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Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2024/052

MARITIMES REGIONAL APPLICATION OF THE NATIONAL FRAMEWORK FOR ASSESSING THE VULNERABILITY OF BIOLOGICAL COMPONENTS TO SHIP-SOURCE OIL SPILLS IN THE MARINE ENVIRONMENT

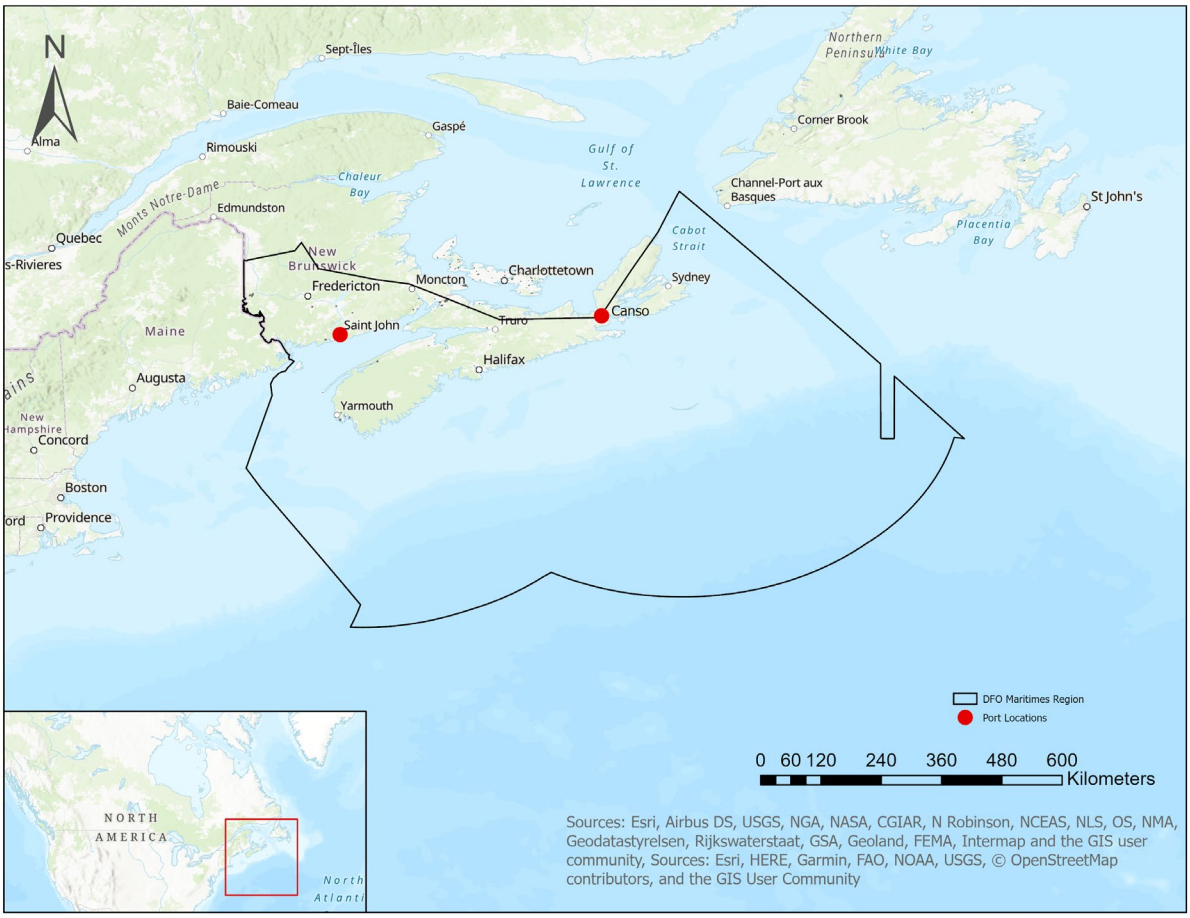

Figure 1. DFO Maritimes Region, geographic scope of this application of the National Framework.

Context:

A National Framework to Assess the Vulnerability of Biological Components to Ship-source Oil Spills in the Marine Environment' (the framework) was developed by Fisheries and Oceans Canada (DFO),and reviewed in March 2016 through a Canadian Science Advice Secretariat (CSAS) National Peer Review (Thornborough et al. 2017).

The framework contributes towards the development of a timely and informed response to ship-source oil spills by identifying biological sub-groups most vulnerable to spilled oil, and focusing data collection for spill response planning. The framework was determined to be appropriate for use in all Canadian

regions with an allowance for regional flexibility - biological sub-groups were anticipated to require tailoring to reflect regional biota.

The DFO Science Branch in the Maritimes Region completed an analysis to adapt and apply the national framework for the Maritimes Region. This Maritimes application of the national framework is intended to help to inform oil-spill response planning within the Maritimes Region (Figure 1) and assist in identifying priority data relevant for those subgroups identified as being most vulnerable to oil.

This Science Advisory Report is from the November 22–24, 2021, regional peer review on the Application of the National Vulnerability Framework in the Maritimes Region, to assess the vulnerability of biological components to ship-source oil spills in the marine environment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Fisheries and Oceans Canada (DFO) Maritimes Science completed a regional application of the National Framework to Assess the Vulnerability of Biological Components to Ship-source Oil Spills in the Marine Environment to support timely and informed response to ship-source oil spills in this region.
- The framework uses a structured method to identify the biological components most vulnerable to direct effects of ship-source oil spill. This is based on a suite of standard screening and ranking criteria that considers direct effects.
- A total of 1,034 marine species were assessed and merged into 116 taxonomic sub-groups. These sub-groups represent the suite of marine biota in this region with sufficient discrimination to score against nationally standardized vulnerability criteria.
- This application applied the “Subtidal” classification across all depths within the region, with no discrete “Off Shelf” category, which resulted in only one classification region-wide.
- This application provided an ecologically and taxonomically based list for all Maritimes Region sub-groups, validated through a literature review, ranked by total vulnerability to ship-source oil spills, which can be used to inform response planning efforts. Of the 116 sub-groups identified, 49 were considered “highly vulnerable”, receiving overall vulnerability scores of 7 or higher (22 received a score of 7; 18 subgroups received a score of 8; and 9 subgroups received a score of 9).
- Analysis suggested that some biological groups in the National Framework would require changes to sub-group breakdown for application in the Maritimes (i.e., marine fishes and marine algae/plants), whereas other biological groups while other groups would require very little change from the National framework (e.g., marine invertebrates). In some cases, additional sub-group levels, reorganization of existing sub-groups, and the addition of new sub-groups would allow for regionally relevant scoring.
- Precautionary scoring in instances where information was limited or conflicting identified data gaps and opportunities for future investigation.
- The sensitivity criterion ‘impairment due to toxicity’ was not effective at differentiating between sub-groups. The “mechanical sensitivity” criterion allowed for further breakdown, but the two conditions were considered to be narrow in scope (i.e., reduction in feeding/photosynthesis and thermoregulation), increasing the potential for underscoring. Further development of the sensitivity category was recommended. Based on expert opinion during the meeting, the population status criterion was expanded (i.e., to include more

information sources related to decline) to more fully meet the “population status” criteria definition as laid out in the national framework.

