5.0 Effects Assessment

Two general types of effects are considered in this document:

1. Effects of the environment on the Project; and
2. Effects of the Project on the environment, particularly the biological environment represented by "Valued Ecosystem Components" (VECs) as described below in Section 5.2.

Methods of effects assessment used here are comparable to those used in recent east coast offshore drilling (e.g., LGL 2005, 2008b) and seismic EAs (e.g., LGL 2008a; LGL 2012). These documents conform to the *Canadian Environmental Assessment Act* (*CEAA*) and associated Responsible Authority's Guide and the CEA Agency Operational Policy Statement (OPS-EPO/5-2000) (CEA Agency 2000). Cumulative effects are incorporated within the procedures in accordance with *CEAA* (CEA Agency 1994) as adapted from Barnes and Davey (1999) and used in the White Rose EA (Husky 2000).

5.1 Scoping

The C-NLOPB provided a Scoping Document (dated March 4, 2013) for the Project which outlined the factors to be considered in the assessment. In addition, various stakeholders were contacted for input (see below). Scoping for the effects assessment also involved reviewing recent regional EAs including (but not limited to) the Orphan Basin SEA (LGL 2003), the Jeanne d'Arc Basin seismic and geohazard program EA for StatoilHydro (LGL 2008a), exploration and drilling EAs and their amendments for Orphan Basin (LGL 2005, 2006b, 2009), Chevron's Labrador and northern Grand Banks seismic EAs (LGL 2010, 2011b respectively), and Husky's Jeanne d'Arc Basin/Flemish Pass seismic EA (LGL 2012). A review of current knowledge of the effects of seismic sound on marine organisms is also included.

Consultations were undertaken with representatives of the fishing industry (e.g., FFAW, One Ocean, and others). The purpose of consultations was to describe HMDC's proposed seismic program, to identify any issues and concerns, and to gather any additional information relevant to the EA. A summary of the results of these consultations is provided in the following section

5.1.1 Consultations

A short description of the program and a location map were sent to the FFAW and One Ocean prior to the consultation meeting. HMDC and its consultant met with representatives of the FFAW and One Ocean on 28 March 2013 to review and discuss the proposed program. In addition, the following individuals and organizations were contacted:

- Michael O'Conner, Fish Harvesting Consultant, Icewater Seafoods
- Tom Osbourne, Arnold's Cove Fish Plant, Icewater Seafoods
- Rick Ellis, Fleet Manager, Ocean Choice International

- Derek Butler, Executive Director, Association of Seafood Producers
- Bruce Chapman, Executive Director, Groundfish Enterprise Allocation Council (GEAC)
- Catherine Boyd, Manager Corporate Affairs, Clearwater Seafoods Ltd.

5.1.1.1 Issues and Concerns

No significant issues/concerns were raised during the consultation meeting with the FFAW and One Ocean. The topics that were discussed included the following:

- Details of crew changes in relation to FLOs;
- Temporal and spatial details related to streamer deployment;
- Necessity of having a paper marine chart at consultation meetings;
- Temporal and spatial details of post-season snow crab survey;
- Single Point of Contact (SPOC);
- A 'seismic protocol' document recently completed by One Ocean; and
- The westward distributional expansion of snow crab in NAFO Unit Areas 3Li and 3Lt to around the 57 fathom depth.

Some of the topics for discussion (e.g., snow crab survey, SPOC) will continue to be addressed during lead up to the program. Other respondents (ASP and GEAC) to date have not identified any issues associated with the proposed project. HMDC will continue to communicate with the FFAW, One Ocean and others throughout the assessment process.

5.2 Valued Ecosystem Components

The Valued Ecosystem Component (VEC) approach was used to focus the assessment on those biological resources of most potential concern and value to society and include the following groups:

- Rare or threatened species or habitats (as defined by the *SARA* and COSEWIC);
- Species or habitats that are either unique to an area or valued for their aesthetic properties;
- Marine species that are harvested by people (e.g., commercial fishery target species); and
- Marine species with some potential to be affected by the Project.

The VECs were identified based on the scoping exercise as described in Section 5.1 above. The VECs and their associated rationale include:

- **Fish and Fish Habitat** with emphasis on the Study Area's four most important (past and present) commercial species: (1) shrimp, (2) snow crab, (3) Greenland halibut (turbot), and (4) Atlantic cod (a representative species with a swim bladder and hence, may be susceptible to seismic survey sound). It is recognized that there are many other fish species, commercial or prey species, that could be considered but it is LGL's professional opinion that this suite of species captures the relevant issues concerning the potential effects of seismic surveys on important invertebrate and fish populations of the Study Area.

- **Commercial fisheries** are directly linked to the fish and fish habitat VEC above but all fisheries (trawling, gillnetting, longlines, pots, etc.) are considered where relevant. The commercial fishery is a universally acknowledged important element in the society, culture, economic and aesthetic environments of Newfoundland and Labrador. This VEC is of prime concern from both a public and scientific perspective, at local, national and international scales.

- **Seabirds** with emphasis on those species most sensitive to seismic activities (e.g., deep divers such as murres) or vessel stranding (e.g., petrels), and *SARA* species (e.g., Ivory Gull). Newfoundland and Labrador waters support some of the largest seabird colonies in the world and the Study Area hosts large populations during all seasons. They are important socially, culturally, economically, aesthetically, ecologically and scientifically. This VEC is of prime concern from both a public and scientific perspective, at local, national and international scales.

- **Marine Mammals** with emphasis on those species potentially most sensitive to low frequency sound (e.g., baleen whales) and *SARA* species (e.g., blue whale). Whales and seals are key elements in the social and biological environments of Newfoundland and Labrador. The economic and aesthetic importance of whales is evidenced by the large number of tour boats that feature whale watching as part of a growing tourist industry. This VEC is also of prime concern from both a public and scientific perspective, at local, national and international scales.

- **Sea Turtles**, uncommon in the Study Area, are mostly *threatened* and *endangered* on a global scale. The leatherback sea turtle that forages in eastern Canadian waters is considered *endangered* under *SARA*. While they are of little or no economic, social or cultural importance to Newfoundland and Labrador, their *endangered* status warrants their inclusion as a VEC. Also, this VEC is of prime concern from both a public and scientific perspective, at national and international scales.

- **Species at Risk** are those listed as *endangered* or *threatened* on Schedule 1 of *SARA*. All species at risk in Newfoundland and Labrador offshore waters are captured in the VECs listed above. However, due to their special status, they are also discussed separately.

5.3 Boundaries

For the purposes of this EA, the following temporal and spatial boundaries were defined.

5.3.1 Temporal

The temporal boundaries for the first 4D survey are 1 May to 31 December in 2013. In subsequent years (2014 to end of the field life--EF), seismic surveys may also occur from 1 May to 31 December.

5.3.2 Spatial

The ***Project Area*** is defined as the area within which geophysical data could be acquired plus an additional area around the outer perimeter of the data acquisition area to accommodate the ships' turning radii (see Figure 1.1).

The ***Study Area***, slightly larger than the Project Area with an additional 20 km buffer, is defined as the area within which any potential effects of the Project on the VECs, based on the scientific literature, could occur. The Study Area is the same as the "Affected Area" as originally defined by *CEAA*.

The ***Regional Area*** is loosely defined as the northern Grand Banks and Orphan Basin (e.g., to include the major Grand Banks developments such as Hibernia, Terra Nova, White Rose, and Hebron). This area is referred to when considering cumulative effects.

5.4 Effects Assessment Procedures

The systematic assessment of the potential effects of the Project involved three major steps:

1. Preparation of interaction matrices (i.e., interactions of Project activities and the environment);
2. Identification and evaluation of potential effects, including description of mitigation measures and residual effects, and
3. Preparation of residual effects summary tables, including evaluation of cumulative effects.

5.4.1 Identification and Evaluation of Effects

Interaction matrices identifying all possible Project activities that could interact with any of the VECs were prepared. The interaction matrices are used to identify potential interactions only and they do not make any assumptions about the potential effects of the interactions.

Interactions were then evaluated for their potential to cause effects. In instances where the potential for an effect of an interaction was deemed impossible or extremely remote, these interactions were not considered further. This approach allows the assessment to focus on key issues and the more substantive environmental effects.

An interaction was considered to be a potential effect if it could change the abundance or distribution of VECs, or change the prey species or habitats used by VECs. The potential for an effect was assessed by considering:

- Location and timing of the interaction;
- Literature on similar interactions and associated effects (seismic EAs for offshore Nova Scotia and Newfoundland and Labrador);
- Consultation with other experts, when necessary; and
- Results of similar effects assessments, especially monitoring studies done in other areas.

If data were insufficient to allow precise effects evaluations, predictions were made based on professional judgement. In such cases, the uncertainty is documented in the EA. Effects were evaluated for the proposed geophysical survey program, and included the consideration of mitigation measures that are either mandatory or have become standard operating procedure in the industry.

5.4.2 Classifying Anticipated Environmental Effects

Classification of environmental effects means determining whether they are negative, positive or neutral. The following are key factors that are considered for determining negative environmental effects, as per the CEA Agency guidelines (CEA Agency 1994):

- Negative effects on the health of biota;
- Loss of rare or *endangered* species;
- Reductions in biological diversity;
- Loss or avoidance of productive habitat;
- Fragmentation of habitat or interruption of movement corridors and migration routes;
- Transformation of natural landscapes;
- discharge of persistent and/or toxic chemicals;
- Toxicity effects on human health;
- either loss of or detrimental change in the current use of lands and resources for traditional purposes;
- Foreclosure of future resource use or production; and
- Negative effects on human health or well-being.

5.4.3 Mitigation

Mitigation measures appropriate for effects predicted in the matrix were identified and the effects of various Project activities were then evaluated assuming the application of appropriate mitigation measures. These effects after application of the mitigation measures are known as ‘residual effects’. Residual effects predictions were made taking into consideration both standard and Project-specific mitigations.

5.4.4 Evaluation Criteria for Assessing Environmental Effects

Several criteria were taken into account when evaluating the nature and extent of environmental effects. These criteria include (as per guidance in CEA Agency 1994):

- Magnitude;
- Geographic extent;
- Duration;
- Frequency;
- Reversibility; and
- Ecological, socio-cultural and economic context.

5.4.4.1 Magnitude

Magnitude describes the nature and extent of the residual effect for each activity.

Ratings for this criterion are defined as:

0 *Negligible* - Measureable effect on individuals but less than the 'low' rating.

1 *Low* - Affecting >0 to 10 percent of individuals in the affected area (i.e. Study Area) (e.g., geographic extent). Effects may include acute mortality, sublethal effects or exclusion due to disturbance.

2 *Medium* - Affecting >10 to 25 percent of individuals in the affected area (i.e. Study Area). Effects may include acute mortality, sublethal effects or exclusion due to disturbance.

3 *High* - Affecting >25 percent of individuals in the affected area (i.e. Study Area). Effects may include acute mortality, sublethal effects or exclusion due to disturbance.

Definitions of magnitude used in this EA have been used previously in numerous offshore oil-related environmental assessments under *CEAA*. Some example assessments include the Petro-Canada seismic EA (LGL 2007a), the White Rose Oilfield Comprehensive Study (Husky 2000), the StatoilHydro Jeanne d'Arc Basin area seismic and geohazard program EA (LGL 2008a), the ConocoPhillips Laurentian Sub-Basin exploration drilling EA (Buchanan et al. 2006), the Chevron Labrador and northern Grand Banks seismic EAs (LGL 2010, 2011b), the Hebron Project Comprehensive Study (ExxonMobil 2011), and Husky seismic EA (LGL 2012).

5.4.4.2 Geographic Extent

Geographic extent refers to the specific area (km^2) of the residual effect caused by the Project activity. Geographic extent will likely vary depending on the activity and the relevant VEC.

Ratings for this criterion are defined as:

1 = <1 km^2
2 = 1-10 km^2
3 = >10-100 km^2
4 = >100-1,000 km^2
5 = >1,000-10,000 km^2
6 = >10,000 km^2

5.4.4.3 Duration and Frequency

Duration describes how long a residual effect will occur.

Ratings for this criterion are defined as:

1 = <1 month
2 = 1 – 12 month
3 = 13 – 36 month
4 = 37 – 72 month
5 = >72 month

Short duration can be considered 12 months or less, medium duration 13 to 36 months, and long duration >36 months.

5.4.4.4 Frequency

Frequency describes how often a residual effect will occur.

Ratings for this criterion are defined as:

1 = <11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

5.4.4.5 Reversibility

Reversibility refers to the capability of a VEC population to return to either its pre-Project or an improved condition, after the Project has ended.

Ratings for this criterion are defined as:

R = reversible
I = Irreversible

5.4.4.6 Ecological, Socio-cultural and Economic Context

The ecological, socio-cultural and economic context refers to the pre-Project status of the Study Area (i.e., potential affected area) in terms of existing environmental effects. The Study Area is not considered to be strongly affected by human activities.

Ratings for this criterion are defined as:

1 = Environment not negatively affected by human activity (i.e., relatively pristine area)
2 = Evidence of existing negative effects on the environment

5.4.5 Cumulative Effects

Projects and activities considered in the cumulative effects assessment include other human activities in Newfoundland and Labrador offshore waters, with emphasis on the Grand Banks Regional Area.

- Within-Project cumulative impacts. For the most part, and unless otherwise indicated, within-Project cumulative effects are fully integrated within this assessment;
- Existing and *in progress* offshore oil developments in Newfoundland and Labrador: Hibernia (GBS platform), Terra Nova FPSO, White Rose FPSO and associated extension, and the Hebron GBS;
- Other offshore oil exploration activity (particularly seismic surveys and exploratory drilling as outlined on the C-NLOPB website). In 2013, other possible oil exploration activity in the Regional Area include 2D/3D seismic surveying by Hebron and the possibility that Chevron will drill an exploratory well in the Orphan Basin (just north of the Grand Banks) in 2013. There is also some potential for several 2D/3D/4D, geohazard and VSP surveys in any given year.
- Fisheries (domestic and foreign commercial, recreational, aboriginal/subsistence);
- Marine transportation (tankers, cargo ships, supply vessels, naval vessels, fishing vessel transits, etc.); and
- Hunting activities (marine birds and seals).

5.4.6 Integrated Residual Environmental Effects

Upon completion of the evaluation, the residual environmental effects are assigned a rating of significance for:

- Each project activity;
- Cumulative effects of activities within the Project; and
- Cumulative effects of combined projects in the Regional Area.

As such, this represents an integrated residual environmental effects evaluation.

The analysis and prediction of the significance of residual environmental effects, including cumulative environmental effects, encompasses the following:

- Determination of the significance of residual environmental effects;
- Establishment of the level of confidence for prediction; and
- Evaluation of the scientific certainty and probability of occurrence of the residual impact prediction.

Ratings for level of confidence associated with each prediction are presented in the table of residual environmental effects. In the case of a significant predictive rating, ratings for probability of occurrence and determination of scientific certainty are also included in the table of residual environmental effects. The guidelines used to determine these ratings are discussed in the following sections.

5.4.6.1 Significance Rating

Significant residual environmental effects are those that are considered to be of sufficient magnitude, duration, frequency, geographic extent, and/or reversibility to cause a change in the VEC that will alter its status or integrity beyond an acceptable level. Establishment of the criterion is based on professional judgment but is transparent and repeatable. In this EA, a significant residual effect is defined as:

> *Having either a high magnitude regardless of duration and geographic extent ratings, or a medium magnitude for more than one year over a geographic extent greater than 100 km*^{2}

A residual effect can be considered *significant* (S), *not significant* (NS), or *positive* (P).

5.4.6.2 Level of Confidence

The significance of the residual environmental effects is based on a review of relevant literature, consultation with experts, and professional judgment. In some instances, making predictions of potential residual environmental effects are difficult due to the limitations of available data (i.e., technical boundaries). Ratings are therefore provided to qualitatively indicate the level of confidence for each prediction. The level of confidence is considered low (1), medium (2) or high (3).

5.4.6.3 Probability of Occurrence

The probability of occurrence of a *significant* residual effect, based on professional judgement, is considered low (1), medium (2) or high (3).

5.4.6.4 Scientific Certainty

The scientific certainty of a *significant* residual effect, based on scientific information, statistical analysis and/or professional judgement, is considered low (1), medium (2) or high (3).

5.5 Effects of the Environment on the Project

The physical environment is summarized in Section 3.0 and the reader is referred to this section and Section 5.5 in LGL (2012) (appended) to assist in determining the effects of the environment on the Project. Furthermore, safety issues are assessed in detail during the permitting and program application processes established by the C-NLOPB as the regulatory authority in this matter. Nonetheless, effects on the Project are important to consider, at least on a high level, because they may sometimes cause effects on the environment. For example, accidental spills may be more likely to occur during rough weather.

Given the Project time window of May to December for seismic operations and the requirement of a seismic survey to avoid periods and locations of sea ice, sea ice should have no effect on the Project. Icebergs in the spring and early summer may cause some survey delays if tracks have to be altered to avoid them. Icebergs may cause some detours in May when iceberg occurrence of any size is on the order of 28% (of total for the year) as opposed to June (9%), July (2%), and August through December (essentially 0%) based on data contained in Table 3.5.3 in LGL (2012).

Most environmental constraints on seismic surveys on the Grand Banks are those imposed by wind and wave. If the Beaufort wind scale is six or greater, there is generally too much noise for seismic data to be of use. A Beaufort wind scale of six is equivalent to wind speeds of 22-27 knots (11.3-13.9 m/s), and is associated with wave heights ranging from 2.4-4.0 m. In the Study Area, these conditions are typically reached at a consistent level in the late autumn and winter months. Certainly, if the sea state exceeds 3.0 m or winds exceed 40 kt (20.6 m/s), then continuation/termination of seismic surveying will be evaluated. The absolute operating limits for seismic vessels are 3.5 m combined sea significant wave height and 45 kt (23.2 m/s) winds. Based on multi-year data at a nearby grid point, these wave limits may be approached about 8% of the time in May, 4% in June, 2% in July, 4% in August, 12% in September, 26% in October, 38% in November, and 55% of the time in December (see Figure 3.2.1 in LGL 2012). Similarly, 23.2 m/s winds might occur 1% or less of the time during the Project time frame based on historical data (see Figure 3.10 in LGL 2012).

As a prediction of the effects of the environment on the Project, some operators have used an estimate of 25% weather-related down time for the project planning purposes. If 25% is used as a guideline, then conditions in November and December might be considered a significant effect on Project logistics and economics by some proponents although this is likely to be variable depending upon the operator.

The Project scheduling avoids most of the continuous extreme weather conditions and HMDC's contractors will be thoroughly familiar with East Coast operating conditions. Seismic vessels typically suspend surveys once wind and wave conditions reach certain levels because the ambient noise affects the data. They also do not want to damage towed gear which would cause costly delays.

Environmental effects on other Project vessels (e.g., picket and service vessels) are likely less than on the seismic vessel which is constrained by safety of towed gear and data quality issues.

Effects of the biological environment on the Project are unlikely although there are anecdotal accounts of sharks attacking and damaging streamers.

The Department of National Defense (DND) will be contacted in regard to potential unexploded ordnance (UXO) in the area prior to any deployment of OBCs.

5.6 Effects of the Project on the Environment

The main pathway that links the Project and environment is the transmission of sound from the seismic survey sources to the various VECs (or "receivers"). The basics of sound and its propagation in the marine environment are described in Richardson et al. (1995). Of principal concern during seismic programs is the potential effects of sound from air sources on VECs as air sources used during marine seismic operations introduce strong sound impulses into the water (see Appendix C *in* LGL 2007a) for a detailed review of the characteristics of air source pulses). The seismic pulses produced by the air sources are intentionally directed downward toward the seafloor, insofar as possible; however, energy will propagate outward from the source through the water. The following sections review the hearing/detection abilities of VECs and the available information on potential effects of sound (as well as other Project activities) from the proposed seismic program on VECs.

5.6.1 Fish and Fish Habitat VEC

There will be interaction between Project activities and the 'fish habitat' component of the Fish and Fish Habitat VEC (i.e., water and sediment quality, phytoplankton, zooplankton, and benthos) (Table 5.1), However, such interactions are so small relative to the overall environments or populations that they are considered *negligible* residual effects and hence *not significant*. The 2013 program will not result in any direct physical disturbance of the bottom substrate. In future years, placement and retrieval of on bottom cables (OBC) which contain receivers (hydrophones) may cause some small disturbance to the seabed but the area involved and the rapid return to normal suggest no change in the prediction of *negligible* residual effects on fish habitat of the Study Area. Also, the probability is very low of any accidental event (i.e., hydrocarbon release) being of large enough magnitude to cause a significant effect on offshore fish habitat. Therefore, except for interactions identified in Table 5.1, no further reference to the 'fish habitat' component of the Fish and Fish Habitat VEC is made in this assessment section.

Ichthyoplankton, invertebrate eggs and larvae, and macrobenthos are considered as part of the 'fish' component of the Fish and Fish Habitat VEC.

Table 5.1 Potential Interactions of the Project Activities and the Fish and Fish Habitat VEC.

Valued Ecosystem Component: Fish and Fish Habitat							
Project Activities	**Non-Biological Environment**	**Feeding**		**Reproduction**		**Adult Stage**	
	Water and Sediment Quality	**Plankton**	**Benthos**	**Eggs and Larvae**	**Juveniles** [a]	**Pelagic Fish**	**Groundfish**
Sound Emissions and Receivers							
Air Sources		X	X	X	X	X	X
Seismic Vessel						X	
Supply Vessel						X	
Picket Vessel						X	
On bottom cables (OBC)	X		X				X
Helicopter [b]							
Echo Sounder						X	
Side Scan Sonar						X	
Boomer			X	X	X	X	X
Vessel Lights							
Vessel Presence							
Seismic Vessel							
Supply Vessel							
Picket Vessel							
Sanitary/Domestic Waste	X	X		X		X	
Atmospheric Emissions	X	X		X		X	
Garbage[c]							
Helicopter Presence[b]							
Shore Facilities [d]							
Accidental Releases	X	X		X		X	
Other Projects and Activities							
Oil & Gas: Grand Banks and Orphan Basin	X	X	X	X	X	X	X
Fisheries (incl. research)	X	X	X	X	X	X	X
Marine Transportation	X	X		X		X	

[a] Juveniles are young fish that have left the plankton and are often found closely associated with substrates.
[b] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[c] Not applicable as garbage will be brought ashore.
[d] There will not be any new onshore facilities. Existing infrastructure will be used.

The following subsections discuss the Project activities that will interact with the Fish and Fish Habitat VEC, and include assessment of the potential effects of these interactions.

5.6.1.1 Sound

The marine acoustic environment is filled with natural and anthropogenic sounds some of which may be influence survival and reproduction of fish (Slabbekoorn et al. 2010). The potential effects of exposure to air source sound on invertebrates and fishes can be categorized as either physical (includes both pathological and physiological) or behavioural. Pathological effects include lethal and sub-lethal damage, physiological effects include temporary primary and secondary stress responses, and behavioural effects refer to deviations from normal behavioural activity. Physical and behavioural effects are likely related in some instances and should therefore not be considered as completely independent of one another.

The following sections provide an overview of available information on relationships of underwater sound to invertebrates and fishes. The overview includes discussion of sound detection, sound production, and possible effects of exposure to air source sounds and higher frequency sounds that could be emitted from survey gear such as sonar.

Sound Detection

Sensory systems, like those that allow for hearing, provide information about an animal's physical, biological, and social environments, in both air and water. Extensive work has been done to understand the structures, mechanisms, and functions of animal sensory systems in aquatic environments (Atema et al. 1988; Kapoor and Hara 2001; Collin and Marshall 2003).

Underwater sound has both a pressure component and a particle displacement component associated with it. While all marine invertebrates and fishes appear to have the capability of detecting the particle displacement component of underwater sound, only certain fish species appear to be sensitive to the pressure component (Breithaupt 2002; Casper and Mann 2006; Popper and Fay 2010).

<u>Invertebrates</u>

The "hearing" abilities of marine invertebrates are the subject of ongoing debate. Aquatic invertebrates (with the exception of aquatic insects) do not possess the equivalent physical structures present in fish and marine mammals that can be stimulated by the pressure component of sound. It appears that marine invertebrates respond to vibrations rather than pressure (Breithaupt 2002). Statocysts (organs of balance containing mineral grains that stimulate sensory cells as the animal moves) apparently function as a vibration detector for at least some species of marine invertebrates (Popper and Fay 1999). The statocyst is a gravity receptor and allows the swimming animal to maintain a suitable orientation.

Among the marine invertebrates, decapod crustaceans have been the most intensively studied in this regard. Crustaceans appear to be the most sensitive to low frequency sounds (i.e., <1,000 Hz) (Budelmann 1992; Popper et al. 2001), with some species being particularly sensitive to low-frequency sound (Lovell et al. 2006). Other studies suggest that some species (such as American lobster) may also be more sensitive to high frequencies than has been previously reported (Pye and Watson III 2004).

It is likely that cephalopods also use statocysts to detect low-frequency aquatic vibrations (Budelmann and Williamson 1994). Kaifu et al. (2008) provided evidence that the cephalopod *Octopus ocellatus* detects particle motion with its statocyst. Studies by Packard et al. (1990), Rawizza (1995), Komak et al. (2005) and Mooney et al. (2010) have quantified some of the optimally detected sound frequencies for various octopus (1–100 Hz), squid (1–500 Hz), and cuttlefish (20–8,000 Hz) species. Using the auditory brainstem response approach, Hu et al. (2009) showed that auditory-evoked potentials can be obtained in the frequency ranges 400–1,500 Hz for the squid *Sepiotheutis lessoniana* and 400–1,000 Hz for the octopus *Octopus vulgaris*, higher than frequencies previously observed to be detectable by cephalopods.

A recent study concluded that planktonic coral larvae can detect and respond to sound, the first description of an auditory response in the invertebrate phylum Cnidaria (Vermeij et al. 2010).

<u>Fishes</u>

Marine fish are known to vary widely in their ability to hear sounds. Although hearing capability data only exist for fewer than 100 of the 27,000 fish species (Hastings and Popper 2005), current data suggest that most species of fish detect sounds below 1,500 Hz (Popper and Fay 2010). Some marine species, such as shads and menhaden, can detect higher frequency sounds above 180 kHz (Mann et al. 1997, 1998, 2001). Also, at least some species are acutely sensitive to infrasound (very low frequency), down to below 1 Hz (Sand and Karlsen 2000). Reviews of fish-hearing mechanisms and capabilities can be found in Fay and Popper (2000) and Ladich and Popper (2004).

All fish species have hearing (inner ear) and skin-based mechanosensory systems (lateral lines). Amoser and Ladich (2005) hypothesized that, as species within a particular family of fish may live under different ambient sound conditions, the hearing abilities of the individual species are likely to have adapted to the dominant conditions of their specific environments. The ability of fish to hear a range of biotic and abiotic sounds may affect their survival rate, with better adapted fish having an advantage over those that cannot detect prevailing sounds (Amoser and Ladich 2005).

Fish ears are able to respond to changes in pressure and particle motion in the water (van Bergeijk 1964; Schuijf 1981; Kalmijn 1988, 1989; Shellert and Popper 1992; Hawkins 1993; Fay 2005). Two major pathways have been identified for sound transmittance: (1) the otoliths, calcium carbonate masses in the inner ear that act as accelerometers when exposed to the particle motion component of sound, which cause shearing forces that stimulate sensory hair cells; and (2) the swim bladder, which expands and contracts in a sound field, re-radiating the sound's signal within the fish and in turn stimulating the inner ear (Popper and Fay 1993).

Researchers have noted that fish without an air-filled cavity (swim bladder), or with a reduced swim bladder or limited connectivity between the swim bladder and inner ear, are limited to detecting particle motion and not pressure, and therefore have relatively poor hearing abilities (Casper and Mann 2006).

These species have commonly been known as ‘hearing generalists’ (Popper and Fay 1999), although a recent reconsideration suggests that this classification is oversimplified (Popper and Fay 2010). Rather, there is a range of hearing capabilities across species that is more like a continuum, presumably based on the relative contributions of pressure to the overall hearing capabilities of a species (Popper and Fay 2010). Results of direct study of fish sensitivity to particle motion have been reported in numerous recently published papers (Horodysky et al. 2008; Wysocki et al. 2009; Kojima et al. 2010).

Sound Production

Many invertebrates and fishes produce sounds. It is believed that these sounds are used for communication in a wide range of behavioural and environmental contexts. The behaviours most often associated with acoustic communication include territorial behaviour, mate finding, courtship and aggression. Sound production provides a means of long distance communication as well as communication when underwater visibility is poor (Zelick et al. 1999).

Invertebrate groups with species capable of producing sound include barnacles, amphipods, shrimps, crabs, and lobsters (Au and Banks 1998; Tolstoganova 2002; Pye and Watson III 2004; Henninger and Watson III 2005; Buscaino et al. 2011). Invertebrates typically produce sound by scraping or rubbing various parts of their bodies, although they also produce sound in other ways.

More than 700 fish species are known to produce sounds (Myrberg 1981, Kaatz 2002 *in* Anderson et al. 2008). Fishes produce sounds mainly by using modified muscles attached to their swim bladders (i.e., drumming) or rubbing body parts together (i.e., stridulating). Examples of ‘soniferous’ fishes include Atlantic cod (Finstad and Nordeide 2004; Rowe and Hutchings 2004), toadfishes (Locascio and Mann 2008; Vasconcelos and Ladich 2008), and basses (Albers 2008; Johnston et al. 2008).

Effects of Exposure to Air source Sound

Most air source sound energy is associated with frequencies <500 Hz, although there is some energy associated with higher frequencies.

Physical Effects

Invertebrates

In a field study, Pearson et al. (1994) exposed Stage II larvae of the Dungeness crab *Cancer magister* to single discharges from a seven-air source array and compared their mortality and development rates with those of unexposed larvae. No statistically significant differences were found in immediate survival, long-term survival, or time to moult between the exposed and unexposed larvae, even those exposed within one metre of the seismic source.

The pathological impacts of seismic survey sound on marine invertebrates were investigated in a pilot study on snow crabs *Chionoecetes opilio* (Christian et al. 2003, 2004). Under controlled field experimental conditions, captive adult male snow crabs, egg-carrying female snow crabs, and fertilized snow crab eggs were exposed to variable Sound Pressure Levels (SPLs) (191 to 221 dB re 1 μPa_{0-p}) and sound exposure levels (SELs) (<130–187 dB re 1 μ$Pa^2 \cdot s$). Neither acute nor chronic (12 weeks post-exposure) mortality was observed for the adult crabs. However, a significant difference in development rate was noted between the exposed and unexposed fertilized eggs/embryos. The egg mass exposed to seismic energy had a higher proportion of less-developed eggs than did the unexposed mass. It should be noted that both egg masses came from a single female and any measure of natural variability was unattainable (Christian et al. 2003, 2004).

In 2003, a collaborative study was conducted in the southern Gulf of St. Lawrence, Canada, to investigate the effects of exposure to sound from a commercial seismic survey on egg-bearing female snow crabs (DFO 2004a). This study had design problems that impacted interpretation of some of the results (DFO 2004b). Caged animals were placed on the ocean bottom at a location within the survey area and at a location outside of the survey area. The maximum received SPL was ~195 dB re 1 μPa_{0-p}. The crabs were exposed for 132 hours of the survey, equivalent to thousands of seismic shots of varying received SPLs. The animals were retrieved and transferred to laboratories for analyses. Neither acute nor chronic lethal or sub-lethal injury to the female crabs or crab embryos was indicated. DFO (2004b) reported that some exposed individuals had short-term soiling of gills, antennules and statocysts, bruising of the hepatopancreas and ovary, and detached outer membranes of oocytes. However, these differences could not be linked conclusively to exposure to seismic survey sound. Boudreau et al. (2009) presented the proceedings of a workshop held in 2007 to evaluate the results of additional studies conducted to answer some questions arising from the original study discussed in DFO (2004b). A series of scientific papers was presented to address issues of concern, including (1) actual sound pressure levels received by the snow crab; (2) reasons for the differences in presence of foreign particles on the gills, antennules and statocysts between study group crabs; (3) effect of seismic surveys on crab distribution and abundance; (4) reasons for differences in the cellular structure of certain organs between study group crabs; (5) reasons for differences in rate of leg loss between study group crabs; and (6) effect of exposure to seismic sound on snow crab embryos (Courtenay et al. 2009). Proceedings of the workshop did not include any more definitive conclusions regarding the original results.

Payne et al. (2007) conducted a pilot study of the effects of exposure to air source sound on various health endpoints of the American lobster. Adult lobsters were exposed either 20 to 200 times to 202 dB re 1μPa_{p-p} or 50 times to 227 dB re 1μPa_{p-p}, and then monitored for changes in survival, food consumption, turnover rate, serum protein level, serum enzyme levels, and serum calcium level. Observations extended over a period of a few days to several months. Results showed no delayed mortality or damage to the mechanosensory systems associated with animal equilibrium and posture (as assessed by turnover rate).

McCauley et al. (2000a, b) exposed caged cephalopods to sound from a single 20 in^3 air source with maximum SPLs of >200 dB re 1 μPa_{0-p}. Statocysts were removed and preserved, but at the time of publication, results of the statocyst analyses were not available. No squid or cuttlefish mortalities were reported as a result of these exposures.

Biochemical responses by marine invertebrates to acoustic exposure have also been studied to a limited degree. Such studies of stress responses could possibly provide some indication of the physiological consequences of acoustic exposure and perhaps any subsequent chronic detrimental effects. Stress responses could potentially affect animal populations by reducing reproductive capacity and adult abundance.

Stress indicators in the haemolymph of adult male snow crabs were monitored immediately after exposure of the animals to seismic survey sound (Christian et al. 2003, 2004) and at various intervals after exposure. No significant acute or chronic differences were found between exposed and unexposed animals in which various stress indicators (e.g., proteins, enzymes, and cell type count) were measured. Payne et al. (2007), in their study of the effects of exposure of adult American lobsters to air source sound, noted decreases in the levels of serum protein, particular serum enzymes and serum calcium, in the haemolymph of animals exposed to the sound pulses. Statistically significant differences ($p=0.05$) were noted in serum protein at 12 days post-exposure, serum enzymes at 5 days post-exposure, and serum calcium at 12 days post-exposure. During the histological analysis conducted 4 months post-exposure, Payne et al. (2007) noted more deposits of PAS-stained material, likely glycogen, in the hepatopancreas of some of the exposed lobsters. Accumulation of glycogen could be due to stress or disturbance of cellular processes.

Price (2007) found that blue mussels *Mytilus edulis* responded to a 10 kHz pure tone continuous signal by decreasing respiration. Smaller mussels did not appear to react until exposed for 30 minutes whereas larger mussels responded after 10 minutes of exposure. The oxygen uptake rate tended to be reduced to a greater degree in the larger mussels than in the smaller animals.

In general, the limited studies done to date on the effects of acoustic exposure on marine invertebrates have not demonstrated any serious pathological and physiological effects.

Fishes

Review papers on the effects of anthropogenic sources of underwater sound on fishes include Payne et al. (2008); Popper (2009); Popper and Hastings (2009a, b). These papers consider various sources of anthropogenic sound, including seismic air sources.

Fertilized capelin (*Mallotus villosus*) eggs and monkfish (*Lophius americanus*) larvae were exposed to seismic air source sound and subsequently examined and monitored for possible effects of the exposure (Payne et al. 2009). The laboratory exposure studies involved a single air source. Approximate received SPLs measured in the capelin egg and monkfish larvae exposures were 199 to 205 dB re 1 μPa_{p-p} and 205 dB re 1 μPa_{p-p}, respectively. The capelin eggs were exposed to either 10 or 20 air source discharges, and the monkfish larvae were exposed to either 10 or 30 discharges. No statistical differences in mortality/morbidity between control and exposed subjects were found at one to four days post-exposure in any of the exposure trials for either the capelin eggs or the monkfish larvae.

In uncontrolled experiments, Kostyuchenko (1973) exposed the eggs of numerous fish species (anchovy, red mullet, crucian carp, blue runner) to various sound sources, including seismic air sources. With the seismic air source discharge as close as 0.5 m from the eggs, over 75% of them survived the exposure.

Egg survival rate increased to over 90% when placed 10 m from the air source sound source. The range of received SPLs was about 215 to 233 dB re 1 µPa_{0-p}.

Eggs, yolk sac larvae, post-yolk sac larvae, post-larvae, and fry of various commercially important fish species (cod, saithe, herring, turbot, and plaice) were exposed to received SPLs ranging from 220 to 242 dB re 1 µPa (unspecified measure type) (Booman et al. 1996). These received levels corresponded to exposure distances ranging from 0.75 to 6 m. The authors reported some cases of injury and mortality but most of these occurred as a result of exposures at very close range (i.e., <15 m).

Saetre and Ona (1996) applied a "worst-case scenario" mathematical model to investigate the effects of seismic sound on fish eggs and larvae. They concluded that mortality rates caused by exposure to seismic air source sound are so low compared to the natural mortality that the impact of seismic surveying on recruitment to a fish stock must be regarded as insignificant.

