5.0 POTENTIAL ENVIRONMENTAL EFFECTS FROM EXPLORATION AND PRODUCTION ACTIVITIES

The SEA has focused on potential effects that are associated with exploration and production activities, specifically sounds, drill muds, miscellaneous discharges, vessel, traffic, animal attraction and accidental events. Mitigation for potential effects is considered, as are potential cumulative effects.

5.1 Sound and Noise Effects

Anthropogenic sound sources have been grouped into six categories: shipping, seismic surveying, sonars, explosions, industrial activity and miscellaneous (NRC 2003a). Effects of underwater sound are based on the *Source - Path - Receiver* concept. The acoustic energy or sound originates with a source. Sound radiates outward from the source and travels through the water as pressure waves. The sound level decreases with increasing distance from the source. The ability of a marine animal to receive sounds is dependant upon the degree of propagation loss between the source and the receiver the hearing abilities of the animal and the amount of natural ambient or background sound in the surrounding sea (LGL 2005b).

A marine animal's ability to detect sounds produced by anthropogenic activities depends on the amount of natural ambient or background sound (LGL 2005b). Wind, thermal sound, precipitation, vessel traffic and biological sources all contribute to ambient sound. Ambient sound is highly variable on oceanic continental shelves and this may result in considerable variability in the range at which marine animals can detect anthropogenic sounds.

There are various potential effects of exposure to sound from seismic and other sources that can be characterized as pathological, physiological or behavioural. The following section will provide an overview of the scientific information on the effects of sound to marine animals.

5.1.1 Invertebrates

The literature covering the effects of seismic sound and noise on invertebrates is limited and incomplete. Much of the existing scientific literature is difficult to compare and draw concrete conclusions as a result of inadequate documentation on measurement methods and units. The end result is that the interpretation of many of the reports with respect to the effects of sounds on invertebrates may be considered to be subjective.

Snow crab eggs were exposed to 221 dB at 2 m in a study and showed possible signs of retarded development (Christian et al. 2004). However, as the eggs are carried by the female and are not pelagic, they are not likely to be exposed at this range or intensity. Pearson et al. (1994) found no significant effects were detected on Dungeness crab larvae exposed to peak levels of 230 dB re 1 μ Pa at a distance of 1 m. This suggests that crab larvae and perhaps other invertebrates (e.g., shrimp) without air pockets are more resistant to the effect of airguns than are fish eggs and larvae. Rather than being sensitive to pressure changes, invertebrates appear to be more sensitive to particle displacement. Decapods, such as crabs, have an array of hair-like receptors in and on their body surface, which could potentially respond to water or substrate displacements. Crustaceans appear to be most sensitive to low frequency sounds, less than 1,000 Hz (Budelmann 1992; Popper et al. 2001). A number of physiological studies of statocysts of marine crabs suggest that some of these species are potentially capable of sound detection (Popper et al. 2001). There are no indications of acute or mid-term mortality on adult snow crab due to seismic activity, nor does there appear to be any effect on the survival of embryos carried on the female or on the locomotion of the larvae after hatch (DFO 2004e). A follow-up review of this study will focus on crab tissue damage and embryo survivability (SPANS, pers. comm.).

Brown shrimp (*Cragnon cragnon*) in the Wadden Sea were exposed by Webb and Kempf (1998) to a 15 gun array (volume 480 cubic inches with source levels of 190 dB re 1µPa at 1 m depth). There was no evidence of mortality or reduced catch rates for the shrimp. The authors attributed the lack of effects to the absence of gas-filled organs and a rigid exoskeleton.

Behavioural effects of exposure of caged cephalopods (50 squid and two cuttlefish) to sound from a single 20-inch airgun have been reported (McCauley et al. 2000a). The behavioural responses included squid firing their ink sacs and moving away from the airgun, startle responses and increased swimming speeds. No squid or cuttlefish mortalities were reported as a result of these exposures to the airgun sources.

Guerra et al. (2004) indicated that two incidents of multiple stranding of the giant squid (*Architeuthis dux*) along the north coast of Spain appeared to be linked to geophysical seismic surveys in the Bay of Biscay. Evidence of acute tissue damage was presented and the authors speculated that one female with extensive tissue damage was affected by the impact of acoustic waves. No detail with respect to the seismic sources, locations and durations of seismic exposure were provided, so limited conclusions can be drawn from this study.

Egg-bearing female snow crabs (*Chionocetes opilio*) were caught, caged and subsequently exposed to seismic energy released during a commercial seismic Survey off Cape Breton, Nova Scotia. Both acute and chronic effects on the adult female crabs, embryos and larvae hatched from the eggs were studied (DFO 2004e). Three definitive observations resulted from this study:

- the seismic survey did not cause any acute or chronic (five months) mortality of the crab, or any changes to the feeding activity of the treated crabs being held in the laboratory;
- neither the survival of embryos being carried by the female crabs during exposure nor the locomotion of the larvae after hatch appeared to be affected; and
- there was acute soiling of gills, antennules and statocysts of the crabs at the exposure site but after five months, all structures had returned to their clean state.

Christian et al. (2004) conducted a behavioural investigation during which caged snow crabs were positioned 50 m below a seven-gun array. Observations on the crabs' responses to seismic shooting were recorded by remote underwater camera. No obvious startle behaviours were observed.

Benthic invertebrates are less likely to be affected by seismic activity because few invertebrates have gas-filled spaces and benthic species are usually more than 20 m away from the seismic source. The resilience of various invertebrates has been tested by exposing them at a short distance to an active airgun (Table 5.1). Lobsters are thought to be resilient to seismic activity because decapods lack the gas-filled voids that would make them sensitive to changes in pressure. Mortality and development rates of Stage II Dungeness crab larvae exposed to single discharges from a seismic array were compared with those of unexposed larvae. No statistically significant differences between the exposed and unexposed larvae were observed with respect to immediate and long-term survival and time to molt, even for those exposed larvae within 1 m of the seismic source (Pearson et al. 1994).

Table 5.1 Observation from Exposures of Marine Macroinvertebrates to Air Sleeves at Close Range

Organism	Exposure Distance from Air Sleeve (m)	Estimated Exposure Level (dB re 1 µ Pa)	Observed Response	Reference
Iceland Scallop (*Acequipecten irradians*)	2	217	Shell split in 1 of 3 tested	Matishov 1992
Sea Urchin (*Strongylocentrotus droebachiensis*)	2	217	15% of spines fell off	Matishov 1992
Mussel (*Mytilus edulis*)	0.5	229	No detectable effect within 30 days	Kosheleva 1992
Periwinkle (*Littorina* spp.)	0.5	229	No detectable effect within 30 days	Kosheleva 1992
Crustacean (*Gammarus locusta*)	0.5	229	No detectable effect within 30 days	Kosheleva1992
Brown Shrimp (*Cragnon cragnon*)	1	190	No mortality	Webb and Kempf 1998

Noise generated during removal of the wellhead and other infrastructure is the primary disturbance associated with decommissioning and abandonment activities. Explosives are sometimes used for difficult wellhead removal (but only if mechanical severance fails). It is a requirement that operators have authorization from C-NLOPB before explosives are used. These activities occur directly at the well site and are usually of short duration.

5.1.2 Fish

5.1.2.1 Behavioural Effects

Behavioural effects of seismic activity on marine fish may include avoidance behaviour, increased swimming speeds, disruption of reproductive behaviour, and alteration of migration routes (McCauley et al. 2000a, 2000b). Noise generated by seismic activity may also cause some species to avoid the zone of influence around the seismic vessel.

Many finfish species display an alarm response of tightening schools, increased swimming speed and moving towards the sea floor at levels between 156 to 168 dB re 1m (McCauley et al. 2000b). McCauley et al. (2000a) studied the responses of fish contained within a 10 x 6 x 3 m cage to a nearby operating airgun. These studies indicated that the effects to fish from nearby airgun operations might include:

- a startle response (C-turn) to short range start up or high level airgun signals. A greater startle response was observed for smaller fish;
- evidence of alarm responses that were more noticeable for received airgun level above approximately 156 to 161 dB re 1 µPa mean squared pressure;
- a lessening of severity of startle and alarm responses through time (habituation);
- an increased use of the lower portion of cage during airgun operation periods;
- the tendency in some trials for faster swimming and formation of tight groups correlating with periods of high airgun levels;
- a general behavioural response of fish to move to bottom, centre of cage in periods of high airgun exposure (for levels greater than 156 to 161 dB re 1 µPa (ms));

- no significant measured stress increases which could be directly attributed to airgun exposure; and
- evidence of damage to the hearing system of exposed fishes in the form of ablated or damaged hair-cells although an exposure regime required to produce this damage was not established and it is believed such damage would require exposure to high level airgun signals at short range from the source.

