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Canadian Science Advisory Secretariat
Quebec Region | Science Advisory Report 2017/044

ADVICE ON THE VULNERABILITY ASSESSMENT OF BIOLOGICAL COMPONENTS OF THE ST. LAWRENCE TO SHIP-SOURCE OIL SPILLS

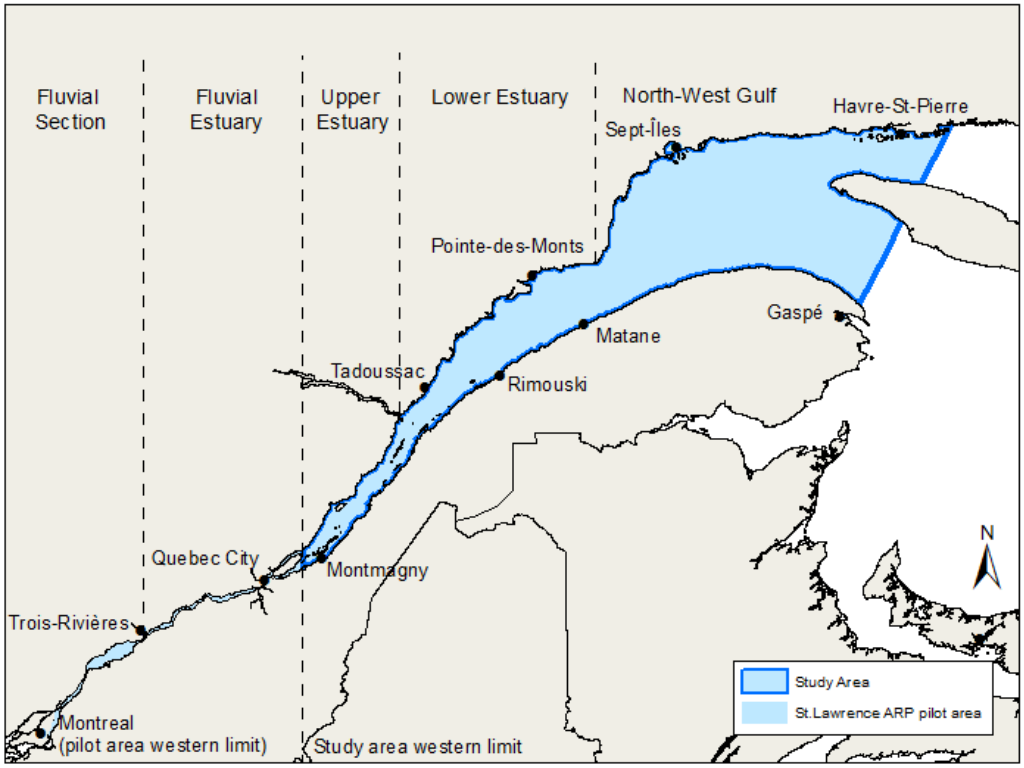

Figure 1. Study area within the St. Lawrence Area Response Plan (ARP) pilot area.

Context:

As part of the review of Canada's Marine Oil Spill Preparedness and Response Regime, Fisheries and Oceans Canada (DFO) is charged with supporting the development of Area Response Plans (ARPs) by sharing data and providing scientific support with respect to at-risk resources in the aquatic environment under its jurisdiction.

In order to fulfill this mandate, DFO has developed a method for assessing the vulnerability of biological components in the marine environment to ship-source oil spills. The results of this assessment will be used to improve the protection of aquatic resources by identifying vulnerable species and incorporating this information into existing spill response and planning processes.