Evidence for air source-induced damage to fish ears has come from studies using pink snapper *Pagrus auratus* (McCauley et al. 2000a, b, 2003). In these experiments, fish were caged and exposed to the sound of a single moving seismic air source every 10 seconds over a period of 1 hour and 41 minutes. The source SPL at 1 m was about 223 dB re 1 µPa at 1 m_{p-p}, and the received SPLs ranged from 165 to 209 dB re 1 µPa_{p-p}. The sound energy was highest over the 20 to 70 Hz frequency range. The pink snapper were exposed to more than 600 air source discharges during the study. In some individual fish, the sensory epithelium of the inner ear sustained extensive damage as indicated by ablated hair cells. Damage was more extensive in fish examined 58 days post-exposure compared to those examined 18 hours post-exposure. There was no evidence of repair or replacement of damaged sensory cells up to 58 days post-exposure. McCauley et al. (2000a, b, 2003) included the following *caveats* in the study reports: (1) fish were caged and unable to swim away from the seismic source, (2) only one species of fish was examined, (3) the impact on the ultimate survival of the fish is unclear, and (4) air source exposure specifics required to cause the observed damage were not obtained (i.e., a few high SPL signals or the cumulative effect of many low to moderate SPL signals).

Popper et al. (2005) tested the hearing sensitivity of three Mackenzie River fish species after exposure to five discharges from a seismic air source. The mean received peak SPL was 205 to 209 dB re 1 µPa per discharge, and the approximate mean received SEL was 176 to 180 dB re 1 µ$Pa^2 \cdot s$ per discharge. While the broad whitefish (*Coregonus nasus*) showed no Temporary Threshold Shift (TTS) as a result of the exposure, adult northern pike (*Esox lucius*; a *hearing generalist*), and lake chub (*Couesius plumbeus*; *a hearing specialist*) exhibited TTSs of 10 to 15 dB, followed by complete recovery within 24 hours of exposure. The same animals were also examined to determine whether there were observable effects on the sensory cells of the inner ear as a result of exposure to seismic sound (Song et al. 2008). No damage to the ears of the fishes was found, including those that exhibited TTS. TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard.

In uncontrolled experiments using a very small sample of different groups of young salmonids, including Arctic cisco (*Coregonus autumnalis*), fish were caged and exposed to various types of sound. One sound type was either a single firing or a series of four firings 10 to 15 seconds apart of a 300 in^3

seismic air source at 2,000 to 2,200 psi (Falk and Lawrence 1973). Swim bladder damage was reported but no mortality was observed when fish were exposed within 1 to 2 m of an air source with source level ~230 dB re 1 µPa at 1 m (unspecified measure) (as estimated by Turnpenny and Nedwell 1994). Considerable uncertainty is associated with this estimation of the source level.

Behavioural Effects

Invertebrates

Some studies have focused on potential behavioural effects on marine invertebrates. Christian et al. (2003) investigated the behavioural effects of exposure to air source sound on snow crabs. Eight animals were equipped with ultrasonic tags, released, and monitored for multiple days prior to exposure and after exposure. Received SPL and SEL were ~191 dB re 1 $\mu Pa_{0\text{-}p}$ and <130 dB re 1 $\mu Pa^2 \cdot s$, respectively. The crabs were exposed to 200 discharges over a 33 minute period. None of the tagged animals left the immediate area after exposure to the seismic survey sound. Five animals were captured in the snow crab commercial fishery the following year, one at the release location, one 35 km from the release location, and three at intermediate distances from the release location.

Another study approach used by Christian et al. (2003) involved monitoring snow crabs with a remote video camera during their exposure to air source sound. The caged animals were placed on the ocean bottom at a depth of 50 m. Received SPL and SEL were ~202 dB re 1 $\mu Pa_{0\text{-}p}$ and 150 dB re 1 $\mu Pa^2 \cdot s$, respectively. The crabs were exposed to 200 discharges over a 33 minute period. They did not exhibit any overt startle response during the exposure period.

Caged female snow crabs exposed to air source sound associated with a recent commercial seismic survey conducted in the southern Gulf of St. Lawrence, Canada, exhibited a higher rate of 'righting' than those crabs not exposed to seismic survey sound (J. Payne, Research Scientist, DFO, St. John's, NL, pers. comm.). 'Righting' refers to a crab's ability to return itself to an upright position after being placed on its back. Christian et al. (2003) made the same observation in their study. Payne et al. (2007), in their study of the effects of exposure to air source sound on adult American lobsters, noted a trend for increased food consumption by the animals exposed to seismic sound.

Caged brown shrimp *Crangon crangon* reared under different acoustical conditions exhibited differences in aggressive behaviour and feeding rate (Lagardère 1982). Those exposed to a continuous sound source showed more aggression and less feeding behaviour. It should be noted that behavioural responses by caged animals may differ from behavioural responses of animals in the wild.

McCauley et al. (2000a, b) provided the first evidence of the behavioural response of southern calamari squid *Sepioteuthis australis* exposed to seismic survey sound. McCauley et al. (2000a, b) reported on the exposure of caged cephalopods (50 squid and two cuttlefish) to sound from a single 20 in^3 air source. The cephalopods were exposed to both stationary and mobile sound sources. The two-run total exposure times during the three trials ranged from 69 to 119 min. at a firing rate of once every 10 to 15 seconds. The maximum SPL was >200 dB re 1 $\mu Pa_{0\text{-}p}$. Some of the squid fired their ink sacs apparently in response to the first shot of one of the trials and then moved quickly away from the air source. In addition to the above-described startle responses, some squid also moved towards the water surface as the air source approached. McCauley et al. (2000a, b) reported that the startle and avoidance responses occurred at a received SPL of 174 dB re 1 μPa_{rms}. They also exposed squid to a ramped approach-depart air source signal whereby the received SPL was gradually increased over time. No strong startle response (i.e., ink discharge) was observed, but alarm responses, including increased swimming speed and movement to the surface, were observed once the received SPL reached a level in the 156 to 161 dB re 1 μPa_{rms} range.

Komak et al. (2005) also reported the results of a study of cephalopod behavioural responses to local water movements. In this case, juvenile cuttlefish *Sepia officinalis* exhibited various behavioural responses to local sinusoidal water movements of different frequencies between 0.01 and 1,000 Hz. These responses included body pattern changing, movement, burrowing, reorientation, and swimming. Similarly, the behavioural responses of the octopus *Octopus ocellatus* to non-impulse sound have been investigated by Kaifu et al. (2007). The sound stimuli, reported as having levels 120 dB re 1 μPa_{rms}, were at various frequencies: 50, 100, 150, 200 and 1,000 Hz. The respiratory activity of the octopus changed when exposed to sound in the 50–150 Hz range but not for sound at 200–1,000 Hz. Respiratory suppression by the octopus might have represented a means of escaping detection by a predator.

Low-frequency sound (<200 Hz) has also been used as a means of preventing settling/fouling by aquatic invertebrates such as zebra mussels *Dreissena polymorpha* (Donskoy and Ludyanskiy 1995) and balanoid barnacles *Balanus* sp. (Branscomb and Rittschof 1984). Price (2007) observed that blue mussels *Mytilus edulis* closed their valves upon exposure to 10 kHz pure tone continuous sound.

Although not demonstrated in the invertebrate literature, masking can be considered a potential effect of anthropogenic underwater sound on marine invertebrates. Some invertebrates are known to produce sounds (Au and Banks 1998; Tolstoganova 2002; Latha et al. 2005). The functionality and biological relevance of these sounds are not understood (Jeffs et al. 2003, 2005; Lovell et al. 2006; Radford et al. 2007). If some of the sounds are of biological significance to some invertebrates, then masking of those sounds or of sounds produced by predators, at least the particle displacement component, could potentially have adverse effects on marine invertebrates. However, even if masking does occur in some invertebrates, the intermittent nature of air source sound is expected to result in less masking effect than would occur with continuous sound.

Invertebrate Fisheries

Christian et al. (2003) investigated the pre- and post-exposure catchability of snow crabs during a commercial fishery. Received SPLs and SELs were not measured directly and likely ranged widely considering the area fished. Maximum SPL and SEL were likely similar to those measured during the telemetry study. There were seven pre-exposure and six post-exposure trap sets. Unfortunately, there was considerable variability in set duration because of poor weather. Results indicated that the catch-per-unit-effort did not decrease after the crabs were exposed to seismic survey sound.

Andriguetto-Filho et al. (2005) attempted to evaluate the impact of seismic survey sound on artisanal shrimp fisheries off Brazil. Bottom trawl yields were measured before and after multiple-day shooting of an air source array. Water depth in the experimental area ranged between 2 and 15 m. Results of the study did not indicate any significant deleterious impact on shrimp catches. Anecdotal information from Newfoundland indicated that catch rates of snow crabs showed a significant reduction immediately following a pass by a seismic survey vessel (G. Chidley, Newfoundland fisherman, pers. comm.). Additional anecdotal information from Newfoundland indicated that a school of shrimp observed via a fishing vessel sounder shifted downwards and away from a nearby seismic air source sound source (H. Thorne, Newfoundland fisherman, pers. comm.). This observed effect was temporary.

Parry and Gason (2006) statistically analyzed data related to rock lobster *Jasus edwardsii* commercial catches and seismic surveying in Australian waters from 1978 to 2004. They did not find any evidence that lobster catch rates were affected by seismic surveys. They also noted that due to natural variability and fishing pressure, a large effect on lobster would be required to make any link to effect of seismic.

Fishes

Pearson et al. (1992) investigated the effects of seismic air source sound on the behaviour of captive rockfishes *Sebastes* sp. exposed to the sound of a single stationary air source at a variety of distances. The air source used in the study had a source SPL at 1 m of 223 dB re 1 µPa at 1 $m_{0\text{-}p}$, and measured received SPLs ranged from 137 to 206 dB re 1 $\mu Pa_{0\text{-}p}$. The authors reported that rockfishes reacted to the air source sounds by exhibiting varying degrees of startle and alarm responses, depending on the species of rockfish and the received SPL. Startle responses were observed at a minimum received SPL of 200 dB re 1 $\mu Pa_{0\text{-}p}$, and alarm responses occurred at a minimum received SPL of 177 dB re 1 $\mu Pa_{0\text{-}p}$. Other observed behavioural changes included the tightening of schools, downward distributional shift, and random movement and orientation. Some fishes ascended in the water column and commenced to mill (i.e., "eddy") at increased speed, while others descended to the bottom of the enclosure and remained motionless. Pre-exposure behaviour was re-established from 20 to 60 minutes after cessation of seismic air source discharge. Pearson et al. (1992) concluded that received SPL thresholds for overt rockfish behavioural response and more subtle rockfish behavioural response are 180 dB re 1 $\mu Pa_{0\text{-}p}$ and 161 dB re 1 $\mu Pa_{0\text{-}p}$, respectively.

Fish exposed to the sound from a single air source in the study by McCauley et al. (2000a,b) exhibited startle responses to short range start up and high level air source signals (i.e., with received SPLs of 182 to 195 dB re 1 μPa_{rms}. Smaller fish were more likely to display a startle response. Responses were observed above received SPLs of 156 to 161 dB re 1 μPa_{rms}. The occurrence of both startle response (classic C-turn response) and alarm responses (e.g., darting movements, flash school expansion, fast swimming) decreased over time. Other observations included downward distributional shift that was restricted by the 10 m x 6 m x 3 m cages, increase in swimming speed, and the formation of denser aggregations. Fish behaviour appeared to return to pre-exposure state 15 to 30 min after cessation of seismic firing.

Using an experimental hook and line fishery approach, Skalski et al. (1992) studied the potential effects of seismic air source sound on the distribution and catchability of rockfishes. The source SPL of the single air source used in the study was 223 dB re 1 µPa at 1 $m_{0\text{-}p}$, and the received SPLs at the bases of the rockfish aggregations ranged from 186 to 191 dB re 1 $\mu Pa_{0\text{-}p}$. Characteristics of the fish aggregations were assessed using echosounders. During long-term stationary seismic air source discharge, there was an overall downward shift in fish distribution. The authors also observed a significant decline in total catch of rockfishes during seismic discharge. It should be noted that this experimental approach was quite different from an actual seismic survey, in that duration of exposure was much longer.

In another study, caged European sea bass *Dicentrarchus labrax* were exposed to multiple discharges from a moving seismic air source array with a source SPL of about 256 dB re 1 µPa at 1 $m_{0\text{-}p}$ (unspecified measure type) (Santulli et al. 1999). The air sources were discharged every 25 seconds during a two hour period. The minimum distance between fish and seismic source was 180 m. The authors did not indicate any observed pathological injury to the sea bass. Blood was collected from both exposed fish (6 h post-exposure) and control fish (6 h pre-exposure) and subsequently analyzed for cortisol, glucose, and lactate levels. Levels of cortisol, glucose, and lactate were significantly higher in the sera of exposed fish compared to sera of control fish. The elevated levels of all three chemicals returned to pre-exposure levels within 72 hours of exposure (Santulli et al. 1999).

Santulli et al. (1999) also used underwater video cameras to monitor fish response to seismic air source discharge. Resultant video indicated slight startle responses by some of the sea bass when the seismic air source array discharged as far as 2.5 km from the cage. The proportion of sea bass that exhibited startle response increased as the air source sound source approached the cage. Once the seismic array was within 180 m of the cage, the sea bass were densely packed at the middle of the enclosure, exhibiting random orientation, and appearing more active than they had been under pre-exposure conditions. Normal behaviour resumed about 2 hours after air source discharge nearest the fish (Santulli et al. 1999).

Boeger et al. (2006) reported observations of coral reef fishes in field enclosures before, during and after exposure to seismic air source sound. This Brazilian study used an array of eight air sources that was presented to the fishes as both a mobile sound source and a static sound source. Minimum distances between the sound source and the fish cage ranged from 0 to 7 m. Received sound levels were not reported by Boeger et al. (2006). Neither mortality nor external damage to the fishes was observed in any of the experimental scenarios. Most of the air source array discharges resulted in startle responses although these behavioural changes lessened with repeated exposures, suggesting habituation.

Chapman and Hawkins (1969) investigated the reactions of free-ranging whiting (silver hake), *Merluccius bilinearis*, to an intermittently discharging stationary air source with a source SPL of 220 dB re 1 µPa at 1 $m_{0\text{-}p}$. Received SPLs were estimated to be 178 dB re 1 $\mu Pa_{0\text{-}p}$. The whiting were monitored with an echosounder. Prior to any air source discharge, the fish were located at a depth range of 25 to 55 m. In apparent response to the air source sound, the fish descended, forming a compact layer at depths greater than 55 m. After an hour of exposure to the air source sound, the fish appeared to have habituated as indicated by their return to the pre-exposure depth range, despite the continuing air source discharge. Air source discharge ceased for a time and upon its resumption, the fish again descended to greater depths, indicating only temporary habituation.

Hassel et al. (2003, 2004) studied the potential effects of exposure to air source sound on the behaviour of captive lesser sandeel, *Ammodytes marinus*. Depth of the study enclosure used to hold the sandeel was about 55 m. The moving air source array had an estimated source SPL of 256 dB re 1 µPa at 1 m (unspecified measure type). Received SPLs were not measured. Exposures were conducted over a three day period in a 10 km x 10 km area with the cage at its centre. The distance between air source array and fish cage ranged from 55 m when the array was overhead to 7.5 km. No mortality attributable to exposure to the air source sound was noted. Behaviour of the fish was monitored using underwater video cameras, echosounders, and commercial fishery data collected close to the Study Area. The approach of the seismic vessel appeared to cause an increase in tail-beat frequency although the sandeels still appeared to swim calmly. During seismic air source discharge, many fish exhibited startle responses, followed by flight from the immediate area. The frequency of occurrence of startle response seemed to increase as the operating seismic array moved closer to the fish. The sandeels stopped exhibiting the startle response once the air source discharge ceased. The sandeel tended to remain higher in the water column during the air source discharge, and none of them were observed burying themselves in the soft substrate. The commercial fishery catch data were inconclusive with respect to behavioural effects.

Various species of demersal fishes, blue whiting, and some small pelagic fishes were exposed to a moving seismic air source array with a source SPL of about 250 dB re 1 µPa at 1 m (unspecified measure type) (Dalen and Knutsen 1986). Received SPLs estimated using the assumption of spherical spreading ranged from 200 to 210 dB re 1 µPa (unspecified measure type). Seismic sound exposures were conducted every 10 seconds during a one week period. The authors used echosounders and sonars to assess the pre- and post-exposure fish distributions. The acoustic mapping results indicated a significant decrease in abundance of demersal fish (36%) after air source discharge but comparative trawl catches did not support this. Non-significant reductions in the abundances of blue whiting and small pelagic fish were also indicated by post-exposure acoustic mapping.

La Bella et al. (1996) studied the effects of exposure to seismic air source sound on fish distribution using echosounder monitoring and changes in catch rate of hake by trawl, and clupeoids by gill netting. The seismic array used was composed of 16 air sources and had a source SPL of 256 dB re 1 µPa at 1 $m_{0\text{-}p}$. The shot interval was 25 seconds, and exposure durations ranged from 4.6 to 12 hours. Horizontal distributions did not appear to change as a result of exposure to seismic discharge, but there was some indication of a downward shift in the vertical distribution. The catch rates during experimental fishing did not differ significantly between pre- and post-seismic fishing periods.

Wardle et al. (2001) used video and telemetry to make behavioural observations of marine fishes (primarily juvenile saithe (*Pollachius virens*), adult pollock (*Pollachius pollachius*), juvenile cod, and adult mackerel) inhabiting an inshore reef off Scotland before, during, and after exposure to discharges of a stationary air source. The received SPLs ranged from about 195 to 218 dB re 1 $\mu Pa_{0\text{-}p}$. Pollock did not move away from the reef in response to the seismic air source sound, and their diurnal rhythm did not appear to be affected. However, there was an indication of a slight effect on the long-term day-to-night movements of the pollock. Video camera observations indicated that fish exhibited startle responses ("C-starts") to all received levels. There were also indications of behavioural responses to visual stimuli. If the seismic source was visible to the fish, they fled from it. However, if the source was not visible to the fish, they often continued to move toward it.

The potential effects of exposure to seismic sound on fish abundance and distribution were also investigated by Slotte et al. (2004). Twelve days of seismic survey operations spread over a period of one month used a seismic air source array with a source SPL of 222.6 dB re 1 µPa at 1 m_{p-p}. The SPLs received by the fish were not measured. Acoustic surveys of the local distributions of various kinds of pelagic fish, including herring, blue whiting (*Micromesistius poutassoa*), and mesopelagic species, were conducted during the seismic surveys. There was no strong evidence of short-term horizontal distributional effects. With respect to vertical distribution, blue whiting and mesopelagics were distributed deeper (20 to 50 m) during the seismic survey compared to pre-exposure. The average densities of fish aggregations were lower within the seismic survey area, and fish abundances appeared to increase in accordance with increasing distance from the seismic survey area.

During a Mackenzie River project, Jorgenson and Gyselman (2009) investigated the behavioural responses of Arctic riverine fishes to seismic air source sound. The mean received peak SPL was 205 to 209 dB re 1 µPa per discharge, and the approximate mean received SEL was 176 to 180 dB re 1 $\mu Pa^2 \cdot s$ per discharge. They used hydroacoustic survey techniques to determine whether fish behaviour upon exposure to air source sound can either mitigate or enhance the potential impact of the sound. The study indicated that fish behavioural characteristics were generally unchanged by the exposure to air source sound. The tracked fish did not exhibit herding behaviour in front of the mobile air source array and, therefore, were not exposed to sustained high sound levels.

Thomsen (2002) exposed rainbow trout (*Oncorhynchus mykiss*) and Atlantic salmon held in aquaculture enclosures to the sounds from a small air source array. Received SPLs were 142 to 186 dB re 1 μPa_{p-p}. The fish were exposed to 124 pulses over a three day period. In addition to monitoring fish behaviour with underwater video cameras, the authors also analyzed cod and haddock catch data from a longline fishing vessel operating in the immediate area. Only eight of the 124 shots appeared to evoke behavioural reactions by the salmonids, but overall impacts were minimal. No fish mortality was observed during or immediately after exposure. The author reported no significant effects on cod and haddock catch rates, and the behavioural effects were hard to differentiate from normal behaviour.

Finfish Fisheries

Early comprehensive experimentation on the effects of seismic air source sound on catchability of fishes was conducted in the Barents Sea by Engås et al. (1993, 1996). They investigated the effects of seismic air source sound on distributions, abundances, and catch rates of cod and haddock using acoustic mapping and experimental fishing with trawls and longlines. The maximum source SPL was about 248 dB re 1 µPa at 1 m_{0-p} based on calculations using sound measurements collected by a hydrophone suspended at a depth of 80 m. No measurements of the received SPLs were made. Davis et al. (1998) estimated the received SPL at the sea bottom immediately below the array and at 18 km from the array to be 205 dB re 1 μPa_{0-p} and 178 dB re 1 μPa_{0-p}, respectively. Engås et al. (1993, 1996) concluded that there were indications of distributional change during and immediately following the seismic air source discharge (45 to 64% decrease in acoustic density according to sonar data). The lowest densities were observed within 9.3 km of the seismic discharge area. The authors indicated that trawl catches of both cod and haddock declined after the seismic operations. While longline catches of haddock also showed decline after seismic air source discharge, those for cod increased.

Dalen and Knutsen (1986), Løkkeborg (1991), and Løkkeborg and Soldal (1993) also examined the effects of seismic air source sound on demersal fish catches. Løkkeborg (1991) examined the effects on cod catches. The source SPL of the air source array used in his study was 239 dB re 1 µPa at 1 m (unspecified measure type), but received SPLs were not measured. Approximately 43 hours of seismic air source discharge occurred during an 11 day period, with a five-second interval between pulses. Catch rate decreases ranging from 55 to 80% within the seismic survey area were observed. This apparent effect persisted for at least 24 hours within about 10 km of the survey area. The effect of exposure to seismic sound on commercial demersal fishes was again studied in 2009 using gillnet and longline fishery methods off the coast of Norway (Løkkeborg et al. 2010). Study results indicated that fishes did react to air source sound based on observed changes in catch rates during seismic shooting. Gillnet catches increased during the seismic shooting, likely a result of increased fish activity, while longline catches decreased overall.

Turnpenny et al. (1994) examined results of these studies as well as the results of other studies on rockfish. They used rough estimations of received SPLs at catch locations and concluded that catchability is reduced when received SPLs exceed 160 to 180 dB re 1 $\mu Pa_{0\text{-}p}$. They also concluded that reaction thresholds of fishes lacking a swim bladder (e.g., flatfish) would likely be about 20 dB higher. Given the considerable variability in sound transmission loss between different geographic locations, the SPLs that were assumed in these studies were likely quite inaccurate. Turnpenny and Nedwell (1994) also reported on the effects of seismic air source discharge on inshore bass fisheries in shallow U.K. waters (5 to 30 m deep). The air source array used had a source level of 250 dB re 1 µPa at 1 $m_{0\text{-}p}$. Received levels in the fishing areas were estimated to range between 163 and 191 dB re 1 $\mu Pa_{0\text{-}p}$. Using fish tagging and catch record methodologies, they concluded that there was not any distinguishable migration from the ensonified area, nor was there any reduction in bass catches on days when seismic air sources were discharged. The authors concluded that effects on fisheries would be smaller in shallow nearshore waters than in deep water because attenuation of sound is often more rapid in shallow water, depending on the physical characteristics of the water and substrate in the area.

Skalski et al. (1992) used a 100 in^3 air source with a source level of 223 dB re 1 µPa at 1 $m_{0\text{-}p}$ to examine the potential effects of air source sound on the catchability of rockfishes. The moving air source was discharged along transects in the study fishing area, after which a fishing vessel deployed a set line, ran three echosounder transects, and then deployed two more set lines. Each fishing experiment lasted one hour and 25 minutes. Received SPLs at the base of the rockfish aggregations ranged from 186 to 191 dB re 1 $\mu Pa_{0\text{-}p}$. The catch-per-unit-effort (CPUE) for rockfish declined on average by 52.4% when the air sources were operating. Skalski et al. (1992) believed that the reduction in catch resulted from a change in behaviour of the fishes. The fish schools descended towards the bottom and their swimming behaviour changed during air source discharge. Although fish dispersal was not observed, the authors hypothesized that it could have occurred at a different location with a different bottom type. Skalski et al. (1992) did not continue fishing after cessation of air source discharge. They speculated that CPUE would quickly return to normal in the experimental area, because fish behaviour appeared to normalize within minutes of cessation of air source discharge. However, in an area where exposure to air source sound might have caused the fish to disperse, the authors suggested that a lower CPUE might persist for a longer period.

European sea bass were exposed to sound from seismic air source arrays with a source SPL of 262 dB re 1 µPa at 1 $m_{0\text{-}p}$ (Pickett et al. 1994). The seismic survey was conducted over a period of four to five months. The study was intended to investigate the effects of seismic air source discharge on inshore bass fisheries. Information was collected through a tag and release program, and from the logbooks of commercial fishermen. Most of the 152 recovered fish from the tagging program were caught within 10 km of the release site, and it was suggested that most of these bass did not leave the area for a prolonged period. With respect to the commercial fishery, no significant changes in catch rate were observed (Pickett et al. 1994).

Effects of Exposure to Marine Vessel Sound

Numerous papers about the behavioural responses of fishes to marine vessel sound have been published in the primary literature. They consider the responses of small pelagic fishes (e.g., Misund et al. 1996; Vabo et al. 2002; Skaret et al. 2005; Ona et al. 2007; Sand et al. 2008), large pelagic fishes (Sarà et al. 2007), and groundfishes (Engås et al. 1998; Handegard et al. 2003; De Robertis et al. 2008). Generally, most of the papers indicate that fishes typically exhibit some level of reaction to the sound of approaching marine vessels, the degree of reaction being dependent on a variety of factors including the activity of the fish at the time of exposure (e.g., reproduction, feeding, and migration), characteristics of the vessel sound, and water depth.

Sound Exposure Effects Assessment

The reader should first refer to the interaction table (Table 5.1) to determine if there are any interactions with Project activities, secondly to the assessment table (Table 5.2) which contains ratings for magnitude, extent, and duration, and thirdly to the significance predictions table (Table 5.3).

It is impossible to assess in detail the potential effects of every type of sound on every species in the Study Area. The best approach, and common practice in EA, is to focus by selecting (1) the strongest sound source, in this case the air source array, and (2) several species that are representative of the different types of sensitivities and offer a relevant literature base. Snow crab and Atlantic cod were selected to serve as surrogates for the discussion of the potential effects of sound on fish species found within the Study Area.

The most notable criteria in the assessment include (1) distance between air source array and animal under normal conditions (post-larval snow crabs remain on bottom, post-larval cod occur in the water column, and larvae of both snow crab and cod are planktonic in upper water column), (2) motility of the animal (post-larval snow crabs much less motile than post-larval cod, and larvae of both are essentially passive drifters), (3) absence or presence of a swim bladder (i.e., auditory sensitivity) (snow crabs without swimbladder and cod with swimbladder), and (4) reproductive strategy (snow crabs carry fertilized eggs at the bottom until larval hatch, and cod eggs are planktonic).

Potential impacts on other marine invertebrate and fish species are inferred from the assessment using snow crab and Atlantic cod as surrogate species. Potential interactions between the proposed Project activities and the Fish and Fish Habitat VEC are shown in Table 5.1.

As already indicated in this section, although research on the effects of exposure to air source sound on marine invertebrates and fishes is increasing, many data gaps remain. Available experimental data suggest that there may be physical impacts on the fertilized eggs of snow crab and on the egg, larval, juvenile and adult stages of cod at very close range. Considering the typical source levels associated with commercial seismic air source arrays, close proximity to the source would result in exposure to very high sound pressure levels. While egg and larval stages are not able to actively escape such an exposure scenario, juvenile and adult cod would most likely avoid it. Developing embryos, juvenile and adult snow crab are benthic and generally far enough from the sound source to receive energy levels well below levels that may have impact. In the case of eggs and larvae, it is likely that the numbers negatively affected by exposure to seismic sound would be negligible when compared to those succumbing to natural mortality (Saetre and Ona 1996). Atlantic cod do have swim bladders and are therefore generally more sensitive to underwater sounds than fishes without swim bladders. Spatial and temporal avoidance of critical life history times (e.g., spawning aggregations) as well as ramp-up should mitigate the effects of exposure to air source sound.

Snow crab, sensitive to the particle displacement component of sound only, will be at least 90 m or more from the air sources and will not likely be affected by any particle displacement resulting from air source discharge.

Limited data regarding physiological impacts on fish and invertebrates indicate that these impacts are both short-term and most obvious after exposure at close range.

The physical effects of exposure to sound with frequencies >500 Hz are *negligible*, based on the available information from the scientific literature. Effects of exposure to <500 Hz sound and marine vessel sound appear to be primarily behavioural and somewhat temporary.

As indicated in Table 5.2, sound produced as a result of the proposed Project (air source array sound being the worst-case scenario) is predicted to have *negligible* to *low* magnitude residual effects on the various life stages of the Fish and Fish Habitat VEC for a duration of *<1 month* to *1 to 12 months* over an area of *<1* to *11-100* km^2. Based on these criteria ratings, the *reversible* residual effects of *continuous* Project-related sound (assumes continuous for the duration of each individual seismic program) on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.3).

5.6.1.2 Other Project Activities

On Bottom Cables

On bottom cables (OBC) house hydrophones and may be used in place of streamers for some seismic programs in future years. The placement and retrieval of these cables may temporarily disturb some benthic invertebrates and fish. However, since this disturbance is so small in area and most recovery times would range from minutes to hours, any disturbance is considered *negligible* (Table 5.2) and hence *not significant* (Table 5.3).

Vessel Lights

As indicated in Table 5.1, there are potential interactions between vessel lights and certain components of the Fish and Fish Habitat VEC. However, other than the relatively neutral effect of attraction of certain species/life stages to the upper water column at night, there will be *negligible* effects of vessel lights on this VEC (Table 5.2). Therefore, the residual effects of vessel lights associated with the proposed Project on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.3).

Table 5.2 Assessment of Effects of Project Activities on the Fish and Fish Habitat VEC.

Valued Ecosystem Component: Fish and Fish Habitat									
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects						
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Sound Emissions and Receivers									
Air Sources	Physical effects (N); Disturbance (N)	Ramp-up of array; Spatial & temporal avoidance	1	1-3	6	1-2	R	2
Seismic Vessel	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1	R	2
Picket Vessel	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1-2	R	2
OBC	Disturbance (N)	Spatial & temporal avoidance	0	1	6	1	R	2
Echo Sounder	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1	R	2
Side Scan Sonar	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1	R	2
Boomer	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1	R	2
Vessel Lights	Neutral effect	-	-	-	-	-	-	-
Sanitary/Domestic Waste	Pathological effects (N); Contamination (N)	Primary treatment	0-1	1	1	1-2	R	2
Atmospheric Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2
Accidental Releases	Pathological effects (N); Contamination (N)	Solid streamers[a]; prevention protocols; Spill Response Plan	0-1	1-2	1	1	R	2

Valued Ecosystem Component: Fish and Fish Habitat								
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context

Key:

Magnitude:
0 = Negligible, essentially no effect
1 = Low
2 = Medium
3 = High

Frequency:
1 = <11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Reversibility:
R = Reversible
I = Irreversible
(refers to population)

Duration:
1 = <1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = >72 months

Geographic Extent:
1 = <1 km^2
2 = 1-10 km^2
3 = 11-100 km^2
4 = 101-1,000 km^2
5 = 1,001-10,000 km^2
6 = $>10,000$ km^2

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not negatively affected by human activity
2 = Evidence of existing negative effects

[a] Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.

Table 5.3 Significance of Potential Residual Environmental Effects of Project Activities on the Fish and Fish Habitat VEC.

Valued Ecosystem Component: Fish and Fish Habitat				
Project Activity	Significance Rating	Level of Confidence	Likelihood[a]	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
Sound Emissions and Receivers				
Air Sources	NS	2-3	-	-
Seismic Vessel	NS	2-3	-	-
Supply Vessel	NS	2-3	-	-
Picket Vessel	NS	2-3	-	-
OBC	NS	2-3	-	-
Echo Sounder	NS	2-3	-	-
Side Scan Sonar	NS	2-3	-	-
Boomer	NS	2-3	-	-
Vessel Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Accidental Releases	NS	2-3	-	-

Key: Residual environmental Effect Rating: S = Significant Negative Environmental Effect NS = Not-significant Negative Environmental Effect P = Positive Environmental Effect Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating). Level of Confidence: based on professional judgment: 1 = Low Level of Confidence 2 = Medium Level of Confidence 3 = High Level of Confidence Probability of Occurrence: based on professional judgment: 1 = Low Probability of Occurrence 2 = Medium Probability of Occurrence 3 = High Probability of Occurrence Scientific Certainty: based on scientific information and statistical analysis or professional judgment: 1 = Low Level of Confidence 2 = Medium Level of Confidence 3 = High Level of Confidence [a] Considered only in the case where 'significant negative effect' is predicted.

Sanitary/Domestic Waste

As indicated in Table 5.1, there are potential interactions between sanitary/domestic waste and certain components of the Fish and Fish Habitat VEC. After application of mitigation measures, including primary treatment of the waste, the residual effects of sanitary/domestic waste on the Fish and Fish Habitat VEC are predicted to be *negligible to low* in magnitude for a duration of *<1 to 1-12 months* over an area of *<1 km^2* (Table 5.2). Based on these criteria ratings, the *reversible* residual effects of *infrequen*t exposure to sanitary/domestic waste associated with the proposed Project on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.3).

Atmospheric Emissions

As indicated in Table 5.1, there are potential interactions between atmospheric emissions and certain components of the Fish and Fish Habitat VEC that occur near surface. Considering that the amount of atmospheric emissions produced during the proposed seismic program will rapidly disperse to undetectable levels, the residual effects of exposure to them on the Fish and Fish Habitat VEC are predicted to be *negligible* (Table 5.2). Therefore, residual effects of atmospheric emissions associated with the proposed Project on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.3).

Accidental Releases

Planktonic invertebrate and fish eggs and larvae are less resistant to effects of contaminants than are adults because they are not physiologically equipped to detoxify them or to actively avoid them. In addition, many eggs and larvae develop at or near the surface where hydrocarbon exposure may be the greatest (Rice 1985). Generally, fish eggs appear to be highly sensitive at certain stages and then become less sensitive just prior to larval hatching (Kühnhold 1978; Rice 1985). Larval sensitivity varies with yolk sac stage and feeding conditions (Rice et al. 1986). Eggs and larvae exposed to high concentrations of hydrocarbons generally exhibit morphological malformations, genetic damage, and reduced growth. Damage to embryos may not be apparent until the larvae hatch. The natural mortality rate in fish eggs and larvae is extremely high and very large numbers would have to be destroyed by anthropogenic sources before effects would be detected in an adult population (Rice 1985).

There is an extensive body of literature regarding the effects of exposure to hydrocarbons on juvenile and adult fish. Although some of the literature describes field observations, most refers to laboratory studies. Reviews of the effects of hydrocarbons on fish have been prepared by Rice et al. (1986); Armstrong et al. (1995), Payne et al. (2003) and numerous other authors. If exposed to hydrocarbons in high enough concentrations, fish may suffer effects ranging from direct physical effects (e.g., coating of gills and suffocation) to more subtle physiological and behavioural effects. Actual effects depend on a variety of factors such as the amount and type of hydrocarbon, environmental conditions, species and life stage, lifestyle, fish condition, degree of confinement of experimental subjects, and others.

As indicated in Table 5.1, there are potential interactions of accidental releases and components of the Fish and Fish Habitat VEC that occur near surface. The effects of hydrocarbon spills on marine invertebrates and fish have been discussed and assessed in numerous recent environmental assessments of proposed offshore drilling programs and assessments have concluded that the residual effects of accidental hydrocarbon releases offshore on the Fish and Fish Habitat VEC are predicted to be *not significant* especially in case of a seismic vessel where most plausible petroleum spills would be small (e.g., streamer fluid or diesel spills).

With proper mitigations in place, the residual effects of an accidental release associated with the HMDC's proposed seismic program on the Fish and Fish habitat VEC would be *negligible* to *low* in magnitude for a duration of *<1 month* over an area of *<1* to *1-10* km^2 (Table 5.2). Based on these criteria ratings and consideration that the probability of accidental hydrocarbon releases during the proposed seismic program are low, the *reversible* residual effects of accidental releases associated with the proposed program on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.3).

5.6.2 Fishery VEC

The potential interactions of Project activities and the Fishery VEC are indicated in Table 5.4. DFO and joint DFO/Industry Research Surveys were included in the assessment of the Fishery VEC.

The seismic survey vessel and Project-related support vessel traffic will be present within NAFO Division 3L. Behavioural changes in commercial species in relation to catchability, and conflict with harvesting activities and fishing gear were raised as potential issues during the consultations and issues scoping for this assessment (see Section 5.1.1). Seismic streamers and vessels can conflict with and damage fishing gear, particularly fixed gear (e.g., snow crab pots or gillnets). Such conflicts have occurred in Atlantic Canada in the past when seismic vessels were operating in heavily fished areas. There is also a potential for interference from seismic activities with DFO and DFO/Industry research surveys if both are being conducted in a same general area at the same time. An accidental release of petroleum hydrocarbons may result in tainting (or perceived tainting) thus affecting product quality and marketing.

Table 5.4 Potential Interactions of Project Activities and the Fishery VEC.