- This application is meant to be used in conjunction with other science tools and data (spatial and non-spatial) to support evidence-based decision making during the response to marine oil spills; more specifically, to be used to support environmental mitigation prioritization discussions.

BACKGROUND

A national framework to assess vulnerability of biological components to ship-source oil spills in the marine environment’ was reviewed in 2016 (DFO 2017). The framework uses a structured method to identify the biological components most vulnerable to direct effects of ship-source oil spill. This is based on a suite of standard screening and ranking criteria that considers direct effects. As an important contribution towards meeting Fisheries and Oceans Canada’s (DFO’s) commitment to ensuring sustainable aquatic ecosystems (Environment Canada 2013), the framework has been successfully applied in both the DFO Pacific and Quebec Regions (Hannah et al. 2017; Desjardins et al. 2018).

DFO Maritimes Science completed a regional application of the National Framework to Assess the Vulnerability of Biological Components to Ship-source Oil Spills in the Marine Environment.to support timely and informed response to ship-source oil spills in this region.

This included a final ranking table, used to strengthen the support “Resources at Risk” information used in oil spill planning and response (Figure 2). Additionally, the rank table can be used to guide the development of future tools and products for use in fulfilling the environmental response support role of DFO Science.

While not a risk assessment, the vulnerability scoring outputs from the Maritimes Region application of the National framework are directly relevant to marine oil spill response. Furthermore, grouping of biological components in this application may be useful to other departmental initiatives examining vulnerability of marine components in the region.

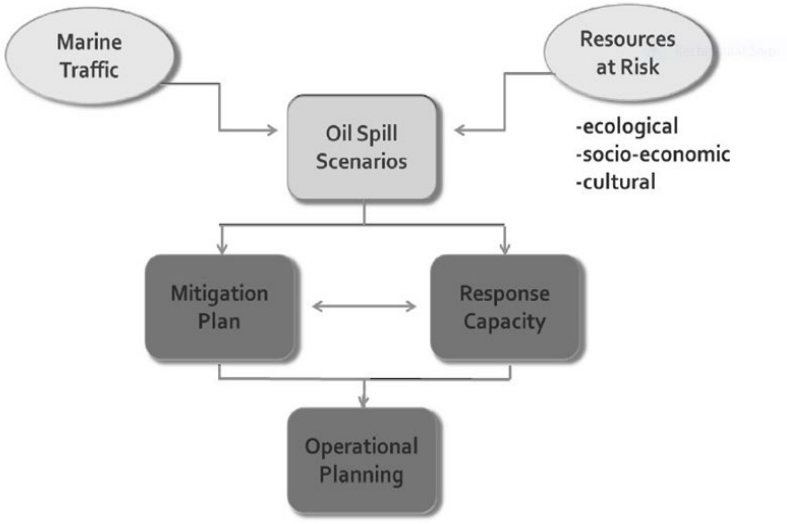

Figure 2. Overview of how the vulnerability framework fits in with the overall model for oil-spill planning and response (“ecological” Resources at Risk).

ASSESSMENT

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 this 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 encompassing a number of criteria used to assess aspects of vulnerability in sub-groups. The most vulnerable biological components are identified through a modified scoring and ranking process described below (Figure 3).

The framework (Thornborough et al. 2017) consists of three key phases:

- grouping of biological components into sub-groups based on similar characteristics related to oil vulnerability;
- binary scoring of sub-groups against vulnerability criteria (under categories of exposure, sensitivity, and recovery); and
- applying a ranking method to identify the most vulnerable sub-groups.

Grouping Biological Components

In the Maritimes Region, sub-group development was completed using a bottom up approach, commencing with the initial development of lists of verified regional species. A total of 1,034 marine species within high-level biological groups (Marine Plants and Algae, Marine Invertebrates, Marine Fishes, Marine Mammals, and Marine Reptiles) were assessed and merged into 116 taxonomic sub-groups. These sub-groups represent the suite of marine biota in this region with sufficient discrimination to score against nationally standardized vulnerability criteria. This application applied the "Subtidal" classification across all depths within the region, with no discrete "Off Shelf" category, which resulted in only one classification region-wide.

In order for a species to be considered a "verified input" for sub-group consideration, its existence in the Maritimes Region was confirmed by a minimum of two observations. This first step increased confidence around sub-group inclusiveness and subsequent scoring and vulnerability rankings. Species lists, while not exhaustive, were considered to be inclusive of a high proportion of Maritimes species in each group, and representative of the differences in ecological and biological traits used in the development of sub-groups.

Using the above approach, 116 Maritimes regional sub-groups were developed (compared to 75 as proposed in the National framework).

Scoring and ranking was applied at the sub-group level, using criteria outlined in the National framework with the following modifications:

1. Within the Exposure category:

- **Concentration (aggregation) and/or site fidelity:** 'site fidelity' was moved to the 'mobility' criterion.
- **Mobility:** mobility criteria changed to 'mobility and/or site fidelity', as site fidelity is used to score **organisms** that may have the ability to move, yet they may not move due to a limited home range.
- **Sea surface interacting:** quantification was deemed necessary for this criteria. Surface layer was defined as 0 to −1 m to better capture the 'sea surface interacting' criteria.

- **Sediment interacting:** was changed to 'seafloor or vegetation interacting' to include interactions with all sediment types and vegetation.

2. In the Sensitivity Category:

- **Mechanical Sensitivity**: two criteria were merged into a single criterion named 'mechanical sensitivity' (reduction of feeding/photosynthesis/thermoregulation).
- **Chemical Sensitivity** criterion was changed to include 'impairment due to toxicity'.

3. In the Recovery Category:

- **Reproductive capacity**: was expanded to include life history traits that can affect **reproductive** potential; as well as low reproductive capacity.
- **Close association to sediments**: was changed to 'close association with unconsolidated substrates'.