McCauley et al (2000b) indicated that a level of 156 dB re 1m can be detectable between 3 and 5 km from a 3D array (2,678 cu in 100 to 120 m of water). As a result, alarm responses could be expected to occur 3 to 5 km from a seismic vessel, with active avoidance behaviour beginning at distances of 1 to 2 km from a source of this level (Mccauley et al. 2000b).

Most schools of fish will not show avoidance if they are not in the path of the approaching seismic vessel (Davis et al. 1998). Observed responses of schooled fish indicate that they are quite variable and depend on species, life history stage, current behaviour, time of day, whether the fish have fed and how the sound propagates in a particular setting. Schools that the vessel passes over may show lateral avoidance or tighten and move towards the bottom. Fish moving towards the seabed appears to be a common response to seismic activity (Davis et al. 1998). Seismic activity has also been shown to reduce the density of demersal species several kilometres from the source, in up to 250 m of water (Engås et al. 1996).

Pearson et al. (1992) studied the effect of sound on rockfish (*Sebastes* spp.) contained in a 4.6 by 3.6 m cage deployed at the water surface. The fish were exposed to signals produced by a 100 cui (1,639 cm) airgun deployed at 6 m depth and operated at a 10 s rate. The fish began milling in increasingly tighter schools with increasing airgun levels, schools collapsed to the cage bottom when airgun operations commenced, and remained stationary near the bottom or rising in the water column on presentation of airgun signals. The sound levels for which subtle changes in behaviour were observed was at 161 dB re 1 µPa and alarm responses were observed at 180 dB re 1 µPa. The fish behaviours observed in the McCauley et al. (2000a) and Pearson et al. (1992) studies indicated that sound effects result in the fish seeking shelter in tight schools near the bottom. Dalen and Raknes (1985) have also suggested that Atlantic cod may also respond to seismic signals by swimming towards the bottom.

Fish sounds are normally generated in the range of 50 to 3,000 Hz. Fish use sound for communication, navigation and sensing of prey and predators. Sound transmission is thought to play an important role in cod and haddock mating (Engen and Folstad 1999; Hawkins and Amorin 2000). Seismic signals are typically in the range of 10 to 200 Hz (Turnpenny and Nedwell 1994) and will therefore overlap slightly with signals produced by fish. However, detecting a signal does not mean the fish will have any measurable reaction to the noise. The hearing ability of fish varies considerably by species, as will the effects of seismic exploration. Variability in effect may also vary within a species because seismic signals have a more pronounced effect on larger fish than of smaller fish of the same species (Engås et al. 1996).

If a seismic survey overlaps with the presence of migrating fish species (such as redfish and cod), startle responses and temporary changes in swimming direction and speed could be expected, but schooling behavior is not expected to be affected (Blaxter et al. 1981). Any temporary change in behavior is not expected to interrupt the natural migration instinct to a spawning or feeding area.

Seismic activity can have a greater spatial effect on the behaviour of fish than on the physiology of fish. Most available literature (Blaxter et al. 1981; Dalen and Raknes 1985; Pearson et al. 1992; McCauley et al. 2000a; 2000b; Davis et al. 1998) seems to indicate that the effects of noise on fish are brief and if the effects are short-lived and outside a critical period, they are expected not to translate into biological or physical effects. It appears that behavioural effects on fish as a result of seismic shooting should result in negligible effects on individuals and populations in most cases. The potential for interactions during particularly sensitive periods, such as spawning or migration, are a concern. Two proposed seismic surveys near Cape Breton were evaluated (C-NSOPB 2002) and results seemed to indicate that displacement of marine fish is short-term. The Environmental Studies Research Fund is currently funding a study regarding behavioural responses to fish from seismic sources.

5.1.2.2 Physical Effects

No mass fish kills associated with the operation of airguns have been recorded (Payne 2004). Since fish are likely to be driven away by approaching seismic shots, mortality of adult fish mortality is not expected (Turnpenny and Nedwell 1994). Depending on source noise level, water depth and distance of the fish relative to the source, injuries (such as eyes and internal organs) would only occur within a few tens of metres, with lesser symptoms such as hearing damage possible out to several hundred metres (Turnpenny and Nedwell 1994).

The mortality rate of plankton during seismic surveys has been estimated from several studies. Up to 1 percent of the plankton in the top 50 m of the water column could be killed during 3-D seismic survey off Nova Scotia (Davis et al. 1998). An estimated 0.45 percent of planktonic organisms in the top 10 m of water in a survey area off Norway could be killed (Saetre and Ona 1996). Kenchington et al. (2001) estimated a plankton mortality rate of 6 percent if they were concentrated in the upper 10 m. Given that seismic-related mortality in fish has not been reported beyond 5 m during field and laboratory studies, these estimates are considered conservative and may apply more to phytoplankton and zooplankton than to planktonic life stages of fish and shellfish. Kostyuchenko (1973) reported more than 75 percent survival of fish eggs at 0.5 m from the source (233 db at 1 m) and more than 90 percent survival at 10 m from the source.

Fish with swim bladders and specialized auditory couplings to the inner ear (e.g.. herring) are highly sensitive to sound pressure. Fish with a swim bladder but without a specialized auditory coupling (e.g., cod and redfish) are moderately sensitive, while fish with a reduced or absent swim bladder (e.g., mackerel and flounder) have low sensitivity (Fay 1988). Fay (1988) has developed an approximate threshold for each of these three classifications of hearing sensitivity. The highly sensitive group has a hearing threshold of less than 80 dB re 1μPa[3]. The moderately sensitive threshold is between 80 and 100 dB re 1μPa and those fish with a low threshold have a sensitivity of greater than 100 dB re 1μPa. These sensitivity thresholds were derived under quiet laboratory conditions, so thresholds to seismic sound pressure in the ocean are thought to be 40 dB higher due to ambient noise and the start and stop nature of the seismic signal. A comparison of moderately sensitive species such as cod, haddock, pollock and redfish determined a measurable behavioural response in the range of 160 to 188 dB re 1μPa (Turnpenny and Nedwell 1994). Source levels during seismic surveys are usually in excess of the noise levels that elicit a response in fish, so the area in which fish react to the noise may extend several kilometres in the open ocean. By comparison, underwater ambient noise in bad weather is in the range of 90 to 100 dB re 1 μPa. As an example, large tankers may have a source noise level of 170 dB re 1 μPa at 1 m.

[3] Unless otherwise indicated, all sound level measurements are reported at 1 m.

There are well documented observations of fish and invertebrates exhibiting behaviours that appeared to be in response to exposure to seismic activity like a startle response, a change in swimming direction and speed, or a change in vertical distribution (Hassel et al. 2003; Wardle et al. 2001; McCauley et al. 2000b; Pearson et al. 1992; Schwarz and Greer 1984; Blaxter et al. 1981) although the significance of these behaviours is unclear. Some studies indicate that such behavioural changes are very temporary while others imply that marine animals might not resume pre-seismic behaviours and/or distributions for a number of days (Løkkeborg 1991; Skalski et al. 1992; Engås et al. 1996).

The expected distance for fish to react to a typical peak source level of 250 to 255 dB re 1 µPa is from 3 to 10 km (Engås et al. 1996). A reaction may simply mean a change in swimming direction. The spatial range of response in fish will vary greatly with changes in the physical environment in which the sounds are emitted. In one environment, fish distribution has been shown to change in an area of 74 x 74 km (40 x 40 nautical miles) and 250 to 280 m deep for more than five days after shooting ended, with fish larger than 60 cm being affected to a greater extent than smaller fish (Engås et al. 1996).

Due to the dampening effects of shallow areas, especially with soft substrates, behavioural responses in shallow waters are less obvious. Two studies in the shallow coastal areas concluded limited changes in fish behaviour in response to seismic noise. In one area with water depths less than 20 m, a seismic signal of 225 dB re 1 µPa at 1 m was emitted and the response of sea bass (*Dicentrarchus labrax*) observed. The study concluded that the bass were not displaced and that they continued to feed (Pickett et al. 1994). In another study, pollock (*Pollachius pollachius*) on a shallow coastal reef were observed during a signal of 230 dB re1 µPa (Wardle et al. 2001). Direct visual observations determined that only minor changes in fish behaviour patterns were detectable around the reef. When smaller pollock passed within a few metres of the array and were exposed to approximately 229 dB, they showed a typical “c-start” response and moved away only a few metres.