Project Activities	Valued Ecosystem Component: Fishery		
	Mobile Invertebrates and Fishes (fixed [e.g., gillnet] and mobile gear [e.g., trawls])	Sedentary Benthic Invertebrates (fixed gear [e.g., crab pots])	Research Surveys (mobile gear-trawls; fixed gear-crab pots)
Sound Emissions and Receivers			
Air Sources	X	X	X
Seismic Vessel	X	X	X
Supply Vessel	X	X	X
Picket Vessel	X	X	X
OBC	X	X	X
Helicopter[a]			
Echo Sounder	X		
Side Scan Sonar	X		X
Boomer	X	X	X
Vessel Lights			
Vessel Presence			
Seismic Vessel	X	X	X
Supply Vessel	X	X	X
Picket Vessel	X	X	X
Sanitary/Domestic Waste	X	X	X
Atmospheric Emissions			
Garbage [b]			
Helicopter Presence[a]			
Shore Facilities[c]			
Accidental Releases	X	X	X
Other Projects and Activities			
Oil & Gas: Grand Banks and Orphan Basin	X	X	X
Fisheries (incl. research)	X	X	X
Marine Transportation	X	X	X

[a] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[b]Not applicable as garbage will be brought ashore.
[c] There will not be any new onshore facilities. Existing infrastructure will be used.

The chief means of mitigating potential impacts on fishery activities is to avoid active fishing areas, particularly fixed gear zones. For the commercial fisheries, gear damage compensation provides a means of final mitigation of impacts, in case a conflict does occur with fishing gear (i.e., accidental contact of gear with the survey air source array, streamers or seismic vessel).

The document *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2012) provides guidance aimed at minimizing any impacts of petroleum industry surveys on commercial fish harvesters and other marine users. The mitigations described below are also relevant to DFO and joint DFO/Industry research surveys. Development of the guidelines was based on best practices applied during previous surveys in Atlantic Canada, as well as guidelines from other national jurisdictions. The relevant guidelines state the following (in Appendix 2 of C-NLOPB (2012) - Environmental Planning, Mitigation and Reporting – II. Interaction with Other Ocean Users):

> ***2D and 3D Seismic Programs***
> *In addition to the measures indicated in Section 1 above, the following mitigation measures should also be implemented.*
> *a) Surveys should be scheduled, to the extent possible, to reduce potential for impact or interference with Department of Fisheries and Ocean (DFO) science surveys. Spatial and temporal logistics should be determined with DFO to reduce overlap of seismic operations with research survey areas, and to allow an adequate temporal buffer between seismic survey operations and DFO research activities.*
> *b) Seismic activities should be scheduled to avoid heavily fished areas, to the extent possible. The operator should implement operational arrangements to ensure that the operator and/or its survey contractor and local fishing interests are informed of each other's planned activities. Communication throughout survey operations with fishing interests in the area should be maintained. The use of a 'Fisheries Liaison Officer' (FLO) onboard the seismic vessel is considered best practice in this respect.*
> *c) Where more than one survey operation is active in a region, the operator(s) should arrange for a 'Single Point of Contact' for marine users that may be used to facilitate communication.*

The following sections assess the potential effects of Project activities on the Fishery VEC.

5.6.2.1 Sound

As indicated in the description of commercial fisheries in Section 4.3, there has been substantial harvesting within NAFO Units 3Lh, 3Li, 3Lr, 3Lt in the Study Area between 2005 and 2010. Snow crab and northern shrimp accounted for most of the commercial harvest within the Study Area during that period.

The potential for impacts on fish harvesting will, therefore, depend on the location and timing of the surveying activities in relation to these fishing areas, and the type of fishing gear used in any given season. If the survey work is situated away from these fishing areas or occur at different times, the likelihood of any impacts on commercial harvesting will be greatly reduced.

The DFO and joint DFO/Industry research surveys are also conducted using fishing gear. As such, the issues related to potential interference with DFO and joint DFO/Industry research surveys are much the same as for commercial fish harvesting (i.e., potential effects on catch rates and conflicts with research vessel operations).

Potential effects on marine fish behaviour are assessed in Section 5.6.1. While adult fish could be injured by air source sound if they are within a few metres of a sound source, this is unlikely since fish are likely to disperse during array ramp-up or vessel approach. Therefore, the most likely type of effect will be behavioural. Seismic surveys could cause reduced trawl and longline catches during and following a survey if the fish exhibit behavioural changes (e.g., horizontal and vertical dispersion). There are various research studies on this subject as discussed in Section 5.6.1. While some of the behavioural effects studies report decreases in catch rates near the seismic survey area, there is some disagreement on the duration and geographical extent of the effect.

Mitigation

Mitigations are detailed in a previous section. The primary measures intended to minimize the effects of Project activities on the harvesting success component of the Fishery VEC include:

- Avoidance in time and space of concentrated fishing areas ;
- Good communications, and
- Deployment of Fisheries Liaison Officers (FLOs).

<u>Avoidance</u>

The potential effects of seismic sound on fishery catch success can be mitigated by avoiding heavily fished areas when these fisheries are active (specifically the shrimp and snow crab areas) to the greatest extent possible. As described in this report, most of the domestic fishing in the past has been concentrated in well-defined areas within the Study Area. During any seismic survey, the location of current fishing activities will be monitored by the ship and the FLO (see below) and fishing boats will be contacted by radio as required. Survey personnel (through the Single Point of Contact (SPOC), described below) will also continue to be updated about fishing activity near the active survey area. The mapping of fishing activities contained in this EA report will also be an important source of fisheries information for the survey operators.

<u>Communications</u>

During the fisheries consultations for this and other surveys, fisheries representatives noted that good communications is one of the best ways to minimize interference between the seismic operations and fishing activities. Communication will be maintained (both directly at sea and through the survey SPOC) to facilitate information exchange, which includes such groups as DFO managers, independent fishers, representatives of fisheries organizations such as the FFAW, and managers of other key corporate fisheries in the area.

Relevant information about the seismic survey operations will also be transmitted using established communications mechanisms, such as the Notices to Shipping (Continuous Marine Broadcast and NavTex), the CBC (Newfoundland) Radio's Fisheries Broadcast, by the FFAW in the FFAW Union Forum (as suggested during previous consultations), and by direct communication between the seismic survey vessels and fishing vessels via marine radio at sea. This includes seismic survey vessel transit before and after the survey itself.

Fisheries Liaison Officer (FLO)

As a specific means of facilitating at-sea communications, and informing the survey vessel operators about local fisheries, when necessary HMDC will have an on-board fisheries industry liaison officer serving as a "fisheries representative". The FLO will remain on the relevant survey vessel for the entire program. This will provide a dedicated marine radio contact for all fishing vessels in the vicinity of seismic operations to discuss interactions and resolve any problems that may arise at sea. This person will inform the vessel's bridge personnel about any local fishing activities.

Appendix 2 contains a description of the FLO responsibilities and qualifications, as agreed in previous discussions with the FFAW.

Assessment of the Effects of Seismic Survey Sound

Since commercial catches are quota based, the overlap between fishing activity and seismic activity is unknown at the moment, but will be determined prior to the commencement of the seismic surveys. The best way to prevent overlap between the DFO and joint DFO/Industry research surveys is to exchange detailed locational information and establish a tailored temporal and spatial separation plan, as was implemented with DFO Newfoundland and Labrador in past seasons. With application of the mitigations discussed above, effects of seismic survey sound on the Fishery VEC are predicted to be a *negligible* to *low* magnitude during *<1* to *1-12 months* over an area of *<1* to *11-100* km^2 (Table 5.5). Based on these criteria ratings, the *reversible* residual effects of seismic survey sound on the Fishery VEC are predicted to be *not significant* (Table 5.6).

Table 5.5 Assessment of Effects of Project Activities on the Fishery VEC.

Valued Ecosystem Component: Fishery								
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Sound Emissions and Receivers								
Air Sources	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0-1	3	6	1-2	R	2
Seismic Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0	1	6	1-2	R	2
Supply Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0	1	1	1-2	R	2
Picket Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0	1	6	1-2	R	2
OBC	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0	1	6	1	R	2
Echo Sounder	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0	1	6	1	R	2
Side Scan Sonar	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0	1	6	1	R	2

Valued Ecosystem Component: Fishery								
Project Activity	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation**	**Evaluation Criteria for Assessing Environmental Effects**					
			Magnitude	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Boomer	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0	1	6	1	R	2
Vessel Presence								
Seismic Vessel	Conflict with gear (N)	FLO; communications; Compensation Plan	0-1	1-3	6	1-2	R	2
Supply Vessel	Conflict with gear (N)	FLO; communications; Compensation Plan	0-1	1-3	1	1	R	2
Picket Vessel	Conflict with gear (N)	FLO; communications; Compensation Plan	0-1	1-3	6	1-2	R	2
Atmospheric Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2
Sanitary/Domestic Wastes	Taint (N); Perceived taint (N)	Primary treatment	0-1	1	1	2	R	2
Accidental Releases	Taint (N); Perceived taint (N)	Solid streamers[c]; prevention protocols; Spill Response Plan; communications; Compensation Plan	0-1	1-2	1	1	R	2

Key:

Magnitude:
0 = Negligible, essentially no effect
1 = Low
2 = Medium
3 = High

Frequency:
1 = < 11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = > 200 events/yr
6 = continuous

Reversibility:
R = Reversible
I = Irreversible
(refers to population)

Duration:
1 = < 1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = > 72 months

Geographic Extent:
1 = < 1-km^2
2 = 1-10-km^2
3 = 11-100-km^2
4 = 101-1,000-km^2
5 = 1,001-10,000-km^2
6 = > 10,000-km^2

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not affected by human activity
2 = Evidence of existing effects

[a] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[b] This is considered negligible since, if a conflict occurs, compensation will eliminate any economic impact.
[c] Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.

Table 5.6 Significance of Potential Residual Environmental Effects on the Fishery VEC.

Valued Ecosystem Component: Fishery				
Project Activity	**Significance Rating**	**Level of Confidence**	**Likelihood [a]**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Sound Emissions and Receivers				
Air source Array	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
OBC	NS	3	-	-
Echo Sounder	NS	2-3	-	-
Side Scan Sonar	NS	2-3	-	-
Boomer	NS	2-3	-	-
Vessel Presence				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Accidental Releases	NS	2-3	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

Level of Confidence: based on professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgment:
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

[a] Considered only in the case where 'significant negative effect' is predicted.

5.6.2.2 Vessel Presence Including Streamers and OBC

Commercial fish harvesting activities occur throughout the May to December period being assessed. Of these, the fixed gear (e.g., pot fishery for snow crab, and to a lesser extent the Greenland halibut gillnet fishery) poses the highest potential for conflict, particularly if they are deployed concurrently with seismic survey operations. During 2D/3D seismic surveying, operations will be conducted continuously for 20-90 days. Because of the length of the streamers being towed behind it, the maneuverability of a seismic vessel is restricted and other mobile vessels must give way. As already noted in the EA, the turning radius required between each track line extends the assessment area beyond the actual survey area. During transit to the seismic survey area, streamers may be deployed. Therefore, a separate route analysis will be prepared and discussions with fishing interests will be conducted before the transit.

OBC's, if used in future programs, would temporarily restrict access to bottom fishing gear; in practice not all that different from a typical streamer towing operation. The use of OBC's could potentially affect a smaller area of the overall fishery than a large steamer operation.

When gear conflict events occur that damage gear or result in gear loss due to the survey they will be assessed and compensation will be paid for losses attributable to the seismic survey.

Mitigation

Mitigations measures intended to minimize the conflict effects of Project activities on the fishing gear component of the Fishery VEC include:

- Avoidance;
- Communications;
- Fisheries Liaison Officers;
- Single Point of Contact; and
- Fishing Gear Compensation

Avoidance

As discussed above, potential impacts on fishing gear will be mitigated by avoiding active fixed gear fishing areas during the seismic survey. If gear is deployed in a survey area, the diligence of the FLO, good at-sea communications and mapping of current fishing locations have usually proven effective at preventing such conflicts.

For streamer deployment during transits to a survey area, the principal mitigation will also be avoidance, based on route selection aimed at deviating around fixed gear fishing areas. Since the patterns of fishing vary by month, a final route, taking into account the avoidance of active areas, will be chosen shortly before the survey work begins. As noted above, a route analysis for this purpose will be prepared and discussions with fishing interests undertaken before the transits.

In addition to avoidance based on route analysis and selection, the onshore SPOC and the at-sea FLO will advise the vessel en-route to ensure fishing gear is avoided. In the case the avoidance mitigate measure fails, a gear damage program will be in place to compensate fishers whose gear is damaged or lost.

As with the commercial fishery, those involved in DFO and joint DFO/Industry research surveys will need to exchange detailed locational information with those involved in the seismic surveying. In 2002 when the plan was first implemented in the eastern Newfoundland Region, positional information was exchanged between DFO and the seismic survey company. A temporal and spatial separation plan was then agreed to with DFO and implemented by the seismic vessel to ensure that seismic operations did not interfere with the research survey. This included adequate "quiet time" before the research vessel arrived at its survey location. The avoidance protocol includes a 30 km (16 nmi) spatial separation and a seven day pre-research survey temporal separation.

Communications

During the fisheries consultations for this and other surveys, fisheries representatives noted that good communications is one of the best ways to minimize interference with fishing activities. Communications will be maintained (directly at sea, and through the survey Single Point of Contact o SPOC) to facilitate information exchange with fisheries participants. This includes such groups as DFO managers, independent fishers, representatives of fisheries organizations such as the FFAW, and managers of other key corporate fisheries in the area.

Relevant information about the survey operations will also be publicized using established communications mechanisms, such as the Notices to Shipping (Continuous Marine Broadcast and NavTex), the CBC (Newfoundland) Radio's Fisheries Broadcast, by the FFAW in the FFAW Union Forum (as suggested during previous consultations), and by direct communication between the survey vessel and fishing vessels via marine radio at sea. This will also include information about transit routes.

Fisheries Liaison Officer

As described above, the on-board fisheries industry FLO will provide a dedicated marine radio contact for all fishing vessels near project operations to help identify gear locations, assess potential interactions and provide guidance to those on the bridge, including during transit to and from St. John’s.

Single Point of Contact

The SPOC has become a standard and effective mitigation for all seismic surveys operating in this sector. The HMDC Environment Advisor/Lead or designate will serve as the survey's Single Point of Contact with the fishing industry, as described in the C-NLOPB Guidelines. The SPOC will endeavour to update vessel personnel (e.g. the FLO) about known fishing activities in the area, and will relay relevant information from DFO and fishing companies.

Fishing Gear Compensation

HMDC has developed a fishing gear damage compensation policy consistent with C-NLOPB guidelines that will be filed with the Board in support of the *Authorization to Conduct a Geophysical Program* application. In case of accidental damage to fishing gear or vessels, HMDC will implement gear damage compensation contingency plans to provide appropriate and timely compensation to any affected fishery participants. The Notices to Shipping, filed by the vessels for surveys and for transits to and from the survey sites, will also inform fishers that they may contact the SPOC if they believe that they have sustained survey-related gear damage. HMDC will follow its C-NLOPB approved Incident Reporting and Investigation Procedure for reporting and documenting incidents associated with fishing gear.

Assessment of the Effects of Vessel and Seismic Equipment Presence

With application of the mitigations discussed above, effects of vessel presence, including all gear being towed by the seismic vessel, on the Fishery VEC are predicted to be a *negligible* to *low* magnitude during *<1* to *1-12 months* over an area of *<1* to *11-100* km^2 (Table 5.5). Based on these criteria ratings, the *reversible* residual effects of vessel presence during the seismic program on the Fishery VEC are predicted to be *not significant* (Tables 5.6).

5.6.2.3 Sanitary/Domestic Wastes

Impacts related to physical effects on fish and invertebrates, including those potentially resulting from releases of sanitary/domestic wastes, are not discussed any further in this section because earlier assessment of the Fish and Fish Habitat VEC predicted that the residual effects of the wastes on that VEC would be *negligible* and hence *not significant*.

5.6.2.4 Accidental Releases

In the event of an accidental release of hydrocarbons (e.g., fuel spill), there is some possibility of the perception of tainting of invertebrate and fish resources in the proximity of a release, even if there is no actual tainting. Perception alone can have economic effects if the invertebrates and fish lose marketability. Preventative measures/protocols, rapid response plans and good communications are essential mitigations to minimize the effects of any accidental hydrocarbon release. In the event of a release, the length of time that fish are exposed is a determining factor in whether or not their health is substantially affected or if there is an actual or perceived tissue tainting. Streamer floatation fluid can be expected to dissipate relatively rapidly. Any effect on access to fishing grounds would be of relatively short duration. In the unlikely event of a substantial hydrocarbon release, the need of compensation for commercial fishers will be determined through the C-NLOPB's guidelines.

With application of the mitigations discussed above, the effect of accidental hydrocarbon releases on the Fishery VEC is predicted have a *negligible* to *low* magnitude during *<1 month* over an area of *<1* to *1-10* km^2 (Table 5.5). Based on these criteria ratings, the *reversible* residual effects of accidental releases on the Fishery VEC during the seismic program are predicted to be *not significant* (Tables 5.6).

5.6.3 Seabirds

There are three main potential types of effect sources on seabirds due to the proposed seismic program: (1) underwater sound from air source arrays; (2) leakage of petroleum product from oil-filled streamer (s) (in the unlikely event of their use); and (3) attraction to ship lights at night and potential stranding. Potential interactions of the Project activities and the Seabird VEC are indicated in Table 5.7, and a review of available information related to potential effects on seabirds is provided in this section.

Table 5.7 Potential Interactions of the Project Activities and the Seabird VEC.

Project Activities	Valued Ecosystem Component: Seabird
Sound Emissions and Receivers	
Air Sources	X
Seismic Vessel	X
Supply Vessel	X
Picket Vessel	X
OBC	-
Helicopter[a]	X
Echo Sounder	X
Side Scan Sonar	X
Boomer	X
Vessel Lights	X
Vessel Presence	
Seismic Vessel	X
Supply Vessel	X
Picket Vessel	X
Sanitary/Domestic Waste	X
Atmospheric Emissions	X
Garbage[b]	-
Helicopter Presence[a]	X
Shore Facilities[c]	-
Accidental Releases	X
Other Projects And Activities	
Oil & Gas: Grand Banks and Orphan Basin	X
Fisheries (incl. research)	X
Marine Transportation	X

[a] A crew change may occur via helicopter if the seismic program is longer than 5-6 weeks.
[b] Not applicable as garbage will be brought ashore.
[c] There will not be any new onshore facilities. Existing infrastructure will be used.

5.6.3.1 Sound

Most of the seabird species expected to occur in the Study Area feed at either the ocean's surface or in the upper metre of the water column. This includes members of *Procellariidae* (Northern Fulmar), *Hydrobatidae* (Wilson's Storm-Petrel and Leach's Storm-Petrel), *Phalaropodinae* (Red Phalarope and Red-necked Phalarope), *Stercorariidae* (Great Skua, South Polar Skua, Pomarine Jaeger, Parasitic Jaeger and Long-tailed Jaeger), and *Laridae* (Herring Gull, Iceland Gull, Glaucous Gull, Great Black-backed Gull, Ivory Gull, Black-legged Kittiwake and Arctic Tern).

Northern Gannet plunge dive to a depth of 10 m. It is below surface for a few seconds during each dive so could possibly have minimal exposure to underwater sound. Great Shearwater, Sooty Shearwater and Manx Shearwater feed mainly at the surface but may also briefly chase prey below surface down to a depth of 2-10 m (Brown et al. 1978, 1981; Ronconi 2010a, b).

One seabird group, *Alcidae* (e.g., Dovekie, Common Murre, Thick-billed Murre, Razorbill and Atlantic Puffin) that occurs regularly in the Study Area, spends a relatively longer time below the ocean's surface to secure food than do other seabirds. Alcids use their wings to propel their bodies rapidly through the water. All are capable of reaching considerable depths and spending considerable time under water (Gaston and Jones 1998). An average duration and depth of dive for the five species of *Alcidae* is 25 to 40 seconds (s) and 20-60 m, respectively. Murres are capable of diving to a 120 m depth for up to 202 s (Gaston and Jones 1998). The effects of underwater sounds on *Alcidae* are unknown. In fact, the effects of underwater sound on birds in general have not been well studied. One study of the effects of underwater seismic survey sound on moulting Long-tailed Ducks in the Beaufort Sea showed little effect on their behaviour (Lacroix et al. 2003). However, the study did not consider potential physical effects on the ducks. The authors suggested caution in interpreting the data because of their limited utility to detect subtle disturbance effects, and recommended studies on other species to better understand the effects of seismic air source sound on seabirds. Sound is probably not important to *Alcidae* for securing food. However, all five species mentioned above are quite vocal out of water at breeding sites, suggesting that auditory capability is important during that part of the life cycle.

The sound from air sources is typically focused downward during seismic surveying. In air, air source sound is reduced to a "muffled shot" that should have little or no effect on seabirds that either have their heads above water or are in flight. It is possible that birds on the ocean's surface and proximate to discharging air sources would be startled by the sound. However, the presence of the ship and the associated seismic equipment in the water should have already warned the bird of unnatural visual and auditory stimuli.

Sound produced as a result of the proposed Project is predicted to cause effects on seabirds of *negligible* to *low* magnitude for a duration of *<1 month* to *1 to 12 months* over a geographic extent of *<1* to *1-10 km²* (Table 5.8). Therefore, the *reversible* residual effects of Project sound on the Seabird VEC are predicted to be *not significant* (Table 5.9).

Table 5.8 Assessment of Potential Effects of Project Activities on the Seabird VEC.

Valued Ecosystem Component: Seabirds									
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects						
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Sound Emissions and Receivers									
Air Sources	Disturbance (N)	-	0	2	6	1-2	R	2
Seismic Vessel	Disturbance (N)	-	0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)	-	0	1	6	1	R	2
Picket Vessel	Disturbance (N)	-	0	1	6	1-2	R	2
OBC	-	-	-	-	-	-	-	-
Helicopter	Disturbance (N)	Avoidance	0-1	2	1	1	R	2
Echosounder	Disturbance (N)	-	0-1	2	6	1	R	2
Side Scan Sonar	Disturbance (N)	-	0-1	1	6	1	R	2
Boomer	Disturbance (N)	-	0-1	1	6	1	R	2
Vessel Lights	Attraction (N)	Reduce lighting (if possible); stranded bird release	1-2	2	2-3	1-2	R	2
Vessel Presence									
Seismic Vessel	Disturbance (N)	Reduce lighting (if possible); stranded bird release	0	2	6	1-2	R	2
Supply Vessel	Disturbance (N)	Reduce lighting (if possible); stranded bird release	0	2	1	1	R	2
Picket Vessel	Disturbance (N)	Reduce lighting (if possible); stranded bird release	0	2	6	1-2	R	2
Atmospheric Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2
Sanitary/Domestic Waste	Increased Food (N/P)	Primary treatment	0	1	1	1-2	R	2
Atmospheric Emissions	Air Contaminants (N)	Equipment maintenance	0	2	6	1-2	R	2
Helicopter Presence	Disturbance (N)	Maintain high altitude	0-1	2	1	1	R	2
Accidental Releases	Mortality (N)	Solid streamer[a]; prevention protocols; Spill Response Plan	1-2	1-2	1	1	R	2

Valued Ecosystem Component: Seabirds									
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects						
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context	

Key:

Magnitude:
0 = Negligible,
1 = Low
2 = Medium
3 = High

Frequency:
1 = <11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Reversibility:
R = Reversible
I = Irreversible
(refers to population)

Duration:
1 = <1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = >72 months

Geographic Extent:
1 = < 1 km^2
2 = 1-10 km^2
3 = 11-100 km^2
4 = 101-1,000 km^2
5 = 1,001-10,000 km^2
6 = >10,000 km^2

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not affected by human activity
2 = Evidence of existing effects

[a] Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.

Table 5.9 Significance of the Potential Residual Effects of the Project Activities on the Seabird VEC.

Valued Ecosystem Component: Seabirds				
Project Activity	Significance Rating	Level of Confidence	Likelihood [a]	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
Sound				
Air Sources	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
OBC	NS	3	-	-
Helicopter	NS	3	-	-
Echosounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Boomer	NS	3	-	-
Vessel Lights	NS	3	-	-
Vessel Presence				
Seismic Vessel and Streamer	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Helicopter Presence	NS	3	-	-

Accidental Releases	NS	2	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

Level of Confidence: based on professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgment:
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

[a] Considered only in the case where 'significant negative effect' is predicted.

5.6.3.2 Vessel Lights

Birds that spend most of their lives at sea are often influenced by artificial light (Montevecchi et al. 1999; Montevecchi 2006). Even before the era of electrical lights, humans used fires on shore to attract seabirds for food (Montevecchi 2006). Birds are more strongly attracted to lights at sea during fog and drizzly conditions. Moisture droplets in the air refract light, thereby increasing illumination and creating a glow around vessels at sea. In Newfoundland waters, the Leach's Storm-Petrel is the species most often stranded on the decks of offshore vessels after being attracted to lights at night (Moulton et al. 2005, 2006; Abgrall et al. 2008a, 2008b 2009). Occasionally, other Newfoundland seabirds (e.g., Great Shearwater, Northern Fulmar, Thick-billed Murre and Dovekie) have stranded on vessels in Newfoundland waters at night, presumably due to the attraction to ship lights. In Alaska, a species related to the Dovekie, the Crested Auklet (*Aethia cristatella*), mass-stranded on a crab fishing boat (Dick and Donaldson 1978). An estimated 1.5 tons of the Crested Auklet either collided with or landed on the brightly lit fishing boat at night. There are not any known mass stranding events involving large numbers of Dovekies or any alcid species on vessels in Newfoundland and Labrador waters.

To date, bird strandings in the Newfoundland offshore have almost all involved Leach's Storm-Petrels. This is not surprising given the large numbers of this species in these waters coupled with their relative inability to become airborne after landing on a ship or platform. Numbers of strandings on seismic vessels have ranged from zero during the early part of the season to tens of birds; mostly late in the season after fledging has occurred. On a Grand Banks seismic vessel, the stranding of tens of birds in one night can be considered a "large scale stranding". The largest single stranding event observed by LGL biologists on seismic vessels was 46 birds, all of which were released live (LGL Limited, unpublished data). This stranding occurred in the Orphan Basin in October 2005.

Monitoring of pelagic seabird stranding on board seismic vessels due to light attraction has been conducted by LGL biologists during 16 seismic programs between 2004 and 2011 off both Newfoundland and Labrador. While seismic programs off Newfoundland and Labrador have been initiated as early as 7 May and terminated as late as 8 November, most have been conducted during the

June to September period. Bird stranding during these seismic programs has been monitored for a total of 888 nights. The number of nights per week with strandings and the number of individuals stranded per night have been highest from late-August to mid-October. This period coincides with the fledging of Leach's Storm-Petrels from Newfoundland colonies. Young of this species fledge from Great Island (Witless Bay), Newfoundland, as early as 10 September but the majority fledges from mid-September to late-October (Huntington et al. 1996). The mean fledging date is 25 September. Juveniles constituted a large majority of stranded Leach's Storm-Petrels near a colony off Scotland (Miles et al. 2010). However, in wintering areas, adult Leach's Storm-Petrels may also strand due to attraction to light (Rodríguez and Rodríguez 2009). Visibility during nights when storm-petrels stranded on seismic vessels off Newfoundland and Labrador was typically reduced due to fog, rain or overcast conditions. This has also been documented for other seabird species (Telfer et al. 1987; Black 2005). It has also been noted that seabird strandings seem to peak around the time of the new moon (i.e., when moonlight levels are lowest) (Telfer et al. 1987; Rodríguez and Rodríguez 2009; Miles et al. 2010).

Birds may be attracted to light because of a preference for bioluminescent prey (Imber 1975) or the red component of lights disrupts their magnetic orientation (Poot et al. 2008). Many seabirds have great difficulty becoming airborne from flat surfaces. Once on a hard surface, stranded seabirds tend to crawl into corners or under objects to hide and may die from exposure, dehydration or starvation over hours or days. A stranded seabird's plumage is prone to oiling from residual oil that may be present on a ship's deck. The open ended structure of the stern of a typical seismic ship allows entry of seabirds to several decks. These decks are lighted to various degrees, sometimes quite brightly. This is unavoidable as seismic surveying is conducted around the clock and adequate lighting is required for safe work practices.

Mitigation measures to rescue stranded storm-petrels on board the seismic vessel will be the responsibility of the MMO and procedures will follow conditions of the CWS *Bird Handling Permit.* In general, the MMO will conduct daily searches of the ship and the ship's crew will also be notified to contact the MMO if a bird is found. Project personnel will also be made aware of bird attraction to the lights on offshore structures. Deck lighting can be minimized (if it is safe and practical to do so) to reduce the likelihood of stranding. A report documenting each stranded bird will be completed and delivered to the CWS by the end of the calendar year. Any oiled birds will be handled according to the CWS bird handling permit.

Mitigation and monitoring for stranded birds will result in residual effects of attraction to lights of *low* to *medium* magnitude for a duration of *<1 month* to *1* to *12 months* over a geographic extent of <1 to *1-10* km^2 (Table 5.8). Therefore, the reversible residual effects of vessel lights on the Seabird VEC are predicted to be *not significant* (Table 5.9).

5.6.3.3 Vessel Presence

The potential effects of the physical presence of vessels are likely minimal. Seabirds may be attracted to the seismic, picket or supply vessel while prospecting for fish wastes associated with fishing vessels. Since there is little or no food made available by these vessels, seabirds are temporarily interested in the vessels and soon go elsewhere in search of food. Seabirds sitting on the water in the path of these vessels can move out of the way. Therefore, the residual effects of vessel presence on the Seabird VEC are predicted to be *negligible* and hence *not significant* (Tables 5.8 and 5.9).

5.6.3.4 Sanitary/Domestic Wastes

Sanitary waste generated by the vessels will be macerated before subsurface discharge. While it is possible that seabirds, primarily gulls, may be attracted to the sewage particles, the small amount discharged below surface over a limited period of time will not likely increase the far-offshore gull populations. Thus, any increase in gull predation on Leach's Storm-Petrels, as suggested by Wiese and Montevecchi (1999), is likely to be minimal. If this event occurs, the number of smaller seabirds involved will likely be low. Therefore, the residual effects of sanitary/domestic wastes on the Seabird VEC are predicted to be *negligible* and hence *not significant* (Tables 5.8 and 5.9).

5.6.3.5 Atmospheric Emissions

Although atmospheric emissions could, in theory, affect the health of some resident seabirds, these effects will be *negligible* considering that emissions of potentially harmful materials will be low and will rapidly disperse to undetectable levels due to their volatility, temperature of emission and the exposed and often windy nature of the offshore. Therefore, the residual effects of atmospheric emissions on the Seabird VEC are predicted to be *not significant* (Tables 5.8 and 5.9).

5.6.3.6 Helicopter Presence

Personnel may be transported to and from the seismic vessel via helicopters if a survey last longer than five to six weeks. Potential effects of helicopters on the marine environment are mainly related to the sound they generate (see a review of the effects of sound on seabirds above) and not their physical presence. Therefore, the residual effects of helicopter presence on the Seabird VEC are predicted to be *negligible* and hence *not significant* (Tables 5.8 and 5.9).

5.6.3.7 Accidental Releases

Seismic contractors may use either solid flotation or a paraffinic hydrocarbon called Isopar to provide buoyancy for streamers. It is ExxonMobil's and HMDC's present policy to only retain seismic contractors that use solid streamers. Solid streamers will be used in 2013 and most likely for any future seismic programs. Isopar is discussed below in the unlikely event that it becomes necessary to use it in the future.

The specific effects of Isopar M on seabirds are not known. However, petroleum products typically have detrimental effects on the insulating attributes of seabird feathers. Isopar M is a kerosene-like product that leaves a relatively thin layered slick on the surface of water and evaporates readily. Typical fluid-filled streamers are constructed of self-contained 100 m long units. Therefore, a single leak in a streamer could result in a maximum loss 208 L of Isopar M.

All seabirds expected to occur in the Study Area, except Arctic Tern, spend considerable time resting on the water. Birds that spend most of their time on water, such as the murres, Dovekie and Atlantic Puffin, are the species most likely to suffer negative effects from an accidental release of Isopar M. Northern Fulmar, the shearwaters and storm-petrels are attracted to sheens but would not likely confuse them with a natural oceanic "sheen" comprised of zooplankton or offal. However, flocks of seabirds resting on the water would not necessarily leave the water if they drifted into an area with Isopar M.

An exposure to a surface release of a kerosene-like substance under calm conditions may harm or kill individual birds. O' Hara and Morandin (2010) demonstrated that it requires only a small amount of oil (e.g., 10 ml) to affect the feather structure of Common Murre and Dovekie with potential to lethally reduce thermoregulation. Such modifications to feather structure cause a loss of insulation, which in turn can result in mortality. However, because potential accidental releases would likely be small and evaporation/dispersion rapid, the effects on seabirds are predicted to have *low* to *medium* magnitude for a duration of *<1 month* over a geographic extent of *<1* km^2 to *1-10* km^2 (Table 5.8). Therefore, the residual effects of an accidental release (e.g., Isopar M) on the seabird VEC are predicted to be *not significant* (Table 5.9).

5.6.4 Marine Mammals and Sea Turtles

The potential effects of marine seismic activities on marine mammals and sea turtles have been reviewed for several recent 3-D seismic projects in the Jeanne d'Arc Basin (e.g., LGL 2007a, 2008a, 2011a, b, 2012 (appended)), Labrador (LGL 2010), Orphan Basin (LGL 2003) and several others (e.g., Gordon et al. 2004; Stone and Tasker 2006; Southall et al. 2007; Abgrall et al. 2008c).

5.6.4.1 Sound

Air source arrays used during marine seismic operations introduce strong sound impulses to the underwater environment. These sound impulses could have several types of effects on marine mammals and sea turtles and represent one of the main issues associated with HMDC's proposed seismic project. The effects of exposure to human-generated underwater sound on marine mammals and sea turtles are quite variable depending on the species involved, the activity of the animal during exposure to the sound, and the distance of the animal from the sound source.

Underwater sound as it relates to marine mammals and sea turtles can be categorized as follows (adapted from Richardson et al. 1995):

- The sound is too weak to be heard at the location of the animal (i.e., lower than the prevailing ambient sound level, the hearing threshold of the animal at relevant frequencies, or both);
- Sound is audible but not strong enough to elicit overt behavioural response, (i.e., the animal may tolerate it, either with or without some deleterious effects such as masking and stress);
- The sound elicits behavioural reactions of variable conspicuousness and relevance to the well-being of the animal, ranging from subtle effects on respiration or other behaviours detectable by statistical analysis only to active avoidance reactions. Upon repeated exposure

to sound, animals may either exhibit diminishing responsiveness (habituation) or the disturbance effects may persist. The latter is most likely with sounds that are highly characteristically variable, unpredictable in terms of occurrence, and associated with situations perceived as threats by the animal;

- The sound has the potential to reduce the animal's capability to hear natural sounds of similar frequency (i.e., masking), including calls from conspecifics, echolocation sounds of odontocetes, and environmental sounds such as surf noise or ice noise. Intermittent air source and sonar pulses would have the potential to cause masking for only a small proportion of the time, given their short durations relative to the inter-pulse intervals; and
- The sound is very strong and has the potential to cause temporary or permanent reduction in hearing sensitivity, and other physical or physiological effects. The received sound levels must far exceed the animal's hearing threshold to cause either temporary threshold shift or permanent hearing impairment.

As part of the assessment of the potential effects of HMDC's proposed seismic program on marine mammals and sea turtles, this section reviews: (1) the hearing abilities of marine mammals and sea turtles; (2) potential masking caused by air source sound; (3) potential disturbance caused by air source sound; (4) potential hearing impairment caused by air source sound; and (5) potential physical and non-auditory physiological effects caused by air source sound.

Hearing Abilities of Marine Mammals and Sea Turtles

Marine mammals and sea turtles use underwater sound to communicate and gain information about their environment. Experiments and monitoring studies suggest that they hear and may react to man-made sounds, including those caused by seismic exploration (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Tyack 2008).

<u>Toothed Whales</u>

The small to moderate-sized toothed whales that have been studied have relatively poor hearing sensitivity at frequencies below 1 kHz, but relatively high sensitivity at frequencies of several kHz. Most of the odontocetes have been classified as having functional hearing over a frequency range of about 150 Hz to 160 kHz (Southall et al. 2007). There are very few data related to the absolute hearing thresholds of most of the larger, deep-diving toothed whales, such as the sperm and beaked whales. However, Cook et al. (2006) reported that a stranded Gervais' beaked whale exhibited evoked potentials at frequencies of 5 to 80 kHz, sensitivity being highest at 80 kHz. In another study, Finneran et al. (2009) observed that an adult Gervais' beaked whale had a similar upper cutoff of 80 to 90 kHz. Pacini et al. (2011) reported a sub-adult Blainville's beaked whale's best hearing range as 40 to 50 kHz. Porpoises have higher functional hearing over a frequency range of 200 Hz to 180 kHz (Southall et al. 2007).

Only a small proportion of air source sound energy occurs at mid- and high-frequencies, with levels progressively decreasing with increasing frequency. In other words, most of the energy in air source sound pulses occurs at the lower frequencies (i.e. <500 Hz). Air source sound levels are high enough and contain sufficient levels of mid- and high-frequency energy so that received levels often remain above the hearing thresholds of large odontocetes at distances of several tens of kilometres from the sound source (Richardson and Würsig 1997). There is no evidence that small odontocetes react to air source pulses at similar long distances. However, beluga whales do seem quite responsive at intermediate distances (10 to 20 km) when sound levels are well above the ambient sound level.

Baleen Whales

The hearing abilities of baleen whales have not been studied directly. Behavioural and anatomical evidence indicates that they hear well at frequencies below 1 kHz (Richardson et al. 1995; Ketten 2000). Baleen whales produce sounds at frequencies up to 8 kHz and, for humpback whales, with components >24 kHz (Au et al. 2006). The anatomy of the baleen whale inner ear seems to be well adapted for detection of low-frequency sounds (Ketten 2000; Parks et al. 2007a). Although humpback and minke whales exhibit auditory sensitivity to frequencies >22 kHz (Berta et al. 2009), baleen whales, as a group, have a functional hearing range of about 7 Hz to 22-25 kHz. Baleen whales are said to constitute the "low-frequency" (LF) hearing group (Southall et al. 2007).