This Science Advisory Report is from the January 24 and 25, 2017, meeting on the vulnerability assessment of biological components of the St. Lawrence to ship-source oil spills. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- The vulnerability assessment of biological components of the St. Lawrence to ship-source oil spills was conducted as part of an Area Response Plan (ARP) pilot project. This assessment is a regional adaptation of the theoretical National Framework for the needs of the St. Lawrence ARP.
- The vulnerability assessment was performed using criteria relating to the exposure potential and resilience of juvenile and adult stages of diadromous, estuarine and marine taxa.
- Relative toxicological sensitivity across taxa was not assessed due to knowledge gaps. Early life stages (eggs and larvae) are considered a priori to be vulnerable.
- The taxa's exposure potential in the event of a spill was assessed based on the following criteria: littoral use, surface interaction, low mobility and aggregation potential.
- The resilience of taxa was assessed based on the following criteria: population status, low recolonization potential, low reproductive capacity and sediment interaction.
- The criteria used to assess exposure potential and resilience are robust and well defined to meet the objectives of the Framework. They are independent and discriminant, and all of the categories of criteria are equally weighted. These criteria can be applied uniformly across all taxa to be assessed.
- In total, 156 taxa of marine and estuarine algae and plants, 372 taxa of marine and estuarine invertebrates, 82 species of marine, estuarine and diadromous fish and 13 marine mammal species were divided into 323 groups of taxa, and then their vulnerability was assessed.
- Of these, 136 groups of taxa (42%) are highly vulnerable: 28% of marine and estuarine algae and plants, 56% of marine and estuarine invertebrates, 23% of marine, estuarine and diadromous fish and 23% of marine mammals.
- The total uncertainty related to the assessment is 20% for algae and plants, 34% for invertebrates and 9% for fish. There is no uncertainty in the scoring of marine mammals. These uncertainties affected the accuracy of the assessment.
- Most of the results were confirmed by experts.
- Vulnerability analysis is a useful reference tool for oil spill response and planning specialists.

INTRODUCTION

Context

In 2013, the Government of Canada mandated an Expert Committee to examine Canada's current Ship-source Oil Spill Preparedness and Response Regime. This review was warranted because the volume of oil transported, the number of vessels and the size of tankers had increased in recent years (Tanker Safety Expert Panel Secretariat 2013).

Some of the recommendations in this report emphasized that oil spill response and planning should be tailored to take into account specific regional issues. The Area Response Planning Initiative (ARPI) led by Transport Canada and the Canadian Coast Guard is the response to this need. The ARPI is a pilot project in which Area Response Plans (ARPs) are developed in four

areas of the country where the risk of spills is highest (WSP 2014). The St. Lawrence ARP pilot area (Figure 1) is one of these areas (Transport Canada 2016).

In support of this initiative, DFO has been mandated to participate in the identification of biological and ecological vulnerabilities in the aquatic environment of the St. Lawrence ARP pilot area. It is essential that stakeholders take these vulnerabilities into account to provide a sound basis for choosing mitigation measures that will limit the impact of a potential spill (Figure 2).

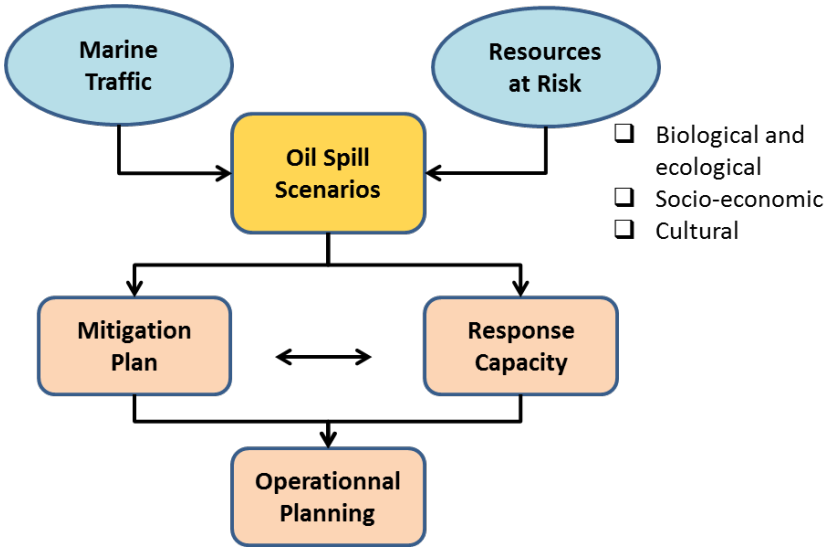

Figure 2. Oil spill response and planning model (Thornborough et al. 2017).

Objectives

In response to this mandate, DFO has developed a theoretical National Framework for defining and assessing the vulnerability of biological components in the marine environment to ship-source oil spills (Thornborough et al. 2017). This framework has been developed so that it can be adapted and used in all pilot areas in Canada.

