); Pacific Sleeper Shark (Data deficient – IUCN 2016); Spiny Dogfish (Special Concern – SARA 2016); Top shark (Special Concern – SARA 2016)	1	Life history features for Bluntnose Sixgill Shark such as longevity (estimated to be 80 years), late age at maturity (estimated at 18-35 years) and low fecundity (47-108) characterise them as vulnerable equilibrium life history strategists. As such, they have a low intrinsic rate of increase, and are unable to recover quickly after population reduction. Spiny dogfish live longer (up to 80 years old) and mature later than any other shark species that has been studied. Females may gestate their eggs for 22 months. (Love 2011)	0	No endemism or isolation	0	Not expected to have regular, close interaction with unconsolidated substrates, as they are placed in the non-benthic category
			Scombrids	Mackerel	0	-	0	-	0	No endemism or isolation	0	Not expected to have regular, close interaction with unconsolidated substrates, as they are placed in the non-benthic category
			Molidae	Ocean sunfish	1	Ocean sunfish (Vulnerable (suspected global decline) – IUCN 2016)	0	Little is known about time to reproductive maturity, but a single 4.5 foot female was found to contain 300 million eggs (Love 1996)	0	No endemism or isolation	0	Not expected to have regular, close interaction with unconsolidated substrates, as they are placed in the non-benthic category
			Ammodytidae	Pacific sand lance	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	1	Sand lance are a midwater schooling species, but generally spend nights and winter buried in sand and fine gravel (Love 2011)
			Engraulidae	Northern anchovy	0	-	0	Most fish species have high fecundity and early reproductive maturity relative to other groups	0	No endemism or isolation	0	Not expected to have regular, close interaction with unconsolidated substrates, as they are placed in the non-benthic category
			Chimaeridae	Spotted ratfish	0	-	1*	Males are estimated to mature at 12 years of age, females at 14 years of age. Females only produce 2 eggs at a time and spawn year-round. Eggs develop for 1 year in egg cases (Love 1996; King & McPhie 2015)	0	No endemism or isolation	1*	Ratfish live over flat, muddy, or sandy substrates. Diet is mostly comprised of benthic and epibenthic species, including clams (Love 2011), so close association is a possibility depending on how extensively they forage into the substrate

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14 APPENDIX F: DETAILED SCORING TABLES WITH JUSTIFICATIONS FOR MARINE REPTILES

*Table F-1. Marine reptile scores for EXPOSURE criteria, the column labelled "S" indicates the score assigned (note: Species list is not exhaustive, and scores with a * next to them indicate a precautionary score due to lack of knowledge)*

SUB-GROUP	**Pacific example species**	**EXPOSURE Criteria**							
		Concentration (aggregation)		**Mobility and/or exhibit site fidelity**		**Sea surface interacting**		**Seafloor or vegetation interacting**	
		S	Justification	S	Justification	S	Justification	S	Justification
Sea Turtles	Leatherback sea turtle; green sea turtle; olive ridley	0	Migratory / Accidental in B.C. waters and not expected to aggregate (SARA 2006)	0	Highly mobile	1	Interact with the sea surface to breathe	0	Sea turtles can interact with the seafloor/vegetation when foraging (Seminoff et al. 2006). However, in B.C. they are accidental visitors and not likely to be actively foraging

*Table F-2. Marine reptile scores for SENSITIVITY criteria, the column labelled "S" indicates the score assigned (note: Species list is not exhaustive, and scores with a * next to them indicate a precautionary score due to lack of knowledge)*

SUB-GROUP	**Pacific example species**	**SENSITIVITY Criteria**			
		Mechanical Sensitivity Reduction of feeding/photosynthesis/insulation		**Chemical Sensitivity Impairment due to toxicity**	
		S	Justification	S	Justification
Sea Turtles	Leatherback sea turtle; green sea turtle; olive ridley	0	Sea turtles do not rely on fur for thermoregulation and do not have filter feeding structures	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on sea turtles

*Table F-3. Marine reptile scores for RECOVERY criteria, the column labelled "S" indicates the score assigned (note: Species list is not exhaustive, and scores with a * next to them indicate a precautionary score due to lack of knowledge)*

SUB-GROUP	**Pacific example species**	**RECOVERY Criteria**							
		Population status		**Reproductive capacity**		**Endemism or Isolation**		**Close association with unconsolidated substrates**	
		S	Justification	S	Justification	S	Justification	S	Justification
Sea Turtles	Leatherback sea turtle; green sea turtle; olive ridley	1	The Pacific leatherback population has collapsed by over 90% in the last generation (Endangered - (COSEWIC, 2012)	1	Marine reptiles have low reproductive capacity relative to other groups in the assessment. Leatherbacks have large clutch sizes (50-170 eggs) and multiple nestings per season (4-10), but age at reproductive maturity and generation time is uncertain (COSEWIC, 2012)	0	No evidence of endemic/isolated populations of species in this group in B.C.	0	Some sea turtles forage deeply within small particle substrate (Seminoff et al. 2006). However, in B.C., sea turtles are accidental visitors and are not likely to be to be actively foraging

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15 APPENDIX G: DETAILED SCORING TABLES WITH JUSTIFICATIONS FOR MARINE MAMMALS

*Table G-1. Marine mammal scores for EXPOSURE criteria, the column labelled ”S” indicates the score assigned (note: Species list is not exhaustive, and scores with a * next to them indicate a precautionary score due to lack of knowledge)*

SUB-GROUP LEVEL			**Example species from the Pacific region**	**EXPOSURE Criteria**							
				Concentration (aggregation)		**Mobility and/or site fidelity**		**Sea Surface interacting**		**Seafloor or Vegetation Interacting**	
1	**2**	**3**		S	Justification	S	Justification	S	Justification	S	Justification
Cetaceans	Toothed	Discrete	Killer whales: residents (Northern and Southern) and offshore populations; Pacific white sided dolphin	1	Resident killer whales form large aggregations, comprising of multiple pods, in specific areas relating to salmon concentrations during spawning runs (Ford et al. 2000). Offshore killer whales are have a small population (~500 coast wide, California to Aleutians) but travel in very large aggregations (100+) (Ford et al. 2000). Pacific white sided dolphins travel in large groups of between 40-100 individuals (Best et al. 2015, Heise 1997) though they are widely distributed in inshore and offshore waters.	0	Highly mobile	1	Regular interaction with the surface to breathe	1*	N. resident killer whales interact with the seafloor at rubbing beaches (Ford et al. 2000). However, the frequency and extent of use is uncertain (hence the *)
		Dispersed	Sperm whale, killer whales (W.coast transients); false killer whale; beaked whales (Baird's, Hubbs', Stejneger's); porpoises (harbour and dall's)	0	The species within this sub-group are generally dispersed in B.C. waters and do not form discrete aggregations, or may be transiting the region. For example, harbour and dall's porpoises usually occur in small groups of < 8 (COSEWIC 2003a; Jefferson 1987; Ford 2014).	0	Highly mobile	1	Regular interaction with the surface to breathe	0	No regular interaction with seafloor or vegetation
	Baleen	Discrete	Humpback whale; grey whale	1	Humpbacks aggregate for feeding in B.C. waters and travel in large, loose groups, with increasing populations in B.C. waters (Dalla Rosa et al. 2012). Grey whales travel in small groups of 1-5 (Ford et al. 2010) during migration population is age class segregated with pregnant females in the lead (Wursig 1990). Grey whales have been reported to concentrate off Southern Vancouver island as part of the Pacific Coast Feeding Aggregation (Calambokidis et al. 2002). Fin whales are common in large groups up to 20 individuals (Best et al. 2015; Ford, 2014) in B.C. waters.	0	Highly mobile	1	Regular interaction with the surface to breathe	1	Grey whales interact with the seabed regularly as they are primarily bottom feeders, consuming benthic and epibenthic invertebrates (Ford 2014). Bottom side roll feeding occurs in atlantic humpbacks but not found in pacific humpbacks (Ware et al. 2013)
		Dispersed	Sei whale; blue whale; fin whale; north pacific right whale; common minke whale	0	The species within this group are generally dispersed in B.C. waters and do not form discrete aggregations, or may be transiting the region. For example common minke whales are primarily seen alone or in similar areas yet independent of one another (Dorsey 1981).	0	Highly mobile	1	Regular interaction with the surface to breathe	0	No regular interaction with seafloor or vegetation