Scoring and Ranking

A binary system was used to score 116 Maritimes Region sub-groups against 10 criteria that comprise the Exposure, Sensitivity, and Recovery vulnerability categories. A score of (1) indicated that the criterion was fulfilled for that sub-group, while a score of (0) denoted a sub-group that did not fulfill the criterion. Scoring decisions were made based on the general guidance tables provided by the National framework for each group as well as the more specific guidance developed in the Maritimes Region.

A referenced justification for each score was included to support decisions that were not intuitive (i.e., based on general biological knowledge, e.g., 'all vascular plants are rooted in substrate'), to ensure scientific integrity of decision making, and to maintain confidence in scoring consistency across the application. The number of justifications varied across categories and sub-groups, and differed in accordance with the availability of definitive conclusions in the scientific literature (e.g., there are few conclusive and comparable studies on chemical toxicity for most sub-groups).

A precautionary approach was taken with regard to scoring sub-groups in the following ways:

- If at least one species within a sub-group was known to fulfill the criterion, the entire sub-group fulfilled the criterion.
- Sub-groups were scored based on the life stages most vulnerable to oil (e.g., juveniles compared to adult) where information was available.
- Where literature was lacking (less than two records) to support a definitive score (0 or 1), a precautionary score of "1P" was assigned for the criterion.

Scoring results for each category were added to determine a total vulnerability score for each sub-group. These sub-groups were then ranked in order of highest (most vulnerable) to lowest (least vulnerable) scores (Appendix 1).

This application provided an ecologically and taxonomically based list for all Maritimes Region sub-groups, validated through a literature review, ranked by total vulnerability to ship-source oil spills, which can be used to inform response planning efforts. Of the 116 sub-groups identified, 49 were considered "highly vulnerable", receiving overall vulnerability scores of 7 or higher (22 received a score of 7; 18 subgroups received a score of 8; and 9 subgroups received a score of 9).

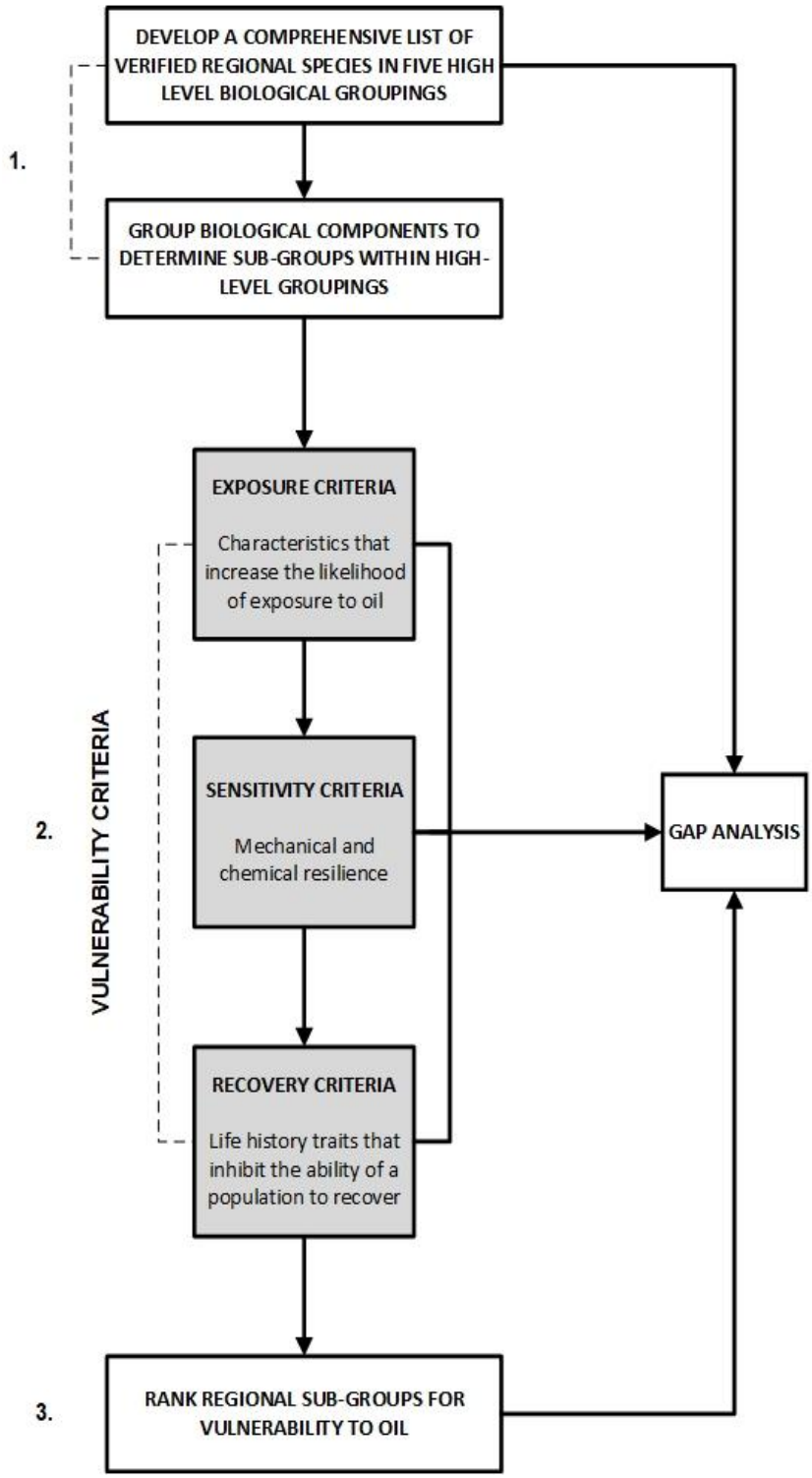

Figure 3. Maritimes Region modification to the National framework process.

Sources of Uncertainty

A key result of the Maritimes Region application of the National vulnerability framework was the identification of sources of scoring uncertainty that created knowledge gaps.

One of the goals of the Maritimes Region application was to minimize sources of uncertainty. This was accomplished by using a bottom up approach to sub-group creation and by performing in-depth literature searches for justifications to lessen the reliance on precautionary scoring. By employing these principles, the Maritimes Region assigned a precautionary score only 19% of the time (across all 116 sub-groups).

Where the literature did not support a binary score (0, 1) directly, a deeper review into difficult to score sub-groups was undertaken with a synthesized 'state of knowledge', provided as a justification to explain why a precautionary score was warranted.

Precautionary scoring in instances where information was limited or conflicting identified data gaps and opportunities for future investigation.