It is assumed that a sound pressure level of 220 dB re 1 µPa0-P is required for egg/larval damage (Table 5.2). A ‘worst-case scenario’ mathematical model was applied to investigate the effects of seismic energy on fish eggs and larvae and concluded that mortality rates caused by exposure to seismic were so low compared to natural mortality, the effect of seismic activity on recruitment to a fish stock would be not significant (Saetre and Ona 1996). In addition, mortality of phytoplankton and zooplankton near the seismic vessel should be sufficiently localized as to negligibly affect food availability for fish, shellfish, birds and mammals.

The abundance or distribution of any population (including larvae and eggs) will not likely be affected by seismic activity for more than one generation, including those species of concern such as cod, redfish or snow crab. Oil exploration generally is considered to have a negligible effect on the survival and recovery of the northern and spotted wolffish populations in the Gulf of St. Lawrence (DFO 2004f), nor are critical habitats of species listed under SARA (see Section 4.7) expected to be affected.

A review of the current scientific literature indicate that egg and larval mortality is limited to within a few metres of the seismic array, physical injury to fish is limited to tens of metres and auditory damage is potentially limited to hundreds of metres (Kostyuchenko 1973; Turnpenny and Nedwell 1994; Saetre and Ona 1996; Kenchington et al. 2001).

Table 5.2 Observations of Exposures of Fish and Shellfish Planktonic Life Stages to Seismic Airguns at Close Range

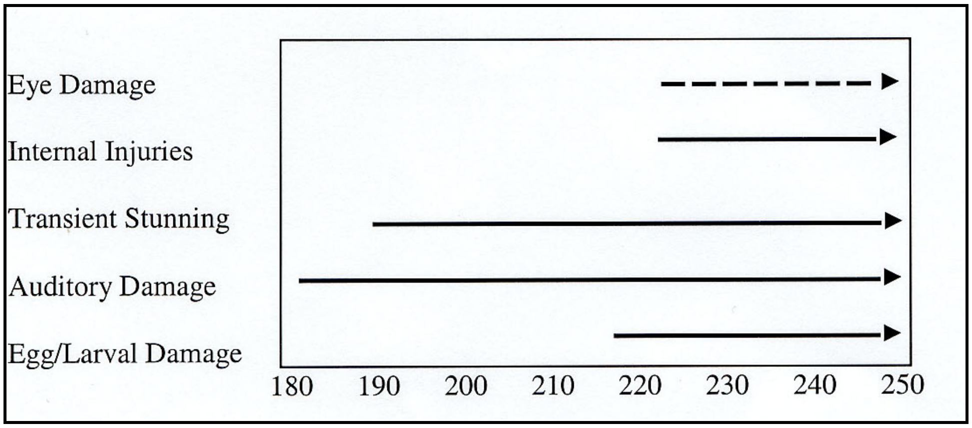
Organism	Life Stage	Exposure Distance from Air Sleeve (m)	Estimated Exposure Level (dB re 1 µ pA)	Observed Response	Reference
Pollock (*Pollachus virens*)	Egg	0.75	242	Some delayed mortality	Booman et al. 1996
Cod (*Gadus morhua*)	Eggs	1 to 10	202 to 220	No signs of injury	Dalen and Knutsen 1987
	Larvae	5	220	Immediate mortality	Booman et al. 1996
	5-day-old larvae	1	250	Delimitation of retina	Matishov 1992
	Fry	1.3	234	Immediate mortality	Booman et al. 1996
Plaice (*Pleuronectes platessa*)	Eggs and larvae	1	220	High mortality (unspecified)	Kosheleva 1992
		2	214	No effect	Kosheleva 1992
Anchovy (*Engraulis mordax*)	Eggs	Unknown	223	8.2% mortality	Holiday et al., in Turnpenny and Nedwell 1994
	2-day-old larvae	3	238	Swimbladder rupture	Holiday et al., in Turnpenny and Nedwell 1994
Red Mullet (*Mullus surmuletus*)	Eggs	1	230	7.8% injured	Kostyuchenko 1973
		10	210	No injuries	Kostyuchenko 1973
Fish (various species)	Eggs	0.5	236	17% dead in 24 hours	Kostyuchenko 1973
		10	210	2.1% dead in 24 hours	Kostyuchenko 1973
Dungeness Crab (*Cancer magister*)	Larvae	1	231	No observed effect on time to molt or long-term survival	Pearson et al. 1994
Source: JWL 2006.					

The potential effect that seismic activities may have on masking communications by fishes is not well documented. There is overlap in the frequency of seismic signals and the sounds emitted by fish, so there is potential for sound reception and production in fish to be reduced (Myrberg 1980). Recent experiments on goldfish indicate that fish are capable of “auditory scene analysis”, meaning that a sound stream of interest can be “heard out” and analyzed for its informational content independently of simultaneous, potentially interfering sounds (Fay 1988). These studies were carried out using repetitive pulses or clicks as signals and as potentially interfering sounds. These results suggest that the presence of intermittent, audible airgun shots would not necessarily impair fish in receiving and appropriately interpreting other biologically relevant sounds from the environment (MMS 2004).

Studies have shown that exposure to intense sound can affect the auditory thresholds of fish resulting in temporary threshold shifts (TTS) under certain conditions (i.e., Amoser and Ladich 2003; Smith et al. 2004). However, these studies focused on captive fish that were exposed to loud (158 dB re 1 µPa) noise for periods of 10 minutes for 12 or 24 hours. TTS may seldom (or never) occur in the wild unless fish are prevented from fleeing the irritant (LGL 2005b). Threshold shifts affect the fish’s ability to hear its natural full range of sound.

Kosheleva (1992) reports no obvious physiological effects beyond 1 m from a source of 220 to 240 dB re 1 µPa. Hastings (1990) reports the lethal threshold for fish beginning at 229 dB and a stunning effect in the 192 to 198 dB range. Turnpenny and Nedwell (1994) deduce that blindness can be caused in fish exposed to air sleeve blasts on the order of 214 dB. A summary of fish injuries caused by exposure to sound pressure is given in Figure 5.1. Auditory damage starts at 180 dB, transient stunning at 192 dB and internal injuries at 220 dB.

Figure 5.1 Sound Pressure Threshold for the Onset of Fish Injuries



Source: adapted from Turnpenny and Nedwell 1994.
Note: Dotted line indicates an assumed sound level rather than an estimated one.

Collins et al. (2002) looked at potential effects on fish catches during and after two independent inshore and near shore seismic surveys undertaken in the Bay St. George and Port au Port areas of western Newfoundland. While not statistically conclusive, their analyses suggested no observable effects on overall fish catches, including snow crab, during or in the years following the seismic surveys. This indicates that fish behaviour was not measurably affected. Turnpenny and Nedwell's (1994) general conclusion is that seismic activity has a reduced affect on fish behaviour inshore, in shallow water because attenuation of the sound is more rapid.

Noise generated during removal of the wellhead and other infrastructure is the primary disturbance associated with decommissioning and abandonment activities. These activities occur directly at the well site and are usually of short duration so short term localized avoidance behaviours may be expected.

5.1.3 Commercial Fisheries

Potential effects of seismic surveys on fisheries catches are a concern to fishers. Engås et al. (1996) found that cod and haddock moved away from a 3 x 10 n mile region (5.6 x 18 km) in which seismic operations were carried out over a five-day period. Reductions in fish catches were observed out to their sampling limit of 33 km. They postulated that the fish may have been responding to continuously discharging airguns by swimming through a gradient of exponentially decreasing sound levels and, as such, habituation may have occurred. Therefore, the fish may have terminated their avoidance reaction at different distances depending on their size and swimming speed. Alternatively, the fish may have responded to the airgun discharges by increasing their swimming speed leading to exhaustion. Avoiding the sound source by prolonged swimming speeds (He 1993) may have produced a response pattern of alternating intervals of swimming and resting until habituation terminated the response at different distances for fish of different sizes. Engås et al. (1996) concluded that the effects of seismic had lasted for at least five days.

Løkkeborg (1991) analyzed longline catches of cod in the presence of seismic surveys and concluded a reduction in catch rate had occurred. Løkkeborg and Soldal (1993) examined catch data obtained from commercial vessels operating on fishing grounds where seismic explorations were being conducted. They found a 56 percent reduction in longline catches of cod and 81percent reduction in the by-catch of cod in shrimp trawling. Skalski et al. (1992) reported that catches of various redfish species (using vertical lines) declined by 50 percent during discharges of a single airgun.