SUB-GROUP LEVEL			Example species from the Pacific region	EXPOSURE Criteria							
				Concentration (aggregation)		Mobility and/or site fidelity		Sea Surface interacting		Seafloor or Vegetation Interacting	
1	**2**	**3**		S	Justification	S	Justification	S	Justification	S	Justification
Pinnepeds	Thermoregulate with fur		Northern fur seal	0	Females and sub-adult males occur off the Canadian west coast (off shelf) during the winter and spring, rarely observed inshore, infrequently come ashore at sea lion haulouts such as Race Rocks (Bigg 1990). Not known to breed in Canada did in the past (Newsome et al. 2007). Pelagic, spending majority of life at sea, rarely haul out in B.C. waters and do not tend to aggregate in B.C. waters (Ford 2014; COSEWIC 2010).	0	Highly mobile	1	Regular interaction with the surface to breathe	0	Feed on schooling fishes and squid, no regular interaction with seafloor or vegetation
	Other pinnipeds	Discrete	Steller sea lion, harbour seal; California sea lion	1	Aggregate at haulout sites for resting and breeding (the second largest breeding aggregation of stellar sea lions in the world is in B.C. at the Scott Islands) (Fisheries and Oceans Canada 2010). Steller sea lions are not migratory and have three types of haulouts: year round, breeding and winter (Ford 2014; Bigg 1985). California sea lions overwinter in B.C. waters and are found in large groups congregated at haul out sites in B.C. waters, such as Race Rocks (Ford 2014).	0	Highly mobile	1	Regular interaction with the surface to breathe	1	Harbour seals forage in unconsolidated substrates and rest on the seafloor. Pups in particular primarily feed on benthic crustaceans (Ford 2014)
		Dispersed	Northern elephant seal	0	N. elephant seals spend majority of life on the high seas under the surface. They may have recently started a small breeding colony in B.C. (Race Rocks) and have begun to be present year round (Ford 2014; Stewart & DeLong 1995). However, over the B.C. Pacific range these species are not considered to aggregate as the majority of breeding and calving occurs outside of B.C. waters. They are generally dispersed in B.C. waters.	0	Highly mobile	1	Regular interaction with the surface to breathe	1*	Generally consume mainly pelagic/demersal fishes above the seabed but N. elephant seals have been observed foraging on the seabed for Hagfishes (Ford 2014). Uncertain of the frequency that this occurs (hence *)
Mustelids			Sea otter	1	Sea otters can be found in large single sex aggregations (DFO 2014)	1	Highly mobile but range is limited to sites on B.C. coast (DF0 2014)	1	Regular interaction with the surface to breathe	1	Sea otters forage for clams in soft bottom substrate, and rest in kelp beds (DFO 2014; Kvitek et al. 1993)

*Table G-2. Marine mammal scores for SENSITIVITY criteria, the column labelled ”S” indicates the score assigned (note: species list is not exhaustive, and scores with a * next to them indicate a precautionary score due to lack of knowledge)*

SUB-GROUP LEVEL			**Example species from the Pacific region**	**SENSITIVITY Criteria**			
				Mechanical Sensitivity Reduction of feeding/photosynthesis/insulation		**Chemical Sensitivity Impairment due to toxicity**	
1	**2**	**3**		S	Justification	S	Justification
Cetaceans	Toothed	Discrete	Resident and offshore killer whales (NE Pacific Northern & Southern resident & NE Pacific offshore); Pacific white sided dolphin	0	Don't rely on fur for thermoregulation and do not have filter feeding structures	1*	Several studies have investigated the toxic effects of oil on toothed cetaceans (mainly killer whales), but a lack of baseline data and standardised methods make results difficult to compare.
		Dispersed	Sperm whale, killer whale (W.coast transient); false killer whale; beaked whales (Baird's, Hubbs' and Stejneger's) harbour porpoise; Dall’s porpoise	0	Don't rely on fur for thermoregulation and do not have filter feeding structures	1*	Several studies have investigated the toxic effects of oil on toothed cetaceans (mainly killer whales), but a lack of baseline data and standardised methods make results difficult to compare
	Baleen	Discrete	Humpback whale; grey whale	1	Filter feeding structures (baleen) can become fouled, reducing ability to feed (Wursig 1990)	1*	A handful of studies have investigated the toxic effects of oil on baleen cetaceans, but a lack of baseline data and standardised methods make results difficult to compare
		Dispersed	Sei whale; blue whale; fin whale; North Pacific right whale; common minke whale	1	Filter feeding structures (baleen) can become fouled, reducing ability to feed (Wursig 1990)	1*	A handful of studies have investigated the toxic effects of oil on baleen cetaceans, but a lack of baseline data and standardised methods make results difficult to compare
Pinnepeds	Thermoregulate with fur		Northern fur seal	1	Rely on fur for thermoregulation. Oil drastically reduces insulative value of pelt (Geraci & St. Aubin 1990)	1*	Precautionary scoring due to a lack of research on the toxic effects of oil on the Northern fur seal
	Other pinnipeds	Discrete	Steller sea lion, harbour seal; California sea lion	0	Don't rely on fur for thermoregulation	1*	A handful of studies have investigated the toxic effects of oil on pinnipeds, but a lack of baseline data and standardised methods makes results difficult to compare
		Dispersed	Northern elephant seal	0	Don't rely on fur for thermoregulation	1*	A handful of studies have investigated the toxic effects of oil on pinnipeds, but a lack of baseline data and standardised methods make results difficult to compare
Mustelids	N/A	N/A	Sea otter	1	Rely on fur for thermoregulation. Oil drastically reduces insulative value of fur (Williams et al. 1988; DFO 2014)	1*	Several studies have investigated the toxic effects of oil on mustelids, but a lack of baseline data and standardised methods make results difficult to compare

*Table G-3. Marine mammal scores for RECOVERY criteria, the column labelled "S" indicates the score assigned (note: Species list is not exhaustive, and scores with a * next to them indicate a precautionary score due to lack of knowledge)*

SUB-GROUP LEVEL			**Example species from the Pacific region**	**RECOVERY criteria**							
				Population status		**Reproductive capacity**		**Endemism or Isolation**		**Close association with unconsolidated substrates**	
1	**2**	**3**		S	Justification	S	Justification	S	Justification	S	Justification
Cetaceans	Toothed	Discrete	Killer whales: Northern resident (NRKW); Southern resident (SRKW); NE Pacific offshore; Pacific white sided dolphin	1	The Southern Resident Killer Whale (SRKW) population is small and declining, with 'Endangered' status (COSEWIC 2008). Offshore killer whale population also very small.	1	Low reproductive capacity: Killer whales are long-lived, slow reproducers: the longevity of the resident populations in B.C. is 80 years for females and 40-50 years for males. Females give birth to their first calf between 12-17 years of age and produce a single calf every 5 years. Generation time is 26-29 years. (COSEWIC 2008). Very low reproductive capacity.	1	The NRKW and SRKW populations are distinct in the region, isolated from each other and other killer whale populations (COSEWIC 2008)	0	Do not closely associate with unconsolidated substrates
		Dispersed	Sperm whale, killer whales (W.Coast transients); false killer whale; Baird's beaked whale; Hubbs' beaked whale; Stejneger's beaked whale; harbour porpoise; Dall's porpoise	1	Sperm whales still have significantly reduced populations from commercial whaling (Taylor et al. 2008). Though the W. coast transient population of killer whales is small, no reduction in the number of mature individuals observed since monitoring began in 1975 (COSEWIC 2008). Harbour porpoise populations in Southern B.C. are suspected to have declined but no clear evidence (COSEWIC 2003).	1	Low reproductive capacity: Killer whales are long lived slow reproducers (COSEWC, 2008). This sub-group also contains some relatively shorter-lived species, such as the harbour porpoise and Dall's porpoise (COSEWIC 2003; Jefferson 1990; Ford 2014). Relative to the other groups in the overall assessment, reproductive capacity Is low.	0	No evidence of endemic/isolated populations of species in this group	0	Do not closely associate with unconsolidated substrates
	Baleen	Discrete	Humpback whale; grey whale	1	Humpback and grey whale populations are still drastically reduced from historic levels due to commercial whaling (COSEWIC 2011; COSEWIC 2004a).	1	Low reproductive capacity: Humpback and Grey whales have a calving interval of 2-3 years; Humpback gestation is 11-12 months and longeivity in Humpback whales is at least 48 years (Jones 1990; COSEWIC 2004a; COSEWIC, 2011). Relative to the other groups in the assessment, reproductive capacity Is low.	1*	The 'Pacific Coast Feeding Aggregation' may be a distinct grey whale population, though evidence is inconclusive (Calambokidis et al. 2002; Ramakrishnan et al. 2001) hence the precautionary 1*.	1	Grey whales forage in unconsolidated substrates at a depth where lingering oil is found (pits ~10cm deep) (Nelson et al. 2006)
		Dispersed	Sei whale; blue whale; fin whale; North Pacific right whale; common minke whale	1	Populations of these species still drastically reduced due to commercial whaling. Blue whales in particular have a greatly reduced population. Sei, blue and North Pacific right whales are 'Endangered; Fin whales are 'Threatened' (COSEWIC 2004b; 2005; 2012; 2013a).	1	Low reproductive capacity: Sei whales reach sexual maturity at 5 - 15 years of age, have a 10-12 month gestation period, and live at least up to 60 years (COSEWIC 2013a). Blue whale females give birth every 2-3 years, with a long gestation period (10-12 months) (Gregr et al., 2006). Relative to other groups in the overall assessment, reproductive capacity is low.	0	No evidence of endemic/isolated populations of species in this group	0	Do not closely associate with unconsolidated substrates