Despite the comprehensive approach to sub-group creation and scoring that was used in the Maritimes Region application, some knowledge gaps were uncovered during its development.

Identified gaps:

- Corals, sponges, phytoplankton, and marine larvae were not well represented in this analysis. Ongoing validation would be required to continue to revise and refine analysis over time.
- Lacking or conflicting information on chemical toxicity across all sub-groups limited the ability to adequately score this criterion. Since oil is believed to be toxic to all organisms at some level, all sub-groups were scored a 1P for this criterion, meaning that chemical toxicity cannot be used to distinguish between sub-group vulnerabilities as the criterion is defined.
- There was a dearth of specific biological information (e.g., life history, habitat types) for some groups. This was especially evident for some invertebrate and fish sub-groups.
- Some scoring criteria were too narrow to score sub-groups adequately. This was evident in the mechanical sensitivity scoring. While the approach was needed to differentiate between sub-groups, its definition may be too limited in scope and likely caused some groups to be underscored (e.g., fish without gill rakers for feeding were scored a 0 but have other structures that could become clogged with oil, such as gills).
- There is limited information on the effect of developmental life stage on vulnerability to oil. In this application, results were reported on the most vulnerable life stage where possible, but an overall lack of information was evident.

CONCLUSIONS

The Maritimes application of the National Framework identified regional variations to either refine the National Framework or allow for more effective implementation in the Maritimes Region. Modification to the way in which sub-groups were created (i.e., in a bottom-up manner using verified species lists prior to scoring, compared to populating sub-groups after scoring) suggested that some biological groups in the National Framework would require changes to sub-group breakdown for application in the Maritimes (i.e., marine fishes and marine algae/plants), while other groups would require very little change from the National framework (e.g., marine invertebrates). In some cases, additional sub-group levels, reorganization of existing sub-groups, and the addition of new sub-groups would allow for regionally relevant scoring.

Sub-groups created in the Maritimes application were considered sufficient to represent the suite of Maritimes Region biota and provided the necessary delineation for effective scoring against vulnerability criteria in most cases.

While the National framework recommended that vulnerability criteria not be changed in order to make direct comparisons across regions straightforward, this analysis suggested that there were a number of general, and sub-group specific, modifications that would improve application for the Maritimes Regions. These small changes were considered necessary to improve understanding of the Maritimes application in general and did not affect the National criteria as proposed.

At present, the sensitivity criterion 'impairment due to toxicity' was not effective at differentiating between sub-groups. The "mechanical sensitivity" criterion allowed for further breakdown, but the two conditions were considered to be narrow in scope (i.e., reduction in feeding/photosynthesis and thermoregulation), increasing the potential for underscoring. Further development of the sensitivity category was recommended. Based on expert opinion during the meeting, the population status criterion was expanded (i.e., to include more information sources related to decline) to more fully meet the "population status" criteria definition as laid out in the national framework.

The binary screening method described in the National application was retained in the Maritimes application, but scores were based on a total across all criteria and not just their recovery score as was presented in the National model.

The Maritimes application did not screen out any sub-groups.

Phytoplankton, zooplankton and most vulnerable life stages were not fully assessed in this application and need further development.

The application provided a valid list for all Maritimes Region sub-groups ranked by total vulnerability to ship-source oil spills, which will be used to inform response efforts. This application is meant to be used in conjunction with other science tools and data (spatial and non-spatial) to support evidence-based decision making during the response to marine oil spills; more specifically, to be used to support environmental mitigation prioritization discussions.

LIST OF MEETING PARTICIPANTS

"Y" = present, "-" = absent

Name	Affiliation	Day 1	Day 2	Day 3
Bone, Bryden	DFO Maritimes / MPC	Y	Y	Y
Brady, Jeff	CCG NCR	Y	Y	-
Breeze, Heather	DFO Maritimes / MPC	Y	Y	Y
Beauchesne, David	Laval University	Y	-	Y
Clermont, Yves	DFO Quebec / Science	Y	Y	Y
Cooper, J. Andrew	DFO Maritimes / Science	Y	Y	Y
Desjardins, Christine	DFO Quebec / Science	Y	-	-
Feyrer, Laura	DFO Maritimes / Science	Y	Y	Y
Girouard, Nathalie	DFO NCR / Science	Y	Y	Y
Greig, Ryan	CCG NCR	Y	Y	Y
Hamer, Adrian	DFO Maritimes / Science	Y	Y	Y
Harvey, Cara	DFO Maritimes / Science	Y	Y	Y
Jeffery, Sharon	DFO Pacific / Science	Y	Y	Y
Jones, Owen	DFO Maritimes / Science	Y	Y	Y
Kelly, Noreen	DFO Maritimes / Science	Y	Y	Y
Lander, Terralynn	DFO Maritimes / Science	Y	Y	Y
Lawton, Peter	DFO Maritimes / Science	Y	Y	Y
MacDonald, Shawn M.	Nova Scotia DFA	Y	-	-
Macisaac, Brittany	DFO Maritimes / Science	Y	Y	-
Matheson, Kyle	DFO NL / Science	Y	Y	Y
Merritt, Vicky	DFO Maritimes / Science	Y	Y	Y
Neves, Barbara	DFO NL / Science	Y	Y	Y
Paul, Stacey D.	DFO Maritimes / Science	Y	Y	-
Robertson, Greg	ECCC	Y	Y	Y
Robinson, Brian	DFO Maritimes / Science	Y	Y	Y
Singh, Rabindra	DFO Maritimes / CSA	Y	Y	Y
St. Germain, Candice	DFO Pacific / Science	Y	-	-
Stortini, Christine	DFO Maritimes / MPC	Y	Y	Y
TeKamp, Mark C.	Nova Scotia DNRR	Y	Y	Y
Wells, Nadine	DFO NL Science	Y	Y	-
Worcester, Tana	DFO Maritimes / CSA	Y	Y	Y

SOURCES OF INFORMATION

This Science Advisory Report is from the November 22-24, 2021, regional peer review on the Application of the National Vulnerability Framework the Maritimes Region, to assess the vulnerability of biological components to ship-source oil spills in the marine environment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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APPENDIX

Table 1. Final ranked list of sub-groups for the Maritimes Region application of the National vulnerability framework produced by scoring sub-groups against EXPOSURE, SENSITIVITY, and RECOVERY criteria. N/A = not applicable.

