Spill Impact Mitigation Assessment (SIMA)
for ExxonMobil Canada Ltd.'s Eastern Newfoundland
Offshore Drilling Project, 2018–2030

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Spill Impact Mitigation Assessment (SIMA) for ExxonMobil Canada Ltd.'s Eastern Newfoundland Offshore Drilling Project, 2018–2030

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Prepared for

ExxonMobil Canada Ltd.

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List of Acronyms and Abbreviations

ADDS	Airborne Dispersant Delivery System
API	The American Petroleum Institute
BdN	Bay du Nord
BP	British Petroleum
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
CERA	Consensus Ecological Risk Assessment
CEWAF	Chemically Enhanced Water Accommodated Fraction
C-NLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DFO	Department of Fisheries and Oceans
DOR	Dispersant to Oil Ratio
DWH	Deep Water Horizon
EBSA	Ecologically and Biologically Significant Area
ECCC-CWS	Environment and Climate Change Canada-Canadian Wildlife Service
ECRC	Eastern Canada Response Corporation
EEM	Environmental Effects Monitoring
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
EL	Exploration License
EPA	Environmental Protection Area
EPLMA	Eastport Peninsula Lobster Management Area
EPS	Extracellular Polymeric Substances
ESA	*Endangered Species Act*
EU	Environmental Unit
FLR	Fisheries and Land Resources
FSC	Food, Social and Ceremonial
GAI	Geographical Area of Interest
GDS	Global Dispersant Stockpile
IBA	Important Bird Areas
ICS	Incident Command System
IMF	Impact Modification Factor
IOGP	International Association of Oil & Gas Production
IPIECA	International Petroleum Industry Environmental Conservation Association
ISB	*In Situ* Burning
ITOPF	International Tanker Owners Pollution Federation Limited
IUCN	International Union for the Conservation of Nature
MFN	Miawpukek First Nation
MOSSFA	Marine Oil Snow Sedimentation and Flocculent Accumulation
MPA	Marine Protected Area
NAFO	Northwest Atlantic Fisheries Organization

NEBA	Net Environmental Benefit Analysis
NL	Newfoundland and Labrador
NMCA	National Marine Conservation Area
NOAA	National Oceanic and Atmospheric Administration
NRC	Natural Research Council
NRI	Numerical Relative Impact
OSAT	Operational Science Advisory Team
OSRL	Oil Spill Response Limited
PAH	Polycyclic Aromatic Hydrocarbons
ppb	Parts per billion
ppm	Parts per million
PRI	Potential Relative Impact
ROC	Resources of Concern
QMFNB	Qualipu Mi'kmaq First Nation Band
ROV	Remotely Operated Vehicle
RRT	Regional Response Teams
RSA	Regional Study Area
SARA	*Species at Risk Act*
SDA	Surface Dispersant Application
SEA	Strategic Environmental Assessment
SFA	Shrimp Fishing Area
SIMA	Spill Impact Mitigation Assessment
SML	Surface Microlayer
SSDI	Subsea Dispersant Injection
THC	Total Hydrocarbon Concentrations
TPH	Total Petroleum Hydrocarbon
UA	Unit Area
US	United States (of America)
USCG	United States Coast Guard
VC	Valued Component
VME	Vulnerable Marine Ecosystem
VOC	Volatile Organic Compound
WAF	Water Accommodated Fraction
WCCD	Worst Credible Case Discharge

1.0 Introduction

1.1 Background

This Spill Impact Mitigation Assessment (SIMA) prepared for ExxonMobil Canada Ltd. (ExxonMobil) serves as part of the contingency planning process for exploration drilling in the northern Flemish Pass area in the Newfoundland and Labrador offshore. The objective of this SIMA is to logistically evaluate feasible response options to minimize impacts from an oil spill in the northern Flemish Pass area. The Flemish Pass area is characterized by some unique meteorological and oceanographic conditions that may complicate oil spill response at certain times of the year but, at the same time, enable a high degree of natural dispersion. Response options that are considered to be both feasible and potentially effective in the Flemish Pass area are evaluated in this report.

A worst-case scenario involving a Tier 3 spill due to an uncontrolled blowout at a potential deep-water drilling site in the northern Flemish Pass is assessed in this SIMA. A Tier 3 spill is a category of oil spill defined by the International Petroleum Industry Environmental Conservation Association (IPIECA) that is based more on the capabilities of the response than on the volume or size of the spill. The worst-case spill scenario allows for the evaluation of all possible response options that are available for implementation by ExxonMobil using their contractual agreements with Eastern Canada Response Corporation (ECRC) and Oil Spill Response Limited (OSRL). The worst-case Tier 3 spill modelling scenario is compared to three other Tier 3 spill scenarios in terms of justifying the selection of the worst-case scenario, and the comparative risks associated with the other Tier 3 spill scenarios. A Tier 1 spill scenario (i.e., surface batch spill of crude or marine diesel) is also briefly considered in this SIMA.

This document is largely based on information provided in the following reports:

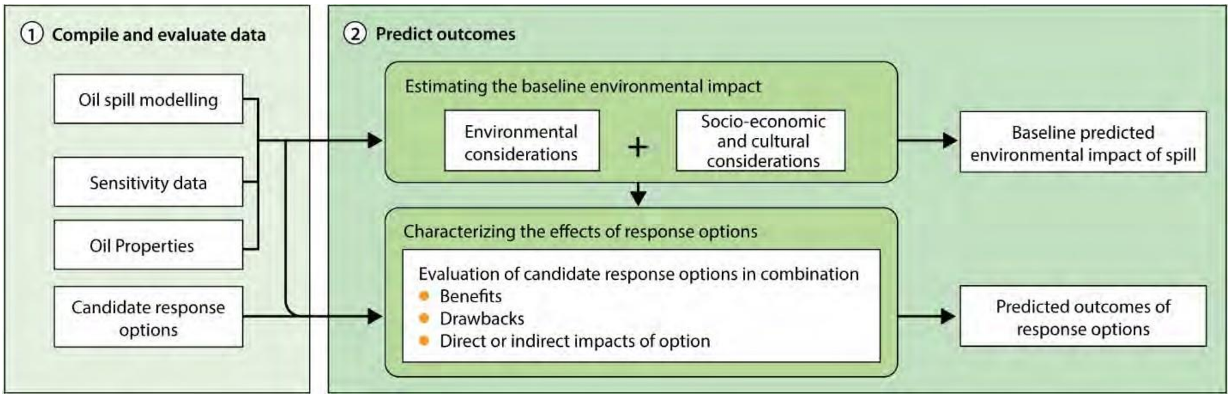
- Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB). 2014. Eastern Newfoundland Strategic Environmental Assessment (SEA) Report. Report by Amec Environment & Infrastructure, St. John’s, NL for C-NLOPB., St. John’s, NL. 527 p. + appendices.
- ExxonMobil Canada Ltd. (ExxonMobil). 2017. Eastern Newfoundland Offshore Exploration Drilling Project (CEAR 80132) – Environmental Impact Statement. Prepared by Amec Foster Wheeler and Stantec Consulting, St. John’s, NL, Canada. November 2017.
- C-NLOPB. 2010. Southern Newfoundland Strategic Environmental Assessment. Report by LGL Limited, St. John’s, NL, Oceans Limited, St. John’s, NL, Canning & Pitt Associates, Inc., St. John's, NL, and PAL Environmental Services, St. John’s, NL, for Canada-Newfoundland and Labrador Offshore Petroleum Board, St. John’s, NL. 333 p. + appendix.

- C-NLOPB. 2008. Strategic Environmental Assessment Labrador Shelf Offshore Area. Report by Sikumiut Environmental Management Ltd., St. John's, NL, for Canada-Newfoundland and Labrador Offshore Petroleum Board, St. John's, NL. 519 p. + appendices.
- RPS. 2017. Trajectory Modelling in Support of the ExxonMobil Exploration Drilling Project. Appendix E of Eastern Newfoundland Offshore Exploration Drilling Project EIS. 135 p.
- RPS. 2018. Trajectory and Fate Modelling in Support of the ExxonMobil Eastern Newfoundland Offshore Exploration Drilling Project. Appendix E of Eastern Newfoundland Offshore Exploration Drilling Project EIS. 75 p.
- ExxonMobil. 2017. Spill Prevention and Response. Appendix H of Eastern Newfoundland Offshore Exploration Drilling Project EIS. 40 p.
- IPIECA (The Global Oil and Gas Industry Association for Environmental and Social Issues) and IOGP (International Association of Oil & Gas Producers). 2015a. Response Strategy Development Using Net Environmental Benefit Analysis (NEBA) – Good practice guidelines for incidental management and emergency response personnel. 32 p. + appendices.
- IPIECA and IOGP. 2015b. Dispersants: subsea application. Good practice guidelines for incident management and emergency response personnel. London, UK. Retrieved from http://www.ipieca.org/resources/good-practice/dispersants-subsea-application-good- practice-guidelines-for-incident-management-and-emergency-response-personnel/
- IPIECA and IOGP. 2016. Controlled in-situ burning of spilled oil. Good practice guidelines for incident management and emergency response personnel. London, UK. Retrieved from http://www.oilspillresponseproject.org/wp-content/uploads/2017/01/Controlled_in- situ_burning_of_spilled_oil_2016.pdf
- IPIECA, API (The American Petroleum Institute) and IOGP. 2017. Guidelines on Implementing Spill Impact Mitigation Assessment (SIMA) – A technical support document to accompany the IPIECA-IOGP guidance on net environmental benefit analysis (NEBA). 30 p. + appendices.

IPIECA and IOGP (2015a) defines the following four stages of the SIMA process.

1) Compile and evaluate data to identify an exposure scenario and potential response options, and to understand the potential impacts of that spill scenario;
2) Predict the outcomes for a given scenario to determine which response techniques are effective and feasible;
3) Balance trade-offs by weighing a range of ecological benefits and drawbacks resulting from each feasible response option. This will also include an evaluation of socio-economic benefits and costs resulting from each feasible response action; and
4) Select the best response options for a given scenario, based on which combination of tools and techniques will minimize impacts.

A high-level representation of the first two stages of the SIMA process listed above is presented below (Figure 1). Stages 1 and 2 of the SIMA process are presented in Sections 2.0–4.0 of this report. The third stage, which involves the conduct of an impact analysis for each response option, is presented in Section 6.0. Recommendations for the most appropriate response options for the ExxonMobil Flemish Pass area are summarized in Section 7.0.



Source: IPIECA (2015).

Figure 1. Types of data used to assist with characterization of response options.

1.2 Overview of SIMA

Net Environmental Benefit Analysis (NEBA) refers to a structured approach used by the response community and stakeholders during oil spill preparedness, planning and response to compare the impact mitigation potential of various response options and develop a response strategy that will minimize the net impact of an oil spill on the environmental and socio-economic resources at risk.

In the past, the selection of the most appropriate response action(s) has been guided by more than just environmental considerations. To better reflect the process and its objectives, the oil and gas industry decided to transition to a different moniker (i.e., SIMA) in 2016. For the purposes of this document, all references to SIMA should be understood to mean NEBA in its broader context.

As already indicated, the objective of SIMA is to provide an evaluation process to aid spill responders and stakeholders choose the response options that would result in the least negative effect on the environment while maintaining the safety of responders. For the majority of spill scenarios, no single response option is likely to be completely effective. Typically, the best approach to minimize environmental impacts is to employ multiple response options. While a risk-based approach is implicit in all response planning, the level of detail required to determine and document the approach depends on the type of incident and the circumstances surrounding it. The SIMA process recognizes that once oil has been spilled, some environmental impact will occur, no matter what spill response options are selected.

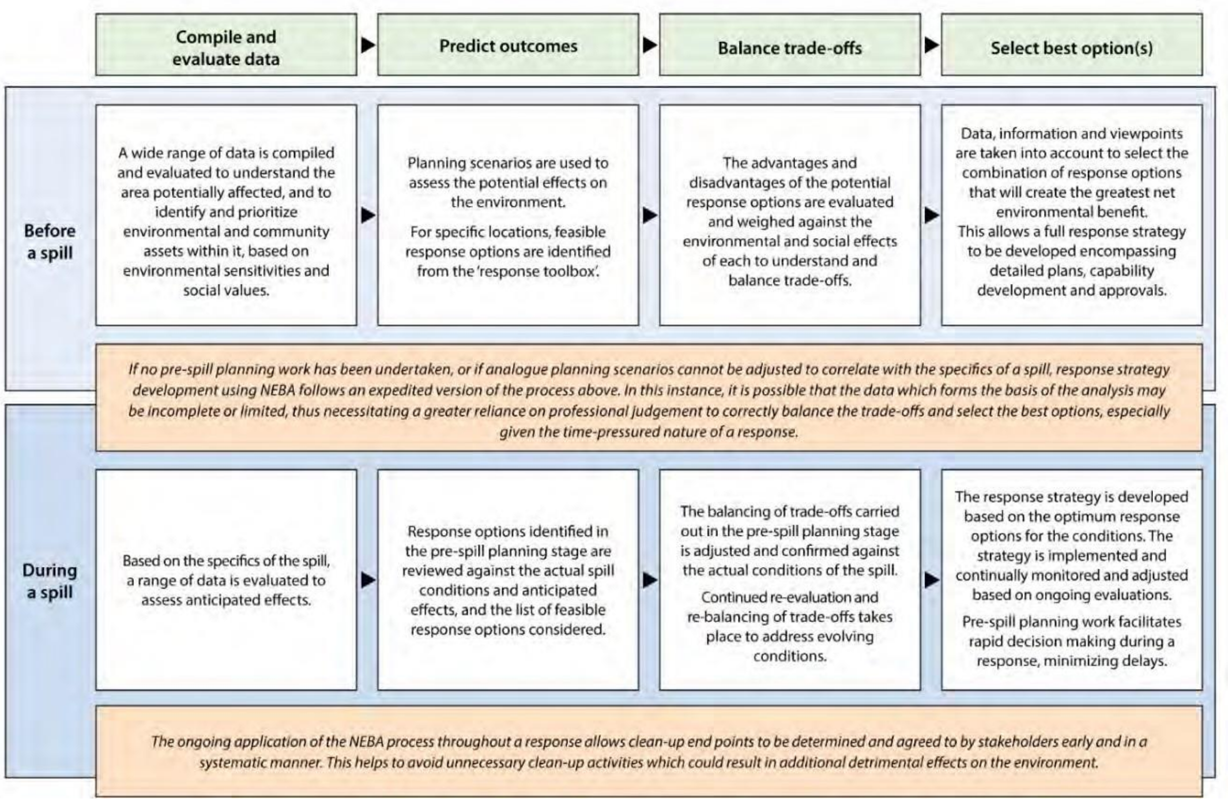
1.3 Using SIMA to Support Contingency Planning and Spill Response

Aspects of emergency management that are supported by the SIMA process include the following:

- **Contingency planning:** SIMA is a fundamental part of the contingency planning process used to ensure that response strategies for planning scenarios are well informed. It can be used to identify relevant scenarios and the best response options for those scenarios. The use of SIMA in contingency planning allows for stakeholder involvement in the planning process.
- **Exercises or drills:** A SIMA that is developed during the contingency planning phase can be fine-tuned to a specific spill scenario or season.
- **Training:** The SIMA can inform the incident management team on the feasibility and effectiveness of various response options in specific locales, and on resource trade-offs that are characteristic when selecting one response option over another.
- **Spill Response:** The SIMA process is used during a response to ensure understanding of evolving conditions such that the response strategy can be adjusted as necessary (i.e., adaptive management).

The SIMA process can be applied both before and during a spill. Its application during a response will differ to some extent from the planning phase, depending on the similarity of an actual spill event to the conditions of the scenario analyzed for the SIMA. An overview of how SIMA is applied in both instances is provided in Figure 2.

A contingency planning SIMA could be invaluable during actual spill responses. Its principles may be utilized to frame and adapt the response as it is being executed, evaluated and modified to fit the situation. During a spill, the SIMA process can function in two ways: (1) when the spill event closely reflects planning, the contingency planning SIMA may be enacted and adjusted to meet scenario specifics that were not included in the planning process; and (2) when the spill event is somewhat different than that associated with the contingency planning SIMA, a SIMA more relevant to the actual spill event can be conducted using an approach that relies heavily on expert judgement of the stakeholders and response subject matter experts.



	Compile and evaluate data	Predict outcomes	Balance trade-offs	Select best option(s)
Before a spill	A wide range of data is compiled and evaluated to understand the area potentially affected, and to identify and prioritize environmental and community assets within it, based on environmental sensitivities and social values.	Planning scenarios are used to assess the potential effects on the environment. For specific locations, feasible response options are identified from the 'response toolbox'.	The advantages and disadvantages of the potential response options are evaluated and weighed against the environmental and social effects of each to understand and balance trade-offs.	Data, information and viewpoints are taken into account to select the combination of response options that will create the greatest net environmental benefit. This allows a full response strategy to be developed encompassing detailed plans, capability development and approvals.
During a spill	Based on the specifics of the spill, a range of data is evaluated to assess anticipated effects.	Response options identified in the pre-spill planning stage are reviewed against the actual spill conditions and anticipated effects, and the list of feasible response options considered.	The balancing of trade-offs carried out in the pre-spill planning stage is adjusted and confirmed against the actual conditions of the spill. Continued re-evaluation and re-balancing of trade-offs takes place to address evolving conditions.	The response strategy is developed based on the optimum response options for the conditions. The strategy is implemented and continually monitored and adjusted based on ongoing evaluations. Pre-spill planning work facilitates rapid decision making during a response, minimizing delays.

If no pre-spill planning work has been undertaken, or if analogue planning scenarios cannot be adjusted to correlate with the specifics of a spill, response strategy development using NEBA follows an expedited version of the process above. In this instance, it is possible that the data which forms the basis of the analysis may be incomplete or limited, thus necessitating a greater reliance on professional judgement to correctly balance the trade-offs and select the best options, especially given the time-pressured nature of a response.

The ongoing application of the NEBA process throughout a response allows clean-up end points to be determined and agreed to by stakeholders early and in a systematic manner. This helps to avoid unnecessary clean-up activities which could result in additional detrimental effects on the environment.

Source: IPIECA (2015).

Figure 2. Application of SIMA before a spill (contingency planning) and during a spill.

In Canada, response actions for a spill are typically managed through use of the Incident Command System (ICS). The ICS, which is used by both regulatory agencies and industry, provides a common functional organizational structure, and standardized nomenclature and terminology. The use of SIMA would occur primarily within the Environmental Unit (EU) which includes industry and agency personnel and advises the incident commander on environmental issues. The EU assesses real-time spill conditions (e.g., oil type, quantity, trajectory, etc.), reconfirms information about ecological and socio-economic resources in the vicinity, and then adapts conclusions from planning SIMAs to the actual spill conditions. The SIMA process is cyclical in that the plan can be adapted to meet changing spill conditions.

SIMA developers must carefully assess any assumptions that have been made while framing the spill scenario. It is important to ensure that strategy selection is made with flexibility and adaptability in mind. This approach will assist responders in shaping the response strategy as event-driven data are gathered and evaluated. An overview of past SIMA usage in Canada and the United States as presented in Slaughter et al. (2017) is provided in Appendix A.

1.4 Overview of Dispersants and Dispersed Oil

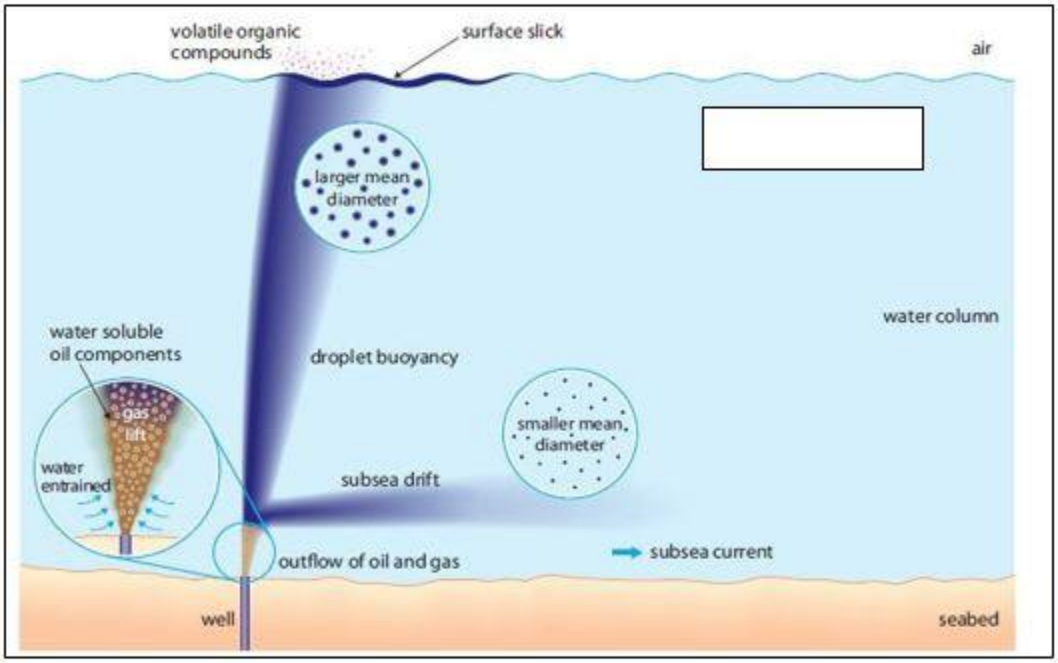
The ExxonMobil Eastern Newfoundland Offshore Exploration Drilling Project Environmental Impact Statement (EIS) (ExxonMobil 2017) provides a detailed discussion of the potential effects of an unmitigated oil spill in its Project Area (Section 15.0 in ExxonMobil 2017). Introductory information on dispersants and dispersed oil are provided here as background for the reader with additional information provided in the following sections of the SIMA report.

The use of dispersants, whether applied at the ocean's surface (SDA) or through subsea injection (SSDI) at the hydrocarbon release location, will change the fate of the oil. For surface dispersant operations, past studies (ocean field trials conducted in the North Sea in 1994 (AEA Technology 1994), in 1995 (AEA Technology 1995; Jones and Petch 1995), and in 1996 (Strøm-Kristiansen et al. 1997; Coelho et al. 1998) and spills (Deep Water Horizon [DWH] - Operational Science Advisory Team [OSAT] 2010) have indicated that surface dispersant application will result in dispersed oil concentrations in the upper few metres of the water column ranging from 10–50 parts per million (ppm) for the first hour after dispersant application. Over the following few hours, rapid horizontal and vertical mixing will quickly reduce those concentrations to below 10 ppm.

The only available information related to dispersed oil concentrations resulting from subsea dispersant injection operations is from the DWH incident. Due to potential conflicts with response operations and safety concerns, most of the subsea monitoring during the DWH response was conducted outside an exclusion zone extending 1 km from the wellhead. Beyond the 1 km exclusion zone, an existent subsea dispersed oil plume was typically narrow, trended away from the site in the direction of very slight subsea currents, and was bounded by water depths ranging from 900–1,200 m. Of the 2,779 individual samples collected in that area, only 33 samples had total petroleum hydrocarbon (TPH) concentrations higher than 10 parts per billion (ppb) (Coelho et al. 2011; Lee et al. 2015).

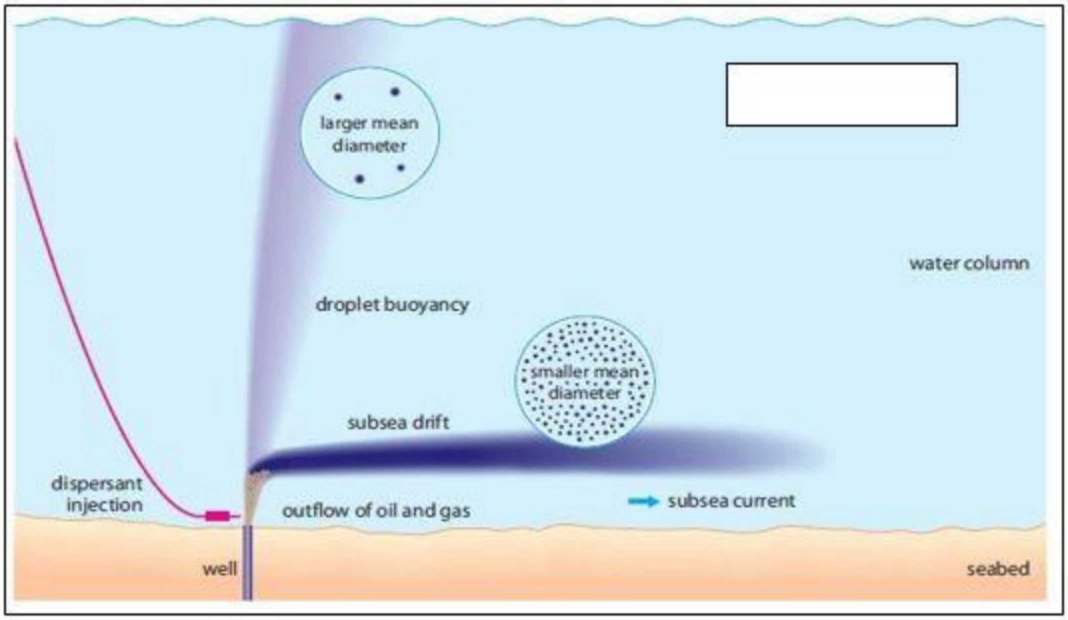
Cross-section illustrations of oil behavior from a hypothetical subsea release are provided for an unmitigated release (Figure 3) and a SSDI-treated release (Figure 4). Estimated oil concentrations in the vicinity of the spill are provided using measured concentrations reported from the 2010 DWH incident (Coelho et al. 2011; National Oceanic and Atmospheric Administration [NOAA] 2012).

Appendix B (from Slaughter et al. 2017) provides a more in-depth discussion on the role of dispersants in oil spill response, including the basic principles of chemical dispersion and factors that affect dispersant effectiveness.



Source: IPIECA (2015).

Figure 3. **Cross section of an unmitigated subsea release (vertical scale exaggerated for illustrative purposes).**



Source: IPIECA (2015).

Figure 4. **Cross section of an unmitigated subsea release treated with SSDI (vertical scale exaggerated for illustrative purposes).**

2.0 ExxonMobil Flemish Pass Area SIMA Overview

Overviews of the Geographical Area of Interest (GAI) (Subsection 2.1), its Physical Environment (Subsection 2.2) and Spill Scenarios (Subsection 2.3) provide information needed to evaluate the potential impacts of an oil spill within the ExxonMobil Flemish Pass Area. The SIMA GAI is equivalent to the Regional Study Area (RSA) defined in the ExxonMobil EIS (ExxonMobil 2017).

The description of the physical environment is based on information provided in three SEAs:

- the Eastern Newfoundland SEA (C-NLOPB 2014);
- the Southern Newfoundland SEA (C-NLOPB 2010); and
- the SEA Labrador Shelf Offshore Area (C-NLOPB 2008).

The spill modelling scenarios presented in this SIMA are based on results presented in the reports for two separate spill modelling exercises:

- Trajectory and Fate Modelling in Support of the ExxonMobil Eastern Newfoundland Offshore Exploration Drilling Project (RPS 2018), and
- Trajectory Modelling in Support of the ExxonMobil Exploration Drilling Project (RPS 2017).

The first modelling report listed above pertains to hydrocarbon releases within Exploration License EL1134, while the second report refers to modelling conducted on releases within EL 1135.

2.1 Geographical Area of Interest

As indicated above, the GAI used in this SIMA is equivalent to the RSA defined in ExxonMobil (2017; Figure 5). It extends approximately 1,000 km east-west and 1,500 km north-south and includes eastern Newfoundland shoreline from the western side of Placentia Bay to just west of Cape Freels on the northeast coast.

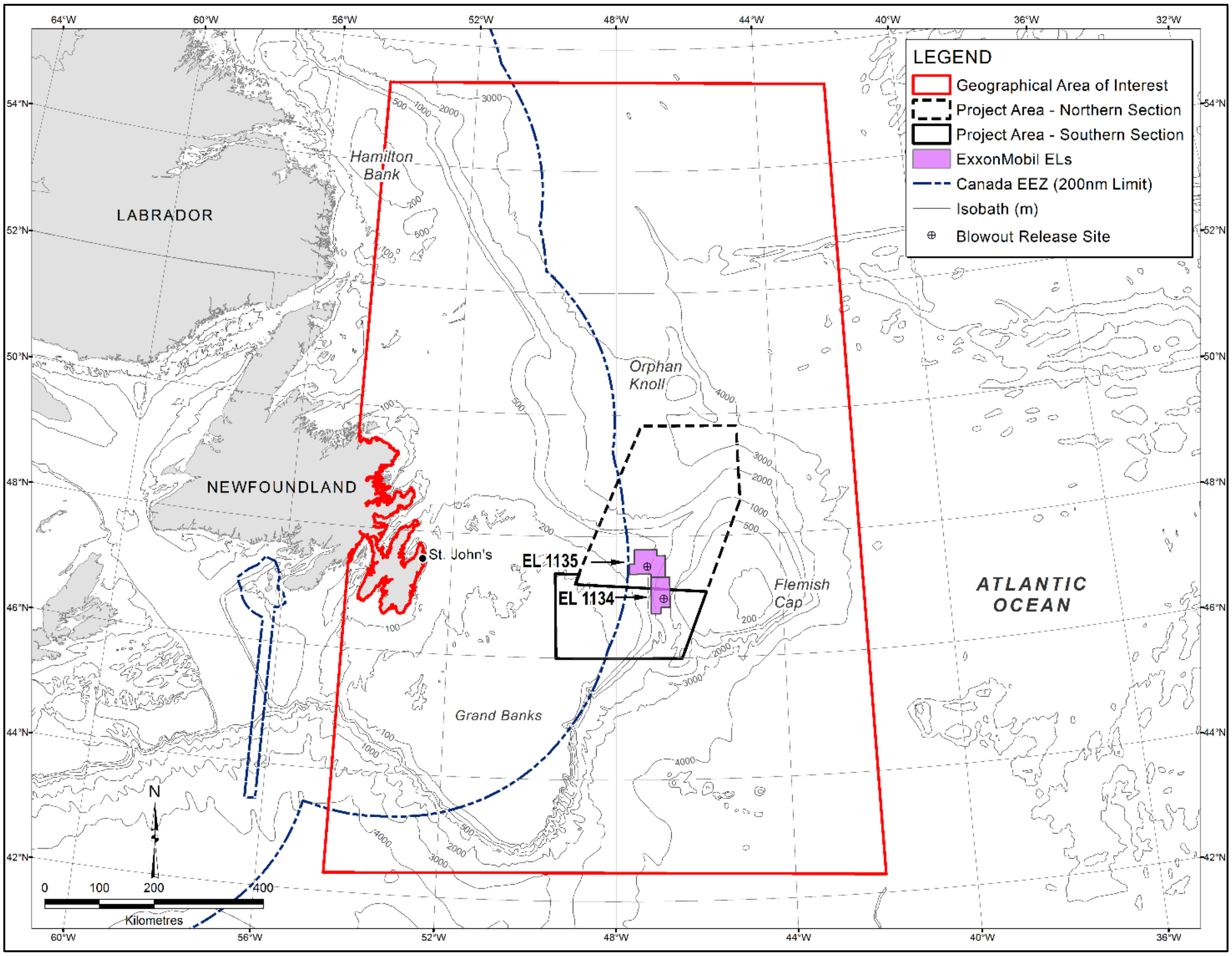


Figure 5. **SIMA Geographical Area of Interest (GAI), ExxonMobil Project Area, and Exploration Licenses of interest.**

2.2 Physical Environment

The description of the physical environment (e.g., oceanography, climatology and meteorology) for the GAI is described in detail in the ExxonMobil EIS (Section 5.0 in ExxonMobil 2017). With the exception of wind speed and wave height (Table 1) and ocean currents (Figure 6), other physical environment data from the EIS have not been reproduced in this SIMA report. Additional information on the physical environment in the GAI is available in the three relevant SEAs (C-NLOPB 2008, 2010, 2014).

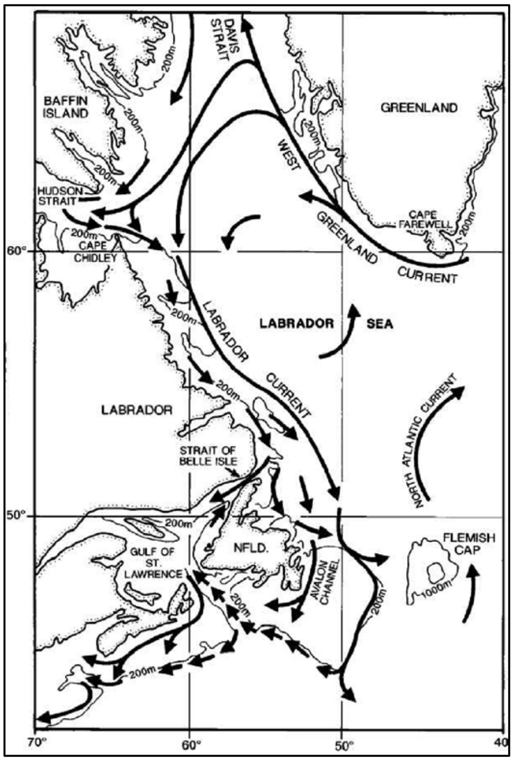
During the development of the EIS, 62 years (1954–2015) of hourly wind and wave data were obtained from five MSC50 grid points within the EIS Project Area. This information is summarized in Table 1. Additional extreme wind and wave data collected from two of the grid points during 1962–2015 were also presented in the EIS.

Table 1. Historical wind and wave data for the EIS Project Area (62-year average)[1].

Month	Mean Wind Speed (m/s)[2]	Most Frequent Wind Direction[3]	Mean Wave Height (m)	Most Frequent Wave Direction[5]
January	11.6	W	4.4	W
February	11.4	W	4.0	W-SW
March	10.2	W	3.4	SW-NW
April	8.6	W-SW	2.8	SW
May	7.4	SW	2.3	SW
June	6.9	SW	2.0	SW
July	6.3	SW	1.8	SW
August	6.7	SW	1.9	SW
September	7.9	W-SW	2.5	SW
October	9.3	W	3.1	SW-NW
November	10.0	W	3.5	NW
December	11.1	W	4.2	W-NW

[1] Based on 62 years of MSC50 hourly wind data from 1954–2015.
[2] Averages of data from all five grid points.
[3] Direction from which winds are blowing.
[4] Average of significant wave height data from all five grid points.
[5] Direction from which waves are propagating.

Source: ExxonMobil 2017.



Source: Colbourne et al. (1997).

Figure 6. Ocean currents in the eastern Newfoundland offshore area.

2.3 Oil Spill Scenarios

Two spill modelling reports (RPS 2017, 2018) provide hypothetical oil spill scenarios developed for a subsea blowout at two locations in the northern Flemish Pass, specifically within ELs 1134 and 1135, during two seasons (winter and summer). The EL 1134 modelling scenarios are characterized by a crude oil release rate of 37,800 bbl/d at a depth of 1,175 m (floor of Flemish Pass), while the EL1135 modelling scenarios are characterized by a release rate of 156,000 bbl/d at a depth of 362 m (upper western slope of Flemish Pass; Figure 7). While the exact locations for exploration wells have yet to be determined, these hypothetical scenarios encompass the range of the anticipated locations and potential crude release volumes of an actual well. General parameters for a source control blowout are summarized in Table 2 and discussed in greater detail in Section 5.0, Oil Spill Modelling.