SUB-GROUP LEVEL			Example species from the Pacific region	RECOVERY criteria							
				Population status		**Reproductive capacity**		**Endemism or Isolation**		**Close association with unconsolidated substrates**	
1	**2**	**3**		S	Justification	S	Justification	S	Justification	S	Justification
Pinnepeds	Thermoregulate with fur		Northern fur seal	1	Pup production in the major breeding colonies has been declining for the last 45 years, has ‘Threatened’ status (COSEWIC 2010).	1	Low reproductive capacity: Northern fur seals are sexually mature at 3-7 years, with a generation time of 10 years. Males have a short reproductive span averaging 1.5 seasons. Females can reproduce into their 20’s with approximately 20 offspring in their lifetime (COSEWIC 2010). Relative to the other groups in the overall assessment, reproductive capacity Is low.	0	No evidence of endemic/isolated populations of species in this group	0	Do not closely associate with unconsolidated substrates
	Other pinnipeds	Discrete	Steller sea lion, harbour seal; California sea lion	0	The steller sea lion population in B.C. is not in decline - the population is at similar levels before harvesting and predator-control programs began in the 1900s (COSEWIC 2013b). No evidence of population decline in harbour seals.	1	Low reproductive capacity: Stellar sea lions are a relatively long-lived and slow reproducing species (COSEWIC 2013b). Marine mammals have low reproductive capacity relative to the other groups in the assessment.	0	No evidence of endemic/isolated populations of species in this group	0	Do not closely associate with unconsolidated substrates
		Dispersed	Northern elephant seal	0	No evidence of population decline, both species have ‘Not at Risk’ COSEWIC status.	1	Low reproductive capacity: N. Elephant seals have somewhat higher reproductive capacity relative to other marine mammals, as they become sexually mature between 2-6 years and produce offspring most years (Reiter & LeBeouf 1991). However, relative to the other groups in the overall assessment, reproductive capacity Is low.	0	No evidence of endemic/isolated populations of species in this group	0	Do not closely associate with unconsolidated substrates
Mustelids	N/A	N/A	Sea otter	1	Sea otter (Special concern - COSEWIC). After reintroduction to B.C. 1969-72 sea otters have repopulated up to 33% of historic B.C. range but the population not yet secure (COSEWIC 2007; DFO 2014).	1	Low reproductive capacity. Sea otters have a higher reproductive capacity than many other marine mammals, as they become sexually mature between 2-6 years and produce offspring most years (Riedman & Estes 1990; Jameson & Johnson 1993). However, relative to the other groups in the overall assessment, reproductive capacity Is low.	0	No evidence of endemic/isolated populations of species in this group	1	Regularly forage and excavate into unconsolidated substrates and so are likely to encounter lingering subsurface oil (Short et al. 2006).

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16 APPENDIX H: CONSEQUENCES OF CHANGE TO EXPOSURE CRITERION FROM SEDIMENT INTERACTING TO SEAFLOOR/VEGETATION INTERACTING.

Analysis of different scoring and screening outcomes when using “Seafloor or vegetation interacting” criterion vs “Sediment interacting” criterion

During scoring, it became evident that oil can be retained for an extended period of time, not just in unconsolidated substrates, but in a number of other marine substrates, including rock crevices and vegetation (Cretney et al. 1978). This extended period increases the amount of time over which new individuals may be acutely exposed to oil, increasing the probability that a large number of individuals will be exposed following a single oil spill event (see Section 0 for full justification) and so it was decided to expand this criterion from ‘sediment interacting’ to ‘seafloor and vegetation interacting’. Before implementing the criterion change, the implications that it would have on the final ranked list were examined.

By definition, when the “Sediment interacting” criterion is used, many sub-groups living on substrates other than soft sediment score lower and are ranked lower than those living on soft substrate. Explanding the criterion affected 13/40 fish sub-groups, 9/16 plant sub-groups, 26/49 invertebrate sub-groups, and the sea turtles. Many benthic fishes, as well as estuarine transient salmon, estuarine resident surfperch, and intertidal non-benthic rockfishes (juveniles) and surfperch, scored one less for exposure and moved down the final ranked list. This was also the case for all rocky habitat plant and algae sub-groups, as well as all rock and rubble dwelling invertebrates. Table H-1 outlines the implications of choosing the “Sediment interacting” criterion over the “Seafloor or vegetation interacting” criterion for those groups with total scores of 7-9. For example, if a manager were to choose a cut-off such that 7 or more criteria must be fulfilled in order for a sub-group to be further processed (e.g. mapped), sub-groups with total scores of 7 that are highlighted in grey would be cut from the list and not processed further (as these scores would drop to 6 if the “Sediment interacting” criterion were used). Groups that would be cut in this scenario include intertidal rock and rubble dwelling molluscs (such as the Olympia oyster), intertidal rock and rubble dwelling echinoderms (sea urchins, sea cucumbers, and sea stars), and subtidal benthic rock and rubble dwelling porifera (glass sponges), to name a few. If the “Seafloor or vegetation interacting” criterion were used, these sub-groups would not be cut from the list in this scenario.

Given the evidence for oil retention in habitats other than unconsolidated substrates, as well as the implications of choosing to only recognise soft sediment as a potential source for extended acute exposure, it was decided to use the “Seafloor or vegetation interacting” criterion for this analysis.

Table H-1. Ranked vulnerability list for those sub-groups with total scores of 7 or more. Total scores for sub-groups highlighted in grey would decrease by 1 if "Sediment interacting" criterion were used instead of "Seafloor or vegetation interacting" criterion.

Sub-groups					***Example species***	**Cumulative Total Score**
1	**2**	**3**	**4**	**5**		
MARINE PLANTS & ALGAE	Intertidal	Vascular Plants	Moderate to low energy unconsolidated habitat	Seagrasses	e.g. *Zostera marina, Z. japonica, Ruppia maritima*	9
MARINE PLANTS & ALGAE	Intertidal	Vascular Plants	Moderate to low energy unconsolidated habitat	Salt marsh grasses	e.g. *Carex lyngbyei, Leymus mollis*	9
MARINE PLANTS & ALGAE	Intertidal	Vascular Plants	Moderate to low energy unconsolidated habitat	Salt marsh succulents	e.g. *Sarcocornia pacifica, S. pacifica, Glaux maritima, Plantago maritima*	9
MARINE MAMMALS	Cetaceans	Baleen	Discrete	N/A	e.g. humpback whales; grey whales; fin whales	9
MARINE MAMMALS	Mustelids	N/A	N/A	N/A	e.g. sea otter	9
MARINE PLANTS & ALGAE	Intertidal	Vascular Plants	High energy, rocky habitat	Seagrasses	*e.g. Phyllospadix scouleri, P. torreyi, P. serrulatus*	8
MARINE INVERTEBRATES	Intertidal	Sediment epifauna	Low mobility	Mollusca	e.g. snails [Gastropoda]	8
MARINE INVERTEBRATES	Intertidal	Sediment epifauna	Low mobility	Cnidaria	e.g. sea pens	8
MARINE INVERTEBRATES	Intertidal	Sediment epifauna	Low mobility	Echinodermata	e.g. sea stars	8
MARINE FISHES	Estuarine	Transient	N/A	Salmon (Salmonidae)	e.g. juvenile and adult salmon & steelhead	8
MARINE FISHES	Intertidal	Benthic	Associated with unconsolidated substrates (Silt/Sand/Gravel) (including eelgrass environments)	Salmonidae (juvenile)	e.g. pink, chum, coho, chinook salmon	8
MARINE PLANTS & ALGAE	Intertidal	Understory / Turf Algae	High energy, rocky habitat	N/A	e.g. *Pelvetiopsis limitata, Cymathere triplicata, Postelsia palmaeformis, Corallina vancouveriensis, Alaria*	7

Sub-groups					***Example species***	**Cumulative Total Score**
1	**2**	**3**	**4**	**5**		
					fistulosa	
MARINE PLANTS & ALGAE	Subtidal	Canopy Algae	Moderate to low energy rocky habitat	N/A	e.g. *Macrocystis integrifolia*	7
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Mollusca	e.g. oysters [Bivalvia]	7
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Low mobility	Echinodermata	e.g. sea urchins [Echinoidea];sea cucumbers [Holothuroidea];sea stars [Asteroidea]	7
MARINE INVERTEBRATES	Intertidal	Sediment infauna	Low mobility	Mollusca	e.g. clams [Bivalvia]; snails [Gastropoda]	7
MARINE INVERTEBRATES	Intertidal	Sediment infauna	Low mobility	Worms	e.g. burrowers	7
MARINE INVERTEBRATES	Intertidal	Sediment infauna	Low mobility	Arthropoda	e.g. sand crabs [Emerita]	7
MARINE INVERTEBRATES	Intertidal	Sediment infauna	Low mobility	Lophophorates	e.g. horseshoe worms [Phoronida]; lampshells [Brachiopoda]	7
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Porifera	e.g. glass sponges	7
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Low mobility	Echinodermata	e.g. sea urchins, sea stars	7
MARINE INVERTEBRATES	Subtidal benthic	Sediment infauna	Low mobility	Mollusca	e.g. clams	7
MARINE INVERTEBRATES	Subtidal benthic	Sediment epifauna	Low mobility	Cnidaria	e.g. sea pens	7
MARINE INVERTEBRATES	Subtidal benthic	Sediment epifauna	Low mobility	Echinodermata	e.g. sea stars	7

Sub-groups					*Example species*	Cumulative Total Score
1	**2**	**3**	**4**	**5**		
MARINE FISHES	Estuarine	Transient	N/A	Sturgeon (Acipenseridae)	e.g. green sturgeon, white sturgeon	7
MARINE FISHES	Intertidal	Benthic	Associated with unconsolidated substrates (Silt/Sand/Gravel) (including eelgrass environments)	Herring (Clupeidae)	e.g. Pacific herring	7
MARINE MAMMALS	Cetaceans	Toothed	Discrete	N/A	e.g. killer whales: residents (Northern and Southern) and offshore populations; Pacific white sided dolphin	7

17 APPENDIX I: GAP ANALYSIS

An important output of this pilot application is to identify and describe knowledge gaps which can be used to prioritise research moving forward. Knowledge gaps were identified and documented during two main stages of the framework adaptation and application processes:

1. while grouping biological components into sub-groups, and
2. while scoring sub-groups against the suite of vulnerability criteria.