The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small toothed whales that have been studied directly. Thus, baleen whales are likely to hear air source pulses at greater distances than small toothed whales and, at closer distances, air source sound may seem more prominent to baleen whales than to toothed whales.

Pinnipeds

Underwater audiograms exist for three species of phocid seals, two species of monachid seals, two species of otariids, and the walrus (reviewed in Richardson et al. 1995: 211*ff*; Kastak and Schusterman 1998, 1999; Kastelein et al. 2002, 2009). The functional hearing range for pinnipeds in water is considered to be 75 Hz to 75 kHz (Southall et al. 2007). Compared to odontocetes, pinnipeds tend to have highest auditory sensitivity at lower frequencies.

At least some of the phocid seals have better sensitivity at low frequencies (≤1 kHz) than do odontocetes. Below 30 to 50 kHz, the hearing thresholds of most species tested are essentially flat down to about 1 kHz, ranging between 60 and 85 dB re 1 µPa. Measurements for harbour seals indicate that, below 1 kHz, their thresholds during quiet background conditions deteriorate gradually to ~75 dB re 1 µPa at 125 Hz (Kastelein et al. 2009).

Sea Turtles

Hearing in sea turtles occurs through a combination of bone and water conduction rather than air conduction (Lenhardt 1982; Lenhardt and Harkins 1983). Although there are limited available data on sea turtle hearing capability, it appears that they are low-frequency specialists with a hearing range of 50 to 1,600 Hz for the species that have been tested (i.e., green, loggerhead, and Kemp's ridley sea turtles). The highest auditory sensitivities of sea turtles appear to be within the frequency range of ~200 to 700

Hz (Ridgway et al. 1969; Bartol et al. 1999; Bartol and Ketten 2006; Ketten and Bartol 2006; Yudhana et al. 2010; Dow Piniak et al. 2012; Lavender et al. 2012). Available information suggests that there is substantial overlap of the frequencies audible to sea turtles and the dominant frequencies of air source pulses. It is likely sea turtles can hear boomer sounds but not those emitted by side scan sonars and echosounders.

Masking

Masking is defined as the obscuring of sounds of interest by interfering sounds generally at similar frequencies (Richardson et al. 1995). Through masking, introduced underwater sound will reduce the effective communication distance of a marine mammal species if the frequency of the introduced sound is similar to the frequency of the sound used as a signal by the marine mammal, and if the introduced sound is occurring for a significant fraction of the time (Richardson et al. 1995; Clark et al. 2009). Therefore, if there is little frequency overlap of the introduced sound and the sound of interest, and, if the occurrence of the introduced sound is infrequent, communication is unlikely to be disrupted. Using an analytical paradigm, Clark et al. (2009) found that of the large baleen whales, the North Atlantic right whale may be most prone to communication masking by commercial vessel traffic noise. They found that two commercial ships in the U.S. Stellwagen Bank National Marine Sanctuary could cause an 84% reduction in the whale's communication space for at least 13.2 h a day. Gedamke (2011) suggested that blue and fin whale communication space may be reduced by 36 to 51% during seismic survey operations. Nieukirk et al. (2011) suggested the potential of masking effects of seismic survey operations sounds on large whales in Fram Strait and the Greenland Sea. The biological repercussions of a temporary loss of communication space are unknown (Clark et al. 2009).

The duty cycle of air sources is low. The air source sounds are pulsed, with relatively quiet periods between pulses. In most situations, strong air source sound will only be received for a brief period (<1 s or much less), and these sound pulses will be separated by at least several seconds of relative silence, longer in the case of deep-penetration surveys or refraction surveys. A single air source array might cause appreciable masking when propagation conditions are such that sound from each air source pulse reverberates strongly and persists for either much or the entire interval until the next air source discharge (e.g., Simard et al. 2005; Clark and Gagnon 2006). Situations with prolonged strong reverberation are typically infrequent. However, it is common for pulse reverberation to cause some lesser degree of elevation of the background sound level between air source pulses (e.g., Guerra et al. 2009), thereby causing reduction in the detection range of calls and other natural sounds to some degree.

Although masking effects of pulsed sounds on marine mammal calls and other natural sounds are expected to be limited, there are few specific studies to support this thought. Some whales continue calling in the presence of seismic pulses and these calls often can be heard between the seismic pulses (e.g., Richardson et al. 1986; Greene et al. 1999a, b; Smultea et al. 2004; Holst et al. 2005a, b, 2006, 2011; Cerchio et al. 2011). However, there is one recent summary report indicating that calling fin whales distributed in one part of the North Atlantic became silent for an extended period starting soon after the onset of a seismic survey in the area (Clark and Gagnon 2006). It is not clear from that report whether the whales ceased calling because of masking, or whether this was a behavioural response not directly involving masking. Castellote et al. (2009, 2010a, b) reported that singing fin whales moved away from an operating air source array rather than cease vocalizations. Bowhead whales in the Beaufort Sea may decrease their call rates in response to seismic survey operations, although movement out of the area might also have contributed to the lower call detection rate (Blackwell et al. 2011). In contrast, Di Iorio and Clark (2010) found that blue whales in the St. Lawrence Estuary increased their call rates during seismic operations using a lower-energy seismic source (i.e., a sparker).

Among the odontocetes, there has been one report that sperm whales ceased calling when exposed to sound pulses from a very distant seismic ship (Bowles et al. 1994). However, more recent studies of sperm whales found that they continued calling in the presence of seismic sound (Madsen et al. 2002; Tyack et al. 2003; Smultea et al. 2004; Holst et al. 2006, 2011; Jochens et al. 2008). Madsen et al. (2006) noted that air source sounds would not be expected to mask sperm whale calls given the intermittent nature of air source pulses. Dolphins and porpoises are also commonly heard calling while air sources are operating (Gordon et al. 2004; Smultea et al. 2004; Holst et al. 2005a, b, 2011; Potter et al. 2007). Masking effects of seismic pulses are expected to be *negligible* in the case of the smaller odontocetes, given the intermittent nature of seismic pulses and that sounds important to them are predominantly at much higher frequencies than are the dominant components of air source sound.

Pinnipeds have best hearing sensitivity and produce most of their sounds at frequencies higher than the dominant components of air source sound although there is some overlap in the frequencies of the air source pulses and the calls. However, the intermittent nature of air source pulses presumably reduces the potential for masking.

A few cetaceans are known to increase the source levels of their calls, to shift their peak frequencies or otherwise modify their vocal behaviour in response to increased levels of introduced sound (reviewed in Richardson et al. 1995:233*ff*, 364*ff*; Lesage et al. 1999; Terhune 1999; Nieukirk et al. 2005; Scheifele et al. 2005; Parks et al. 2007b, 2009, 2011; Hanser et al. 2009; Holt et al. 2009; Castellote et al. 2010a, b; Di Iorio and Clark 2010). It is not known how often these types of responses occur upon exposure to air source sounds. However, blue whales in the St. Lawrence Estuary significantly increased their call rates during sparker operations (Di Iorio and Clark 2010). The sparker, used to obtain seismic reflection data, emitted frequencies of 30 to 450 Hz with a source level of 193 dB re 1 μPa_{pk-pk}. If cetaceans exposed to air source sounds sometimes respond by changing their vocal behaviour, this adaptation along with directional hearing and preadaptation to tolerate some masking by natural sounds (Richardson et al. 1995), would all reduce the masking effect.

It has been suggested (Eckert 2000) that sea turtles use passive reception of acoustic signals to detect the hunting sonar of killer whales. However, the echolocation calls of killer whales are at frequencies that are probably too high for sea turtles to detect. Some studies suggest that visual, wave, and magnetic cues are the main navigational cues used by sea turtles, at least by hatchlings and juveniles (Lohmann et al. 1997, 2001; Lohmann and Lohmann 1998). Therefore, masking is probably not relevant to sea turtles. Even if acoustic signals were important to sea turtles, their hearing is best at frequencies slightly higher (200 to 700 Hz) than the dominant frequencies of air source sound (<200 Hz). If sea turtles do rely on acoustic cues from the environment, the relatively long interval between seismic and sonar pulses should allow them to receive these cues during survey operations. Thus, masking is unlikely to be a significant issue for either marine mammals or sea turtles exposed to the pulsed sounds emitted during seismic survey operations.

Disturbance

Disturbance includes a variety of effects, including subtle to conspicuous changes in behaviour, movement, and displacement. Behavioural reactions of marine mammals to sound are difficult to predict in the absence of site- and context-specific data. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007). If a marine mammal reacts to an underwater sound by changing its behaviour or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (e.g., Lusseau and Bejder 2007; Weilgart 2007). Also, various authors have noted that even marine mammals that show no obvious avoidance or behavioural changes may still be adversely affected by noise (Brodie 1981; Richardson et al. 1995: 317*ff*; Romano et al. 2004; Weilgart 2007; Wright et al. 2009, 2011). For example, some research suggests that animals in poor condition or in an already stressed state may not react as strongly to human disturbance as would more robust animals (e.g., Beale and Monaghan 2004).

A committee of specialists on noise impact issues has proposed new science-based impact criteria (Southall et al. 2007). Available detailed data on reactions of marine mammals to air source sounds (and other anthropogenic sounds) are limited to relatively few species and situations (see Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007). Detailed studies have been done on humpback, grey, bowhead and sperm whales, and on ringed seals. Fewer detailed data are available for some other species of baleen whales, small toothed whales, and sea turtles, but for many species there are no data on responses to marine seismic surveys.

<u>Baleen Whales</u>

Baleen whales generally tend to avoid operating air sources but avoidance radii are quite variable depending on species, location, whale activity, oceanographic conditions affecting sound propagation, etc. (reviewed in Richardson et al. 1995; Gordon et al. 2004). It is often reported that whales show no overt reactions to pulses from large arrays of air sources at distances beyond a few kilometres, even though the sound levels remain well above ambient sound levels at greater distances from the air sources. However, baleen whales exposed to strong sound pulses from air sources often react by deviating from their normal migration route and/or interrupting their feeding and moving away from the sound source. Some of the major studies and reviews on this topic are Malme et al. (1984, 1985, 1988), Richardson et al. (1986, 1995, 1999), Ljungblad et al. (1988), Richardson and Malme (1993), McCauley et al. (1998, 2000a,b), Miller et al. (1999, 2005), Gordon et al. (2004), Stone and Tasker (2006), Johnson et al. (2007), Nowacek et al. (2007), Weir (2008a), and Moulton and Holst (2010). Although baleen whales often show only slight overt responses to operating air source arrays (e.g., Stone and Tasker 2006; Weir 2008a; Moulton and Holst 2010), strong avoidance reactions by several species of mysticetes have been observed as far as 20 to 30 km from the source vessel when large arrays of air sources were used (e.g., Miller et al. 1999; Richardson et al. 1999). Experiments have shown that bowhead, humpback and grey whales exhibited localized avoidance to a single air source of 20 to 100 in^3 (Malme et al. 1984, 1985, 1986, 1988; Richardson et al. 1986; McCauley et al. 1998, 2000a,b).

Studies of grey, bowhead, and humpback whales have shown that seismic sound pulses with received levels of 160 to 170 dB re 1 μPa_{rms} seem to cause obvious avoidance behaviour in a substantial portion of the exposed animals (Richardson et al. 1995). In many areas, seismic sound pulses from large air source arrays diminish to those levels at distances ranging from 4 to 15 km from the source. More recent studies have shown that some species of baleen whales, particularly bowheads and humpbacks, sometimes show strong avoidance at received levels lower than 160 to 170 dB re 1 μPa_{rms}. The largest observed avoidance radius involved migrating bowhead whales avoiding an operating seismic vessel by 20 to 30 km (Miller et al. 1999; Richardson et al. 1999; Manly et al. 2007). In the cases of migrating bowhead and grey whales, the observed changes in behaviour appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees but still remained within the natural boundaries of the migration corridors (Malme et al. 1984; Malme and Miles 1985; Richardson et al. 1995). Feeding bowhead whales, in contrast to migrating whales, exhibit much smaller avoidance distances (Miller et al. 2005; Harris et al. 2007), presumably because moving away from a food concentration has greater cost to the whales than does course deviation during migration.

The following sections provide more details on the documented responses of particular species and groups of baleen whales to marine seismic operations.

Humpback Whales

Responses of humpback whales to seismic surveys have been studied during migration, on the summer feeding grounds, and on Angolan winter breeding grounds; there has also been discussion of effects on the Brazilian wintering grounds. McCauley et al. (1998, 2000a) studied the responses of migrating humpback whales off western Australia to a full-scale seismic survey with a 16 air source 2,678 in^3 array, and to a single 20 in^3 air source with a (horizontal) source level of 227 dB re 1 $\mu Pa \cdot m_{p-p}$. They found that the overall distribution of humpbacks migrating through their study area was unaffected by the full-scale seismic program, although localized displacement varied with pod composition, behaviour, and received sound levels. Observations were made from the seismic vessel, from which the maximum viewing distance was indicated as 14 km. Avoidance reactions (course and speed changes) began at four to five km for traveling pods; with the closest point of approach (CPA) being three to four km at an estimated received level of 157 to 164 dB re 1 μPa_{rms} (McCauley et al. 1998, 2000a). A greater stand-off range of 7 to 12 km was observed for more sensitive resting pods (cow-calf pairs; McCauley et al. 1998, 2000a). The mean received level for initial avoidance of an approaching air source was 140 dB re 1 μPa_{rms} for humpback pods containing females, and at the mean CPA distance the received level was 143 dB re 1 μPa_{rms}. One startle response was reported at 112 dB re 1 μPa_{rms}. The initial avoidance response generally occurred at distances of five to eight km from the air source array and two km from the single air source. However, some individual humpback whales, especially males, approached within distances of 100 to 400 m, where the maximum received level was 179 dB re 1 μPa_{rms}. The McCauley et al. (1998, 2000a, b) studies show evidence of greater avoidance of seismic air source sounds by pods with females than by other pods during humpback migration off Western Australia. Studies examining the behavioural response of humpback whales off Eastern Australia are currently underway (Cato et al. 2011).

Humpback whales on their summer feeding grounds in southeast Alaska did not exhibit persistent avoidance when exposed to seismic pulses from a 1.64 L (100 in^3) air source (Malme et al. 1985). Some humpbacks seemed "startled" at received levels of 150 to 169 dB re 1 μPa. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 μPa on an approximate rms basis. However, Moulton and Holst (2010) reported that humpback whales monitored during seismic surveys in the NW Atlantic had significantly lower sighting and were most often seen swimming away from the vessel during seismic periods compared with periods when air sources were silent.

Among wintering humpback whales off Angola (n=52 useable groups), there were no significant differences in encounter rates (sightings/hr) between times when a 24 air source array (3,147 in^3 or 5,085 in^3) was operating and times with no operating air sources (Weir 2008a). There was also no significant difference in the mean CPA distance of the humpback sightings between times when air sources were discharging versus times when they were not (3,050 m vs. 2,700 m, respectively). Cerchio et al. (2011) suggested that the breeding display of humpback whales off Angola may be disrupted by seismic sounds, as singing activity declined with increasing received levels.

It has been suggested that South Atlantic humpback whales wintering off Brazil may be displaced or may even strand upon exposure to seismic surveys (Engel et al. 2004). The evidence for this was circumstantial and subject to alternative explanations (IAGC 2004). Also, the evidence was not consistent with subsequent results from the same area of Brazil (Parente et al. 2006a), or with direct studies of humpbacks exposed to seismic surveys in other areas and seasons (see above). After allowance for data from subsequent years, there was "no observable direct correlation" between strandings and seismic surveys (IWC 2007, p. 236).

Rorquals

Blue, sei, fin, and minke whales (all of which are members of the genus Balaenoptera) often have been seen in areas ensonified by air source pulses (Stone 2003; MacLean and Haley 2004; Stone and Tasker 2006; Moulton and Holst 2010), and calls from blue and fin whales have been localized in areas with air source operations (e.g., McDonald et al. 1995; Dunn and Hernandez 2009; Castellote et al. 2010a, b). Sightings by observers on seismic vessels during 110 large-source seismic surveys off the U.K. from 1997 to 2000 suggest that, during times of good visibility, sighting rates for mysticetes (mainly fin and sei whales) were similar when large arrays of air sources were discharging and when they were not (Stone 2003; Stone and Tasker 2006). However, these whales tended to exhibit localized avoidance, remaining significantly further (on average) from the air source array during seismic operations compared with non-seismic periods (Stone and Tasker 2006). The average CPA distances for baleen whales sighted when large air source arrays were operating and not operating silent were 1.6 km and 1.0 km, respectively.

Baleen whales, as a group, were more often oriented away from the vessel while a large air source array was shooting compared with periods of no shooting (Stone and Tasker 2006). Similarly, Castellote et al. (2009, 2010a,b) reported that singing fin whales in the Mediterranean moved away from an operating air source array and avoided the area of operations even for days after air source activity had ceased. In addition, Stone (2003) noted that fin/sei whales were less likely to remain submerged during periods of seismic shooting.

Blue whales were seen significantly farther from the vessel during single air source operations, ramp-up, and all other air source operations compared with non-seismic periods (Moulton and Holst 2010). Similarly, the mean CPA distance for fin whales was significantly greater during ramp up than during periods without air source operations. There was also a trend for fin whales to be sighted farther from the vessel during other air source operations, but the difference was not significant (Moulton and Holst 2010). Minke whales were also seen significantly closer to the vessel during non-seismic periods compared with periods of seismic operations (Moulton and Holst 2010). Minke whales were also more likely to swim away and less likely to approach during seismic operations compared to periods when air sources were not operating (Moulton and Holst 2010). MacLean and Haley (2004) occasionally observed minke whales approaching active air source arrays where received sound levels were estimated to be near 170 to 180 dB re 1 µPa.

Conclusions

Baleen whales generally tend to avoid operating air sources but avoidance radii are quite variable in length. Whales are often reported to show no overt reactions to air source pulses at distances beyond a few kilometres, even though the air source pulses remain well above ambient noise levels out to much longer distances. However, studies since the late 1990s on migrating humpback and bowhead whales show whale reactions, including avoidance, that sometimes extend to greater distances than earlier documented. Avoidance distances often exceed the maximum distances at which boat-based observers can see whales, so observations from the source vessel can be biased.

Some baleen whales show considerable tolerance of seismic pulses. However, when the pulses are strong enough, avoidance or other behavioural changes become evident. Because the responses become less obvious with diminishing received sound level, it has been difficult to determine the maximum distance (or minimum received sound level) at which reactions to seismic become evident and, hence, how many whales are affected.

Studies of grey, bowhead, and humpback whales have determined that received levels of pulses in the 160 to 170 dB re 1 μPa_{rms} range seem to cause obvious avoidance behaviour in a substantial fraction of the animals exposed. In many areas, seismic pulses diminish to these levels at distances ranging from 4 to 15 km from the source. A substantial proportion of the baleen whales within such distances may show avoidance or other strong disturbance reactions to the operating air source array. However, in other situations, various mysticetes tolerate exposure to full-scale air source arrays operating at even closer distances, with only localized avoidance and minor changes in activities. At the other extreme, in migrating bowhead whales, avoidance often extends to considerably larger distances (20 to 30 km) and lower received sound levels (120 to 130 dB re 1 μPa_{rms}). Also, even in cases where there is no conspicuous avoidance or change in activity upon exposure to sound pulses from distant seismic operations, there are sometimes subtle changes in behaviour (e.g., surfacing–respiration–dive cycles) that are only evident through detailed statistical analysis (e.g., Richardson et al. 1986; Gailey et al. 2007).

Mitigation measures for seismic surveys, especially nighttime seismic surveys, typically assume that many marine mammals (at least baleen whales) tend to avoid approaching air sources, or the seismic vessel itself, before being exposed to levels high enough for there to be any possibility of injury. This assumes that the ramp-up (soft-start) procedure is used when commencing air source operations, to give whales near the vessel the opportunity to move away before they are exposed to sound levels that might be strong enough to elicit Temporary Threshold Shift (TTS). As noted above, single-air source experiments with three species of baleen whales show that those species typically do tend to move away when a single air source starts firing nearby, simulating the onset of a ramp-up. The three species that showed avoidance when exposed to the onset of pulses from a single air source were grey whales (Malme et al. 1984, 1986, 1988); bowhead whales (Richardson et al. 1986; Ljungblad et al. 1988); and humpback whales (Malme et al. 1985; McCauley et al. 1998, 2000a, b). In addition, results from Moulton and Holst (2010) showed that blue whales were seen significantly farther from the vessel during operations with a single air source and during ramp-up compared with periods without air source operations. Since startup of a single air source is equivalent to the start of a ramp-up (i.e., soft start), this strongly suggests that many baleen whales will likely begin to move away during the initial stages of a ramp-up.

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. Castellote et al. (2009) reported that fin whales avoided their potential winter ground for an extended period of time (at least 10 days) after seismic operations in the Mediterranean Sea had ceased. However, grey whales have continued to migrate annually along the west coast of North America despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A in Malme et al. 1984; Richardson et al. 1995). There has also been a substantial increase in that grey whale population over recent decades (Allen and Angliss 2010). The W Pacific grey whale population did not seem affected by a seismic survey in its feeding ground during a prior year (Johnson et al. 2007). Similarly, bowhead whales have continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987). In addition, bowhead numbers have increased notably (Allen and Angliss 2010). Bowheads also have been observed over periods of days or weeks in areas ensonified repeatedly by seismic pulses (Richardson et al. 1987; Harris et al. 2007). However, it is generally not known whether the same individual bowheads were involved in these repeated observations (within and between years) in strongly ensonified areas. In any event, in the absence of some unusual circumstances, the history of coexistence between seismic surveys and baleen whales suggests that brief exposures to sound pulses from any single seismic survey are unlikely to result in prolonged effects.

Toothed Whales

Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above have been reported for toothed whales. However, there are recent systematic data on sperm whales (e.g., Gordon et al. 2006; Madsen et al. 2006; Winsor and Mate 2006; Jochens et al. 2008; Miller et al. 2009). There is also an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies (e.g., Stone 2003; Smultea et al. 2004; Bain and Williams 2006; Holst et al. 2006; Stone and Tasker 2006; Potter et al. 2007; Hauser et al. 2008; Holst and Smultea 2008; Weir 2008a; Barkaszi et al. 2009; Richardson et al. 2009; Moulton and Holst 2010).

Delphinids (Dolphins and similar) and Monodontids (Beluga)

Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating air source arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Goold 1996a, b, c; Calambokidis and Osmek 1998; Stone 2003; Moulton and Miller 2005; Holst et al. 2006; Stone and Tasker 2006; Weir 2008a; Richardson et al. 2009; Barkaszi et al. 2009; Moulton and Holst 2010). In most cases, the lengths of avoidance radii for delphinids appear to be small, on the order of 1 km or less, and some individuals show no apparent avoidance. Studies that have reported cases of small toothed whales close to the operating air sources include Duncan (1985), Arnold (1996), Stone (2003), and Holst et al. (2006). When a 3,959 in^3, 18 air source array was firing off California, toothed whales behaved in a manner similar to that observed when the air sources were silent (Arnold 1996). Some dolphins seem to be attracted to the seismic vessel and floats, and some ride the bow wave of the seismic vessel even when a large array of air sources is discharging (e.g., Moulton and Miller 2005). Nonetheless, small toothed whales more often tend to head away or maintain a somewhat greater distance from the vessel when a large array of air sources is operating compared to when it is not operating (e.g., Stone and Tasker 2006; Weir 2008a; Barry et al. 2012; Moulton and Holst 2010).

Weir (2008b) noted that a group of short-finned pilot whales initially showed an avoidance response to ramp-up of a large air source array, but that this response was limited in time and space. Moulton and Holst (2010) did not find any indications that long-finned pilot whales, or delphinids as a group, responded to ramp-ups by moving away from the seismic vessel during surveys in the NW Atlantic (Moulton and Holst 2010).

Goold (1996a, b, c) studied the effects on common dolphins of 2-D seismic surveys in the Irish Sea. Passive acoustic surveys were conducted from the “guard ship” that towed a hydrophone. The results indicated that there was a local displacement of dolphins around the seismic operation. However, observations indicated that the animals were tolerant of the sounds at distances outside a 1-km radius from the air sources (Goold 1996a). Initial reports of larger-scale displacement were later shown to represent a normal autumn migration of dolphins through the area, and were not attributable to seismic surveys (Goold 1996 a, b, c). Based on data from 21 offshore surveys from 2001-2008, Barry et al. (2012) found that bottlenose and short-beaked common dolphins were seen exhibiting “close to boat” behaviours more often during non-seismic periods than seismic periods, and that higher proportions of both species were seen “travelling” during seismic operations compared with non-seismic periods.

The beluga is a species that (at least at times) shows long-distance avoidance of seismic vessels. Aerial surveys conducted in the southeastern Beaufort Sea in summer found that sighting rates of belugas were significantly lower at distances 10 to 20 km compared with 20 to 30 km from an operating air source array (Miller et al. 2005). The low number of beluga sightings by marine mammal observers on the vessel seemed to confirm there was a strong avoidance response to the 2,250 in^3 air source array. More recent seismic monitoring studies in the same area have confirmed that the apparent displacement effect on belugas extended farther than has been shown for other small odontocetes exposed to air source pulses (e.g., Harris et al. 2007).

Observers stationed on seismic vessels operating off the U.K. from 1997 to 2000 have provided data on the occurrence and behaviour of various toothed whales exposed to seismic pulses (Stone 2003; Gordon et al. 2004; Stone and Tasker 2006). Dolphins of various species often showed more evidence of avoidance of operating air source arrays than has been reported previously for small odontocetes. Sighting rates of white-sided dolphins, white-beaked dolphins, *Lagenorhynchus* spp., and all small odontocetes combined were significantly lower during periods when large-volume[1] air source arrays were shooting. Except for pilot whale and bottlenose dolphin, CPA distances for all of the small odontocete species tested, including killer whales, were significantly greater from large air source arrays during periods of shooting compared with periods of no shooting. Pilot whales were less responsive than other small odontocetes in the presence of seismic surveys (Stone and Tasker 2006). For small odontocetes as a group, and most individual species, orientations differed between times when large air source arrays were operating vs. silent, with significantly fewer animals traveling towards and/or more traveling away from the vessel during shooting (Stone and Tasker 2006). Observers’ records suggested that fewer cetaceans were feeding and fewer were interacting with the survey vessel (e.g., bow-riding) during periods with air sources operating, and small odontocetes tended to swim faster during periods of shooting (Stone and Tasker 2006). For most types of small odontocetes sighted by observers on seismic vessels, the median CPA distance was ≥0.5 km larger during air source operations (Stone and Tasker 2006). Killer whales appeared to be more tolerant of seismic shooting in deeper waters.

Data collected during seismic operations in the Gulf of Mexico and off Central America show similar patterns. A summary of vessel-based monitoring data from the Gulf of Mexico during 2003 to 2008 showed that delphinids were generally seen farther from the vessel during seismic than during non-seismic periods (based on Barkaszi et al. 2009, excluding sperm whales). Similarly, during two National Science Foundation (NSF)-funded Lamont-Doherty Earth Observatory of Columbia University (L-DEO) seismic surveys that used a large 20 air source array (~7,000 in^3), sighting rates of delphinids were lower and initial sighting distances from the vessel were greater during seismic than non-seismic periods (Smultea et al. 2004; Holst et al. 2005a, 2006; Richardson et al. 2009). Monitoring results during a seismic survey in the southeast Caribbean showed that the mean CPA of delphinids during seismic operations was 991 m during seismic operations compared to 172 m when the air sources were not operational (Smultea et al. 2004). Surprisingly, nearly all acoustic detections via a towed passive

[1] Large volume means at least 1,300 in^3, with most (79%) at least 3,000 in^3.

acoustic monitoring (PAM) array (including both delphinids and sperm whales) were made when the air sources were operating (Smultea et al. 2004). Although the number of sightings during monitoring of a seismic survey off the Yucatán Peninsula, Mexico, was small (*n* = 19), the results showed that the mean CPA distance of delphinids during seismic operations there was 472 m during seismic operations compared to 178 m when the air sources were silent (Holst et al. 2005a). The acoustic detection rates were nearly five times higher during non-seismic compared with seismic operations (Holst et al. 2005a).

For two additional NSF-funded L-DEO seismic surveys in the eastern Tropical Pacific, both using a large 36 air source array (~6,600 in^3), the results are less easily interpreted (Richardson et al. 2009). During both surveys, the delphinid detection rate was lower during seismic than during non-seismic periods, as found in various other projects, but the mean CPA distance of delphinids was less during seismic periods (Hauser et al. 2008; Holst and Smultea 2008).

During seismic surveys in the NW Atlantic, delphinids as a group showed some localized avoidance of the operating array (Moulton and Holst 2010). The mean initial detection distance was significantly greater (by approximately 200 m) during seismic operations compared with non-seismic periods; however, there was no significant difference between sighting rates (Moulton and Holst 2010). The same results were evident when only long-finned pilot whales were considered.

Among Atlantic spotted dolphins off Angola (*n* = 16 useable groups), marked short-term and localized displacement was found in response to seismic operations conducted with a 24 air source array (3,147 in^3 or 5,085 in^3) (Weir 2008a). Sample sizes were low, but CPA distances of dolphin groups were significantly larger when air sources were operating (mean 1,080 m) compared to when they were not (mean 209 m). No Atlantic spotted dolphins were seen within 500 m of the air sources when they were operating, whereas all sightings when air sources were silent occurred within 500 m, including the only recorded "positive approach" behaviours.

Reactions of toothed whales to a single air source or other small air source sources are not well documented, but tend to be less substantial than reactions to large air source arrays (e.g., Stone 2003; Stone and Tasker 2006). During 91 site surveys off the U.K. in 1997 to 2000, sighting rates of all small odontocetes combined were significantly lower during periods the low-volume[2] air source sources were operating, and effects on orientation were evident for all species and groups tested (Stone and Tasker 2006). Results from four NSF-funded L-DEO seismic surveys using small arrays (up to 3 GI guns and 315 in^3) were inconclusive. During surveys in the eastern Tropical Pacific (Holst et al. 2005b) and in the NW Atlantic (Haley and Koski 2004), detection rates were slightly lower during seismic compared to non-seismic periods. However, mean CPAs were less during seismic operations during one cruise (Holst et al. 2005b) and greater during the other cruise (Haley and Koski 2004). Interpretation of the data was confounded by the fact that survey effort and/or number of sightings during non-seismic periods during both surveys was small. Results from two small-array surveys in southeast Alaska were even more variable (MacLean and Koski 2005; Smultea and Holst 2003).

[2] For low volume arrays, maximum volume was 820 in^3, with most (87%) $\leq$180 in^3.

Captive bottlenose dolphins and beluga whales exhibited changes in behaviour when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002, 2005). Finneran et al. (2002) exposed a captive bottlenose dolphin and beluga to single impulses from a water gun (80 in^3). Compared to air source pulses, water gun impulses were expected to contain proportionally more energy at higher frequencies because there is no significant gas-filled bubble, and thus little low-frequency bubble-pulse energy (Hutchinson and Detrick 1984). The captive animals sometimes vocalized after exposure and exhibited reluctance to station at the test site where subsequent exposure to impulses would be implemented (Finneran et al. 2002). Similar behaviours were exhibited by captive bottlenose dolphins and a beluga exposed to single underwater pulses designed to simulate those produced by distant underwater explosions (Finneran et al. 2000). It is uncertain what relevance these observed behaviours in captive, trained marine mammals exposed to single transient sounds may have to free-ranging animals exposed to multiple pulses. In any event, the animals tolerated rather high received levels of sound before exhibiting the aversive behaviours mentioned above.

Odontocete responses (or lack of responses) to noise pulses from underwater explosions (as opposed to air source pulses) may be indicative of odontocete responses to very strong noise pulses. During the 1950s, small explosive charges were dropped into an Alaskan river in attempts to scare belugas away from salmon. Success was limited (Fish and Vania 1971; Frost et al. 1984). Small explosive charges were “not always effective” in moving bottlenose dolphins away from sites in the Gulf of Mexico where larger demolition blasts were about to occur (Klima et al. 1988). Odontocetes may be attracted to fish killed by explosions, and thus attracted rather than repelled by “scare” charges. Captive false killer whales showed no obvious reaction to single noise pulses from small (10 g) charges with received levels of about185 dB re 1 μPa (Akamatsu et al. 1993). Jefferson and Curry (1994) reviewed several additional studies that found limited or no effects of noise pulses from small explosive charges on killer whales and other odontocetes. Aside from the potential for causing auditory impairment (see below), the tolerance to these charges may indicate a lack of effect, or the failure to move away may simply indicate a stronger desire to feed, regardless of circumstances.

Phocoenids (Porpoises)

Porpoises, like delphinids, show variable reactions to seismic operations, and reactions apparently depend on species. The limited available data suggest that the harbour porpoise shows stronger avoidance of seismic operations than Dall’s porpoise (Stone 2003; MacLean and Koski 2005; Bain and Williams 2006). In Washington State waters, the harbour porpoise—despite being considered a high-frequency specialist—appeared to be the species affected by the lowest received level of air source sound (<145 dB re 1 μPa_{rms} at a distance >70 km; Bain and Williams 2006). Similarly, during seismic surveys with large air source arrays off the U.K. in 1997 to 2000, there were significant differences in directions of travel by harbour porpoises between periods when the air sources were shooting and those without air source discharging (Stone 2003; Stone and Tasker 2006). A captive harbour porpoise exposed to single sound pulses from a small air source showed aversive behaviour upon receipt of a pulse with a received level above 174 dB re 1 μPa_{pk-pk} or SEL >145 dB re 1 $\mu Pa^2 \cdot s$ (Lucke et al. 2009). In contrast, Dall’s porpoises seem relatively tolerant of air source operations (MacLean and Koski 2005; Bain and Williams 2006), although they too have been observed to avoid large arrays of operating air sources (Calambokidis and Osmek 1998; Bain and Williams 2006). The apparent tendency for greater responsiveness by harbour porpoise is consistent with their relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007).

Beaked Whales

There are almost no specific data on the behavioural reactions of beaked whales to seismic surveys. Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986), although it is uncertain how much longer such dives may be as compared to dives by undisturbed beaked whales which also are often quite long (Baird et al. 2006; Tyack et al. 2006a, b). In any event, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel, regardless of whether or not the air sources are operating. However, this has not been documented explicitly. Northern bottlenose whales sometimes are quite tolerant of slow-moving vessels not emitting air source pulses (Reeves et al. 1993; Hooker et al. 2001). Several studies have indicated that some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (Gosselin and Lawson 2004; Laurinolli and Cochrane 2005; Simard et al. 2005; Potter et al. 2007). Moulton and Holst (2010) reported 15 sightings of beaked whales during seismic studies in the NW Atlantic. Seven of those sightings were made at times when at least one air source was operating. There was little evidence to indicate that beaked whale behaviour was affected by air source operations since sighting rates and distances were similar during seismic and non-seismic periods (Moulton and Holst 2010).

Sperm Whales

All three species of sperm whales have been reported to show avoidance reactions to standard vessels not emitting air source sounds (e.g., Richardson et al. 1995; Würsig et al. 1998; McAlpine 2002; Baird 2005). However, most studies of sperm whales exposed to air source sounds indicate that this species shows considerable tolerance of air source pulses. The whales usually do not show strong avoidance (i.e., they do not leave the area) and they continue to call.

There were some early and limited observations suggesting that sperm whales in the Southern Ocean ceased calling during some of the times when exposed to weak noise pulses from extremely distant (>300 km) seismic exploration. However, other operations in the area could also have been a factor (Bowles et al. 1994). This "quieting" was suspected to represent a disturbance effect, in part because sperm whales exposed to pulsed man-made sounds at higher frequencies often cease calling (Watkins and Schevill 1975; Watkins et al. 1985). Also, there was an early preliminary account of possible long-range avoidance of seismic vessels by sperm whales in the Gulf of Mexico (Mate et al. 1994). However, this has not been substantiated by subsequent more detailed work in that area (Gordon et al. 2006; Winsor and Mate 2006; Jochens et al. 2008; Miller et al. 2009).

Recent and more extensive data from vessel-based monitoring programs in U.K. waters, the NW Atlantic, and off Angola suggest that sperm whales in those areas show little evidence of avoidance or behavioural disruption in the presence of operating seismic vessels (Stone 2003; Stone and Tasker 2006;

Weir 2008a; Moulton and Holst 2010). Among sperm whales off Angola (*n* = 96 useable groups), there were no significant differences in encounter rates (sightings/h) between times when a 24 air source array (3,147 in^3 or 5,085 in^3) was operating and times without operating air sources. The encounter rate tended to increase over the 10 month duration of the seismic survey (Weir 2008a). There was also no significant difference in the CPA distances of the sperm whale sightings between times when air sources were operating and times when they were not (means 3,039 m vs. 2,594 m, respectively). Similarly, in the NW Atlantic, sighting rates and distances of sperm whales did not differ between seismic and non-seismic periods (Moulton and Holst 2010). These types of observations are difficult to interpret because the observers are stationed on or near the seismic vessel, and may underestimate reactions by some of the more responsive animals which may be beyond visual range. However, these results do seem to indicate considerable tolerance of seismic surveys by at least some sperm whales. Also, a study off northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 $\mu Pa_{p\text{-}p}$ (Madsen et al. 2002).

Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale vocalizations at various distances from an active seismic program did not detect any obvious changes in the distribution or behaviour of sperm whales (McCall Howard 1999). Sightings of sperm whales by observers on seismic vessels operating in the Gulf of Mexico during 2003 to 2008 were at very similar average distances regardless of whether the air sources were operating or not (Barkaszi et al. 2009). For example, the mean sighting distance was 1,839 m when the air source array was in full operation (*n*=612) and 1,960 m when all air sources were off (*n*=66).

A detailed study of sperm whale reactions to seismic surveys has been done recently in the Gulf of Mexico ― the Sperm Whale Seismic Study or SWSS (Gordon et al. 2006; Madsen et al. 2006; Winsor and Mate 2006; Jochens et al. 2008; Miller et al. 2009). During SWSS, D-tags (Johnson and Tyack 2003) were used to record the movement and acoustic exposure of eight foraging sperm whales before, during, and after controlled exposures to sound from air source arrays (Jochens et al. 2008; Miller et al. 2009).

Whales were exposed to maximum received sound levels of 111 to 147 dB re 1 μPa_{rms} (131 to 162 dB re 1 $\mu Pa_{pk\text{-}pk}$) at ranges of ~1.4 to 12.8 km from the sound source (Miller et al. 2009). Although the tagged whales showed no discernible horizontal avoidance, some whales showed changes in diving and foraging behaviour during full-array exposure, possibly indicative of subtle negative effects on foraging (Jochens et al. 2008; Miller et al. 2009; Tyack 2009). Two indicators of foraging that they studied included oscillations in pitch and occurrence of echolocation buzzes, both of which tend to occur when a sperm whale closes in on prey. "Oscillations in pitch generated by swimming movements during foraging dives were on average 6% lower during exposure than during the immediately following post-exposure period, with all seven foraging whales exhibiting less pitching (p = 0.014). Buzz rates, a proxy for attempts to capture prey, were 19% lower during exposure…" (Miller et al. 2009). Although the latter difference was not statistically significant (p = 0.141), the percentage difference in buzz rate during exposure vs. post-exposure conditions appeared to be strongly correlated with air source-whale distance (Miller et al. 2009: Fig. 5; Tyack 2009).

Conclusions

Dolphins and porpoises are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bow riding). However, some studies near the U.K., Newfoundland, Angola, in the Gulf of Mexico, and off Central America have shown localized avoidance. Also, belugas summering in the Canadian Beaufort Sea showed larger-scale avoidance, tending to avoid waters out to 10 to 20 km from operating seismic vessels. In contrast, recent studies show little evidence of conspicuous reactions by sperm whales to air source pulses, contrary to earlier indications.

There are almost no specific data on responses of beaked whales to seismic surveys, but it is likely that most if not all species show strong avoidance. Northern bottlenose whales seem to continue to call when exposed to pulses from distant seismic vessels.

Overall, odontocete reactions to large arrays of air sources are variable and, at least for delphinids and some porpoises, seem to be confined to a smaller reaction radius than has been observed for some mysticetes. However, other data suggest that some odontocetes species, including belugas and harbour porpoises, may be more responsive than might be expected given their poor low-frequency hearing. Reactions at longer distances may be particularly likely when sound propagation conditions are conducive to transmission of the higher-frequency components of air source sound to the animals' location (DeRuiter et al. 2006; Goold and Coates 2006; Tyack et al. 2006a,b; Potter et al. 2007).

For delphinids, and possibly the Dall's porpoise, the available data suggest that a ≥170 dB re 1 μPa_{rms} disturbance criterion (rather than ≥160 dB) would be appropriate. With a medium to large air source array, received levels typically diminish to 170 dB within 1 to 4 km, whereas levels typically remain above 160 dB out to 4 to 15 km (e.g., Tolstoy et al. 2009). Reaction distances for delphinids are more consistent with the typical 170 dB re 1 μPa_{rms} distances. The 160 dB (rms) criterion currently applied by NMFS was based primarily on data from grey and bowhead whales. Avoidance distances for delphinids and Dall's porpoises tend to be less than for those two mysticete species. For delphinids and Dall's porpoises, there is no indication of strong avoidance or other disruption of behaviour at distances beyond those where received levels would be ~170 dB re 1 μPa_{rms} (on the order of 2 or 3 km for a large air source array).

<u>Pinnipeds</u>

Few studies of the reactions of pinnipeds to noise from open-water seismic exploration have been published (for review of the early literature, see Richardson et al. 1995). However, pinnipeds have been observed during a number of seismic monitoring studies. Monitoring in the Beaufort Sea during 1996 to 2002 provided a substantial amount of information on avoidance responses (or lack of) and associated behaviour. Additional monitoring of that type has been done in the Beaufort and Chukchi seas in 2006 to 2010. Pinnipeds exposed to air source sounds have also been observed during seismic surveys along the U.S. west coast. Some limited data are available on physiological responses of pinnipeds exposed to seismic sound, as studied with the aid of radio telemetry. Also, there are data on the reactions of pinnipeds to various other related types of impulsive sounds.

Early observations provided considerable evidence that pinnipeds are often quite tolerant of strong pulsed sounds. During seismic exploration off Nova Scotia, grey seals exposed to noise from air sources and linear explosive charges reportedly did not react strongly (J. Parsons *in* Greene et al. 1985). An air source caused an initial startle reaction among South African fur seals but was ineffective in scaring them away from fishing gear (Anonymous 1975). Pinnipeds in both water and air sometimes tolerate strong noise pulses from non-explosive and explosive scaring devices, especially if attracted to the area for feeding or reproduction (Mate and Harvey 1987; Reeves et al. 1996). Thus, pinnipeds are expected to be either tolerant of or able to habituate to repeated underwater sounds from distant seismic sources, at least when the animals are strongly attracted to the area.

In the U.K., a radio-telemetry study demonstrated short-term changes in the behaviour of harbour and grey seals exposed to air source pulses (Thompson et al. 1998). Harbour seals were exposed to seismic pulses from a 90 in^3 array (3 × 30 in^3 air sources), and behavioural responses differed among individuals. One harbour seal avoided the array at distances up to 2.5 km from the source and only resumed foraging dives after seismic stopped. Another harbour seal exposed to the same small air source array showed no detectable behavioural response, even when the array was within 500 m. Grey seals exposed to a single 10 in^3 air source showed an avoidance reaction. They moved away from the source, increased swim speed and/or dive duration, and switched from foraging dives to predominantly transit dives. These effects appeared to be short-term as grey seals either remained in, or returned at least once to, the foraging area where they had been exposed to seismic pulses. These results suggest that there are interspecific as well as individual differences in seal responses to seismic sounds.

Off California, visual observations from a seismic vessel showed that California sea lions “typically ignored the vessel and array. When [they] displayed behaviour modifications, they often appeared to be reacting visually to the sight of the towed array. At times, California sea lions were attracted to the array, even when it was on. At other times, these animals would appear to be actively avoiding the vessel and array” (Arnold 1996). In Puget Sound, sighting distances for harbour seals and California sea lions tended to be greater when air sources were operating; both species tended to orient away whether or not the air sources were firing (Calambokidis and Osmek 1998). Bain and Williams (2006) also observed that their small sample of harbour seals and sea lions tended to orient and/or move away upon exposure to sounds from a large air source array.

Monitoring work in the Alaskan Beaufort Sea during 1996 to 2001 provided considerable information regarding the behaviour of seals exposed to seismic pulses (Harris et al. 2001; Moulton and Lawson 2002). Those seismic projects usually involved arrays of 6 to 16 air sources with total volumes 560 to 1,500 in^3. Subsequent monitoring work in the Canadian Beaufort Sea in 2001 to 2002, with a somewhat larger air source system (24 air sources, 2,250 in^3), provided similar results (Miller et al. 2005).

The combined results suggest that some seals avoid the immediate area around seismic vessels. In most survey years, ringed seal sightings were, on average, farther away from the seismic vessel when the air sources were operating than when they were not (Moulton and Lawson 2002). Also, seal sighting rates at the water surface were lower during air source array operations than during no- air source periods in each survey year except 1997. However, the avoidance movements were relatively small, on the order of 100 m to (at most) a few hundreds of metres, with many seals remaining within 100 to 200 m of the trackline as the operating air source array passed by.

The operation of the air source array had minor and variable effects on the behaviour of seals visible at the surface within a few hundred metres of the air source (Moulton and Lawson 2002). The behavioural data indicated that some seals were more likely to swim away from the source vessel during periods of air source operations and more likely to swim towards or parallel to the vessel during non-seismic periods. No consistent relationship was observed between exposure to air source noise and proportions of seals engaged in other recognizable behaviours, e.g., "looked" and "dove". Such a relationship might have occurred if seals seek to reduce exposure to strong seismic pulses, given the reduced air source noise levels close to the surface where "looking" occurs (Moulton and Lawson 2002).

Monitoring results from the Canadian Beaufort Sea during 2001 to 2002 were more variable (Miller et al. 2005). During 2001, sighting rates of seals (mostly ringed seals) were similar during all seismic states, including periods without air source operations. However, seals tended to be seen closer to the vessel during non-seismic than during seismic periods. In contrast, during 2002, sighting rates of seals were higher during non-seismic periods than during seismic operations, and seals were seen farther from the vessel during non-seismic compared to seismic activity (a marginally significant result). The combined data for both years showed that sighting rates were higher during non-seismic periods compared to seismic periods, and that sighting distances were similar during both seismic states. Miller et al. (2005) concluded that seals showed very limited avoidance to the operating air source array.

Vessel-based monitoring also took place in the Alaskan Chukchi and Beaufort seas from 2006 to 2008 (Funk et al. 2010). In the Chukchi Sea, seal sightings rates were greater from non-seismic monitoring than source vessels at locations with received sound levels ≥160 and 159-120 dB rms, and sighting rates were greater from source than monitoring vessels at locations with received sound levels were <120 dB rms (Haley et al. 2010). In the Beaufort Sea, sighting rates for seals exposed to received sound levels ≥160 dB rms were also significantly higher from monitoring than from seismic source vessels, and sighting rates were significantly higher from source vessels in areas exposed to <120 compared to ≥160 dB rms (Savarese et al. 2010). In addition, seals tended to stay farther away and swam away from source vessels more frequently than from monitoring vessels when received sound levels were ≥160 dB rms. These observations are indicative of a tendency for phocid seals to exhibit localized avoidance of the seismic source vessel when air sources are firing (Funk et al. 2010). Over the three years, seal sightings rates were greater from monitoring than source vessels at locations with received sound levels ≥160 and 159-120 dB rms, whereas seal sighting rates were greater from source than monitoring vessels at locations with received sound levels were <120 dB rms, suggesting that seals may be reacting to active air sources by moving away from the source vessel.

Conclusions

Visual monitoring from seismic vessels has shown only slight (if any) avoidance of air sources by pinnipeds, and only slight (if any) changes in behaviour. These studies show that many pinnipeds do not avoid the area within a few hundred metres of an operating air source array. However, based on the studies with large sample size, observations from a separate monitoring vessel, or radio telemetry, it is apparent that some phocid seals do show localized avoidance of operating air sources. The limited nature of this tendency for avoidance is a concern. It suggests that one cannot rely on pinnipeds to move away, or to move very far away, before received levels of sound from an approaching seismic survey vessel approach those that may cause hearing impairment.

Sea Turtles

There have been few studies of the effects of air source noise (or indeed any type of noise) on sea turtles, and little is known about the sound levels that will elicit various types of behavioural reactions. There have been four directed studies that focused on short-term behavioural responses of sea turtles in enclosures to single air sources. However, comparisons of results among studies are difficult because experimental designs and reporting procedures have varied greatly, and only one of the studies provided specific information about the levels of the air source pulses received by the turtles. Although monitoring studies are now providing some information on responses (or lack of) of free-ranging sea turtles to seismic surveys are now being reported, HMDC is not aware of any directed studies on responses of free-ranging sea turtles to seismic sounds or on the long-term effects of exposure of sea turtles to seismic or other sounds.

The most recent of the studies of caged sea turtles exposed to air source pulses was a study by McCauley et al. (2000a, b) off Western Australia. This is apparently the only such study in which received sound levels were estimated carefully. The authors exposed caged green and loggerhead sea turtles (one of each) to pulses from an approaching and then receding 20 in^3 air source operating at 1,500 psi and 5 m air source depth. The single air source fired every 10 s. There were two trials separated by two days; the first trial involved ~2 h of air source exposure and the second ~1 h. The results from the two trials showed that, above a received level of 166 dB re 1 μPa (rms), the turtles noticeably increased their swim speed relative to periods when no air sources were operating. The behaviour of the sea turtles became more erratic when received levels exceeded 175 dB re 1 μPa rms. The authors suggested that the erratic behaviour exhibited by the caged sea turtles would likely, in unrestrained turtles, be expressed as an avoidance response (McCauley et al. 2000a, b).

O'Hara and Wilcox (1990) tested the reactions to air sources by loggerhead sea turtles held in a 300 x 45 m area of a canal in Florida with a bottom depth of 10 m. Nine turtles were tested at different times. The sound source consisted of one 10 in^3 air source plus two 0.8 in^3 "poppers" operating at 2,000 psi [3] and air source depth of 2 m for prolonged periods of 20 to 36 hours in duration. The turtles maintained a standoff range of about 30 m when exposed to air source pulses every 15 s or every 7.5 s. It was also possible that some turtles remained on the bottom of the enclosure when exposed to air source pulses. O'Hara and Wilcox (1990) did not measure the received air source sound levels. McCauley et al. (2000a, b) estimated that "the level at which O'Hara saw avoidance was around 175 to 176 dB re 1 μPa rms." The levels received by the turtles in the Florida study probably were actually a few dB less than 175 to 176 dB because the calculations by McCauley et al. (2000a, b) apparently did not allow for the

[3] There was no significant reaction by five turtles during an initial series of tests with the airguns operating at the unusually low pressure of 1,000 psi. The source and received levels of airgun sounds would have been substantially lower when the air pressure was only 1,000 psi than when it was at the more typical operating pressure of 2,000 psi.

shallow 2 m air source depth in the Florida study. The effective source level of air source is less when they are near 2 m depth than at 5 m (Greene et al. 2000).

Moein et al. (1994) investigated the avoidance behaviour and physiological responses of loggerhead turtles exposed to an operating air source, as well as the effects on their hearing as summarized earlier. The turtles were held in a netted enclosure ~18 m by 61 m by 3.6 m deep, with an air source of unspecified size at each end. Only one air source was operated at any one time; the firing rate was one shot every 5 to 6 s. Ten turtles were tested individually, and seven of these were retested several days later. The air source was initially discharged when the turtles were near the center of the enclosure and the subsequent movements of the turtles were documented. The turtles exhibited avoidance during the first presentation of air source sounds at a mean range of 24 m, but the avoidance response waned quickly. Additional trials conducted on the same turtles several days later did not show statistically significant avoidance reactions. However, there was an indication of slight initial avoidance followed by rapid waning of the avoidance response which the authors described as “habituation.” Their auditory study indicated that exposure to the air source pulses may have resulted in TTS (discussed earlier). Reduced hearing sensitivity may also have contributed to the waning response upon continued exposure. Based on physiological measurements, there was some evidence of increased stress in the sea turtles, but this stress could also have resulted from handling of the turtles.

Inconsistencies in reporting procedures and experimental design prevent direct comparison of this study with either McCauley et al. (2000a, b) or O’Hara and Wilcox (1990). Moein et al. (1994) stated, without further details, that “three different decibel levels (175, 177, 179) were utilised” during each test. These sound levels probably are received levels in dB re 1 μPa, and probably relate to the initial exposure distance (mean 24 m), but these details were not specified. Also, it was not specified whether these values were measured or estimated, or whether they are expressed in peak-peak, peak, rms, SEL, or some other units. Given the shallow water in the enclosure (3.6 m), any estimates based on simple assumptions about propagation would be suspect.

Despite the problems in comparing these studies, there is a consistent trend showing that, at some received level, sea turtles show avoidance of an operating air source. Lenhardt (2002) reported behavioural responses to Bolt 600 air sources at received levels of 151 to 161 dB SPL re 1 μm, and initial avoidance responses at received levels near 175 dB. McCauley et al. (2000a, b) found evidence of behavioural responses when the received level from a single small air source was 166 dB re 1 μPa rms, and avoidance responses at 175 dB re 1 μPa rms. Based on these data, McCauley et al. (2000a,b) estimated that, for a typical air source array (2,678 in^3, 12 elements) operating in 100 to 120 m water depth, sea turtles may exhibit behavioural changes at approximately 2 km and avoidance around 1 km. These estimates are subject to great variation, depending on the seismic source and local propagation conditions.

A further potential complication is that sea turtles on or near the bottom may receive sediment-borne “headwave” signals from the air sources (McCauley et al. 2000a, b). As previously discussed, it is believed that sea turtles use bone conduction to hear. It is unknown how sea turtles might respond to the headwave component of an air source impulse, or to bottom vibrations.

Two studies involving stimuli other than air sources may also be relevant:

1. Two loggerhead turtles resting on the bottom of shallow tanks responded repeatedly to low-frequency (20 to 80 Hz) tones by becoming active and swimming to the surface. They remained at the surface or only slightly submerged for the remainder of the 1 min trial (Lenhardt 1994). Although no detailed data on sound levels at the bottom vs. surface were reported, the surfacing response probably reduced the levels of underwater sound to which the turtles were exposed.

2. In a separate study, a loggerhead and a Kemp's Ridley sea turtle responded similarly when 1 s vibratory stimuli at 250 or 500 Hz were applied to the head for 1 s (Lenhardt et al. 1983). There appeared to be rapid habituation to these vibratory stimuli.

The tones and vibratory stimuli used in these studies were quite different from air source pulses. However, it is possible that resting sea turtles may exhibit a similar "alarm" response, possibly including surfacing or alternatively diving, when exposed to any audible noise, regardless of whether it is a pulsed sound or tone.

Data on sea turtle behaviour near air source operations have also been collected during marine mammal and sea turtle monitoring and mitigation programs associated with various seismic operations around the world. Results suggest it is likely that sea turtles will exhibit behavioural changes and/or avoidance within an area of unknown size near a seismic vessel. During six large-source (10 to 20 air sources; 3,050 to 8,760 in^3) and small-source (up to six air sources or three GI guns; 75 to 1,350 in^3) surveys conducted by L-DEO during 2003 to 2005, the mean closest point of approach (CPA) for turtles was less during non-seismic than seismic periods: 139 m vs. 228 m and 120 m vs. 285 m, respectively (Holst et al. 2006). During one of these surveys an observer sighted an olive Ridley sea turtle (*Lepidochelys olivacea*) which appeared at the surface within the 190 dB re 1 µPa isopleth while the 10 air source array was operating (Holst et al. 2005a). The turtle was "logging sedately" at the surface for a period, during which it floated within about 10 m of the array and then swam away. Based on the observed behaviour, it was surmised that the turtle was agitated by its exposure to the sound source (Holst et al. 2005a). During a seismic survey off the Pacific coast of Central America, the turtle sighting rate during non-seismic periods was seven times greater than that during seismic periods (Holst and Smultea 2008). In addition, turtles were seen significantly farther from the air source array when it was operating (mean 159 m, n=77) than when the air sources were off (mean 188 m, n=69; Mann-Whitney U test, $P<0.001$) (Holst and Smultea 2008). During another survey in the eastern Tropical Pacific, the turtle sighting rate during non-seismic was 1.5 times greater than that during seismic periods; however, turtles tended to be seen closer to the air source array when it was operating (Hauser et al. 2008).

Weir (2007) reported on the behaviour of sea turtles near seismic exploration operations off Angola, West Africa. A total of 240 sea turtles were seen during 676 h of associated marine mammal mitigation and monitoring observations. Alternating air source arrays with total volumes 5,085 and 3,147 in^3 were used during the seismic program. Sea turtles were seen closer to the seismic source and sighting rates were twice as high during non-seismic vs. seismic periods (Weir 2007). However, there was no significant difference in the median distance of turtle sightings from the array during non-seismic vs. seismic periods (means of 743 m [*n*=112] and 779 m [*n*=57]). Off northeastern Brazil, 46 sea turtles were seen during 2,028 h of marine mammal mitigation and monitoring of seismic exploration using 4 to 8 GI air sources; no evidence of adverse impacts on sea turtles from seismic operations was apparent (Parente et al. 2006b). A recent paper by DeRuiter and Doukara (2012) reports observations of loggerhead turtles during a seismic survey in the Mediterranean Sea in 2009. Over 50% of the turtles being visually tracked dove at or before their closest point of approach to the air source arrays. DeRuiter and Doukara (2012) suggested that this diving behavior might be an avoidance response to the air source sound.

The paucity of data precludes specific predictions as to how free-ranging sea turtles respond to seismic sounds. The possible responses could include one or more of the following: (1) avoidance of the entire seismic survey area to the extent that the turtles move to less preferred habitat; (2) avoidance of only the immediate area around the active seismic vessel, i.e., local avoidance of the source vessel but remain in the general area; and/or (3) no appreciable avoidance, although short-term behavioural reactions are likely.

The potential alteration of a migration route might have negative impacts. However, it is not known whether the alteration would ever be on a sufficient geographic scale, or be sufficiently prolonged, to prevent turtles from reaching an important destination.

Avoidance of a preferred foraging area because of seismic survey noise may prevent sea turtles from obtaining preferred prey species and hence could impact their nutritional status. However, it is highly unlikely that sea turtles would completely avoid a large area along a migration route. Available evidence suggests that the zone of avoidance around seismic sources is not likely to exceed a few kilometres (McCauley et al. 2000b). Avoidance reactions on that scale could prevent sea turtles from using an important coastal area or bay if there was a prolonged seismic operation in the area. Sea turtles might be excluded from the area for the duration of the seismic operation, or they might remain but exhibit abnormal behavioural patterns (e.g., lingering at the surface where received sound levels are lower). Whether those that were displaced would return quickly after the seismic operation ended is generally unknown. Again, this is not a likely possibility in the circumstances of the present project, since operations will be in offshore areas that are not known or expected to be preferred foraging habitat.

The results of experiments and monitoring studies on responses of marine mammals and fish to seismic surveys show that behavioural responses are possible, depending on species, time of year, activity of the animal, and other unknown factors. The same species may show different kinds of responses at different times of year or even on different days (Richardson et al. 1995). It is reasonable to expect similar variability in the case of sea turtles exposed to air source sounds. For example, sea turtles of different ages have very different sizes, behaviour, feeding habits, and preferred water depths. Nothing specific is known about the ways in which these factors may be related to air source sound effects on sea turtles. However, it is reasonable to expect lesser effects in young turtles concentrated near the surface (where levels of air source sounds are attenuated) as compared with older turtles that spend more time at depth where air source sounds are generally stronger.

Conclusions

Most studies on sea turtles have been conducted on species not common on the Grand Banks, in shallow water, enclosed areas and thus are not directly applicable to the Study Area. The limited available data indicate that sea turtles will hear air source sounds. Based on available data, it is likely that sea turtles will exhibit behavioural changes and/or avoidance within an area of unknown size near a seismic vessel. Sound from seismic operations in or near areas where turtles concentrate is likely to have the greatest effect. There are no specific data that demonstrate the consequences to sea turtles if seismic operations do occur in important areas at important times of year. The Study Area is not a breeding area for sea turtles and it is not known or thought to be an important feeding or migration area; thus, high concentrations of sea turtles are unlikely.

Hearing Impairment

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. Temporary threshold shift (TTS) has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed in Southall et al. 2007). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., permanent threshold shift (PTS), in free-ranging marine mammals exposed to sequences of air source pulses during realistic field conditions. Current National Marine Fisheries Service (NMFS) policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds ≥180 and 190 dB re 1 μPa_{rms}, respectively (NMFS 2000). Those criteria have been used in establishing the safety (=shut-down) radii planned for numerous seismic surveys conducted under U.S. jurisdiction. Those criteria have also been used in establishing the safety (=power-down) zones for seismic surveys in some parts of Canada. However, those criteria were established before there was any information about the minimum received levels of sounds necessary to cause TTS in marine mammals. The 180 dB criterion for cetaceans is probably conservative for at least some species including bottlenose dolphin and beluga, i.e., lower than necessary to avoid temporary auditory impairment let alone permanent auditory injury.

Recommendations for new science-based noise exposure criteria for marine mammals, frequency-weighting procedures, and related matters have been published (Southall et al. 2007). Those recommendations have not, as of 2011, been formally adopted by NMFS for use in regulatory processes and during mitigation programs associated with seismic surveys. However, some aspects of the recommendations have been taken into account in certain EAs and small-take authorizations, and NMFS is moving toward adoption of new procedures taking at least some of Southall et al. 2007 recommendations into account (Scholik-Schlomer 2012). Preliminary information about possible changes in the regulatory and mitigation requirements, and about the possible structure of new criteria, was given by Wieting (2004) and NMFS (2005).

Several aspects of the planned monitoring and mitigation measures for the proposed project are designed to detect marine mammals occurring near the air source array (i.e., MMOs), and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment. In addition, many cetaceans and (to a limited degree) pinnipeds show some avoidance of the area where received levels of air source sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves will reduce or (most likely) avoid the possibility of hearing impairment.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur include stress, neurological effects, bubble formation, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong pulsed sounds. The following sections summarize available data on noise-induced hearing impairment and non-auditory physical effects.

Temporary Threshold Shift (TTS)

TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. It is a temporary phenomenon, and (especially when mild) is not considered to represent physical damage or “injury” (Southall et al. 2007; Le Prell 2012). Rather, the onset of TTS is an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility.

The magnitude of TTS depends on the level and duration of noise exposure, and to some degree on frequency, among other considerations (Kryter 1985; Richardson et al. 1995; Southall et al. 2007). For sound exposures at or somewhat above the TTS threshold, hearing sensitivity recovers rapidly after exposure to the noise ends. Extensive studies on terrestrial mammal hearing in air show that TTS can last from minutes or hours to (in cases of strong TTS) days. More limited data from odontocetes and pinnipeds show similar patterns (e.g., Mooney et al. 2009a, b; Finneran et al. 2010a). However, none of the published data concern TTS elicited by exposure to multiple pulses of sound during operational seismic surveys (Southall et al. 2007).

Toothed Whales

There are empirical data on the sound exposures that elicit onset of TTS in captive bottlenose dolphins, belugas, and finless porpoise. The majority of these data concern non-impulse sound, but there are some limited published data concerning TTS onset upon exposure to a single pulse of sound from a watergun (Finneran et al. 2002). A detailed review of all TTS data from marine mammals can be found in Southall et al. (2007). The following summarizes some of the key results on odontocetes.

Recent information corroborates earlier expectations that the effect of exposure to strong transient sounds is closely related to the total amount of acoustic energy that is received. Finneran et al. (2005) examined the effects of tone duration on TTS in bottlenose dolphins. Bottlenose dolphins were exposed to 3 kHz tones (non-impulsive) for periods of 1, 2, 4 or 8 s, with hearing tested at 4.5 kHz. For 1 s exposures, TTS occurred with SELs of 197 dB, and for exposures >1 s, SEL >195 dB resulted in TTS (SEL is equivalent to energy flux, in dB re 1 μPa2 · s). At an SEL of 195 dB, the mean TTS (4 min after exposure) was 2.8 dB. Finneran et al. (2005) suggested that an SEL of 195 dB is the likely threshold for the onset of TTS in dolphins and belugas exposed to tones of durations 1 to 8 s (i.e., TTS onset occurs at a near-constant SEL, independent of exposure duration). That implies that, at least for non-impulsive tones, a doubling of exposure time results in a 3 dB lower TTS threshold.

The assumption that, in marine mammals, the occurrence and magnitude of TTS is a function of cumulative acoustic energy (SEL) is probably an oversimplification (Finneran 2012). Kastak et al. (2005) reported preliminary evidence from pinnipeds that, for prolonged non-impulse noise, higher SELs were required to elicit a given TTS if exposure duration was short than if it was longer, i.e., the results were not fully consistent with an equal-energy model to predict TTS onset. Mooney et al. (2009a) showed this in a bottlenose dolphin exposed to octave-band non-impulse noise ranging from 4 to 8 kHz at SPLs of 130 to 178 dB re 1 μPa for periods of 1.88 to 30 min. Higher SELs were required to induce a given TTS if exposure duration was short than if it was longer. Exposure of the aforementioned bottlenose dolphin to a sequence of brief sonar signals showed that, with those brief (but non-impulse) sounds, the received energy (SEL) necessary to elicit TTS was higher than was the case with exposure to the more prolonged octave-band noise (Mooney et al. 2009b). Those authors concluded that, when using (non-impulse) acoustic signals of duration ~0.5 s, SEL must be at least 210 to 214 dB re 1 μPa2 · s to induce TTS in the bottlenose dolphin. Popov et al. (2011) examined the effects of fatiguing noise on the hearing threshold of Yangtze finless porpoises when exposed to frequencies of 32–128 kHz at 140 to 160 dB re 1 μPa for 1–30 min. They found that an exposure of higher level and shorter duration produced a higher TTS than an exposure of equal SEL but of lower level and longer duration.

On the other hand, the TTS threshold for odontocetes exposed to a single impulse from a watergun (Finneran et al. 2002) appeared to be somewhat lower than for exposure to non-impulse sound. This was expected, based on evidence from terrestrial mammals showing that broadband pulsed sounds with rapid rise times have greater auditory effect than do non-impulse sounds (Southall et al. 2007). The received energy level of a single seismic pulse that caused the onset of mild TTS in the beluga, as measured without frequency weighting, was ~186 dB re 1 µPa2 · s or 186 dB SEL (Finneran et al. 2002).[4] The rms level of an air source pulse (in dB re 1 μPa measured over the duration of the pulse) is typically 10 to 15 dB higher than the SEL for the same pulse when received within a few kilometres of the air sources. Thus, a single air source pulse might need to have a received level of ~196 to 201 dB re 1 µParms in order to produce brief, mild TTS. Exposure to several strong seismic pulses that each has a flat-weighted received level near 190 dBrms (175 to 180 dB SEL) could result in cumulative exposure of ~186 dB SEL (flat-weighted) or ~183 dB SEL (Mmf-weighted), and thus slight TTS in a small odontocete. That assumes that the TTS threshold upon exposure to multiple pulses is (to a first approximation) a function of the total received pulse energy, without allowance for any recovery between pulses. However, recent data have shown that the SEL required for TTS onset to occur increases with intermittent exposures, with some auditory recovery during silent periods between signals (Finneran et al. 2010b; Finneran and Schlundt 2011). For example, Finneran et al. (2011) reported no

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[4] If the low-frequency components of the watergun sound used in the experiments of Finneran et al. (2002) are downweighted as recommended by Miller et al. (2005) and Southall et al. (2007) using their M_{mf}-weighting curve, the effective exposure level for onset of mild TTS was 183 dB re 1 μPa^2 · s (Southall et al. 2007).

measurable TTS in bottlenose dolphins after exposure to 10 impulses from a seismic air source with a cumulative SEL of ~195 dB re 1 μPa2 · s.

The conclusion that TTS threshold is higher for non-impulse sound than for impulse sound is somewhat speculative. The available TTS data for a beluga exposed to impulse sound are extremely limited, and the TTS data from the beluga and bottlenose dolphin exposed to non-pulse sound pertain to sounds at 3 kHz and above. Follow-on work has shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012).

The above TTS information for odontocetes is derived from studies on the bottlenose dolphin and beluga. For the one harbour porpoise tested, the received sound level of air source sound that elicited onset of TTS was lower. The animal was exposed to single pulses from a small (20 in^3) air source, and auditory evoked potential methods were used to test the animal's hearing sensitivity at frequencies of 4, 32, or 100 kHz after each exposure (Lucke et al. 2009). Based on the measurements at 4 kHz, TTS occurred upon exposure to one air source pulse with received level ~200 dB re 1 μPapk-pk or an SEL of 164.3 dB re 1 μPa2 · s. If these results from a single animal are representative, it is inappropriate to assume that onset of TTS occurs at similar received levels in all odontocetes (cf. Southall et al. 2007). Some cetaceans apparently can incur TTS at considerably lower sound exposures than are necessary to elicit TTS in the beluga or bottlenose dolphin.

Insofar as we are aware, there are no published data confirming that the auditory effect of a sequence of air source pulses received by an odontocete is a function of their cumulative energy. Southall et al. (2007) consider that to be a reasonable, but probably somewhat precautionary, assumption. It is precautionary because, based on data from terrestrial mammals, one would expect that a given energy exposure would have somewhat less effect if separated into discrete pulses, with potential opportunity for partial auditory recovery between pulses. However, as yet there has been little study of the rate of recovery from TTS in marine mammals, and in humans and other terrestrial mammals the available data on recovery are quite variable. Southall et al. (2007) concluded that—until relevant data on recovery are available from marine mammals—it is appropriate not to allow for any assumed recovery during the intervals between pulses within a pulse sequence.

Additional data are needed to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of air source sound with variable received levels. To determine how close an air source array would need to approach in order to elicit TTS, one would (as a minimum) need to allow for the sequence of distances at which air source shots would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Erbe and King 2009; Breitzke and Bohlen 2010; Laws 2012). At the present state of knowledge, it is also necessary to assume that the effect is directly related to total received energy even though that energy is received in multiple pulses separated by gaps. The lack of data on the exposure levels necessary to cause TTS in toothed whales when the signal is a series of pulsed sounds, separated by silent periods, remains a data gap, as is the lack of published data on TTS in odontocetes other than the beluga, bottlenose dolphin, and harbour porpoise.

Baleen Whales

There are no data, direct or indirect, on levels or properties of sound that are required to induce TTS in any baleen whale. The frequencies to which mysticetes are most sensitive are assumed to be lower than those to which odontocetes are most sensitive, and natural background noise levels at those low frequencies tend to be higher. As a result, auditory thresholds of baleen whales within their frequency band of best hearing are believed to be higher (less sensitive) than are those of odontocetes at their best frequencies (Clark and Ellison 2004). From this, it is suspected that received levels causing TTS onset may also be higher in mysticetes (Southall et al. 2007). However, based on preliminary simulation modeling that attempted to allow for various uncertainties in assumptions and variability around population means, Gedamke et al. (2011) suggested that some baleen whales whose closest point of approach to a seismic vessel is 1 km or more could experience TTS.

In practice during seismic surveys, few if any cases of TTS are expected given the strong likelihood that baleen whales would avoid the approaching air sources (or vessel) before being exposed to levels high enough for there to be any possibility of TTS (see above for evidence concerning avoidance responses by baleen whales). This assumes that the ramp-up (soft-start) procedure is used when commencing air source operations, to give whales near the vessel the opportunity to move away before they are exposed to sound levels that might be strong enough to elicit TTS. As discussed earlier, results from numerous studies indicate that many baleen whales; particularly bowhead, grey, humpback, and blue whales are likely to move away from the source vessel during the initial stages of a ramp-up.

Pinnipeds

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Two California sea lions did not incur TTS when exposed to single brief pulses with received levels of ~178 and 183 dB re 1 μPa_{rms} and total energy fluxes of 161 and 163 dB re 1 $\mu Pa^2 \cdot s$ (Finneran et al. 2003). However, initial evidence from more prolonged (non-pulse and pulse) exposures suggested that some pinnipeds (harbour seals in particular) incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999, 2005; Ketten et al. 2001; Kastelein et al. 2011). Kastak et al. (2005) reported that the amount of threshold shift increased with increasing SEL in a California sea lion and harbour seal. They noted that, for non-impulse sound, doubling the exposure duration from 25 to 50 min (i.e., a +3 dB change in SEL) had a greater effect on TTS than an increase of 15 dB (95 vs. 80 dB) in exposure level. Mean threshold shifts ranged from 2.9 to 12.2 dB, with full recovery within 24 h (Kastak et al. 2005). Kastak et al. (2005) suggested that, for non-impulse sound, SELs resulting in TTS onset in three species of pinnipeds may range from 183 to 206 dB re 1 $\mu Pa^2 \cdot s$, depending on the absolute hearing sensitivity.

As noted above for odontocetes, it is expected that—for impulse as opposed to non-impulse sound—the onset of TTS would occur at a lower cumulative SEL given the assumed greater auditory effect of broadband impulses with rapid rise times. The threshold for onset of mild TTS upon exposure of a harbour seal to impulse sounds has been estimated indirectly as being an SEL of ~171 dB re 1 $\mu Pa^2 \cdot s$ (Southall et al. 2007). That would be approximately equivalent to a single pulse with received level ~181 to 186 dB re 1 μPa_{rms}, or a series of pulses for which the highest rms values are a few dB lower.

At least for non-impulse sounds, TTS onset occurs at appreciably higher received levels in California sea lions and northern elephant seals than in harbour seals (Kastak et al. 2005). Thus, the former two species would presumably need to be closer to an air source array than would a harbour seal before TTS is a possibility. Insofar as we are aware, there are no data to indicate whether the TTS thresholds of other pinniped species are more similar to those of the harbour seal or to those of the two less-sensitive species.

Sea Turtles

Few studies have directly investigated hearing or noise-induced hearing loss in sea turtles. Moein et al. (1994) studied the effect of sound pulses from a single air source of unspecified size on loggerhead sea turtles. Apparent TTS was observed after exposure to a few hundred air source pulses at distances no more than 65 m. The hearing capabilities had returned to "normal" when the turtles were re-tested two weeks later. Similarly, Lenhardt (2002) exposed loggerhead turtles in a large net enclosure to air source pulses. They noted TTS of >15 dB in one loggerhead turtle, with recovery occurring in two weeks. Turtles in the open sea might have moved away from an air source operating at a fixed location, and in the more typical case of a towed air source or air source array, very few shots would occur at or around one location. Thus, exposure to underwater sound during net-enclosure experiments was not typical of that expected during an operational seismic survey.