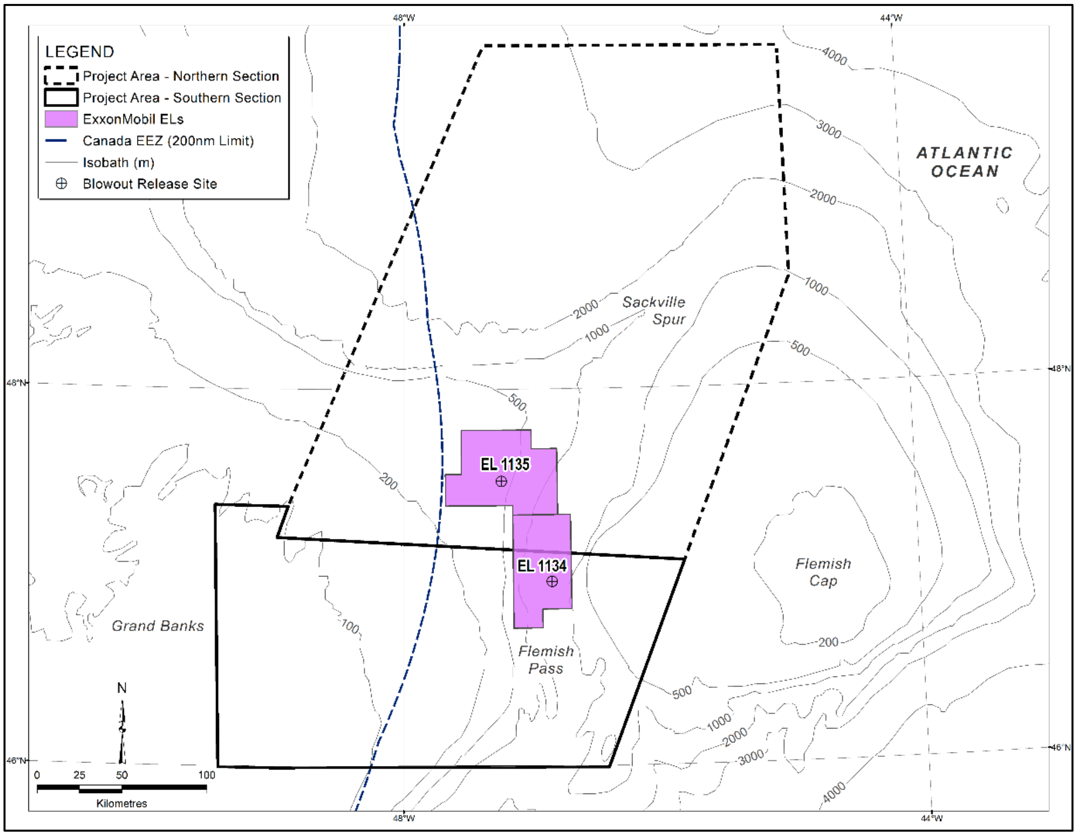


Figure 7. Locations of hydrocarbon release sites within EL1134 and EL1135.

Table 2. General parameters for Tier 3 hypothetical source control blowouts at the two release locations within ELs 1134 and 1135.

Parameter	**Exploration Licence**	
	EL 1134	**EL 1135**
Source of Spill	Blowout at Seafloor	Blowout at Seafloor
Crude Oil Type (API gravity)	Ben Nevis (30.6)	Bay du Nord (35.8)
Release Location Coordinates	46° 58’ 45.5’’ N, 46° 50’ 56.9’’ W	47° 30’ 44.5’’ N, 47° 14’ 9.9’’ W
Water Depth	1,175 m	362 m
Timing of Release	Summer; Winter	Summer; Winter
Duration of Release	113-day continuous	113-day continuous
Rate of Release	37,800 bbl/d	156,000 bbl/d
Model Duration	160 d	160 d

Note: bbl/d denotes barrels per day.

The Ben Nevis and Bay du Nord (BdN) crude oils are the reference oil types for the spill modeling in EL1134 and EL1135, respectively. Since these large-scale releases would require the broadest range of oil spill response options, they form the basis for the risk analysis conducted in Section 6.0.

For the purposes of this SIMA, the Worst Credible Case Discharge (WCCD) refers to the worst credible consequence that could occur over a 160-day modelled time period, from an environmental impact and emergency response perspective. The WCCD oil spill modelling was used to generate both stochastic and deterministic simulations for summer and winter seasons. Stochastic modelling predicts the probability of sea surface, shoreline, or water column contact that could occur for a given spill event. The model runs numerous individual spill trajectory simulations using a range of meteorological and oceanographic (metocean) data, including wind and currents. When combined, these trajectories produce statistical outputs that predict the probability of where oil may travel or occur. Stochastic model outputs do not represent the extent of any one spill event but instead provide a summary of the total individual simulations for a given spill scenario. In contrast, deterministic modelling predicts the fate and transport of oil resulting from a single hypothetical spill event using predefined metocean data. Therefore, the use of both stochastic and deterministic modelling provides an indication of the likelihood and magnitude of the potential effects of the spill scenarios considered for this SIMA.

The analysis of the trajectories of Tier 3 scenarios in both summer and winter has two objectives: (1) to evaluate the differences in reasonable response operational effectiveness across the two modelled seasons; and (2) to evaluate the impact of the response operations to the regional resources of concern across two seasons. For the stochastic modelling described in the EIS, ‘Summer’ and ‘Winter’ seasons represent two periods of time. For the purposes of this SIMA, summer is defined as the May–October period, and winter is defined as the November–April period. Deterministic modelling was derived from stochastic simulations that predicted the worst environmental impacts from an emergency response point of view and which were assessed in the EIS as an unmitigated spill result. For the ExxonMobil SIMA, these resulting deterministic simulations represent unmitigated spill scenarios with natural attenuation for both the summer and winter seasons.

3.0 Response Options

The six spill response options considered in this SIMA are:

- Natural attenuation (i.e., no intervention);
- Shoreline protection and recovery;
- On-water mechanical recovery;
- In-situ burning;
- Surface dispersant application (SDA); and
- Surface dispersant application in combination with subsea dispersant injection (SSDI).

This section provides a summary for each response option listed above to ensure a common framework of understanding for the SIMA analysis. Note that Subsection 3.6 discusses SSDI only, not the combination of SDA and SSDI. Since every response option has benefits and limitations, a full discussion of response options and tactics will be available in the ExxonMobil Oil Spill Response Plan and Manual and associated Emergency Response Plans have been revised to include information on indigenous consultation workshop which were conducted in April and October of 2018 and resubmitted to CNLOPB. There were no additional revisions related to strategic operational responses which would impact the overall conclusions of this SIMA .

Factors considered while assessing the efficacy of potential response methods include metocean data, oil characteristics, the nature and location of the release, and regulatory and logistical considerations. For most spill events, optimal response actions vary depending on many factors. During any given event, several response methods are likely to be used concurrently.

In addition to the six response options, there is another section that addresses potential responses to an oil spill in areas with ice presence.

3.1 Natural Attenuation

Natural attenuation (i.e., 'no intervention') is the baseline to which all other potential response options are compared in this SIMA risk analysis. Without any intervention, spilled oil will drift with the winds and currents, gradually weathering until it evaporates, dissolves, and disperses into the water column, and possibly strands on a shoreline. If stranding occurs, weathering of oil will continue, and it will gradually biodegrade or be incorporated into the sediments. It is also possible that oil stranded on shorelines could be re-mobilized from the shoreline and redistributed several times until it is finally degraded, consumed by organisms, or buried through natural tidal processes. Natural attenuation may be an appropriate option for open ocean spills that do not threaten worker health and safety, marine species of importance, shorelines and/or potentially sensitive environmental areas. Remote sensing, real time modelling and monitoring at sea and on potentially affected shorelines would be conducted to track the fate of naturally weathering oil slicks or stranded oil.

Benefits: As indicated above, natural attenuation may be an appropriate option for spills at sea which do not threaten shoreline, protected habitats, sensitive marine species, or occur during periods of high sea state (winter months, storm events) that facilitate natural oil dispersion but prevent safe deployment of other response options. Natural attenuation may also be appropriate for certain sensitive shoreline habitats where intrusion by people and equipment may cause more environmental damage than naturally degrading oil.

Limitations: Natural attenuation may result in persistence of oil slicks on the sea surface, which may range from hours for light oil in high seas to months for heavier or emulsified oils in relatively calm conditions. It could also result in oil reaching shoreline areas. Reliance on natural attenuation could also affect emergency response capabilities at the well site given the higher potential for exposure of surface vessels and personnel to the volatile organic compounds (VOCs) of crude oil, thereby creating a health and safety risk.

3.2 Shoreline Protection and Recovery

Since shoreline protection (e.g., diversion and deflection booming of oil) and recovery (manual retrieval of oil) are two response techniques that are typically used in combination, they are addressed together in this subsection. The trajectory modelling conducted for both EL1134 and EL1135 demonstrates that there is limited probability of spilled oil reaching the shoreline of Newfoundland. Shoreline protection and recovery are considered important tools when oil cannot be effectively treated or collected at sea prior to its encounter with shoreline areas.

Typically, both shoreline protection and recovery are labour intensive in that large numbers of responders must be trained, transported, housed, and managed. The logistics associated with these operations can be complex, particularly if they are to occur in remote areas or under adverse weather conditions such as those that may be experienced in coastal areas of Newfoundland and Labrador. In addition, worker personal protective equipment, hand tools, washing equipment, protective and containment boom, and any appropriate mechanical equipment must be provided, stored, transported and maintained. Obstacles to gaining access to impacted shorelines can make this response option operationally difficult.

Protective booming strategies may vary depending on tides, currents and weather conditions. These static boom systems require relatively calm waters as they will likely fail in sea states above 1–2 m. High winds, tides and currents can also pose challenges. For the specific spill location considered, the options listed below are the most typical shoreline recovery options that may be utilized if oil does reach Newfoundland shorelines. Operations would be prioritized based on the varying sensitivity of the affected shoreline.

- Manual removal – removal of surface oil by manual means (hands, rakes, shovels, buckets, scrappers, sorbents, etc.);

- Debris removal – manual or mechanical removal of debris (oiled and unoiled) from the shore or water surface to prevent additional sources of contamination;
- Low-pressure cold-water flushing; and
- Limited use of mechanical recovery equipment in accessible areas, if justified by the contamination level.

Benefits: Since booming can only protect relatively short stretches of the shoreline, it should be used strategically in selected areas requiring protection of ecologically or socially important areas. The use of strategic protective booming should be based on the forecasted spill trajectory, the environmental context, and conditions at the time of the incident. Once oil reaches the shoreline, the potential benefits of shoreline recovery options relative to natural attenuation include the following:

- Reduction in shoreline oiling;
- Physical removal of oil from the environment;
- Recycling or proper disposal of recovered oil; and
- Mitigation of impacts to culturally, environmentally or economically important areas.

Limitations: While protective booming can be valuable, it can also create a risk of collateral damage due to physical disturbance caused by the work crews installing, maintaining and dismantling the boom. This may include disturbance from anchoring the materials to soils, sediments or plants, along with increased erosion of shoreline and sediments while the boom moves in place. This potential damage is considered minor when compared to the damage likely to result from the oil if no response was made. The use of protective booms is also highly dependent on weather, type of shoreline, topography and hydrographic conditions.

For shoreline recovery, the use of heavy machinery and intrusion by humans on foot can have negative impacts on some shorelines. In marsh and wetland habitats, the activity associated with the cleanup can often be more damaging than the effects of the oil itself. The cleanup operations can drive the contaminants below the surface and make them available to the root systems of the plants and the organisms that burrow into the sediments. It is common practice to allow the oil to remain on the surface of the sediments in combination with the placement of sorbents at the edge of the water line to passively collect any oil that re-floats. Shoreline recovery tends to be more intrusive than any of the on-water response options and can only be conducted during daylight hours when weather conditions are conducive to worker safety. Given the logistical challenges and limitations, on-water cleanup with the goal of preventing the oil from reaching the shoreline will almost always be environmentally preferable to on-shore recovery. The recovery of a shoreline impacted by oil may take weeks to years, depending on the type of oil spilled and the different environmental variables (e.g., wave energy, amount of solar exposure, rainfall, shoreline type and erosion processes).

3.3 On-Water Mechanical Recovery

On-water mechanical recovery typically involves the use of skimming vessels, support vessels, storage barges, spotter aircraft, booms, and skimmers to redirect, contain and remove oil from the ocean's surface. The success rate of oil removal by means of on-water mechanical recovery depends on various factors including wind, waves, and daylight. Since vessels pulling skimmers typically travel at speeds on the order of one knot, the rate of encountered oil is relatively low. Once oil has been removed from the ocean's surface, it must be stored in either tanks on vessels or in floating temporary storage devices such as towable bladders. Once the oil storage devices are full, they must be returned to an onshore operational base for offloading and either recycling or disposal. Although there have been some advances in using night vision devices to support nighttime operations, on-water mechanical recovery is typically conducted only during the day in conditions with relatively good visibility. Monitoring to determine the effectiveness of on-water mechanical recovery is limited to visual observations from surveillance aircraft or satellite imagery.

Benefits: The primary benefit of on-water mechanical recovery is that the recovered oil is physically and permanently removed from the environment. As a result, public acceptance for use of on-water mechanical recovery is relatively high. Since oil can still be recovered after some weathering has occurred, skimming can usually continue to operate for longer periods of time than other on-water response methods. Generally, this response option would be implemented if it is safe to do so.

Limitations: On-water mechanical recovery is constrained by weather restrictions, its limitation to daylight operations, time required for mobilize to the Flemish Pass (i.e., 48–72 hours), and relatively low operational efficiency. Although there will be available recovery vessels in the area to assist with the immediate response, these vessels will have a limited recovery capability. Therefore, there will be a lag between the time of the spill and the onset of large-scale on-water mechanical recovery operations. This reduces the window of opportunity to conduct on-water mechanical recovery. Once additional equipment has been deployed from a supply base, the low oil encounter rate and the need to dispose of captured oil limit the effectiveness of this response option. Beyond the encounter rate limitations, typical wave heights are a key consideration in the SIMA GAI. For example, open water booming associated with oil skimming operations begins to fail in sea states with wave heights exceeding 2 m. However, equipment capable of functioning in high sea states will also be available during an actual spill. In the ExxonMobil EIS Project Area, wave heights typically exceed this operational limit during the September–May period (see Table 1). Even when sea states are favourable for on-water mechanical recovery operations, these techniques typically recover less than 10% of the oil spilled in open ocean environments. During the DWH response period when wave height was seldom restrictive, it was estimated that less than 5% of the oil released was removed (Federal Interagency Solutions Group 2010). Despite the logistical and operational limitations on the effectiveness of on-water mechanical recovery, this response option remains desirable since it is the only method that physically and immediately removes oil from the environment. For that reason, mechanical recovery equipment will be maintained on site and used if necessary while weather conditions are favorable.

3.4 *In Situ* Burning

In situ burning (ISB) is similar to on-water mechanical recovery in that it involves collection and concentration of oil on the surface using vessels and booms. However, the few key differences are as follow:

- the booms used to collect the oil must be fire resistant;
- while herding agents may be used to aid in the containment or thickening of the oil, none of the available herding agents are currently approved for use in Canada; and
- heavy oils and highly weathered oils are less amenable to burning.

A test burn is typically conducted on spilled oil to determine if ISB will work. Once oil is collected and concentrated to a thickness that will support combustion, it is ignited using flares, torches, or improvised ignition devices. The collected oil will burn as long as an oil thickness of 2–5 mm is maintained (IPIECA and IOGP 2016). The dense black smoke plumes produced during ISB consist primarily of small carbon particles which disperse into the atmosphere. A small amount of oil residue typically remains on the surface after burning but its quantity is too low for collection. Air monitoring may be appropriate, depending on the potential for exposure of humans to the smoke plumes. In the SIMA GAI, the only likely human exposures would be to response workers as these plumes would dissipate before reaching any populated land mass.

Benefits: ISB significantly reduces the amount of oil that remains in the aquatic environment. Since oil is not collected for disposal, at sea storage is not required and there is no need to transfer oil to shore for recycling and/or disposal. Under optimal conditions, ISB can reduce significantly more oil from the water surface than on-water mechanical collection and disposal. For deep water spill responses, the considerable distance from shore means that the ISB smoke plume would not typically affect humans on shore. Therefore, ISB is considered a primary response option for offshore response.

Limitations: The decision to use ISB is dependent on its feasibility under existing environmental conditions at the time of an incident. Reduction in air quality due to gases and particulate material produced during burning may be a concern in some jurisdictions if there are populated areas nearby. ISB also creates limited by-product burn residues that can potentially sink into the water column and not be recovered. This response option has many of the same limitations that on-water mechanical recovery has with respect to speed, weather, and daylight. Oil must first be collected using vessels and booms resulting in a relatively low oil encounter rate. In addition, fire resistant booms designed for ISB operations (i.e., specialized ‘fire booms’) must be used.

In the SIMA GAI, the most significant limitation affecting ISB is wave height. This response option is more sensitive to wave height than on-water mechanical recovery because the booms must concentrate oil to a greater thickness for burning purposes, and wave action is disruptive to combustion. Effective ISB typically requires wave heights <1 m and wind speeds <10 knots (5.1 m/s) (IPIECA and IOGP 2016), conditions that rarely exist in the ExxonMobil Project Area (see Table 1). Although *in-situ* burning was used as a response method during the DWH incident while sea states were essentially flat, a recovery rate of only about 5% was reported (Federal Interagency Solutions Group 2010).

3.5 Surface Dispersant Application

Surface dispersant application involves the use of aircraft and/or spray-boom fitted vessels to apply dispersants on the water surface. The commercial dispersants function as surfactants, breaking oil into small droplets that will disperse into the water column. Ideally, oil droplets that are 10–200+ µm in diameter will remain dispersed in the top few metres of the water column. However, droplets that are ≤70 µm will be more "permanently" dispersed (Li et al. 2009a). Studies have shown that the application of a chemical dispersant will substantially decrease the size of oil droplets down to 10 µm or less in diameter and this effect is significantly influenced by wave-generated mixing energy (Li et al. 2009a,b). Plunging breaking waves are the most effective at decreasing droplet size and increasing the percentage fraction of oil dispersed in the water column compared to spilling breaking waves and nonbreaking waves. By breaking floating oil into small, dispersed droplets, the surface area to volume ratio is increased, thereby increasing the rate of dissolution of oil constituents, dilution, weathering and microbial biodegradation. Biodegradation is discussed in more detail in Subsection 6.2.2.

Since the dispersants can be applied from aircraft and/or relatively fast vessels, the surface oil encounter rate is higher than those associated with other surface response methods. With sufficient wave action, which is typical in the ExxonMobil Project Area, floating oil should disperse into the upper 10 m of the water column rapidly.

For surface applications, dispersants are typically applied at a dispersant to oil ratio (DOR) of about 1:20. Since the DOR can vary depending on oil type and the degree of weathering, it will be monitored and adjusted accordingly to optimize the efficacy of the surface application. Due to the considerable transit distances from St. John's airport to the ExxonMobil Project Area, large aircraft such as a C-130 equipped with a 5,280-gallon (20 m^3) Airborne Dispersant Delivery System (ADDS Pack) or the new OSRL 727 aircraft must be used. These large aircraft can treat up to 400 m^3 of oil in one sortie. Spotter aircraft would also be used to assist in targeting dispersible surface slicks for the dispersant spraying aircraft. Dispersant-carrying aircraft would be on site within 24 hours of spill notification, and ready for operation by Day 2 of a spill.

Surface dispersant application requires daylight and good visibility to visually target thick oil, to ensure that humans and relevant megafauna are not in the spray area, and to observe the effectiveness of the dispersant application (e.g., colour change). Surface-applied dispersants also require minimal wave action (approximate wave height of 0.5 m) to be effective. Dispersants can typically be applied in high wind and wave conditions as long as aircraft can be operated safely. Maximum treatable wave heights are generally on the order of 4 m.

Dispersants can also be applied from vessels either deployed from shore or already in the vicinity of the spill (e.g., Emergency Response and Rescue Vessel, Platform Supply Vessel). Although the oil encounter rate is lower using the vessel approach, targeting of the oil can be more accurate. During the DWH response, vessels were used to treat surface oil in the vicinity of well containment and response operations to reduce exposure risks to workers.

Dispersants work more efficiently on fresh oil than on weathered oil. For application scenarios that involve a one-time batch spill, there is a "window of opportunity" within which surface dispersant application will be effective that depends on many factors including oil type, emulsification rates, etc. For continuous releases, such as a subsea blow out, surface dispersant application could continue until the source is contained.

Determination of the effectiveness of the dispersant application is typically done during a post-spill environmental effects monitoring (EEM) program. The EEM program would include aerial observational flights to estimate the amount of oil remaining at surface, *in situ* water sampling at surface and near-surface, and bird surveys.

Benefits: The primary benefits of surface dispersant application, relative to other response options, include the speed of deployment and the relatively high oil encounter rate. The application of surface dispersants reduces the oil at the water surface, thereby reducing levels of VOCs at the water surface and increasing the safety of workers.

Limitations: The limitations on the efficacy of surface dispersant application in the ExxonMobil Project Area are related primarily to environmental conditions in which aircraft or spray-vessels can be used safely. Aerial application requires daylight and good visibility while vessel-mounted spray brooms require a suitable sea state. High wind and wave conditions not only affect the safety of surface dispersant operations, they also affect the efficacy of dispersants. At wave heights above 4 m, breaking waves entrain oil in the water column and prevent appropriate interaction between the oil and the dispersant.

Although ExxonMobil has four supply vessels that are equipped to carry and apply dispersants, it does not currently have a stock of dispersants in Newfoundland and Labrador, neither onshore nor on its supply vessels.

3.6 Subsea Dispersant Injection

SSDI is used to inject dispersant directly into the flow of subsea oil released from a fixed location. This response option was first conducted during the DWH incident in 2010. Dispersants were applied almost continuously at the well head opening near the sea floor. Subsea dispersant injection operations are conducted from a vessel that contains storage for dispersants, and pumps and coiled tubing to deliver dispersants to the release point. Prior to capping stack deployment, dedicated remotely operated vehicles (ROVs) are typically used to oversee the operation, deploy injection equipment, and assist in monitoring to ensure dispersant efficacy. Although configuring and loading a vessel to support SSDI takes several days, SSDI operations are less sensitive to weather than other response methods and can therefore continue 24 hours a day. In the SIMA GAI, it is assumed that SSDI operations could be deployed by Day 10 of a subsea spill.

In general, the same chemical dispersion principles discussed in the SDA subsection apply to SSDI, with a few key differences. With SSDI, the oil encounter rate is extremely high because the dispersant is being applied directly to the oil as it is released near the sea floor. Because of the high encounter rate, an initial DOR of 1:100 should be targeted, and then adjusted based on real-time monitoring (Brandvik et al. 2014; IPIECA and IOGP 2015a; API 2017). The lower subsea DOR of 1:100, compared to the target DOR of 1:20 associated with SDA means that less dispersant is required for SSDI. Since the dispersant injection is occurring near the sea floor, the dispersed oil will dilute vertically and horizontally in a much greater volume of water. Rapid dilution means lower concentrations of dispersed oil compared to those associated with SDA in which the dispersed oil is typically limited to 10 m of vertical dilution. During the DWH incident, dispersed oil concentrations at 1 km from the well head and at a depth of 1,200 m were consistently below 1 ppm.

Monitoring of SSDI dispersant efficacy includes visual and sensor observations at the injection site by ROVs (e.g., underwater camera and particle size detector), and by aircraft observations or satellite imagery at the surface. Since effective SSDI operations reduce VOC levels at the water surface, air monitoring near the release point can also provide an indication of dispersant efficacy. Ideally, adjustments to the initial 1:100 DOR, in conjunction with monitoring, should allow optimization of the dispersant injection rate for a particular oil type and flow rate (IPIECA and IOGP 2015b; API 2017).

Benefits: SSDI use offers several unique benefits compared to those associated with other response methods. The principal benefits include improved worker safety, higher oil encounter rates, lower DORs, lower sensitivity to weather conditions, lack of daylight restrictions, and the ability to operate continuously.

During the DWH response, it was observed that SSDI reduced the size and thickness of surface slicks, and VOC levels at the surface. This lowers the risk to workers in the immediate release area by reducing the potential for fire, explosions, and inhalation risks for VOCs. Ultimately, SSDI allows workers to more effectively engage in well capping and source control operations.

Since most of the SSDI operations are conducted by ROVs at the sea floor, the potential for worker exposure to oil, dispersants, and dispersed oil is also lower than for most other response methods.

Once SSDI vessels and equipment are in place, dispersant injection operations can run continuously in much higher sea states than either ISB (limited to <1 m) or mechanical recovery (limited to <2 m). In the ExxonMobil Project Area, metocean conditions could hamper SSDI logistics when sea states are above 5 m.

Limitations: The acquisition and transport of vessels, equipment and dispersant supplies to conduct SSDI operations at the response site can take considerable time. After the dispersant and ROV operation vessels are deployed to the well location and a dispersant manifold is positioned on the dispersant supply vessel, the coiled tubing is deployed to the seafloor via ROVs. A minimum of two ROVs are needed for this operation, one for dispersant injection into the oil release point, and the other for observation and the determination of dispersant efficacy.

Public perception of SSDI is often negative due to misunderstandings about dispersed oil fate and transport. Since dispersed oil occurs in the water column and cannot be readily seen, the public may incorrectly assume that the oil is sinking rather than dispersing and will subsequently surface in the future. However, during the DWH response, continuous sampling and monitoring at thousands of locations failed to detect the presence of undispersed subsea oil slicks (OSAT 2010).

3.7 Potential Response Options in Areas with Ice

The formation and development of sea ice follows a progression of stages. The exact timing of these stages at any location varies from year to year because of subtle differences in climatic conditions. The movement and behavior of released oil is greatly affected by the presence of ice. For 0 to 30% ice coverage, the ice does not seem to affect advection or weathering of oil floating at surface. However, with 30 to 80% ice coverage, oil advection is forced to the right of ice motion, surface oil thickness tends to increase due to ice-restricted spreading, and evaporation and entrainment are both reduced by damping/shielding of the water surface from wind and waves (RPS 2017).

The effectiveness of oil recovery operations on oil spills in ice-covered waters varies depending on seasonal ice extent, ice type and other environmental conditions. Oil can be removed from ice-covered waters mechanically (skimmers), chemically (dispersants) and physically (*in* situ burning). It is difficult to establish the ranges of environmental conditions in which each response option can operate effectively. There needs to be a research focus on establishing the efficiency and effectiveness of each response option under a range of ice and weather conditions (Wilkinson et al. (2017).

4.0 Resources of Concern

The framework for identifying Resources of Concern (ROC) for the ExxonMobil Flemish Pass SIMA requires understanding the ecosystem health, human safety and socioeconomic concerns in the Project Area and GAI. Within this framework, key resources are identified using physical, biological and socio-economic data related to the Project Area and GAI presented in the ExxonMobil Eastern Newfoundland Offshore Exploration Drilling Project EIS (ExxonMobil 2017) and the three relevant SEAs (C-NLOPB 2008, 2010, 2014).

In addition, key resources have been identified through ExxonMobil's engagement with various government regulators and stakeholders during development of the EIS (ExxonMobil 2017). The engagement process also provides a forum for understanding stakeholders' concerns and priorities, which are taken into consideration and incorporated in the SIMA's resources of concern.

In addition to the information provided in the EIS, the fate and behavior of oil in the Project Area and GAI are studied to identify resources that may be distinctively affected due to age, species type, sensitivity to oil, etc. These resources are taken into consideration during the risk assessment phase of the SIMA (Section 6.0).

Under the framework described above, the following are identified as the ecological and socio-economic ROC for the ExxonMobil Flemish Pass SIMA.

- Fish and Fish Habitat;
- Migratory Birds;
- Marine Mammals;
- Sea Turtles; and
- Fisheries.

Note the constituents of the following ROC:

- Fish and Fish Habitat ROC includes coastal -algae, phytoplankton, zooplankton, ichthyoplankton (i.e., fish eggs and larvae), invertebrate eggs and larvae, and juvenile and adult stages of fishes and invertebrates;
- Migratory Bird ROC includes seabirds, shorebirds and waterfowl; and
- Fisheries includes commercial fisheries, indigenous fisheries, recreational fisheries and aquaculture.

Note that the selected ROCs encompass the following Valued Components (VCs) defined and used in the ExxonMobil EIS (ExxonMobil 2017).

- Marine Fish and Fish Habitat (including Species at Risk);
- Marine and Migratory Birds (including Species at Risk);
- Marine Mammals and Sea Turtles (including Species at Risk);
- Special Areas;
- Indigenous Communities and Activities; and
- Commercial Fisheries and Other Ocean Users.

A geographical area, habitat and brief description of each environmental compartment are provided in the ROC table (Table 3), provided to emphasize the difference between offshore and inshore habitats. The assessment is based on the generalized ecological communities and/or habitat types present in the affected area since this SIMA is intended to consider a holistic protection of the environment, not the protection of individuals or specific species.

Supporting information to identify species present in the GAI include seasonal distribution and life stages of wildlife, which are summarized in the EIS (ExxonMobil 2017). The EIS also lists species occurring in the area that are designated as threatened or endangered under the *Species at Risk Act (SARA*) or the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Although some of these protected species are uncommon in the Project Area, they are still considered in the analysis due to their designated status in Canada and elsewhere. Additional areas of potential environmental sensitivity are identified in the EIS. These Special Areas, including Ecologically and Biologically Significant Areas (EBSAs), have been designated because of their biodiversity and ecological importance in Canada's oceans, and the need to proactively conserve and protect marine ecosystem functions for future generations. However, specific Species at Risk (SAR) and Special Areas are not included in the ROC (Table 3) or in the Comparative Risk Matrix in Section 6.0 because the components of these areas are already captured under the broader areas, habitats and environmental compartments listed in the ROC table. Similarly, SAR are already considered when evaluating its broader resource category (e.g., migratory birds) for each habitat being evaluated. Subsection 6.3 provides more information on how SAR and Special Areas are considered in the SIMA process.

Table 3. Resources of Concern developed for the ExxonMobil SIMA Geographic Area of Interest.

Habitat Compartment	Specific Habitat	Description of Specific Habitat	Ecological and Socio-Economic Resources of Concern
Shoreline	Intertidal zone and shallow subtidal zone (i.e., <20 m depth) of Newfoundland mainland and island shoreline with some probability of contact with crude	Marine intertidal zone is defined as the area of the foreshore and seabed that is exposed during low tide and submerged during high tide	Fish and Fish Habitat Migratory Birds Marine Mammals Fisheries
Continental Shelf (subtidal zone to shelf break)	Sea surface	Under calm seas, the sea surface microlayer (SML) is the upper 1 mm of the ocean's surface where exchanges occur between the atmosphere and the ocean. Under higher sea state conditions with breaking waves, the exchange layer between the atmosphere and water	Migratory Birds Marine Mammals Sea Turtles Fisheries

Habitat Compartment	Specific Habitat	Description of Specific Habitat	Ecological and Socio-Economic Resources of Concern
		column extends much deeper into the water column.	
	Upper water column (≤20 m depth)	The oceanic mixed layer pelagic environment	Fish and Fish Habitat Migratory Birds Marine Mammals Sea Turtles Fisheries
	Lower water column (>20 m depth)	The marine pelagic environment from the mixed layer to the seabed	Fish and Fish Habitat Migratory Birds Marine Mammals Sea Turtles Fisheries
	Seabed (benthic)	Surficial sediment surface and sub-surface	Fish and Fish Habitat Marine Mammals Fisheries
Continental Slope (offshore of shelf break)	Sea surface	The sea surface microlayer (SML) is the upper 1 mm of the ocean's surface where exchanges occur between the atmosphere and the ocean	Migratory Birds Marine Mammals Sea Turtles Fisheries
	Upper water column (≤20 m depth)	The oceanic mixed layer pelagic environment	Fish and Fish Habitat Migratory Birds Marine Mammals Sea Turtles Fisheries
	Lower water column (>20 m depth)	The marine pelagic environment from the mixed layer to the seabed	Fish and Fish Habitat Migratory Birds Marine Mammals Sea Turtles Fisheries
	Seabed (benthic)	Surficial sediment surface and sub-surface	Fish and Fish Habitat Marine Mammals Fisheries

In addition to ecological ROCs, Table 3 includes the socio-economic ROC Fisheries since a high level of importance is attached to the constituents of this ROC, as outlined in the EIS. As indicated above, commercial fisheries, indigenous fisheries, recreational fisheries and aquaculture are included in the Fisheries ROC.

The following subsections provide more detail on the ROCs being considered in this SIMA. Note that the subsections for the Fish and Fish Habitat, Migratory Bird and Fisheries ROCs are longer and more detailed than those for the Marine Mammal and Sea Turtle ROCs. New data that was not available during the preparation of the ExxonMobil EIS (ExxonMobil 2017) and the three supporting SEAs are presented in this document for fish and fish habitat, migratory birds and fisheries, thereby resulting in longer, more detailed subsections.

4.1 Fish and Fish Habitat

Fish and Fish Habitat has been selected as a ROC due to the ecological and economical importance of its constituents (i.e., algae, phytoplankton, zooplankton, ichthyoplankton, invertebrate eggs and larvae, invertebrates and fishes) within the GAI (see Subsection 4.5, Fisheries), and the potential for interactions between its constituents and the hypothetical release scenario. Fish and fish habitat within the GAI is summarized in the following SIMA subsections.

4.1.1 Pelagic Fish and Fish Habitat

The pelagic environment is comprised of the entire oceanic water column within the GAI, including open ocean waters of the Labrador and Grand Bank shelves and slopes, the Flemish Pass and Cap, portions of the Orphan Basin and other oceanic waters beyond the continental shelf. Water depths in the GAI range from the intertidal zone to >4,000 m. The Flemish Cap is considered a relatively closed marine ecosystem (Perez-Rodriguez et al. 2012 *in* ExxonMobil 2017) that is influenced by mixed currents and characterized by highly oxygenated waters rich in nutrients (Barrio Frojàn et al. 2012 and Altuna et al. 2013 *in* ExxonMobil 2017). These conditions allow for elevated biodiversity in the Flemish Cap area relative to the NL shelf habitats (Altuna et al. 2013 *in* ExxonMobil 2017).

Plankton is comprised of marine organisms that predominantly or entirely drift passively with oceanographic processes, including phytoplankton, zooplankton, ichthyoplankton, bacteria, fungi and viruses (C-NLOPB 2014). The majority of primary plankton productivity occurs within the upper 200 m of the water column (Licandro et al. 2015 *in* ExxonMobil 2017), particularly in continental slope upwelling areas within the GAI (Maillet et al. 2015 *in* ExxonMobil 2017). Oderin Bank located in the outer portion of Placentia Bay, Newfoundland is also known to be a productive area due to summer upwelling (Ramey and Snelgrove 2003). The spring plankton bloom typically begins in late-March/April, peaking on the Grand Banks and Flemish Cap about a month later, and on the Labrador shelf slightly later in the spring (Fuentes-Yaco et al. 2007 *in* ExxonMobil 2017). Zooplankton abundance increases in response to phytoplankton blooms, with copepods and euphausiids (including krill) serving as key food sources for macroinvertebrates, fishes and other marine animals in the region. The majority of zooplankton within the GAI is comprised of three large species of copepod: (1) *Calanus finmarchicus* (largest and most abundant); (2) *C. glacialis*; and; (3) *C. hyperboreus*. All three species typically overwinter at depths ranging from 600–1,400 m, followed by migration towards the surface to mature and reproduce in late-winter/spring (Melle et al. 2014, Wang and Greenan 2014 and Jónasdóttir et al. 2015 *in* ExxonMobil 2017). Several commercially important fish and invertebrate species are largely dependent on copepod availability during various life stages (e.g., larval and adult male shrimp, and larval redfish [*Sebastes* sp.]) (Anderson 1994 and Fuentes-Yaco et al. 2007 *in* ExxonMobil 2017).