1. Gaps identified during sub-group breakdown process

Sub-group breakdown required several iterations. This process required an extensive literature search, and the acquisition of expert input. Through these efforts, several gaps were identified.

1.1 Fishes:

Fishes are a very complex group, and lumping them together or splitting them apart based on physical or life history characteristics that make them similarly vulnerable or resilient to oil was challenging. In general, fish groupings as they stand performed well in the framework, but more thought could be given to further optimizing fish groupings given available knowledge on common characteristics and vulnerabilities to oil. Finally, further research should be done to assess the impacts of oil to all fishes, which would further inform the sub-group breakdown exercise.

1.2 Invertebrates:

No major gaps remain for this sub-group with respect to sub-group breakdown, but due to the complexity and diversity of this group, more thought should be given on how to best capture the more obscure sub-groups, or those that do not fall neatly into a given category. To fill this gap, it might be possible to look at whether using indicator species, or associated species, to represent those species that are missed with the current methodology.

1.3 Marine Mammals and Reptiles:

No major gaps remain for this sub-group with respect to sub-group breakdown, but further thought should be given to the definition for discrete vs. dispersed as it relates to sub-group breakdown. Discrete vs. dispersed can be viewed in terms of species range, or in terms of aggregating behaviours, so further research and expert consultation to define this term would be useful.

1.4 Marine Plants and Algae:

Generally, the marine algae and plants sub-group breakdown performed well, but a few sub-groups have gaps outstanding:

- Intertidal and sub-tidal canopy algae: “canopy” can be defined based strictly on the height of a plant, or it can be defined by whether it provides cover to other plants. The specific definition has implications for sub-group breakdown and scoring, so further thought should be given to the best definition within this framework for a canopy plant.
- High energy vs. low energy shores: It was initially assumed that oil would be more persistent on lower wave energy shores compared with high energy shores, and sub-groups were separated accordingly. Although this assumption seems logical, desktop research did not

substantiate this assumption; studies were found where species from high wave energy areas such as surfgrasses retained oil after being exposed to a spill. Research efforts should further investigate this assumption to determine temporal aspects of oil persistence in different wave exposure regimes for use during sub-group breakdown and subsequent scoring.

- Surface texture: It was initially assumed that species with rough surfaces would retain more oil than those with smooth or slippery surfaces, and sub-groups were separated accordingly. Although this assumption also seemed logical, the literature did not support it, and the division was removed. Research efforts should further investigate this assumption to determine its validity with respect to impacts from oil and for use during sub-group breakdown.

2. Gaps identified during scoring process

Knowledge gaps encountered during scoring were generally divided into species biological or ecological knowledge gaps, and knowledge gaps specific to the effects of oil on species sub-groups. With respect to the oiling impacts, in some cases, scientific knowledge was abundant, but consensus was low to nonexistent. In several cases, research conclusions were conflicting. Regardless of the reason, whenever knowledge gaps prevented well-informed and defensible scoring of biological sub-groups against criteria, a precautionary score of 1* was given to the sub-group for the criterion lacking certainty. The gaps were then flagged for inclusion in this section.

Table I-1 outlines the total number of scores assigned a score of 1* listed by major sub-group. Note: 1*s for “impairment due to toxicity” are not included as all sub-groups scored 1* for this criterion.

Table I-1. Precautionary 1 score totals by major groupings and criteria.*

	Criteria	**Total number of scores assigned 1***				
		Plants/ Algae	**Invertebrates**	**Fishes**	**Reptiles**	**Marine mammals**
	Total # sub-groups scored per criterion	**16**	**54**	**40**	**1**	**8**
	Total # 1* scored per major sub-group	**17**	**9**	**7**	**0**	**3**
Exposure	Concentration/ Aggregation	2	9	1	0	0
	Mobility/Site Fidelity	0	0	0	0	0
	Sea surface interacting	0	0	0	0	0
	Seafloor or vegetation interacting	2	0	1	0	2

	Criteria	Total number of scores assigned 1*				
		Plants/ Algae	**Invertebrates**	**Fishes**	**Reptiles**	**Marine mammals**
Sensitivity	Reduction of feeding/ photosynthesis	5	0	0	0	0
	Impairment due to toxicity	N/A	N/A	N/A	N/A	N/A
Recovery	Population status	4	0	2	0	0
	Reproductive capacity	4	0	2	0	0
	Endemism or isolation	0	0	0	0	1
	Close association w/ unconsolidated substrate	0	0	1	0	0

2.1 Marine Plants and Algae

Marine plants and algae sub-group had the greatest number of precautionary scores. It is important to note that precautionary scores are not only given due to a knowledge gap; sometimes 1*s are assigned when a sub-group cannot be scored definitively under a criterion. An example of this is intertidal canopy algae on high energy rocky shores, which was scored as 1* for seafloor interacting because it wasn't known whether rocky shores in a high energy environment would retain oil long enough to expose the associated algae.

Outstanding knowledge gaps for plants and algae include:

- Toxic effects of oil on marine algae and plants.
- Whether or not higher energy environments retain oil less than lower energy environments.
- Whether or not photosynthetic impairment due to smothering would be lower in high energy environments as a result of lower oil retention compared to wave sheltered environments.
- Whether or not algae sheltered by canopy species experience lower photosynthetic impairment due to a sheltering effect.
- Population status and trends for marine plants and algae. Few plants or algae are well studied with the possible exception of canopy kelps such as *Nereocystis* and *Macrocystis*. The population status of these kelps has been monitored by some groups in recent years and there is some evidence of population decline. More research should be done to assess whether these declines are a short-term response to the Pacific Decadal Ocean Index (PDO), or longer term trends.
- Reproductive capacity of intertidal, vascular plants such as seagrasses, salt marsh grasses, and salt marsh succulents.

2.2 Invertebrates

Invertebrates had the second greatest number of precautionary 1* scores, but it is also the major biological grouping with the greatest number of sub-groups. With the exception of the precautionary scores assigned to all sub-groups for the criterion “impairment due to toxicity”, all precautionary 1*scores were assigned under the exposure criterion “concentration/aggregation”.

Outstanding knowledge gaps for invertebrates include:

- Reproductive capacities of reef-building sponges.
- Whether any invertebrate species are experiencing population declines in B.C.
- Which invertebrate groups specifically require research to fill basic knowledge gaps.
- Toxic effects of oil on invertebrates in B.C.

2.3 Fishes

Fishes had a total of 7 precautionary scores assigned. As with all other major biological groups, all fishes were also assigned precautionary 1* scores under “impairment due to toxicity”.

Outstanding knowledge gaps for fishes include:

- Toxic effects of oil on the various life history stages of the suite of fish species in B.C. (where this information is lacking).
- Identification of all genetically isolated fish populations in B.C.
- Population statuses of adult and juvenile lingcod, and hagfishes.
- Reproductive capacities of hagfishes and basking sharks.

2.4 Marine mammals and reptiles

Marine mammals are a very well-studied group in B.C. Other than the precautionary scores assigned to all sub-groups under “impairment due to toxicity”, there were only three precautionary scores assigned to marine mammals. Two relate to knowledge gaps regarding the regularity of seafloor interactions of the Northern resident population of killer whales and the dispersed “other” pinnipeds, and one relates to the endemism or isolation of discrete baleen whale populations. There were no precautionary scores assigned to reptiles.