Biological Group	FRAMEWORK SUB–GROUPS					Maritime example species	Exposure Score (/4)	Sensitivity Score (/2)	Recovery Score (/4)	Total Vulnerability Score (/10)
	Sub–group Level 1	Sub–group Level 2	Sub–group Level 3	Sub–group Level 4	Sub–group Level 5					
MARINE PLANTS AND ALGAE	Intertidal	Vascular	N/A	Moderate to low energy unconsolidated habitat	Saltmarsh grass	*Carex paleacea, Juncus gerardii, Juncus caesariensis, Puccinellia maritima, Spartina alterniflora*	4	2	3	9
MARINE PLANTS AND ALGAE	Intertidal	Vascular	N/A	Moderate to low energy unconsolidated habitat	Seagrasses	*Ruppia maritima, Zostera marina*	4	2	3	**9**
MARINE PLANTS AND ALGAE	Intertidal	Non–vascular	Understory and turf	High energy consolidated habitat	N/A	*Chondrus crispus, Fucus endentatus, Fucus spiralis, Porphyra purpurea, Corallina officinalis*	4	2	3	**9**
MARINE PLANTS AND ALGAE	Intertidal	Non–vascular	Understory and turf	Moderate to low energy consolidated habitat	N/A	*Chorda tomentosa, Polysiphonia stricta, Ptilota elegans, Ulva intestinalis, Ulva lactuca, Corallina officinalis*	4	2	3	**9**
MARINE INVERTEBRATES	Intertidal	Sediment infauna	Low mobility	N/A	Mollusca	Clams, Astartes [Bivalvia]; Moonsnails [Gastropoda]	4	2	3	9
MARINE INVERTEBRATES	Pelagic	LARVAE		Mollusca			4	2	3	9
MARINE FISHES	Estuarine	Estuarine transient	Benthic	Associated with unconsolidated substrates (silt/mud/sand/gravel)	Sturgeon (Acipenseridae)	Shortnose sturgeon, Atlantic sturgeon	4	1	4	9
MARINE FISHES	Estuarine	Estuarine transient	Benthic	Associated with consolidated substrates (cobble/boulder/bedrock)	Sturgeon (Acipenseridae)	Shortnose sturgeon, Atlantic sturgeon	4	1	4	9
MARINE MAMMALS	Pinnipeds	Other pinnipeds	Dispersed	N/A	N/A	Grey seal, Ringed seal, Bearded seal, Hooded seal	4	2	3	9

Biological Group	FRAMEWORK SUB–GROUPS					Maritime example species	Exposure Score (/4)	Sensitivity Score (/2)	Recovery Score (/4)	Total Vulnerability Score (/10)
	Sub–group Level 1	Sub–group Level 2	Sub–group Level 3	Sub–group Level 4	Sub–group Level 5					
MARINE PLANTS AND ALGAE	Intertidal	Vascular	N/A	Moderate to low energy unconsolidated habitat	Saltmarsh non–grass	*Achillea millefolium, Plantago maritima, Limonium carolinianum, Triglochin maritimum*	4	2	2	8
MARINE PLANTS AND ALGAE	Intertidal	Vascular	N/A	Moderate to low energy unconsolidated habitat	Saltmarsh succulent	*Crassula aquatic, Honckenya peploides, Salicornia europae/S. depressa*	4	2	2	8
MARINE PLANTS AND ALGAE	Intertidal	Non–vascular	Canopy	High energy consolidated habitat	N/A	*Alaria esculenta, Laminaria digitata, Saccharina latissima*	3	2	3	**8**
MARINE PLANTS AND ALGAE	Subtidal	Non–vascular	Canopy	High energy consolidated habitat	N/A	*Alaria esculenta, Laminaria digitata, Saccharina latissima*	4	2	2	**8**
MARINE PLANTS AND ALGAE	Subtidal	Non–vascular	Canopy	Moderate to low energy consolidated habitat	N/A	*Agarum clathratum, Halosiphon tomentosus, Laminaria digitata, Saccharina latissima*	4	2	2	**8**
MARINE PLANTS AND ALGAE	Subtidal	Non–vascular	Understory and turf	High energy consolidated habitat	N/A	*Chondrus crispus, Chorda tomentosa, Desmarestia viridis, Euthora cristata, Furcellaria lumbricalis*	4	2	2	**8**
MARINE FISHES	Marine	Subtidal	Benthic	Associated with unconsolidated substrates (silt/mud/sand/gravel)	Sturgeon (Acipenseridae)	Shortnose sturgeon, Atlantic sturgeon	3	1	4	8
MARINE FISHES	Marine	Subtidal	Benthic	Associated with consolidated substrates (cobble/boulder/bedrock)	Sturgeon (Acipenseridae)	Shortnose sturgeon, Atlantic sturgeon	3	1	4	8
MARINE FISHES	Marine	Subtidal	Non–benthic (pelagic and demersal)	N/A	Eels (Anguillidae)	American eel	4	1	3	8
MARINE FISHES	Estuarine	Estuarine transient	Benthic	Associated with unconsolidated substrates (silt/mud/sand/gravel)	Eels (Anguillidae)	American eel	4	1	3	8

Biological Group	FRAMEWORK SUB–GROUPS					Maritime example species	Exposure Score (/4)	Sensitivity Score (/2)	Recovery Score (/4)	Total Vulnerability Score (/10)
	Sub–group Level 1	Sub–group Level 2	Sub–group Level 3	Sub–group Level 4	Sub–group Level 5					
MARINE FISHES	Estuarine	Estuarine transient	Non–benthic (pelagic and demersal	N/A	Salmon (Salmonidae)	Atlantic salmon	4	1	3	8
MARINE FISHES	Estuarine	Estuarine transient	Non–benthic (pelagic and demersal	N/A	Clupeidae	American shad, Blueback herring, Alewife	4	2	2	8
MARINE MAMMALS	Cetaceans	Toothed	Discrete	N/A	N/A	Killer whale, Long–finned pilot whale, Northern bottlenose whale, Atlantic white–sided dolphin	3	1	4	8
MARINE MAMMALS	Cetaceans	Baleen	Discrete	N/A	N/A	Fin whale, Humpback whale, North Atlantic Right Whale	3	2	3	8
MARINE MAMMALS	Cetaceans	Baleen	Dispersed	N/A	N/A	Minke whale, Blue whale, Sei whale	3	2	3	8
MARINE REPTILES	Sea turtles	N/A	N/A	N/A	N/A	Leatherback sea turtle, Loggerhead sea turtle, Kemp's ridley	4	1	3	8
MARINE FISHES	Marine	Intertidal	Non–benthic (pelagic and demersal)	N/A	Sticklebacks (Gasterosteidae)	Blackspotted stickleback, Fourspine stickleback, Threespine stickleback	4	2	2	8
MARINE INVERTEBRATES	Intertidal	Sediment epifauna	Low mobility	N/A	Echinodermata	Brittle stars [Ophiuroidea]; Sea stars [Asteroidea]; Sea cucumbers [Holothuroidea]	4	2	2	**8**
MARINE PLANTS AND ALGAE	Intertidal	Non–vascular	Encrusting	Consolidated habitat	N/A	Coralline encrusting algae, e.g., *Lithothamnion glaciale*	3	2	2	**7**