These observations suggested that the fish had responded by either avoiding the sound field of operating seismic vessels or their behavioural state was changed and as such they were no longer available to the fishing techniques tested. Løkkeborg and Soldal (1993) suggested that behavioural changes that forced fish to the bottom acted to temporarily increase catch rates of cod in the trawls during seismic activities.

Seismic activity inshore can have its greatest effect if the program overlaps spatially and temporally with the occurrence of concentrations of fish eggs or larvae. Temporal overlap will occur because there are eggs or larvae in the water column year-round and all of the fish and shellfish assessed can have pelagic eggs and larvae in the water column during August and September. July, August and September are when most species are expected to have eggs or larvae present in the water column. In order for an interaction to occur between fish eggs and larvae and seismic activity, there must be spatial as well as temporal overlap with the SEA Area.

The potential seismic effects on fish do not necessarily translate to disruptions to commercial fisheries. For many fish species any behavioural changes or avoidance effects may involve little if any risk factor. Thus a thorough understanding of fish response to seismic, proper risk assessment procedures and good communication between seismic operators and fisherman should negate any potential or perceived problems.

5.1.4 Marine Birds

5.1.4.1 Sound Effects Associated with Seismic Activities

There is limited data available with respect to the effects of underwater sound on birds. The sound created by airguns is focused toward the substrate, below the surface of the water. Above the water, sound is reduced to a muffled noise that should have little or no effect on birds that have their heads above water or are in flight. Most species of seabirds that may be present in the SEA Area spend only a few seconds underwater during a foraging dive; therefore, there would be minimal opportunity for exposure to noise associated with seismic shooting.

Only the Alcidae (Dovekie, Common Murre, Thick-billed Murre, Razorbill, Black Guillemot and Atlantic Puffin) spend measureable time underwater during forage dives. They typically spend 25 to 40 seconds underwater during each dive (Gaston and Jones 1998), reaching depths of 20 to 60 m and have the potential to be exposed to the sounds produced by seismic shooting. The effects of seismic noise on Alcids are not well known. Alcids are a vocal species; the call of the Thick-billed Murre covers a frequency range of 1 to 4 kHz (Gaston and Jones 1998), indicating that auditory capabilities play an important role in their activities, particularly during breeding season.

5.1.4.2 Vessel and Air Traffic

Birds on the south coast are exposed to heavy vessel and ferry traffic. Some species are attracted to ships, while some avoid interactions with vessels, so it is possible that traffic could affect foraging birds at sea. It is not anticipated that vessels travelling to and from the SEA Area will cause disturbance to seabird colonies (JWL 2006).

Aircraft activity in the vicinity of seabird colonies can result in mortality of chicks due to panic responses of adult birds. Helicopters servicing projects in the SEA Area will be required to avoid major colonies along the western Avalon Peninsula, Burin Peninsula and south coast. Disturbance to marine birds on the water surface will be negligible when aircraft are 600 m above the sea surface. Marine birds in the vicinity of helicopters taking off and landing on platforms may be disturbed. However, birds that associate with the offshore platforms will likely become habituated (JWL 2006).

5.1.5 Marine Mammals and Sea Turtles

Underwater sounds produced during the exploration can be classified into two broad categories. Sounds of short duration that are produced intermittently or at regular intervals, such as that produced by airguns, are classified as "pulsed". Sounds produced for extended periods, such as sounds from generators or drilling are classified as "continuous". Sounds from moving sources, such as ships, can be continuous, but for an animal at a given location, these sounds are "transient" (i.e., increasing in level as the ship approaches and then diminishing as it moves away). Studies indicate that marine animals respond somewhat differently to the three categories of noise. Masking effects are expected to be less severe when sounds are pulsed or transient than when they are continuous.

The measurements of sounds for the purposes of potential effects to marine organisms are currently reported as root mean square (rms) pressures. The size of the averaging window greatly affects the measured rms level by 2 to 12 dB (Madsen 2005). It has been suggested that peak-peak and energy flux density measures are more relevant for transient (pulsive) sounds, since high peak pressures could affect animals and energy flux density measures the energy flow per unit area received by the animal (Madsen 2005). Madsen (2005) showed that several sounds with the same peak-peak values can have very different rms levels and energy flux densities. Marine animals are one of the receivers of sound within the marine environment. Impact criteria for potential damage or disturbance to marine mammals are currently being developed for peak-peak and energy flux density measures of sounds. Impact criteria of rms sound pressure levels have been estimated by the National Marine Fisheries Service (NMFS) in the United States.

In shallow waters of continental shelves, the acoustic properties of the seabed may be the dominant with respect to acoustic propagation (Duncan and McCauley 2000). The determination of relevant substrate properties for the SEA Area may be a potential data gap with respect to the modelling of seismic activity and its effects on marine mammals.

5.1.5.1 Continuous Sounds

Continuous sounds occur for extended periods. Fixed-location continuous sounds are associated with underwater pumps, the use of generators and drilling operations. Transient continuous sounds are produced by moving sources such as ships. These sounds normally increase in level as they approach a location and then diminish as they move away.

Whales may be disturbed by continuous noises above a criterion level of 120 dB re 1 µPa (rms), according to current NMFS standards. Baleen whales have been shown to respond to drillship noises at or above 120 dB (Richardson et al. 1990). The same criterion levels are currently used for pinnipeds. Based on the literature reviewed in Richardson et al. (1995), it is apparent that most small and medium-sized toothed whales exposed to prolonged or repeated underwater sounds are unlikely to be displaced unless the overall received level is at least 140 dB re 1 µPa.

5.1.5.2 Pulsed Sounds

Pulsive sounds are of short duration and occur intermittently or at regular intervals. Pile driving using an impact hammer and seismic airgun blasts are examples of underwater noise that are characterized as pulsed sound. They produce brief noise pulses whose peak levels are much higher than those of most continuous or intermittent noises.

For pulsed sounds, a broadband received sound pressure level of 180 dB re 1 µPa (rms) or greater is to be used as an indication of potential concern about temporary and/or permanent hearing impairment (Level A Harassment) to cetaceans (NMFS 2003; Madsen 2005). Level A Harassment is defined as “any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild” (NRC 2003a). The criterion to reduce the potential for Level A Harassment to pinnipeds from pulsive sounds is exposure to received levels of 190 dB re 1 µPa (rms) or greater.

A broadband received sound pressure level of 160 dB re 1 µPa (rms) or greater is currently the best estimate available to indicate potential concern to cause disruption of behavioural patterns (Level B Harassment) to marine mammals. Level B Harassment is defined as “any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioural patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but which does not have the potential to injure a marine mammal or marine mammal stock in the wild” (NRC 2003a).

5.1.5.3 Intermittent Noise

Intermittent noise is noise that is discontinuous or widely variable in level, but not pulsive. The 120 dB re 1 µPa (rms) criterion selected for continuous noise is used to evaluate effects of intermittent underwater noise.

5.1.5.4 Sound Exposure Level and Sound Pressure Level

Existing safety radii regulations in the United States are based on the 90 percent rms sound pressure level metric for pulsive noise sources. Although one can easily measure the 90 percent rms sound pressure level (SPL in situ), this metric is extremely difficult to model in general, since the adaptive integration period, implicit in the definition of the 90 percent rms level, is highly sensitive to the specific multipath arrival pattern from an acoustic source. To accurately predict the 90 percent rms, it is necessary to model acoustic dispersion.

When underwater noise can be assumed to originate from identifiable sources of specified directivity and given transmitted spectral content, high-quality models exist to predict the spectral levels of the received signal. Propagation models use bathymetric databases, geoacoustic information, oceanographic parameters and boundary roughness models to produce estimates of the acoustic field at any point far from the source. The quality of the received level estimate is directly related to the quality of the environmental information used in the model. Sound propagation models coupled with accurate source and receiver models can provide invaluable tools for predicting potential effects but care must be taking in specifying the environmental parameters for the area under study.

Industry estimates of rms threshold-based safety radii for airgun arrays are generally computed under the simplifying assumption that no acoustic energy is returned to the water column via bottom reflections. In the relatively shallow waters where the water depth is at most a few hundred metres, these safety-radius estimates must be considered approximate at best. If multipath reflections were taken into account, the resultant spreading of the seismic pulse would most certainly change the estimates. For in situ measurements, the 90 percent rms SPL can be computed from the sound exposure level (SEL) via a simple relation that depends only on the rms integration period T:

$$\mathrm{SPL}_{\mathrm{RMS90}} = \mathrm{SEL} - 10\log(T) - 0.458,$$

where the last term accounts for the fact that only 90 percent of the acoustic pulse energy is delivered over the standard integration period. However, in the absence of in situ measurements, the integration period is difficult to predict with any reasonable degree of accuracy. It should be noted that the rms level itself has no special biological significance with regards to marine mammal hearing.