3. Recommendations for closing the gaps.

Table I-2. Recommendations for closing gaps identified for each major grouping

Biological group	Gap	Short term recommendation	Long term recommendation
Marine plants/ algae	Toxic impairment due to oil for marine plants and algae in B.C.	Desktop research/extensive literature review	Primary research
	Photosynthetic impairment due to oiling in different environments, different ecological configurations, and on different plant surfaces	Desktop research/extensive literature review	Primary research
	Population status and trends for marine plants and algae, with an initial focus on bull kelp	Desktop research/extensive literature review, and modelling exercises.	Primary research
	Reproductive capacity of intertidal vascular plants	Infer from similar species or different ecotypes of the	Primary research

Biological group	Gap	Short term recommendation	Long term recommendation
		same species. Meta-analysis.	
Inverte-brates	Reproductive capacity of reef-building sponges	Infer from similar species or different ecotypes of the same species. Meta-analysis.	Primary research
	Population status of B.C. invertebrate species	Desktop research/extensive literature review, and modelling exercises.	Primary research
	Toxic impairment due to oiling of under-studied invertebrate species in B.C.	Desktop research/extensive literature review, and modelling exercises.	Primary research
Fishes	Toxic effects of oil on under-studied populations of B.C. fishes	Desktop research/extensive literature review	Primary research
	Identify genetically isolated populations of fishes in B.C.	Desktop research/extensive literature review	Primary research
	Population status of adult and juvenile lingcod, and hagfishes	Modelling exercises if adequate information exists	Primary research
	Reproductive capacities of hagfishes and basking sharks	Infer from similar species or different ecotypes of the same species. Meta-analysis	Primary research
Marine Mammals	Regularity of seafloor interactions in the Southern resident killer whale population	Consult marine mammal experts	Primary research
	Frequency of Northern elephant seals foraging for hagfish on the seafloor	Review literature/video of this behaviour	Primary research
	Whether “Pacific coast feeding aggregation” of grey whales is a distinct population	Desktop research/extensive literature review	Primary research
Marine Reptiles	None		Primary research

18 APPENDIX J: LIST OF SUBJECT MATTER EXPERTS (SMES) CONSULTED

Table J-1. List of subject matter experts (SMEs) consulted

SME Name	Subject of review	Date of review	Affiliation at the time of review
Sharon Jeffery	Marine algae/plant sub-groups	April 2016	Private consultant
Joanne Lessard	Marine algae/plant sub-groups	April 2016	DFO
Robert DeWreede	Marine algae/plant sub-groups and scoring	July 2016	UBC
Anya Dunham	Marine invertebrate sub-groups and scoring	July 2016	DFO
Heidi Garter	Marine invertebrate sub-groups and scoring	July 2016	Royal B.C. Museum
Dana Haggarty (Pacific fish expert)	Marine fishes sub-groups and scoring Pacific fish expert	February, May and July 2016	DFO
Jacqueline King (Chondrichthyan expert)	Marine fishes sub-groups and scoring	July 2016	DFO
John Ford	Marine mammals Sub-groups and scoring	July 2016	DFO
Peter Ross	Marine mammals Sub-groups and scoring	July 2016	Vancouver Aquarium
Linda Nichol	Marine mammals Sub-groups and scoring	July 2016	DFO
Lisa Spaven	Marine reptiles Scoring	October 2016	DFO
L. Miller, M. Foreman, J. Gower, C. Hannah, C. Dubetz	Depth of sea surface for the region	August 2016	DFO

19 APPENDIX K: SUMMARY OF REVIEWER COMMENTS

Table K-1. Summary of comments from reviewers during development of the Pacific region application. Rows with white background indicate a scoring change suggestion; rows with light grey background indicate a change to the criteria; and rows highlighted in dark grey indicate a change to the sub-groupings.

#	Grouping	Reviewer	Comment	Changes made/Comments
1	Marine Plants/Algae	J. Lessard	Low energy shores are poorly named as some example species for the sub-group require some water exchange	Modified sub-group name to be 'Moderate to low energy' rather than just 'low energy'
2	Marine Plants/Algae	J. Lessard	Surprised that kelp were scored for potentially getting covered with oil and requested better literature references	Conducted more thorough literature review and inserted extra references wherever possible to support the scores
3	Marine Plants/Algae	J. Lessard	Questioned justification for intertidal and subtidal breakdown in sub-groups as many species live in both	Did not remove sub-group division by tidal exposure as the few species that were exclusive to either intertidal or subtidal resulted in scoring differences between the two groups for several criteria so it was a useful division to keep
4	Marine Plants/Algae	J. Lessard	Commented that if *Phyllospadix* rhizomes could retain oil, so could *Macrocystis* holdfasts	This comment was made for the intertidal sub-group containing *Macrocystis,* and *Macrocystis* was removed as a species example from that group based on recommendations from R. DeWreede. For subtidal algae, the holdfast was considered too small a percentage of the total plant to warrant scoring for oil retention
5	Marine Plants/Algae	J. Lessard	Believes that kelp decline may be due to warm water temperatures	Changed sub-group score from 1 to 1* to account for uncertainty in scoring and will investigate published trends more fully to determine how far back in time the population reduction has been noted (as per DeWreede's suggestion)
6	Marine Plants/Algae	R. DeWreede	Suggested reorganizing the canopy algae species so that the distinction from understory plants is based on whether a species forms a canopy over other species, or lives beneath other species, as opposed to dividing species based on arbitrary heights	Adopted the suggestion initially, although the change did not result in different sub-group scores, just different species examples for the sub-groups, but undid the change after the edits were checked by another reviewer that found the breakdown of species by sub-groups confusing
7	Marine Plants/Algae	R. DeWreede	Suggested removing *Macrocystis* from the list of species examples for intertidal canopy algae	Removed *Macrocystis* as a species example in intertidal
8	Marine Plants/Algae	R. DeWreede	Was not convinced that decline in *Nereocystis* is anything more than a short-term phenomenon, but since he had not kept up on the literature recently he suggested reviewing the	Changed the score for subtidal canopy algae in high and low energy rocky habitats from 1 to 1* until a thorough literature review can be completed

#	Grouping	Reviewer	Comment	Changes made/Comments
			literature to see what length of time the declines spanned and defining this in the justification for scoring	
9	Marine Plants/Algae	R. DeWreede	*Pterygophera* and *Laminaria setchellii* are both long-lived with delayed maturity	Changed score for sub-groups containing these species (from 0 to 1 for reproductive capacity
10	Marine Invertebrates	A. Dunham	Glass sponge age at maturity and reproductive output is data limited	Scored glass sponges as 1 for reproductive capacity as per H. Gartner comments
11	Marine Invertebrates	A. Dunham	Geoduck have low recruitment	Changed sub-group score to 1 for reproductive capacity
12	Marine Invertebrates	A. Dunham	Gorgonian corals can be slow to reach maturity	Changed score for this sub-group to 1 for reproductive capacity
13	Marine Invertebrates	A. Dunham	Sea pens are slow to mature	Changed score for this sub-group to 1 for reproductive capacity
14	Marine Invertebrates	A. Dunham	Some invertebrate species may be limited to B.C. based on a paper provided (Austin 1999)	More recent work has found the species in question outside B.C. so did not incorporate this suggestion
15	Marine Invertebrates	A. Dunham	Sea pens are found in aggregations	Changed both groupings (intertidal and subtidal) to 1
16	Marine Invertebrates	H. Gartner	Suggested changing sub-group level 4 headings from Ascidia to Chordata to be in keeping with other headings that were listed as phyla rather than genus’	Renamed sub-group heading for tunicates ‘Urochordata’ as a compromise since the phylum Chordata contains many non-invertebrate species
17	Marine Invertebrates	H. Gartner	Suggested changing sub-group level 4 headings from Crustacea to arthropoda to be in keeping with other headings that were listed as phyla rather than class	Made change as suggested
18	Marine Invertebrates	H. Gartner	Suggested changing sea stars from low mobility to high mobility	Did not make the change as suggested because seastars are not high mobility at the scale of an oil spill or as compared to other sub-groups
19	Marine Invertebrates	H. Gartner	Suggested adding a sub-group for bryozoans	Grouped bryozoans with other lophophorates and added sub-groups for them under several higher level divisions to account for the variety of urochordate growth forms
20	Marine Invertebrates	H. Gartner	Corals, glass sponges, some clams and red urchins are very slow to reach maturity	Changed score for sub-groups containing these species from 0 to 1 for reproductive capacity, except urchins which have very high reproductive output and for which no information was found about delayed maturity
21	Marine Invertebrates	H. Gartner	Sea pens and sea whips are found in aggregations	Changed both sub-group scores (intertidal and subtidal) from 0 to 1 for aggregation
22	Marine Invertebrates	H. Gartner	Sea stars such as *Pisaster* aggregate for feeding	Changed the echinoderm sub-group score from 0 to 1 for aggregation
23	Marine Invertebrates	H. Gartner	Infaunal annelids and subtidal epifaunal molluscs are both found in aggregations	Changed sub-groups scores from 0 to 1 for aggregation
24	Marine Invertebrates	H. Gartner	Predatory gastropods such as *Nucella* can be highly aggregated	Found evidence of aggregation in the literature, so changed score