This advisory report provides information on:

1) The vulnerability of biological components of the St. Lawrence to ship-source oil spills;
2) Adequacy and applicability of the changes to the National Framework for the Quebec Region.

It identifies the key taxa that should be included in the oil spill response and planning process.

Limitations

The vulnerability analysis of the biological components of the St. Lawrence ARP:

- Is a semi-quantitative analysis;
- Considers all types of oil, regardless of their specific differences, and does not cover other hazardous products;
- Is limited to the direct effects of oil on biological components and does not include indirect effects such as the transfer of contaminants into the food chain;

- Is limited to estuarine and marine species for which DFO is responsible as well as diadromous species in the study area, and therefore does not include birds or freshwater species;
- Is limited to juvenile and adult stages. The Precautionary Principle applies to early life stages (eggs and larvae), which are then all considered vulnerable components to be prioritized in the event of an oil spill.

ASSESSMENT

Method

Study area

The St. Lawrence ARP pilot area extends from Montreal to Anticosti Island. To meet the objectives of the mandate while respecting the limitations of the assessment, a smaller study area was defined within this area (Figure 1). The study area extends over 600 km and, from upstream to downstream, includes the upper estuary, lower estuary and part of the Northwestern Gulf. It does not include the Saguenay River and the tributaries of the St. Lawrence. In the coastal area, it is bounded by the higher high water, large tide line.

Vulnerability concept

The proposed vulnerability assessment method is an adaptation of the National Framework for the St. Lawrence ARP. It is based on taxa exposure potential and population resilience. However, the concept of vulnerability also includes organisms' toxicological sensitivity to oil (De Lange et al. 2010; Thornborough et al. 2017). However, toxicological sensitivity was not assessed due to significant knowledge gaps. The assumption that all species are sensitive to oil was considered viable for this analysis.

Description

This method uses four criteria to assess exposure potential (hereinafter *Exposure*: Table 1) and four criteria to assess population resilience (hereinafter *Resilience*: Table 2). Four biological components were analyzed: *Marine and estuarine algae and plants*, *Marine and estuarine invertebrates*, *Marine, estuarine and diadromous fish* and *Marine mammals*. For each component, a list of taxa was compiled from bibliographic references and confirmed by experts. Taxa were classified into various levels, based on taxonomy, way of life and/or vertical zonation, (M: midlittoral, I: infralittoral [0–20 m], CB: circalittoral and bathyal [20 m or more], UEP: upper epipelagic [0–40 m], GEP: glacial epipelagic [40–200 m] and MP: mesopelagic [200 m or more]).

Table 1. Exposure potential criteria

Littoral use	
Question	Does the taxon use the littoral zone?
Rationale	In the event that an oil slick reaches the shore, the littoral zone is more at risk of oiling and contamination by dissolved toxic compounds.
Guideline	The littoral zone extends along the coast from the high water mark to a maximum depth of 10 metres from chart datum.
Scoring	The taxon is attributed a scoring of 1 if it uses the littoral zone in a recurring or permanent manner.
Surface interaction	
Question	Is the taxon dependent on the surface or does it interacts with the surface on a regular basis?
Rationale	In the event of an oil spill, the surface is the first point of contact between the oil and the aquatic environment.
Guideline	The surface includes the air-water interface, the first metre of the water column and the midlittoral zone.
Scoring	The taxon is attributed a scoring of 1 if it interacts with the surface on a regular basis.
Low mobility	
Question	Is the taxon sessile or does it have low mobility?
Rationale	A taxon that has low mobility is more likely to be exposed to oil than taxa that are able to flee from the spill.
Guideline	Mobility is considered limited when it is less than 50 km within 48 hours.
Scoring	The taxon is attributed a scoring of 1 if it is sessile or has low mobility.
Aggregation potential	
Question	Do individuals of the taxon have the potential to aggregate or are they gregarious?
Rationale	A spill is more likely to affect a large number of individuals of the same taxon if they aggregate in one location.
Guideline	Individuals of the taxon must generally aggregate in a specific habitat that is the same size as or smaller than a bay or aggregate to perform a specific vital activity or be gregarious.
Scoring	The taxon is attributed a scoring of 1 if it has aggregation potential.