Biological Group	FRAMEWORK SUB–GROUPS					Maritime example species	Exposure Score (/4)	Sensitivity Score (/2)	Recovery Score (/4)	Total Vulnerability Score (/10)
	Sub–group Level 1	Sub–group Level 2	Sub–group Level 3	Sub–group Level 4	Sub–group Level 5					
MARINE PLANTS AND ALGAE	Subtidal	Non–vascular	Understory and turf	Moderate to low energy consolidated habitat	N/A	*Desmarestia aculeata, Desmarestia viridis, Euthora cristata, Petalonia fascia, Ulva intestinalis, Spongomorpha arcta (Acrosiphonia arcta)*	3	2	2	**7**
MARINE PLANTS AND ALGAE	Subtidal	Non–vascular	Encrusting	Consolidated habitat	N/A	Coralline encrusting algae, e.g., *Lithothamnion glaciale*	3	2	2	**7**
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	N/A	Porifera	Sponges [CL. Demospongiae, Calcarea]	4	2	1	7
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	N/A	Cnidaria	Colonial hydroids [Hydrozoa]; Stalked jellyfish [Staurozoa]	4	2	1	7
MARINE INVERTEBRATES	Intertidal	Sediment infauna	Low mobility	N/A	Arthropoda	Mud crab [Decapoda, Panopeidae]; Tube–building gammarid amphipods [Amphipoda]	4	2	1	7
MARINE INVERTEBRATES	Intertidal	Sediment epifauna	High mobility	N/A	Arthropoda	Crabs, Lobsters [Decapoda]	4	1	2	**7**
MARINE INVERTEBRATES	Intertidal	Sediment epifauna	Low mobility	N/A	Cnidaria	Starlet anemones, Sand anemones [Anthozoa]	4	2	1	7
MARINE INVERTEBRATES	Subtidal benthic	Sediment epifauna	Low mobility	N/A	Echinodermata	Sand dollars [Echinoidea]; Cushion stars, Mud stars [Asteroidea]; Sea cucumbers [Holothuroidea]	3	2	2	**7**
MARINE INVERTEBRATES	Subtidal benthic	Sediment infauna	Low mobility	N/A	Echinodermata	Sea cucumbers (e.g., *Caudina arenata*) [Holothuroidea]	3	2	2	**7**
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Low mobility	N/A	Echinodermata	Sea stars [Asteroidea]; Sea urchins [Echinoidea]; Sea cucumbers [Holothuroidea]	4	2	1	**7**

Biological Group	FRAMEWORK SUB–GROUPS					Maritime example species	Exposure Score (/4)	Sensitivity Score (/2)	Recovery Score (/4)	Total Vulnerability Score (/10)
	Sub–group Level 1	Sub–group Level 2	Sub–group Level 3	Sub–group Level 4	Sub–group Level 5					
MARINE INVERTEBRATES	Intertidal	Sediment epifauna	Low mobility	N/A	Mollusca	Nudibranchs [Gastropoda, Nudibranchia]; Snails [Gastropoda]; Scallops [Bivalvia]	4	2	1	7
MARINE INVERTEBRATES	Pelagic	LARVAE		Cnidaria			4	2	1	7
MARINE INVERTEBRATES	Pelagic	LARVAE		Worms			4	2	1	7
MARINE INVERTEBRATES	Pelagic	LARVAE		Lophophorates			4	2	1	7
MARINE INVERTEBRATES	Pelagic	LARVAE		Echinodermata			4	2	1	7
MARINE INVERTEBRATES	Pelagic	LARVAE		Hemichordata			4	2	1	7
MARINE INVERTEBRATES	Pelagic	LARVAE		Arthropoda			4	2	1	7
MARINE FISHES	Marine	Subtidal	Benthic	Associated with unconsolidated substrates (silt/mud/sand/gravel)	Redfish (Sebastidae)	Acadian redfish	3	1	3	7
MARINE FISHES	Marine	Subtidal	Non–benthic (pelagic and demersal)	N/A	Clupeidae	Atlantic herring, American shad, Blueback herring, Alewife	3	2	2	**7**
MARINE FISHES	Estuarine	Estuarine transient	Non–benthic (pelagic and demersal	N/A	Sticklebacks (Gasterosteidae)	Threespine stickleback	4	1	2	7
MARINE MAMMALS	Cetaceans	Toothed	Dispersed	N/A	N/A	Harbour porpoise, Sperm whale, Cuvier's beaked whale, Sowerby's whale, True's beaked whale, Blainville's beaked whale	3	1	3	7
MARINE PLANTS AND ALGAE	Epi–pelagic	Non–vascular	PHYTOPLANKTON				3	2	1	**6**

Biological Group	FRAMEWORK SUB–GROUPS					Maritime example species	Exposure Score (/4)	Sensitivity Score (/2)	Recovery Score (/4)	Total Vulnerability Score (/10)
	Sub–group Level 1	Sub–group Level 2	Sub–group Level 3	Sub–group Level 4	Sub–group Level 5					
MARINE FISHES	Marine	Subtidal	Benthic	Associated with consolidated substrates (cobble/boulder/bedrock)	Wolffishes (Anarhichadidae)	Atlantic wolffish, Spotted wolffish, Northern wolffish	2	1	3	6
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	N/A	Worms	Tube worms [Polychaeta]	4	2	0	6
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	N/A	Lophophorates	Marine bryozoans [Bryozoa]; Lampshells [Branchiopoda]	4	2	0	6
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	N/A	Mollusca	Oysters, Mussels [Bivalvia]; Snails [Gastropoda]	4	2	0	6
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	N/A	Hemichordata	Sea peaches, Sea squirts [Ascidiacea]	4	2	0	6
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Sessile (attached to hard substrate)	N/A	Arthropoda	Barnacles [CL. Hexanauplia]	4	2	0	6
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Low mobility	N/A	Cnidaria	Anemones [Anthozoa]	4	2	0	6
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	High mobility	N/A	Arthropoda	Crabs, Lobsters [Decapoda]	4	1	1	**6**
MARINE INVERTEBRATES	Intertidal	Sediment infauna	Low mobility	N/A	Worms	Sandworms, Lugworms, other burrowers [Polychaeta]; Nemertean worms [Paleonemertea]; Sipuncula worms [Sipunculidea]; Flatworms [Platyhelminthes]	4	1	1	6