#	Grouping	Reviewer	Comment	Changes made/Comments
			during breeding	for aggregation criterion from 0 to 1 for intertidal predatory gastropods
25	Marine Invertebrates	H. Gartner	Urchin barrens are an example that urchins aggregate	Found evidence of aggregation in the literature, so changed score for aggregation criterion from 0 to 1 for urchins
26	Marine Invertebrates	H. Gartner	Most intertidal isopods are either gregarious, or in high abundance	Found a reference to support aggregation for reproductions so changed score for aggregation criterion from 0 to 1
27	Marine Fish	J. King	Some skates and rays are known to deposit eggs in aggregations	Changed score for subtidal skates and rays from 0 to 1 for aggregation
28	Marine Fish	J. King	Ratfish occur in very large schools	Did not change score for aggregation from 0 to 1 because there was no evidence that these school were for reproductive purposes
29	Marine Fish	J. King	Sixgill sharks occupy surface waters in the summer	Changed score for subtidal , pelagic elasmobranchs from 0 to 1 for surface interaction
30	Marine Fish	J. King	Ratfish have been observed to undergo diel vertical migrations and occupy surface waters at night	Changed score for subtidal , pelagic chimaeridae from 0 to 1 for surface interaction
31	Marine Fish	D. Haggarty	Assumption that most fish species have high fecundity is incorrect; life history strategies that result in low reproductive capacity need to be expanded	Expanded reproductive capacity criterion to include delayed maturity, and infrequent reproductive success. Changed scores for sub-groups with these behaviours from 0 to 1
32	Marine Fish	D. Haggarty	The habitat and ecosystem effects of oiling vegetation needs to be considered here along with soft sediments	Changed ‘sediment interacting’ criterion to seafloor/plant interacting’ to capture risk to animals that associate with oiled vegetation
33	Marine Fish	D. Haggarty	Application of schooling criteria is too narrow and should include juvenile fish aggregations in rearing habitats	Added rearing to list of behaviours that score for aggregation and provided justification for not scoring most schooling behavior as 1
34	Marine Fish	D. Haggarty	Sockeye salmon juveniles and anchovy use gill rakers for feeding	Changed score for sub-groups containing these species from 0 to 1 for reduction of feeding criterion
35	Marine Fish	D. Haggarty	Fouling of gills with oil will also impair a fish’s ability to breath; presumably fish with longer gill rakers for feeding will be more susceptible to fouling	Did not change scoring to include fish that would have breathing impairment due to gill fouling because this is possible for all fish species and would not help differentiate sub-groups
36	Marine Fish	D. Haggarty	Did not agree that most fish are mobile relative to an oil spill and pointed out that just because a fish can move does not mean that it will	Moved site fidelity from Aggregation criterion to Mobility criterion and scored fish that have very small home ranges as 1 for mobility
37	Marine Fish	D. Haggarty	Felt that the value of important rearing habitats for fishes such as estuaries, eelgrass beds and kelp beds/forests is not addressed in this assessment	Eelgrass habitat was captured by including ‘plant interacting’ in the exposure criterion “Seabed interacting”

#	Grouping	Reviewer	Comment	Changes made/Comments
38	Marine Fish	D. Haggarty	Seasonality is not addressed in framework	It will be incorporated into the next stages of this process
39	Marine Fish	D. Haggarty	Docks, pilings, piers and other similar structures concentrate fish. Fish that aggregate under these structures frequently should be considered 'aggregating'	Changed aggregation score from 0 to 1 for species that concentrate under structures frequently
40	Marine Fish	D. Haggarty	Sturgeon use barbels in soft sediment	Changed seafloor interacting score from 0 to 1 for sturgeon
41	Marine Fish	D. Haggarty	Shiner perch aggregate for spawning and giving birth	Changed aggregation score from 0 to 1 for perch
42	Marine Fish	D. Haggarty	Concerned that vulnerability of fish that associate with rocks was not captured as oil will stick to rocks and impact all benthic fishes, not just those on soft sediment	Did some research on oil retention on rocks and found that in low wave exposure environments, oil can persist on rocks for many months. Changed 'sediment interacting' criterion to seafloor/plant interacting' to score any fish that associates with the benthos as 1
43	Marine Fish	D. Haggarty	Midshipmen bury themselves in soft substrates in the intertidal for spawning	Added midshipmen to Intertidal sub-group containing sculpins
44	Marine Fish	D. Haggarty	Some species of rockfish (Black and yellow-tail) interact with the surface regularly at night	Changed surface interaction score for non-benthic rockfish from 0 to 1
45	Marine Fish	D. Haggarty	Ratfish must feed in soft sediments because one of their major food sources is clams	Changed seafloor interacting score from 0 to 1 for ratfish
46	Marine Fish	D. Haggarty	Live bearing fish species have low fecundity	Changed score from 0 to 1 for sub-groups containing perch and pipefish (as they have limited brood sizes due to physical constraints)
47	Marine Fish	D. Haggarty	Nest guarding species such as gunnels have low fecundity given the high parental investment	Disagreed with this comment as the action of guarding eggs doesn't limit how many can be laid. Also, many fish species guard their egg masses so this criterion would not be very effective at screening sub-groups out if groups with nest guarding were scored as 1
48	Marine Fish	D. Haggarty	Intertidal spawning populations of pink and chum salmon would interact with seafloor	Changed seafloor interaction score for intertidal salmon from 0 to 1
49	Marine Mammals	P. Ross	Overall concern about the definition and assignment of species into discrete and dispersed groupings	Refined the definition of discrete and dispersed
50	Marine Mammals	P. Ross	Minke whales are primarily seen alone or in similar areas, yet independent of one another	Moved from discrete to dispersed sub-group
51	Marine Mammals	P. Ross	Fin whales occur in large groups in B.C.	Moved from dispersed to discrete sub-group
52	Marine Mammals	P. Ross	California sea lions occur in large groups	Moved from dispersed to discrete sub-group
53	Marine Mammals	P. Ross	Harbour and Dall's porpoises occur in small groups	Moved from discrete to dispersed sub-group
54	Marine Mammals	P. Ross	Offshore killer whales aggregate in large groups	Moved from dispersed to discrete sub-group

#	Grouping	Reviewer	Comment	Changes made/Comments
55	Marine Mammals	J. Ford	Northern elephant seals forage on the seabed for hagfish, so should score 1 for seafloor interaction	Changed score for seafloor interaction from 0 to 1* until literature can be reviewed for evidence of ‘frequent’ interaction with the seafloor.
56	Marine Mammals	J. Ford	Humpback whales do not overwinter for feeding aggregations- they aggregate for feeding in summer and fall	Removed reference to humpback whales overwintering in justification for scoring the aggregation criterion. This did not affect the score for this sub-group
57	Marine Mammals	J. Ford	Northern fur seals do not overwinter in B.C.- they occur in B.C. during the spring, but not in aggregations	Removed the word ‘overwinter’ from the aggregation score justification
58	Marine Reptiles	L. Spaven	Hard shelled turtles known to exist in B.C. waters, though more rarely are greens, Olive Ridley’s and Loggerheads. Normally they would interact with the sea floor or vegetation in foraging, but since they are typically accidental visitors here they may not in fact be feeding. I don’t think a comparison to Baja would be just given the differences in temperature etc.	Changed score from 1 to 0 for 2 criteria: (1) seafloor/ vegetation interaction and (2) close association with unconsolidated substrate. These were scored based on a study from Baja
59	Regional sea surface depth to use in the application (default in the framework is -10cm) but can vary based on regional conditions (i.e. localised hydrodynamics).	L. Miller M. Foreman J. Gower C. Hannah C. Dubetz	The depth of the surface layer (e.g. sea-air interface) used in a default of -10 cm but could vary based on Pacific region experts concurred that a shallow range of -1 m is appropriate to capture the intent of the “surface interacting” criterion (to assign higher vulnerability to organisms interacting with a surface oil slick). It allows for some mixing at the surface, but discerns the higher exposure experienced by truly surface interacting organisms.	A surface layer depth of -1 m was selected for this application

20 APPENDIX L: STANDARDISATION OF VULNERABILITY SCORES

In the Pacific region pilot application, the screening and ranking method chosen required sub-groups to be ranked by the total additive score across all criteria. Given that there is an uneven number of criteria within each of the criteria categories (exposure: 4 criteria; sensitivity: 2 criteria; recovery: 4 criteria), adding all scores may introduce unintentional bias toward one or more criteria categories. Standardisation was investigated as a method to minimize this bias, but was not applied to the final ranked list reported in the main document. Standardisation is commonly used with continuous variables, but traditional standardisation methods are not appropriate for binary variables (e.g. Cross Validated 2013), such as the binary scores in this analysis. Despite this, in this appendix all criteria categories were brought to the same scale before adding scores together to see how the adjusted vulnerability rankings would compare with those reported in the main document.

To bring criteria categories to the same scale, the sensitivity category criteria scores were multiplied by 2 so that each of the criteria categories (exposure, sensitivity, and recovery) would have the same maximum total of 4. Using these adjusted vulnerability scores, the rankings at the top and bottom of the list were very similar to those in the list presented in the main document, while rankings in the middle of the list varied (Table L-1). Regardless, when bins were assigned for high (vulnerability scores 7-9, adjusted scores 9-12), medium (vulnerability scores 4-6, adjusted scores 5-8), and low (vulnerability scores 1-3, adjusted scores 1-4), only two sub-groups changed bins: estuarine > transient > sturgeon and cetaceans > toothed > discreet both changed from high to medium.

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).

Table L-1. Final ranked list of screened sub-groups for the Pacific regional application of the vulnerability framework ranked by vulnerability score and showing adjusted vulnerability scores for each sub-group. Alternating light grey and white shading indicates bins for high, medium, and low vulnerability (vulnerability scores of 7-9, 4-6, and 1-3, respectively). Double lines surround sub-groups where adjustment caused them to change bins (2 sub-groups). Dark grey shading indicates sub-groups that were screened out of the analysis (at the bottom of the table).