Table 2. Resilience assessment criteria

Population status	
Question	Does the species or any of its populations have official status?
Rationale	An oil spill would increase the stress on a previously weakened species or population.
Guideline	The status of the species or population must have been assessed by a competent international (International Union for Conservation of Nature (IUCN); Near Threatened, Vulnerable, Endangered statuses), federal (Committee on the Status of Endangered Wildlife in Canada (COSEWIC); Special concern, Threatened, Endangered statuses) or provincial authority (*Act respecting threatened or vulnerable species* (ARTVS); Vulnerable, Threatened statuses).
Scoring	The species is attributed a scoring of 1 if one of its populations present in the study area has official status. The species is attributed a scoring of 1* if it is identified as vulnerable or threatened by the Canadian Endangered Species Conservation Council (CESCC 2016), but has not yet been assessed by COSEWIC. The species is attributed a scoring of 1' (Precautionary Principle) if it has not been assessed.
Low recolonization potential	
Question	Does the taxon have low recolonization potential?
Rationale	A taxon with low recolonization potential will take longer to re-establish itself in its original range following an oil spill than taxa with high recolonization potential.
Guideline	Recolonization potential is defined by dispersion and/or isolation.
Scoring	The taxon is attributed a scoring of 1 if its recolonization potential is low.
Low reproductive capacity	
Question	Does the taxon have low reproductive capacity?
Rationale	A taxon with low reproductive capacity will take longer to return to its original population level following an oil spill than taxa with high reproductive capacity.
Guideline	A taxon's reproductive capacity is based on parental care, fertility and mode of reproduction.
Scoring	The taxon is attributed a scoring of 1 if it has low reproductive capacity.
Sediment interaction	
Question	Does the taxon interact closely with sediment?
Rationale	Close interaction with sediment predisposes the taxon to chronic exposure to persistent oil.
Guideline	Close interaction with sediment involves moving the sediment.
Scoring	The taxon is attributed a scoring of 1 if it interacts closely with sediment.

For each taxon or group of taxa, a vulnerability assessment has been completed, and it includes a scoring of 0 or 1 for each criterion. This scoring is accompanied by one or more references. If there was not enough information to assess a criterion, a scoring of 1 or 0 followed by an asterisk was used (1* or 0*) when the information was partial, and a scoring of 1 prime (1') was used when the information was not available (Precautionary Principle). These two types of gaps are used to calculate the level of uncertainty in the analysis.

Once the vulnerability assessment tables were completed, taxa with at least one point in each category of criteria were placed in vulnerability matrices based on the sum of the scores obtained for each of the two categories. The position of taxa in the matrix indicates their level of vulnerability: high (dark grey), medium (medium grey) and low (light grey).

RESULTS

The results presented in this section describe only the high level of vulnerability. The full results are available in the associated research document (Desjardins et al. 2018).

Marine and estuarine algae and plants

This component contains 54 groups of taxa that include 152 species of benthic algae (Couillard et al. 1973; Cardinal 1990), 3 plant species and phytoplankton. Despite its high level of species diversity, phytoplankton was treated as a unique group of pelagic protists. The taxa were classified into 5 levels, based on a review of the literature:

1) Vertical zonation,
2) Distribution,
3) Type of growth,
4) Taxonomic division,
5) Shape of the thallus.

The vulnerability assessment (Figure 3) identified six major groups of algae, phytoplankton and two groups of plants. The major group of midlittoral/infralittoral algae with limited distribution as well as common eelgrass (infralittoral plant) are highly vulnerable, which is equivalent to 28% of the groups of taxa analyzed (15 out of 54).

In general, littoral use as well as low mobility (*Exposure*) increase the vulnerability of all taxa in this component. However, taxa occupying the midlittoral zone have a higher exposure potential due to their recurring interaction with the surface (*Exposure*). In terms of *Resilience*, the population status criterion applies to all algae because the Precautionary Principle applies, which is not the case for plants that instead meet the sediment interaction criterion. Highly vulnerable taxa stand out from the group because of their low recolonization potential, as is the case for eelgrass and algae with limited distribution.