Subsection 6.1.5 of the EIS (ExxonMobil 2017) describes pelagic macroinvertebrates in the SIMA GAI. Among the most prevalent pelagic macroinvertebrates occurring within the GAI are shortfin squid (*Illex illecebrosus*) adult northern shrimp (*Pandalus borealis*), jellyfish, North Atlantic octopus (*Bathypolypus arcticus*), mysids and other shrimps, salps, and free-floating gelatinous filter feeders (see Table 6.2 *in* ExxonMobil 2017). Jellyfish are most abundant along the shelf edge of the Grand Banks and Flemish Cap, with peak abundance between June and August (Gibbons and Richardson 2009 *in* ExxonMobil 2017). Pelagic macroinvertebrates are an important prey for larger pelagic fish. For example, salps and jellyfish are eaten by bluefin tuna (*Thunnus thynnus*) (Dragovich 1970 and Fromentin and Powers 2005 *in* ExxonMobil 2017) and sunfish (*Mola mola*) (Potter and Howell *in* ExxonMobil 2017), and squid are prey for a variety of fish species including various sharks, hake and monkfish (Bowman et al. 2000 *in* ExxonMobil 2017).

Key marine finfish species that occur within the GAI are described in Subsection 6.1.7 of the ExxonMobil EIS (ExxonMobil 2017), Subsections 4.2, 4.3 and 4.8 of the Labrador Shelf SEA (C-NLOPB 2008), Subsection 4.2.1.6 of the Eastern Newfoundland SEA (C-NLOPB 2014), and Subsection 3.2 of the Southern Newfoundland SEA (C-NLOPB 2010). Pelagic fish species occurring in the GAI include resident fishes, such as capelin (*Mallotus villosus*), and migratory fishes, such as swordfish (*Xiphias gladius*), tunas and sharks. Capelin are a keystone planktivorous species in the region, principally occurring on the continental shelf and Flemish Cap. While most capelin migrate to inshore Newfoundland areas to spawn during late-spring to early-summer, some capelin spawn on the Flemish Cap. Migratory pelagic fish within the GAI are typically large-bodied predators, including swordfish, tunas and sharks, and several smaller species such as Atlantic salmon (*Salmo salar*), American eel (*Anguilla rostrata*), Atlantic mackerel (*Scomber scombrus*), Atlantic herring (*Clupea harrengus*) and Atlantic saury (*Scomberesox saurus*) (C-NLOPB 2014; ExxonMobil 2017).

4.1.1.1 Pelagic Fish Species at Risk

Pelagic fishes in the GAI that are considered species at risk are listed in Table 4.

Table 4. Pelagic fishes that may occur within the GAI identified as species at risk under the *SARA*, COSEWIC, NL *Endangered Species Act (ESA)*, and/or International Union for the Conservation of Nature (IUCN).

Species	***SARA*[1]**			**COSEWIC[2]**			***ESA*[3]**			**IUCN[4]**				
	E	**T**	**SC**	**E**	**T**	**SC**	**E**	**T**	**V**	**CE**	**E**	**V**	**NT**	**LC**
American Eel (*Anguilla rostrata*)					X				X		X			
Albacore Tuna (*Thunnus alalonga*)													X	
Atlantic Bluefin Tuna (*Thunnus thynnus*)				X							X			
Bigeye Tuna (*Thunnus obesus*)												X		
Skipjack Tuna (*Katsuwonus pelamis*)														X

Species	*SARA*[1]			COSEWIC[2]			*ESA*[3]			IUCN[4]				
	E	T	SC	E	T	SC	E	T	V	CE	E	V	NT	LC
Atlantic Salmon (*Salmo salar*) Inner Bay of Fundy population	S1			X										X
South Newfoundland population					X									X
Quebec Eastern North Shore population						X								X
Quebec Western North Shore population						X								X
Anticosti Island population				X										X
Inner St. Lawrence population						X								X
Gaspe-Southern Gulf of St. Lawrence population						X								X
Eastern Cape Breton population				X										X
Nova Scotia Southern Upland population				X										X
Outer Bay of Fundy population				X										X
Atlantic Sturgeon (*Acipencer oxyrinchus*) St. Lawrence populations					X									
Maritimes populations					X									
Lanternfish (Myctophidae)														X
Porbeagle Shark (*Lamna nasus*)				X								X		
Shortfin Mako Shark (*Isurus oxyrinchus*)						X						X		
White Shark (*Carcharodon carcharias*; Atlantic population)	S1			X								X		

Note:
E = Endangered; T = Threatened; SC = Special Concern; V = Vulnerable; CE = Critically Endangered; NT = Near Threatened; LC = Least Concern; S = Schedule.

[1] *SARA* website (http://www.sararegistry.gc.ca/search/SpeciesSearch_e.cfm) accessed September 2018.

[2] COSEWIC website (https://www.canada.ca/en/environment-climate-change/services/committee-status-endangered-wildlife.html) accessed September 2018.

[3] Government of Newfoundland and Labrador Fisheries and Land Resources Species at Risk website (https://www.flr.gov.nl.ca/wildlife/endangeredspecies/index.html) accessed September 2018.

[4] IUCN Red List of Threatened Species website (https://newredlist.iucnredlist.org/) accessed September 2018.

4.1.2 Benthic Fish and Fish Habitat

The Newfoundland coastline within the GAI is considered high-exposure, frequently subjected to storm surges and waves and variably encroached by sea ice. Major Newfoundland coastal features within the GAI include rocky outcrops and cliffs, fjords (e.g., Conception Bay), fjord-like bays (e.g., Trinity Bay), estuaries, lagoons, tidal inlets, beaches and barrier systems with sediments ranging from mud, gravel and sand to well-sorted pebbles, cobbles and boulders, coastal sand dunes, and ice-generated boulder barricades/clusters (Forbes 1984). Within the GAI, the wave-dominated, exposed coarse sand and fine-gravel shorelines of Newfoundland are of particular ecological importance, as they are preferentially utilized by spawning capelin

(Templeman 1966 *in* Catto et al. 1999), in turn supporting a variety of predators that feed on dead capelin and capelin eggs. Sheltered vertical bedrock or cliff faces within the GAI host various species of lichens, seaweeds and invertebrates, such as *Littorina* periwinkles and *Mytilus* mussels, while estuaries along the Newfoundland coastline often serve as shelter for sea-run trout or salmon (Catto et al. 1999). Periwinkles are also prevalent within moderately-sheltered Newfoundland shores, where their grazing activity typically restricts macroalgae to patchy rockweed distribution and crustose species (Catto et al. 1999).

Seabed sediments within the GAI are predominantly fine. Substrates on the Grand Bank shelf region of the GAI are dominated by sand with lesser quantities of gravel (Husky Energy 2013 and Suncor Energy 2013 *in* ExxonMobil 2017). The slopes of the Grand Banks and Flemish Cap are predominantly comprised of sandy and clay-silt sediments at bottom depths between ~600–1,400 m, where exposure to commercial trawling has resulted in relatively low species diversity (ExxonMobil 2017). The Flemish Cap seabed surficial sediment is primarily sand and silty-sand, with areas of gravel and silty-sand along the shallower slopes (~200–500 m depth) (ExxonMobil 2017). The substrate is increasingly silty-clay or mud in deeper areas of the Flemish Cap and Pass (Murillo et al. 2012, 2016 *in* ExxonMobil 2017), with the greatest species diversity observed within seabed depths of 500–1,000 m (Vàzquez et al. 2013 and Murillo et al. 2016 *in* ExxonMobil 2017). The upper slope of the Orphan Basin (300–700 m depth) is predominantly composed of gravel and sandy-mud substrates. The middle Basin slope (700–2,000 m) is mainly mud, and the lower slope consists of mud, sandy-mud and gravel (ExxonMobil 2017).

Macroalgae and sea grasses enhance coastal productivity and provide habitat for benthic marine organisms. Rockweeds are predominant within the intertidal portions of the GAI, while broad-leafed, filamentous and coralline macroalgae occur primarily in shallow subtidal habitats. Rockweeds grow on relatively stable hard substrate and require years of successional growth to develop (Catto et al. 1999). Eelgrass (*Zostera marina*) inhabits sandy, relatively sheltered and shallow inshore areas (Catto et al. 1999), including Newfoundland subtidal regions within the GAI. Eelgrass beds are ecologically and economically important to the NL region, being biologically productive and hosting or sheltering a variety of seaweeds and commercial groundfish and invertebrate species (Catto et al. 1999). The sand surrounding eelgrass roots can serve as habitat for a variety of burrowing invertebrates (see DFO 2018a). Eelgrass beds are important feeding and resting areas for some fishes, including Atlantic salmon (*Salmo salar*) and various trout species (Catto et al. 1999). Eelgrass also serves to stabilize sandy sediment, the loss of which can result in severe erosion issues (Catto et al. 1999).

Benthic invertebrates within the GAI are described in Subsection 6.1.6 of the EIS (ExxonMobil 2017). At least 118 benthic invertebrate taxa inhabit the muddy inshore sediment in Placentia Bay, including polychaetes, bivalves and amphipods (Ramey and Snelgrove 2003). Deep-sea benthic invertebrate species are typically characterized by lower metabolic and growth rates, later maturity, lower recruitment levels and longer lifespans than benthic invertebrates occurring inshore (Beazley et al. 2013a, McClain and Schalcher 2015 and Murillo et al. 2016 *in*

ExxonMobil 2017). Predominant benthic invertebrate species and/or groups within the offshore portion of the GAI are provided in Table 5.

Table 5. Predominant offshore benthic invertebrates within the GAI by region.

Region	Subregion	Invertebrate Species/Group
Grand Bank Shelf	N/A	Infauna: Polychaetes; Bivalves; Amphipods; Molluscs; Barnacles; Isopods Epifauna: Polychaetes; Clams (including propeller clams *Cyrtodaria siliqua*); Sand Dollars (*Echinarachnius parma*); Sea Urchins; Snow Crabs (*Chionoecetes opilio*); Hermit Crabs; Sea Stars; Scallops; Soft Corals; Whelks
Grand Bank and Flemish Cap Slopes	N/A	Sponges (principally of the Order Astrophorida; on sandy, silty or clay sediments at depths between ~700–1,400 m)
Flemish Pass and Flemish Cap	N/A	Corals (e.g., black, cup, soft and gorgonian corals and sea pens); Sponges; Echinoderms; Arthropods; Molluscs; Cnidarians
Orphan Basin	Upper Slope (300–700 m)	Polychaetes; Bivalves; Echinoderms (including brittle stars); Sponges; Bryozoans and Brachiopods (on cobbles/boulders)
	Middle Slope (700–2,000 m)	Cnidarians; Polychaetes; Echinoderms (including brittle stars)
	Lower Slope (2,000–2,500 m)	Polychaetes; Ophuroids; Molluscs

Source: ExxonMobil (2017).

Predominant groundfish species that occur within the GAI are provided in Table 6.

Table 6. Predominant groundfish within the GAI.

Finfish Species/Group	Predominant Region within GAI
Atlantic cod (*Gadus morhua*)	Grand Bank/Labrador shelves and slopes; Flemish Cap shelf (<500 m); coastal Newfoundland (summer)
Atlantic haddock (*Melanogrammus aeglefinus*)	Grand Bank shelf and slope (southern)
Pollock (*Pollachius virens*)	Grand Bank/Labrador shelves (primarily <200 m); inshore waters (juveniles)
Sand Lance (*Ammodytes dubius*)	Grand Bank/Labrador shelf (<90 m)
Deepwater Redfish (*Sebastes mentella*)	Grand Bank/Labrador/Flemish Cap slopes; Flemish Pass
Acadian Redfish (*Sebastes fasciatus*)	Flemish Cap shelf and slope (<600 m)
Golden Redfish (*Sebastes norvegicus*)	Flemish Cap shelf and slope (<600 m)
Blue Hake (*Antimora rostrata*)	Grand Bank/Labrador slope (lower); Flemish Pass; Flemish Cap slope
White Hake (*Urophycis tenuis*)	Water depths >600 m
Sculpin (*Triglops* sp.)	Grand Bank shelf; coastal Newfoundland
Atlantic Hookear Sculpin (*Artediellus atlanticus*)	Grand Bank/Labrador shelves; coastal Newfoundland (northeast and southeast)
Monkfish (*Lophius americanus*)	Grand Bank/Labrador shelf and slope (<700 m); coastal Newfoundland
Roughhead Grenadier (*Macrourus berglax*)	Grand Bank/Labrador/Flemish Cap slopes; Flemish Pass
Roundnose Grenadier (*Coryphaenoides rupestris*)	Water depths >600 m
Common Grenadier (marlin spike) (*Nezumia bairdii*)	Grand Bank/Labrador/Flemish Cap slopes; Flemish Pass
Vahl’s Eelpout (*Lycodes vahlii*)	Labrador shelf; Grand Bank shelf (northern); Grand Bank/Labrador slopes; Flemish Pass; coastal Newfoundland (northern)
Eelpout (*Lycodes* sp.)	Labrador shelf; Grand Bank shelf (northern); Grand Bank slope (northeastern); coastal Newfoundland (northern and southeastern)
Longnose Eel (*Synaphobranchus kaupii*)	Grand Bank/Labrador/Flemish Cap slopes (>500 m); Flemish Pass
Northern Wolffish (*Anarhichas denticulatus*)	Grand Bank/Labrador/Flemish Cap shelves and slopes; Flemish Pass; coastal Newfoundland (principally water depths 300–1,200 m)
Spotted Wolffish (*Anarhichas minor*)	Grand Bank/Labrador/Flemish Cap shelves and slopes; coastal Newfoundland (principally water depths 100–800 m)
Atlantic (striped) Wolffish (*Anarhichas lupus*)	Grand Bank/Labrador shelves and slopes; coastal Newfoundland (principally water depths 50–450 m)
American Plaice (*Hippoglossoides platessoides*)	Grand Bank/Labrador shelves and slopes; Flemish Cap shelf (<500 m); coastal Newfoundland
Greenland Halibut (*Reinhardtius hippoglossoides*)	Labrador shelf; Grand Bank shelf (northern); Grand Bank/Labrador/Flemish Cap slopes; Flemish Pass; coastal Newfoundland (northern)
Yellowtail Flounder (*Pleuronectes ferruginea*)	Grand Bank shelf (eastern and southern)
Witch Flounder (*Glyptocephalus cynoglossus*)	Water depths >600 m
Thorny Skate (*Amlyraja radiata*)	Water depths ~200–1,000 m
Black Dogfish (*Centroscyllium fabricii*)	Water depths >1,000 m

Sources: C-NLOPB (2008, 2010, 2014); ExxonMobil (2017).

4.1.2.1 Shellfish and Finfish Species at Risk

Shellfish and finfish species at risk within the GAI are listed in Table 7.

Table 7. Shellfish and finfish species that may occur within the GAI identified as species at risk under the *SARA*, COSEWIC, NL ESA, and/or IUCN.

Species	*SARA*[1]			COSEWIC[2]			*ESA*[3]			IUCN[4]				
	E	**T**	**SC**	**E**	**T**	**SC**	**E**	**T**	**V**	**CE**	**E**	**V**	**NT**	**LC**
American Lobster (*Homarus americanus*)														X
Acadian Redfish (*Sebastes fasciatus*) Atlantic population					X						X			
Bonne Bay population						X					X			
Deepwater Redfish (*Sebastes mentella*; Northern population)					X									X
Atlantic Cod (*Gadus morhua*; Newfoundland and Labrador population)				X								X		
Lumpfish (*Cyclopterus lumpus*)					X									
Atlantic Wolffish (*Anarhichas lupus*)			S1			X								
Northern (striped) Wolffish (*Anarhichas denticulatus*)		S1			X									
Spotted Wolffish (*Anarhichas minor*)		S1			X									
Roughhead Grenadier (*Macrourus berglax*)						X								
Roundnose Grenadier (*Coryphaenoides rupestris*)				X						X				
White Hake (*Urophycis tenuis*; Atlantic and Northern Gulf of St. Lawrence population)				X										
Cusk (*Brosme brosme*)				X										
American Plaice (*Hippoglossoides platessoides*; Newfoundland and Labrador population					X									
Atlantic Halibut (*Hippoglossus hippoglossus*)											X			
Black Dogfish Shark (*Centroscyllium fabricii*)														X
Spiny Dogfish Shark (*Squalus acanthias*; Atlantic population)						X						X		
Portuguese Dogfish Shark (*Centroscymnus coelolepis*)													X	
Greenland Shark (*Somniosus microcephalus*)													X	

Species	***SARA*[1]**			**COSEWIC[2]**			***ESA*[3]**			**IUCN[4]**				
	E	**T**	**SC**	**E**	**T**	**SC**	**E**	**T**	**V**	**CE**	**E**	**V**	**NT**	**LC**
Smooth Skate (*Malacoraja senta*) Funk Island Deep population				X							X			
Laurentian-Scotian population						X					X			
Thorny Skate (*Amblyraja radiata*)						X						X		
Winter Skate (*Leucoraja ocellata*; Eastern Scotian Shelf – Newfoundland population)				X							X			
Barndoor Skate (*Dipturus laevis*)											X			
Spinytail Skate (*Bathyraja spinicauda*)													X	

Note:
E = Endangered; T = Threatened; SC = Special Concern; V = Vulnerable; CE = Critically Endangered; NT = Near Threatened; LC = Least Concern; S = Schedule.

[1] *SARA* website (http://www.sararegistry.gc.ca/search/SpeciesSearch_e.cfm) accessed September 2018.

[2] COSEWIC website (https://www.canada.ca/en/environment-climate-change/services/committee-status-endangered-wildlife.html) accessed September 2018.

[3] Government of Newfoundland and Labrador Fisheries and Land Resources Species at Risk website (https://www.flr.gov.nl.ca/wildlife/endangeredspecies/index.html) accessed September 2018.

[4] IUCN Red List of Threatened Species website (https://newredlist.iucnredlist.org/) accessed September 2018.

4.1.3 Corals and Sponges

Many benthic deep-sea invertebrates, such as corals and sponges, are immobile and inhabit stable environmental conditions, making them sensitive to anthropogenic disturbance (Curtis et al. 2013, Deblois et al. 2014, Barrio Frojàn et al. 2015, Cordes et al. 2016, Clark et al. 2016 and Murillo et al. 2016 *in* ExxonMobil 2017). The fragile nature of corals and sponges increases their vulnerability to habitat disturbances. With the exception of some specialized habitats, such as hydrothermal vents, recovery for most deep-sea ecosystems can be very slow after disturbance (William et al. 2010, Schalcher 2014, Van Dover et al. 2014, Clark et al. 2016 and Van Reusel et al. 2016 *in* ExxonMobil 2017).

The presence of corals and sponges can affect the distribution and activities of other benthic marine species (C-NLOPB 2014). For example, some fish species selectively occupy complex habitats (Baker et al. 2012 *in* ExxonMobil 2017) such as those formed by corals and sponges, and taxa indicative of Vulnerable Marine Ecosystems (VMEs) have been found to have elevated species richness, abundance and biomass within NAFO VME coral, sponge and sea pen closure areas (see Subsection 4.1.4, Sensitive Fish Habitat *in* ExxonMobil 2017). The Sackville Spur portion of the Flemish Cap with depths between 1,000–1,700 m is a high-density area for deep-sea sponge assemblages that are associated with high benthic species richness and high bottom currents (Knudby et al. 2013, Barrio Frojàn et al. 2015, Beazley and Kenchington 2015 and Murillo et al. 2016 *in* ExxonMobil 2017).

Corals and sponges within the GAI are described in Subsection 6.1.6.5 of the EIS (ExxonMobil 2017). At least 50 species of corals and sea pens and 32 species of sponges have been identified within the GAI (Wareham 2009, Murillo et al. 2011, 2012, Beazley et al. 2013a, Knudby et al. 2013, Vàsquez et al. 2013, Baillon et al. 2014a,b and Beazley and Kenchington 2015 *in* ExxonMobil 2017; DFO 2017). Coral and sponges are most prevalent on the slope regions of the GAI.

4.1.4 Sensitive Fish Habitat

Special areas (i.e., sensitive fish habitat) within the GAI are described in Subsections 6.1.10 and 6.4 of the EIS (ExxonMobil 2017). Additional sensitive habitat information is provided Subsection 4.11 of the Labrador SEA (C-NLOPB 2008), Subsection 4.2.4 of the Eastern Newfoundland SEA (C-NLOPB 2014), and Subsection 3.8 of the Southern Newfoundland SEA (C-NLOPB 2010). Sensitive fish habitat is included as a ROC for SIMA evaluation due to ecological/conservation importance and the potential to interact with the hypothetical release scenario. Sensitive fish habitats within the GAI are provided below. Important Bird Areas (IBAs) that include marine waters are provided in Subsection 4.2.

4.1.4.1 Sensitive Coastal Fish Habitat

Sensitive areas which include coastal fish habitat components within the GAI that could potentially be affected by an oil spill are provided in Table 8 and Figure 8.

Table 8. Sensitive coastal fish habitat within the GAI.

Sensitive Habitat	Governing Body	Name	Source
Ecologically and Biologically Significant Areas (EBSAs)	Government of Canada	1. Fogo Shelf 2. Bonavista Bay 3. Smith Sound 4. Baccalieu Island 5. Eastern Avalon 6. St. Mary's Bay 7. Placentia Bay	1, 2
Provincial Protected Areas	Government of Newfoundland and Labrador	1. Deadman's Bay Provincial Park 2. Windmill Bight Provincial Park 3. Dungeon Provincial Park 4. Bellevue Beach Provincial Park 5. Baccalieu Island Ecological Reserve 6. Marine Drive Provincial Park 7. Witless Bay Ecological Reserve 8. La Manche Provincial Park 9. Chance Cove Provincial Park 10. Mistaken Point Ecological Reserve 11. Cape St. Mary's Ecological Reserve 12. Gooseberry Cove Provincial Park 13. Jack's Pond Provincial Park	3
National Park	Government of Canada	Terra Nova National Park	4

Sensitive Habitat	Governing Body	Name	Source
Marine Protected Areas (MPAs)	Government of Canada	1. Eastport – Duck Islands MPA 2. Eastport – Round Island MPA	5
Federal Fishing Closure Area	Government of Canada	Eastport Peninsula Lobster Management Area (EPLMA)	6
Preliminary Representative Marine Area	Government of Canada	Northwestern Conception Bay	7

Source: [1] Wells et al. (2017); [2] N. Wells, Biologist, Northwest Atlantic Fisheries Centre, DFO, pers. comm., 28 February 2018; [3] GNL (2018); [4] GoC (2018); [5] DFO (2018b); [6] DFO (2013); [7] ExxonMobil (2017).

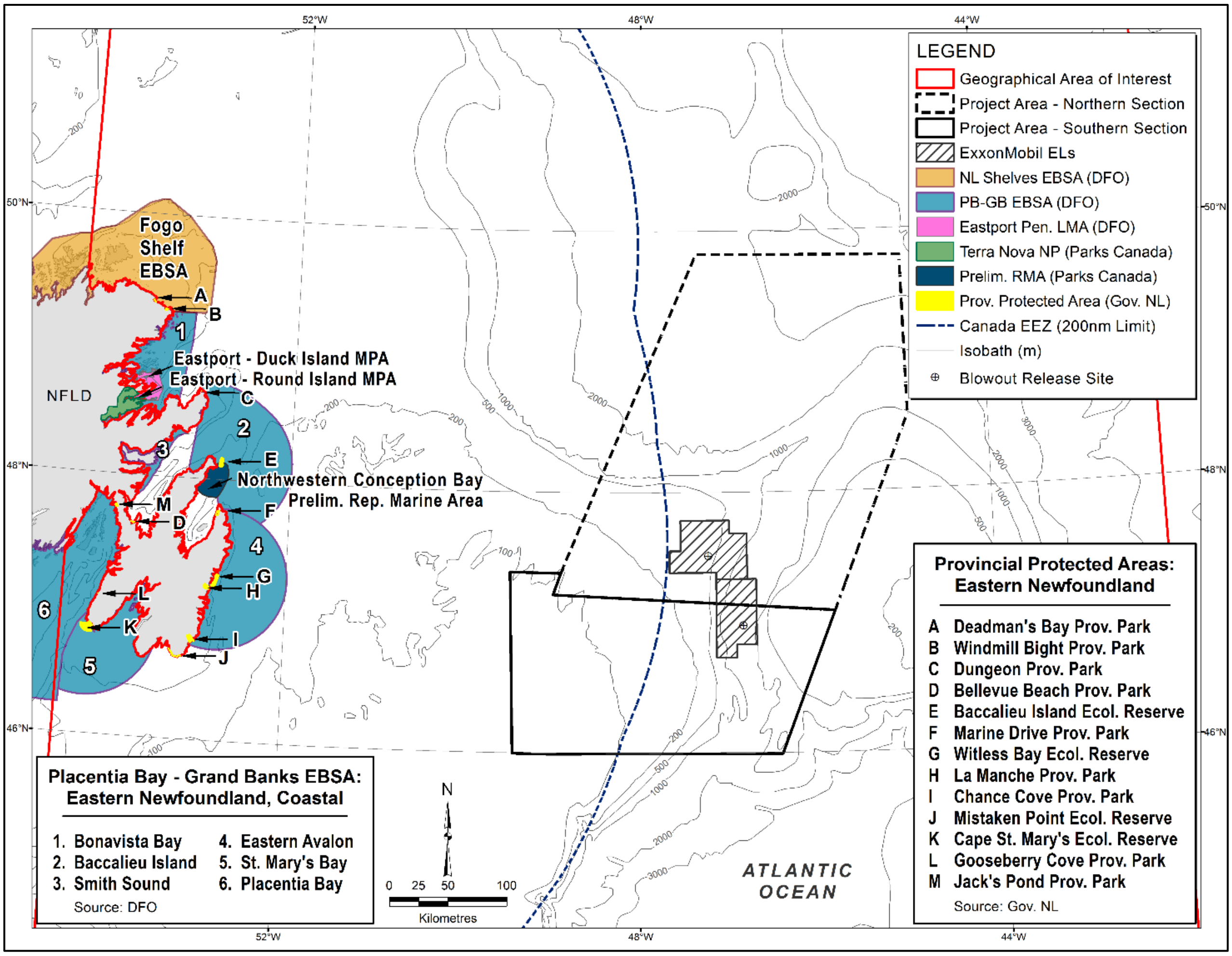


Figure 8. **Sensitive coastal fish habitat within the GAI.**

4.1.4.2 Sensitive Offshore Fish Habitat

Sensitive offshore fish habitat areas in the GAI that could potentially be affected by an oil spill are provided in Table 9 and Figures 9–11. New DFO standards for ocean protection are available at https://www.canada.ca/en/fisheries-oceans/news/2019/04/canada-announces-new-standards-for-protecting-our-oceans.html

Table 9. Sensitive offshore fish habitat within the GAI.

Sensitive Habitat	Governing Body	Name	Source
Ecologically and Biologically Significant Areas (EBSAs)[a]	Government of Canada	Labrador Slope Labrador Marginal Trough Grey Islands Notre Dame Channel Orphan Spur Fogo Shelf Bonavista Bay Northeast Slope Baccalieu Island Eastern Avalon Placentia Bay St. Mary's Bay Virgin Rocks Haddock Channel Sponges Southwest Slope Southeast Shoal Lilly Canyon-Carson Canyon	1, 2
EBSA	Convention on Biological Diversity	Orphan Knoll Slopes of the Flemish Cap and Grand Bank Southeast Shoal and Adjacent Areas on the Tail of the Grand Bank	3
Candidate National Marine Conservation Area (NMCA)	Government of Canada	Labrador Coast (B)	4
Seasonal Shrimp Closure Area[b]	NAFO	Within NAFO Div. 3M	5
Vulnerable Marine Ecosystem (VME) Closures: Seamount Closures	NAFO	Orphan Knoll Newfoundland Seamounts Fogo Seamount 1	6
VME Closures: Sponge, Coral and Sea Pen Closures	NAFO	Tail of the Bank (1) Flemish Pass/Eastern Canyon (2) Beothuk Knoll (3) Eastern Flemish Cap (4) Northeast Flemish Cap (5) Sackville Spur (6) Northern Flemish Cap (7) Northern Flemish Cap (8) Northern Flemish Cap (9) Northwest Flemish Cap (10) Northwest Flemish Cap (11) Northwest Flemish Cap (12) Beothuk Knoll (13) Eastern Flemish Cap (14)	6
Voluntary Industry Closure Area	Fishing Industry	Bonavista Cod Box	7
Preliminary Representative Marine Area	Government of Canada	Virgin Rocks South Grand Bank Area	8
Critical Habitat	Government of Canada	Northern Wolffish (proposed) Spotted Wolffish (proposed)	9
Marine Refuge	Government of Canada	Division 3O Coral Closure Funk Island Deep Closure Hawke Channel Closure Hopedale Saddle Closure Northeast Newfoundland Slope Closure	10, 11

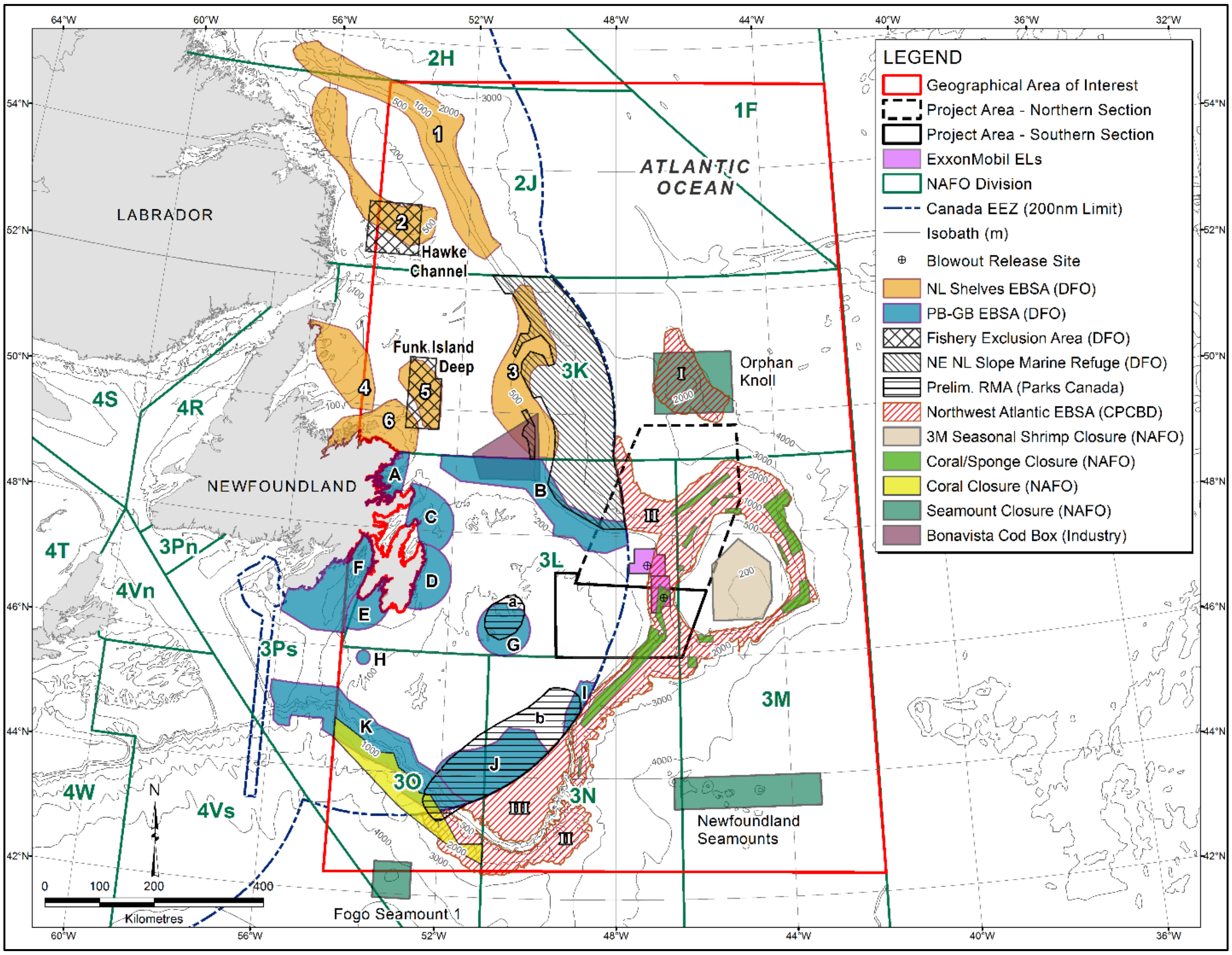
Note:

[a] Some EBSAs are also listed under Coastal Sensitive Fish Habitat (see Table 8), as they include designated coastal and marine extents.

[b] No vessel is permitted to fish for shrimp within this Closure Area between 1 June and 31 December.