Biological group	**Sub-groups**				**Pacific example species**	**Vulnerability score (0-10)**	**Adjusted vulnerability score (0-12)**
	Sub-group level 1	**Sub-group level 2**	**Sub-group level 3**	**Sub-group level 4**			
MARINE PLANTS & ALGAE	Intertidal	Vascular Plants	Low energy unconsolidated habitat	Seagrasses	e.g. *Zostera marina, Z. japonica, Ruppia maritima*	9	11
MARINE PLANTS & ALGAE	Intertidal	Vascular Plants	Low energy unconsolidated habitat	Salt marsh grasses	e.g. *Carex lyngbyei, Leymus mollis*	9	11
MARINE PLANTS & ALGAE	Intertidal	Vascular Plants	Low energy unconsolidated habitat	Salt marsh succulents	e.g. *Sarcocornia pacifica, S. pacifica, Glaux maritima, Plantago maritima*	9	11
MARINE MAMMALS	Cetaceans	Baleen	Discrete	N/A	e.g. humpback whales; grey whales	9	11
MARINE MAMMALS	Mustelids	N/A	N/A	N/A	e.g. sea otter	9	11
MARINE PLANTS & ALGAE	Intertidal	Vascular Plants	High energy, rocky habitat	Seagrasses	*e.g. Phyllospadix scouleri, P. torreyi, P. serrulatus*	8	10
MARINE INVERTEBRATES	Intertidal	Sediment epifauna	Low mobility	Mollusca	e.g. snails [Gastropoda]	8	10
MARINE INVERTEBRATES	Intertidal	Sediment epifauna	Low mobility	Cnidaria	e.g. sea pens	8	10
MARINE INVERTEBRATES	Intertidal	Sediment epifauna	Low mobility	Echinodermata	e.g. sea stars	8	10
MARINE FISHES	Estuarine	Transient	N/A	Salmon (Salmonidae)	e.g. juvenile and adult salmon & steelhead	8	10

Biological group	Sub-groups				Pacific example species	Vulnerability score (0-10)	Adjusted vulnerability score (0-12)
	Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4			
MARINE FISHES	Intertidal	Benthic	Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass environments)	Salmonidae (juvenile)	e.g. pink, chum, coho, chinook salmon	8	10
MARINE PLANTS & ALGAE	Intertidal	Understory / Turf Algae	High energy, rocky habitat	N/A	e.g. *Pelvetiopsis limitata, Cymathere triplicata, Postelsia palmaeformis, Corallina vancouveriensis, Alaria fistulosa*	7	9
MARINE PLANTS & ALGAE	Subtidal	Canopy Algae	Moderate to low energy rocky habitat	N/A	e.g. *Macrocystis integrifolia*	7	9
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Mollusca	e.g. oysters [Bivalvia]	7	9
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Low mobility	Echinodermata	e.g. sea urchins [Echinoidea];sea cucumbers [Holothuroidea];sea stars [Asteroidea]	7	9
MARINE INVERTEBRATES	Intertidal	Sediment infauna	Low mobility	Mollusca	e.g. clams [Bivalvia]; snails [Gastropoda]	7	9
MARINE INVERTEBRATES	Intertidal	Sediment infauna	Low mobility	Worms	e.g. burrowers	7	9
MARINE INVERTEBRATES	Intertidal	Sediment infauna	Low mobility	Arthropoda	e.g. sand crabs [Emerita]	7	9
MARINE INVERTEBRATES	Intertidal	Sediment infauna	Low mobility	Lophophorates	e.g. horseshoe worms [Phoronida]; lampshells [Brachiopoda]	7	9

Biological group	Sub-groups				Pacific example species	Vulnerability score (0-10)	Adjusted vulnerability score (0-12)
	Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4			
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Porifera	e.g. glass sponges	7	9
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Low mobility	Echinodermata	e.g. sea urchins, sea stars	7	9
MARINE INVERTEBRATES	Subtidal benthic	Sediment infauna	Low mobility	Mollusca	e.g. clams	7	9
MARINE INVERTEBRATES	Subtidal benthic	Sediment epifauna	Low mobility	Cnidaria	e.g. sea pens	7	9
MARINE INVERTEBRATES	Subtidal benthic	Sediment epifauna	Low mobility	Echinodermata	e.g. sea stars	7	9
MARINE FISHES	Estuarine	Transient	N/A	Sturgeon (Acipenseridae)	e.g. green sturgeon, white sturgeon	7	8
MARINE FISHES	Intertidal	Benthic	Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass environments)	Herring (Clupeidae)	e.g. Pacific herring	7	9
MARINE MAMMALS	Cetaceans	Toothed	Discrete	N/A	e.g. killer whales: residents (Northern and Southern) and offshore populations; Pacific white sided dolphin	7	8
MARINE PLANTS & ALGAE	Intertidal	Understory / Turf Algae	Moderate to low energy rocky habitat	N/A	e.g. *Fucus gardneri, Neorhodomela larix, Desmarestia sp., Laminaria saccharina, Calliarthron* spp.	6	8

Biological group	**Sub-groups**				**Pacific example species**	**Vulnerability score (0-10)**	**Adjusted vulnerability score (0-12)**
	Sub-group level 1	**Sub-group level 2**	**Sub-group level 3**	**Sub-group level 4**			
MARINE PLANTS & ALGAE	Subtidal	Canopy Algae	High energy, rocky habitat	N/A	e.g. *Nereocystis leutkeana, Egregia menziesii*	6	8
MARINE PLANTS & ALGAE	Subtidal	Understory Algae	Rocky habitat	With tall, woody stipes or floats	e.g. *Pterygophera californica, Sargassum muticum, Lessoniopsis littoralis*	6	8
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Arthropoda	e.g. barnacles [Cirripedia]	6	8
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Cnidaria	e.g. coral	6	8
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Porifera	e.g. demosponges	6	8
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Worms	e.g. tube worms [Polychaeta: Sedentaria]	6	8
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Urochordata	e.g. sea squirts	6	8
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	Lophophorates	e.g.bryozoans [Ectoprocta]; lampshells [Brachiopoda]	6	8
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Low mobility	Arthropoda	e.g. isopods [Isopoda]	6	8
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Low mobility	Cnidaria	e.g. sea anemones	6	8
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Cnidaria	e.g. coral	6	8
MARINE INVERTEBRATES	Subtidal benthic	Sediment infauna	Low mobility	Worms	e.g. annelids	6	8

Biological group	Sub-groups				Pacific example species	Vulnerability score (0-10)	Adjusted vulnerability score (0-12)
	Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4			
MARINE INVERTEBRATES	Subtidal benthic	Sediment infauna	Low mobility	Lophophorates	e.g. horseshoe worms [Phoronida]; lampshells [Brachiopoda]	6	8
MARINE INVERTEBRATES	Subtidal benthic	Sediment epifauna	Low mobility	Mollusca	e.g. snails [Gastropoda]	6	8
MARINE INVERTEBRATES	Pelagic	Larvae	N/A	Mollusca	N/A	6	8
MARINE INVERTEBRATES	Pelagic	Larvae	N/A	Echinodermata	N/A	6	8
MARINE FISHES	Subtidal	Benthic	Associated with unconsolidated substrate (silt/sand/gravel)	Elasmobranchs	e.g. big skate	6	7
MARINE PLANTS & ALGAE	Intertidal	Canopy Algae	N/A	N/A	e.g. *Egregia menziesii*	5	7
MARINE PLANTS & ALGAE	Intertidal	Encrusting Algae	Rocky habitat	N/A	e.g. Coralline algae, *Codium setchellii, Hildenbrandia* sp., *Mastocarpus* (crust form), *Ralfsia pacifica*	5	7
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Low mobility	Worms	e.g. polychaetes [Errantia]; nemerteans	5	6
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Low mobility	Mollusca	e.g. chitons [Polyplacopora]; snails [Gastropoda]	5	6
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	High mobility	Arthropoda (filter feeders)	e.g. porcelain crabs	5	7
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	High mobility	Mollusca	e.g. octopuses	5	6

Biological group	Sub-groups				Pacific example species	Vulnerability score (0-10)	Adjusted vulnerability score (0-12)
	Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4			
MARINE INVERTEBRATES	Intertidal	Sediment epifauna	High mobility	Arthropoda	e.g. crabs	5	6
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Arthropoda	e.g. barnacles [Cirripedia]	5	7
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Mollusca	e.g. rock scallops [Bivalvia]	5	7
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Worms	e.g. tube worms [Polychaeta: Sedentaria]	5	7
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Urochordata	e.g. sea squirts	5	7
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	Lophophorates	e.g.bryozoans [Ectoprocta]; lampshells [Brachiopoda]	5	7
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Low mobility	Worms	e.g. annelids	5	7
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Low mobility	Cnidaria	e.g. sea anemones	5	7
MARINE INVERTEBRATES	Pelagic	N/A	Low mobility	Zooplankton (other than larvae)	N/A	5	7
MARINE INVERTEBRATES	Pelagic	N/A	Low mobility	Cnidaria	e.g. jellyfish	5	7
MARINE INVERTEBRATES	Pelagic	Larvae	N/A	Cnidaria	N/A	5	7
MARINE INVERTEBRATES	Pelagic	Larvae	N/A	Worms	N/A	5	7
MARINE INVERTEBRATES	Pelagic	Larvae	N/A	Arthropoda	N/A	5	7
MARINE INVERTEBRATES	Pelagic	Larvae	N/A	Lophophorates	N/A	5	7