RESILIENCE			EXPOSITION POTENTIAL: High (3-4 criteria)	EXPOSITION POTENTIAL: Medium (2 criteria)	EXPOSITION POTENTIAL: Low (1 criterion)
Low	3-4 criteria				
Medium	2 criteria		Algae, limited distribution, non-aggregated (M/I) Plant (I, Eelgrass)	Algae, limited distribution, non-aggregated (I)	
High	1 criterion		Algae, wide distribution, aggregated (M/I) Algae, wide distribution, non-aggregated (M/I) Algae, wide distribution, aggregated (I) Phytoplankton (EP) Plant (M/I, Common Three-Square Bulrush , Smooth Cordgrass)	Algae, wide distribution, non-aggregated (I)	

Figure 3. Vulnerability matrix for marine and estuarine algae and plants.

Marine and estuarine invertebrates

This component includes 372 taxa divided into 181 groups of taxa. The taxa were selected and classified based on a list containing 1174 taxa present in the area according to Brunel et al. (1998) and information taken from the Atlantic Zone Monitoring Program (AZMP). Each group of taxa was named after one of the species that was representative of the group or based on classification levels. These groups were classified into three levels:

1) Taxonomic;
2) Vertical zonation;
3) Specific response to the criteria.

To make it easier to read the results, the groups of taxa are presented in 6 branch groups.

The vulnerability assessment (Figures 4 to 9) shows that 56% of groups of invertebrate taxa are highly vulnerable (101 out of 181). These groups include 31% of Porifera, Cnidaria and Ctenophora (8 out of 26), 83% of Vermiforms (24 out of 29), 60% of Shellfish (25 out of 42), 60% of Arthropods (32 out of 53), 33% of Echinoderms (6 out of 18) and 46% of Other Branches (6 out of 13). The percentage of groups of highly vulnerable taxa is higher in Vermiforms, Shellfish and Arthropods. However, Vermiforms are the group with the highest level of uncertainty with respect to their scoring.

Virtually all highly vulnerable invertebrates have low mobility (99%, *Exposure*) and most of them meet the population status criterion (97%, *Resilience*) based on the Precautionary Principle. Most of them also met the littoral use (83%, *Exposure*), aggregation potential (82%, *Exposure*) and sediment interaction (79%, *Resilience*) criteria.

RESILIENCE	EXPOSITION POTENTIAL: High (3-4 criteria)	EXPOSITION POTENTIAL: Medium (2 criteria)	EXPOSITION POTENTIAL: Low (1 criterion)
Low (3-4 criteria)	Fixed Jellyfish (M)	Sea Anemone, sed. (CB)	
Medium (2 criteria)	Silver Spotted Anemone (M) Northern Cerianthid (I) Sponge (I) Hydroid (CB) Lepto- and anthomedusa (UEP) Lion's Mane (UEP)	Swimming Anemone (I) Rugose Anemone (CB) Leptomedusa (GEP) Sea Pen (CB)	Many-tentacled sea anemone (CB)
High (1 criterion)	Anémone: Northern Red Anemone (M) Neritic Comb Jellies (UEP) Oceanic Comb Jellies (UEP) Sponge (M) Calcareous Sponge (I) Hydroid (M and I) Helmet Jelly (UEP) Siphonophore (UEP) Trachymedusa (UEP)	Clonal Plumose Anemone (I) Soft Coral (I) Narcomedusa (GEP)	

Figure 4. Vulnerability matrix for Marine and estuarine invertebrates: Porifera, Cnidaria and Ctenophora.

RESILIENCE	EXPOSITION POTENTIAL: High (3-4 criteria)	EXPOSITION POTENTIAL: Medium (2 criteria)	EXPOSITION POTENTIAL: Low (1 criterion)
Low (3-4 criteria)	*Alitta* , *Eteone and Glycera* (M/I) *Arenicola marina* (M) *Harmothoe imbricata* (M) Nematode (M) Ribbon Worm (M) *Nicomache lumbricalis* (M) *Melinna cristata* (I) Polychaete, rep and sed. (I) Polycladida (M), Priapulid (I)	Acoelous (I) Acorn worm (CB) Nematode (I) Oligochaete (I) Polychaete, rep. and sed. (CB) Sipunculid, rec. (I)	Oligochaete (CB)
Medium (2 criteria)	*Maldane sarsi* (I) *Nephtys caeca* (M) Oligochaete (M) *Pectinaria gouldii* (M) Phoronid (I) Polychaete, sed. (I) Sipunculid (I) *Spirorbis spirorbis* (M)	Echiurid (I) Polychaete (UEP) Polychaete, sed. (CB)	
High (1 criterion)	Polychaete, hard substrate (I)		

Figure 5. Vulnerability matrix for Marine and estuarine invertebrates: Vermiforms.