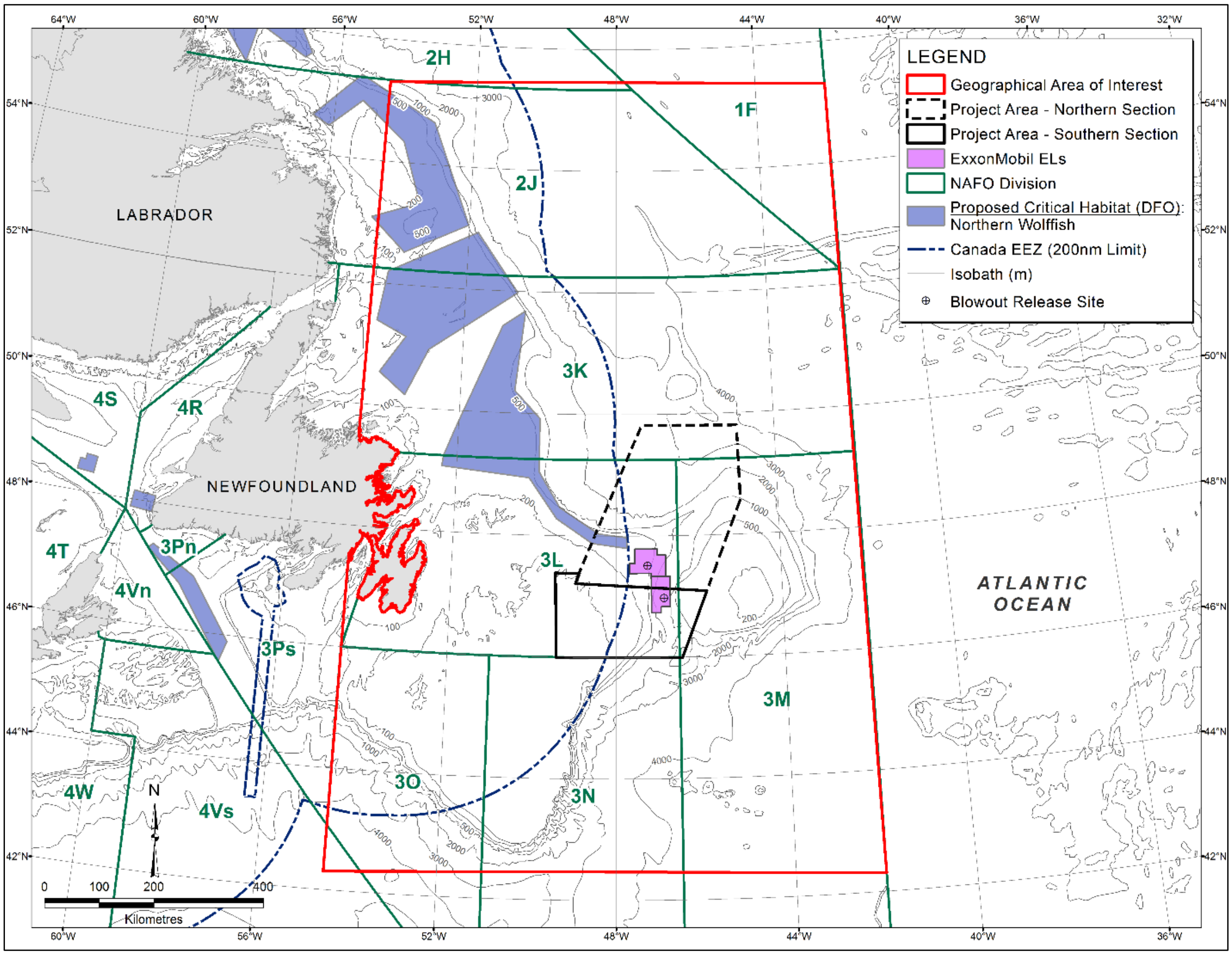
[1] Wells et al. (2017); [2] N. Wells, Biologist, Northwest Atlantic Fisheries Centre, DFO, pers. comm., 28 February 2018; [3] CBD (n.d.); [4] F. Mercier, A/Manager, Marine Establishment, Protected Areas Establishment Branch, Parks Canada, pers. comm., 9 February 2018); [5] NAFO (2018a);

[6] NAFO (2018b); [7] C-NLOPB (2014); [8] ExxonMobil (2017); [9] DFO (2018d); [10] DFO (2018c); [11] https://www.dfo-mpo.gc.ca/oceans/oeabcm-amcepz/refuges/index-eng.html



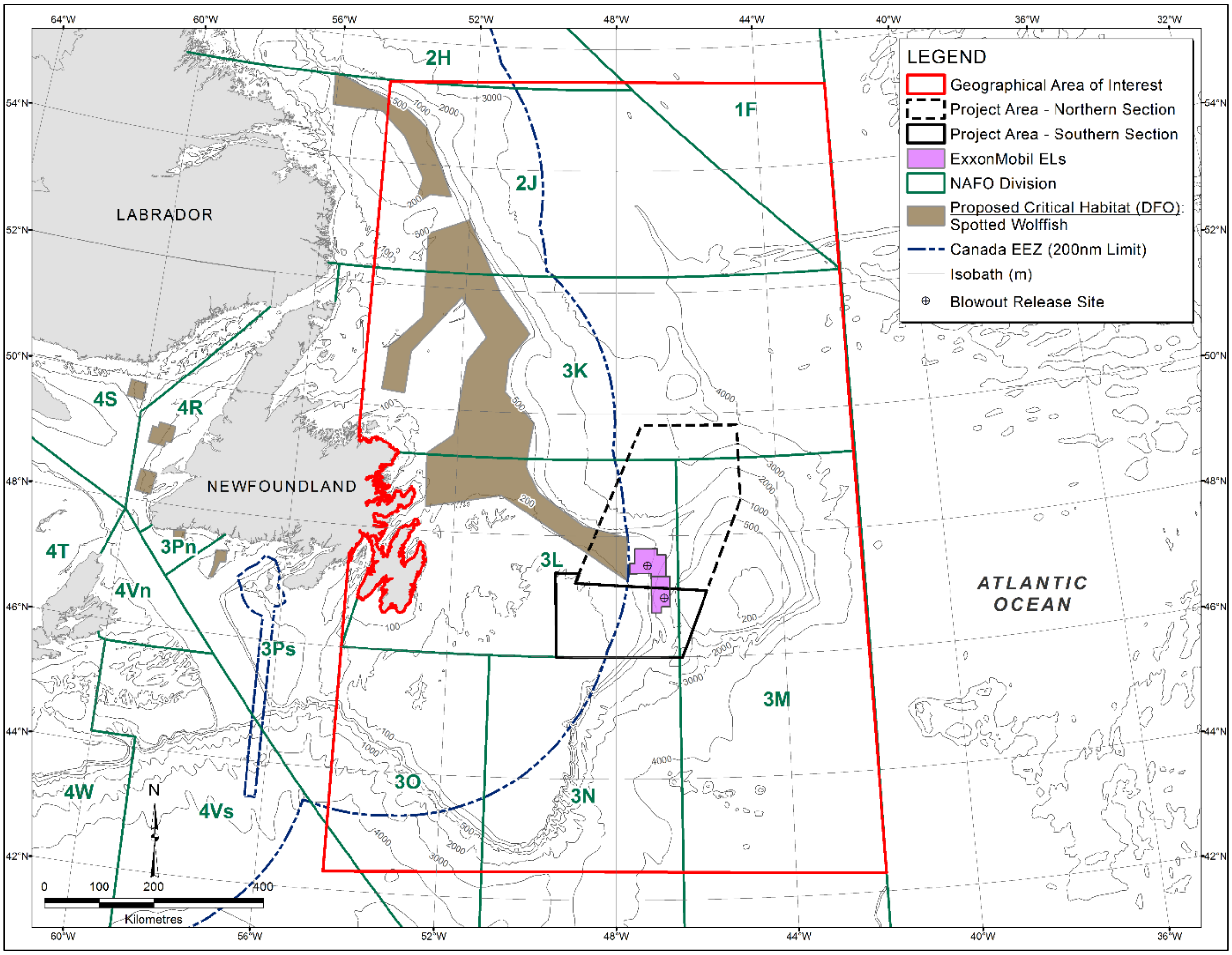
Alphanumeric labels: *NL Shelves EBSAs:* 1. Labrador Slope; 2. Labrador Marginal Trough; 3. Orphan Spur; 4. Grey Islands; 5. Notre Dame Channel; 6. Fogo Shelf; *Placentia Bay-Grand Bank EBSAs:* A. Bonavista Bay; B. Northeast Slope; C. Baccalieu Island; D. Eastern Avalon; E. St. Mary's Bay; F. Placentia Bay; G. Virgin Rocks; H. Haddock Channel Sponges; I. Lilly Canyon-Carson Canyon; J. Southeast Shoal; K. Southwest Slope; *Northwest Atlantic EBSAs:* I. Orphan Knoll; II. Slopes of Flemish Cap and Grand bank; III. Southeast Shoal and Adjacent Areas on the Tail of the Grand Bank; *Preliminary Representative Marine Areas:* a. Virgin Rocks; b. South Grand Bank Area.

Figure 9. Sensitive offshore fish habitat within the GAI.



Source: DFO (2018d).

Figure 10. Proposed northern wolffish critical habitat within the GAI.



Source: DFO (2018d).

Figure 11. **Proposed spotted wolffish critical habitat within the GAI.**

4.2 Migratory Birds

The ExxonMobil SIMA GAI includes the highly productive shelf waters of the Grand Banks, the Flemish Cap, and areas well beyond the shelf break. It also includes coastal areas of the Avalon Peninsula extending north to Cape Freels and Fogo Island. The GAI includes a number of different habitats that might be used by marine birds for breeding, foraging, moulting and wintering.

4.2.1 Seabirds

This subsection provides relevant information for various seabird species that typically occur in the offshore of the SIMA GAI.

4.2.1.1 Northern Gannet

In North America, Northern Gannet breed at six main colonies, three of which are on the coast of Newfoundland. The Newfoundland colonies are at Cape St. Mary's (25,972 individuals), Funk Island (19,674 individuals) and Baccalieu Island (3,424 individuals), all of which are within the GAI (ECCC-CWS 2018) (Figure 12). Gannets are found in low densities around the coast of the Avalon Peninsula and offshore over the tail of the Grand Banks from April–July, and almost exclusively close to the Avalon Peninsula coast during August–November. From December–March they are almost entirely absent from the GAI (Bolduc et al. 2018).

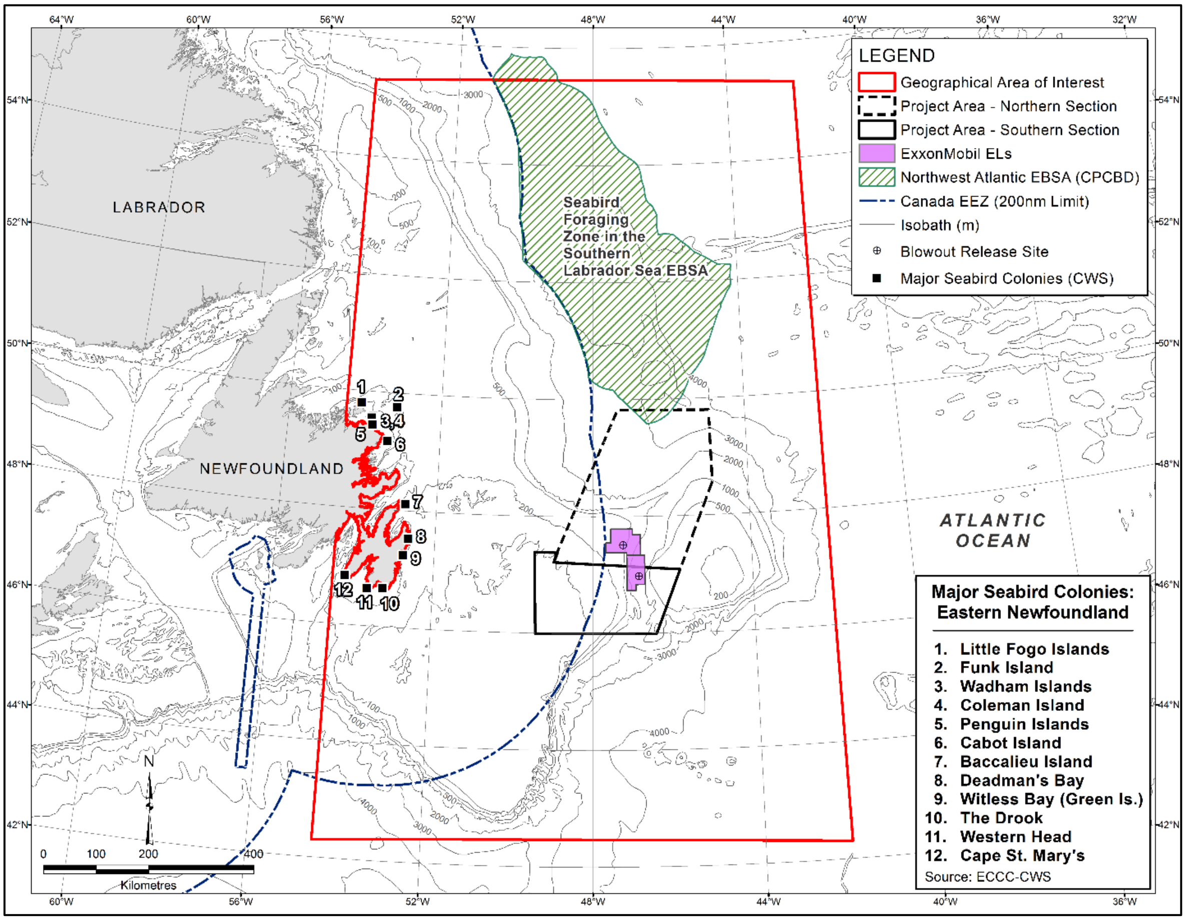


Figure 12. Locations of major seabird colonies within the GAI.

Gannets feed primarily on shoaling fish by making dramatic plunge dives from the air (Mowbray 2002). Two types of dives have been observed: (1) short, shallow dives; and (2) long, deep, "U-shaped" dives. Most dives are short and shallow, generally less than 8 seconds in duration with a mean depth of 3.5 m. Only 10% of dives were deeper than 10 m, up to 22 m in depth and 38 seconds in duration (Garthe et al. 2000). Gannets also spend time on the surface of the water after their dives, bathing or preening.

4.2.1.2 Northern Fulmar

Northern Fulmar breed in small numbers (300 birds total) at seven colonies along the coast of Newfoundland, five of which are within the GAI (ECCC-CWS 2018) (see Figure 12). Birds from these colonies, along with non-breeders, are present during the summer months. In autumn, these birds are joined by large numbers of fulmars from the breeding colonies in the eastern Canadian Arctic, where roughly 200,000 pairs breed in ten colonies (Gaston et al. 2006). Birds return to the high north colonies in late-April or early-May and leave by mid-October (Mallory et al. 2012). The densities are highest in late summer (August–November) when densities of 48–399.4 birds per km^2 are typical along the continental slope from the Flemish Pass north to Baffin Island (Bolduc et al. 2018).

Fulmars are seldom encountered over the shelf but concentrations are found throughout the year over the shelf break and slope along the Labrador coast, the Orphan Basin and the Flemish Cap (Bolduc et al. 2018).

Fulmars feed from the water, either by picking up prey from the surface or by diving short distances (up to 3 m). They are evidently unable to feed from the air (Mallory et al. 2012).

4.2.1.3 Shearwaters – Great, Sooty, Manx

Shearwaters are present in the GAI, primarily in the Summer period (June–November), although small numbers return to the area in late-May, and a few Great Shearwaters are still present in early-December (Bolduc et al. 2018). Great Shearwater and Sooty Shearwater both breed in the southern hemisphere and travel to the North Atlantic during the austral winter (northern summer) to take advantage of the rich feeding grounds during their annual moult (BirdLife International 2018). Great Shearwater is by far the most abundant species of shearwater present in the GAI, reaching densities of up to 33.6–59.5 birds per km^2 during the late summer months of August–November. Sooty Shearwater by contrast is found at densities of 1.6–12.5 birds per km^2 primarily on the southern Grand Banks in April–July and at lower densities of 1.3–6.4 birds per km^2 in August–November, by which time they have moved into the area of the Flemish Cap in greater numbers (Bolduc et al. 2018).

There is only one known breeding location for Manx Shearwaters in Canada; a colony of 200 birds present on Middle Lawn Island, off the Burin Peninsula on the southern coast of Newfoundland (outside of the GAI) (ECCC-CWS 2018). There are scattered records of Manx Shearwater across the Grand Banks during the summer months, most in May–July (Bolduc et al. 2018). The highest densities of this species 1.4–2.2 birds per km^2, and mostly south of the Grand Banks (Bolduc et al. 2018).

While shearwaters spend most of their time either in flight or on the waters' surface, they are capable of diving into the water column. A study of Sooty Shearwaters in New Zealand found that they regularly dive to depths of 40–60 m (Weimerskirch and Sagar 1996). When Great Shearwaters are moulting in North Atlantic waters, they spend more time on the water and may therefore be more susceptible to oil spills.

4.2.1.4 Storm-Petrels – Leach's & Wilson's

Leach's Storm-Petrels breed in large numbers in colonies on the coast of Newfoundland, especially between the Bonavista Peninsula and Fogo Island. The largest colonies found in the GAI include Little Fogo Islands (76,000 birds), Coleman Island (10,000 birds), Wadham Islands (23,876 birds), and the Penguin Islands (18,000 birds) (ECCC-CWS 2018) (see Figure 12). The largest Leach's Storm-Petrel colony in the world is found at Baccalieu Island (also in the GAI) which numbers 6,720,000 birds or roughly 30% of the world's population (ECCC-CWS 2018). During the breeding season (June–October) birds feed within 200 km of the colonies (Huntington et al. 1996). In April–July, Leach's Storm-Petrel densities are highest (5.9–25.9 birds per km^2) northeast of the main colonies and out to the Orphan Basin. From August–October the area of highest density (5.5–31.7 birds per km^2) shifts south to the shelf break around the tail of the Grand Banks (Bolduc et al. 2018). They are largely absent from the GAI during the winter months.

Wilson's Storm-Petrels breed in Antarctica and on sub-Antarctic islands but migrate north, including to the North Atlantic during their non-breeding season (Birdlife International 2018). They are present in the GAI in small numbers from April–October (Bolduc et al. 2018).

Leach's Storm-Petrels feed on plankton and small fish picked off the water surface while hovering or while sitting on the water but there are no reports of diving (Huntington et al. 1996).

4.2.1.5 Black-legged Kittiwake

Black-legged Kittiwake is present over shelf and deeper waters and is the most pelagic species of gull found in the GAI, occurring far offshore. They nest in colonies on inaccessible cliffs around the coast. Over 130,000 breed in colonies around Newfoundland, some with just a few pairs and others with over 20,000 birds (ECCC-CWS 2018). The largest colonies in the GAI include Cape St. Mary's (20,000 birds), Western Head (2,000 birds), The Drook (3,600 birds), Green Island in Witless Bay (20,000 birds), Deadman's Bay (3,500 birds) and Baccalieu Island (25,950 birds) (ECCC-CWS 2018) (see Figure 12). Kittiwakes are widespread offshore throughout the GAI, reaching the highest densities in the winter months (Bolduc et al. 2018).

Kittiwakes feed primarily at the surface, occasionally making short dives of 0.5–1 m depth (Hatch et al. 2009).

4.2.1.6 Alcids – Atlantic Puffin, Common Murre, Thick-billed Murre, Razorbill, Black Guillemot, Dovekie

Five species of alcids (Atlantic Puffin, Common Murre, Thick-billed Murre, Razorbill and Black Guillemot) breed in the GAI and one species (Dovekie) is a winter resident. Alcids are stocky seabirds that are excellent divers which spend much of their time in the water column.

Atlantic Puffin breed on 19 colonies in the GAI, the largest of which are found at Whadham Islands (50,236 birds), Baccalieu Island (60,000 birds) and Green Island in Witless Bay (40,000 birds) (ECCC-CWS 2018) (see Figure 12). Puffins are found closer to shore while at their breeding colonies from April–July but during the rest of the year may be found further offshore including the Flemish Pass (Bolduc et al. 2018). Common Murres breed at five large colonies in the GAI: Funk Island (825,046 birds), Cabot Island (6,646 birds), Baccalieu Island (8,000 birds), Green Island in Witless Bay (148,000 birds) and Cape St. Mary's (20,000 birds) (ECCC-CWS 2018). The colony at Funk Island represents approximately 4% of the global population and two thirds of the eastern North American population (IBA Canada 2018). Four of those colonies are also used by smaller numbers of Thick-billed Murres (Funk Island - 500 birds; Baccalieu Island - 750 birds; Witless Bay - 1,200 birds and Cape St. Mary's - 2,000 birds) (ECCC-CWS 2018). Razorbills breed at 10 colonies in the GAI, ranging in size from as few as 10 birds at the Drook to 546 birds in the Wadham Islands (ECCC-CWS 2018).

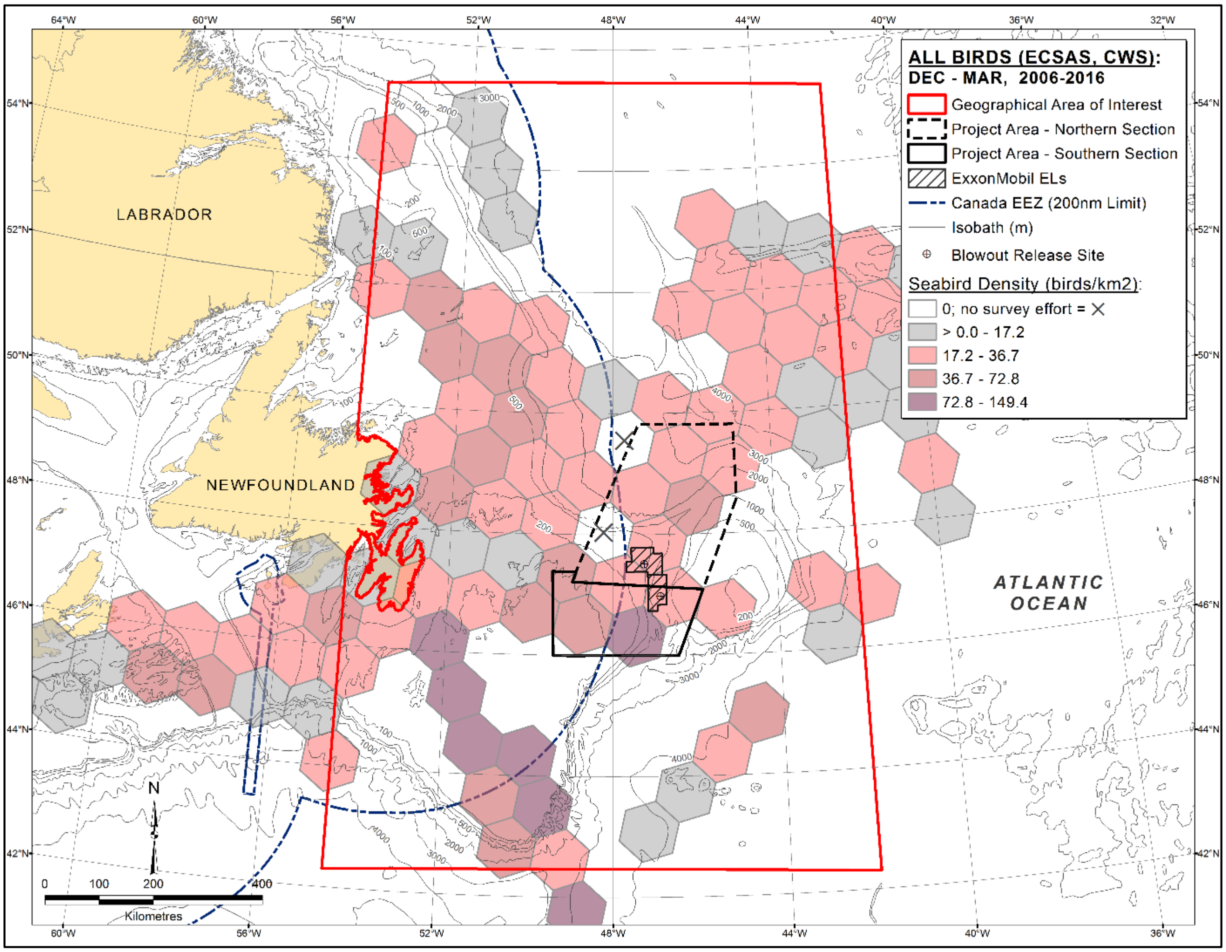
Black Guillemots nest in scattered small colonies, typically of less than 100 individuals, around the coast of Newfoundland. At least 24 of these small colonies are found in the GAI (ECCC-CWS 2018). Black Guillemots are typically found close to shore and prefer inshore waters less than 35 m deep (Butler and Buckley 2002).

Dovekies nest in small numbers on Baffin Island but more importantly a population of up to 20 million pairs nest in northwest Greenland (Montevecchi and Stenhouse 2002). Many of these birds migrate south to Newfoundland and Labrador during the winter months. Densities in the GAI are highest from December–March, in the range of 9.0–32.6 birds per km^2 (Bolduc et al. 2018).

Murres and Razorbills are the strongest divers of the alcids and have been recorded diving to maximum depths of 180 m and 120 m respectively (Piatt and Nettleship 1985). Puffins generally forage at depths of less than 60 m but have been recorded as diving up to 68 m (Burger and Simpson 1986). Black Guillemots were recorded diving to 50 m (Piatt and Nettleship 1985). Maximum dive depths for Dovekies were recorded as 19–35 m (Falk et al. 2000).

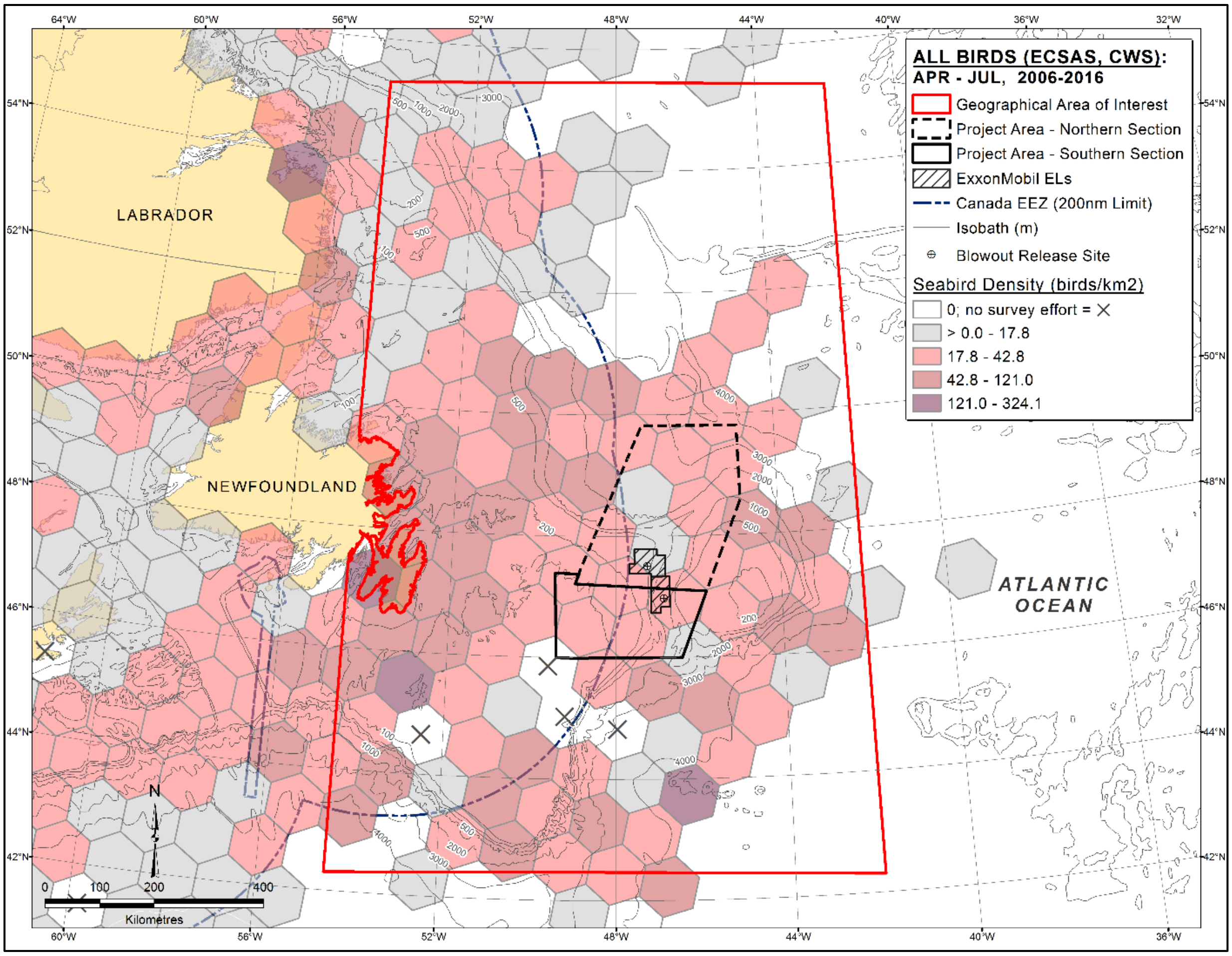
4.2.1.7 Seabird Distribution and Densities within the GAI

Seabird distribution and densities within the GAI during 2006–2016 are shown in Figures 13–15. The data are presented in three four-month time periods; December–March, April–July, and August–November.



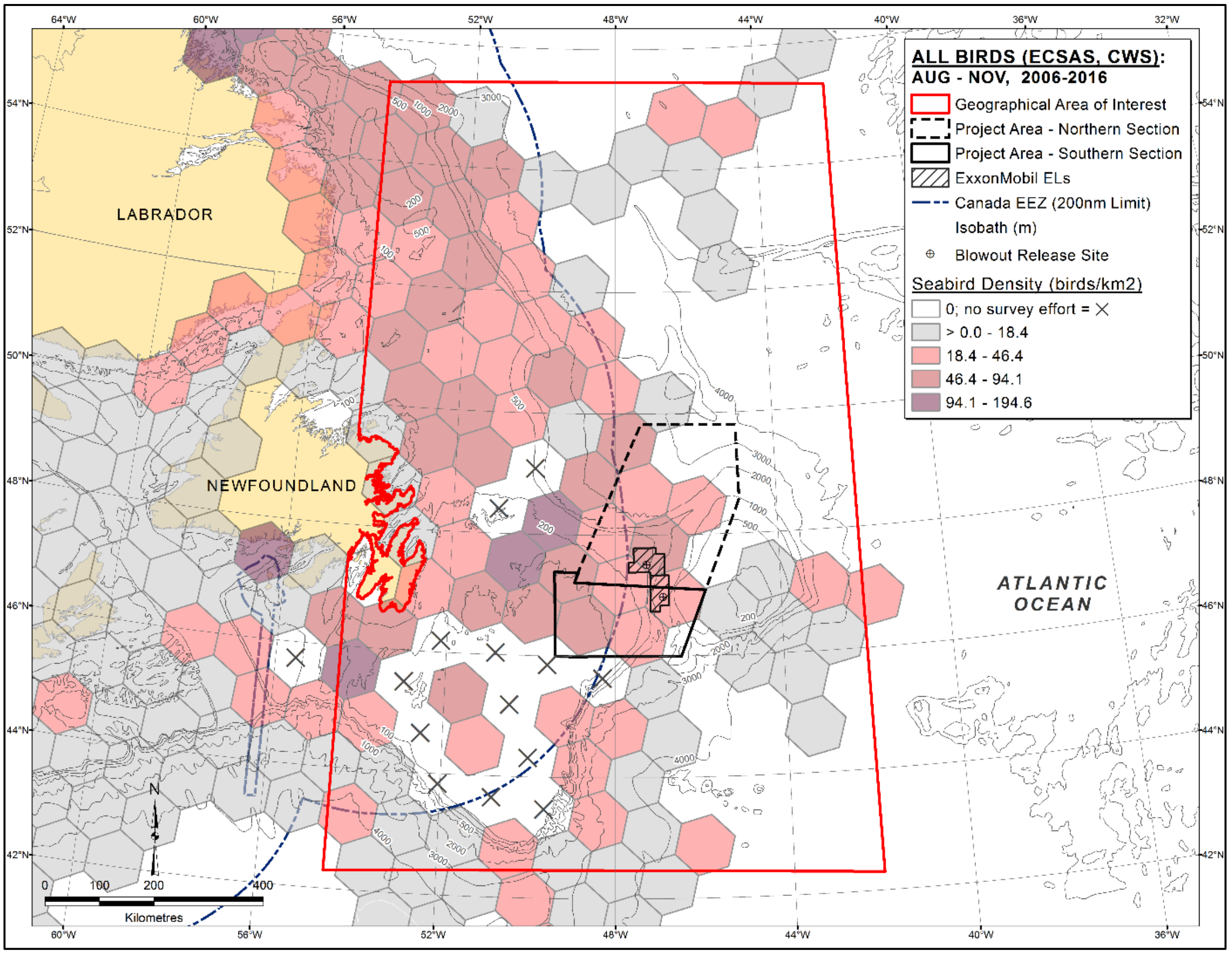
Source: Bolduc et al. (2018).

Figure 13. Seabird distribution and densities within the GAI during December–March 2006–2016.



Source: Bolduc et al. (2018).

Figure 14. Seabird distribution and densities within the GAI during April–July 2006–2016.



Source: Bolduc et al. (2018).

Figure 15. Seabird distribution and densities within the GAI during August–November 2006–2016.

4.2.2 Shorebirds and Waterfowl

Many species of shorebird pass through the GAI during migration (especially during the protracted fall migration from July–October) and Purple Sandpipers and small numbers of Ruddy Turnstones are present in the winter months (AMEC 2014). During migration shorebirds are widespread in appropriate habitat along the coastline. Some portions of the shoreline are particularly attractive to wintering Purple Sandpipers, such as the Mistaken Point area which has consistently held roughly 1% of the North American population (IBA Canada 2018).

Various waterfowl also occur along the Newfoundland shoreline section occurring within the GAI (e.g., Common Eider [*Somateria mollissima*], Harlequin Duck [*Histrionicus histrionicus*]).

4.2.3 Important Bird Areas

Important Bird Areas (IBAs) are sites of international significance to birds either because they support large congregations of birds, threatened species or species that are range or habitat restricted (IBA Canada 2018). They designated according to internationally agreed upon standards, but the sites are not necessarily protected by any level of government. In the GAI there are 10 IBAs (Table 10; Figure 16).

Table 10. Important Bird Areas Occurring within the SIMA GAI.

Important Bird Area	Reason for Designation	Key Species
Funk Island	Globally significant colonial seabird concentrations	Common Murre Northern Gannet
Wadham Islands and adjacent marine area	Globally significant colonial waterbird/seabird concentrations	Atlantic Puffin Common Eider
Cape Freels Coastline and Cabot Island	Continentally significant concentrations of waterbirds	Common Eider Waterbirds
Grates Point	Nationally significant concentrations of waterbirds	Common Eider
Baccalieu Island	Globally significant colonial seabird concentrations	Leach's Storm-Petrel Atlantic Puffin Black-legged Kittiwake Northern Gannet
Cape St. Francis	Continentally significant concentrations of congretatory species	Dovekie
Witless Bay Islands	Globally significant colonial seabird concentrations	Atlantic Puffin Common Murre Razorbill Black-legged Kittiwake Herring Gull Leach's Storm-Petrel
Mistaken Point	Globally significant concentrations of congretatory species	Common Eider Purple Sandpiper Manx Shearwater
Cape St. Mary's	Globally significant colonial seabird concentrations; continentally significant concentrations of congretatory species	Northern Gannet Black-legged Kittiwake Harlequin Duck
Placentia Bay	Globally significant concentrations of congretatory species	Shearwaters

4.2.4 Migratory Bird Species at Risk

Six species designated by COSEWIC as species at risk occur in the GAI: Barrow's Goldeneye, Harlequin Duck, Ivory Gull, Piping Plover, Red Knot and Red-necked Phalarope. The eastern population of Barrow's Goldeneye is considered Special Concern. One of the main wintering areas of this population is found along the eastern coast of Newfoundland, within the GAI (Robert et al. 2000). The eastern population of Harlequin Duck is also considered Special Concern. Harlequin Duck winters along the southern coast of the Avalon Peninsula and Cape St. Mary's is a known moulting site (Thomas and Robert 2001).