Current seismic safety radii are intended to satisfy thresholds that have been cast in terms of the rms sound level metric and the only true way to estimate these radii would be through actual field measurements, in situ. Care must be taken in directly comparing SEL and rms SPL estimates, due to the difficulty in accurately estimating the rms sound level a priori. In 2003, measurements of ambient noise prior to seismic operations were conducted in the Sable Island Gully Marine Protected Area and, specifically, the Gully whale sanctuary (McQuinn and Carrier 2005). The results of this study indicated that environmental assessment predictions for noise levels were underestimated by 8 dB on average. This finding was considered noteworthy because sound propagation model results are used to define the safety radii for marine mammals around seismic arrays. This study highlights the importance of accurate model inputs such as bathymetric, topographic, geoacoustic and oceanographic data, as well as the necessity to measure variability around mean sound levels.

Marine mammals use sound to communicate and gain information about their environment and as such sound plays an important role in their daily activities. It is clear from scientific investigations of many marine mammals that the production and reception of certain sounds are critical in various aspects of life history. It is also evident that certain sounds (both natural and anthropogenic) have the potential to interfere with these functions.

The marine environment contains many natural sources of noise (e.g., surf, wind, earthquakes, biological activity) that may impede acoustic communication and other vital functions, but to which marine animals have evolved to accommodate. Anthropogenic sounds are a recent advent to the marine environment, having essentially begun with the introduction of industrialization. Anthropogenic sounds have the potential to disturb behavior and/or interfere with important functions (Richardson et al. 1995; NRC 2003a). Richardson et al. (1995) reported that marine mammals tend not to respond overtly to audible but weak man-made sounds.

Behavioral responses of marine mammals to noise are highly variable and dependent on a suite of internal and external factors (NRC 2003a). Internal factors include:

- individual hearing sensitivity, activity pattern, and motivational and behavioural state at time of exposure;
- past exposure of the animal to the noise, which may have led to habituation or sensitization;
- individual noise tolerance; and

- demographic factors such as age, sex, and presence of dependent offspring.

External factors include:

- non-acoustic characteristics of the sound source, such as whether it is stationary or moving;
- environmental factors that influence sound transmission;
- habitat characteristics, such as being in a confined location; and
- location, such as proximity to a shoreline.

There are few studies on the effects of sound on sea turtles as compared to marine mammals and fish.

The noise generated due to the presence of a drilling platform could result in the temporary avoidance of an area by marine mammals. Noise from a drilling platform is detectable no more than 2 km away near a shelf break under typical ambient noise conditions at low frequency (Richardson and Malme 1993). The spatial extent of avoidance behaviour by most common marine mammal species in the area (i.e., humpback and minke whales) can be expected to be 0.5 to 1 km (JWL 2006). Humpbacks exposed to simulated semi-submersible and drill platform noises did not exhibit avoidance behaviors (Malme et al. 1985). Once the source is removed, marine mammals are expected to return to the avoided area (Davis et al. 1987), thus the effect of noise on marine mammals is considered highly reversible.

Noise generated during removal of the wellhead and other infrastructure is the primary disturbance associated with decommissioning and abandonment activities. Explosives are sometimes used for difficult wellhead removal (but only if mechanical severance fails). It is a requirement that operators have authorization from C-NLOPB before explosives are used. These activities occur directly at the well site and are usually of short duration so short term localized avoidance behaviours may be expected.

Seismic exploration has the potential to affect marine mammals and, therefore, affect those tourism ventures that rely on their presence - namely, whale watching operations. Whale populations may learn to avoid high noise areas. If whales were to start avoiding the south coast area due to noise emissions, the success rate of whale watching ventures in the area may be affected and the commercial viability of whale watching operations may be compromised. It must be noted that there are potential sound effects associated with the whale watching activities though not to the degree associated with offshore exploration and production activities.

5.1.5.5 Masking

Underwater ambient sound may prevent an animal from detecting another sound through a process known as masking. Masking can occur as a result of either natural sounds (e.g., periods of strong winds or heavy rainfall) or anthropogenic sounds (e.g., ship propeller sound). The sea is a naturally noisy environment and even in the absence of anthropogenic sounds, this natural sound can "drown out" or mask weak signals from distant sources.

Marine mammals are highly dependent on sound for communicating, detecting predators, locating prey and, in toothed whales, echolocation (Lawson et al. 2000, in LGL 2005b). Natural ambient noise created by wind, waves, ice and precipitation alone can cause masking or interfere with an animal's ability to detect a sound. Marine animals themselves also contribute to the level of natural ambient noise. The calls of a blue whale have been recorded for 600 km (Stafford et al. 1998). A sperm whale call can be as loud as 232 dB re 1µPa at 1 m (rms) (Møhl et al. 2003) and a species of shrimp has been recorded at 185 to 188 dB re 1µPa at 1 m (Au and Banks 1998). In areas where natural background noise is relatively high, such as near a shelf break or high surf, anthropomorphic noise itself can be masked and reduce the area in which it is detectable. The anthropomorphic noise is undetectable for marine mammals once it falls below ambient noise level or the hearing threshold of the animal. Given this and the fact that mammal response will vary by species and between individuals, the zone of potential influence of noise on marine mammals is highly variable.

Marine mammals have evolved in an environment that contains a variety of natural sounds and as such some degree of masking occurs and thus marine mammals have evolved systems and behaviour to reduce the impacts of masking (NRC 2003a). Since little is known about the significance of how a temporary interruption in sound detection affects mammals (Richardson et al. 1995), it is very difficult to assess the impact. In general, the impact of both natural and man-made noise is less severe when it is intermittent rather than continuous (NRC 2003a). The level of masking may be significantly reduced if the anthropogenic noise originates from a different direction than the mammal vocalization (NRC 2003a). While marine mammals may adapt behaviour changes to reduce masking, the physiological costs associated with the behavioural changes can not be estimated at this time (NRC 2003a).

The low frequency spectrum of industrial noise will not overlap with the high frequency echolocation of belugas, dolphins, or pilot whales, for example. The frequencies do overlap with the sounds of baleen whales and will reduce the area of auditable sound for the whale. The impact of such a reduction is unknown (NRC 2003a). Toothed whales and presumably other species have demonstrated the ability to alter the frequencies and increase the level of transmission when competing with ambient noise (NRC 2003a).

The masking effect from the seismic survey is expected to be limited. LGL (2005b) reports that some marine mammals continue calling in the presence of seismic operations, which typically emit an impulse every 11 seconds. It has been postulated that an increase in interval time will enable mammals to receive communications that persist through the survey operation, as reported during other surveys (Richardson et al. 1986; McDonald et al. 1995; Greene and McLennan 2000; Madsen et al. 2002; Jochens and Briggs 2003). However, other factors may limit the potential effectiveness of increased interval time to mitigate concerns regarding interruptions to marine mammal communications as a result of seismic activities.