RESILIENCE		EXPOSITION POTENTIAL: High (3-4 criteria)	Medium (2 criteria)	Low (1 criterion)
Low (3-4 criteria)		*Astarte* (I) Bubble (I) Chaetoderma (I) Minute Hydrobe (M) Rough Periwinkle (M) Arctic Surfclam (I) Black Mussel (I) American Pelicanfoot (I) Atlantic Dogwinkle (M)	Heterodont Bivalve (CB) Ocean Quahog (I) Neogastropod (CB)	Cephalopod (CB)
Medium (2 criteria)		Whelk (M), Bubble (I) Greenland Smoothcockle (I) Pale Lacuna (I) Common Periwinkle (M) Softshell Clam (M) Moonsnail (M) Nuculana and Yoldia (I) Oenopota (I), Limpet (I) Scaphopod (I), Margarites (I) Turretsnail (I)	Pteriomorph Bivalve (CB) Cephalaspid (CB) Littorinomorpha (CB) Scaphopod (CB) Broad Yoldia (CB)	
High (1 criterion)		Sea Angel (UEP) Chiton (M and I) Common Northern Lacuna (M) Blue Mussel (M) Nudibranch (M and I) Limpet (M) Keyhole Limpet (I) Scallop (I)	*Xylophaga atlantica* (I)	

Figure 6. Vulnerability matrix for Marine and estuarine invertebrates: Shellfish.

RESILIENCE		EXPOSITION POTENTIAL: High (3-4 criteria)	Medium (2 criteria)	Low (1 criterion)
Low (3-4 criteria)		Mite (M) Benthic Amphipod (M and I), rec. (M) Cumacean (M and I) Isopod (I) *Limnoria lignorum* (I) Mysid (M and I) Ostracod (I) Sea Spider (I) Tanaid (I)	Mite (I) Benthic/Suprabenthic Amphipod (CB) Templeman's lobster shrimp (CB) Sculptured Shrimp (I) Cumacean (CB) Isopod (CB) Squat Lobster (CB) Mysid (CB) Nebaliacean (I)	
Medium (2 criteria)		Suprabenthic Amphipod (M and I) Hippolytid Shrimp (M and I) Cyclopoid (I) Euphausiid (UEP) Harpacticoid (M) Hemiptera (M) Isopod (M)	Hippolytid Shrimp (CB) Ostracod (GEP)	
High (1 criterion)		Barnacle (M and I) Hermit Crab (I) Water Flea (UEP) Neritic/Oceanic Copepod (UEP) Atlantic Rock Crab (M) Snow Crab (I) Crangon Shrimp (I) American Lobster (I) Hyperiid (UEP)	Barnacle (CB) Oceanic Copepod (UEP) Northern Stone Crab (CB) Crangon Shrimp (CB) Striped Pink and Northern Shrimp (CB) Hyperiid (UMP) Glass Shrimp (UMP)	

Figure 7. Vulnerability matrix for Marine and estuarine invertebrates: Arthropods.

RESILIENCE	EXPOSITION POTENTIAL: High (3-4 criteria)	EXPOSITION POTENTIAL: Medium (2 criteria)	EXPOSITION POTENTIAL: Low (1 criterion)
Low (3-4 criteria)	Polar Sea Star (M) Brittle Star: *Stegophiura nodosa* (I)	Sar's Brittle Star (CB)	
Medium (2 criteria)	Common Starfish (M) Gorgon's head (I) Brittle Star: *Ophiura robusta* (I)	Sea Star (I)	
High (1 criterion)	*Chitidota laevis* (M) Sand Dollar (I) Daisy Brittle Star (I) *Pentamera calcigera* (M)	*Molpadia* (CB) Heart Urchin (CB) Sun Star (I)	Cushion Star (CB)

Figure 8. Vulnerability matrix for Marine and estuarine invertebrates: Echinoderms.