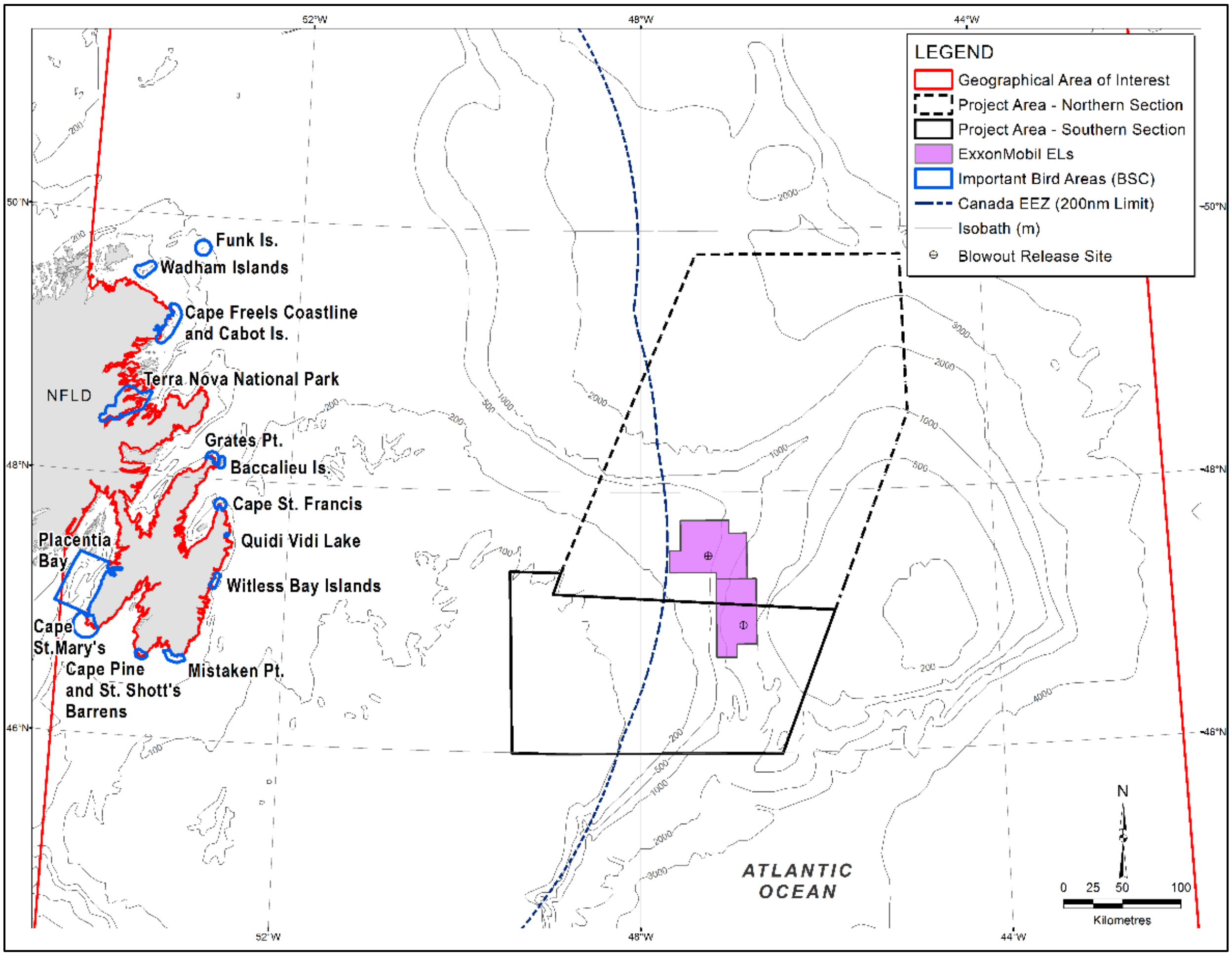


Figure 16. **Important Bird Areas along Shoreline Potentially Affected by Summer Blowout in EL1134.**

Ivory Gulls, considered Endangered by COSEWIC, breed in the High Arctic and winter in the pack ice or along the ice edge (COSEWIC 2006). A large portion of the Ivory Gull population winters in the Labrador Sea and some individuals occur farther south, extending into the GAI (Sikumiat 2008; AMEC 2014).

Piping Plovers are considered Endangered but are generally not found within the GAI. However, in 2013 one pair was found nesting at Deadman's Point Provincial Park on the Bonavista Peninsula (AMEC 2014). The *rufa* subspecies of Red Knot is considered Endangered by COSEWIC, and passes through the GAI during migration, and may occur in coastal areas (ECCC 2016; AMEC 2014).

Red-necked Phalaropes are considered a species of Special Concern by COSEWIC. They breed in the Arctic and low subarctic but during migration and winter they are primarily pelagic

(Rubega et al. 2000). They are recorded in the GAI in small numbers during migration, from April–October (Bolduc et al. 2018).

4.3 Marine Mammals

The Flemish Pass area, adjacent shelf/slope regions of the Grand Banks, and Orphan Basin provide important habitat for many marine mammal species. There are six species of mysticetes (blue, North Atlantic right, fin, sei, humpback, and minke whales), nine species of odontocetes (sperm, northern bottlenose, Sowerby's beaked, long-finned pilot, and killer whales; Atlantic-white sided, common, white-beaked dolphins; and harbour porpoise), and four species of seals (harp, hooded, harbour, and grey seals) that are known to regularly occur in the Project Area and surrounding GAI. Polar bears may occasionally occur in the northern GAI during periods when pack ice is present. While some species of marine mammals remain in the waters off Newfoundland year-round, many species arrive in the late spring and early summer and remain until the fall during which time they forage. Of particular relevance to this SIMA is that small numbers of harbour and grey seals are known to use haul-out sites along the coasts of the Avalon and Burin peninsulas. Detailed biological background information on marine mammals in the GAI is provided in Subsection 6.3 of ExxonMobil (2017).

Several marine mammal species are listed as Endangered (blue whale, North Atlantic right whale, northern bottlenose whale [Scotian Shelf population]) and Special Concern (fin whale, Sowerby's beaked whale) on Schedule 1 of *SARA*. Critical habitat has not been designated for these species in the GAI but it has been designated for North Atlantic right whales (Roseway Basin, Grand Manan Basin) and northern bottlenose whales (Gully, Shortland and Haldimand canyons) offshore Nova Scotia.

Note that spill response activities may require an application for an Authorization to Disturb a Marine Mammal (http://www.dfo-mpo.gc.ca/species-especes/mammals-mammiferes/section38/form-forme-eng.html).

4.4 Sea Turtles

Sea turtles are considered uncommon transients in the Project Area; however, two species regularly occur in low numbers in the GAI—leatherback sea turtles (*Dermochelys coriacea*) and loggerhead sea turtles (*Caretta caretta*). Both species are considered Endangered under *SARA* and by COSEWIC. Leatherback sea turtles are the most likely species of sea turtle to occur off eastern Newfoundland, primarily along the south coast where they migrate to forage primarily in summer. Critical habitat for leatherback turtles in Atlantic Canada has been proposed but not yet formally designated under *SARA* (DFO 2018e). One of the areas proposed as critical habitat occurs adjacent to the GAI in the western portion of Placentia Bay. There is less known about loggerhead sea turtles but this species undertakes a spring migration to Atlantic Canadian waters including the Grand Banks where they forage in the summer and fall, before returning south for the winter breeding season (COSEWIC 2010). Detailed biological background information on sea turtles in the GAI is provided in Subsection 6.3 of ExxonMobil (2017).

4.5 Fisheries

Fisheries within the GAI are described in Subsection 7.1 of the EIS (ExxonMobil 2017), Subsection 4.10 of the Labrador Shelf SEA (C-NLOPB 2008), Subsection 4.3.4 of the Eastern Newfoundland SEA (C-NLOPB 2014), and Subsection 3.3.1 of the South Newfoundland SEA (C-NLOPB 2010). Fisheries productivity within the Canadian 200-nm Exclusive Economic Zone (EEZ) is protected under the federal *Fisheries Act*. Benthos and groundfish beyond the EEZ are managed by the North Atlantic Fisheries Organization (NAFO). Fisheries are included as a ROC due to the cultural and economic importance of fishing activities within the GAI, and the potential for interaction with oil from the release scenario.

The GAI overlaps NAFO Div. 1F, 2J, and 3KLMNOPs, which are further subdivided into Unit Areas (UAs) (Table 11). The GAI also includes the entirety of the NAFO fishing footprint (see Subsection 7.1.5 of the EIS [ExxonMobil 2017]). Commercial fisheries are pursued year-round for some species, while others, such as snow crab, are harvested during specified seasons as per annual management decisions by DFO and NAFO (DFO 2018a; NAFO 2018a). The majority of harvest within the GAI occurs during spring and summer (see Subsection 7.1.4 *in* ExxonMobil 2017). Commercial fisheries species, harvest quantities and fishing gears used within the GAI during 2011–2015 are described in Subsections 7.1.3–7.1.7 and of the EIS (ExxonMobil 2017). Domestic shellfish, pelagic and groundfish commercial fisheries within the GAI during 2016 are summarized in Subsections 4.5.1 and 4.5.2. Aquaculture is discussed in Subsection 4.5.3.

Table 11. NAFO Divisions and Unit Areas entirely or partially within the GAI.

Division	Unit Area
1F	1F
2J	2Jc, 2Je, 2Jf, 2Jg, 2Ji, 2Jj, 2Jl, 2Jn
3K	3Ka, 3Kb, 3Kc, 3Kd, 3Ke, 3Kf, 3Kg, 3Kk, 3Kh, **3Ki**
3L	**3La**, **3Lb**, 3Lc, 3Ld, 3Le, **3Lf**, 3Lg, 3Lh, 3Li, **3Lj**, **3Lq**, 3Ls, 3Lr, 3Lt
3M	3Ma, 3Mb, 3Mc, 3Md, 3Mm
3N	3Na, 3Nb, 3Nc, 3Nd, 3Ne, 3Nf
3O	3Oa, 3Ob, 3Oc, 3Od, 3Oe
3Ps	**3PSc**, 3PSf, 3PSh

Note:
*Units in **bold text** include coastal Newfoundland components within the GAI.

4.5.1 Domestic Shrimp and Pelagic Commercial Fisheries

Inshore domestic shrimp and pelagic commercial fisheries within the GAI during 2016 included harvest locations within NAFO UAs 3Ki; 3La, 3Lb, 3Lf; and 3PSc. Harvested species included capelin, Atlantic herring, northern shrimp and bluefin tuna, with capelin and Atlantic herring accounting for the majority of catch weight and value. Most of the inshore commercial catch occurred during July (principally capelin) and to a lesser extent in December (Atlantic herring).

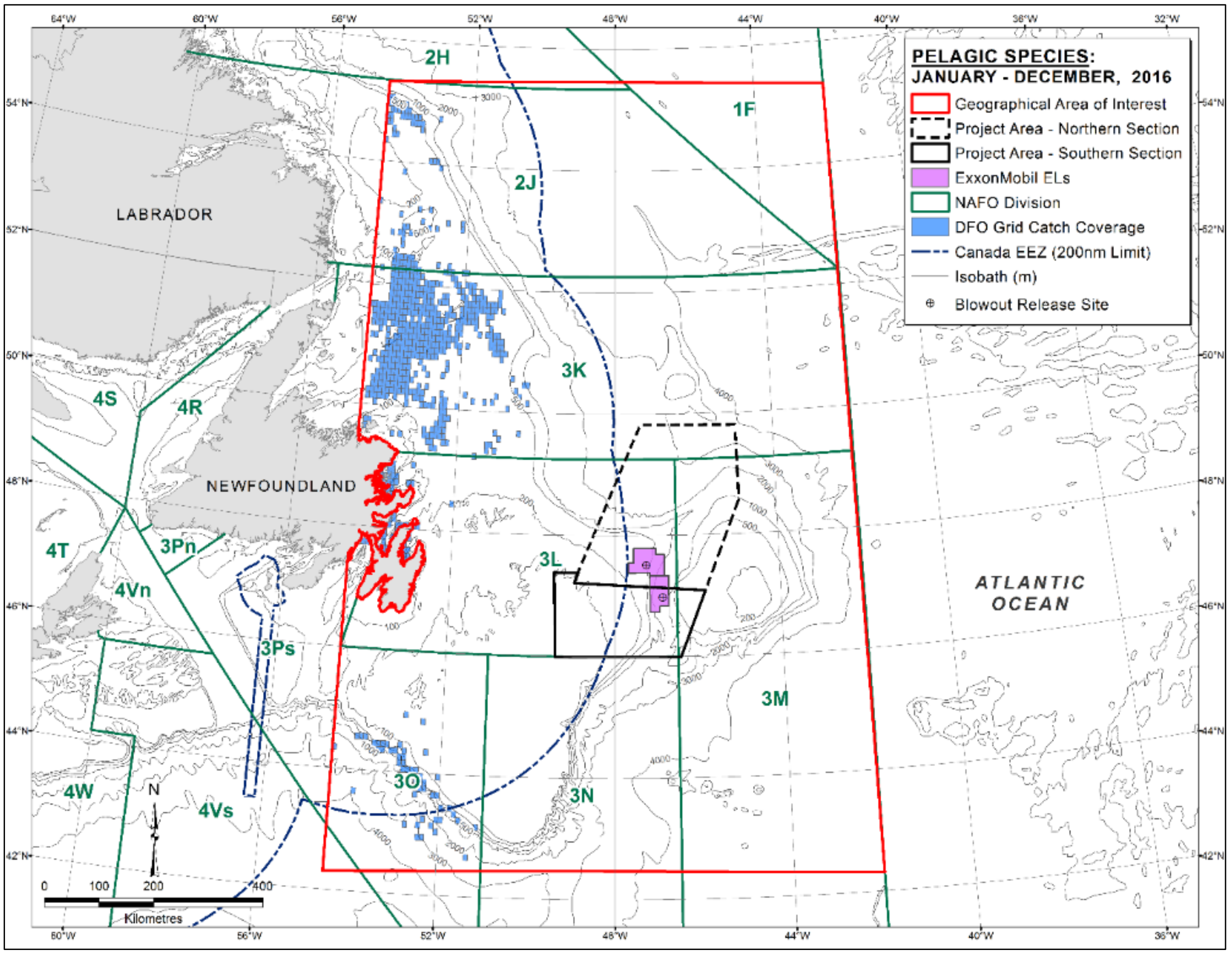
Inshore commercial harvest was mainly taken using mobile fishing gears, including beach and bar, tuck and purse seines for capelin and Atlantic herring, shrimp trawl for northern shrimp, and rod and reed (trolling) for bluefin tuna. Capelin were also caught using trap nets, a fixed gear. Virtually all of the inshore domestic pelagic catch was harvested by fishers from Newfoundland and Labrador, with a minor proportion of northern shrimp caught by Nova Scotian fishers.

Offshore domestic shrimp and pelagic commercial fisheries within the GAI during 2016 occurred within NAFO UAs 2Jc,e,f,i,n; 3Ka,b,c,d,e,f,g,h; 3Lc; and 3Oc,d,e. Commercial shrimp and pelagic harvests principally consisted of northern shrimp, followed by striped shrimp (*Pandalus montagui*), swordfish, mako shark, bigeye, bluefin and albacore tuna, Atlantic herring, mackerel and dolphinfish (mahi mahi; *Coryphaena hippurus*). Harvesting occurred during January–May and July–December, with the majority of catch taken during March, August and September and relatively little catch during December. Most of the offshore shrimp and pelagic commercial fisheries were conducted using mobile fishing gears, including shrimp trawls for northern and striped shrimp, and purse seines for Atlantic herring and mackerel. Longlines, a fixed gear, were used to harvest swordfishes, sharks, tunas and dolphinfishes. Approximately 75% of the domestic pelagic commercial harvest was taken by fishers from Newfoundland and Labrador, with the remainder harvested by fishers from Nova Scotia.

Domestic shrimp and pelagic commercial fisheries catch locations within the GAI during 2016 are shown in Figure 17.

4.5.2 Domestic Shellfish and Groundfish Commercial Fisheries

Inshore domestic shellfish and groundfish commercial fisheries within the GAI during 2016 included harvest locations within NAFO UAs 3Ki; 3La,b,f,j,q; and 3PSc. Since the establishment of the cod moratorium in 1992, other groundfish species have contributed a significant proportion of the total catch and crustacean fisheries such as snow crab and lobster have become highly valuable in Newfoundland (DFO 2019). In descending order of catch weight, harvested species included snow crab, Atlantic cod, American plaice, sea scallop, Greenland halibut, Iceland scallop, toad crab, skate, redfish, whelk, Atlantic halibut and winter flounder. Snow crab and Atlantic cod were the most valuable species harvested, followed by sea scallop, American plaice and Greenland halibut. Most of the inshore shellfish and groundfish catch was taken during April–June (predominantly snow crab), followed by July–September (mainly Atlantic cod). Fixed fishing gears were used to harvest the majority of inshore domestic catch, including gillnets, longlines, trap nets and pots. Mobile gears included baited hand lines and boat-based dredges. All of the inshore domestic shellfish and groundfish commercial catch was harvested by fishers from Newfoundland and Labrador.

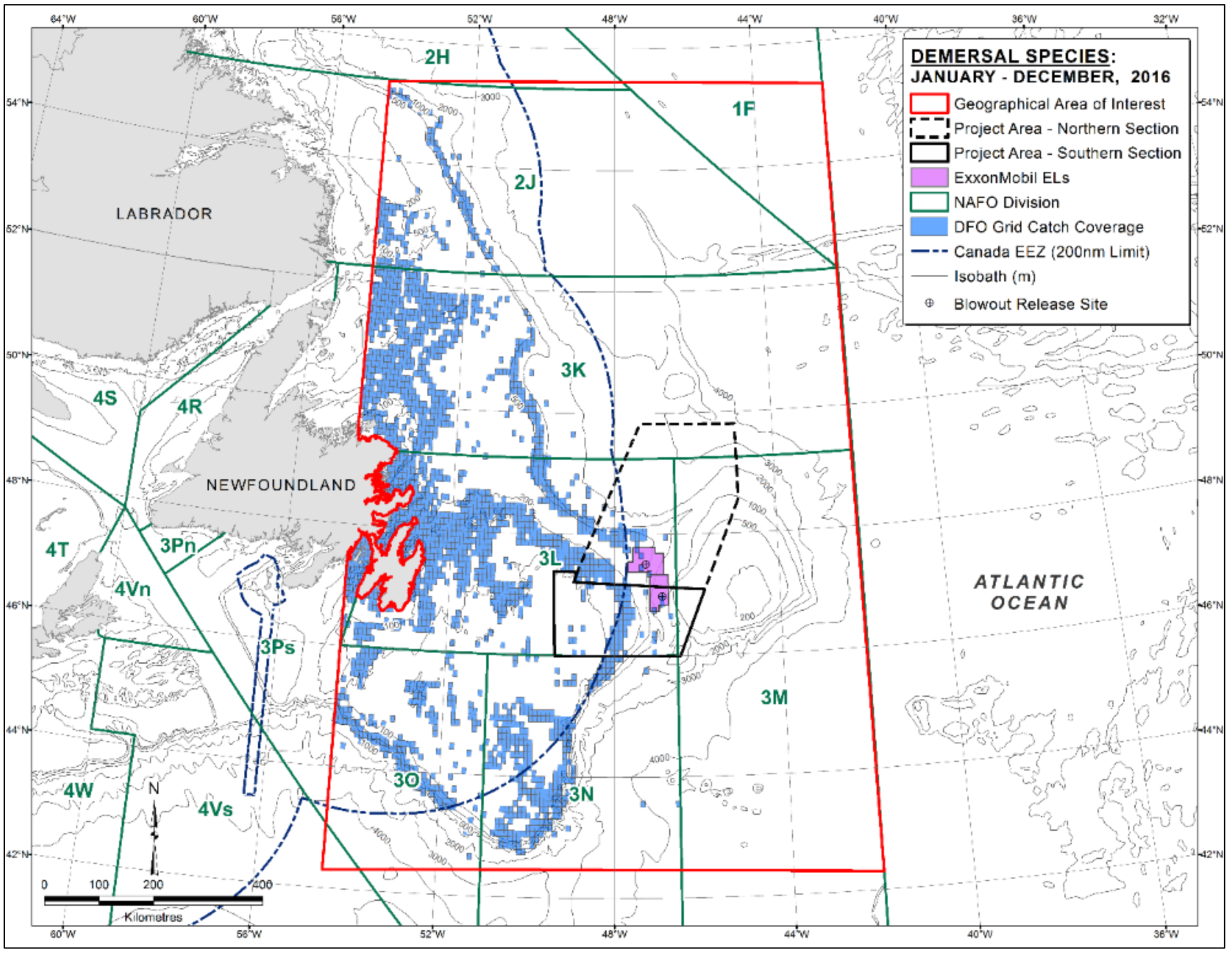


Source: DFO commercial landings database, 2016.

Figure 17. Domestic shrimp and pelagic commercial fisheries catch locations of all species within the GAI during 2016.

Offshore domestic shellfish and groundfish commercial fisheries within the GAI during 2016 occurred within NAFO UAs 2Jc,e,f,g,i,l,n,f; 3Ka,b,c,d,e,f,g,h; 3Lc,d,e,g,h,i,r,s,t; 3Na,b,c,d,e,f; 3Oa,b,c,d,e; and 3PSf. Snow crab comprised the majority of commercial shellfish/groundfish offshore harvests, followed in order of decreasing catch weight by Atlantic and Greenland halibut, yellowtail flounder, American plaice, Atlantic cod, redfish, witch flounder, white hake, Atlantic haddock, monkfish, Stimpson's surf clam, cockle, propeller clam, cusk, skates, pollock, roughhead grenadier, silver hake, wolffishes, and dogfishes. Commercial harvests for shellfish and groundfish species occurred throughout the full year, with the majority of catch taken during April–July, principally of snow crab. Fixed and mobile fishing each accounted for roughly half of the total catch, with fixed gears including gillnets, longlines and pots and mobile gears including stern bottom otter trawls and boat-based dredges. The majority of offshore shellfish and groundfish commercial catches were harvested by fishers from Newfoundland and Labrador, with relatively small portions of the total catch harvested by fishers from Nova Scotia and Quebec.

Domestic shellfish and groundfish commercial fisheries catch locations within the GAI during 2016 are shown in Figure 18.



Source: DFO commercial landings database, 2016.

Figure 18. **Domestic shellfish and groundfish commercial fisheries catch locations of all species within the GAI during 2016.**

4.5.3 Indigenous Fisheries

The five Indigenous Groups in Newfoundland and Labrador are as follow:

1. Nunatsiavut Government;
2. Innu Nation;
3. NunatuKavut Community Council;
4. Qalipu Mi'kmaq First Nation Band (QMFNB); and
5. Miawpukek First Nation (MFN).

There are two types of fisheries associated with the various Indigenous groups consulted during the preparation of the ExxonMobil EIS: (1) Food, Social and Ceremonial (FSC) fishing; and (2) Commercial-Communal fishing. The former typically includes the harvesting of various species in freshwater, estuarine and/or inshore waters (e.g., Atlantic salmon, American eel), while the latter relates more to the harvesting of various species in offshore waters (e.g., shrimp, Greenland halibut, snow crab cod, swordfish). Various Indigenous groups have been issued licenses by DFO that give them access to fishery resources in NAFO Divisions that overlap with the ExxonMobil SIMA GAI (see Subsection 7.3 in ExxonMobil 2017).

Two species of relatively high concern to the Indigenous groups are the Atlantic salmon and the American eel, two fishes that divide their life histories between freshwater and marine environments. Both species are important to the FSC fishery. Atlantic salmon spawn in freshwater and mature/feed in the marine environment while American eels spawn in the marine environment and mature/feed in freshwater systems. In both cases, migration between freshwater and the marine environment is necessary. There are telemetry data supporting Atlantic salmon and American eel presence in the offshore portion of the SIMA GAI, primarily for migration purposes but perhaps also for feeding and overwintering in the case of Atlantic salmon. Indigenous traditional knowledge is considered during scientific processes and management decisions (DFO 2019).

4.5.4 Aquaculture

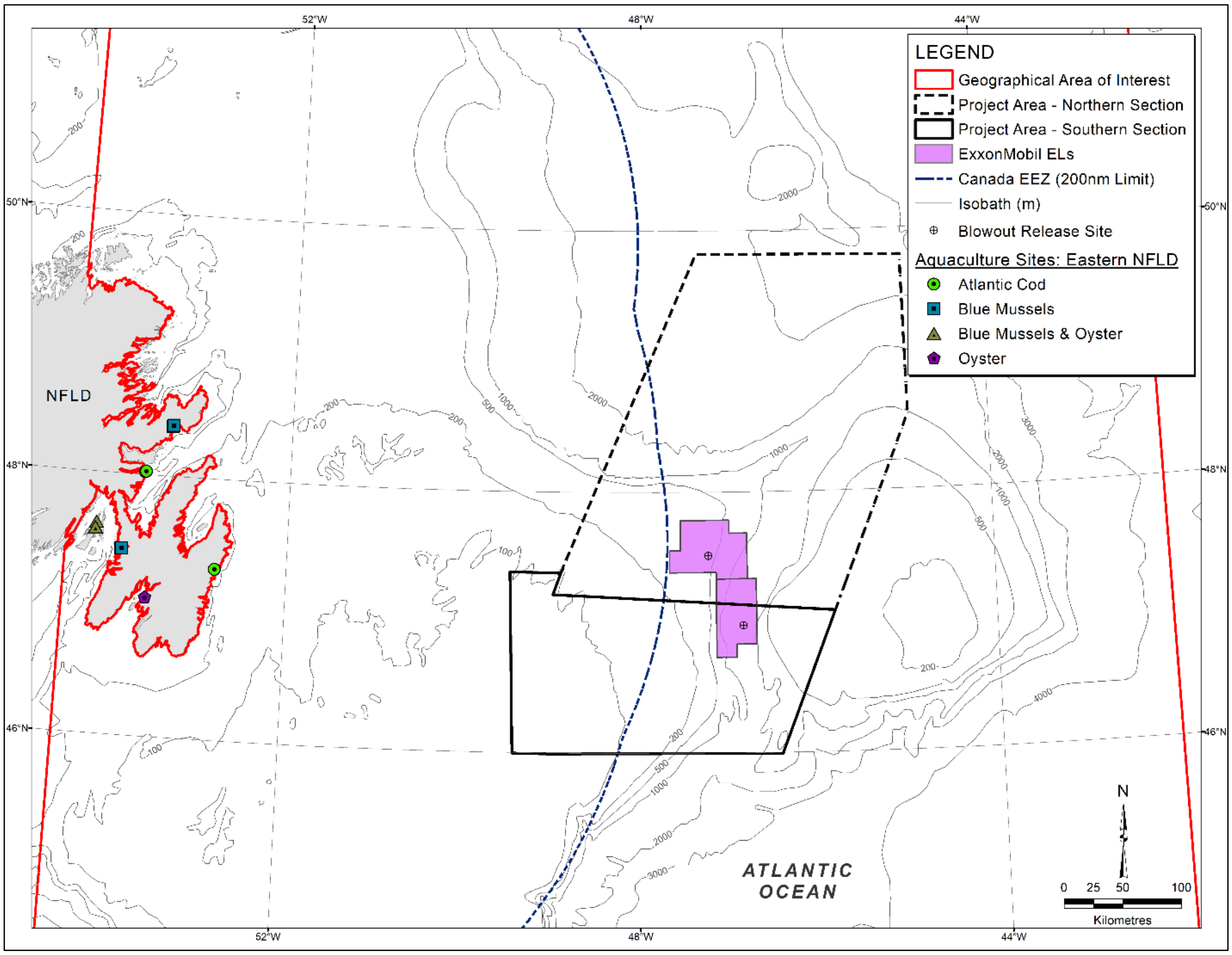
Aquaculture within the GAI is summarized in Subsection 7.1.9 of the EIS (ExxonMobil 2017) and Subsection 4.3.4.3 of the Eastern Newfoundland SEA (C-NLOPB 2014). The main species farmed in NL include Atlantic salmon, steelhead trout (*Onchorhynchus mykiss*) and blue mussel (*Mytilus edulis*). After reaching peak production during 2016, aquaculture production in NL declined by 24% during 2017, from 28,622 mt and $276 million to 21,712 mt and ~$221 million, respectively (FLR 2018). This was largely due to decreased salmonid production (FLR 2018). However, progressive growth in the industry is anticipated to lead to increased production above the 2016 peak by 2019, particularly for salmonids (FLR 2018). By 2022, salmonid and blue mussel production levels are expected to exceed 50,000 mt and 10,000 mt, respectively (FLR 2018). There are 10 coastal licensed aquaculture sites within the GAI that could interact with the hypothetical release scenario (Table 12 and Figure 19). There are no offshore aquaculture sites within the GAI.

Table 12. Licensed aquaculture sites within the GAI that could be affected by the hypothetical release scenario.

Operator	Location	Species Farmed
Claude Seward and Valerie Johnson (Gooseberry Cove Cod)	Ship Cove, Heart’s Ease Inlet, Trinity Bay Square Cliff, Heart’s Ease Inlet, Trinity Bay	Atlantic Cod

Shells & Fins Inc.	Cap Cove, Lockston, Trinity Bay Northwest Arm, Trinity Bay	Blue Mussel
Merasheen Mussel Farms Inc.	Merasheen Island, Placentia Bay Big South West Cove, Merasheen Island, Placentia Bay	Blue Mussel Oyster
Sapphire Sea Farms Ltd.	Bay Bulls	Atlantic Cod
HSF Ocean Products Ltd.	O'Donnell's, St. Mary's Bay	Oyster

Sources: FLR (2015); T. Budgell, pers. comm. 2016 *in* ExxonMobil (2017).



Source: FLR (2015).

Figure 19. **Licensed aquaculture sites within the GAI that could be affected by the hypothetical release scenario.**

5.0 Spill Modelling

5.1 Background and Approach

Spill modelling relevant to the ExxonMobil Eastern Newfoundland Offshore Exploration Drilling Project was performed as part of the EIS to evaluate the effects of potential spill scenarios. Spill modelling for hydrocarbon releases in EL1134 and EL1135 was conducted separately, in 2017 for EL1135 (RPS 2017) and in 2018 for EL1134 (RPS 2018). The scope of the modelling described in the EIS for an unmitigated subsea blowout scenario included several factors:

- a prediction of the movement and weathering of the oil originating from two different release sites using spatial wind data, current data and specific hydrocarbon properties;
- seasonal variation in the modelled impacts during summer and winter conditions;
- modelling to predict the probability and areal extent of oiling above threshold levels at the sea surface, on shorelines and in the water column for each scenario;
- modelling to show the single spill trajectory with the highest amount of oil reaching the shore; and
- a calculation of the maximum amount of shoreline oiling.

The hypothetical release scenarios were simulated using the OILMAPDeep blowout model and the SIMAP oil trajectory and fate model. OILMAPDeep was used to define the near-field dynamics of the subsurface blowout plume, which in turn was used to initialize the far-field modelling conducted in SIMAP. Two approaches were used during the spill modelling: (1) stochastic; and (2) deterministic. More detailed information related to the spill modelling approach is contained in Subsections 2.2 of RPS (2017, 2018).

5.1.1 Stochastic Approach

The stochastic approach was used to determine the probability footprints of areas that are at increased risk of exposure to oil based on the potential variability of meteorological and hydrodynamic conditions during and after a release. The stochastic approach is a statistical analysis of results generated from many different individual trajectories of the same release scenario (171 runs for EL1134, and 119 runs for EL1135). Each trajectory starts at a randomized time from a relatively long-term window. For the stochastic modelling associated with EL1134 and EL1135, individual trajectory start dates were selected randomly every 14 days throughout the window of environmental data coverage to ensure that these data were adequately sampled. Results of the stochastic approach provide the probable behavior of potential releases, including the areas associated with probability of oil exposure at some time during the or after a release, and the shortest time required for oil to reach any point within the areas predicted to be exposed above a specified threshold.

5.1.2 Deterministic Approach

Individual trajectories of interest are identified and selected from the stochastic ensemble of results for the deterministic analysis. The deterministic trajectory and fate simulations provide an estimate of the oil's fate and transport through the environment as well as its physical and chemical behavior for a specific set of environmental conditions. While the stochastic analysis provides insight into the probable behavior of oil spills given historic wind and current data for the geographical area of interest, the deterministic analysis provides individual trajectory oil weathering information, expected concentrations and thicknesses of oil contamination, mass balance, and other information related to a single release at a given location and time. Results of the deterministic simulations provide a history of the fate and weathering of oil over the duration of the release (i.e., mass balance) expressed as the percentage of released oil on the water surface, on the shoreline, evaporated, entrained in the water column, and degraded. In addition, cumulative footprints of the individual trajectories over the course of the entire modeling duration will depict the cumulative path of floating surface oil, mass of shoreline oil, and the maximum concentration of dissolved hydrocarbons in the water column at any point in time.

5.1.3 Spill Scenarios

For the stochastic modelling, 'Summer' and 'Winter' seasons represent mean weather conditions for two periods of time: (1) May–October for 'Summer'; and (2) November–April for 'Winter'. Stochastic modelling for EL1134 included 80 winter and 91 summer individual simulations within each stochastic scenario, while modelling for EL1135 included 55 winter and 64 summer individual simulations within each stochastic scenario. Deterministic modelling was derived from stochastic simulations that produced the worst environmental impacts from an emergency response point of view and analyzed in the EIS as an unmitigated spill result.

For the ExxonMobil Flemish Pass SIMA, the unmitigated deterministic simulations represent a natural attenuation unmitigated spill scenario for both summer and winter at two well locations. Thus, the four spill scenarios considered are as follow:

- EL1134 - Summer
- EL1134 - Winter
- EL1135 - Summer
- EL1135 - Winter

All four scenarios are characterized by a 113-day release duration over a modeling period of 160 days.

Note that further deterministic modelling was performed for EL1135 using ASD only, and combined ASD/SSDI response scenarios. No modelling that included the use of dispersants was conducted for EL1134.

5.2 Modelling Results

As mentioned above, two locations (one within each of EL1134 and EL1135) were selected for SIMA modelling to evaluate a WCCD scenario for the proposed well drilling locations shown in Figure 7.

To facilitate a comparison of environmental impacts associated with the different locations, seasons, and spill scenarios, 'EL1134 - Summer' was selected as the primary scenario for analysis in this SIMA, after discussion with ExxonMobil (C. Hollett, Hebron E&R Advisor II, ExxonMobil Canada Ltd., pers. comm., September 2018) and the RPS modeller (M. Horn, Director of Science, RPS, pers. comm., September 2018). The EL1134 - Summer scenario yielded the most challenging spill response conditions based on initial time to landfall, and extent and duration of oil exposure to ROCs. In addition, ROCs are more susceptible during the summer given the increased level of plankton and invertebrate/fish eggs and larvae in the water column, the increased numbers of marine mammals and sea turtles feeding in the area, and the considerable effort in the commercial fisheries.

The other three spill scenarios (i.e., EL1134 -Winter, EL1135-Summer, and EL1135 – Winter) are briefly compared to 'EL1134 - Summer' in terms of alternate scenario risk ratings in Subsection 6.4.7.

5.2.1 EL1134 - Summer

As indicated above, this modelling scenario is characterized by a 113-day release duration and a modeling period of 160-day. All details associated with the spill modelling for a release location within EL1134 are available in RPS (2018).

5.2.1.1 Thickness of Crude Oil on Sea Surface

The areas associated with the probability of surface oil thickness exceeding 0.04 µm during a summer subsea blowout within EL1134 are indicated in Figure 4-4 and Table 4-1 of RPS (2018). The predicted areas of the ocean surface with oil thickness exceeding threshold for 1%, 10% and 90% probability contours are 3,402,000 km^2, 2,488,000 km^2, and 1,390,000 km^2, respectively.

Figure 4-22 of RPS (2018) indicates the deterministic modelling results for surface oil thickness associated with the representative worst case for shoreline contact resulting from a 113-day subsurface blowout in EL1134. The plot is dominated by two ranges of surface oil thickness: (1) 1–10 µm, and (2) 10–100 µm. The predominant thickness range related to improbable shoreline contact is 1–10 µm. Note that the ecological and socio-economic thresholds for the thickness of crude at the ocean's surface are 10 µm and 0.04 µm, respectively.

5.2.1.2 Dissolved Hydrocarbons in Water Column

The areas associated with the probability of dissolved hydrocarbons in the water column exceeding 1 µg/L (i.e., 1 ppb) during a summer subsea blowout within EL1134 are indicated in Figure 4-10 and Table 4-1 of RPS (2018). The predicted areas of the ocean with dissolved hydrocarbons in the water column exceeding threshold for 1%, 10% and 90% probability contours are 2,475,000 km^2, 1,835,000 km^2, and 752,400 km^2, respectively.

Figure 4-23 of RPS (2018) indicates the deterministic modelling results for maximum concentrations of dissolved hydrocarbons (i.e., PAHs) at any depth in the water column associated with the representative worst case for shoreline contact resulting from a 113-day subsurface blowout in EL1134. While the predicted maximum concentrations in the immediate area of the blowout range from 50–150 µg/L, most of the plotted maximum concentrations range between 1 and 50 µg/L. Note that the ecological threshold for concentrations of dissolved hydrocarbons in the water column is 1 µg/L (i.e., 1 ppb) (see Table 2-2 in RPS 2018).