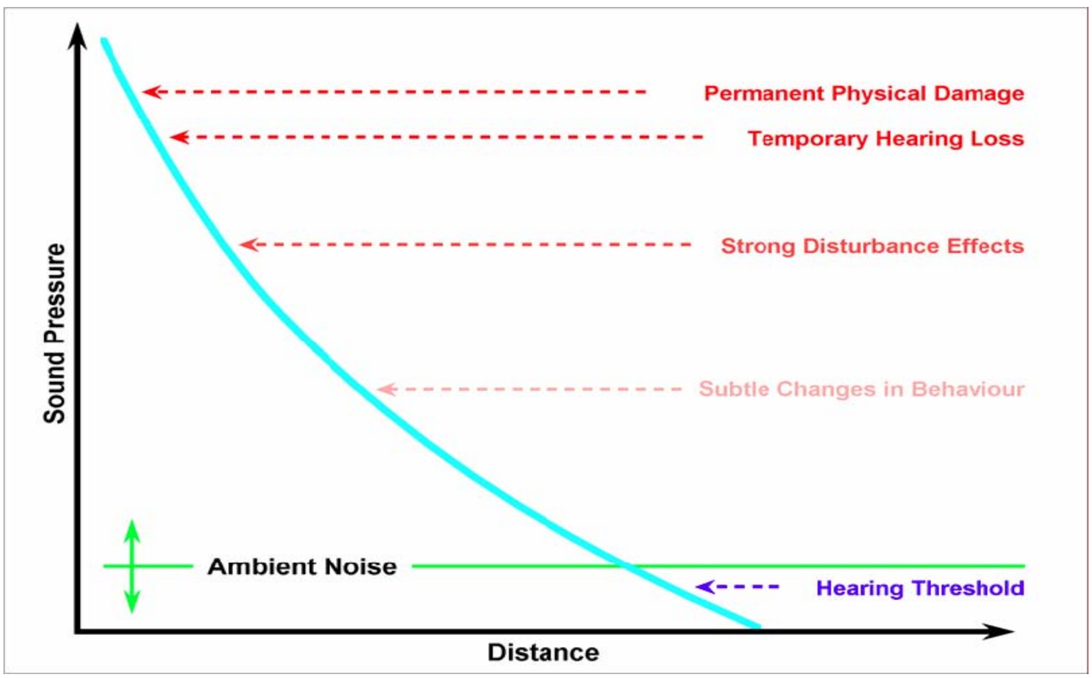
5.1.5.6 Hearing Impairment

Extended periods of moderate noise levels under water can cause a reduction in hearing sensitivity in some marine mammals ((TSS) (i.e., hearing loss is recovered) Kastack et al. 2005). At TTS exposure levels, hearing sensitivity is generally restored quickly after the sound dissipates. A permanent threshold shift (PTS) (i.e., hearing loss is not recovered) (Finneran et al. 2002) may be a symptom of physical damage and may alter the functional sensitivity at some or all frequencies. Although there are no data to quantify sound levels required to cause a PTS, it is believed that a source level would have to far exceed the level required for a TTS, the exposure would have to be prolonged, or the rise level would be extremely short (LGL 2005b). Richardson et al. (1995) hypothesized that permanent hearing impairment of marine mammals would not likely occur with prolonged exposure to continuous man-made sound of approximately 200 dB re 1 μPa-m.

Research has shown that a marine mammal exposed to intense sound may exhibit a decreased hearing sensitivity (or 'threshold shift') following cessation of the sound (e.g., Au et al. 1999; Kastak et al. 1999; Schlundt et al. 2000). TTS have been observed in captive marine mammals exposed to pulsed sounds in experimental conditions (Finneran et al. 2002), but the likelihood of these effects occurring have not been evaluated under field operating conditions. There is currently no agreement as to what level of TTS and time to recovery would present unacceptable risk to a marine mammal. NMFS policy is under review and currently states that cetaceans and pinnipeds should not be exposed to pulsive sounds exceeding 180 and 190 dB re 1 µPa (rms), respectively (NMFS 2000). Exposure to high-intensity pulsed sound can cause other, non-auditory physical effects such as stress, neurological effects, bubble formation, resonance effects and other types of organ or tissue damage (LGL 2005b, NRC 2003a). Little is known about the potential for the sounds produced during geohazard surveys to cause auditory threshold shifts or other effects in marine mammals and turtles. Data suggest that if these effects do occur, they would only occur in close proximity to the sound sources. Thus, species that show behavioral avoidance of seismic vessels, including most baleen whales, some toothed whales and some pinnipeds would not likely experience threshold shifts or other physical effects (LGL 2005b).

Criteria can be established for zones of influence based on ambient sound levels, absolute hearing thresholds of the species of interest, slight changes in behavior of the species of interest (including habituation), stronger disturbance effects (e.g., avoidance), temporary hearing impairment and permanent hearing or other physical damage, as illustrated in Figure 5.2 (Lawson et al. 2000 as cited in LGL 2005b).

Figure 5.2 Schematic Representation of Zones of Potential Effects Associated with Anthropogenic Sounds on Marine Mammals



Source: Lawson et al. 2000; in LGL 2005b.
Note: Vertical distances between various effects are not drawn to scale.

5.1.5.7 Baleen Whales

Baleen whales communicate using low frequency sounds (generally between 25 Hz and 4 kHz (Richardson et al. 1995)) that can propagate for long distances. These sounds range in duration from 50 msec thumps produced by minke whales (Winn and Perkins 1976; Thompson et al. 1979) to moans produced by blue whales, which can have durations up to 36 sec (Cummings and Thompson 1971). Acoustic energy in the sound pulses produced by seismic airguns and sub-bottom profilers overlap with frequencies used by baleen whales, but the discontinuous, short duration nature of these pulses is expected to result in limited masking of baleen whale calls. Side-scan sonar and echo-sounder signals do not overlap with the predominant frequencies of baleen whale calls, which avoids measureable masking. Several species of baleen whales have been observed to continue calling in the presence of seismic pulses, including bowhead whales (*Balaena mysticetus*) (Richardson et al. 1986), blue whales and fin whales (McDonald et al. 1995).

While the hearing abilities of baleen whales have not been studied directly, behavioral evidence suggests that these animals hear well at frequencies below 1 kHz (Richardson et al. 1995) and the anatomy of the baleen whale inner ear seems to be well adapted for low frequency hearing (Ketten 1991; 1992; 1994; 2000). Baleen whales commonly use frequencies below 1 kHz for communication over long distances (Richardson et al. 1995). It is therefore likely that baleen whales can hear airgun pulses at considerable distances from survey vessels and avoidance behaviour has been documented for several baleen whale species. Strong avoidance behavior may be seen at received levels lower than 160 to 170 dB re 1 µPa (rms) (Gordon et al. 2004). Observers on seismic vessels off the UK from 1997 to 2000 reported that in good sighting conditions, the number of baleen whales seen when airguns were shooting was similar to the number seen when airguns were not shooting. However, baleen whales remained considerably farther from the airguns and exhibited more frequent alterations in course (usually away from the vessel) when airguns were shooting (Stone 2003). Humpback whales, gray whales (*Eschrichtius robustus*), and bowhead whales react to seismic noise pulses by deviating from their normal migration route and/or interrupting feeding and moving away from the sound source (e.g., Richardson et al. 1986; 1995; 1999; Ljungblad et al. 1988; Richardson and Malme 1993). Fin and blue whales also show some behavioural reactions to airgun noise (McDonald et al. 1995; Stone 2003). Fin whales and sei whales (*Balenoptera borealis*) are less likely to remain submerged during periods of shooting (LGL 2005b). Bowhead whales migrating off the Alaskan coast have been shown to avoid seismic survey vessels to a distance of more than 24 km (Jasny et al. 2005). Baleen whales may strand after exposure to seismic sounds. Jasny et al. (2005) report that the stranding of eight humpback whales was correlated with the opening of the area to oil exploration.

McCauley et al. (2000b) examined data from whale observations made from the seismic survey vessel north east of North West Cape, off Exmouth. They found that there were no discernible differences in the number of whales sighted per observation block (40-minute period) between observation blocks with the guns-on or guns-off. In depth examination of the data found that the guns-off sighting rates were considerably higher from ranges near the vessel to 3 km than the guns-on sightings in the same range category. This suggests localized avoidance of the operating airgun vessel during periods with the airguns on and is consistent with published findings.

These findings indicate that at most whales will avoid an operating seismic vessel. Richardson et al (1995) noted that most research indicated that gray and bowhead whales generally avoid seismic vessels where the received sound level is between 150 to 180 dB re 1 µPa (rms). The level at 3 km from the seismic vessel from which the humpback observations were made was in the range 157 to 164 dB re 1 µPa (rms) for a receiver at 32 m depth, which is in agreement with the standoff level provided or gray and bowhead whales (McCauley et al. 2000a).

McCauley et al. (2000b) noted that pod sighting rates observed when the airguns were switched on/off or off/on were higher than the sighting rates during which airguns were continually on or continually off for distances between 0.75 to 3 km. These higher pod sightings may be explained by a startle response bringing animals to the surface for airguns turned on after being off for a protracted period; an investigative response where whales tend to come to the surface for airguns turned off after being on for a protracted period.

Startle responses by humpback whales to seismic survey sounds have been reported at levels between 150 to 69 dB re 1 µPa (effective pulse pressure, believed equivalent to rms measure) by Malme et al. (1985).

McCauley et al. (2000b) conducted approach trials out in Exmouth Gulf that found humpback whale pods with females consistently avoided an approaching single operating airgun (Bolt 600B, 20-cubic inch chamber) at a mean range of 1.3 km. Avoidance maneuvers were evident before standoff at ranges from 1.22 to 4.4 km.