RESILIENCE	EXPOSITION POTENTIAL: High (3-4 criteria)	EXPOSITION POTENTIAL: Medium (2 criteria)	EXPOSITION POTENTIAL: Low (1 criterion)
Low (3-4 criteria)			
Medium (2 criteria)	Lamp Shell (I) Bryozoan (M and I) Entoproct (M and I) Colonial Tunicate (I)	Bryozoan (CB)	
High (1 criterion)	Appendicularian (UEP) Neritic/Oceanic Arrow Worm (UEP) Tunicate (M) Tunicate: Sea Potato (I)	Arrow Worm (UMP)	

Figure 9. Vulnerability matrix for Marine and estuarine invertebrates: Other Branches.

Marine, estuarine and diadromous fish

This component includes 75 taxa representing 82 species. This list of species is taken from Dutil et al. (2015). The taxa were classified based on one criterion: way of life (diadromous, pelagic and demersal).

The vulnerability assessment (Figure 10) shows that 23% of fish taxa are highly vulnerable (17 out of 75): 44% of diadromous species (7 out of 16), 17% of demersal species (8 out of 46) and 15% of pelagic species (2 out of 13). This vulnerability is owing primarily to littoral use (94%, *Exposure*), sediment interaction (88%, *Resilience*), low reproductive capacity (82%, *Resilience*), surface interaction (82%, *Exposure*) and low mobility (76%, *Exposure*). Response to the other criteria is more variable.

			EXPOSITION POTENTIAL		
			High	Medium	Low
			3-4 criteria	2 criteria	1 criterion
RESILIENCE	Low	3-4 criteria	Ocean Pout Fish Doctor	Atlantic Sturgeon Lumpfish Atlantic Softpout	Twohorn Sculpin Snailfish Eelpout Atlantic Hagfish Sea Tadpole
	Medium	2 criteria	American Shad Grubby Stickleback (4 sp.) Sea Raven Atlantic Seasnail Atlantic Salmon Rock Gunnel Wrymouth Radiated Shanny	American Eel Shorthorn Sculpin Daubed Shanny Witch Flounder Atlantic Tomcod	Moustache Sculpin Marlin-spike Atlantic Hookear Sculpin Spatulate Sculpin Variegated Snailfish Snakeblenny Porbeagle American Plaice Basking Shark, Redfish
	High	1 criterion	Striped Bass, Capelin Rainbow Smelt Atlantic Herring Sea Lamprey American Sand Lance Atlantic Mackerel Brook Trout Smooth Flounder, Winter Flounder	Silver Hake Greenland Cod Atlantic Spiny Lumpsucker Arctic Shanny	Atlantic Poacher Black Dogfish Northern Sand Lance Yellowtail Flounder White Hake Atlantic Cod Fourbeard Rockling Fourline Snakeblenny Arctic Staghorn Sculpin

Figure 10. Vulnerability matrix for Marine, estuarine and diadromous fish.

Marine mammals

This component includes 13 species (Lesage et al. 2007; Richard Sears, Mingan Islands Cetacean Study, personal communication) that were individually assessed.

The vulnerability assessment (Figure 11) shows that 23% of marine mammal species are highly vulnerable (3 out of 13). The Beluga Whale, Harbour Seal and Grey Seal meet the same three criteria for exposure potential: littoral use, surface interaction and aggregation potential. As for resilience, they all have low reproductive capacity (like all marine mammals) and interact with sediment. The Beluga Whale is more vulnerable to potential oil spills than the Harbour Seal or Grey Seal because of its population status and low recolonization potential.

RESILIENCE	EXPOSITION POTENTIAL: High (3-4 criteria)	EXPOSITION POTENTIAL: Medium (2 criteria)	EXPOSITION POTENTIAL: Low (1 criterion)
Low (3-4 criteria)	Beluga whale		North Atlantic Right Whale
Medium (2 criteria)	Harbour Seal Grey Seal		Sperm Whale Harbor Porpoise Blue Whale Fin Whale
High (1 criterion)		Atlantic White-Sided Dolphin Minke Whale	Hooded Seal Harp Seal Humpback Whale

Figure 11. Marine mammal vulnerability matrix.

Sources of uncertainty

The total uncertainty of the vulnerability analysis is 24%. Uncertainty is particularly high, over 20%, for the assessment of invertebrate exposure, invertebrate resilience and algae and plant resilience (Table 3).