Figure 4-24 of RPS (2018) indicates the deterministic modelling results for the maximum total hydrocarbon concentrations (THC) at any depth in the water column associated with the representative worst case for shoreline contact resulting from a 113-day subsurface blowout in EL1134. The predominant range of maximum THC at any depth in the water column is ≤50 µg/L. Higher predicted maximum concentrations of THC in the water column are evident for areas more proximate to the release location in EL1134. Note that the ecological threshold for concentrations of THC in the water column is 100 µg/L (i.e., 100 ppb) (see Table 2-2 in RPS 2018).

5.2.1.3 Amount of Crude Oil on Shoreline

The areas associated with the probability of the amount of crude oil on the shoreline exceeding 1 g/m^2 during a summer subsea blowout within EL1134 are indicated in Figure 4-16 and Table 4-1 of RPS (2018). The predicted areas of shoreline with the amount of crude oil exceeding threshold for 1–5% and 5–15% probability ranges are 847 km and 761 km, respectively.

Figure 4-25 of RPS (2018) indicates the deterministic modelling results for the THC on the shore and seafloor sediment associated with the representative worst case for shoreline contact resulting from a 113-day subsurface blowout in EL1134. With respect to shoreline, the predominant predicted amounts of crude at shore are 100–500 g/m^2, and ≤0.5 g/m^2 for seafloor sediment. Note that the ecological and socio-economic thresholds for the amount of crude oil on shoreline or seafloor sediment is 100 g/m^2 and 1 g/m^2, respectively (see Table 2-2 in RPS 2018).

5.2.1.4 Mass Balance Plot

The mass balance plot of the scenario for shoreline contact resulting from a 113-day subsurface blowout within EL1134 after 160 days of model run indicates about 32% of the crude evaporating into the atmosphere, <1% on shore, ~10% remaining on surface, ~2% entrained in the water column, ~38% degraded, and ~18% outside of the modelling grid (see Figure 4-21 in RPS 2018).

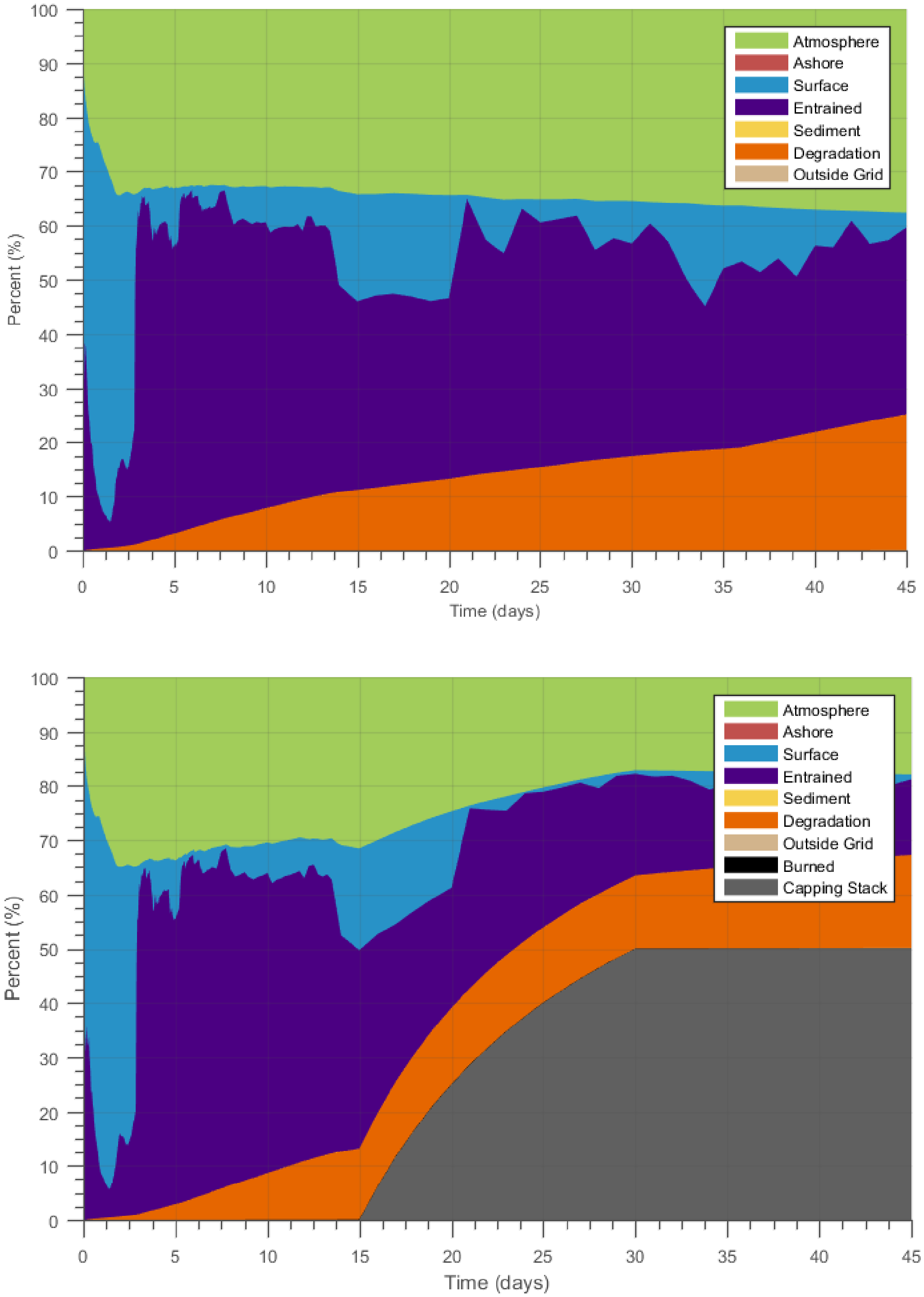


Figure 5.5-1: Mass balance predictions of the 95th percentile average surface oil thickness case for the unmitigated 30-day blowout at EL 1135 (top) and the same mitigated scenario with response options (bottom).

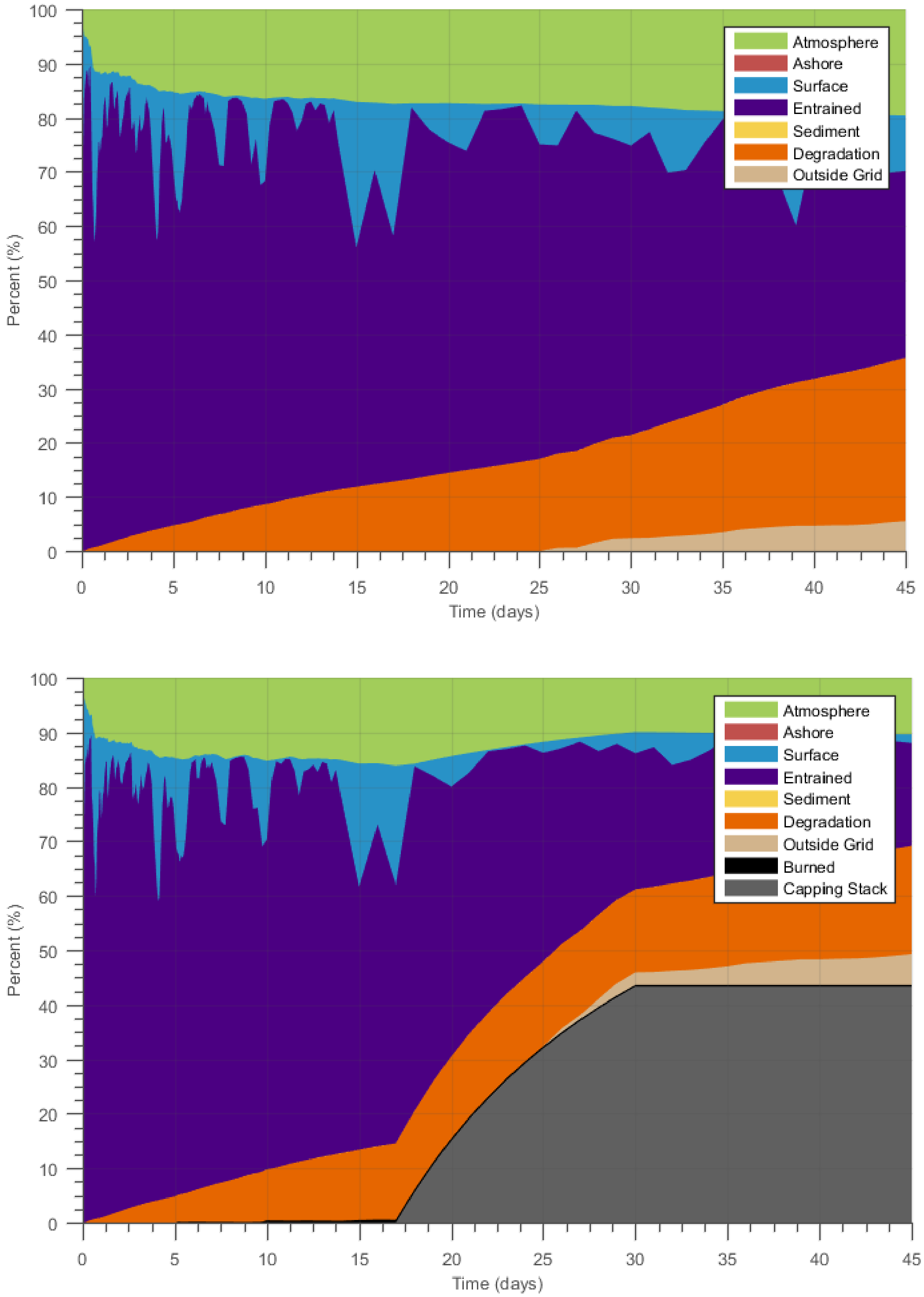


Figure 5.5-2: Mass balance predictions of the 95th percentile average surface oil thickness case for the unmitigated 30-day blowout at EL 1137 (top) and the same mitigated scenario with response options (bottom).

5.2.1.5 Rationale for Selection of EL1134-Summer as Primary Scenario for SIMA Analysis

Comparison of stochastic results generated by seasonal spill modelling in EL1134 with those associated with modelling in EL1135 indicates that a subsea blowout in EL1134 would potentially result in the worst-case scenario compared to a subsea blowout in EL1135. This pertains to all three variables; surface oil thickness, dissolved hydrocarbons in the water column, and the amount of oil on the shoreline (Table 13).

Table 13. Comparison of stochastic modelling results by location and season.

Season	Probability Contour	Area of Ocean with Surface Oil Thickness >0.04 µm		Area of Ocean with Water Column TDH* >1 g/m^2		Probability Range	Area of Shoreline Oil >1 g/m^2	
		EL1134	EL1135	EL1134	EL1135		EL1134	EL1135
Summer	1%	3,402,000	1,341,000	2,475,000	153,700	1–5%	847	205
	10%	2,488,000	560,400	1,835,000	73,170	5–15%	761	-
	90%	1,394,000	18,370	752,400	3,123	15–25%	-	-
Winter	1%	3,528,000	1,406,000	2,678,000	157,000	1–5%	1,859	175
	10%	2,885,000	623,300	2,047,000	88,200	5–15%	1,678	-
	90%	1,286,000	23,730	714,200	5,686	15–25%	107	-

Note:
*TDH denotes ‘total dissolved hydrocarbons’.

The modelling for EL1134 also indicates that this scenario has higher average and maximum probabilities of shoreline contamination and lower minimum times for oil reaching shore than EL1135. Note that EL1135 modelling showed a lower maximum time for oil reaching the shoreline than the EL1134 modelling.

Comparison of summer and winter modelling results for EL1134 indicates that there are potentially slightly greater ocean and shoreline areas with exceedances of all three variable thresholds in the winter scenario. The EL1134 modelling also indicates higher average and maximum probabilities, and a lower minimum time for oil to reach the shoreline for the winter scenario. However, considering the minimal differences between winter and summer modelling results, the higher susceptibility of ROC to a summer blowout, and the considerably higher commercial fishery activity during the summer period, the ‘EL1134-Summer’ scenario was selected as the primary one for SIMA analysis.

6.0 Risk Assessment of Response Options

This section provides discussion and ultimately the Comparative Risk Matrix in relation to assessment of the response options.

6.1 Potential Risks for Natural Attenuation

The ExxonMobil EIS (ExxonMobil 2017) describes the risks of mortality, injury or habitat quality for resources due to an unmitigated subsea blowout oil spill. The potential exposure pathways, toxicity and effects of an unmitigated spill associated with various resources are briefly summarized below. More detailed information is provided in the EIS (Subsections 15.5.1–15.5.6 in ExxonMobil 2017).

The following sections provide brief summaries of the potential effects of exposure to crude oil on the various ROCs and ROC constituents identified in Section 4.0.

6.1.1 Fish and Fish Habitat

Risks for fish and fish habitats exposed to an oil spill could include the following:

- reduction of water and/or sediment quality;
- reduction of primary productivity (phytoplankton and zooplankton) due to lower air-water gas exchanges and light penetration;
- disruption in food web dynamics;
- lethal and sub-lethal effects from acute or chronic exposure to water-soluble fractions of hydrocarbons; and
- reduced oxygen levels associated with increased bacterial activity (i.e., biodegradation).

Thick, buoyant oil slicks decrease light penetration into surface waters which inhibits photosynthesis by phytoplankton and air-sea gas exchange (Gonzalez et al 2009 *in* Abbriano et al 2011). Greater concentrations of total hydrocarbons in the surface mixed layer following a subsea blowout could result in higher mortalities and sub-lethal effects on fish and invertebrate eggs and larvae, and juvenile fishes. If dissolved hydrocarbons are transported towards inshore waters, residual effects of exposure to them on various stages of fish and invertebrate species could potentially remain sub-lethal and/or lethal.

In the event of a blowout scenario, there would likely be a temporary decline in the abundance of phytoplankton in the immediate area of the spill. While some zooplankton (i.e., those with higher motility) might be able to avoid exposure to the dissolved hydrocarbons (Seuront 2010), others would not.

Algae, considered a component of fish habitat, would be most susceptible to exposure to hydrocarbons should oil reach the shoreline (i.e., intertidal and shallow subtidal zones) due to its immobility. Capelin spawning beaches along the Newfoundland shoreline might also be susceptible to exposure to oil. In addition to potential effects of direct contact between capelin eggs/larvae and spilled oil, presence of oil on the beach could result in reduced oxygen levels which also could potentially affect the capelin eggs and larvae.

Following the DWH spill, it was observed that concentrations of alkanes and PAHs in oiled saltmarshes decreased significantly, possibly due to microbial biodegradation. PAHs are extremely toxic to marine plants and animals and are a minor constituent of crude oils, such as the oil released during the DWH spill. Microbial oil biodegradation coverts PAHs into useable biomass, carbon dioxide, and hydrogen, usually under aerobic conditions. Anaerobic degradation of petroleum hydrocarbons does occur but at a much slower rate. The microbial community require additional elements such as nitrates, phosphates, and iron, which are limiting factors to the biodegradation process (Atlas and Hazen 2011).This process tends to be enhanced by higher water temperatures (Beazley et al 2012). Given an increase in bacterial abundance following the spill and an accompanying reduction of oxygen, biodegradation may have caused hypoxic conditions in certain parts of the water column. Hypoxia has been shown to enhance the toxicity of PAHs in fish, for example altering gene expression, abnormal body functions, and altered growth (Dasgupta et al. 2015).

Coastal and offshore sensitive fish habitat areas occurring within the GAI are shown in Figures 8 and 9, respectively, in Section 4.0 of this SIMA. Proposed critical habitat areas for northern and spotted wolffishes, both being Species at Risk, are shown in Figures 10 and 11 in Section 4.0.

6.1.2 Migratory Birds

Aquatic migratory birds are among the most vulnerable and visible species to be affected by oil spills. Risk of adverse effects to birds exposed to oil can occur through three main pathways: (1) external exposure to oil (resulting in coating of oil on feathers); (2) inhalation of particulate oil and volatile hydrocarbons; and (3) ingestion of oil through preening or oiled prey.

Exposure to hydrocarbons frequently leads to hypothermia and deaths of affected marine birds. Although some may survive these immediate effects, long-term physiological changes may eventually result in lower reproductive rates or premature death. While oil is degraded by natural weathering processes (Payne et al. 1991), it is not clear how its degradation affects toxicity to seabirds (see Leighton et al. 1985; Leighton 1993; Stubblefield et al. 1995a,b).

In 1995, the effect of naturally weathered *Exxon Valdez* crude on the Mallard Duck (*Anas platyrhynchos*) was assessed, noting the occurrence of deleterious effects only at the highest concentrations. This suggested that weathered oil was substantially less toxic to Mallard Ducks and their developing embryos than fresh oil (Stubblefield et al. 1995). Sub-lethal effects of hydrocarbons ingested by marine birds may affect their reproductive rates or survival rates (Fingas 2015). Sub-lethal effects could persist for years, depending on generation times of affected species and the persistence of spilled hydrocarbons.

Adult marine birds foraging offshore to provide for their young could become oiled while at sea and subsequently transfer hydrocarbons back to shore. This could contaminate their eggs or nestlings, and cause embryo or nestling mortality. While the survival rate for oiled birds typically depends on the extent of oiling, the survival rate for heavily oiled birds is low (French-McCay 2009).

The chance of lethal effects of exposure to oil on birds is primarily dependent on the probability of exposure, which is influenced by bird behaviours such as time spent in contact with the water in the open ocean and along the shoreline, and avoidance behavior (French-McCay 2009).

Figures 13–15 in Section 4.0 show the seabird distributions and densities within the GAI during 2006–2016. The locations of major seabird colonies and IBAs that occur within the GAI are shown in Figures 12 and 16, respectively.

6.1.3 Marine Mammals

Risk to marine mammals exposed to surface oil could occur through three main exposure pathways: (1) external coatings of oil (e.g., interaction with surface slicks when animals surface for air); (2) inhalation of aerosols of particulate oil and hydrocarbons; and (3) and ingestion of contaminated prey (Lee et al. 2015).

Direct contact with surface oil could cause fouling in fur-bearing marine mammals such as seals, thereby reducing thermoregulation abilities (Kooyman et al. 1977). However, hypothermia may be offset to a degree by thick layers of blubber (Lee et al. 2015). Most marine mammals could withstand some physical oiling without toxic or hypothermic effects. Whales and seals maintain core body temperature by the existence of blubber which is not affected by a covering of oil. Hypothermia is more probable for young seal pups covered in oil because the blubber layer takes several months to develop to the stage where there it is sufficient to maintain body temperature.

In some cases, hydrocarbon exposure from the DWH spill inflicted internal tissue and organ damage to multiple marine mammal species including dolphins, whales, and the West Indian manatee (*Trichechus mantus*) which subsequently was reported to cause reproductive failure, adrenal disease, lung disease, liver failure, anemia, and mortality (Beresford et al. 2019).

The extent of the potential effects depends on how the spill and marine mammal distributions overlap spatially and temporally. For this SIMA, a 10 μm thick layer of oil on water is used as the threshold concentration for potential lethal effects on marine mammals (French et al. 1996; French-McCay and Rowe 2004; French-McCay 2009). When marine mammals congregate in high numbers, there is potential for higher impact.

Very little is known about the impacts of exposure to low concentrations of dispersed oil in the water column on marine mammals. While this is clearly a consideration, it is assumed that the exposure to dispersed oil in the water column would be less of a concern than physical oiling of marine mammals at surface.

6.1.4 Sea Turtles

Sea turtles are susceptible to effects from exposure to oil and dispersants during all life stages. As turtles must surface to breathe, they may be exposed to oil and dispersants on the surface and subsequently inhale vapours (Vander Zanden et al. 2016).

Exposure pathways for effects on sea turtles are the same as those associated with marine mammals. It is unknown whether sea turtles can detect oil spills or not, but evidence suggests that they do not avoid oil at sea (Gramentz 1988; Milton et al. 2010). Sea turtles exposed to oil during experimentation have shown a limited ability to avoid oil (Vargo et al. 1986) and petroleum fumes (Milton et al. 2010).

The extent of the potential effects of a subsea well blowout depends on how the distribution of the spill and sea turtles overlap spatially and temporally. There are few studies related to the effects of oil exposure on sea turtles, and mortality thresholds are often based on studies involving other species (e.g., marine mammals, marine birds) that may have different life stage exposure probabilities and sensitivities. As with marine mammals, a 10 μm thick layer of oil on water is used as the threshold concentration for potentially lethal effects on sea turtles (French et al. 1996; French-McCay and Rowe 2004; French-McCay 2009).

Sea turtles are vulnerable to oil and dispersants at all life stages. As turtles must surface to breathe, they may be exposed to oil slicks and dispersants on the surface and may inhale vapours (Vander Zanden et al 2016). During the DWH spill, the habitat of the floating algae species *Sargassum* was reduced by over 20 % which is a key food source and refuge area for juvenile sea turtles. Analysis of bile samples from oiled sea turtles during the DWH spill confirmed internal exposure and absorption and metabolism of PAHs (Ylitalo et al. 2017). If oil from a spill makes landfall, turtle eggs and hatchlings will also be at risk. Vander Zanden et al. (2016) found that sea turtles within the area of the DWH spill failed to leave the oiled area and instead continued to forage, increasing their chronic exposure to oil and the associated dispersants.

In addition to potential risk of oil exposure, response activities to the DWH spill (e.g., boat traffic, dredging, clean-up activities) severely disrupted sea turtle nesting behavior due to an increase of personnel, vehicles, and lighting on the beaches. It has been estimated that over 35,000 hatchlings were injured by the DWH response activities (Beresford et al. 2019).

6.1.5 Fisheries

The subsea oil spill scenarios considered in this assessment could result in effects on the availability of fisheries resources, access to fisheries resources, fouling of fishing or cultivation gear, and market perception. Hydrocarbons could reach active fishing areas within the ExxonMobil SIMA GAI where harvesting is more concentrated. Under some circumstances, oil could reach coastal locations, potentially interacting with nearshore fisheries and aquaculture operations. As indicated in the EIS (ExxonMobil 2017), free-swimming adult fishes rarely suffer long-term damage from oil spills, primarily due to a fish's ability to actively avoid an area contaminated by oil. Sedentary species, such as edible seaweeds and shellfish, are particularly sensitive to oiling due to their inability to move away from a contaminated area (ITOPF 2011).

Effects on fisheries resources could vary depending on the spill location, timing, and the amount of spilled oil that reaches a fisheries resource. In addition, changes in harvesting can be due to other factors, such as natural fluctuations in target species populations, variation in fishing effort, climatic effects, and/or contamination from other sources. These other factors can sometimes make it difficult to assess the direct implications of an oil spill on fisheries resources (ITOPF 2011).

The distributions of domestic shrimp/pelagic and shellfish/groundfish commercial fishery harvesting during 2016 within the GAI are shown in Figures 17 and 18, respectively. Locations of nearshore licensed aquaculture sites currently listed within the GAI are shown in Figure 19 in Section 4.0.

Probably the greatest effect of a blowout on the fisheries would be on public perception. Just the idea that fishery target species are tainted by an oil spill can have significant effect on any desire to consume the invertebrates and fishes involved. Other potential effects of an oil spill include gear fouling and loss of access to fishing grounds.

6.1.6 Special Areas

Special Areas could be compromised as a result of a subsea blowout for the same reasons provided above for fish and fish habitat, migratory birds, marine mammals and sea turtles. Which aspects of a Tier 3 spill potentially causing the most effects on a Special Area depends on the attributes that make it a Special Area. For example, if an area is deemed to be a Special Area because of high concentrations of ichthyoplankton, then dissolved hydrocarbons in the water column would be most relevant to that area. For areas deemed to be Special Areas because of high concentrations of migratory seabirds in one area and inshore critical nursey habitat within another area, the aspects of a spill most relevant to these areas would likely be thickness of surface oil and oil contact with shore, respectively.

The release location for the 'EL1134-Summer' spill scenario is located within one of the coral/sponge closure areas and the NW Atlantic EBSA known as 'Slopes of Flemish Cap and Grand Bank' (see Figure 9 in Section 4.0). Numerous other coral/sponge closure areas and the PB-GB EBSA known as the 'Northeast Slope' are also located relatively close to the spill release location (see Figure 9). The Northeast Slope EBSA is characterized by concentrations of spotted wolffish and Greenland halibut in the spring and is thought to be an important feeding area for marine mammals. Proposed critical habitat identified for the fish Species at Risk spotted wolffish and northern wolfish occurs within 100–150 km of the spill release location in EL1134 (see Figures 10 and 11).

6.2 Risks Associated with Dispersants and Dispersed Oil Exposure

The toxicity- and biodegradation-associated risks related to exposure to dispersants and dispersed oil are discussed in this subsection.

6.2.1 Toxicity

The toxicity of dispersants maintained within the Global Dispersant Stockpile (GDS) is less than the toxicity of the crude oil itself. The GDS currently stocks three dispersants – Dasic Slickgone NS, Finasol OSR 52, and Corexit EC9500A (OSRL 2017). In Canada, only EC9500A is currently approved, and there is an extensive dataset on the toxicity of this commercial product to a variety of species. It is important to note that dispersant-only studies are frequently conducted in laboratory settings for the purposes of screening one dispersant against another, or to meet regulatory product listing requirements, but are not particularly relevant to real world spill conditions. Regardless, laboratory tests have consistently shown that EC9500A is considerably less toxic than oil (Fingas et al. 1995; Environmental Protection Area [EPA] Office of Research and Development 2010). Since the exposure concentrations associated with dispersant use are low due to the low application rates needed to disperse the oil, the additional toxicity risk from dispersants alone is very low.

This SIMA assumes that a properly deployed dispersant operation uses visual monitoring (e.g., ROVs or spotter aircraft) to ensure that dispersants are properly applied to concentrated areas of oil, resulting in a chemically dispersed plume of oil. As such, we have limited our discussion of toxicity to dispersed oil, since there is no reason to expect that a dispersant-only condition would exist during an actual response. For this reason, the decision to use dispersants would be based on the assessment of the risks posed by dispersed oil, compared to risk of not dispersing the oil. Dispersed oil exposures in the water are the predominant exposure pathways for environmental considerations. Controlled studies at wave basins, such as the test facility used by DFO, and monitoring after actual spills, such as the *Sea Empress* and DWH incidents, has shown that sediments rarely have accumulations of dispersed oil at levels that pose environmental concerns. This is because dispersed oil does not adhere to sediments as easily as crude oil not treated with dispersants.

The toxicity of dispersed oil in the water column is related to three factors:

- Exposure concentrations that develop after the oil is spilled and treated;
- Duration of exposure; and
- Toxicological sensitivity of the exposed species.

The toxicity of oil is determined by its chemical makeup. Although certain compounds such as benzene, toluene, ethylbenzene and xylenes (known as BTEX) are acutely toxic, they are also quite volatile and tend to evaporate rapidly (Njobuenwu et al. 2008). Other compounds that make up the oil are partially soluble and are released slowly into the water column. These compounds are known collectively as the "water accommodated fraction," or WAF. Dispersants can increase the dissolution of BTEX into the water column, thereby preventing evaporation of VOCs that pose a risk to response workers. In the case of SSDI where fresh oil is being treated with dispersants at the sea floor, these soluble components will instead dissolve into the deeper water column. A review of hydrocarbon measurements taken in the vicinity of DWH Source Control during SSDI operations indicates BTEX concentrations up to 200 ppb were recorded in deep sea dispersed oil plumes located 1 km from the blowout at approximately 1,200 m depth. BTEX rapidly diluted to non-detectable levels at distances greater than 10 km from Source Control (Coelho et al. 2011). Although the potential aquatic impacts of these soluble concentrations to exposed deep water organisms is poorly understood, the field data confirm that concentrations rapidly dilute within a few kilometers of the SSDI operation. Fate and transport models predict similar results for simulated blowouts (Gros et al. 2017; French-McCay et al. 2017). While the overall toxicity of dispersed oil is determined primarily by the toxicity of the oil and not the dispersant, dispersants serve to make the oil more bioavailable to organisms in the water column due to the increased dissolution of the soluble components, and the formation of small stable oil droplets that will include polycyclic aromatic hydrocarbons (PAHs) and alkylated homologues. Since there is a wide range of sensitivities among species and life stages of the same species, it is important to identify the species and life stages living in the area to be treated with dispersants to ensure decisions are based on local environmental conditions. For most aquatic organisms, the 96-hour LC50 (concentration that causes mortality in 50% of test organisms within 96 hours) for dispersed oil is on the order of 20–50 ppm TPH. Larval and embryonic life stages of some organisms can be much more sensitive and may exhibit sub-lethal effects, such as delayed or abnormal development, at concentrations as low as a 1–5 ppm TPH (NRC 1989, 2003, 2005).

The concentrations of dispersed oil in the water column following surface application of dispersants under typical conditions may approach 30–50 ppm TPH in the upper 10 m of the water column. However, those concentrations rapidly dilute to <10 ppm within the first hour and to <1 ppm within a few hours. Therefore, for surface dispersant application, durations of exposures of organisms to dissolved TPH are relatively short and only occur in the upper few meters of the water column. The relative sensitivity of TPH exposure is species-specific. A study on the acute toxicity of dispersed crude oil on three Arctic invertebrate and fish species indicated that the median lethal levels of TPHs were 1.6-4.9 mg/L for WAF treatments and 22-62 mg/L for CEWAF (chemically enhanced water accommodated fraction) treatments (Gardiner et al. 2013).

During the DWH incident, SSDI was used almost continuously and concentrations of dispersed oil were monitored throughout the duration of the response. Due to safety concerns and potential conflicts with response operations, most of the subsea monitoring was conducted outside of a surface vessel exclusion zone of 1 km from the well head. Beyond this exclusion zone, a subsea dispersed oil plume usually occurred but was typically narrow, trended away from the site in the direction of very slight subsea currents, and was bounded by depths of about 1,100–1,300 m.

Within that plume, dispersed oil concentrations were typically very low (i.e., 100 ppb to several ppm) (NOAA 2012; IPIECA and IOGP 2015a).

However, in some areas in the vicinity of the DWH wellhead, >90 % of deep-sea corals exhibited signs of injury (Fisher et al 2014b *in* Beyer et al 2016). Studies assessing the effect of oil and dispersants on deep water coral species found that treatments of dispersant alone and in combination with oil were significantly more toxic to coral species than in treatments using only oil (DeLeo et al 2015 *in* Beyer et al 2016). At a location 13 km from the DWH wellhead, many coral species were covered in brown flocculent, but after 16 months, the corals showed some signs of recovery (Fisher et al 2014b *in* Beyer et al. 2016). Gorgonian corals exposed to weathered oil, dispersants, and a mixture of the two were largely unaffected by the weathered oil but the corals exposed to dispersants alone and a mixture of oil and dispersants exhibited fragment mortality after 48 hours (Fromet et al 2017 *in* Nexen 2018).

In 2014, research examining the toxic effects of dispersed oil on deep sea organisms was initiated under an API Joint Industry Task Force since previous research had focused on shallow water organisms. While results are still preliminary, a recent presentation by Naile (2016) suggests that the sablefish, a deepwater species, may have exposure thresholds similar to more commonly tested shallow water species. These new findings provide some insight into how the scientific community can apply existing data on shallow water species to deep water environments.

Marine snow, which typically consists of aggregates of plankton, fecal matter, live and dead bacteria, and minerals, will eventually sink to the seafloor (Wotton 2004 *in* van Eenennaam et al 2016). It has been suggested that the marine snow aggregates that settled on the seafloor during the DWH spill covered and suffocated benthic communities which may have led to temporary anoxic conditions (Brooks et al 2015). During the DWH spill, an abnormally large amount of marine snow was observed in the vicinity of surface oil and the sub-surface oil plumes (Daly et al 2016). The particles that make up marine snow can be aggregated by Extracellular Polymeric Substances (EPS) which are naturally excreted by cyanobacteria. The marine snow settled on the benthos with oil and clay minerals as an oily sludge in an area as expansive as 1,200 mile^2 during a process called marine oil snow sedimentation and flocculent accumulation (MOSSFA) (van Eenennaam et al 2016). The high amount of marine snow that formed during the DWH spill was thought to be due to the use of chemical dispersants in the presence of cyanobacteria living in association with the phytoplankton. The dispersant may have served as an energy and carbon source for the bacteria to thrive (van Eenennaam et al 2016). Since the DWH spill occurred in the spring and summer, the amounts of bacteria and phytoplankton were at a maximum. The DWH wellhead was situated near to the Mississippi River so there were high rates of suspended particle discharge and enhanced phytoplankton production which led to high abundance of marine snow (Daly et al 2016).

The DWH spill had a severe impact on meiofauna occurring within 3 km of the wellhead and a moderate impact within 60 km. These impacts were assessed based on community structure changes, the primary ones being an increase of nematode worms, indicators of organic pollution and a decrease in copepod abundance compared to unimpacted sites (Montagna et al 2013, Baguley et al 2015 *in* Daly et al 2016). Flocculent material containing oil was observed on 90 % of corals occurring within six km of the wellhead. There was evidence of stress with these corals, including excess mucus production, tissue loss, and sclerite enlargement (DeLeo et al 2015 *in* Daly et al 2016). Since many invertebrates and fishes use corals as feeding, nursing, and refuge grounds, the impact the spill had on the benthic habitat was community-wide and complex (Daly et al 2016). This is also seen in studies that detected elevated levels of PAHs in the bile of fish species such as the red snapper (*Lutjanus campechanus*), golden tilefish (*Lopholatilus chamaeleonticeps*) and the king snake eel (*Ophichthus rex*) (Murawski et al 2014, Snyder et al 2015 *in* Daly et al 2016). Elevated PAHs in fishes has been linked to impaired growth, reduced larval survival, reduced fecundity, and an increase in the susceptibility to diseases (Snyder et al 2015 *in* Daly et al 2016). It is thought that 14% of the total oil released during the DWH spill accumulated at the seafloor (Daly et al 2016).

Seabirds are at risk of being exposed to high concentrations of dispersants that are applied at surface from either an aircraft or marine vessel during a spill which can result in conjunctivitis and reduce tear production. Seabirds exposed to a mixture of dispersant and oil may also develop corneal ulcers (Fiorello et al 2016). Additionally, birds exposed to oil and/or to a dispersant during a spill may have their feathers fouled preventing them from escaping the area and potentially enhancing the effects associated with exposure (i.e., hypothermia) (Fiorello et al 2016).

Common murres exposed to a high concentration of a dispersant were found to have reduced feather waterproofing and buoyancy (Whitmer et al 2018). Birds exposed to a dispersant alone experienced a complete loss of buoyancy in a laboratory study and had to be manually retrieved from the water to prevent them from drowning. Twenty-four hours after exposure, the birds showed some improvement in waterproofing. Birds exposed to only oil alone and an oil-dispersant mixture were not able to recover with time (i.e., feather structure was significantly depressed and waterproofing capabilities were significantly affected). (Whitmer et al 2018).

A more robust discussion about the role of dispersants, the principles of chemical dispersion, and the factors that affect dispersant effectiveness is provided in Appendix B. In addition, a recent publication summarizes information on the sensitivities of Arctic species to both physically and chemically dispersed oil (Bejarano et al. 2017).

6.2.2 Biodegradation

The specific effects of SSDI on deepwater micro-organisms remain unclear. As is often the case during an oil spill response, scientists do not have the benefit of adequate control populations to quantify biological effects from oil spills, dispersant use and the resulting dispersed oil concentrations. The one apparent exception to this was the real-time study of bacterial populations during the DWH incident. Ongoing laboratory-based studies are also examining the effects of dispersed oil and high pressure on deepwater species. Since one of the key justifications for dispersant use is to promote biodegradation of oil in the open ocean before floating oil reaches sensitive shoreline habitats, it is critical that decision makers understand biodegradation.