Biological Group	FRAMEWORK SUB–GROUPS					Maritime example species	Exposure Score (/4)	Sensitivity Score (/2)	Recovery Score (/4)	Total Vulnerability Score (/10)
	Sub–group Level 1	Sub–group Level 2	Sub–group Level 3	Sub–group Level 4	Sub–group Level 5					
MARINE INVERTEBRATES	Intertidal	Sediment epifauna	Low mobility	N/A	Arthropoda	Hermit crabs [Decapoda]; Sand fleas and other amphipods [Amphipoda]; Sea spiders [Pycnogonida]; Isopods [Isopoda]	4	1	1	6
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	N/A	Porifera	Boring sponges, Breadcrumb sponges, Encrusting sponges [CL. Demospongiae, Calcarea]	3	2	1	6
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	N/A	Cnidaria	Colonial hydroids [Hydrozoa]; Soft corals [Anthozoa]; Stalked jellyfish [Staurozoa]	3	2	1	6
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Low mobility	N/A	Echinodermata	Sea stars [Asteroidea]; Sea cucumbers [Holothuroidea]; Basket stars, Brittle stars [Ophiuroidea]; Sea urchins [Echinoidea]	3	2	1	**6**
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Low mobility	N/A	Cnidaria	Anemones [Anthozoa]; Colonial hydroids [Hydrozoa]	3	2	1	6
MARINE INVERTEBRATES	Subtidal benthic	Sediment infauna	Low mobility	N/A	Cnidaria	Burrowing anemones [Anthozoa]	3	2	1	6
MARINE INVERTEBRATES	Subtidal benthic	Sediment infauna	Low mobility	N/A	Worms	Polychaete worms [Polychaeta]; Flatworms [Platyhelmintes]; Nemertean worms [Pilidiophora]; Peanut worms [Sipunculidea]	3	2	1	6
MARINE INVERTEBRATES	Subtidal benthic	Sediment infauna	Low mobility	N/A	Mollusca	Clams [Bivalvia]	3	2	1	6
MARINE INVERTEBRATES	Subtidal benthic	Sediment infauna	Low mobility	N/A	Arthropoda	Amphipods [Amphipoda, Cumacea]	3	2	1	6

Biological Group	FRAMEWORK SUB–GROUPS					Maritime example species	Exposure Score (/4)	Sensitivity Score (/2)	Recovery Score (/4)	Total Vulnerability Score (/10)
	Sub–group Level 1	Sub–group Level 2	Sub–group Level 3	Sub–group Level 4	Sub–group Level 5					
MARINE INVERTEBRATES	Subtidal benthic	Sediment infauna	Low mobility	N/A	Lophophorates	Marine bryozoans [Bryozoa]; Lampshells [Branchiopoda]	3	2	1	6
MARINE INVERTEBRATES	Subtidal benthic	Sediment epifauna	Low mobility	N/A	Cnidaria	Anemones [Anthozoa]	3	2	1	6
MARINE INVERTEBRATES	Subtidal benthic	Sediment epifauna	Low mobility	N/A	Mollusca	Nudibranchs, Whelks, Moonsnails [Gastropoda]; Quahogs, Scallops [Bivalvia]	3	2	1	6
MARINE INVERTEBRATES	Subtidal benthic	Sediment epifauna	High mobility	N/A	Arthropoda	Crabs, Lobsters [Decapoda]	3	1	2	**6**
MARINE INVERTEBRATES	Pelagic	N/A	High mobility	N/A	Mollusca	Squid [Cephalopoda]	4	1	1	6
MARINE INVERTEBRATES	Pelagic	LARVAE		Porifera			4	1	1	6
MARINE FISHES	Marine	Intertidal	Benthic	Associated with unconsolidated substrates (silt/mud/sand/gravel)	Snailfishes (Liparidae)	Atlantic snailfish	3	1	2	6
MARINE FISHES	Marine	Intertidal	Benthic	Associated with unconsolidated substrates (silt/mud/sand/gravel)	Cryptacanthodidae	Wrymouth	3	1	2	6
MARINE FISHES	Marine	Intertidal	Benthic	Associated with consolidated substrates (cobble/boulder/bedrock)	Snailfishes (Liparidae)	Atlantic snailfish	3	1	2	6
MARINE FISHES	Marine	Intertidal	Non–benthic (pelagic and demersal)	N/A	Silversides (Atherinopsidae)	Atlantic silverside	4	1	1	6
MARINE FISHES	Marine	Subtidal	Benthic	Associated with unconsolidated substrates (silt/mud/sand/gravel)	Flatfishes (Pleuronectidae)	Winter flounder, Yellowtail flounder, Atlantic halibut, Windowpane, American plaice	1	1	4	6
MARINE FISHES	Marine	Subtidal	Benthic	Associated with unconsolidated substrates (silt/mud/sand/gravel)	Myxinidae	Atlantic hagfish	3	1	2	6

Biological Group	FRAMEWORK SUB–GROUPS					Maritime example species	Exposure Score (/4)	Sensitivity Score (/2)	Recovery Score (/4)	Total Vulnerability Score (/10)
	Sub–group Level 1	Sub–group Level 2	Sub–group Level 3	Sub–group Level 4	Sub–group Level 5					
MARINE FISHES	Marine	Subtidal	Benthic	Associated with unconsolidated substrates (silt/mud/sand/gravel)	Lophiidae	Monkfish	2	1	3	**6**
MARINE FISHES	Marine	Subtidal	Benthic	Associated with consolidated substrates (cobble/boulder/bedrock)	Lumpfishes (Cyclopteridae)	Atlantic spiny lumpsucker, lumpfish	3	1	2	6
MARINE FISHES	Estuarine	Estuarine transient	Non–benthic (pelagic and demersal	N/A	Silversides (Atherinopsidae)	Atlantic silverside	4	1	1	6
MARINE FISHES	Estuarine	Estuarine resident	Non–benthic (pelagic and demersal	N/A	Fundulidae	Mummichog	3	1	2	6
MARINE FISHES	Estuarine	Estuarine resident	Non–benthic (pelagic and demersal	N/A	Syngnathidae	Northern pipefish	3	1	2	6
MARINE MAMMALS	Pinnipeds	Other pinnipeds	Discrete	N/A	N/A	Harbour seal, Harp seal	3	1	2	**6**
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Low mobility	N/A	Worms	Bloodworms [Polychaeta]; Flatworms [Platyhelminthes]; Nemertean worms	4	1	0	5
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Low mobility	N/A	Mollusca	Chitons [Polyplacophora]; Whelks, Limpets, Snails [Gastropoda]	4	1	0	5
MARINE INVERTEBRATES	Intertidal	Rock and rubble dwellers	Low mobility	N/A	Arthropoda	Amphipods [Amphipoda]; Isopods [Isopoda]	4	1	0	5
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	N/A	Worms	Tube worms [Polychaeta]	3	2	0	5