Studies with terrestrial reptiles have also demonstrated that exposure to impulse noise can cause hearing loss. For example, desert tortoises (*Gopherus agassizii*) exhibited TTS after exposure to repeated high-intensity sonic booms (Bowles et al. 1999). Recovery from these temporary hearing losses was usually rapid (<1 h), which suggested that tortoises can tolerate these exposures without permanent injury (Bowles et al. 1999). However, there are no data to indicate whether or not there are any plausible situations in which exposure to repeated air source pulses at close range could cause permanent hearing impairment in sea turtles.

Turtles in the area of seismic operations prior to start-up may not have time to move out of the area even if standard ramp-up (i.e., soft-start) procedures are in effect. It has been proposed that sea turtles require a longer ramp-up period because of their relatively slow swimming speeds (Eckert 2000). However, it is unclear at what distance from a seismic source sea turtles will sustain hearing impairment, and whether there would ever be a possibility of exposure to sufficiently high levels for a sufficiently long period to cause irreversible hearing damage.

Likelihood of Incurring TTS

A marine mammal within a radius of ≤100 m around a typical array of operating air sources might be exposed to a few seismic pulses with levels of ≥205 dB, and possibly more pulses if the mammal moved with the seismic vessel.

Most cetaceans show some degree of avoidance of seismic vessels operating an air source array (see above). It is unlikely that these cetaceans would be exposed to air source pulses at a sufficiently high level for a sufficiently long period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal. TTS would be more likely in any odontocetes that bow- or wake-ride or otherwise linger near the air sources. However, while bow- or wake-riding, odontocetes would be at the surface and thus not exposed to strong sound pulses given the pressure-release and Lloyd Mirror effects at the surface. But if bow- or wake-riding animals were to dive intermittently near air sources, they would be exposed to strong sound pulses, possibly repeatedly.

If some cetaceans did incur mild or moderate TTS through exposure to air source sounds in this manner, this would very likely be a temporary and reversible phenomenon. However, even a temporary reduction in hearing sensitivity could be deleterious in the event that, during that period of reduced sensitivity, a marine mammal needed its full hearing sensitivity to detect approaching predators, or for some other reason.

Some pinnipeds show avoidance reactions to air sources, but their avoidance reactions are generally not as strong or consistent as those of cetaceans. Pinnipeds occasionally seem to be attracted to operating seismic vessels. There are no specific data on TTS thresholds of pinnipeds exposed to single or multiple low-frequency pulses. However, given the indirect indications of a lower TTS threshold for the harbour seal than for odontocetes exposed to impulse sound (see above), it is possible that some pinnipeds close to a large air source array could incur TTS.

NMFS (1995, 2000) concluded that cetaceans should not be exposed to pulsed underwater noise at received levels >180 dB re 1 μPa_{rms}. The corresponding limit for pinnipeds has been set by NMFS at 190 dB, although the HESS Team (HESS 1999) recommended a 180 dB limit for pinnipeds in California. The 180 and 190 dB re 1 μPa_{rms} levels have not been considered to be the levels above which TTS might occur. Rather, they were the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As summarized above, data that are now available imply that TTS is unlikely to occur in various odontocetes (and probably mysticetes as well) unless they are exposed to a sequence of several air source pulses in which the strongest pulse has a received level substantially exceeding 190 dB re 1 μPa_{rms}. On the other hand, for the harbour seal, harbour porpoise, and perhaps some other species, TTS may occur upon exposure to one or more air source pulses whose received level equals the NMFS "do not exceed" value of 190 dB re 1 μPa_{rms}. That criterion corresponds to a single pulse with a SEL of 175 to 180 dB re 1 $\mu Pa^2 \cdot s$ in typical conditions, whereas TTS is suspected to be possible in harbour seals and harbour porpoises with a cumulative SEL of ~171 and ~164 dB re 1 $\mu Pa^2 \cdot s$, respectively.

It has been shown that most large whales and many smaller odontocetes (especially the harbour porpoise) show at least localized avoidance of ships and/or seismic operations (see above). Even when avoidance is limited to the area within a few hundred metres of an air source array, that should usually be sufficient to avoid the possibility of TTS based on what is currently known about thresholds for TTS onset in cetaceans. In addition, ramping up air source arrays, which is standard operational protocol for many seismic operators, should allow cetaceans near the air sources at the time of startup to move away from the seismic source and to avoid being exposed to the full acoustic output of the air source array (see above). Thus, most baleen whales likely will not be exposed to high levels of air source sounds provided the ramp-up procedure is applied. Likewise, many odontocetes close to the trackline are likely to move away before the sounds from an approaching seismic vessel become sufficiently strong for there to be any potential for TTS or other hearing impairment. Therefore, there is little potential for baleen whales or odontocetes that show avoidance of ships or air sources to be close enough to an air source array to experience TTS. In the event that a few individual cetaceans did incur TTS through exposure to strong air source sounds, this is a temporary and reversible phenomenon unless the exposure exceeds the TTS-onset threshold by a sufficient amount for PTS to be incurred (see below). If TTS but not PTS were incurred, it would most likely be mild, in which case recovery is expected to be quick (probably within minutes).

There have been few studies that have directly investigated hearing or noise-induced hearing loss in sea turtles. The apparent occurrence of TTS in loggerhead turtles exposed too many pulses from a single air source ≤65 m away (Moein et al. 1994) suggests that sounds from an air source array could cause at least temporary hearing impairment in sea turtles if they do not avoid the (unknown) radius where TTS occurs. There is also the possibility of permanent hearing damage to turtles close to the air sources. However, there are few data on temporary hearing loss and no data on permanent hearing loss in sea turtles exposed to air source pulses.

Permanent Threshold Shift (PTS)

When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, whereas in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges (Kryter 1985). Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if they have very short rise times. [Rise time is the interval required for sound pressure to increase from the baseline pressure to peak pressure.]

There is no specific evidence that exposure to pulses of air source sound can cause PTS in any marine mammal or sea turtle, even with large arrays of air sources. However, given the likelihood that some animals close to an air source array might incur at least mild TTS (see above), there has been further speculation about the possibility that some individuals occurring very close to air sources might incur PTS (e.g., Richardson et al. 1995, p. 372*ff*; Gedamke et al. 2011). Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS. In terrestrial animals, exposure to sounds sufficiently strong to elicit a large TTS induces physiological and structural changes in the inner ear, and at some high level of sound exposure, these phenomena become non-recoverable (Le Prell 2012). At this level of sound exposure, TTS grades into PTS.

Relationships between TTS and PTS thresholds have not been studied in marine mammals, but are assumed to be similar to those in humans and other terrestrial mammals (Southall et al. 2007). Based on data from terrestrial mammals, a precautionary assumption is that the PTS threshold for impulse sounds (such as air source pulses as received close to the source) is at least 6 dB higher than the TTS threshold on a peak-pressure basis, and probably >6 dB higher (Southall et al. 2007). The low-to-moderate levels of TTS that have been induced in captive odontocetes and pinnipeds during controlled studies of TTS have been confirmed to be temporary, with no measurable residual PTS (Kastak et al. 1999; Schlundt et al. 2000; Finneran et al. 2002, 2005; Nachtigall et al. 2003, 2004). However, very prolonged exposure to sound strong enough to elicit TTS, or shorter-term exposure to sound levels well above the TTS threshold, can cause PTS, at least in terrestrial mammals (Kryter 1985). In terrestrial mammals, the received sound level from a single non-impulsive sound exposure must be far above the TTS threshold for any risk of permanent hearing damage (Kryter 1994; Richardson et al. 1995; Southall et al. 2007). However, there is special concern about strong sounds whose pulses have very rapid rise times. In terrestrial mammals, there are situations when pulses with rapid rise times (e.g., from explosions) can result in PTS even though their peak levels are only a few dB higher than the level causing slight TTS. The rise time of air source pulses is fast, but not as fast as that of an explosion.

Some factors that contribute to onset of PTS, at least in terrestrial mammals, are as follows:

- Exposure to single very intense sound;
- Fast rise time from baseline to peak pressure;
- Repetitive exposure to intense sounds that individually cause TTS but not PTS; and
- Recurrent ear infections or (in captive animals) exposure to certain drugs.

Cavanagh (2000) reviewed the thresholds used to define TTS and PTS. Based on this review and SACLANT (1998), it is reasonable to assume that PTS might occur at a received sound level 20 dB or more above that inducing mild TTS. However, for PTS to occur at a received level only 20 dB above the TTS threshold, the animal probably would have to be exposed to a strong sound for an extended period, or to a strong sound with rather rapid rise time.

More recently, Southall et al. (2007) estimated that received levels would need to exceed the TTS threshold by at least 15 dB, on an SEL basis, for there to be risk of PTS. Thus, for cetaceans exposed to a sequence of sound pulses, they estimate that the PTS threshold might be an M-weighted SEL (for the sequence of received pulses) of ~198 dB re 1 $\mu Pa^2 \cdot s$ (15 dB higher than the M_{mf}-weighted TTS threshold, in a beluga, for a watergun impulse). Additional assumptions had to be made to derive a corresponding estimate for pinnipeds, as the only available data on TTS-thresholds in pinnipeds pertain to non-impulse sound (see above). Southall et al. (2007) estimated that the PTS threshold could be a cumulative M_{pw}-weighted SEL of ~186 dB re 1 $\mu Pa^2 \cdot s$ in the case of a harbour seal exposed to impulse sound. The PTS threshold for the California sea lion and northern elephant seal would probably be higher given the higher TTS thresholds in those species. Southall et al. (2007) also note that, regardless of the SEL, there is concern about the possibility of PTS if a cetacean or pinniped received one or more pulses with peak pressure exceeding 230 or 218 dB re 1 μPa, respectively. Thus, PTS might be expected upon exposure of cetaceans to either SEL ≥198 dB re 1 $\mu Pa^2 \cdot s$ or peak pressure ≥230 dB re 1 μPa. Corresponding proposed dual criteria for pinnipeds (at least harbour seals) are ≥186 dB SEL and ≥ 218 dB peak pressure (Southall et al. 2007).

These estimates are all first approximations, given the limited underlying data, numerous assumptions, and species differences. Also, data have been published subsequent to Southall et al. (2007) indicating that, at least for non-pulse sounds, the "equal energy" model is not be entirely correct ―TTS and presumably PTS thresholds may depend somewhat on the duration over which sound energy is accumulated, the frequency of the sound, whether or not there are gaps, and probably other factors (Ketten 1994). PTS effects may also be influenced strongly by the health of the receiver's ear.

As described above for TTS, to estimate the amount of sound energy required for onset of TTS (and PTS), it is assumed that the auditory effect of a given cumulative SEL from a series of pulses is the same as if that amount of sound energy were received as a single strong sound. There are no data from marine mammals concerning the occurrence or magnitude of a potential partial recovery effect between pulses. In deriving the estimates of PTS (and TTS) thresholds quoted here, Southall et al. (2007) made the precautionary assumption that no recovery would occur between pulses.

The TTS section (above) concludes that exposure to several strong seismic pulses that each have flat-weighted received levels near 190 dB re 1 μPa_{rms} (175 to 180 dB re 1 $\mu Pa^2 \cdot s$ SEL) could result in cumulative exposure of ~186 dB SEL (flat-weighted) or ~183 dB SEL (M_{mf}-weighted), and thus slight TTS in a small odontocete. Allowing for the assumed 15 dB offset, expressed on an SEL basis, between PTS and TTS thresholds, exposure to several strong seismic pulses that each have flat-weighted received levels near 205 dB_{rms} (190 to 195 dB SEL) could result in cumulative exposure of ~198 dB SEL (M_{mf}-weighted), and thus slight PTS in a small odontocete. However, the levels of successive pulses that will be received by a marine mammal that is below the surface as a seismic vessel approaches, passes and moves away will tend to increase gradually and then decrease gradually, with periodic decreases superimposed on this pattern when the animal comes to the surface to breathe. To estimate how close an odontocete's CPA distance would have to be for the cumulative SEL to exceed 198 dB SEL (M_{mf}-weighted), one would (as a minimum) need to allow for the sequence of distances at which air source shots would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Erbe and King 2009).

It is unlikely that an odontocete would remain close enough to a large air source array long enough to incur PTS. There is some concern about bow-riding odontocetes, but for animals at or near the surface, auditory effects are reduced by Lloyd's mirror and surface release effects. The presence of the vessel between the air source array and bow-riding odontocetes could also, in some but probably not all cases reduce the levels received by bow-riding animals (e.g., Gabriele and Kipple 2009). The TTS (and thus PTS) thresholds of baleen whales are unknown but, as an interim measure, assumed to be no lower than those of odontocetes. Also, baleen whales generally avoid the immediate area around operating seismic vessels, so it is unlikely that a baleen whale could incur PTS from exposure to air source pulses. The TTS (and thus PTS) thresholds of some pinnipeds (e.g., harbour seal) as well as the harbour porpoise may be lower (Kastak et al. 2005; Southall et al. 2007; Lucke et al. 2009; Kastelein et al. 2011). If so, TTS and potentially PTS may extend to a somewhat greater distance for those animals. Again, Lloyd's mirror and surface release effects will ameliorate the effects for animals at or near the surface.

In theory, a reduction in hearing sensitivity, either temporary or permanent, may be harmful for sea turtles. However, very little is known about the role of sound perception in the sea turtle's normal activities. Hence, it is not possible to estimate how much of a problem it would be for a turtle to have either temporary or permanent hearing impairment. It is noted above that sea turtles are unlikely to use passive reception of acoustic signals to detect the hunting sonar of killer whales, because the echolocation signals of killer whales are likely inaudible to sea turtles. Hearing is also unlikely to play a major role in their navigation. However, hearing impairment, either temporary or permanent, might inhibit a turtle's ability to avoid injury from vessels, because they may not hear them in time to move out of their way. In any event, sea turtles are unlikely to be at great risk of hearing impairment.

Although it is unlikely that air source operations during most seismic surveys would cause PTS in marine mammals or sea turtles, caution is warranted given:

- Limited knowledge about noise-induced hearing damage in sea turtles and marine mammals (particularly baleen whales and pinnipeds);
- The seemingly greater susceptibility of certain species (e.g., harbour porpoise and harbour seal) to TTS and presumably also PTS; and
- Lack of knowledge about TTS and PTS thresholds in many species, including various species closely related to the harbour porpoise and harbour seal.

The avoidance reactions of many marine mammals and sea turtles, along with commonly-applied monitoring and mitigation measures (visual and passive acoustic monitoring, ramp-ups, and power downs or shut downs when mammals are detected within or approaching the "safety radii"), would reduce the already-low probability of exposure of marine mammals and sea turtles to sounds strong enough to induce PTS.

Physical and Non-Auditory Physiological Effects

<u>Strandings and Mortality</u>

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys (reviewed in LGL 2012 appended). However, Gray and Van Waerebeek (2011) have suggested a cause-effect relationship between a seismic survey off Liberia in 2009 and the erratic movement, postural instability, and akinesia in a pantropical spotted dolphin based on spatially and temporally close association with the air source array. Additionally, a few cases of strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings. Suggestions that there was a link between seismic surveys and strandings of humpback whales in Brazil (Engel et al. 2004) were not well founded (IAGC 2004; IWC 2007). In September 2002, there was a stranding of two Cuvier's beaked whales in the Gulf of California, Mexico, when the L-DEO seismic vessel R/V *Maurice Ewing* was operating a 20 air source, 8,490 in^3 air source array in the general area. The evidence linking the stranding to the seismic survey was inconclusive and not based on any physical evidence (Hogarth 2002; Yoder 2002). The ship was also operating its multibeam echosounder at the same time, but this had much less potential than the aforementioned naval sonars to affect beaked whales, given its downward-directed beams, much shorter pulse durations, and lower duty cycle. Nonetheless, the Gulf of California incident plus the beaked whale strandings near naval exercises involving use of mid-frequency sonar suggest a need for caution in conducting seismic surveys in areas occupied by beaked whales until more is known about effects of seismic surveys on those species (Hildebrand 2005).

The monitoring and mitigation measures built into HMDC's proposed Project reduce the risk to beaked whales (and other species of cetaceans) that might otherwise exist. Use of ramp-up procedures, in conjunction with the (presumed) natural tendency of beaked whales to avoid an approaching vessel, will reduce exposure.

Potential direct physical effects to sea turtles during seismic operations include entanglement with seismic gear (e.g., cables, buoys, streamers, etc.) and ship strikes (Pendoley 1997; Hazel et al. 2007; Ketos Ecology 2007; Weir 2007). Entanglement of sea turtles with marine debris, fishing gear, dredging operations, and equipment operations are a documented occurrence and of elevated concern for sea turtles. Turtles can become wrapped around cables, lines, nets, or other objects suspended in the water column and become injured or fatally wounded, drowned, or suffocated (e.g., Lutcavage et al. 1997; NMFS 2007). Seismic personnel have reported that sea turtles (number unspecified) became fatally entrapped between gaps in tail-buoys associated with industrial seismic vessel gear deployed off West Africa in 2003 (Weir 2007). With dedicated monitoring by trained biological observers, no incidents of entanglements of sea turtles with this gear have been documented in over 40,000 nmi (74,000 km) of previous NSF-funded seismic surveys (e.g., Holst and Smultea 2008). Towing of the hydrophone streamer or other equipment is not expected to significantly interfere with sea turtle movements, including migration, unless they were to become entrapped as indicated above.

The Study Area is not a breeding area for sea turtles and it is not known or thought to be an important feeding or migration area; thus, it is not expected that high concentrations of sea turtles could potentially be physically affected.

Non-auditory Physiological Effects

Based on evidence from terrestrial mammals and humans, sound is a potential source of stress (Wright and Kuczaj 2007; Wright et al. 2011). However, almost no information is available on sound-induced stress in marine mammals, or on its potential (alone or in combination with other stressors) to affect the long-term well-being or reproductive success of marine mammals (Fair and Becker 2000; Hildebrand 2005; Wright et al. 2007).

Aside from stress, other types of physiological effects that might, in theory, be involved in beaked whale strandings upon exposure to naval sonar (Cox et al. 2006), such as resonance and gas bubble formation, have not been demonstrated and are not expected upon exposure to air source pulses (see preceding section). If seismic surveys disrupt diving patterns of deep-diving species, this might perhaps result in bubble formation and a form of "the bends", as speculated to occur in beaked whales exposed to sonar. However, there is no specific evidence that exposure to air source pulses has this effect.

In summary, very little is known about the potential for seismic survey sounds (or other types of strong underwater sounds) to cause direct physical and non-auditory physiological effects in marine mammals or sea turtles. Such effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. The available data do not allow identification of a specific exposure level above which non-auditory effects can be expected (Southall et al. 2007), or any meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in these ways.

Summary of Effects of Exposure to Sound

Based on the above review, marine mammals and sea turtles will likely exhibit certain behavioural reactions, including displacement from an area around seismic acoustic sources. The size of this displacement area will likely vary amongst species, during different times of the year, and even amongst individuals within a given species. There is also a risk that marine mammals (and perhaps sea turtles) that are very close to a seismic array may incur temporary hearing impairment. The assessment of impacts presented here is based upon the best available information. Note that we have discussed potential impacts separately for toothed whales, baleen whales, seals, and sea turtles given their different hearing abilities and sensitivities to sound. Potential interactions between Project activities and marine mammals and sea turtles are shown in Table 5.10.

Table 5.10 Potential Interactions of Project Activities and the Marine Mammal and Sea Turtle VEC.

Valued Ecosystem Components: Marine Mammal and Sea Turtle				
Project Activities	**Toothed Whales**	**Baleen Whales**	**Seals**	**Sea Turtles**
Sound Emissions and Receivers				
Air sources	X	X	X	X
Seismic Vessel	X	X	X	X
Supply Vessel	X	X	X	X
Picket Vessel	X	X	X	X
OBC	-	-	-	-
Helicopter [a]	X	X	X	X
Echo Sounder	X	X	X	X
Side Scan Sonar	X	X	X	X
Boomer	X	X	X	X
Vessel Lights				
Vessel Presence				
Seismic Vessel	X	X	X	X
Supply Vessel	X	X	X	X
Picket Vessel	X	X	X	X
Sanitary/Domestic Waste	X	X	X	X
Atmospheric Emissions	X	X	X	X
Garbage[b]	-	-	-	-
Helicopter Presence[a]	X	X	X	X
Shore Facilities[c]				
Accidental Releases	X	X	X	X
Other Projects and Activities				

Valued Ecosystem Components: Marine Mammal and Sea Turtle				
Project Activities	**Toothed Whales**	**Baleen Whales**	**Seals**	**Sea Turtles**
Oil & Gas: Grand Banks and Orphan Basin	X	X	X	X
Fisheries (incl. research)	X	X	X	X
Marine Transportation	X	X	X	X
[a] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks. [b] Not applicable as garbage will be brought ashore. [c] There will not be any new onshore facilities. Existing infrastructure will be used.				

Sound Criteria for Assessing Effects

Impact zones for marine mammals are commonly defined by the areas within which specific received sound level thresholds are exceeded. The U.S NMFS (1995, 2000) has concluded that cetaceans should not be exposed to pulsed underwater noise at received levels exceeding 180 dB re 1 µPa (*rms*). The corresponding limit for seals has been set at 190 dB re 1 µPa (*rms*). These sound levels are the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS, one cannot be certain that there will be no injurious effects, auditory or otherwise, to marine mammals. For over a decade, it has been common for marine seismic surveys conducted in some areas of U.S. jurisdiction and in some areas of Canada (Canadian Beaufort Sea and on the Scotian Shelf), to include a "shutdown" requirement for cetaceans based on the distance from the air source array at which the received level of underwater sounds is expected to diminish below 180 dB re 1 µPa (*rms*). As discussed above in "*Hearing Impairment Effects*", data that are now available imply that TTS is unlikely to occur in various odontocetes (and probably mysticetes as well) unless they are exposed to a sequence of several air source pulses in which the strongest pulse has a received level substantially exceeding 190 dB re 1 µPa (*rms*).

An additional criterion that is often used in predicting "disturbance" impacts is 160 dB re 1 µPa; at this received level, some marine mammals exhibit behavioural effects in response to pulsed sound. There is ongoing debate about the appropriateness of these parameters for impact predictions and mitigation (see Appendix C in LGL 2007a).

For marine seismic programs in Newfoundland and Labrador, the C-NLOPB (2013) recommends that seismic operators follow the "*Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*" (hereafter referred to as the *Statement*) issued by the DFO and incorporated into the C-NLOPB guidelines that are a condition of project authorizations. The *Statement* does not include noise criteria as part of the recommended mitigation measures; rather it defines (see Point 6.a) a safety zone as "a circle with a radius of at least 500 metres as measured from the centre of the air source array (s)".

In the absence of site-specific acoustic modelling, the acoustic monitoring results in Austin and Carr (2005) have been used to provide guidance on the ranges one might expect sound levels to be 190, 180 and 160 dB re 1 µPa (*rms*) (from a 28 air source 3,090 in^3 array). The 180 and 190 dB zones were estimated at 700 m and 300 m, respectively. The 160 dB zone occurred at distances of 5,123 m to 6,393 m. The distance of 6.5 km was used as a guide when estimating disturbance effects on marine mammals. It is recognized that the distances from air source arrays where received sound levels exceed these noise criteria are dependent upon the configuration of a specific air source array and site-specific variations in the environment that influence underwater sound propagation.

Assessment of Effects of Sound on Marine Mammals

The marine mammal effects assessment is summarized in Table 5.11 and discussed in detail below.

Toothed Whales

Despite the relatively poor hearing sensitivity of toothed whales (at least the smaller species that have been studied) at the low frequencies that contribute most of the energy in seismic pulses, sounds are sufficiently strong that they remain above the hearing threshold of odontocetes at tens of kilometres from the source.

Species of most concern are those that are designated under *SARA* and that may occur in the Study Area. Sowerby's beaked whales, northern bottlenose whales, killer whales, and harbour porpoises, all with special status by COSEWIC, are not expected to occur in large numbers in the Project Area.

The received sound level of 180 dB re 1 µPa (*rms*) criterion is accepted as a level that below which there is no physical effect on toothed whales. It is assumed that disturbance effects for toothed whales may occur at received sound levels at or above 160 dB re 1 µPa (*rms*). However, it is noted that there is no good scientific basis for using this 160 dB criterion for odontocetes and that a 170 dB re 1 µPa (*rms*) is a more realistic indicator of the disturbance area.

Hearing Impairment and Physical Effects

Given that whales typically avoid at least the immediate area around seismic (and other strong) noise sources, whales in and near the Project Area will likely not be exposed to levels of sound from the air source array that are high enough to cause non-auditory physical effects or hearing impairment. It is highly unlikely that toothed whales will experience mortality or strand as a result of Project activities. The mitigation measure of ramping-up the air source array (over a 30 min period) will allow any whales close to the air sources to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Also, the air source array will not be started if a toothed whale is sighted within the 500 m safety zone. There is little potential for toothed whales being close enough to the array to experience hearing impairment. If some whales did experience TTS, the effects would likely be quite "temporary". The seismic project is predicted to have *negligible to low* hearing impairment and physical effects on toothed whales for a duration of *<1 month to 1-12 months* (20 to 60 days in 2012) over an area *<1 to 1-10 km*^{2} (Table 5.11). Therefore, any residual effects of hearing impairment and/or physical effects on toothed whales would be *not significant* (Table 5.12).

Table 5.11 Assessment of Effects of Project Activities on Marine Mammals.

Valued Ecosystem Components: Marine Mammal and Sea Turtle								
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Sound Emissions and Receivers								
Air sources	Disturbance (N) Hearing Impairment (N) Physical Effects (N)	Ramp-up; delay start; shutdown [a]	1	3-4	6	1-2	R	2
Seismic Vessel	Disturbance (N)	-	0-1	1-2	6	1-2	R	2
Supply Vessel	Disturbance (N)	-	0-1	1-2	6	1	R	2
Picket Vessel	Disturbance (N)	-	0-1	1-2	6	1-2	R	2
OBS	-	-	-	-	-	-	-	-
Helicopter [b]	Disturbance (N)	Maintain high altitude	0-1	1-2	1	1	R	2
Echo Sounder	Disturbance (N)	-	0-1	1	6	1	R	2
Side Scan Sonar	Disturbance (N)	-	0-1	1	6	1	R	2
Boomer	Disturbance (N)	-	0-1	1	6	1	R	2
Vessel Lights		-						
Vessel Presence								
Seismic Vessel	Disturbance (N)	-	0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)	-	0-1	1	1	1	R	2
Picket Vessel	Disturbance (N)	-	0-1	1	6	1	R	2
Sanitary/Domestic Waste	Increased Food (N/P); pathology	Primary treatment	0-1	1	1	1-2	R	2
Atmospheric Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2
Helicopter Presence	Disturbance (N)	Maintain high altitude	0-1	1-2	1	1	R	2
Accidental Releases	Injury/Mortality (N)	Solid streamer[c]; prevention protocols; Spill Response Plan	1	1-2	1	1	R	2

Key:

Magnitude:
0 = Negligible, essentially no effect
1 = Low
2 = Medium
3 = High

Frequency:
1 = <11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Reversibility:
R = Reversible
I = Irreversible
(refers to population)

Duration:
1 = <1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = >72 months

Geographic Extent:
1 = $<1\ km^2$

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not negatively affected by human activity

Valued Ecosystem Components: Marine Mammal and Sea Turtle								
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context

2 = 1-10 km^2 — 2 = Evidence of existing negative effects
3 = 11-100 km^2
4 = 101-1,000 km^2
5 = 1,001-10,000 km^2
6 = >10,000 km^2

[a] The air source arrays will be shutdown if an *endangered* (or *threatened*) marine mammal or sea turtle is sighted within 500 m of the array.
[b] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[c] Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.

Table 5.12 Significance of Potential Residual Environmental Effects of the Project Activities on Marine Mammals.

Valued Ecosystem Component: Marine Mammal and Sea Turtle				
Project Activity	Significance Rating	Level of Confidence	Likelihood [a]	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
Sound				
Air sources	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
OBS	NS	3	-	-
Helicopter	NS	3	-	-
Echo Sounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Boomer	NS	3	-	-
Vessel Lights				
Vessel Presence				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Helicopter Presence	NS	3	-	-
Accidental Releases	NS	3	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

Level of Confidence: based on professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgment:
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

[a] Considered only in the case where 'significant negative effect' is predicted.

Disturbance Effects

Based on the above review, there could be behavioural effects on some species of toothed whales within the Study Area. Known effects may range from changes in swimming behaviour to avoidance of the seismic vessel. Based on available literature, a 160 dB re 1 µPa (*rms*) sound level is used to assess disturbance effects, more specifically potential displacement from the area around the seismic source. This is likely a conservative criterion since some toothed whale species:

- have been observed in other areas relatively close to an active seismic source where received sound levels are greater than 160 dB; and
- may be temporarily displaced from an area will not be significantly impacted by this displacement.

It is uncertain how many toothed whales may occur in the Study Area at various times of the year. The Study Area is not known to be an important feeding or breeding areas for toothed whales. Disturbance effects from Project noise on toothed whales would likely be *low* for a *<1 month* to *1-12 months* over an area of *11-100* to *101-1,000* km^2 (Table 5.11). Therefore, potential residual effects related to disturbance, are judged to be *not significant* for toothed whales (Table 5.12).

Prey Species

It is unlikely that prey species for toothed whales will be impacted by seismic activities to a degree that inhibits their foraging success. If prey species exhibit avoidance of the seismic ship it will likely be transitory in nature (see Section 5.6.1) and over a small portion of a whale's foraging range within the Project Area. Potential effects of reduced prey availability on toothed whales are predicted to be negligible.

Baleen Whales

Baleen whales are thought to be sensitive to low frequency sounds such as those that contribute most of the energy in seismic pulses. Species of most concern are those that are designated under *SARA* and that may occur in and near the Project Area (e.g., blue whales). As with toothed whales, the 180 dB re 1 µPa (*rms*) criterion is used when estimating the area where hearing impairment and/or physical effects may occur for baleen whales (although there are no data to support this criterion for baleen whales). For all baleen whale species, it is assumed that disturbance effects (avoidance) may occur at sound levels greater than 160 dB re 1 µPa (*rms*).

Hearing Impairment and Physical Effects

Given that baleen whales typically exhibit at least localized avoidance of seismic (and other strong) noise, baleen whales will likely not be exposed to levels of sound from the air source array high enough to cause non-auditory physical effects or hearing damage. The mitigation measure of ramping-up the air source array will allow any whales close to the air sources to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Also, the air source array will not be started if a baleen whale is sighted within the 500 m safety zone. Therefore, there is little potential for baleen whales being close enough to the array to experience hearing impairment. If some whales did experience TTS, the effects would likely be quite “temporary”. The proposed seismic project is predicted to have *negligible to low* hearing impairment and physical effects on baleen whales for a duration of *<1 month to 1-12 months* over an area *<1 to 1-10* km^2 (Table 5.11). Therefore, hearing impairment and/or physical effects on baleen whales would be *not significant* (Table 5.12).

Disturbance Effects

Based on the above review, there could be behavioural effects on some species of baleen whales in the Study Area. Reported effects range from changes in swimming behaviour to avoidance of the seismic vessel. The area where displacement would most likely occur would have a predicted geographic extent of *11-100* km^2 *to 10-1,000* km^2. This is likely a conservative estimate given that:

- Some baleen whale species have been observed in areas relatively close to an active seismic source; and
- It is unlikely that displacement from an area constitutes a significant impact for baleen whales in the Study Area.

It is uncertain how many baleen whales may occur in the Study Area during the period when seismic activity is most likely to occur (May to December). The Project Area is not known to be a unique feeding or breeding area for baleen whales. Disturbance effects on species of baleen whales would likely be *low* for a duration of *<1 month* to *1-12 months* over an area of *11-100* km^2 to *101-1,000* km^2 (Table 5.11). Therefore, residual effects related to disturbance, are judged to be *not significant* for baleen whales (Table 5.12).

Prey Species

It is unlikely that prey species for baleen whales, particularly euphausiids, will be impacted by seismic activities to a degree that inhibits their foraging success. If prey species exhibit avoidance of the seismic ship it will likely be transitory in nature (see Section 5.6.1) and over a small portion of a whale's foraging range within the seismic area. Potential effects of reduced prey availability on baleen whales are predicted to be *negligible*.

Seals

Seals are not expected to be abundant within the Study Area, particularly in the time period when seismic operations will likely occur. Harp and hooded seals are expected to have a more northerly distribution during the survey period (May to December), although they could be moving through the Study Area. Grey seals are likely uncommon and would be most common in coastal areas. None of the species of seal that occur within the Study Area are considered at risk by COSEWIC or are designated on a *SARA* schedule.

Hearing Impairment and Physical Effects

Given that seals typically avoid the immediate area around a seismic array, seals will likely not be exposed to levels of sound from the air source array (and other noise sources) high enough to cause non-auditory physical effects or hearing impairment. The mitigation measure of ramping-up the air source array will allow any seals close to the air sources to move away before the sounds become sufficiently strong to have potential for hearing impairment. Also, a ramp-up will not be initiated if a seal is sighted within the 500 m safety zone. Therefore, there is limited potential for seals being close enough to an array to experience hearing impairment. If some seals did experience TTS, the effects would likely be quite "temporary". The seismic project is predicted to have *negligible* to *low* hearing impairment and/or physical effects on seals for a duration of *<1 month* to *1-12 months* over an area *<1* km^2 (Table 5.11). Therefore, and residual effects of hearing impairment and physical effects on seals would be *not significant* (Table 5.12).

Disturbance Effects

Based on the above review, there could be behavioural effects on seals in the Study Area. Known effects include changes in diving behaviour and localized avoidance of the seismic vessel. It is uncertain how many seals may occur in the Study Area during the period when seismic activities are most likely to occur (May to December). There are no available criteria for assessing the sound level most likely to elicit avoidance reactions in seals. It is noteworthy that seals have been sighted inside the radius thought to cause TTS (190 dB) in other areas. A 160 dB re 1 µPa (rms) sound level has been conservatively used to assess disturbance effects, more specifically potential displacement from the area around the seismic source. Therefore, the area where displacement may occur would have a scale of potential effect at *11-100 to 101-1,000* km^2. This estimated area around the seismic vessels would be ensonified periodically for a duration of *<1 month to 1-12 months* (Table 5.11). The seismic project is predicted to have *low* disturbance effects on seals. Therefore, residual effects related to disturbance, are judged to be *not significant* for seals (Table 5.12).

Assessment of Effects of Sound on Sea Turtles

The effects assessment for sea turtles is summarized in Table 5.13.

Hearing Impairment and Physical Effects

Based on available data, it is likely that sea turtles might exhibit temporary hearing loss if the turtles are close to the air sources (Moulton and Richardson 2000). However, there is not enough information on sea turtle temporary hearing loss and no data on permanent hearing loss to reach any definitive conclusions about received sound levels that trigger TTS. Also, it is likely that sea turtles will exhibit behavioural reactions or avoidance within an area of unknown size around a seismic vessel. The mitigation measure of ramping-up the air source array over a 30 min period should permit sea turtles close to the air sources to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Also, ramp-up will not commence if a sea turtle is sighted within the 500 m safety zone and the air source array will be shutdown if a leatherback or loggerhead sea turtle is sighted within the safety zone.

It is very unlikely that many sea turtles will occur in the Study Area. Therefore, there is likely limited potential for sea turtles to be close enough to an array to experience hearing impairment. If some turtles did experience TTS, the effects would likely be "temporary" and hence *reversible*. The seismic project is predicted to have *negligible to low* physical effects on sea turtles for a duration of *<1 month to 1-12* months over an area *<1 to 1-10 km* ^{2}(Table 5.13). Therefore, residual auditory and physical effects on sea turtles would be *not significant* (Table 5.14).

Table 5.13 Assessment of Effects of Project Activities on Sea Turtles.

Valued Ecosystem Component: Marine Mammal Sea Turtle								
			Evaluation Criteria for Assessing Environmental Effects					
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Sound Emissions and Receivers								
Air sources	Disturbance (N) Hearing Impairment (N) Physical Effects (N)	Ramp-up; delay start; shutdown [a]	1	3	6	1-2	R	2
Seismic Vessel	Disturbance (N)	-	0-1	1-2	6	1-2	R	2
Supply Vessel	Disturbance (N)	-	0-1	1-2	6	1	R	2
Picket Vessel	Disturbance (N)	-	0-1	1-2	6	1-2	R	2
OBC	-	-	-	-	-	-	-	-

Valued Ecosystem Component: Marine Mammal Sea Turtle								
Project Activity	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation**	**Evaluation Criteria for Assessing Environmental Effects**					
			Magnitude	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Helicopter [b]	Disturbance (N)	Maintain high altitude	0-1	1-2	1	1	R	2
Echo Sounder	Disturbance (N)	-	0-1	1	6	1	R	2
Side Scan Sonar	Disturbance (N)	-	0-1	1	6	1	R	2
Boomer	Disturbance (N)	-	0-1	1	6	1	R	2
Vessel Lights		-						
Vessel Presence								
Seismic Vessel	Disturbance (N)	-	0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)	-	0-1	1	1	1	R	2
Picket Vessel	Disturbance (N)	-	0-1	1	6	1-2	R	2
Sanitary/Domestic Waste	Increased Food (N/P); pathology	Primary treatment	0-1	1	1	1-2	R	2
Atmospheric Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2
Helicopter Presence	Disturbance (N)	Maintain high altitude	0	1-2	1	1	R	2
Accidental Releases	Injury/Mortality (N)	Solid streamers[c]; prevention protocols; Spill Response Plan	1	1-2	1	1	R	2

Key:

Magnitude:
0 = Negligible, essentially no effect
1 = Low
2 = Medium
3 = High

Frequency:
1 = <11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Reversibility:
R = Reversible
I = Irreversible
(refers to population)

Duration:
1 = <1 month
2 =1-12 months
3 = 13-36 months
4 = 37-72 months
5 = >72 months

Geographic Extent:
1 = <1 km^2
2 = 1-10 km^2
3 = 11-100 km^2
4 = 101-1,000 km^2
5 = 1,001-10,000 km^2
6 = >10,000 km^2

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not negatively affected by human activity
2 = Evidence of existing negative effects

[a] The air source arrays will be shutdown if an *endangered* (or *threatened*) marine mammal or sea turtle is sighted within 500 m of the array.
[b] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[c] Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.