Biodegradation is the process wherein living microorganisms (e.g., bacteria, yeasts, molds, and filamentous fungi) alter and/or metabolize complex hydrocarbon compounds into simpler products in order to obtain energy and nutrients. It is a natural process that actively removes organic matter, such as oil, from the environment. Biodegradation is the ultimate fate for oil released from natural oil seeps and for non-recovered oil following unintentional releases. Many different communities of microorganisms work together to degrade the wide range of hydrocarbon compounds found in oil. Baelum et al. (2012) found that *Colwellia* sp., an indigenous hydrocarbon-degrading bacterium from deep waters in the Gulf of Mexico, could rapidly degrade up to 75 % of crude oil at 5°C in laboratory experiments and was likely a dominant species in the microbial community during the DWH spill.

Oil biodegradation is dependent on both biotic (e.g., microbial growth and enzymatic activity) and abiotic factors (e.g., water temperature, water salinity, wind and wave energy, oxygen and nutrient levels). In addition, the quantity and quality of the hydrocarbon mixture and the properties of the affected ecosystem also affect oil biodegradation. Ranking of easily biodegraded hydrocarbons to more slowly processed hydrocarbon classes is provided below.

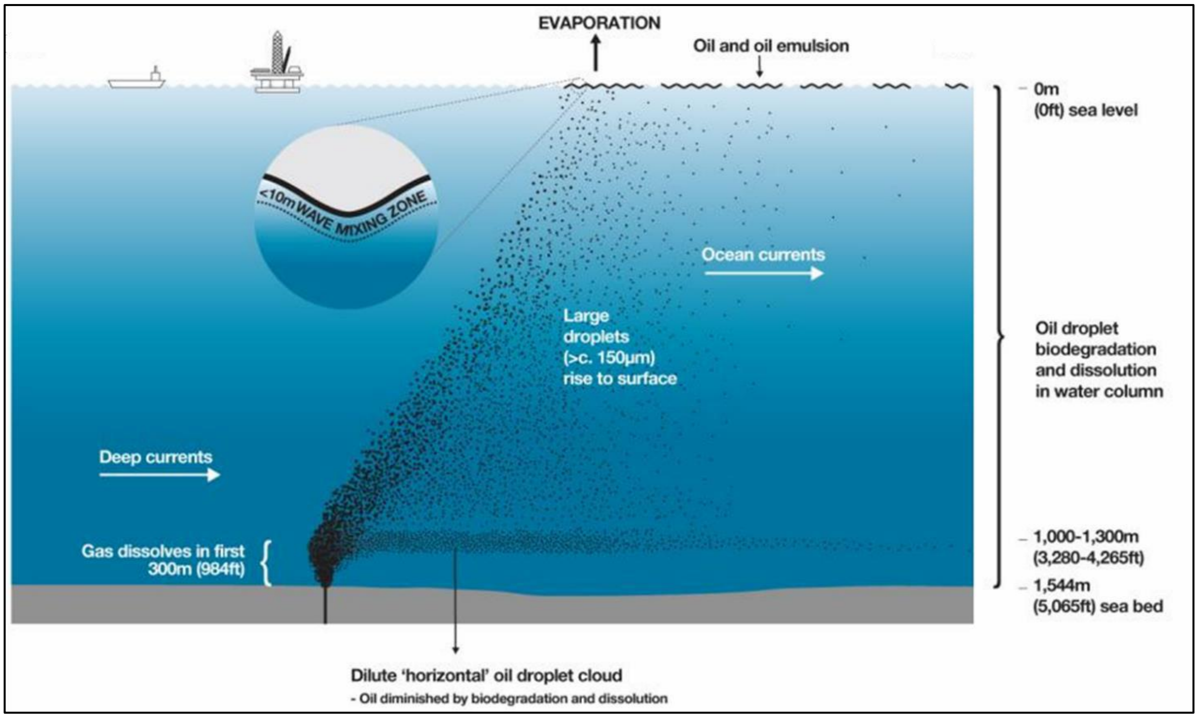
linear alkanes > branched alkanes > small aromatics > cyclic alkanes

Some compounds, such as the very high molecular weight PAHs, may degrade very slowly if at all, depending on the local populations of microbes.

Most oil biodegradation occurs via aerobic respiration. Oil-degrading microorganisms take up oxygen and metabolize hydrocarbons for energy. Some microbes can degrade oil under anaerobic conditions (absence of oxygen) but at a much slower rate. The key step of hydrocarbon degradation is the addition of one or more oxygen atoms to the hydrocarbon molecule which is then converted into an alkanol. This process makes the hydrocarbon more soluble in water. Some essential nutrients, such as nitrogen and phosphorus, are also required to support microbial growth during the biodegradation processes. The end-products of a complete aerobic biodegradation of many oil components are carbon dioxide and water and the main intermediates of the alkane degradation are fatty acids. Fatty acids may serve as an additional carbon source for the microbial community and enhance the degradation of hydrocarbon, however, they may also interfere with cell membranes of the bacteria and inhibit growth which can provoke a toxic response (Hassanshahian and Capello 2013).

The rate of biodegradation is also dependent upon the composition and the quantity of oil available to the microbes. Biodegradation rates are related to the molecular weight and the structure of the oil, with the lower molecular weight fractions being utilized first by microbes. Light crude oils (i.e., oils with a low density, viscosity, and specific gravity, and high API gravity) are readily biodegraded. Heavy crude (oils with a high density, viscosity, and specific gravity, and a low API gravity) biodegrade more slowly because it takes longer for microbes to process the higher proportion of high molecular weight hydrocarbons that constitute these types of crude oils. Similarly, refined oil products show a range in biodegradation rates, with lighter fuels such as diesel biodegrading at faster rates than lubricating oils that contain large, long-chained paraffinic molecules.

The biodegradation process begins on the oil components left in the environment after evaporative losses. In the case of a subsea oil blowout, biodegradation begins almost immediately as rising and entrained oil droplets in the intrusion zone (typically at 1,000–1,300 m) are colonized by deep water microbial communities (Figure 20).



Source: IPIECA and IOGP 2015a.

Figure 3. Schematic of oil transport in deep water seafloor blowout.

Within a few days following an oil spill, the populations of oil-degrading microorganisms will increase in number, with the population's higher metabolic demands supported by the presence of readily-degradable hydrocarbons. This is a natural process by which hydrocarbons are transformed into less harmful compounds through the metabolic or enzymatic activity of microorganisms that gain energy as well as carbon from this process. Petroleum hydrocarbons may be degraded to carbon dioxide, water and cellular biomass or degraded to smaller products that can undergo successive degradations until the compound is fully mineralized (Kissin 1987; Mango 1997).

Unless conducted as part of a routine water sampling analysis, it isn't possible to determine the exact make-up of the microbial community prior to an oil spill. There are several types of marine bacteria that carry out similar functions, but the overall function of the microbial community remains relatively constant. Although different genera of oil degrading bacteria likely occur at different depths and temperatures in the water column all of them have the capability to degrade at least some constituents of crude oil rapidly when the oil is dispersed as small droplets (Røy 2012). Studies conducted by both Hazen et al. (2010) and Valentine et al. (2011) following the DWH incident documented the dynamic changes in the microbial communities in the water column following the subsea blowout. Although the characteristics of the community changed as oil residues peaked and decreased during the incident, monitoring after the well was capped showed population trends moving back to the expected pre-spill quantities and composition.

6.2.2.1 Effect of Dispersants on Biodegradation

Effectively applied dispersants can potentially increase the rate and extent of biodegradation by moving a relatively thick and extensive oil slick into the water column as micro-sized (<300 µm) oil droplets. This essentially creates more oil surface area on which microbial communities may colonize. This also reduces the tendency of oil to form tar balls or mousse. It also enables the retention of dispersed oil droplets in the water column rather than risking the potential for untreated oil slicks to strand on shorelines or become entrained in the sediment where degradation rates are commonly much slower.

A recent Norwegian laboratory flume study assessed degradation rates of physically and chemically dispersed Macondo oil (Brakstad et al. 2014). This study demonstrated that the use of Corexit 9500A resulted in smaller median droplet sizes compared to untreated oil. These smaller droplets were more susceptible to biodegradation. Within the first hour, accelerated n-alkane degradation was apparent in the lighter alkanes (below approximately nC-24) of chemically dispersed oil. Within one day, the degradation of the n-alkanes (up to and beyond nC-30) was nearly complete in chemically dispersed oil.

Another recent biodegradation study focused specifically on crude oil, with and without dispersant application, at environmentally relevant concentrations in Arctic waters (McFarlin et al. 2014). Researchers concluded that biodegradation was stimulated by dispersants, especially during the first few weeks (McFarlin et al. 2014). In another recent study of the effects of temperature and Corexit 9500A on biodegradation rates, Techtmann et al. (2017) concluded that the presence of dispersant resulted in slight increases in biodegradation rates at temperatures of 5ºC and 25ºC. While some changes were observed in microbial community structures at 25ºC, none were noted at 5ºC. Likewise, in a study conducted in a wave tank in Canada, researchers found that an indigenous bacterial community from Halifax harbor exhibited a large increase in oil degrading phyla within 24 hours of dispersant treatment while little change of that sort was observed for untreated oil. Researchers concluded that dispersant improved the availability of oil to hydrocarbon degrading microbes in this mesocosm study. A more recent field study conducted by some of the same research team members concluded that the addition of dispersant to crude oil enhanced oil degradation rates in open ocean surface waters (Tremblay et al. 2017). Modelling work by French-McCay et al. (2017) concluded that SSDI substantially increased dissolution and degradation rates of soluble hydrocarbons (e.g., BTEX), thereby reducing VOC emissions at the waters' surface, the amount of oil and emulsified oil on surface, and the overall footprint of floating oil.

6.2.2.2 Global Implications

Other studies have also confirmed that these types of findings are not limited to the relatively warm, nutrient rich waters of the Gulf of Mexico. Hazen et al. (2016) reported that oil degrading bacteria occur in virtually all of the world's oceans. Liu et al. (2017) found rapid changes in naturally-occurring bacterial communities in the Mediterranean deep sea when exposed to simulated oil spills. Both the community structures and the biodegradation rates observed were similar to those observed during the DWH incident. Campeão et al. (2017) found that the deepwater microbial communities occurring in the Amazonian margin deep sea water are capable of degrading oil within 48 hrs.

Several studies have therefore validated the findings of research conducted during the DWH incident on the impacts of dispersed crude oil on populations and community structures of oil degrading microbes. They have confirmed that some constituents of crude oil can be degraded rapidly regardless of depth and temperature. The presence of dispersant may affect the community structure of oil degrading microbes at some depths and temperatures, but degradation remains rapid for at least some crude oil components.

6.3 Risk Analysis Process

A new methodology for studying risk in oil spill response was recently developed (IPIECA et al. 2017). It helps to deal with challenges experienced in both scoring and acquiring stakeholder concurrence in past risk assessments. This newly drafted risk method uses a single comparative matrix instead of the more typical square risk reporting matrix, and it incorporates four elements: (1) Potential Relative Impact Assessment; (2) Impact Modification Factor; (3) Relative Impact Mitigation Score using mean environmental compartment impact scores, if necessary; and (4) Total

Impact Mitigation Score. These elements provide a method to score the response options for each ROC or ROC constituent. The overall score is a qualitative prediction of how each response option might mitigate the overall impacts to the resources of concern when compared to "natural attenuation" (i.e., no intervention).

For this ExxonMobil Flemish Pass SIMA, the ROCs/ROC constituents described in Section 4.0 are consolidated into various environmental compartments. This consolidation allows for a more manageable risk assessment which is particularly important if the final Comparative Risk Matrix needs to be quickly revised for a future spill exercise or actual incident.
The environmental compartments and their associated ROCs/ROC constituents for the risk assessment in this SIMA include the following.

- Shoreline (intertidal and shallow subtidal <20 m depth) – algae, migratory birds, invertebrates, fishes and marine mammals;
- Ocean Surface – migratory birds, marine mammals, and sea turtles;
- Upper Water Column (≤20 m depth) – phytoplankton and zooplankton, ichthyoplankton and invertebrate eggs/larvae, invertebrates, fishes, diving migratory birds, marine mammal, and sea turtles;
- Lower Water Column (>20 m depth) – phytoplankton and zooplankton, ichthyoplankton and invertebrate eggs/larvae, invertebrates, fishes, diving migratory birds, marine mammal, and sea turtles;
- Seabed – corals and sponges, other invertebrates, fish and invertebrate eggs/larvae, and fishes; and
- Socio-economic – fisheries (including commercial fisheries, indigenous fisheries, recreational fisheries and aquaculture)

The above ROCs/ROC constituents include Species at Risk and Special Areas. During a spill, actual slick surveillance would identify which Species at Risk and Special Areas might be affected, and those local resource experts would be consulted. At the same time, the risk matrix would be adapted to real time conditions (e.g., on that day, in that location). Justifications for the scoring, in consultation with appropriate stakeholders, would explain which areas might serve as "drivers" in the decision-making process, based on the specific resources threatened by advancing oil or dispersed oil. Furthermore, the SIMA process may need to be revised multiple times during a spill, as different seasonal resources, such as migratory birds, enter the response area.

The Special Areas should be used to prioritize the application of response tactics during an ongoing spill response. Decisions, such as when and where to apply dispersants, for example, would be made by stakeholder and designated agencies and would be outside of the scope of this SIMA. As already stated earlier in this document, this SIMA focuses on a holistic approach to the protection of the environment and not on the protection of specific species or individual organisms.

The following subsections represent the steps for the single comparative matrix process which analyzes the impacts of oil spill response options described in Section 3.0 against the SIMA GAI ROCs/ROC constituents. More detailed information on the SIMA guidelines is provided in IPIECA et al. (2017).

6.3.1 (1) Potential Relative Impact Assessment

Each ROC/ROC constituent is given a potential relative impact rating that corresponds to a numerical weight (e.g., none = 1; low = 2; medium = 3; and high = 4). The weight attributed to each ROC/ROC constituent is unique and tailored to the specific SIMA.

The basic principle of assigning a potential relative impact or weight requires the estimation of the proportion of the resource affected and time to recovery. It also considers the spatial scale for each individual ROC/ROC constituent being considered. For purposes of this SIMA, a "Local" impact is assumed to be one that is potentially limited to somewhat finite area while a "Regional" impact could potentially occur within a much larger area. The Local (L) spatial scale has been applied to the ROCs/ROC constituents associated with the Newfoundland shoreline and seabed environmental compartments, as well as recreational fishing, aquaculture and seabird hunting in some of the environmental compartments. The Regional (R) spatial scale has been applied to the ROCs/ROC constituents associated with the other environmental compartments (i.e., ocean surface, upper water column and lower water column) as well as commercial and Indigenous fisheries in some of the environmental compartments.

In addition to the spatial scale designations, Table 14 also includes the potential relative impact (PRI) and numerical relative impact (NRI) ratings developed for the ExxonMobil Flemish Pass SIMA. The PRIs and NRIs provide a relative sense of potential impact of a naturally attenuating crude oil spill on the various ROCs/ROC constituents in the various environmental compartments.

Table 14. Potential relative impact assessment.

Environmental Compartment	ROC/ROC Constituent	Spatial Scale	Natural Attenuation	
			Potential Relative Impact	Numerical Relative Impact (A)
Shoreline (Newfoundland)	Algae	L	Low	2
	Invertebrates	L	Low	2
	Fishes	L	Low	2
	Migratory Birds	L	Medium	3
	Marine Mammals	L	Low	2
	Shoreline Compartment Average			
Ocean Surface	Migratory Birds	R	Medium	3
	Marine Mammals	R	Low	2
	Sea Turtles	R	Low	2
	Fisheries (commercial, Indigenous)	R	High	4
	Fisheries (recreational, aquaculture)	L	Medium	3

Environmental Compartment	**ROC/ROC Constituent**	**Spatial Scale**	**Natural Attenuation**	
			Potential Relative Impact	**Numerical Relative Impact (A)**
	Seabird hunting	L	Medium	3
	Ocean Surface Compartment Average			
Upper Water Column (≤20 m depth)	Phytoplankton and Zooplankton	R	Medium	3
	Ichthyoplankton and Invertebrate Eggs/Larvae	R	Medium	3
	Invertebrates	R	Low	2
	Fishes	R	Low	2
	Diving Migratory Birds	R	Medium	3
	Marine Mammals	R	Low	2
	Sea Turtles	R	Low	2
	Fisheries (commercial, Indigenous)	R	High	4
	Fisheries (recreational, aquaculture)	L	Medium	3
	Seabird hunting	L	Medium	3
	Upper Water Column Compartment Average			
Lower Water Column (>20 m depth)	Zooplankton	R	Low	2
	Ichthyoplankton and Invertebrate Eggs/Larvae	R	Low	2
	Invertebrates	R	Low	2
	Fishes	R	Low	2
	Marine Mammals	R	Low	2
	Sea Turtles	R	Low	2
	Fisheries (commercial, Indigenous)	R	High	4
	Fisheries (recreational, aquaculture)	L	Medium	3
	Lower Water Column Compartment Average			
Seabed (benthic)	Corals and Sponges	L	Medium	3
	Other Invertebrates	L	Low	2
	Fish and Invertebrate Eggs/Larvae	L	Low	2
	Fishes	L	Low	2
	Fisheries (commercial, Indigenous)	R	High	4
	Fisheries (recreational, aquaculture)	L	Medium	3
	Seabed (benthic) Compartment Average			

Note:
L denotes Local; R denotes Regional.

6.3.1.1 Rationale for Selection of PRIs and NRIs Associated with Natural Attenuation of Spilled Crude Oil

Shoreline

Given the relatively low probability of crude oil even reaching the Newfoundland shore, all ROC/ROC constituents, except for migratory birds, were assigned a Low-2 PRI/NRI rating. Considering how susceptible birds are to oiling, this ROC was assigned a Medium-3 PRI/NRI rating.

Ocean Surface

From a biological perspective, the marine mammal and sea turtle ROCs were assigned a Low-2 PRI/NRI rating given the transient nature of these animals and the relatively low probability of interaction with crude oil at surface. As with the shoreline environmental compartment, migratory birds were assigned a Medium-3 PRI/NRI rating due to potential acute effects of exposure of birds to crude oil.

From a socio-economic perspective, commercial and Indigenous fisheries was assigned a High-4 PRI/NRI rating given the perception of tainting and how that could affect commercial and ceremonial value, the possibility of gear fouling, and actual tainting of fishery resource. Recreational fishery, aquaculture and seabird hunting were assigned Medium-3 ratings, again primarily to the public perception of tainting of species involved. Both of these activities are considered to be Local in spatial scale compared to the wider spatial scales (i.e. Regional) associated with commercial and Indigenous fisheries; thus the lower PRI/NRI ratings.

Upper Water Column

From a biological perspective, the ROCs/ROC constituents that typically spend most of their time in the upper 20 m of the water column during the summer months were assigned higher PRIs/NRIs. The upper water column is where elements of the crude oil at surface mostly dissolve (water soluble elements) or disperse (oil droplets) into the sea water. Plankton, including phytoplankton, zooplankton, ichthyoplankton and invertebrate eggs and larvae, and diving seabirds were considered to be the most at risk in this part of the water column and were therefore assigned a PRI/NRI of Medium-3. Other biological ROCs/ROC constituents (invertebrates, fishes, marine mammals and sea turtles) have been assigned the PRI/NRI rating Low-2 given their abilities to avoid the upper water column by directed movement.

From a socio-economic perspective, commercial and Indigenous fisheries was assigned a High-4 PRI/NRI rating given the perception of tainting and how that could affect commercial and ceremonial value, the possibility of gear fouling, and actual tainting of fishery resource. Recreational fishery, aquaculture and seabird hunting were assigned Medium-3 ratings, again primarily to the public perception of tainting of species involved. Both of these activities are considered to be Local in spatial scale compared to the wider spatial scales (i.e. Regional) associated with commercial and Indigenous fisheries; thus the lower PRI/NRI ratings.

Lower Water Column

Given the uncertainty associated with the extent of crude oil occurrence in the portion of the water column below 20 m (levels of dissolution and dispersion) due to variability in oceanographic conditions such as sea state, all biological ROCs/ROC constituents (zooplankton, ichthyoplankton, invertebrate eggs and larvae, invertebrates, fishes, marine mammals and sea turtles) were assigned the PRI/NRI Low-2. Untreated sinking oil is mainly a function of suspended organic particulate matter (i.e., marine snow) within the water whose levels in the offshore are likely low compared to the inshore. Much of the suspended particulate matter in the ocean enters from river discharge and other ecological processes along the shoreline.

From a socio-economic perspective, commercial and Indigenous fisheries was assigned a High-4 PRI/NRI rating given the perception of tainting and how that could affect commercial and ceremonial value, the possibility of gear fouling, and actual tainting of fishery resource. Recreational fishery and aquaculture were assigned Medium-3 ratings, again primarily due to the public perception of tainting of species involved. Both of these activities are considered to be Local in spatial scale compared to the wider spatial scales (i.e. Regional) associated with commercial and Indigenous fisheries; thus the lower PRI/NRI ratings.

Seabed

The transport of crude oil from a naturally attenuating spill to the seabed is predicted to be minimal (i.e., <0.02% of released crude). As with the lower water column discussed above, untreated sinking oil is mainly a function of the marine snow levels within the water column. Given the low amounts of crude oil predicted to reach the seabed, the ROCs/ROC constituents associated with this environmental compartment (i.e., corals and sponges, other invertebrates, fish and invertebrate eggs and larvae, and fishes) uncertainty associated with the extent of crude oil occurrence in the portion of the water column were assigned the PRI/NRI Low-2.

From a socio-economic perspective, commercial and Indigenous fisheries was assigned a High-4 PRI/NRI rating given the perception of tainting and how that could affect commercial and ceremonial value, the possibility of gear fouling, and actual tainting of fishery resource. Recreational fishery and aquaculture were assigned Medium-3 ratings, again primarily due to the public perception of tainting of species involved. Both of these activities are considered to be Local in spatial scale compared to the wider spatial scales (i.e. Regional) associated with commercial and Indigenous fisheries; thus the lower PRI/NRI ratings.

6.3.2 (2) Impact Modification Factor

As each feasible response option is evaluated, it is assigned an impact modification factor (IMF) (Table 15) to indicate the level of impact a given response could affect a ROC/ROC constituent when compared to the natural attenuation option. For purposes of this assessment, all options are assumed to be feasible, although that may not be the case at the actual time of a response.

Table 15. Impact Modification Factor.

Impact Modification Factor	Description
+4	Major mitigation of impact
+3	Moderate mitigation of impact
+2	Minor mitigation of impact
+1	Negligible mitigation of impact
0	No alteration of impact
-1	Negligible additional impact
-2	Minor additional impact
-3	Moderate additional impact
-4	Major additional impact

For this SIMA, the impact modification factors are assigned for each response option (i.e., shoreline protection and recovery, on-water mechanical recovery, *in situ* burning (ISB), surface dispersant application (SDA) and a combination of surface dispersant application and subsea dispersant application [SDA/SSDI]) based on a qualitative review of published information and professional judgement for each of the ecological and socio-economic resources when compared to the natural attenuation option. The basic principle of assigning an impact modification factor requires estimating the proportion of the resource affected and how long it would take for that resource to recover. The IPIECA Guidelines (IPIECA et al. 2017) provides guidelines for assigning impact modification factors.

6.3.2.1 Rationale for Selection of IMFs Associated with the Various Response Options/ROCs and ROC Constituents

Shoreline Protection and Recovery

The shoreline protection and recovery response option really only applies to the ROCs/ROC constituents associated with the shoreline environmental compartment. Oil spill modelling has predicted that the probability of crude oil reaching the Newfoundland shoreline is low under the natural attenuation scenario and any oil that did reach shore would be heavily weathered. If other response options are applied to an oil spill, that probability is even less. Therefore, the shoreline protection and recovery option IMF assigned to all of the shoreline ROCs/ROC constituents is +1 (negligible mitigation of impact), the lowest positive value. All other IMFs assigned for this response option are 0 (no alteration of impact) given the lack of association between this response option and the other four environmental compartments

On-water Mechanical Recovery

The success rate of oil removal using the on-water mechanical recovery response option is dependent on a number of factors, including wind, waves and available daylight hours to conduct this response option. Typically, the rate of encountered oil using this option is quite low (estimated on-water mechanical recovery during Deepwater Horizon spill was 5% of released oil). From a public perception perspective, acceptance of this response option is relatively high.

The primary benefit of this response option is the permanent physical removal of crude oil from the environment which can only be regarded as positive for the potentially affected ROCs/ROC constituents in the various environmental compartments. Given the removal of some of the surface oil and the low probability of spilled crude oil reaching the Newfoundland shoreline, an IMF of +1 was assigned to all of the ROCs/ROC constituents in the shoreline environmental compartment except for migratory birds which was assigned an IMF of +2 due to bird vulnerability to oiling. Similar logic was applied to the ROCs/ROC constituents in the ocean surface and upper water column environmental compartments. Given the likely low success rate of mechanical removal of crude oil from the ocean's surface, all non-bird ROCs/ROC constituents, including fisheries and sea bird hunting, in these environmental compartments were assigned a +1 IMF (negligible mitigation). The migratory bird ROC was assigned a +2 IMF (minor mitigation of impact) in both instances. Slightly less crude oil on surface should also translate to slightly less dissolution and dispersion into the upper water column. On-water mechanical recovery will be seen by the public as a positive move, thereby slightly improving the perceptions regarding commercial, Indigenous, and recreational fisheries, aquaculture and seabird hunting.

Regarding the lower water column and seabed environmental compartments, minimal crude oil is predicted to sink to these areas under the natural attenuation scenario. Therefore, the same is true under the on-water mechanical recovery option. All biological and socio-economic ROCs/ROC constituents, except for zooplankton, ichthyoplankton and invertebrate eggs and larvae associated with the lower water column environmental compartment, were therefore assigned a +1 IMF, the lowest rating for mitigation of impact. The lower water column ROC/ROC constituent exceptions were assigned a 0 IMF rating because the abundance of these plankton in the lower water column is likely less than the abundance in the upper water column where the plankton were assigned a +1 IMF.

In-Situ Burning (ISB)

While in-situ burning can reduce the amount of crude oil on the surface significantly more than on-water mechanical removal, it is necessary to have a surface oil thickness of at least 2-5 mm. In other words, the oil still has to be collected using vessels and booms which results in a low oil encounter rate. This response option has the same limitations as mechanical recovery (e.g., wind, waves, available daylight hours to conduct the ISB). Practical recovery rate success is similar to that for on-water mechanical recovery. Based on its similarity to on-water mechanical recovery in terms of environmental limitations, speed of the process, and primary benefit (i.e., removal of crude oil from ocean surface, the IMF ratings assigned to the various ROCs/ROC constituents in the five environmental compartments are the same as those indicated in the previous section.

Surface Dispersant Application (SDA)

As indicated earlier in this document, dispersants function as surfactants, breaking the crude oil into droplets that will disperse primarily into the upper water column. The breaking of crude oil into small droplets results in a greater surface area: volume ratio, thereby increasing the rate of dissolution of oil elements, dilution, weathering and microbial degradation (i.e., biodegradation). Since surface dispersants can be applied from either aircrafts or relatively fast vessels, the surface oil encounter rate is higher than those for on-water mechanical recovery and in-situ burning response options. With sufficient wave action, which is typical in the Newfoundland offshore, floating oil would disperse into the upper 10 m of the water column quite rapidly. This aircraft-mediated response option requires daylight and good visibility to target oil, to ensure that megafauna (e.g., marine mammals) are not in the application area, and to ensure that the dispersant is effective (i.e., surface colour change). Dispersant application from a marine vessel requires a suitable sea state. At wave heights above 4 m, breaking waves entrain oil in the water column and prevent appropriate interaction between the oil and the dispersant. Given that the primary function of dispersants is to disperse oil into the water column, particularly the upper water column, biota that spend most of their time in the upper water column are most susceptible to exposure to hydrocarbons.

Dispersants would not likely be applied to inshore surface oil so the IMFs assigned to the ROCs/ROC constituents in the shoreline environmental compartment are the same as for on-water mechanical recovery and ISB. Algae, invertebrates, fishes and marine mammals have been assigned +1 IMFs, and the migratory bird ROC has been assigned a +2 IMF. Any response option that removes oil from surface and promotes dissolution is positive for biota occurring on the shoreline.

For the ocean surface environmental compartment, the IMFs for the biological ROCs/ROC constituents all indicate some mitigation of impact. While removal of surface oil is typically good for seabirds, there is relatively little known about the effects of exposure of birds to dispersants and dispersants + oil. Therefore, a minor mitigation of impact IMF of +2 has been assigned to the migratory bird ROC. The other two ROCs associated with this environmental compartment, marine mammals and sea turtles, have been assigned the negligible mitigation of impact IMF of +1 since there is less crude oil at surface. All the socio-economic ROCs/ROC constituents have been assigned additional impact IMFs, again primarily due to the perception of tainted animals targeted in the fisheries. There is a possibility that the public will see the surface application of dispersants as the addition of toxic substances to the marine environment. Because the commercial fishery and Indigenous fisheries are rated as Regional in scale and the recreational fisheries, aquaculture and seabird hunting are rated as Local in scale, the former are assigned -2 IMFs and the latter are assigned -1 IMFs.

As implied above, the surface application of dispersants results in more hydrocarbons entering the upper water column. Therefore, all ROCs/ROC constituents on the upper water column environmental compartment have been assigned negative IMFs, an indication of potential additional impact. Plankton and diving birds have been assigned IMFs of -2 since they directly interact with the upper water column. Invertebrates, fishes, marine mammals and sea turtles have been assigned -1 IMFs since these animals can potentially avoid the upper water column. As with the ocean surface environmental compartment, the socio-economic ROCs/ROC constituents have been assigned either -1 or -2 IMFs for the same reasons as stated in the above paragraph.

The lower water column would not likely be affected by surface dispersant application to the same degree as the upper water column. While oil contaminated marine snow will likely sink slowly through the lower water column, the organic particulates in the water column should be less abundant than in waters closer to shore. Plankton have been assigned IMFs of 0 in this environmental compartment. Although some plankton are expected to occur in the water column below the depth of 20 m, most will be in the upper water column. All other ROCs/ROC constituents associated with the lower water column environmental compartment have been assigned IMFs of -1 since these animals have greater potential to encounter oil in the lower water column compared to the plankton. As with the upper water column environmental compartment, the socio-economic ROCs/ROC constituents have been assigned either -1 or -2 IMFs for the same reasons as stated in the above paragraph.

As with the lower water column, the seabed would not likely be affected by surface dispersant application to the same degree as the upper water column. While the amount of oil reaching the seabed should be minimal as a result of surface dispersant application, it has potential to exceed impact on the seabed under the natural attenuation scenario. Therefore, all biological and socio-economic ROCs/ROC constituents associated with this environmental compartment has been assigned an IMF of -1.

SDA and Subsea Dispersant Injection (SDA+SSDI)

The SSDI component of this response option would take considerably longer to put into operation than would the SDA component. However, once operational, SSDI has fewer environmental limitations than the previously discussed response options. The combined means of dispersant application also results in the highest spilled oil encounter rate of all response options.

Dispersants applied at both surface and at the blowout will result in considerably less crude oil reaching surface. This may mean that the probability of oil reaching the Newfoundland shoreline is even less than that probability associated with the other response options and natural attenuation. For this reason all ROCs/ROC constituents in the shoreline environmental compartment, except for migratory birds, have been assigned the IMF of +2 (minor mitigation of impact). Migratory birds, which are quite sensitive to oiling effects, has been assigned the IMF of +3.

With respect to the ocean surface environmental compartment, the lesser amount of oil either remaining on surface or even reaching surface lowers the risk to biota that interact with the ocean surface. All biological ROCs/ROC constituents have been assigned positive IMFs (mitigation of impact), +3 for migratory birds and +1 for marine mammals and sea turtles. The same negative IMFs assigned to the socio-economic ROCs/ROC constituents of this environmental compartment for SDI, were also assigned for the SDA+SSDI; -2 for commercial and Indigenous fisheries and -1 for recreational fisheries, aquaculture and seabird hunting.

Although the SDI component will promote the dissolution and dispersion of oil into the water column, the SSDI component of this response option, which will have the highest oil encounter rate, will substantially lower the amount of crude oil reaching the ocean surface. This in turn should result in less oil being dissolved and dispersed in the upper water column. Based on this rationale, there should be a mitigation of impact in this environmental compartment. Therefore, all biological ROCs/C constituents have been assigned positive IMFs. The plankton and diving migratory birds have been assigned the +2 IMF while invertebrates, fishes, marine mammals and sea turtles have been assigned the +1 IMF. The same negative IMFs assigned to the socio-economic ROCs/ROC constituents of this environmental compartment for SDI, were also assigned for the SDA+SSDI; -2 for commercial and Indigenous fisheries and -1 for recreational fisheries, aquaculture and seabird hunting.

The subsea application of dispersants may have a unique effect on the lower water column, particularly the deeper areas of the water column. During the Deepwater Horizon event, large plumes of dispersed oil were observed at substantial depths (i.e., 1,000 m+). These large plumes formed because of the high encounter rate with oil, resulting in substantial amounts of spilled crude becoming neutrally buoyant and remaining in the water column. While plankton will likely not be impacted in the shallower region of the lower water column (IMF=0), all other ROCs/ROC constituents could be impacted more than under the natural attenuation scenario. Invertebrates and fishes have been assigned -2 IMFs and marine mammals and sea turtles have been assigned -1 IMFs. From a socio-economic perspective, the application of dispersants at surface and at the blowout itself could intensify negative public perception regarding animals harvested in fisheries and aquaculture. For this reason, commercial and Indigenous fisheries have been assigned a -3 IMF and the recreational fisheries and aquaculture at a more local spatial scale have been assigned a -1 IMF.

Results of some studies associated with the Deepwater Horizon blowout event indicated more impact of the oil spill on the benthic habitat than anticipated. These impacts are attributed to the large deep water plumes of dispersed oil that formed after SSDI. Based on findings from DWH studies, sensitive sessile corals and sponges have been assigned a -3 IMF, other invertebrates and fish/invertebrate eggs and larvae have been assigned a -2 IMF, and fishes, which are mobile, have been assigned a -1 IMF. The IMFs assigned to the socio-economic fisheries ROCs/ROC constituents for the lower water column environmental have also been assigned for the seabed environmental compartment.

6.3.3 (3) Relative Impact Mitigation Scores

For each ROC/ROC constituent, the Numerical Relative Impact value (Table 16) is multiplied by the associated Impact Modification Factor (IMF) (see Table 15) to create a relative impact mitigation score for a response option, as shown generically in Table RIMS for the environmental compartment ‘Shoreline’. The score for each ROC/ROC constituent-response option combination represents the relative change that the response option would have on the impact. By using a qualitative ranking of impacts, a numerical value can be generated. The relative impact mitigation score is generated by assessing response options and ROC/ROC constituent using four possible numerical impact values (1, 2, 3 and 4) and nine impact modification factors (+4 to -4), resulting in 36 possible scoring possibilities per resource.

Table 16. Relative impact mitigation scores.

Environmental Compartment	ROC/ROC Constituent	Spatial Scale	Natural Attenuation		Response Option	
			Potential Relative Impact	**Numerical Relative Impact (A)**	**Impact Modification Factors (B_1)**	**Relative Impact Mitigation Score (AxB_1)**
Shoreline (Newfoundland)	Algae	L	Low	2	+2	+4
	Invertebrates	L	Low	2	+2	+4
	Fishes	R	Low	2	+1	+2
	Migratory Birds	R	Medium	3	+3	+9
	Marine Mammals	R	Low	2	+2	+4
	Shoreline Compartment Average					5

Note:
L denotes Local; R denotes Regional.

Within each environmental compartment, a mean relative impact mitigation score (rounded off to nearest whole number) is then calculated across ROCs/ROC constituents (see Table 16). This step allows environmental compartments such as “Shoreline” (contains three ROCs/ROC constituents; algae, invertebrates, fishes, migratory birds and marine mammals) to be compared without bias to other environmental compartments, regardless of the number of ROCs/ROC constituents within that compartment.