Biological Group	FRAMEWORK SUB–GROUPS					Maritime example species	Exposure Score (/4)	Sensitivity Score (/2)	Recovery Score (/4)	Total Vulnerability Score (/10)
	Sub–group Level 1	Sub–group Level 2	Sub–group Level 3	Sub–group Level 4	Sub–group Level 5					
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	N/A	Lophophorates	Marine bryozoans [Bryozoa]; Lampshells [Branchiopoda]	3	2	0	5
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	N/A	Mollusca	Slipper limpets [Gastropoda]; Mussels, Oysters, Comb bathyarks [Bivalvia]	3	2	0	5
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	N/A	Hemichordata	Ascidians (Tunicates, Sea squirts, Sea grapes) [Ascidiacea]	3	2	0	5
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Sessile (attached to hard substrate)	N/A	Arthropoda	Barnacles [CL. Hexanauplia]	3	2	0	5
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Low mobility	N/A	Worms	Ribbon worms [Hoplonemertea]; Polychaete worms [Polychaeta]; Flatworms [Platyhelminthes]	3	2	0	5
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	Low mobility	N/A	Mollusca	Nudibranchs, Whelks, Periwinkles [Gastropoda]; Scallops [Bivalvia]	3	2	0	5
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	High mobility	N/A	Arthropoda	Crabs, Lobsters [Decapoda]	3	1	1	**5**
MARINE INVERTEBRATES	Pelagic	N/A	Low mobility	N/A	Cnidaria	Moon jellies [Scyphozoa]; Hydromesusae [Hydrozoa]; Jelly fish [Scyphozoa]	3	2	0	5
MARINE INVERTEBRATES	Pelagic	N/A	Low mobility	N/A	Ctenophora	Comb jellies [CL. Nuda, Tentaculata]	3	2	0	5
MARINE INVERTEBRATES	Pelagic	N/A	Low mobility	N/A	Zooplankton	Copepods, Mysids	3	2	0	5
MARINE INVERTEBRATES	Pelagic	LARVAE		Ctenophora			3	2	0	5

Biological Group	FRAMEWORK SUB–GROUPS					Maritime example species	Exposure Score (/4)	Sensitivity Score (/2)	Recovery Score (/4)	Total Vulnerability Score (/10)
	Sub–group Level 1	Sub–group Level 2	Sub–group Level 3	Sub–group Level 4	Sub–group Level 5					
MARINE FISHES	Marine	Intertidal	Benthic	Associated with unconsolidated substrates (silt/mud/sand/gravel)	Pout (Zoarcidae)	Ocean pout	2	1	2	5
MARINE FISHES	Marine	Intertidal	Benthic	Associated with consolidated substrates (cobble/boulder/bedrock)	Pout (Zoarcidae)	Ocean pout	2	1	2	**5**
MARINE FISHES	Marine	Intertidal	Benthic	Associated with consolidated substrates (cobble/boulder/bedrock)	Pholidae	Rock gunnel	2	1	2	**5**
MARINE FISHES	Marine	Subtidal	Benthic	Associated with unconsolidated substrates (silt/mud/sand/gravel)	Skates (Rajidae)	Little skate, Thorny skate, Smooth skate	1	1	3	5
MARINE FISHES	Marine	Subtidal	Benthic	Associated with unconsolidated substrates (silt/mud/sand/gravel)	Sculpins (Cottidae)	Shorthorn sculpin, Longhorn sculpin, Moustache sculpin	2	1	2	**5**
MARINE FISHES	Marine	Subtidal	Benthic	Associated with consolidated substrates (cobble/boulder/bedrock)	Sculpins (Cottidae)	Snowflake hookear sculpin, Longhorn sculpin, Shorthorn sculpin	2	1	2	**5**
MARINE FISHES	Marine	Subtidal	Non–benthic (pelagic and demersal)	N/A	Cod (Gadidae)	Atlantic cod, Arctic cod, Tomcod, Pollock	2	1	2	5
MARINE FISHES	Marine	Subtidal	Non–benthic (pelagic and demersal)	N/A	Elasmobranchs	Shortfin mako, Porbeagle, Blue shark	2	1	2	5
MARINE FISHES	Marine	Subtidal	Non–benthic (pelagic and demersal)	N/A	Salmon (Salmonidae)	Atlantic salmon	1	1	3	5
MARINE FISHES	Marine	Subtidal	Non–benthic (pelagic and demersal)	N/A	Scombridae	Atlantic mackerel, Atlantic bluefin tuna	2	2	1	5

Biological Group	FRAMEWORK SUB–GROUPS					Maritime example species	Exposure Score (/4)	Sensitivity Score (/2)	Recovery Score (/4)	Total Vulnerability Score (/10)
	Sub–group Level 1	Sub–group Level 2	Sub–group Level 3	Sub–group Level 4	Sub–group Level 5					
MARINE FISHES	Marine	Subtidal	Non–benthic (pelagic and demersal)	N/A	Osmeridae	Rainbow smelt, Capelin	3	1	1	5
MARINE INVERTEBRATES	Subtidal benthic	Rock and rubble dwellers	High mobility	N/A	Mollusca	North Atlantic octopus [Cephalopoda]	2	1	1	4
MARINE INVERTEBRATES	Subtidal benthic	Sediment epifauna	Low mobility	N/A	Worms	Sea mouse [Polychaeta]	2	1	1	4
MARINE FISHES	Marine	Subtidal	Benthic	Associated with unconsolidated substrates (silt/mud/sand/gravel)	Pout (Zoarcidae)	Ocean pout	1	1	2	4
MARINE FISHES	Estuarine	Estuarine transient	Non–benthic (pelagic and demersal	N/A	Petromyzontidae	Sea lamprey	3	1	0	4

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