Table 5.14 Significance of Potential Residual Environmental Effects of Project Activities on Sea Turtles.

Valued Ecosystem Component: Marine Mammal and Sea Turtle				
Project Activity	Significance Rating	Level of Confidence	Likelihood [a]	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
Sound Emissions and Receivers				
Air sources	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
OBC	NS	3	-	-
Helicopter	NS	3	-	-
Echo Sounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Boomer	NS	3	-	-
Vessel Lights				
Vessel Presence				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Helicopter Presence	NS	3	-	-
Accidental Releases	NS	2	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

Level of Confidence: based on professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgment:
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

[a] Considered only in the case where 'significant negative effect' is predicted.

Disturbance Effects

It is possible that sea turtles will occur in the Study Area, although the cooler water temperatures likely preclude some species from occurring there. If sea turtles did occur near the seismic vessel, it is likely that sea turtles would exhibit avoidance within a localized area. Based on observations of green and loggerhead sea turtles, behavioural avoidance may occur at received sound levels of 166 dB re 1 μPa *rms*. Based on available evidence, the area where displacement would most likely occur would have a scale of impact at 11 to 100 km^2. The seismic project is predicted to have *low* disturbance effects on sea turtles for a duration of *<1 month* to *1-12 months* over an area *11-100* km^2 (Table 5.13). Therefore, reversible residual effects related to disturbance, are judged to be *not significant* for sea turtles (Table 5.14).

Prey Species

Leatherback sea turtles are expected to feed primarily on jellyfish. It is unknown how jellyfish react to seismic noise sources, if these invertebrates react at all. Leatherbacks are also known to feed on sea urchins, tunicates, squid, crustaceans, fish, blue-green algae, and floating seaweed. It is possible that some prey species may exhibit localized avoidance of the seismic array but this is unlikely to impact sea turtles, which are also likely to avoid the seismic vessel and are known to search for aggregations of prey. Potential effects of reduced prey availability are predicted to be *negligible* and hence *not significant*.

5.6.4.2 Effects of Helicopter Overflights

A crew change may occur via helicopter if the seismic program is longer than five to six weeks, depending on the contractor. The 2013 seismic survey is anticipated to be short in duration, so a helicopter crew change may not be necessary. However, some contractors may choose to conduct crew changes in port. Helicopters will maintain a regulated flight altitude above sea level unless it is necessary to fly lower for safety reasons.

Marine Mammals

Available information indicates that single or occasional aircraft overflights will cause no more than brief behavioural responses in baleen whales, toothed whales and seals (summarized in Richardson et al. 1995). Disturbance effects are assessed as *negligible* to *low* for a duration of *<1 month* over an area *1-10* km^2 to *11-100* km^2 (Table 5.11). Therefore, reversible residual effects related to disturbance, are judged to be *not significant* for marine mammals (Table 5.12).

Sea Turtles

To the best of our knowledge, there are no systematic data on sea turtle reactions to helicopter overflights. Given the hearing sensitivities of sea turtles, they can likely hear helicopters, at least when the helicopters are at lower altitudes and the turtles are in relatively shallow waters. It is unknown how sea turtles would respond, but single or occasional overflights by helicopters would likely only elicit a brief behavioural response. Disturbance effects are assessed as *negligible* Table 5.13. Therefore, residual effects related to disturbance, are judged to be *not significant* for sea turtles (Table 5.14).

5.6.4.3 Effects of Presence of Vessels

During the proposed seismic program, there will be one seismic ship at all times and a picket vessel on site during most of the program (30-120 days in 2013). It is anticipated that a supply ship will also be on site occasionally. There is some risk for collision between marine mammals and vessels, but given the slow surveying speed (4.5 to 5 knots; 8.3 to 9.3 km/h) of the seismic vessel (and its picket vessel); this risk is minimal (Laist et al. 2001; Vanderlaan and Taggart 2007). Marine mammal responses to ships are presumably responses to noise, but visual or other cues are also likely involved. Marine mammal response (or lack thereof) to ships and boats (pre-1995 studies) are summarized in Richardson et al. (1995), p. 252 to 274. More recent studies are described in LGL (2007a). Marine mammal responses to the presence of vessels are variable. Seals often show considerable tolerance to vessels. Toothed whales sometimes show no avoidance reactions and occasionally approach them; however, some species are displaced by vessels. Baleen whales often interrupt their normal behaviour and swim rapidly away from vessels that have strong or rapidly changing noise, especially when a vessel heads directly towards a whale. Stationary vessels or slow-moving, “non-aggressive” vessels typically elicit very little response from baleen whales.

To the best of our knowledge, there are few systematic studies on sea turtle reactions to ships and boats but it is thought that response would be minimal relative to responses to seismic sound. Hazel et al. (2007) evaluated behavioural responses of green turtles to a research vessel approaching at slow, moderate, or fast speeds (4, 11, and 19 km/h, respectively). Proportionately fewer turtles fled from the approaching vessel as speed increased, and turtles that fled from moderate to fast approaches did so at significantly shorter distances from the vessel than those that fled from slow approaches. The authors conclude that sea turtles cannot be relied on to avoid vessels with speeds greater than 4 km/h. However, studies were conducted in a 6 m aluminum boat powered by an outboard engine, which would presumably be more challenging for a sea turtle to detect than a seismic or supply vessel.

Effects of the presence of vessels on marine mammals or sea turtles, including the risk of collisions, are predicted to be *negligible* to *low for* a duration of *<1 month to 1-12 months* over an area of *1-10* km^2. Therefore, *reversible* residual effects related to the presence of vessels, are judged to be *not significant* for marine mammals and sea turtles (Tables 5.11 to 5.14).

5.6.4.4 Effects of Accidental Releases

All petroleum hydrocarbon handling and reporting procedures on board will be consistent with HMDC’s policy, and handling and reporting procedures. In the unlikely event that fluid-filled streamers are used in future surveys after 2013 (i.e., 2014 to EF), it is possible that small amounts of Isopar could be leaked from the streamers; a fuel spill may occur from the seismic ship and/or its support vessels. Any spills would likely be small and quickly dispersed by wind, wave, and ship’s propeller action. The effects of hydrocarbon spills on marine mammals and sea turtles were reviewed in Husky (2000) in sections 5.9.1.3 and 5.9.2.3, respectively and are not repeated here. Based on multiple studies, whales and seals do not exhibit large behavioural or physiological responses to limited surface oiling, incidental exposure to contaminated food, or ingestion of oil (St. Aubin 1990; Williams et al. 1994). Sea turtles are thought to be more susceptible to the effects of exposure to hydrocarbons than marine mammals (Husky 2000). Effects of an accidental release on marine mammals or sea turtles would be *low* for a duration of *<1 month* over an area *<1 km*^{2} to *1-10 km*^{2} and are *reversible* residual effects are judged to be *not significant* (Tables 5.11 to 5.14).

5.6.4.5 Effects of Other Project Activities

There is potential for marine mammals and sea turtles to interact with domestic and sanitary wastes, and air emissions from the seismic ship and its support vessels. Any effects from these interactions are predicted to be *negligible* and, therefore *not significant* (Tables 5.11 to 5.14).

It is unlikely that marine mammals or sea turtles would interact with OBC cables laid on the seabed and thus *no effect* is predicted.

5.6.5 Species at Risk

A biological overview of all species considered *endangered* or *threatened* under Schedule 1 of the *SARA* that may occur in the Study Area was provided in Section 4.6. No critical habitat has been defined for the Study Area. As discussed in previous sections and presented in Table 4.13, *SARA* species of relevance to the Study Area include:

- Northern, spotted, and Atlantic wolffish, and white shark;
- Ivory Gull;
- Blue and North Atlantic right whale; and
- Leatherback sea turtle.

Species not currently designated (see Table 4.13) on Schedule 1 of *SARA* but listed on Schedule 2 or 3 or being considered for addition to Schedule 1 (as per their current COSEWIC listing of *endangered, threatened* or *special concern*), are not included in the SAR VEC but have been assessed in the appropriate VEC section (i.e., Section 5.6.1 (Fish), Section 5.6.3 (Seabirds) and Section 5.6.4 (Marine Mammals and Sea Turtles) of this EA. If species not currently designated on Schedule 1 of *SARA* do become listed on this legal list during the remainder of the temporal scope of the Project (2012 to EF), the Proponent will re-assess these species considering the prohibitions of *SARA* and any new recovery strategies, action plans, and (or) management plans that may be in place, as well as the identification of critical habitat. Possible mitigation measures as they relate to Species at Risk will be reviewed with DFO and EC. Potential interactions between the Project and SAR are shown in Table 5.15.

The mitigation measure of ramping up the air source array (over a 30 min period) is expected to minimize the potential for impacts on white sharks and wolffishes. As per the detailed effects assessment contained in Section 5.6.1, physical effects of the Project on the various life stages of the white shark and two wolffish species will range from *negligible* to *low* for a duration of *<1 month* to

1-12 months over an area of *<1 km²* (Table 5.16). Reversible residual behavioural effects may extend out to a larger area but are still predicted to be *not significant* (Table 5.17).

Ivory Gull foraging behaviour would not expose it to underwater sound, and this species is unlikely to occur in the Study Area during the time when seismic surveys will be conducted. Furthermore, Ivory Gulls are not known to strand on vessels. The mitigation measures of monitoring the seismic vessel and releasing stranded birds (in the unlikely event that an Ivory Gull did strand on the vessel) and ramping up the air source array will minimize any potential for impacts on this species. [Any injured Ivory Gull would be immediately reported to CWS.] As per the detailed effects assessment in Section 5.6.3, the predicted effects of the Project on Ivory Gulls will be *negligible*. Therefore, the predicted residual effects of the Project on Ivory Gulls are predicted to be *not significant*

Table 5.15 Potential Interactions of Project Activities and the Species at Risk VEC.

Valued Ecosystem Components: Species at Risk					
Project Activities	**White Shark**	**Wolffishes**	**Ivory Gull**	**Blue and Right Whales**	**Leatherback Sea Turtle**
Sound Emissions and Receivers					
Air sources	X	X	X	X	X
Seismic Vessel	X	X	X	X	X
Supply Vessel	X	X	X	X	X
Picket Vessel	X	X	X	X	X
OBC	-	X	-	-	-
Helicopter [a]			X	X	X
Echosounder	X	X	X	X	X
Side Scan Sonar	X	X	X	X	X
Boomer	X	X	X	X	X
Vessel Lights	X	X	X		
Vessel Presence					
Seismic Vessel			X	X	X
Supply Vessel			X	X	X
Picket Vessel			X	X	X
Sanitary/ Domestic Waste	X	X	X	X	X
Atmospheric Emissions	X	X	X	X	X
Garbage[b]					
Helicopter Presence[a]			X	X	X
Shore Facilities[c]					
Accidental Releases	X	X	X	X	X
Other Projects and Activities					
Oil & Gas: Grand Banks and Orphan	X	X	X	X	X
Fisheries (incl. research)	X	X	X	X	X
Marine Transportation	X	X	X	X	X

[a] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[b] Not applicable as garbage will be brought ashore.
[c] There will not be any new onshore facilities. Existing infrastructure will be used.

Table 5.16 Assessment of Effects of Project Activities on the Species at Risk VEC.

Valued Ecosystem Component: Species At Risk								
			Evaluation Criteria for Assessing Environmental Effects					
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Sound Emissions and Receivers								
Air sources	Disturbance (N) Hearing Impairment (N) Physical Effects (N)	Ramp-up; delay start[a]; shutdown [b]	0-1	3-4	6	1-2	R	2
Seismic Vessel	Disturbance (N)	-	0-1	1-2	6	1-2	R	2
Supply Vessel	Disturbance (N)	-	0-1	1-2	6	1	R	2
Picket Vessel	Disturbance (N)	-	0-1	1-2	6	1	R	2
OBC	Disturbance (N)	-	0-1	1-2	6	1	R	2
Helicopter [b]	Disturbance (N)	Maintain high altitude	0-1	1-2	1	1	R	2
Echosounder	Disturbance (N)	-	0-1	1-2	6	1	R	2
Side Scan Sonar	Disturbance (N)	-	0-1	1-2	6	1	R	2
Boomer	Disturbance (N)	Gradual power increase; delay start; shutdown	0-1	1-2	6	1	R	2
Vessel Lights	Attraction (N); Mortality (N)	Reduce lighting (if safe); conditions in CWS permit	0-2	1-2	2-3	1-2	R	2
Vessel Presence								
Seismic Vessel	Disturbance (N)	-	0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)	-	0-1	1	1	1	R	2
Picket Vessel	Disturbance (N)	-	0-1	1	6	1	R	2
Sanitary/Domestic Waste	Increased food (N/P)	Primary treatment	0-1	1	1	1-2	R	2
Atmospheric Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2
Helicopter Presence	Disturbance (N)	Maintain high altitude	0	1-2	1	1	R	2
Accidental Releases	Injury/Mortality (N)	Solid Streamer[c]; prevention protocols; Spill Response Plan	1-2	1-3	1	1-2	R	2

Key:

Magnitude:
0 = Negligible, essentially no effect
1 = Low
2 = Medium
3 = High

Frequency:
1 = <11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Reversibility:
R = Reversible
I = Irreversible
(refers to population)

Duration:
1 = <1 month
2 =1-12 months
3 = 13-36 months
4 = 37-72 months
5 = >72 months

Geographic Extent:
1 = <1 km^2
2 = 1-10 km^2
3 = 11-100 km^2
4 = 101-1,000 km^2
5 = 1,001-10,000 km^2
6 = >10,000 km^2

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not negatively affected by human activity
2 = Evidence of existing negative effects

[a] The air source arrays will be shutdown if an *endangered* (or *threatened*) marine mammal or sea turtle is sighted within 500 m of the array.
[b] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[c] Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.

Table 5.17 Significance of Potential Residual Environmental Effects of Project Activities on the Species at Risk VEC.

Valued Ecosystem Component: Species At Risk				
Project Activity	Significance Rating	Level of Confidence	Likelihood [a]	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
Sound Emissions and Receivers				
Air sources	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
OBC	NS	3	-	-
Helicopter	NS	3	-	-
Echosounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Boomer	NS	3	-	-
Vessel Lights	NS	3	-	-
Vessel Presence				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Helicopter Presence	NS	3	-	-
Accidental Releases	NS	2-3	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

Level of Confidence: based on professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgment:
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

[a] Considered only in the case where 'significant negative effect' is predicted.

Based on available information, blue whales, right whales and leatherback sea turtles are not expected to occur regularly in the Study Area. It is extremely unlikely that a North Atlantic right whale will occur in the Study Area. There is a finalized recovery strategy for blue whales in Atlantic Canada (Beauchamp et al. 2009) as well as a final recovery strategy for North Atlantic right whales (Brown et al. 2009). A recovery strategy for leatherback sea turtles is also available (ALTRT 2006). However, critical habitat in the Study Area has not been proposed or designated for any SAR whales or leatherback sea turtles. Mitigation and monitoring designed to minimize potential effects of air source array noise on *SARA*-listed marine mammals and sea turtles will include:

- Ramp-up of the air source array over a 30 min period;
- Monitoring by MMO (s) during daylight hours that the air source array is active;
- Shutdown of the air source array when an *endangered* or *threatened* marine mammal or sea turtle is sighted within the 500 m safety zone; and
- Delay of ramp-up if any marine mammal or sea turtle is sighted within the 500 m safety zone.

With these mitigation measures in place and as per the detailed effects assessment in Section 5.6.4, the predicted effects of the Project on blue whales, right whales and leatherback sea turtles will range from *negligible* to *low* for a duration of *<1 month* to *1-12 months* over an area of *<1* to *101-1,000* km^2 (Table 5.16). Based on these criteria, the predicted residual effects of the Project on blue whales, right whales and leatherback sea turtles are predicted to be *not significant* (Table 5.17).

In summary and based upon the preceding discussion, the potential effects of HMDC's proposed seismic program are not expected to contravene the prohibitions of *SARA* (Sections 32(1), 33, 58(1)).

5.7 Cumulative Effects

This EA has assessed cumulative effects within the Project and thus, the residual effects described in preceding sections include any potential cumulative effects from the HMDC seismic program activities in the Project Area.

It is also necessary to assess cumulative effects from other non-Project activities that are occurring or planned for the Regional Area. These activities may include:

- Commercial and research survey fishing;
- Vessel traffic (e.g., transportation, defense, yachts);
- Hunting (e.g., seabirds, seals), and
- Offshore oil and gas industry.

Fishing has been discussed and assessed in detail in Section 5.6.2. Fishing activities, by their nature, cause mortality and disturbance to fish populations and may cause incidental mortalities or disturbance to seabirds, marine mammals, and sea turtles. It is predicted that the seismic surveys will not cause any mortality to these VECs (with the potential exception of small numbers of petrels) and thus, there will be either *no* or *negligible* cumulative mortality effect. There is some potential for cumulative disturbance effect (e.g., fishing vessel noise) but there will be directed attempts by both industries to mitigate such effects by avoiding each other's active areas and times. The seismic surveying will also spatially and temporally avoid DFO research vessels during multi-species trawl surveys. Any cumulative effects (i.e., disturbance), if they occur, will be additive (not multiplicative or synergistic) and predicted to be *not significant*.

In the summer, the main North Atlantic shipping lanes between Europe and North America lie to the north of the Grand Banks into the Strait of Belle Isle. In the winter, that traffic shifts to the main shipping lanes along the southern Grand Banks into the Gulf of St. Lawrence. Thus, potential for cumulative effects with other shipping is predicted to be *low*.

The vast majority of hunting of seabirds (mostly murres) in Newfoundland and Labrador waters occurs near shore from small boats. Also, it is predicted that no murres will suffer mortality from the Project's routine activities. Thus, there is little or no potential for cumulative effects on this VEC. Similarly, most, if not all, seal hunting would occur inshore of the Project Area and the Project will cause no mortality to seals even in the event of an accidental spill of petroleum hydrocarbons.

Potential offshore oil and gas industry activities in the Regional Area (as per the C-NLOPB public registry, www.cnlopb.nl.ca) include:

- Hebron;
- Husky White Rose Extension Project (WREP);
- Multi Klient Invest ASA (MKI) 2D seismic program on Northeast Newfoundland Shelf (i.e., Labrador Basin, Orphan Basin, Flemish Pass, Jeanne d'Arc Basin), 2012-2017
- Statoil 3D/2D geophysical program including geohazard and electromagnetic surveys in Jeanne d'Arc and Central Ridge/Flemish Pass Basins, 2011-2019;
- WesternGeco 3D/2D seismic program in the Jeanne d'Arc Basin, 2012-2015;
- Investcan Energy Corporation 2D/3D seismic program including geohazard and VSP surveys on Labrador Shelf, 2010-2017;
- Chevron Canada Resources 3D/2D seismic program including geohazard survey in offshore Labrador, 2010-2017;
- Chevron Canada Resources exploratory drilling program Orphan Basin;
- Chevron Canada Resources 3D and/or 2D seismic program including geohazard survey in the North Grand Banks Region, 2011-2017;
- Statoil exploration, appraisal, and delineation drilling program in Jeanne d'Arc Basin area, 2008-2016;
- Suncor exploration drilling in Jeanne d'Arc Basin, 2009-2017;
- Husky White Rose new drill centre construction and operations program, 2008-2015; and
- Husky exploration and delineation drilling program in Jeanne d'Arc Basin, 2008-2017.

In addition, the following Grand Banks projects are presently undergoing EA (C-NLOPB website 29 Feb 2013):

- GXT Technology Canada Ltd. 2D Seismic, Gravity, and Magnetic Survey for the Labrador Shelf Area (2013-2015);

- ARKeX Ltd. North Flemish Pass Gravity Gradient Survey (2013-2017);
- Husky Jeanne d'Arc Basin/ Flemish Pass Regional Seismic Program 2012-2020;
- Husky Sydney Basin Seismic Program 2010-2018;
- Husky 2-D and 3-D Seismic and Geohazard Surveys on Labrador Shelf 2009-2017; and
- Suncor exploration drilling program within Jeanne d'Arc Basin 2009-2017.

While the above lists suggest potential for many programs to run concurrently, it should be noted that the East Coast operators tend to coordinate their logistics. As a result, based on historical levels of activities, there typically would be no more than two or three drill rigs and two or three seismic programs operating off Newfoundland and Labrador during any one season.

In addition, there are three existing offshore production developments (Hibernia, Terra Nova, and White Rose) on the northeastern part of the Grand Banks. Additional production developments (Hebron and WREP) are anticipated to commence installation in the near future. These existing developments fall inside the boundaries of the HMDC's Study Area but do not create the same levels of underwater noise as seismic programs. Any cumulative effects (i.e., disturbance), if they occur, are predicted to be additive (not multiplicative or synergistic) and *not significant*.

There is potential for cumulative effects with other seismic programs that will be active for 2013 (e.g., Hebron and possibly a brief Husky geohazard survey in July). Hebron and HMDC will use the same survey vessel so that any cumulative effects will be minimal. In future years, different seismic programs could potentially be operating in relatively close proximity. During these periods, VECs may be exposed to noise from more than one of the seismic survey programs. It will be in the interests of the different parties for good coordination between programs in order to provide sufficient buffers and to minimize acoustic interference. HMDC will participate in a coordinated effort to provide sufficient spatial buffers between seismic vessels operating concurrently in the northern Grand Banks area.

Assuming maintenance of sufficient separation of seismic vessels operating concurrently in the Project Area, cumulative effects of seismic sound on fish and fish habitat, fisheries, seabirds, marine mammals, sea turtles and species at risk are predicted to be *not significant*. However, there are uncertainties regarding this prediction. The potential for temporal and spatial overlap of future activity of seismic programs (2014-EF) in the area will be assessed in the EA update process.

As discussed in this EA, negative effects on key sensitive VECs such as marine mammals appear unlikely beyond a localized area from the sound source. In addition, all programs will use mitigation measures such as ramp-ups, delayed startups, and shutdowns of the air source arrays. Thus, it seems likely that while some animals may receive sound from one or more geophysical programs, the current scientific prediction is that *no significant residual effects* will result.

5.8 Mitigations and Follow-up

Project mitigations have been detailed in the various individual sections of the preceding EA and are summarized in the text provided below and in Table 5.18. HMDC and contractors will adhere to mitigations detailed in Appendix C of the *Geophysical, Geological, Environmental and Program Guidelines* (C-NLOPB 2012) including those in the *Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*.

While this EA covers 2013 to EF, details on any post-2013 surveys will be provided in EA validation documents to be submitted to the C-NLOPB.

Table 5.18 Summary of Mitigation Measures.

Potential Effects	Primary Mitigations
Interference with fishing vessels	• Conduct upfront planning to avoid high concentrations of fishing vessels • Request input from fishing captains through FFAW PIL regarding streamer deployment and testing plan • Utilize Single Point of Contact (SPOC) • Release advisories and communications • Employ FLO and picket vessel • Plan transit route to and between Survey Areas (if required)
Fishing gear damage	• Conduct upfront planning to avoid high concentrations of fishing gear • Utilize SPOC • Release advisories and communications • Employ FLO and picket vessel • Compensation Plan • Plan transit route to and between Survey Areas (if required)
Interference with shipping	• Utilize SPOC • Release divisories and communications • Employ FLO and picket vessel
Interference with DFO/FFAW research vessels	• Maintain communications and scheduling
Temporary or permanent hearing damage/disturbance to marine animals	• Delay start-up if marine mammals or sea turtles are within 500 m. • Ramp-up of air sources over 30 min-period • Shutdown air source arrays for endangered or threatened marine mammals and sea turtles within 500 m • Use qualified MMO(s) to monitor for marine mammals and sea turtles during daylight seismic operations
Temporary or permanent hearing damage/ disturbance to Species at Risk or key habitats	• Delay start-up if any marine mammals or sea turtles are within 500 m • Ramp-up air sources • Shutdown air source arrays for endangered or threatened marine mammals and sea turtles • Use qualified MMO(s) to monitor for marine mammals and sea turtles during daylight seismic operations.
Injury (mortality) to stranded seabirds	• Monitor vessel daily • Comply with conditions in CWS permit • Minimize lighting if safe
Exposure to hydrocarbons	• Adhere to International Convention for the Prevention of Pollution from Ships (MARPOL) • Prevention protocols • Utilize Spill Response Plan • Use solid streamer when feasible

5.8.1 Marine Mammals and Sea Turtles

Several environmental factors are known to affect the ability of a MMO to visually detect a marine mammal. Offshore Newfoundland, these factors include darkness, fog, sea state, swell, glare, and precipitation. In June and July, when fog was most prevalent, visibility was <500 m (minimum safety zone for marine mammals) during ~40% of the MMO effort when air sources were active in the NW Atlantic (Moulton et al. 2009). Considering that daylight hours account for ~65% of the day during June and July in the NW Atlantic and assuming that air sources were active throughout the day and night, the 500-m safety zone could be fully monitored (visually) only ~39% of the time, on average (minimum 25%) in months during which seismic exploration commonly occurs (Moulton et al. 2009).

The *Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment* (the *Statement*) states that when the full safety zone (minimum of 500 m from the air source array) is not visible, cetacean detection technology such as Passive Acoustic Monitoring should be used in areas identified as critical habitat (for a vocalizing cetacean listed as endangered or threatened on Schedule 1 of the *Species at Risk Act*) or in areas where a vocalizing cetacean occurs that has been identified through the environmental assessment process as a species for which there could be significant adverse effects. Critical habitat for marine mammals has not been identified in the Study Area and significant adverse effects on marine mammals are not predicted in the environmental assessment.

Given the large portion of time that the full safety zone may not be visible, the use of a single air source during line changes has been used in some previous seismic programs in Atlantic Canada to "warn" marine mammals so that they will not approach the air source array. The *Statement* gives the seismic operator the option of shutting down all air sources or operating a single air source during line changes (or periods of equipment maintenance). It is unclear if operating a single air source between seismic survey lines in periods of poor visibility, i.e., when the 500 m safety zone is not visible, will deter marine mammals from approaching closely to the air source array. There is evidence that, in some species of marine mammals, some individuals do show avoidance reactions to the onset of sound from a single air source. Experiments with a single air source showed that bowhead, humpback, and gray whales all showed localized avoidance of a single air source of 20–100 in^3 (see Moulton et al. 2009 for a review). It seems likely that species known to show strong avoidance responses to various sources of anthropogenic sound, such as most beaked whales and harbour porpoises would also show avoidance during periods when a single air source was active, but insofar as we know this has not been documented empirically. The other option of shutting down all air sources during line changes reduces the amount of seismic sound introduced into the water column, hence avoids any impacts of this sound on marine mammals. A ramp up procedure, starting with the smallest air source in the array, would be required before the air source arrays are activated at full power. The ramp up procedure is theorized to deter marine mammals from the immediate area around the air source array before animals are exposed to maximum sound levels.

Mitigation measures designed to reduce the likelihood of impacts on marine mammals and sea turtles will include ramp-ups, no initiation of air source array if a marine mammal or sea turtle is sighted 30 min prior to ramp-up within 500 m safety zone of the energy source, shutdown of the energy source if an *endangered* (or *threatened*) whale or sea turtle is observed within the 500 m safety zone. Prior to the onset of the seismic survey, the air source array will be gradually ramped up. One air source will be activated first and then the volume of the array will be increased gradually over a recommended 30 min period. An observer aboard the seismic ship will watch for marine mammals and sea turtles 30 min prior to ramp-up. If a marine mammal or sea turtle is sighted within 500 m of the array, then ramp-up will not commence until the animal has moved beyond the 500 m zone or 20 min have elapsed since the last sighting. The observers will watch for marine mammals and sea turtles when the air source array is active (during daylight periods) and note the location and behaviour of these animals. The seismic array will be shut down if an *endangered* (or *threatened*) marine mammal or sea turtle is sighted within the safety zone. The planned monitoring and mitigation measures, including ramp-ups, visual monitoring, and shut-down of the air sources when *endangered* or *threatened* marine mammals or turtles are seen within the "safety radii", will minimize the already-low probability of exposure of marine animals to sounds strong enough to induce hearing impairment. Any dead or distressed marine mammals or sea turtles will be recorded and reported to the C-NLOPB.

5.8.2 Seabirds

HMDC will follow all requirements specified in the CWS seabird handling permit. These typically include:

Live Birds:

1. Uninjured, non-oiled birds must be captured and released as per "Williams and Chardine" protocol.
2. Storm-petrels showing signs of possible oiling must be captured and released as per "Williams and Chardine" protocol.
3. Injured birds: Sabina Wilhelm, Canadian Wildlife Service (709-764-1957 sabina.wilhelm@ec.gc.ca) must be notified and contacted for instructions immediately upon discovery.

Dead Birds:

1. Non-oiled birds found dead or that die before release should be identified, recorded and disposed of at sea.

Oiled Birds:

1. If oil contamination is noted on any live or deceased birds, immediately notify Canadian Coast Guard 1-800-563-9089 and proceed as instructed.

Report:

A written report detailing numbers of all birds (oiled or not) that were captured and released as well as those deceased during each year's survey is required by end of January following each year's seismic program.

Any seabird survey data collection will be consistent with protocols provided by CWS in Gjerdrum et al. (2012). Data will be collected by a qualified MMO or MMO/SBO.

5.8.3 Fisheries

Fishers who may be operating in the area will be notified of the timing and location of planned activities by means of a CCG "Notice to Mariners" and a "Notice to Fishers" on the CBC Radio Fisheries Broadcast. In addition, if necessary, individual fixed gear fishers will be contacted to arrange mutual avoidance. Any contacts with fishing gear, with any identifiable markings, will be reported to the C-NLOPB immediately. Fishing gear may only be retrieved from the water by the gear owner (i.e. fishing license owner). This includes buoys, radar reflectors, rope, nets, pots, etc. associated with fishing gear and/or activity. If gear contact is made during seismic operations it should not be retrieved or retained by the seismic vessel. There are conditions that may warrant gear being retrieved or retained if it becomes entangled with seismic gear; however, further clarification on rules and regulations regarding fishing gear should be directed to the Conservation and Protection Division of Fisheries and Oceans Canada (NL Region). HMDC will advise the C-NLOPB prior to compensating and settling all valid lost gear/income claims promptly and satisfactorily.

Specific mitigations to minimize potential conflicts and any negative effects with other vessels; these include:

- Timely and clear communications (VHF, HF, Satellite, etc.);
- Utilization of fisheries liaison officers (FLOs) for advice and coordination in regard to avoiding fishing vessels and fishing gear;
- MMO(s) and FLO onboard;
- Posting of advisories with the Canadian Coast Guard and the CBC Fisheries Broadcast;
- Compensation program in the event any project vessels damage fishing gear; and
- Single Point of Contact (SPOC).

HMDC will also coordinate with DFO, St. John's, and the FFAW to avoid any potential conflicts with survey vessels that may be operating in the area. HMDC commits to ongoing communications with other operators with active seismic programs within the general vicinity of its seismic program to minimize the potential for cumulative effects on the VECs.

While this EA covers the Project from 2013 to EF, details on any post-2013 surveys will be provided in EA validation documents to be submitted to the C-NLOPB. For seismic projects conducted beyond

2013, this EA will be updated accordingly if it is determined the project differs substantially from the activity assessed herein.

5.9 Residual Effects of the Project

A summary of the Project's residual effects on the environment, in other words those effects that remain after mitigations have been instituted, are shown in Table 5.19. HMDC's seismic program is predicted to have *no significant effects* on the VECs.

Table 5.19 Significance of Potential Residual Environmental Effects of HMDC's Proposed Seismic Program on VECs in the Study Area.

Valued Ecosystem Component: Fish and Fish Habitat, Fishery, Seabirds, Marine Mammals and Sea Turtles, Species at Risk				
Project Activity	Significance Rating	Level of Confidence	Likelihood [a]	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
Sound Emissions and Receivers				
Air sources	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Picket vessel	NS	3		
Supply Vessel	NS	3	-	-
OBC	NS	3	-	-
Helicopter	NS	3	-	-
Echosounder	NS	2-3	-	-
Side Scan Sonar	NS	2-3	-	-
Boomer	NS	2-3	-	-
Vessel Lights	NS	3	-	-
Vessel Presence				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Helicopter Presence	NS	3	-	-
Accidental Releases	NS	2-3	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

Level of Confidence: based on professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgment:
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

[a] Considered only in the case where 'significant negative effect' is predicted.

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Appendices

Appendix 1: Most Recent Grand Banks Seismic EA (LGL 2012, electronic version)

See attached disc (if using hard copy of this HMDC EA) or download from http://www.cnlopb.nl.ca/pdfs/huskyenergy/eareport.pdf (if using electronic copy of this HMDC EA)

Appendix 2: SPOC (and FLO) Protocols, Procedures and Reporting Forms

See attached One Ocean Guidelines

Appendix 1: Most Recent Grand Banks Seismic EA (LGL 2012, electronic version)

See attached disc.

Appendix 2: SPOC (and FLO) Protocols, Procedures and Reporting Forms

One Ocean Protocol for Seismic Survey Programs in Newfoundland and Labrador

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One Ocean

In the province of Newfoundland and Labrador, a unique model has been developed to facilitate effective communication between the offshore fishing and petroleum sectors. In 2002, One Ocean was established as a voluntary, inter-industry liaison organization providing a neutral and practical medium for information exchange. The model promotes mutual awareness and understanding of industry operational activities and its proactive approach to address areas of potential concern is enhanced through its commitment to cooperation and transparency.

One Ocean initiates industry specific activities to meet regional challenges and participates in Research and Development projects relating to potential environmental effects of the fishing and petroleum industries to ensure sustainable and safe practices in the marine environment. Research entities are referenced in Appendix B.

The organization consists of a Chairperson, Secretariat, Industry Board and Working Group. The One Ocean Industry Board is a core component of the organization and is comprised of equal, senior-level representation from the two industry sectors. Fishing industry members are represented by the Fish, Food and Allied Workers (FFAW) union and the Association of Seafood Producers (ASP). Petroleum industry members are affiliates of the Canadian Association of Petroleum Producers (CAPP). The Please see Appendix A for more information on One Ocean member entities.

One Ocean is an industry driven organization not mandated by government. Members identified the value of having industry regulators represented on the Board in the capacity of Official Observers including the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB), regulator for the offshore petroleum industry and Fisheries and Oceans Canada (DFO), regulator for the fishing industry. Other Official Observers include the Fisheries and Marine Institute of Memorial University of Newfoundland (Marine Institute) and the Canadian Coast Guard (CCG).

To enhance the functioning of One Ocean, the Industry Board appointed a Working Group in 2009 to provide recommendations and working level support. The Working Group consists of Industry Board entity members from the fishing and petroleum industries.

Please see http://www.oneocean.ca for more information.

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EXECUTIVE SUMMARY

In 2011, One Ocean reviewed fishing and petroleum industry practices and processes related to offshore seismic survey programs in Newfoundland and Labrador. The objective was to identify opportunities to better understand and improve operational processes that would mutually benefit both industries.

The results of the review are incorporated in this document, *One Ocean Protocol for Seismic Survey Programs in Newfoundland and Labrador*, (Seismic Protocol) and outline practices and processes to facilitate seismic survey program planning and execution for the provincial fishing and petroleum industries including:

1. A sequential overview of a seismic survey program process;
2. The qualifications, objectives, duties and responsibilities of a Fisheries Liaison Officer (FLO) and Single Point of Contact (SPOC);
3. One Ocean initiatives such as the *Risk Management Matrix Guidelines for the Utilization of Fisheries Liaison Officers and Fisheries Guide Vessels for the Fishing and Petroleum Industries of Newfoundland and Labrador* (Matrix), Vessel Monitoring System (VMS) access and Industry Consultations; and
4. Frequently Asked Questions on seismic survey programs.

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LIST OF ACRONYMS

2D	Two-Dimensional Seismic Surveys
3D	Three-Dimensional Seismic Surveys
4D	Four-Dimensional Seismic Surveys
Accord Acts	*Canada-Newfoundland Atlantic Accord Implementation Act*, the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act*
ASP	Association of Seafood Producers
CAPP	Canadian Association of Petroleum Producers
CCG	Canadian Coast Guard
CFV	Canadian Fishing Vessel
C-NLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
DFO	Fisheries and Oceans Canada
FFAW	Fish, Food and Allied Workers
FLO	Fisheries Liaison Officer
GGEG	Geophysical, Geological, Environmental and Geotechnical Program Guidelines
GPS	Global Positioning System
HSE	Health Safety and Environment
HUET	Helicopter Underwater Escape Training
HUEBA	Helicopter Underwater Escape Breathing Apparatus
MED	Marine Emergency Duties
NL	Newfoundland and Labrador
OCR	Onboard Client Representative
PIL	Petroleum Industry Liaison
ROC-MC	Marine Radio Operator's Certificate
SOCP	*Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment*
SPOC	Single Point of Contact
STCW	Standards of Training, Certification and Watch Keeping
VSP	Vertical Seismic Profiling
WHMIS	Workplace Hazardous Material Information System
WSS	Well Site Survey

1.0 INTRODUCTION

In 2011, One Ocean reviewed fishing and petroleum industry processes and practices for offshore seismic survey programs in Newfoundland and Labrador. The objective was to identify opportunities to better understand and improve operational processes that would mutually benefit both industries.