Biological group	Sub-groups				Pacific example species	Vulnerability score (0-10)	Adjusted vulnerability score (0-12)
	Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4			
MARINE FISHES	Estuarine	Transient	N/A	Osmeridae	e.g. eulachon	5	6
MARINE FISHES	Estuarine	Resident	N/A	Surfperches (Embiotocidae)	e.g. shiner perch	5	6
MARINE FISHES	Intertidal	Benthic	Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass environments)	Ammodytidae & Osmeridae	e.g. Pacific sand lance, surf smelt	5	6
MARINE FISHES	Intertidal	Benthic	Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass environments)	Other species (e.g. sculpins , gobies)	e.g. staghorn sculpin, plainfin midshipmen	5	6
MARINE FISHES	Subtidal	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Rockfishes (Scorpaenidae)	e.g. quillback, yelloweye, tiger & china rockfish	5	6
MARINE FISHES	Subtidal	Benthic	Associated with unconsolidated substrate (silt/sand/gravel)	Rockfishes (Scorpaenidae)	e.g. dark-blotched rockfish, canary rockfish	5	6
MARINE FISHES	Subtidal	Non-benthic (pelagic, midwater and demersal)	N/A	Rockfishes (Scorpaenidae)	e.g. yellowtail, blue, widow rockfishes, bocaccio	5	6
MARINE FISHES	Subtidal	Non-benthic (pelagic, midwater and demersal)	N/A	Elasmobranchs	e.g. spiny dogfish, sixgill sharks	5	6
MARINE FISHES	Subtidal	Non-benthic (pelagic, midwater and demersal)	N/A	Elasmobranchs filter feeder	e.g. basking shark	5	7
MARINE FISHES	Subtidal	Non-benthic (pelagic, midwater and demersal)	N/A	Chimaeridae	e.g. spotted ratfish	5	6

Biological group	Sub-groups				Pacific example species	Vulnerability score (0-10)	Adjusted vulnerability score (0-12)
	Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4			
MARINE MAMMALS	Cetaceans	Baleen	Dispersed	N/A	e.g. sei whale; blue whale; fin whale; North Pacific right whale; common minke whale	5	7
MARINE MAMMALS	Pinnipeds	Thermoregulate with fur	N/A	N/A	e.g. Northern fur seal	5	7
MARINE MAMMALS	Pinnipeds	Other pinnipeds	Discrete	N/A	e.g. Steller sea lion, harbour seal	5	6
MARINE PLANTS & ALGAE	Subtidal	Understory Algae	Rocky habitat	Without tall, woody stipes or floats	e.g. *Desmarestia* sp, *Agarum fimbriatum, Laminaria* sp., *Prionitis lyallii*	4	6
MARINE PLANTS & ALGAE	Subtidal	Turf Algae	Rocky habitat	N/A	e.g. *Callophyllis* sp.; *Dictyota binghamiae, Sarcodiotheca furcata, Rhodymenia pacifica*	4	6
MARINE PLANTS & ALGAE	Subtidal	Encrusting Algae	Rocky habitat	N/A	e.g. Coralline algal crusts, *Hildenbrandia* sp.	4	6
MARINE PLANTS & ALGAE	Pelagic	Phytoplankton	N/A	N/A	N/A	4	5
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	High mobility	Arthropoda	e.g. crabs [Decapoda]	4	5
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Low mobility	Mollusca	e.g. snails [Gastropoda]	4	5
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	High mobility	Mollusca	e.g. octopuses	4	5
MARINE INVERTEBRATES	Subtidal benthic	Sediment epifauna	High mobility	Arthropoda	e.g. crabs	4	5

Biological group	Sub-groups				Pacific example species	Vulnerability score (0-10)	Adjusted vulnerability score (0-12)
	Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4			
MARINE INVERTEBRATES	Pelagic	Larvae	N/A	Porifera	N/A	4	5
MARINE INVERTEBRATES	Pelagic	Larvae	N/A	Chordata	N/A	4	5
MARINE FISHES	Estuarine	Transient	N/A	Sticklebacks (Gasterosteidae)	e.g. threespine stickleback	4	5
MARINE FISHES	Intertidal	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Snailfishes (Liparidae)	e.g. tidepool snailfish	4	5
MARINE FISHES	Intertidal	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Clingfishes (Gobiesocidae)	e.g. Northern clingfish	4	5
MARINE FISHES	Intertidal	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Blennies (Stichaeidae & Pholidae)	e.g. penpoint gunnel, crescent gunnel, high cockscomb	4	5
MARINE FISHES	Intertidal	Benthic	Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass environments)	Pipefish (Sygnathidae)	e.g. bay pipefish	4	5
MARINE FISHES	Intertidal	Benthic	Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass environments)	Greenlings (Hexagrammidae)	e.g. lingcod- juvenile	4	5
MARINE FISHES	Intertidal	Non-benthic (pelagic and demersal)	N/A	Surfperch (Embiotocidae)	e.g. shiner perch, striped perch, pile perch	4	5

Biological group	Sub-groups				Pacific example species	Vulnerability score (0-10)	Adjusted vulnerability score (0-12)
	Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4			
MARINE FISHES	Intertidal	Non-benthic (pelagic and demersal)	N/A	Rockfishes (juvenile)	e.g. black rockfish, copper rockfish	4	5
MARINE FISHES	Subtidal	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Wolf fish (Anarhichadidae)	e.g. wolf-eel	4	5
MARINE FISHES	Subtidal	Benthic	Associated with consolidated substrates (cobble, boulder, bedrock)	Greenlings (Hexagrammidae) & Sculpins (Cottidae)	e.g. lingcod (adult), cabezon	4	5
MARINE FISHES	Subtidal	Benthic	Associated with unconsolidated substrate (silt/sand/gravel)	Flatfishes (Pleuronectidae)	e.g. English sole, starry flounder, Pacific halibut	4	5
MARINE FISHES	Subtidal	Non-benthic (pelagic, midwater and demersal)	N/A	Ammodytidae	e.g. Pacific sand lance	4	5
MARINE FISHES	Subtidal	Non-benthic (pelagic, midwater and demersal)	N/A	Engraulidae	e.g. Northern anchovy	4	6
MARINE REPTILES	Sea turtles	N/A	N/A	N/A	e.g. leatherback sea turtle; green sea turtle; olive ridley	4	5
MARINE MAMMALS	Cetaceans	Toothed	Dispersed	N/A	e.g. sperm whales, killer whales (W.Coast transients); false killer whale; beaked whales (Baird's, Hubbs' and Stejneger's) harbour porpoise; Dall's porpoise	4	5
MARINE MAMMALS	Pinnipeds	Other pinnipeds	Dispersed	N/A	e.g. Northern elephant seal; California sea lion	4	5

Biological group	Sub-groups				Pacific example species	Vulnerability score (0-10)	Adjusted vulnerability score (0-12)
	Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4			
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	High mobility	Arthropoda	e.g. crabs	3	4
MARINE INVERTEBRATES	Pelagic	N/A	High mobility	Mollusca	e.g. squid	3	4
MARINE FISHES	Estuarine	Transient	N/A	Lampreys	e.g. river & Pacific lamprey	3	4
MARINE FISHES	Estuarine	Transient	N/A	Sculpins (Cottidae)	e.g. prickly sculpin	3	4
MARINE FISHES	Estuarine	Transient	N/A	Flatfishes (Pleuronectiformes)	e.g. starry flounder, juvenile English sole	3	4
MARINE FISHES	Estuarine	Resident	N/A	Sculpins (Cottidae)	e.g. staghorn sculpin	3	4
MARINE FISHES	Estuarine	Resident	N/A	Salmonidae	e.g. cutthroat trout and Dolly Varden	3	4
MARINE FISHES	Intertidal	Benthic	Associated with unconsolidated substrates (silt/sand/gravel) (including eelgrass environments)	Flatfishes- juvenile (Pleuronectidae)	e.g. English sole, starry flounder	3	4
MARINE FISHES	Subtidal	Benthic	Associated with unconsolidated substrate (silt/sand/gravel)	Hagfishes (Myxinidae)	e.g. Pacific hagfish	3	4
MARINE FISHES	Subtidal	Non-benthic (pelagic, midwater and demersal)	N/A	Cod (Gadidae)	e.g. Pacific cod, hake, Pacific tomcod, walleye pollock	3	4
MARINE FISHES	Subtidal	Non-benthic (pelagic, midwater and demersal)	N/A	Molidae	e.g. ocean sunfish	3	4

Biological group	Sub-groups				Pacific example species	Vulnerability score (0-10)	Adjusted vulnerability score (0-12)
	Sub-group level 1	Sub-group level 2	Sub-group level 3	Sub-group level 4			
MARINE FISHES	Subtidal	Non-benthic (pelagic, midwater and demersal)	N/A	Misc species	e.g. sablefish (Anaplopomatidae), salmon (Salmonidae), surfperch (Embiotocidae), herring (Clupeidae)	2	3
MARINE FISHES	Estuarine	Transient	N/A	Cod (Gadidae)	e.g. Pacific tomcod, walleye pollock *(juveniles)*	1	2
MARINE FISHES	Subtidal	Non-benthic (pelagic, midwater and demersal)	N/A	Scombrids	e.g. mackerel	1	2