To provide a visual reference for the relative impact mitigation score, each cell is coded with a colour based on a range of equal interval scores. For the ExxonMobil Flemish Pass SIMA, Table 17 displays the colour code as a scale from red to dark green indicating major increase in impact to major impact mitigation, respectively.

Table 17. Range of Score Colour Coding.

Range of Scores	Colour Code	Description
>+15	🟩	Major mitigation of impact
+11 to +15	🟩	Moderate mitigation of impact
+6 to +10	🟩	Minor mitigation of impact
+1 to +5	🟩	Negligible mitigation of impact
0		No alteration of impact
-5 to -1	🟨	Negligible additional impact
-10 to -6	🟨	Minor additional impact
-15 to -11	🟧	Moderate additional impact
<-15	🟥	Major additional impact

6.3.4 (4) Total Impact Mitigation Scores

The Total Impact Mitigation scores, which are the totals of the mean environmental compartment scores for each response option, are located on the bottom row of the Comparative Risk Matrix (Table 18) presented in the following subsection. This overall score is a qualitative prediction of how each response option might mitigate the overall impacts when compared to natural attenuation or no intervention for a specific scenario. The IPIECA Guidelines (IPIECA et al. 2017) provides guidelines on using the finalized comparative risk matrix.

6.4 Risk Assessment Results

A single Comparative Risk Matrix (Table 18) for the response options was generated for the 'EL1134-Summer' scenario, taking into consideration the resources of concern identified for the ExxonMobil SIMA GAI. The 'EL1134-Summer' spill scenario was used because it posed some of the greatest challenges from an emergency response perspective, and sensitive, threatened or endangered species were predicted to be relatively more abundant in the study area during that time of the year. Results for the 'EL1134-Summer' scenario were then reviewed and briefly compared to the other three spill scenarios initially considered during the selection of the primary spill scenario (i.e., EL1134-Summer).

The following subsections discuss the results shown in the Comparative Risk Matrix (Table 18). This discussion is presented by response option.

Table 18. Relative Impact Mitigation Scores.

Environmental Compartment	ROC/ROC Constituent	Spatial Scale	Response Options											
			Natural Attenuation		Shoreline Protection and Recovery		On-water Mechanical Recovery		*In Situ* Burning (ISB)		Surface Dispersant Application (SDA)		SDA+ Subsea Dispersant Injection (SDA+SSDI)	
			Potential Relative Impact	Numerical Relative Impact	Impact Modification Factors	Relative Impact Mitigation Score	Impact Modification Factors	Relative Impact Mitigation Score	Impact Modification Factors	Relative Impact Mitigation Score	Impact Modification Factors	Relative Impact Mitigation Score	Impact Modification Factors	Relative Impact Mitigation Score
				A	**B_1**	**Ax B_1**	**B_2**	**AxB_2**	**B_3**	**Ax B_3**	**B_4**	**AxB_4**	**B_5**	**AxB_5**
Shoreline (Newfoundland)	Algae	L	Low	2	+1	+2	+1	+2	+1	+2	+1	+2	+2	+4
	Invertebrates	L	Low	2	+1	+2	+1	+2	+1	+2	+1	+2	+2	+4
	Fishes	L	Low	2	+1	+2	+1	+2	+1	+2	+1	+2	+2	+4
	Migratory Birds	L	Medium	3	+1	+3	+2	+6	+2	+6	+2	+6	+3	+9
	Marine Mammals	L	Low	2	+1	+2	+1	+2	+1	+2	+1	+2	+2	+4
	Shoreline Compartment Average					**+2**		**+3**		**+3**		**+3**		**+5**
Ocean Surface	Migratory Birds	R	Medium	3	0	0	+2	+6	+2	+6	+3	+6	+3	+9
	Marine Mammals	R	Low	2	0	0	+1	+2	+1	+2	+1	+2	+1	+2

	Sea Turtles	R	Low	2	0	0	+1	+2	+1	+2	+1	+2	+1	+2
	Fisheries (commercial, Indigenous)	R	High	4	0	0	+1	+4	+1	+4	-2	-8	-2	-8
	Fisheries (recreational, aquaculture)	L	Medium	3	0	0	+1	+3	+1	+3	-1	-3	-1	-3
	Seabird hunting	L	Medium	3	0	0	+1	+3	+1	+3	-1	-3	-1	-3
	Ocean Surface Compartment Average					**0**		**+3**		**+3**		**-1**		**0**
Upper Water Column (≤20 m depth)	Phytoplankton and Zooplankton	R	Medium	3	0	0	+1	+3	+1	+3	-2	-6	+2	+6
	Ichthyoplankton and Invertebrate Eggs/Larvae	R	Medium	3	0	0	+1	+3	+1	+3	-2	-6	+2	+6
	Invertebrates	R	Low	2	0	0	+1	+2	+1	+2	-1	-2	+1	+2
	Fishes	R	Low	2	0	0	+1	+2	+1	+2	-1	-2	+1	+2
	Diving Migratory Birds	R	Medium	3	0	0	+2	+6	+2	+6	-2	-6	+2	+6
	Marine Mammals	R	Low	2	0	0	+1	+2	+1	+2	-1	-2	+1	+2
	Sea Turtles	R	Low	2	0	0	+1	+2	+1	+2	-1	-2	+1	+2
	Fisheries (commercial, Indigenous)	R	High	4	0	0	+1	+4	+1	+4	-2	-8	-2	-8
	Fisheries (recreational, aquaculture)	L	Medium	3	0	0	+1	+3	+1	+3	-1	-3	-1	-3
	Seabird hunting	L	Medium	3	0	0	+1	+3	+1	+3	-1	-3	-1	-3
	Upper Water Column Compartment Average					**0**		**+3**		**+3**		**-4**		**+1**
Lower Water Column (>20 m depth)	Zooplankton	R	Low	2	0	0	0	0	0	0	0	0	0	0
	Ichthyoplankton and Invertebrate Eggs/Larvae	R	Low	2	0	0	0	0	0	0	0	0	0	0
	Invertebrates	R	Low	2	0	0	+1	+3	+1	+3	-1	-3	-2	-6
	Fishes	R	Low	2	0	0	+1	+3	+1	+3	-1	-3	-2	-6
	Marine Mammals	R	Low	2	0	0	+1	+2	+1	+2	-1	-2	-1	-2
	Sea Turtles	R	Low	2	0	0	+1	+2	+1	+2	-1	-2	-1	-2
	Fisheries	R	High	4	0	0	+1	+4	+1	+4	-2	-8	-3	-12

	(commercial, Indigenous)													
	Fisheries (recreational, aquaculture)	L	Medium	3	0	0	+1	+3	+1	+3	-1	-3	-1	-3
	Lower Water Column Compartment Average					**0**		**+2**		**+2**		**-3**		**-4**
Seabed (benthic)	Corals and Sponges	L	Low	2	0	0	+1	+2	+1	+2	-1	-2	-3	-6
	Other Invertebrates	L	Low	2	0	0	+1	+2	+1	+2	-1	-2	-2	-4
	Fish and Invertebrate Eggs and Larvae	L	Low	2	0	0	+1	+2	+1	+2	-1	-2	-2	-4
	Fishes	L	Low	2	0	0	+1	+2	+1	+2	-1	+2	-1	-2
	Fisheries (commercial, Indigenous)	R	High	4	0	0	+1	+4	+1	+4	-1	-4	-3	-12
	Fisheries (recreational, aquaculture)	L	Medium	3	0	0	+1	+3	+1	+3	-1	-3	-1	-3
	Seabed (benthic) Compartment Average					**0**		**+3**		**+3**		**-2**		**-4**
TOTAL					**+2**		**+14**		**+14**		**-7**		**-2**	

Note:
L denotes Local; R denotes Regional.

6.4.1 Natural Attenuation

The rationale for the assignment of ratings for potential relative impacts/numerical relative impacts (PRI/NRI) associated with the ROCs/ROC constituents in each environmental compartment has been provided in Section 6.3.1.1. Under the natural attenuation scenario, the highest risks to ROCs/ROC constituents are associated with interactions between biota and the ocean surface and upper water column.

6.4.2 Shoreline Protection and Recovery

The rationale for the assignment of ratings for impact modification factors associated with this response option has been provided in Section 6.3.2.1. Shoreline protection and recovery is defined as the placement of booms and any other mechanical diversion devices in strategic locations that will prevent oil from reaching particularly sensitive areas. Such devices may herd oil into areas where it can be recovered with skimmers or other mechanical devices. The Shoreline Protection and Recovery response option described in Subsection 3.2 really pertains to the shoreline environmental compartment only. As indicated in Table 18, the total of the relative impact mitigation scores of each environmental compartment for this response option is +2.

6.4.3 On-water Mechanical Recovery

The rationale for the assignment of ratings for impact modification factors associated with this response option has been provided in Section 6.3.2.1. On-water mechanical recovery involves the use of booms and skimmers to redirect, contain and remove oil from the ocean's surface. On-water mechanical recovery of surface oil in the offshore could potentially lessen the probability of oil reaching any Newfoundland shoreline, although this option typically results in the physical removal of <10% of all surface oil. This response option, discussed in more detail in Subsection 3.3, pertains to all five environmental compartments. As indicated in Table 18, the total of the relative impact mitigation scores of each environmental compartment for this response option is +14.

6.4.4 *In Situ* Burning

The rationale for the assignment of ratings for impact modification factors associated with this response option has been provided in Section 6.3.2.1. This response option is quite similar to the on-water mechanical recovery option in that oil is removed from the ocean's surface. However, since there is no need to separate collected oil from water fractions and store it for later disposal, ISB can proceed at a faster rate than on-water mechanical recovery. This option, discussed in more detail in Subsection 3.4, pertains to all five environmental compartments. As indicated in Table 18, the total of the relative impact mitigation scores of each environmental compartment for this response option is +14.

6.4.5 Surface Dispersant Application (SDA)

The rationale for the assignment of ratings for impact modification factors associated with this response option has been provided in Section 6.3.2.1. This response option involves the use of aircraft and/or spray-boom fitted vessels to apply dispersants on the ocean's surface. This option, discussed in more detail in Subsection 3.5, pertains to all five environmental compartments. As indicated in Table 18, the total of the relative impact mitigation scores of each environmental compartment for this response option is -7.

6.4.6 Surface Dispersant Application in Combination with Subsea Dispersant Injection (SDA+SSDI)

The rationale for the assignment of ratings for impact modification factors associated with this response option has been provided in Section 6.3.2.1. This response option involves the combination of the use of aircraft and/or spray-boom fitted vessels to apply dispersants on the ocean's surface, and the injection of dispersant directly into the subsea flow of oil at the wellhead. This response option has an even much higher oil encounter rate compared to surface application of dispersants only. Much of the released oil will remain submerged due to the application of dispersants at the wellhead. This method is also less weather dependent and can be conducted continuously. This response option would result in higher dissolution and dispersion of oil into the water column, thereby increasing the chances of encounters between the hydrocarbons and the biological ROCs within the water column. This option, discussed in more detail in Subsection 3.6, pertains to all five environmental compartments. As indicated in Table 18, the total of the relative impact mitigation scores of each environmental compartment for this response option is -2.

6.4.7 Summary of Relative Impact Mitigation Scores

Based on the results displayed in Table 18, the two response options that would provide most mitigation of impact are on-water mechanical removal and in-situ burning, both with a +14 total relative impact mitigation score. While the proportion of spilled oil at surface that would be removed from the ocean environment is likely low (i.e., <10%), most of the crude oil effect would be at surface and in the upper water column. Some crude oil could reach the lower water column and seabed through association with marine snow but these amounts should be minimal.

The next highest relative impact mitigation score, +2, is associated with the shoreline protection and recovery response option. As has been indicated frequently in this document, the probability of crude oil reaching the Newfoundland shoreline is low primarily because of the distance between the modelled release location in EL1134 and the shoreline.

The two response options involving the application of dispersants scored the lowest of the response options, -2 for the combination of surface and subsea application of dispersants, and -7 for only surface application of dispersants. The primary reason for the difference between the two options relates to the amount of oil that would occur on the ocean surface and upper water column. Using the surface application only involves most of the oil being released reaching the ocean surface. With the combined surface and subsea application, less released oil will reach the ocean surface and upper water column, thus lowering risk for migratory birds and various plankton types. On the other hand, subsea dispersant application will likely result in the formation of deep-water plumes of dispersed oil which could potentially have more effect on biota occurring in the lower water column and on the seabed.

From a socio-economic perspective, negative perception of an oil spill will persist, regardless of the response option used. This negative perception would probably be the primary socio-economic effect of an oil spill. Other potential socio-economic effects on various fisheries and seabird hunting include gear fouling, loss of access to fishing grounds, and actual tainting of invertebrates, fishes and seabirds.

6.4.7 Impact of Alternative Scenarios on Risk Ratings

In this subsection, the relative impacts associated with the other three spill scenarios originally considered for assessment in this SIMA are briefly examined.

6.4.7.1 EL1134-Winter

The time period used for modelling the EL1134-Winter scenario is November–April. Due to the adverse weather conditions, all response methods that relate to surface oil have lower encounter rates, on a daily basis, and were found to be less efficient than during the summer season. The primary differences in spill behavior and environmental conditions that could influence risk scoring are as follow:

- The range of mean wave heights is higher (2.8–4.4 m compared to 1.8–3.1 m during the summer period [see Table 1]);
- The range of mean wind speeds is higher (8.6–11.6 m/s compared to 6.3–9.3 m/s during the summer period [see Table 1]);
- The average probability of oil reaching shoreline is about 6% compared to 4% for the summer period;
- The minimum time to shoreline is 8 days compared to 27 days for the summer period;
- The length of shoreline with 15–25% probability of shoreline oil, on average, exceeding 1 g/m^2 is 107 km compared to none for the summer period;
- The 90% probability contour, on average, for surface oil thickness exceeding 0.04 µm delineates an area of 1,286,000 km^2 compared to 1,394,000 km^2 for the summer period;
- The 90% probability contour for the concentration of dissolved hydrocarbons in the water column exceeding 1µg/L delineates an area of 714,200 km^2 compared to 752,400 km^2 for the summer period; and
- The relative abundances of sensitive environmental receptors (i.e., ROCs) are lower during the winter period.

The differences in weather conditions had the net effect of increasing natural oil dispersion and evaporation, which resulted in a reduction of oil quantities on the surface during the winter period. Although the EL1134-Winter scenario is characterized by shorter times for oil to reach shore and a greater length of shoreline impacted, the probability of any oil reaching the Newfoundland shoreline is low. The areas of surface oil thickness and water column dissolved hydrocarbon threshold exceedances are less during the winter than during the summer, thereby reducing the chances of interactions of the ROCs with surface oil and dissolved hydrocarbons in the upper water column during the winter. Probably the most important difference between EL1134-Summer and EL1134-Winter is the far greater abundances of the ROCs/ROC constituents during the summer period, making risk of interaction with the oil greater during the summer period.

6.4.7.2 EL1135-Summer

The time period used for modelling the EL1135-Summer scenario is May–October. The same weather conditions used for EL1134-Summer modelling were used for EL1135-Summer modelling, and therefore, efficiencies of the different response options affected by weather are the same. The primary differences in spill behavior that could influence risk scoring are as follow:

- The average probability of oil reaching shoreline is about 2% compared to 4% for the EL1134-Summer scenario;
- The minimum time to shoreline is 31 days compared to 27 days for the EL1134-Summer scenario;
- The 90% probability contour, on average, for surface oil thickness exceeding 0.04 µm delineates an area of 18,370 km^2 compared to 1,394,000 km^2 for the EL1134-Summer scenario;

- The 90% probability contour for the concentration of dissolved hydrocarbons in the water column exceeding 1µg/L delineates an area of 3,123 km^2 compared to 752,400 km^2 for the EL1134-Summer scenario; and
- The relative abundances of sensitive environmental receptors (i.e., ROCs) are the same as those for the EL1134-Summer scenario.

The predicted shoreline, ocean surface and water column oiling characteristics for this scenario present less risk to the ROCs than during the EL1134-Summer scenario despite the abundances of the ROCs/ROC constituents being the same since both scenarios are during the summer period.

6.4.7.3 EL1135-Winter

The time period used for modelling the EL1135-Winter scenario is November–April. Because of more adverse weather conditions, all response methods that relate to surface oil have lower encounter rates, on a daily basis, and were found to be less efficient than during the summer season. The primary differences in spill behavior and environmental conditions that could influence risk scoring are as follow:

- The range of mean wave heights is higher (2.8–4.4 m compared to 1.8–3.1 m during the summer period [see Table 1]);
- The range of mean wind speeds is higher (8.6–11.6 m/s compared to 6.3–9.3 m/s during the summer period [see Table 1]);
- The average probability of oil reaching shoreline is about 2% compared to 4% for the EL1134-Summer scenario;
- The minimum time to shoreline is 30 days compared to 27 days for the EL1134-Summer scenario;
- The 90% probability contour, on average, for surface oil thickness exceeding 0.04 µm delineates an area of 23,730 km^2 compared to 1,394,000 km^2 for the EL1134-Summer scenario;
- The 90% probability contour for the concentration of dissolved hydrocarbons in the water column exceeding 1 µg/L delineates an area of 5,686 km^2 compared to 752,400 km^2 for the summer period; and
- The relative abundances of sensitive environmental receptors (i.e., ROCs) are lower during the winter period.

The differences in weather conditions had the net effect of increasing natural oil dispersion and evaporation, which resulted in a reduction of oil quantities on the surface during the winter period. The areas of surface oil thickness and water column dissolved hydrocarbon threshold exceedances are far less during the EL1135-Winter scenario compared to the EL1134-Summer scenario, thereby reducing the chances of interactions of the ROCs with surface oil and dissolved hydrocarbons in the upper water column during the EL1135-Winter scenario. Another important difference between EL1134-Summer and EL1135-Winter is the far greater abundances of the ROCs/ROC constituents during the summer period, making risk of interaction with the oil greater during the EL1134-Summer scenario.

6.4.7.4 Summary

The above comparisons of the other three spill scenarios originally considered for assessment in this SIMA with the EL1134-Summer scenario justify the choice of the EL1134-Summer scenario as the worst-case scenario involving a Tier 3 spill due to an uncontrolled blowout at a potential deep-water drilling site in the northern Flemish Pass.

6.5 Consideration of a Smaller Tier 1 Scenario

Major Tier 3 oil spill scenarios were used for the summer and winter impact mitigation analyses performed above so that a wide range of response options could be evaluated. Given the low probability of a Tier 3 spill, an additional spill scenario for a Tier 1 spill is examined in this subsection. For the purposes of this SIMA, the following assumptions have been made regarding available on-site Tier 1 response capabilities in Flemish Pass (Table 19).

Table 19. Available On-Site Tier 1 Response Capabilities.

Response Option	Assumed Tier 1 Capability (on site)
Natural Attenuation	Conduct aerial monitoring of the spill and conduct surveillance on any resources that may be impacted.
On-Water Mechanical Recovery	Single vessel side sweep systems available through mutual aid and other support vessels in region; use of sorbent boom.
In Situ Burn	Not applicable for Tier 1 batch spill.
Surface Dispersant Application	Dispersant available on-site within 24 hours. Can be applied through vessel-mounted spray booms or platform-mounted spray system.
Aerial Application of Dispersant	Not applicable for Tier 1 surface spill.
Subsea Dispersant Injection	Not applicable for Tier 1 surface spill.

For a batch spill on open water, although not insignificant, this size spill is a relatively small compared to the Tier 3 scenarios assessed in Subsection 5.2.

At higher sea states mechanical recovery operations may be limited, however, surface dispersant spraying using a vessel or platform is a response option that could be rapidly deployed, and therefore has the greatest potential for removing significant amounts of oil from the water surface in these conditions.

Because of the ephemeral nature of very small spills, it is unlikely that the Fish and Fish Habitat, Marine Mammal or Sea Turtle ROCs would come into contact with the spill. However, Migratory Birds in the immediate vicinity could become oiled. Due to the small spill volume, impacts to the

Upper and Lower Water Column and Seabed environmental compartments are unlikely to occur, and therefore, impacts to the Fisheries ROC are also unlikely to occur.

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Appendix A

Historical Use of SIMA in the United States and Canada[1]

The integration of NEBA into oil spill response planning in the U.S. ramped up in the mid-1990s, when the United States Coast Guard (USCG) developed a multi-agency approach to evaluate the ecological effects from various response options. The effort was spurred from a publication in Spill Science and Technology (Aurand 1995) which outlined the essential elements of what was, at that time, referred to as "Consensus Ecological Risk Assessment (CERA)." The USCG fostered the development of a "Guidelines" document, which provided a practical approach to conducting the environmental analysis. The document entitled "Developing Consensus Ecological Risk Assessments: Environmental Protection in Oil Spill Response Planning: A Guidebook" was published in 2000, after a four-year interagency development period (Aurand et al. 2000).

USCG, with support from a variety of other U.S. Federal and state agencies, including EPA, NOAA, U.S. Fish and Wildlife Service, Texas General Land Office, and California Office of Spill Prevention and Response, has sponsored more than twenty Ecological Risk Assessment workshops in the US that have considered the impacts and ecosystem recovery rates from various oil spill response options at hypothetical open water and inland spills. In each of these workshops, participants evaluated surface dispersant use along with other oil spill response strategies, with the goal of preparing a response option trade-off analysis.

Facilitated workshop locations included:

- Puget Sound (1998–2000);
- Galveston Bay (1999);
- San Francisco Bay (1999);
- Mississippi Sound (2000);
- Long Island Sound (2001);
- Santa Barbara Channel (2002);
- Chesapeake Bay (2002);
- Upper Florida Keys (2002);
- Casco Bay, Maine (2003);
- US and British Virgin Islands (2003);
- Upper Mississippi River (2004);
- Cape Flattery, WA (2004–2005);
- Delaware Bay (2005);

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[1] From: Slaughter, A., G. Coelho, and J. Staves. 2017. Spill Impact Mitigation Assessment in Support of BP Canada Energy Group ULC Scotian Basin Exploration Project. Sponson Group Inc. Technical Project Report 17-03. Mansfield, TX, USA.

- Mexico – United States Pacific Coastal Border Region (2006);
- Guayanilla Bay Area, Puerto Rico (2007);
- Mexico- United States Gulf of Mexico Coastal Border Region (2008);
- Northwest Arctic Alaska (2012); and
- Delaware Bay - Bakken and Dilbit transportation (2016).

In addition, Regional Response Teams (RRT) (members from state and federal agencies) conducted several dozen additional ERA workshops “in house” (e.g., without the use of a contracted facilitator). Each CERA involved a several-month process to:

- develop scenarios and identify Resources at Risk;
- conduct multi-day workshops involving more than a dozen different federal and state agencies, academic institutions, oil and gas companies, oil spill response organizations, and non-governmental organizations; and
- publish a final report.

While early workshops focused purely on environmental considerations, the process was eventually adapted to include some socio-economic considerations such as commercial fishing and marine transportation, subsistence uses of marine and coastal areas, and recreational use of coastal areas and beaches.

All of the workshops resulted in final publications (available from USCG) that were delivered to the Area Committees and RRTs to assist with response planning. An example of using this CERA/NEBA process to inform dispersant use decision-making is summarized in several papers authored by regulators in the state of California (Addassi and Faurot-Daniels 2005; Addassi et al. 2005). The applicability of the CERA/NEBA process as a tool for facilitating dispersant decision-making during spill response and planning was also evaluated by NOAA. Ultimately, the USCG and U.S. EPA used their CERAs to help establish dispersant pre-authorization zones across many offshore regions in the US.

In addition to being an ideal team-building mechanism to bring many federal, state, and local organizations together, the CERA process has helped build relationships between response technology experts and decision-makers. One of the outcomes of these workshops was the development of a series of habitat fact sheets that were developed by the workshop participants, which considered the impacts of oil on various important natural resources or ecosystems, and assisted the CERA participants with making response option trade-off analyses. The fact sheets were modified and evolved with each workshop, and were eventually published as a series of NOAA publications.

Since the DWH incident in 2010, interest in routinely conducting NEBAs/SIMAs for offshore drilling locations has increased in the U.S., and beginning in 2012, have been routinely integrated into contingency plans and exercises in U.S. and Canadian waters, as summarized below.

- In 2012–2013, a series of NEBA workshops were conducted for an ongoing response in the Gulf of Mexico. The project involved multiple inter-agency and industry workshops to examine the potential ecological impacts of response alternatives being considered for sheen abatement for the remnants of the Taylor Energy Company, LLC MC-20A Platform in the Gulf of Mexico, which was destroyed during a subsea mudslide;
- In 2013, a NEBA was conducted to evaluate dispersant use for spills in the Newfoundland Grand Banks region in Eastern Canada;
- In early 2014, an expedited NEBA was prepared for a Freeport McMoRan exercise in the Gulf of Mexico. The resultant findings led to the first ever "mock approval" of SSDI during a U.S. offshore blowout/Source Control exercise;
- Later in 2014, a more comprehensive NEBA was prepared for a BP exercise in the Gulf of Mexico. This is the first time that modeling results were incorporated into a US NEBA for the purposes of a blowout/Source Control exercise. This NEBA set the standard for how NEBA has since been applied to response exercises in the US;
- In 2014–2015, a Shelburne Basin NEBA was prepared for Shell Canada. This project involved close coordination with and involvement of regional and national Canadian regulators and stakeholders, including the Canada-Nova Scotia Offshore Petroleum Board, Canadian Coast Guard, Environment Canada, and Fisheries and Oceans Canada;
- In 2015, an Expedited NEBA was prepared for BP Alaska. This NEBA resulted in the first ever "mock exercise" surface dispersant application approval in US Arctic Alaska;
- In 2016, another expedited NEBA was prepared for LLOG drilling operations in support of a drill in the Gulf of Mexico drill. After this drill concluded, the RRT in that region has taken steps to formalize the process for using SIMAs as a required component for requesting surface dispersant and/or SSDI approval during spill responses in the Gulf of Mexico. The guidance document was released in 2017 (API 2017);
- In 2016, a Comparative Risk Assessment study was conducted to evaluate response options for a deepwater blowout, both with and without the use of SSDI. The study culminated in a workshop with US agency representatives in November 2016. While the final report is still under preparation, a summary of the study was recently presented at IOSC (French-McCay et al. 2017). The report concluded that "SSDI substantially decreased the amount of oil on the water surface and on the shoreline and … decreased VOC emissions to the atmosphere";
- In March 2017, an expedited SIMA was prepared for Anadarko for drilling operations in the Gulf of Mexico. This effort was coordinated within a larger U.S.-Mexico source control drill. One of the outcomes for the overall activity was the need for greater emphasis on data management during a spill of national significance; and
- In 2017, a SIMA was conducted for Statoil exploration efforts in Flemish Pass, in coordination with the Canada-Newfoundland Labrador Offshore Petroleum Board.

Suggested Additional Reading:

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Appendix B
An Overview of Dispersants[2]

The Role of Dispersants in Oil Spill Response

Industry is committed to responding to any open water oil spill with a full complement of response strategies, including mechanical on-water recovery, dispersants, *in situ* burning, shoreline recovery, and preventative containment booming. In numerous regions, mechanical recovery is the preferred method of many regulating agencies to remove oil from the surface of the water when environmental conditions permit. However, past government and industry experience with responding to open water oil spills has demonstrated that mechanical recovery alone has traditionally yielded poor rates of recovery because of low encounter rates and reduced efficiency due to higher wave conditions offshore. As industry operates in deeper waters farther offshore, there are additional limitations for greater transit distances by boats supporting the response, and adverse weather conditions that can hamper safe operations and returns to port.

For these reasons, the appropriate use of dispersants, applied either at the ocean's surface or subsea, may provide the only means of removing significant quantities of oil from the surface quickly, therefore rapidly and efficiently reducing overall environmental impacts from the spill to nearshore, shallow water environments. Industry and government agencies are working together to use SIMA principles to consider the consequences of using dispersants to move the oil into the water column where it can be rapidly biodegraded, against the impacts of oil remaining on the water surface or oil stranding on the shoreline if mechanical containment and recovery efforts are ineffective or inefficient.

In cases where dispersants are a viable strategy as part of an overall oil spill response, they should be considered as a primary response tool. As is the case with every response option, the decision to use dispersants must be carefully considered to determine if the oil is dispersible, if environmental conditions are appropriate for safe application and surveillance, and if the dispersant application will result in improved recovery of the ecosystem once the spill response has concluded.

When dispersants are considered a viable option, it is important to use high-quality dispersant products. The following guidelines should be considered when selecting a dispersant.

- The dispersant degrades into environmentally safe bi-products and does not contain endocrine disruptors;

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[2] From: Slaughter, A., G. Coelho, and J. Staves. 2017. Spill Impact Mitigation Assessment in Support of BP Canada Energy Group ULC Scotian Basin Exploration Project. Sponson Group Inc. Technical Project Report 17-03. Mansfield, TX, USA.

- The dispersant is effective over a wide range of spill conditions (including broad range of oil types, weathering states, and environmental conditions);

- Low aquatic toxicity at dispersant concentrations that are relevant to field application is documented; and
- The availability of the dispersant is in sufficient quantity to quickly respond to a worst-case discharge event.

Dispersants, when applied properly in the right situations, can produce higher levels of environmental protection than other response strategies. Dispersants increase the amount of oil that dissipates into the water column, and reduce the amount of oil remaining on the surface. Dispersant use, therefore, reduces the potential for floating oil to reach ecologically and economically sensitive open water or shoreline environments. The oil that disperses into the water column may pose temporary elevated exposures to organisms in the immediate area, but research and experience has shown that those exposures are rapidly mitigated by the effects of dilution and microbial degradation of the dispersed oil.

Principles of Chemical Dispersion

Natural dispersion of floating oil is a process facilitated by wave action that breaks the oil into small droplets and disperses them into the water column. It is affected by the properties of the oil and the amount of wave energy at the sea surface. In general, oils with lower viscosity are more amenable to natural dispersion than those with higher viscosity, and higher wave energy produces more natural dispersion. Very small oil droplets (less than 70 µm in diameter) generally tend to stay suspended in the water column, while larger ones are more likely to float to the surface and can re-coalesce into a slick.

Natural dispersion also occurs during subsea discharges but is largely dependent on droplet size which, in turn, is dependent on discharge velocity, rate, and oil to gas ratios. Like surface spills, droplet sizes less than 70 µm in diameter typically remain dispersed in the water column whereas larger droplets are more buoyant and will generally float to the surface and form floating oil slicks.

Chemical dispersants are surfactants that enhance natural dispersion by reducing the surface tension at the oil/water interface, making it easier for waves or turbulence to create small oil droplets. Modern chemical dispersants are a blend of surfactants (surface active agents or soap) in a solvent. The solvent has two functions: 1) to reduce the viscosity of the surfactant, which enables it to be sprayed, and 2) to promote the penetration of the surfactant into the oil slick. The surfactant molecules are the key component of the dispersant. They are made up of two parts: an oleophilic part (oil-loving) and a hydrophilic part (water-loving). When dispersants are sprayed onto an oil slick, the solvent transports and distributes the surfactants into the oil slick and the surfactants reduce the surface tension at the oil/water interface. As a result, small oil droplets are formed, which break away from the oil slick with the help of wave energy. Re-coalescence is minimized by the presence of the surfactant molecules on the droplet surface.

Dispersants have traditionally been applied to the surface by properly equipped vessels, helicopters, and fixed-wing aircraft. There are many examples of surface dispersant use in North America since 1990 that involved smaller volumes of dispersant application, including these events:

- T/V Mega Borg – 1990 (dispersant test only);
- West Cameron Block 168 Oil Spill – 1995;
- High Island Pipeline System Spill – 1998;
- T/V Red Seagull – 1998;
- BP-Chevron Pipeline – 1999;
- Blue Master – 1999;
- Poseidon Pipeline – 2000;
- Main Pass 69 Oil Spill – 2004;
- Shell Pipeline Ship Shoal Block 142 – 2009; and
- Galveston Endeavor vs. M/T Krymsk – 2009.

Another notable example of dispersant use is the *Sea Empress* oil spill (1996) where significant volumes of dispersants were used near-shore to help protect sensitive resources from the impacts of floating oil. The use of around 445 tonnes of chemical dispersants sprayed by aircraft onto the oil slicks at sea prevented at least 36,000 tonnes of oil, from the *Sea Empress* coming ashore in this sensitive region of Wales.

The DWH incident was the first continuous, uncontrolled release of oil into the ocean where large quantities of dispersants (approximately 53,000 tonnes) were applied using a combination of aerial, vessel, and subsea dispersant application methods. As a result of the innovative use of SSDI during the DWH incident, new technologies for subsea dispersant use are evolving rapidly.

Factors that Affect Dispersant Effectiveness

Dispersant effectiveness for surface applications is influenced by the efficiency of the application process (encounter rate), the dispersibility of the oil, and the sea state (wave energy). Factors that affect oil dispersibility include the viscosity, pour point, chemical composition, and the degree of weathering. Many crude and some refined oils tend to form stable emulsions over time when mixed with water by wave action and these emulsions can be difficult to break and disperse. For surface oil, the time window within which dispersants are effective is generally less than a few days, after which the oil becomes too viscous or emulsified. Another important limitation for surface dispersant application is visibility. Aerial dispersant application can only be performed under conditions where visibility is sufficient to allow accurate slick targeting. Therefore, aerial dispersant application can be restricted by poor weather (i.e., low cloud ceiling) and can only be conducted during daylight hours.

The encounter rate for surface dispersant application is affected by the speed of the delivery system (i.e., workboat vs. multi engine aircraft), the amount of dispersant that can be carried, the width of the spray pattern, and the ability to deliver dispersants in small droplets capable of entering the oil without “punching through” to the water below. The optimum droplet size is generally considered to be about 600–800 µm. The targeted DOR for surface application of modern dispersants is generally around 1:20.

Sea state is important for surface dispersant application because it affects both the distribution of the oil and the mixing energy available for breaking slicks into small droplets. If the wave energy is too low, the oil may not be effectively dispersed into the water column and droplets may resurface. If wave energy is too high, the oil can be submerged by breaking waves, preventing direct contact between the dispersant and oil. Poor weather conditions can also affect the safety of surface spraying operations. Optimum wind speeds for surface dispersant application is about 5–25 knots.

The viscosity and pour point of a given oil provide a good indication of its dispersibility. As a general rule, fresh light to medium crude oils are considered to be readily dispersible whereas highly viscous oils are not. The upper limit of dispersibility is likely to be reached with heavier oils. As a general rule, dispersant effectiveness will decrease as oil viscosities increase. They are likely to be ineffective for oils with an initial viscosity above 10,000 cSt at the time they are spilled. Pour point is also an important parameter. Any oil with a pour point higher than the ambient temperature will start to become very viscous as it cools after spillage.

Subsea dispersant application was first used in the DWH response in 2010. To date, industry, academia and other research organizations are making concerted efforts to learn more about the effectiveness of this response option and the potential fate and effects to the deepwater environment. Research has been recently published on how various factors, such as temperature, pressure, gas-to-oil ratio, etc., affect subsea dispersant application methodology and effectiveness. Additionally, testing of low-solvent dispersants is underway to assess their utility for subsea injection, and a new protein-based dispersant hit the US market in 2016 and is undergoing further evaluation.

Several of the limitations that apply to surface application may not affect SSDI. For example, subsea injection is relatively unaffected by weather and sea state. As the encounter rate is much higher due to more accurate targeting of the released oil by the dispersant application system, the DOR required to promote effective dispersion is much lower. The rate can be adjusted during a response event to optimize the effectiveness, based on real-time subsea dispersant monitoring data.

Suggested Additional Reading

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