The results of the review are outlined in this document, *One Ocean Protocol for Seismic Survey Programs in Newfoundland and Labrador*, (Seismic Protocol) and reference streamlined information on suggested operational procedures and processes to facilitate planning and execution of seismic survey programs for the provincial fishing and petroleum industries.

The content of this Seismic Protocol is not meant to influence, form or be adopted by regulatory entities or referenced as a requirement. The Seismic Protocol is a property of One Ocean, strictly for information purposes and as such One Ocean members assume no liability for its use or application. One Ocean reserves the right to make changes to the Seismic Protocol without notice.

2.0 OFFSHORE SEISMIC SURVEY PROGRAM OVERVIEW

For reference purposes, One Ocean has developed a seismic survey program overview, providing insight on sequential processes and practices inclusive of but not exclusive to:

1. Information on proposed offshore seismic programs is frequently shared between fishing and petroleum industry members of One Ocean (Appendix A) in advance of formal and/or regulatory notices;

2. The Canada-Newfoundland and Labrador Offshore Petroleum Board, (C-NLOPB) is the regulator for the provincial offshore petroleum industry (Section 7.10). The C-NLOPB notifies relevant government departments and agencies, One Ocean and fishing industry representatives of proposed seismic survey activities and provides documentation regarding the program for review and comment;

3. The C-NLOPB begins its review process (Sections 7.10) and may consult with federal departments including Fisheries and Oceans Canada, (DFO) regulator for the fishing industry (7.11);

4. The proponent company (Operator) and/or fishing industry representatives: Association of Seafood Producers (ASP); Fish Food and Allied Workers (FFAW) union, may contact One Ocean to discuss planning details of the seismic survey program in preparation for consultation meetings (Section 3.2);

5. The Operator, One Ocean, ASP and the Petroleum Industry Liaison (PIL) at the FFAW (Section 3.1) schedule consultation meetings;

6. The Operator incorporates details of consultation meetings with the fishing industry and One Ocean, including proposed mitigation measures, into its environmental document and submits it to the C-NLOPB;

7. The fishing industry may submit comments to the C-NLOPB pertaining to the proposed seismic program;

8. Seismic survey initiatives developed by members of One Ocean (Section 3.0) are reviewed once the Operator is in a position to communicate timing, space and logistical details of the program to the fishing industry. This may occur at initial consultation or subsequent meetings;

9. The Operator and/or the fishing industry may contact One Ocean to provide assistance with items identified at consultation and/or subsequent meetings;

10. For 2D and 3D seismic programs, (other programs when deemed necessary) the Operator should contract a Fishery Liaison Officer (FLO) to support the program (Section 4.0). The FFAW provides FLO services and maintains an updated list of qualified FLOs and certification requirements;

11. The Operator will arrange for Notice to Shipping, including contact information for the Single Point of Contact (SPOC) [Section 6.0];

12. The Seismic Survey Contact List (Section 4.4; Appendix C) is completed by the Operator and shared with the fishing industry and One Ocean;

13. The PIL prepares a Summary Report on fishing activity for the FLO, including Vessel Monitoring System, (VMS) data (Section 3.4) for pre-departure;

14. The Operator and/or the FFAW will arrange for the provision of VMS data to the FLO while on board the seismic vessel on an as needed basis for the duration of the program;

15. Arrangements are made by the Operator and the FFAW for the FLO to board the seismic vessel;

16. Pre-departure tasks are completed and confirmed by the FLO and onboard Client Representative and reviewed with senior vessel crew (Section 4.4);

17. The FLO participates in pre-departure, Orientation/Safety session(s). The CAPP-FLO video (Section 3.6) is presented at this time;

18. The FLO commences offshore duties (Sections 4.6-4.10).

19. The FLO records activities, observations and communications three times a day in the Daily Report (Section 4.7) and submits it to the onboard Client Representative;

20. In the event of physical contact with fishing gear, (Section 4.9) the FLO will advise the onboard Client Representative and vessel Master, complete a Fishing Gear Incident Report (Appendix F) and submit it to the onboard Client Representative;

21. The onboard Client Representative will notify the Operator of the incident and the Operator will contact the SPOC, if needed and advise the C-NLOPB of the incident (Section 5.0). The Operator will notify the FFAW within 24 hours of the incident.

22. Communication between the Operator, the fishing industry and One Ocean is maintained on an as needed basis throughout the program;

23. At the end of the seismic program, the FLO or contracted Service Provider is responsible for providing the Operator with a complete record of FLO activities, observations and communications;

24. Upon completion of the offshore seismic survey program, the Operator may host a Close-out meeting with One Ocean and fishing industry representatives.

3.0 ONE OCEAN SEISMIC SURVEY INITIATIVES

In an effort to enhance cooperation, information exchange, mitigation measures and safe practices between the fishing and petroleum industries, One Ocean developed several projects that apply to offshore seismic survey programs.

3.1 Petroleum Industry Liaison Position

To provide effective technical capacity to the FFAW regarding the petroleum industry, an arrangement was undertaken by One Ocean in 2006 for the employment of a Petroleum Industry Liaison (PIL) at the FFAW. The principle objective of the PIL is to ensure the views and concerns of fish harvesters are considered by the offshore petroleum industry and regulators during the development, review and execution of exploration, development and production activities. The PIL is the main contact for petroleum related activities at the FFAW.

3.2 One Ocean Matrix

In 2010, One Ocean produced the *Risk Management Matrix Guidelines for the Utilization of Fisheries Liaison Officers and Fisheries Guide Vessels for the Fishing and Petroleum Industries of Newfoundland and Labrador* (Matrix). Fisheries Liaison Officer (FLO) participation in offshore seismic survey programs is outlined in C-NLOPB guidelines and is referenced in the Matrix. The use of Fisheries Guide Vessels (FGV) is offered as a consideration in the Matrix for transit and tow operations; not for seismic programs. The Matrix outlines considerations to advance industry consultations but does not in any way replace them. The Matrix is available on the One Ocean website: http://www.oneocean.ca

3.3 Vessel Monitoring System

One Ocean and Fisheries and Oceans Canada (DFO) have an arrangement to provide Vessel Monitoring System (VMS) information to petroleum company members of One Ocean. The VMS program at DFO Newfoundland Region provides a satellite based, near real time, positional tracking system of fishing vessels within the Canadian Exclusive Economic Zone (EEZ), as well as foreign and domestic vessels in the Northwest Atlantic Fisheries Organization (NAFO) Regulatory Area outside the 200 nautical mile limit. The ability to access current fisheries data (location of activity) is an important component in the development of operational plans for offshore petroleum related activities. The VMS data generated by DFO consists of coordinates only and does not divulge information of a confidential or sensitive nature. Please contact One Ocean for more information.

3.4 Canada-Newfoundland and Labrador Offshore Petroleum Board Map

In 2011, One Ocean requested the C-NLOPB incorporate Northwest Atlantic Fisheries Organization (NAFO) Divisions and Shrimp Fishing Areas (SFA) on its maps illustrating petroleum industry licenses. The map is an important tool to facilitate joint planning and information exchange between the fishing and petroleum industries regarding common offshore areas of operations. A link to the map is available on the One Ocean website: http://www.oneocean.ca

3.5 Canadian Association of Petroleum Producers Fishery Liaison Officer Video

In 2012, the Canadian Association of Petroleum Producers (CAPP) developed a ten-minute video to communicate the importance of FLO participation in offshore Newfoundland and Labrador exploration activities. The video highlights the role of the FLO and interaction with vessel crew and Client Representatives. The FLO Video is available on the One Ocean and CAPP websites: http://www.oneocean.ca
http://www.capp.ca/environmentCommunity/relationshipPartners/Pages/FishingIndustry.aspx

3.6 Fact Sheet for Non-One Ocean Petroleum Industry Members

The *Fact Sheet for Non-One Ocean Petroleum Industry Members* (Fact Sheet) was developed for non-One Ocean petroleum members to provide information on current practices and expectations between the fishing and petroleum industries in Newfoundland and Labrador. The Fact Sheet provides details on One Ocean, its initiatives and member contact information to facilitate effective communication on proposed offshore petroleum exploration activities.

3.7 Industry Consultations

The *One Ocean Protocol for Consultation Meetings: Recommendations for the Fishing and Petroleum Industries in Newfoundland and Labrador*, (Consultation Protocol) outlines recommendations for preparing and holding a consultation meeting as well as follow-up meetings. Its purpose is to streamline the process and expectations for both sectors. Joint industry consultation provides a valuable opportunity to effectively exchange information and facilitate understanding of each other's operational activities; especially time and location details. Information exchange has assisted the two industries in determining best operational time frames and mitigation measures. The Consultation Protocol is available on the One Ocean website: http://www.oneocean.ca

4.0 FISHERIES LIAISON OFFICER ACTIVITIES

Fisheries Liaison Officer (FLO) participation in offshore petroleum industry seismic survey programs is considered a practice of mitigation under the C-NLOPB's *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* for 2D and 3D seismic programs.

A FLO is engaged to monitor fishing and petroleum industry activities during offshore seismic survey programs. The FLO is tasked with identifying issues and offering advice that may prevent potential at-sea conflicts associated with time and space overlap between fishing and petroleum sectors. A FLO is stationed on board the seismic vessel for the duration of the seismic survey program to observe, record and report activities of and interactions between the seismic vessel and commercial fishing vessels to petroleum and fishing industry representatives.

As the liaison, FLOs will initiate and maintain communication with fish harvesters in the project area to gain insight on fishing activity and share details of the seismic survey program. At-sea communication with fish harvesters enables the FLO to collaborate with the onboard Client Representative and senior vessel crew to ensure effective planning and mitigate potential conflict. FLOs must have knowledge of fisheries and fishery operations, demonstrated communication and writing skills and possess valid training and certification to work offshore.

4.1 Objectives of the FLO Program

1. Provide information to identify potential at-sea conflicts with fishing activities during the offshore seismic program;
2. Build and maintain trust between the petroleum and fishing industries;
3. Provide the fishing industry and Operator with feedback on fisheries issues.

4.2 FLO Training and Certification Requirements

1. Marine Radio Operator's Certificate (ROC-MC);
2. Basic First Aid Certificate (or Marine Basic First Aid);
3. Marine Emergency Duties (MED) Certificate that includes:
    a. A1 Basic Safety;
    b. B1 Survival Craft;
    c. B2 Marine Firefighting; or
    d. Standards of Training, Certification and Watch keeping, (STCW) Basic Safety, Survival Craft, and Advanced Firefighting;
4. Seafarer's Medical Certificate;
5. Workplace Hazardous Material Information System (WHMIS) certificate;
6. Helicopter Underwater Escape Training (HUET) and Helicopter Underwater Escape Breathing Apparatus (HUEBA) training (if helicopter transfers are required).

4.3 FLO Qualifications

1. An ability to work independently and in a team environment;
2. Knowledgeable of offshore area fisheries and industry operations;
3. A working knowledge of seismic survey programs including vessels, equipment and operational routes;
4. An ability to initiate and maintain effective communication with fish harvesters, senior vessel crew and the onboard Client Representative during at-sea operations'
5. The capacity to assert authority and control in critical situations;
6. Ability to understand and interpret navigational charts;
7. Proficiency in offshore communication systems (radio, satellite telephones);
8. Ability to produce daily and weekly reports and other correspondence as required in either electronic and/or written format as requested by the Operator;
9. Marine Mammal and Seabird Observation training is an asset;
10. Possess a valid passport.

4.4 FLO Pre-Departure Preparation and Duties

1. The FLO will provide the onboard and/or shore-based Client Representative(s) with a pre-departure Summary Report, prepared by the Petroleum Industry Liaison (PIL), on fishing activity for the deployment and seismic survey program areas identifying approximate number of active fishing vessels, specie(s) actively harvested and gear type(s). Vessel Monitoring System (VMS) information should be included for reference;
2. The FLO will review the Summary Report with onboard and/or shore-based Client Representative(s) and senior vessel crew at pre-departure briefing;
3. The FLO and the onboard and/or shore-based Client Representative(s) will review and confirm information provided by the Operator in the Seismic Survey Program Contact List (Appendix C);
4. The FLO participates in pre-departure Orientation/Safety session(s); the CAPP-FLO video is presented at this time;
5. The FLO and the onboard and/or shore-based Client Representative(s) will review and confirm the Seismic Survey Program Check List provided by the Operator (Appendix D).

4.5 FLO Equipment

The Service Provider is responsible for supplying the FLO with:

1. Binoculars;
2. Laptop;
3. Camera;
4. Contact Information Sheet;
5. Daily/Weekly Report Forms;
6. Fishing Gear Incident Report Forms;
7. Fisheries information (As detailed in the EA and supplemented in Summary Report);

8. Copy of the One Ocean Seismic Protocol;
9. Copy of the One Ocean Matrix.

4.6 FLO Operational Responsibilities, Protocols and Communications

The FLO is the liaison between the commercial fishing industry and the petroleum industry during seismic survey programs. In the role of liaison, the FLO is tasked with identifying potential at-sea conflicts between fishing and petroleum operations. Specific activities include:

1. Stationed on the project seismic vessel, observe activities which may affect the fishing industry and petroleum operations;
2. Initiate and maintain radio contact with fishing boats in the area and ensure all communication with fishing vessels is conducted via the FLO;
3. Inform fishers nearby about the seismic survey program and provide coordinates and relevant spatial and temporal details;
4. Help identify/locate any fishing gear in and near the seismic survey program area so it can be avoided;
5. Determine gear type, layout, fishing plans (when in area, when leaving);
6. Advise bridge about best course of action to avoid gear and/or fishing activities;
7. Serve as initial contact if damaged gear is encountered, verify damage, help identify owners and file an incident report;
8. Regularly discuss/convey fisheries related aspects including changes in relevant fisheries, status of species quotas and closures with the onboard Client Representative;
9. Report to and confer with the onboard Client Representative regarding operational situations;
10. Attend regular operations briefings;
11. Attend safety meetings and participate in all relevant Health Safety and Environment (HSE) initiatives and procedures as requested;
12. Complete and submit a daily report (electronic/hardcopy) including all observations, communications and meetings attended to the onboard Client Representative;
13. Other duties as identified and approved through consultation with the Operator and Service Provider.

4.7 FLO Daily-Weekly Reports

The FFAW provides the FLO with a laptop containing electronically formatted Daily Report spreadsheets (Appendix E). The Daily Report is completed at three specific times per day and compiled for weekly reports. The spreadsheet captures specific information regarding activities, observations and communications for the project and area fisheries and is submitted daily to the onboard Client Representative. In addition to relevant information about the project and area fisheries, the Daily Reports supply relevant details of all fisheries-related gear observations (Section 4.8) and associated radio communication. Fishing gear incidents (Section 4.9) require a separate report but are recorded in the daily log.

4.8 Fishing Gear Observations Recording and Reporting

1. All fishing vessels and gear in the path of the petroleum exploration work should be avoided and clear areas pursued. Fish harvesters are not required to move their vessels or gear from the seismic survey program area and should not be told to do so;
2. If personnel onboard the seismic and/or scout vessel observe fishing gear (abandoned, adrift or active) it should be communicated to the FLO. Gear should not be touched / retrieved by project personnel as it is illegal for anyone but the gear owner to move the gear;
3. If the scout vessel makes the observation, personnel should record exact positions and name or Canadian Fishing Vessel (CFV) number on the gear (buoy/highflyer) and report it to the FLO;
4. The FLO will communicate with fishing vessels in the vicinity in an attempt to identify the gear owner;
5. If the CFV number is known, the FLO may be able to identify and contact the owner;
6. If identification and contact with the gear owner is successful, the FLO will attempt to determine the plans/schedule of the gear owner with respect to the gear and will encourage the owner to communicate with the FLO at sea;
7. If it is not possible to contact the gear owner the exploration vessel should attempt to work in another area and return to the location at a later time;
8. The FLO will record the information in the daily report and submit it to the onboard Client representative.

4.9 Fishing Gear Incident Recording and Reporting

1. Commercial fisheries gear incidents/accidents means a physical interaction versus an observation;
2. If there is any indication a project vessel or its equipment made contact with fishing gear it should be communicated to the FLO immediately;
3. The FLO should contact the onboard Client Representative and vessel Master as soon as possible after discovery of the incident;
4. The FLO will take all reasonable action to prevent any further or continuing damage;
5. If possible, photograph the gear or gear debris in the water and after recovery;
6. If necessary, secure and retain any of the gear debris;
7. Record the incident in the Daily Report;
8. File a Fishing Gear Incident Report (Appendix F) and distribute to the onboard Client Representative.

5.0 Regulatory Requirements for Reporting an Incident

The Canada-Newfoundland Offshore Petroleum Board (C-NLOPB) Guidelines state contact with fishing gear must be reported immediately even if no damage to the gear has occurred. The C-NLOPB maintains a 24-hour answering service at (709) 682-4426 for this purpose and can also be contacted during working hours at (709) 778-1400. Reports on contacts with fishing gear should include the exact time and location of initial contact, loss of contact and a description of any identifying markings on the gear. Incidents will be reported by the onboard Client Representative to the Operator who will report it to the C-NLOPB per the Board's incident reporting guidelines and/or the authorization requirements.

6.0 Single Point of Contact (SPOC)

Single Point of Contact (SPOC) is referenced as a practice of mitigation under the C-NLOPB's *Geophysical, Geological, Environmental and Geotechnical Program Guidelines*:

> "Where more than one survey operation is active in a region, the operator(s) should arrange for a 'Single Point of Contact' for marine users that may be used to facilitate communication."

Operator's may designate a SPOC internally or contract for the service. The Operator will notify relevant entities of the designated SPOC and provide contact information prior to the seismic survey program start-up. Details of the SPOC will also be included in Notices to Shipping.

As the land-based fisheries contact for the Operator, the SPOC provides support to the offshore project as requested by the Operator. The role may include but is not limited to:

1. File Notices to Shipping;
2. For the purpose of determining fishing plans, if the FLO is unable to identify and/or contact a gear owner(s) the SPOC may be asked to assist;
3. In the event of a gear incident and the FLO is the initial contact, the SPOC may be requested to:
    a. Identify and/or contact owner and notify of damage;
    b. Use the FLO's Incident Report Form as a reference to investigate details of the incident (dates, location activities) with the fish harvester, FLO and/or onboard Client Representative and obtain information on other vessels in the area at the time;
    c. Provide fish harvester with relevant form for the claim and follow through on its submission;
    d. Provide a comprehensive report to the Operator.

4. In the event the SPOC is contacted directly by a fish harvester claiming gear loss/damage in relation to the seismic survey program, the SPOC will document information on the fish harvester and incident and contact the Operator. The SPOC may be requested to:
    a. Confirm if the FLO and/or onboard Client Representative are aware of the incident.

5. If the FLO has reported the incident, the SPOC may be asked to:
    a. Use the Incident Report Form as a reference to investigate details of the incident (dates, location activities) with the fish harvester, FLO and/or onboard Client Representative and obtain information on other vessels in the area at the time;
    b. Provide fish harvester with relevant form for the claim and follow through on its submission;
    c. Provide a comprehensive report to the Operator.

6. If the FLO and/or onboard Client Representative are unaware of the incident the SPOC may be asked to:
    a. Coordinate with the FLO and/or onboard Client Representative to obtain information on the seismic vessel location, timing and activity as well as details of other vessels in the area to determine if the incident is related to the seismic survey program;
    b. Provide fish harvester with relevant form for the claim and follow through on its submission;
    c. Provide a comprehensive report to the Operator.

The reporting of all fishing gear incidents to the C-NLOPB will be conducted by the Operator as stated in Section 5.0.

7.0 FREQUENTLY ASKED QUESTIONS ABOUT SEISMIC SURVEYS

7.1 How Does Seismic Surveying Work and how is the Information Used?

Seismic surveys to visualize rock strata below the seabed are a key component of the petroleum exploration industry. Marine seismic surveying applies the science of sound energy and seismology to map geological structures under the seabed. Towed devices produce bursts of acoustic (sound) waves that travel through the water and then bounce back to receivers that measure the strength and return time of each wave. These surveys are the first step in a process of physical exploration for oil and gas which can lead to exploration and delineation drilling and, if economically viable reserves of oil or gas are found, production and transportation of these reserves to market.

Seismic surveys of various types and extent have been taking place in the Newfoundland and Labrador offshore since the 1960's. Close to two million line kilometers of these surveys have been carried out around the island of Newfoundland and along the Labrador coast during that time. As elsewhere in the world, these surveys range from local and specialized surveys within a few kilometers or less of drilling or production platforms to surveys over thousands of square kilometers of seafloor in the search for promising geological formations.

In marine seismic surveys, reflected sound waves, called signals, are combined and interpreted electronically or reproduced on graphic paper recorders. This data gives the company information on the depth, position and shape of underground geological formations that may contain crude oil or natural gas.

To reach the desired depths below the seabed, seismic surveys use high energy, low frequency sound waves that can penetrate more than 6,000 meters (20,000 feet) below the sea floor. The survey results do not show definitely whether oil or gas is present, but they do indicate where hydrocarbons are likely to be found and can help narrow the search area. If the information indicates rock formations or geological structures that could contain hydrocarbons, a company may decide to seek approval to drill an exploratory well.

7.2 What Equipment is used for a Seismic Surveys?

Marine seismic surveys require special ships 75 to 90 meters long (250 to 300 feet) with a crew of between 30 and 65 mariners, survey engineers and technicians. During a survey, the seismic vessel travels approximately 5 knots (9 kilometers) per hour over a predetermined survey pattern and tows:

- One or two sets of underwater equipment immediately behind the ship to generate sound waves;
- One or several long cables or "streamers," each containing several hundred evenly spaced individual listening devices called hydrophones.

The position of the vessel and the signal recording equipment must be closely controlled to ensure geological features can be pinpointed accurately. Modern seismic vessels carry advanced navigation and acoustic systems that permit very accurate positioning. Each streamer can be up to 6000 meters (3.2 miles) long and is towed at a depth of 6 to 12 meters (20 to 40 feet) below the surface to reduce the effect of surface waves. Modern streamers carry multiple global positioning system (GPS) sensors to more accurately establish their position in relation to the earth's surface and the vessel. In the most technically advanced seismic surveys, up to eight streamers are towed at the same time, each about 50 to 120 meters (180 to 400 feet) apart.

7.3 Are There Different Types of Seismic Surveys?

Oil and gas companies routinely carry out two types of seismic programs. Two dimensional (2-D) surveys use one sound source and one set of receivers. These surveys are usually conducted along a grid with parallel lines up to five kilometers apart. The technology provides a general picture of the geological characteristics of an area, including type and size of structures present.
Three-dimensional (3-D) surveys use two sound sources and multiple sets of receivers. They are usually carried out over a much smaller grid to get more detailed information about geological features. The pattern of survey lines used by industry is similar to a "racetrack" pattern to ensure the survey is efficient as possible and for control of the steamers towed behind the vessel.

Electromagnetic surveys are a relatively new technique used in deep water (>500m) to discriminate between water and petroleum in known reservoir formations. This involves placing a grid pattern of receivers, in degradable weights, on the seafloor and towing low frequency source of alternating current near the seafloor (~ 50 m) over the area and mapping the induced electrical resistivity.

Exploration for crude oil and natural gas is not the only reason for conducting seismic surveys. For example, natural gas under pressure in shallow geological formations could present a safety hazard during the early stages of drilling before blowout preventers are in place. Therefore, shallow seismic surveys (Well-site/Geo-hazard) are conducted around every proposed well site to find out if any subsurface features could cause problems. Well-site/Geo-hazard surveys use low sound sources and are usually a very short duration.

Four-dimensional (4D) seismic surveys have been conducted over a producing field at various stages of its producing life. The objective is to determine the changes occurring in the reservoir, over time, as a result of hydrocarbon production or injection of water or gas into the reservoir by comparing repeated datasets. 4D data indicates a shift from a purely geophysical interpretation tool to a reservoir management tool, which can be used to assess remaining hydrocarbon volumes and optimize the recovery strategy.

Vertical Seismic Profiling, (VSP) measures acoustic waves between a well bore and the surface. VSP permits calibration of surface seismic data and provides “images” within the vicinity of the well bore that could otherwise not be defined by surface seismic data. VSP consists of an airgun array sound source, typically less powerful than those used during routine seismic surveys, deployed at locations near a drill rig with receivers placed in the well. The purpose of the technique is to tie in or ground-truth the geological data with geophysical information. VSPs vary in type (Zero-offset; Offset, Walkaway) in the positioning of the sound source in proximity of the well bore and its distance from the receivers; zero-offset source is at the drill rig and a walkaway source is 1 or 2km from the drill rig as the survey progresses. VSP Acquisition times are dependent on the type of VSP and acquisition tool but they normally vary between 8-36 hours per well.

7.4 Why Do Seismic Survey Programs Occur During Peak Fishing Season?

The duration of a seismic survey program (2D, 3D) is typically 30 to 60 days. Since rough seas affect the quality of the data collected, programs are usually scheduled from June to September in optimal weather conditions as seismic vessels cannot operate effectively if waves are higher than about 3 meters (10 feet).

7.5 How is Seismic Data Collected?

As the vessel moves along the survey path, computers control the simultaneous discharge of a brief pulse of compressed air from the sound sources, (traditionally called air guns) usually once every 10 seconds. The generated sound waves travel down through rock formations under the sea floor. When they encounter a boundary between different formations, some sound waves are reflected toward the surface where individual hydrophones in each streamer intercept them. Signals from each hydrophone are sent back to high-capacity computers on board the vessel that record, check and store the large volumes of seismic data collected.

7.6 Why Do Seismic Vessels Request a Large At-Sea Berth During the Program?

Operators make every effort to communicate the presence of the seismic survey ship to other vessels in the area before and during the survey. Company representatives communicate the location of the planned seismic program through official radio broadcasts and notices to mariners. A wide berth is often requested as the survey ship cannot change direction quickly when it is towing equipment; deployed streamers can range from 6 to 8km in length and 1 to 2km in width.

7.7 How is the Seismic Survey Information Used?

The collected data go through several processing steps to improve the quality of the signals and filter out background “noise.” Geophysicists then interpret the information to develop a detailed picture of the structures and rock formations in the survey area. The results of the survey are interpreted lines and maps showing geological features. Companies look for specific features that indicate whether oil or gas might be present. These include former sedimentary basins, buried former beaches, faults and ancient reefs that can act as underground traps for crude oil and natural gas.

7.8 Why Do Operators Repeat Seismic Surveys in the Same Offshore Area?

Seismic surveying is an essential part of exploring for oil and gas. 2D surveys are typically the first step in the process and normally cover wide areas with wider line spacing between the streamers. The data collected will help Operators decide if the features found do not warrant further interest or additional surveys may be needed to better define the structures. Usually if more information is needed, Operators will conduct a 3D seismic survey program. A 3D survey is more localized and intense in terms of coverage and is focused on geological areas of interest identified through analysis of 2D data.

7.9 Who Authorizes Seismic Survey Programs and what is the Process? [1]

The Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) is the regulator for the offshore petroleum industry. Oil and Gas companies must obtain authorization from the C-NLOPB before conducting seismic survey work in provincial offshore areas. The regulatory board establishes the conditions for the survey program and the environmental protection conditions that must be followed.

Regulatory authority for seismic surveys (Geophysical Program Operation) in the Newfoundland and Labrador Offshore Area is pursuant to the *Canada-Newfoundland Atlantic Accord Implementation Act*, S.C. 1987, c.3 and the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act*, R.S.N.L. 1990, c. C-2, (Accord Acts). Authorization for seismic survey programs (2-D, 3-D, Vertical Seismic Profiling, Electromagnetic and Well-site/Geo-hazard surveys) under the Accord Acts follow Section 138 (1) (b); Section 134 (1)(b) and Section 139 (4) (b).

7.10 How Do Fish Harvesters Communicate with the C-NLOPB Regarding Proposed Seismic Survey Programs and Mitigation Practices?

Public participation for seismic survey programs is at the discretion of the C-NLOPB. The Geophysical, Geological, Environmental and Geotechnical Program Guidelines, (GGEG) recommend Operators undertake consultation meetings at the early stage of the process with the fishing industry including the FFAW, ASP and One Ocean. The Operator must report on consultations and how issues, if any, were addressed; the C-NLOPB determines adequacy of consultation meetings.

[1] The *Canadian Environmental Assessment Act* does not apply to Seismic Survey Programs. References in this document pertaining to seismic authorization and environmental criteria reflect C-NLOPB legislation at the time this document was written and may require future amendments.

The GGEG lists mitigations to be employed to reduce/eliminate potential impacts to fish and commercial fishery operations. All mitigations a proponent will implement for a seismic survey program are outlined in the environmental document; examples include:

1. Avoidance of heavily fished areas;
2. Timing and spatial avoidance to reduce conflict with DFO Research Vessels surveys;
3. Notice to Mariners;
4. Fisheries Liaison Officer (FLO);
5. Communication with Fishing Industry;
6. Gear Compensation Program;
7. Single Point of Contact (SPOC);
8. Authorization may include additional, warranted mitigations:
    a. The C-NLOPB considers concerns/issues raised by fishers when issuing seismic survey authorization; concerns raised by fishers have resulted in changes to program design (e.g., timing delay to avoid spawning/migration times).

7.11 What is the Role of DFO in Seismic Survey Programs?

The C-NLOPB may request DFO to provide expert advice on environmental criteria related to marine seismic exploration projects. The *Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment* (SOCP) was developed by federal and provincial experts in marine regulatory policy and practice and is based upon a DFO sponsored peer review of seismic surveys by Canadian and international science experts with the objective to develop scientific conclusions and advice on the potential impact of seismic sound on marine life. The SOCP specifies the mitigation requirements that must be met during the planning and conduct of marine seismic surveys to minimize impacts on life in the oceans.

APPENDIX A: ONE OCEAN FISHING AND PETROLEUM MEMBERS

A.1 Association of Seafood Producers

ASP is a not-for-profit corporation representing the interests of seafood producers generally in Newfoundland and Labrador. ASP provides effective input into policy decisions and regulatory matters at all levels of government, engages in media relations on matters of interest to industry, and participates in programs of direct benefit to the fishing industry including research and development. ASP is also the lead processors' representative for collective bargaining negotiations for fish prices under provincial legislation. ASP Members operate processing plants throughout rural Newfoundland and Labrador and source raw material mainly from independent harvesters in the NL inshore fishery, as well as externally. Members are also involved in directed harvesting activities in the offshore fishery. Most NL seafood is sold in international markets including the US, Europe, Africa, and Asia.

A.2 Fish, Food and Allied Workers Union

Fish harvesters and fish plant workers in Newfoundland and most of Labrador are represented by one organization – the FFAW. The fishing industry provides over 22,000 direct employment opportunities in the province and has an annual value of $ 1 billion. There are 40 species of fish harvested in NL; the most lucrative being snow crab and shrimp. Together, these fisheries represent close to 80% of the provincial landed value and are harvested in close proximity to existing petroleum installations and areas of exploration.

A.3 Canadian Association of Petroleum Producers

The Canadian Association of Petroleum Producers (CAPP) represents companies, large and small, that explore for, develop and produce natural gas and crude oil throughout Canada. CAPP's member companies produce more than 90 per cent of Canada's natural gas and crude oil. CAPP's associate members provide a wide range of services that support the upstream crude oil and natural gas industry. Together CAPP's members and associate members are an important part of a national industry with revenues of about $100 billion-a-year. CAPP has offices in St. John's, Newfoundland and Labrador, Halifax, Nova Scotia, Calgary, Alberta and Ottawa, Ontario.

A.4 One Ocean Working Group

To enhance the functioning of the One Ocean organization, a Working Group was formed in 2009. One Ocean Working Group members are representatives of the fishing and petroleum entities on the One Ocean Board and appointed by its Directors. At the direction of the Board, the Working Group reviews joint industry initiatives providing insight and perspective at the working level and brings its considerations and recommendations to the Board. This process optimizes the Board's ability to make informed decisions in a timely and comprehensive manner when it convenes four times a year.

APPENDIX B: RESEARCH ENTITIES

There are several entities which facilitate and fund petroleum related research and development projects. The scope of the research varies from international, national to local initiatives and includes health and safety, security, social responsibility and physical and biological environmental studies. For more information on these organizations and to access reports on seismic research, the following links are provided for reference:

- Petroleum Research Newfoundland and Labrador: http://www.pr-ac.ca
- Environmental Studies Research Funds: http://www.esrfunds.org
- Offshore Energy Environmental Research: http://www.offshoreenergyresearch.ca
- International Association of Oil and Gas Producers: http://www.ogp.org.uk

Appendix C: Seismic Survey Program Contact List

SEISMIC SURVEY PROGRAM CONTACT LIST	
PROGRAM	
Program Name:	
Program Date: (day/month/year) Start:	To:
SEISMIC VESSEL	
Name:	Master:
Bridge Cell:	Master Cell
Fax Cell:	Inmarsat:
SCOUT/CHASE VESSEL	
Name:	Master:
Bridge Cell:	Master Cell
Fax Cell:	Inmarsat:
OTHER VESSEL	
Name:	Master:
Bridge Cell:	Master Cell
Fax Cell:	Inmarsat:
FISHERIES LIAISON OFFICER (FLO)	**ONBOARD CLIENT REPRESENTATIVE**
Name:	Name:
Email:	Email:
Contact Number:	Contact number:
Vessel Aboard:	Vessel Aboard:
SINGLE POINT OF CONTACT (SPOC)	**PETROLEUM INDUSTRY LIAISON**
Name:	Name:
Email:	Email:
Contact Number:	Contact number:
OPERATOR ENVIRONMENTAL LEAD	**OPERATOR REGULATORY ADVISOR**
Name:	Name:
Email:	Email:
Contact Number:	Contact number:
Address:	Address:

Appendix D: Seismic Survey Program Check List

SEISMIC SURVEY PROGRAM CHECK LIST		
PROGRAM		
Program Name:		
Program Date: (day/month/year) Start:	To:	
CHECKLIST: Onboard Client Representative (OCR) and Fisheries Liaison Officer (FLO)		
Contract Agreement for FLO services complete; required certification confirmed	FLO □	OCR □
Confirm FLO Objectives, Operational Responsibilities, Protocols and Communications	FLO □	OCR □
Confirm reporting protocol for fishery gear observations and incidents with Operator and Client Representative		
Confirm FLO has required equipment: Laptop Binoculars Camera Fisheries Summary Report Seismic Survey Contact List Daily and Weekly Report Forms Incident Report Forms One Ocean Seismic Protocol One Ocean Matrix	FLO □	OCR □
Review Summary Report prepared by PIL	FLO □	OCR □
Confirm the provision of daily VMS data to the CR and FLO by the Operator	FLO □	OCR □
Participate in pre-departure orientation/safety meeting	FLO □	OCR □
Confirm Seismic Survey Program Contact List has been received and information verified		
Confirm FLO has been introduced to Vessel Master and CR	FLO □	OCR □
Participate in CAPP, FLO Video presentation at pre-departure	FLO □	OCR □

Appendix E: The Daily Report Spreadsheet

1. Name of FLO
2. Date and time of entry (three specific times 0600, 1200 and 1800)
3. Name of Seismic Vessel
4. Seismic Program
5. Latitude
6. Longitude
7. Activity of Seismic Vessel
8. Fishing Activity
9. Name of Fishing Vessel
10. Number of Fishing Vessel
11. Vessels Contacted
12. Activity of Fishing Vessel
13. Water Depth
14. Gear Type
15. Weather/Wind
16. Visibility
17. Sea State
18. Incidents
19. Comments

Fishing Gear Observations:

20. Time of sighting
21. Gear Type and Quantity (if known)
22. Latitude and Longitude
23. Owner (if known)
24. Condition of gear (active, abandoned or adrift)
25. Type of Communication made (observation, radio, information relayed from a project vessel).

Appendix F: Fishing Gear Incident Report Form

1. Exploration Vessel Name:
2. Did fishing gear appear to be damaged by the contact? Y N
3. Person completing report:
4. Position
5. E-mail/Phone No:
6. How was incident discovered and by whom:
7. Date of incident:
8. Time of incident/discovery:
9. Location of the incident: Lat: Long:
10. Name of fishing vessel (if known):
11. CFV No (on gear/buoy):
12. Vessel Skipper/Owner:
13. Address:
14. Telephone/Fax No:
15. Wind / weather / visibility / sea state at time of incident or discovery:
16. Describe the type and quantity gear recovered (including any identifying marks / numbers, etc.):
17. Describe what the exploration vessel was doing at the time of the incident and retain any data on the ship's positions during the preceding 24 hours:
18. Describe what the fishing vessel was doing at the time of the incident:
19. Draw a sketch/diagram showing the position of the exploration vessel/gear in relation to the gear, fishing vessel:
20. Note if photographs were taken:
21. Describe any measures the exploration vessel took to recover gear, or to stop or limit the damage or loss:
22. Names of any other vessels in the area before/during the time of the incident:
23. Describes steps taken to notify fishing vessel or others:
24. Other pertinent information / remarks (use extra sheets if necessary):