During the approach trials single, large, mature humpbacks approached the operating airgun, coming to within 100 to 400 m, investigated it, then swam off (McCauley 2000b). These approaches were deliberate, direct and at considerable speed. These whales would have been exposed to airgun signals of 100 m of 179 dB re 1 µPa (rms) (or 195 dB re 1 µPa peak-peak). This level is equivalent to the highest peak-peak source level (level at 1 m) of song components measured in the 1994 humpback whale song in Hervey Bay by McCauley et al. (1996), or as given by Thompson et al. (1986) for humpback whale sounds in Alaska, of 192 dB re 1µPa peak-peak @ 1 m.

McCauley et al. (2000b) concluded that it is probable that humpback whales are not at physiological risk unless at short range from a large airgun array. McCauley et al. (2000b) further concluded that displacements to migratory humpback whales were comparatively short in time, involved limited ranges changes, a low probability for physiological effects and therefore there appears to be a low risk for migratory humpback whales exposed to seismic activity.

There are no data on the level or properties of sound that are required to induce a TTS in any baleen whale (LGL 2005b).

The noise generated due to the presence of a drilling platform could result in the temporary avoidance of an area by marine mammals. Noise from a drilling platform is detectable no more than 2 km away near a shelf break under typical ambient noise conditions, low frequency (Richardson and Malme 1995). The spatial extent of avoidance behaviour for noise generated by routine exploration and production activities by most common marine mammal species in the area (i.e., humpback and minke whales) can be expected to be 0.5 to 1 km (JWL 2006). Humpbacks exposed to simulated semi-submersible and drill platform noises did not exhibit avoidance behaviors (Malme et al. 1985). Once the source is removed, marine mammals are expected to return to the avoided area (Davis et al. 1987), thus the effect of noise on marine mammals is considered highly reversible.

Reactions of baleen whales to vessels have been studied directly for species such as gray whales, humpback whales, and bowhead whales. Reactions have been found to vary from approach to avoidance. In general, baleen whales tend to change their behaviour in response to strong or rapidly changing vessel noise (Watkins 1986; Beach and Weinrich 1989). Behavioural changes include course changes, changes in surfacing and respiration patterns, and displays such as breaching, flipper slapping and tail slapping (Wyrick 1954; Edds and Macfarlane 1987; Stone et al. 1992).

5.1.5.8 Toothed Whales

Toothed whales communicate using two types of sounds: 1) continuous, narrowband, frequency-modulated signals which range in duration from several tenths of a second to several seconds and range in frequency from approximately 2 to 25 kHz (Tyack and Clark 2000); and 2) broadband click trains with peak frequencies that vary from tens of kilohertz to well over 100 kHz (Norris and Evans 1966; Au 1980). Click trains contain few to hundreds of clicks and are used for communication, navigation and object detection and discrimination (Au 1993). Because seismic and sub-bottom profiler pulses are intermittent and predominantly low frequency, masking effects are expected to be negligible for toothed whales. However, while Madsen et al. (2002) reported that sperm whales off northern Norway continued calling in the presence of seismic pulses, Bowles et al. (1994) reported that sperm whales ceased calling when exposed to pulses from a distant seismic ship. Some pulses emitted by side-scan sonars and echo-sounders are likely audible to toothed whales, but measureable masking of communication signals is improbable due to the fact that the pulses are short and have narrow beamwidths.

The hearing capabilities of several species of toothed whales have been studied directly (Richardson et al. 1995; Au et al. 2000). The small to medium-sized toothed whale species that have been studied have relatively poor hearing sensitivity below 1 kHz and very good sensitivity above several kiloHertz. The sounds produced by seismic airguns are in the frequency range of low hearing sensitivity for toothed whales. However, they are high intensity sounds and their received levels can sometimes remain above the hearing thresholds of toothed whales for distances out to several tens of kilometres (Richardson and Würsig 1997).

Responses of toothed whales to vessels vary within and among species and range from avoidance to approach and bowriding (Baird and Stacey 1991a; 1991b; Stacey and Baird 1991; Mullin et al. 1994a; 1994b). For dolphins, reactions to vessels appear to be related to the dolphins' activity state and their history of harassment. Dolphins that are resting tend to avoid vessels, those that are foraging tend to ignore vessels and those that are socializing may approach vessels (Richardson et al. 1995). Dolphins that have been sensitized by previous harassment tend to avoid vessels (Au and Perryman 1982). Larger toothed whales, such as sperm whales and beaked whales, generally seem to avoid survey vessels (Sorensen et al. 1984).

A beluga whale exposed to a single peak-to-peak pressure of 226 dB re 1 μPa experienced TTS to within 2 dB for 4 minutes after exposure (Finneran et al. 2002). A bottlenose dolphin exposed to a single 228 dB re 1 μPa sound did not experience TTS (Finneran et al. 2002). Exposure to several seismic pulses at received levels near 200 to 205 dB (rms), which may be experienced within 100 m of a source vessel, may result in slight TTS in small-toothed marine mammals (LGL 2005b).

Dolphins and porpoises are often seen by observers on seismic vessels (Stone 2003); however, dramatic avoidance responses at considerable distances from the array have been exhibited by species such as harbour porpoises (Jasny et al. 2005). In addition, Stone (2003) noted localized avoidance of seismic vessels by dolphins off the UK. While the distribution of sperm whales in the northern GOM has been observed to change in response to seismic operations (Mate et al. 1994), other studies report little evidence of reactions by sperm whales to seismic pulses (Madsen et al. 2002; Jochens and Biggs 2003; Stone 2003). There is increasing evidence that beaked whales may strand after exposure to intense sound from sonars. Sonar surveying is a separate activity from seismic surveying and may be used during geohazard surveys. Several Cuvier's beaked whale (*Ziphius cavirostris*) strandings have been reported coincident with seismic operations (Gentry 2002; Jasny et al. 2005).

5.1.5.9 Pinnipeds

Most pinnipeds produce sounds with dominant frequencies between 0.1 and 3 kHz (Richardson et al. 1995). The individual calls of harp seals range from less than 0.1 sec to greater than 1 sec in duration

(Watkins and Schevill 1979). The frequencies contained in seismic and sub-bottom profiler pulses do overlap with some frequencies used by pinnipeds, but the discontinuous, short duration nature of the pulses is expected to result in limited masking of pinniped calls. Side-scan sonar and echo-sounder signals do not overlap with the predominant frequencies of pinniped calls, which avoids measureable masking.

Data on underwater hearing sensitivities are available for three species of phocoenid seals, two species of monachid seals, two species of otariids and the walrus (*Odobenus rosmarus*) (reviewed in Richardson et al. 1995; Kastak and Shusterman 1998; 1999; Kastelein et al. 2002). The hearing sensitivity of most pinniped species that have been tested ranges between 60 and 85 dB re 1 μPa from 1 kHz to 30 to 50 kHz. In the harbour seal, thresholds deteriorate gradually below 1 kHz to approximately 97 dB re 1 μPa at 100 Hz (Kastak and Schusterman 1998). Based on these data, it is likely that airgun pulses are readily audible to pinnipeds. Pinnipeds exposed to 2500 Hz at 80 and 95 dB for 22, 25 and 50 minutes experienced TTS ranging from 2.9 to 12.2 minutes, but recovered fully with 24 hours of noise exposure (Kastack et al. 2005).

Ringed seals *(Phoca hispida)* near an artificial-island drilling site were monitored before and during development of the site. Although air and underwater sound was audible to the seals for up to 5 km, there was no change in their density in that area between breeding seasons before and breeding seasons after development began (Moulton et al. 2003).

Very little information exists on the reactions of pinnipeds to sounds from seismic exploration in open water (Richardson et al. 1995). Visual monitoring from seismic vessels has shown that pinnipeds frequently do not avoid the area within a few hundred metres of an operating airgun array (Harris et al. 2001). However, the telemetry research of Thompson et al. (1998) suggests that reactions may be stronger than has been evident from visual studies. Based on anecdotal evidence, pinnipeds appear to show little reaction to vessels in open water (Richardson et al. 1995). However, there are few studies that describe the responses of pinnipeds in the water to vessel traffic.

5.1.5.10 Sea Turtles

The frequency of hearing sensitivity for sea turtles has been reported as 250 to 300 Hz to 500 to 700 Hz (Ridgway et al. 1969; Bartol et al. 1999), which is higher than the frequencies where most seismic sounds are produced and lower than side-scan sonar frequencies. However, these frequencies do overlap with those prominent in airgun pulses. It is therefore likely that airguns are audible to sea turtles. The distance over which an airgun array might be audible to a sea turtle is impossible to estimate due to an absence of absolute hearing threshold data. However, because of the high source levels of airgun pulses, this distance is likely to be considerable.