The total uncertainty relating to the plant and algae criteria scoring is 20%. The highest percentage of uncertainty is associated with the population status criterion (96%, *Resilience*).

The total uncertainty for invertebrates is 34%, ranging from 30 to 41% depending on branch groups. Criteria where uncertainty is highest are aggregation potential (77%, *Exposure*), population status (86%, *Resilience*) and low reproductive capacity (51%, *Resilience*).

The total uncertainty for fish is 9%. The highest percentages of uncertainty are related to the low mobility (24%, *Exposure*) and aggregation potential (23%, *Exposure*) criteria.

There is no uncertainty (0%) involved in assessing the vulnerability of marine mammals.

Table 3. Total uncertainty in scoring by category of criteria and component of the St. Lawrence ARP.

	Uncertainty (%)		
Component	Exposure Potential Criteria	Resilience Criteria	All Criteria
Algae/Plants	0.5	39.8	20.1
Invertebrates	21.8	46.4	34.1
Fish	11.7	7.0	9.3
Marine mammals	0.0	0.0	0.0
All components	15.0	34.5	24.7

Adaptation of the National Framework

The National Framework has been amended to tailor the method to the specific characteristics of the St. Lawrence study area and the issues raised during its implementation. The main changes are:

- changes in the proposed groups and subgroups to adapt them to the taxa in the St. Lawrence Area Response Planning (ARP) area;
- improvement in the accuracy of the analysis by increasing the number of individual species and taxa groups assessed and by creating a new criterion: *Littoral use*;
- elimination of the *Sediment interaction* criterion in the *Exposure* category of criteria because it was also used in the *Resilience* category of criteria;
- elimination of all criteria associated with sensitivity to oil (the number of criteria assessed decreases from 11 to 8);
- changes to the definitions of some criteria and addition of guidelines to make the scoring more uniform across all taxa and components;
- presentation of the results in a matrix to simplify oil spill response and planning.

CONCLUSION AND ADVICE

The vulnerability assessment results indicate that 136 groups of taxa (42%) are highly vulnerable: 28% of marine and estuarine algae and plants, 56% of marine and estuarine invertebrates, 23% of marine, estuarine and diadromous fish and 23% of marine mammals.

The total uncertainty related to the assessment is 25%: 20% for algae and plants, 34% for invertebrates, 9% for fish and nil for marine mammals. These uncertainties affected scoring accuracy. They are attributable mainly to the population status criterion.

The National Framework was adapted regionally to take into account the specific biological characteristics of the St. Lawrence ARP study area.

The criteria are sufficiently robust and well defined to meet the objectives of the Framework. They are independent and discriminant, and all of the categories of criteria are equally weighted. They can also be applied uniformly across components.

Changes to the National Framework are adequate and have also improved the accuracy of the analysis. Presenting the results in a matrix simplifies oil spill response and planning.

Vulnerability assessment is a useful reference tool for oil spill response and planning specialists. This tool can be used to create many other even more synthetic tools tailored to various response levels.

Relative toxicological sensitivity to oil across species and various life stages of the same species were not assessed due to knowledge gaps. Including this information would provide a more comprehensive analysis.

Recommendations

- Existing DFO databases on taxa identified as vulnerable will be made available to Environment and Climate Change Canada's National Environmental Emergencies Centre (NEEC).
- The assessment results can be used to improve the protection of vulnerable biological components in the context of ship-source oil spill response and planning in the Quebec Region.
- If the vulnerability of the St. Lawrence ARP study area is reassessed, the analysis should increase its focus on the sensitivity of taxa to oil. The acquisition of new knowledge should be considered.

SOURCES OF INFORMATION

This Science Advisory Report is from the January 24 and 25, 2017, meeting on the vulnerability assessment of biological components of the St. Lawrence to ship-source oil spills. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada Science Advisory Schedule as they become available.

Brunel, P., Bossé, L. and Lamarche, G. 1998. Catalogue of the Marine Invertebrates of the Estuary and Gulf of St. Lawrence. Canadian Special Publications in Fisheries and Aquatic Sciences 126. 405 p.

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G5H 3Z4

Telephone: 418-775-0825
Email: bras@dfo-mpo.gc.ca
Internet Address:

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