It has been suggested that sound may play a role in navigation but recent studies suggest that visual, wave and magnetic cues are the main navigational cues used by hatchling and juvenile sea turtles (Lohmann and Lohmann 1998; Lohmann et al. 2001). Thus, masking is unlikely to be an important issue for sea turtles exposed to pulsed sounds from geohazard surveys.

Studies carried out by Lenhardt (1994) showed that sea turtles increase their movements after airgun shots and do not return to the depth where they usually rest.

McCauley et al (2000b) conducted two trials with caged sea turtles and an approaching-departing single airgun (Bolt 600B, 20-cubic inch chamber) to gauge behavioural responses by the green (*Chelonia mydas*) and loggerhead (*Cartetta caretta*) turtle. The first trial involved 2:04 hrs of airgun exposure and the second 1:01 hr. Each trial used a 10 s repetition rate. The two trials showed that above an airgun level of approximately 166 dB re 1 µPa (rms) resulted in the turtles noticeably increased their swimming activity compared to non airgun operation periods. Airgun levels above 175 dB re 1 µPa (rms) resulted in the turtle's behaviour became more erratic possibly indicating the turtles were in an agitated state (McCauley et al. 2000b). The increase in swimming behaviour tracked the received airgun level, in that the turtles spent increasingly more time swimming as the airgun level increased. The point at which the turtles showed the more erratic behaviour would be expected to approximately equal the point at which avoidance would occur for unrestrained turtles.

O'Hara and Wilcox (1990) conducted studies on loggerhead turtles in a 300 x 45 m enclosure in a 10 m deep canal. The sound source was a Bolt 600B airgun with 10-cubic inch chamber and two Bolt 'poppers', all operating at 2,000 psi (14 MPa), suspended at 2 m depth and operated at a 15 s interval. The turtles maintained a stand off range of approximately 30 m. The received airgun levels were not measured and, as such, data for study comparability are missing. McCauley et al. (2000a) estimated that the level at which O'Hara and Wilcox (1990) observed avoidance behaviour was around 175 to 176 dB re 1 µPa (rms).

Moein et al. (1994) studied loggerhead turtles avoidance behaviour, physiological response and electroencephalogram measurements of hearing capability, in response to an operating airgun. The turtles were held in an 18 m x 61 m x 3.6 m netted enclosure in a river. The airguns were deployed and operated from the net ends at 5 to 6 s intervals for five-minute periods.

Details of the airgun, its operational pressure, deployment depth and sound levels experienced by the turtles throughout the cage were not given. Avoidance behaviour was observed during the first presentation of the airgun exposure at a mean range of 24 m. Further trials several days afterwards did not elicit statistically significant avoidance behaviour.

The physiological measures did show evidence of increased stress; however, the effects of handling turtles was not taken into accounted and, therefore, the increased stress could not be attributed to the airgun operations. A temporary reduction in hearing capability was evident from the neurophysiological measurements but this effect was temporary and the turtles hearing returned to pre-test levels at the end of two weeks. Moein et al. (1994) concluded that this might have been due to either habituation or a temporary shift in the turtles hearing capability.

The available evidence from the scientific literature suggests that sea-turtles may show behavioural responses to an approaching airgun array at a received level around 166 dB re 1 µPa (rms) and avoidance at approximately 175 dB re 1 µPa (rms). McCauley et al. (2000b) estimated that this corresponds to behavioural changes occurring at approximately 2 km and avoidance approximately 1 km for seismic vessel operating 3-D airgun arrays in 100 to 120 m water depth. It is necessary to note that important sea turtle habitats mostly occur in shallower water, often less than 20 m deep. The propagation of an airgun array in such water depths may be vastly different than that for the array measured in 120 m water depth.

5.1.6 Species at Risk

The marine mammal species at risk that could occur in the SEA Area include the blue whale (listed as endangered under SARA Schedule 1), beluga whale (St. Lawrence Estuary population, listed as threatened under SARA Schedule 1), North Atlantic right whale (listed as endangered under SARA Schedule 1), and fin whale (Atlantic population listed as special concern under SARA Schedule 1). The leatherback turtle is listed as endangered under SARA Schedule 1. Marine birds species at risk that could occur in the SEA Area are the Piping Plover (listed as endangered under Sara Schedule 1). Fish species at risk that could occur in the SEA Area are the northern and spotted wolffish (both are listed as threatened under SARA Schedule 1 and the Atlantic wolffish (listed as a species of special concern under SARA Schedule 1).

5.1.6.1 Marine Mammals

The actual effects of sound (seismic) on marine mammals are described in detail in Section 5.1.5 and would be considered the same for the SARA marine mammals. However, while these effects may not be detrimental to marine mammals with stable populations, such is not necessarily the case with respect to the SARA listed species.

Behavioural effects such as avoidance, deviation from normal migration routes, interruption of feeding, moving away from the noise sources, reduced surface interval, reduced dive duration, and lower numbers of blows all may be associated with sound (i.e., Richardson et al. 1986; 1995; 1999; Ljungblad et al. 1988; Richardson and Malme 1993; McCauley et al. 2000a; 2000b; Gordon et al. 2004; LGL 2005b). These studies indicate that these displacements due to behavioural effects tend to be short term, with the marine mammals returning to previous patterns. Although the behavioural effects may be short term, these effects could be very important to the SARA listed species in that effects on a single individual could be ultimately affect the population. The effects of displacement from or deprivation of access to critical habitats is important knowledge with respect to SARA Species.

There is the potential that behavioural effects could cause increased levels of physiological stress that may result in an individual becoming immune-compromised or having reduced reproductive output. Knowledge of how short-term stress response may affect the long-term health of marine mammals is unknown (NRC 2003a) and, as such, makes it a matter of concern (Gordon et al. 2004), particularly with respect to the SARA-listed species. NRC (2003a) noted that a decrease in feeding rate for marine mammals might potentially equate to a year's delay in attaining sexual maturity, a small increase in infant mortality, or a slightly shorter life span that may not be important to an individual but could negatively affect the recovery for SARA species.

The biological implications of signal masking will depend greatly on the function of the signal and the context. In a healthy marine mammal population the introduction of masking noise might have minimal effect. Even if the females' ability to make a mating choice were diminished, they would still be likely to find a mate. In the case of a severely depleted marine mammal population, the ability of males and females to find each other using acoustic cues could become vital for the well-being of the species (NRC 2003a).

The biological implications of signal masking depend on the function of the signal and the context. Understanding of the mechanics of signal masking is limited and how marine mammals use acoustic cues in the marine environment is even more poorly understood than masking of communication (NRC 2003b). These are important data gaps, particularly in reference to SARA listed marine mammals as the ability of males and females to find each other using acoustic cues could become vital for the well-being of the species.

5.1.6.2 Marine Birds

Feeding areas for the Piping Plover include intertidal portions of ocean beaches, mudflats, sandflats and shorelines of coastal ponds, lagoons, or salt marshes. Sound from seismic activities is anticipated to have little interaction with exploration-related activities.

5.1.6.3 Marine Fish

A recent allowable harm assessment (DFO 2004f) concluded that oil exploration activities were determined to have negligible effects on the ability of both northern and spotted wolffish to survive and recover. Sound from seismic activities would unlikely affect the northern and spotted wolffish.

5.1.7 Sensitive Areas

The effect of sound would be expected to have little or no environmental effect on sensitive areas. The effect of sound from seismic activities is related to the marine animals that use the sensitive areas as critical habitat and is addressed as such.

5.1.8 Mitigations

The effects of sound as a result of seismic activities and vessel traffic have the potential to affect marine animals and, in particular, marine mammals. There are standard mitigation measures required during geophysical, geotechnical and seismic surveys to assist in the protection of marine animals. The mitigations are detailed in Appendix 2 of the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines, Newfoundland Offshore Area*, April 2004).

Mitigations for noise associated with seismic survey activities and other exploration and production activities, include but are not limited to:

- ramp-up procedures as outlined in Geophysical, Geological, Environmental and Geotechnical Program Guidelines, Newfoundland Offshore Area, April 2004;
- airgun shut down (when active and not only during ramp-up procedures) if a SARA-List endangered or threatened marine mammal or Sea turtle is sighted within 500 m of the array;
- a Marine Mammal and Seabird Observation program;
- publishing a Canadian Coast Guard “Notice to Mariners” and a “Notice to Fishers” via the CBC Radio program Fisheries Broadcast;
- guidelines established by the Canadian Wildlife Service (based on Nettleship 1980) require aircraft to remain at least 8 km on the seaward side and 3 km on the landward side away from major seabird colonies between April and November (JWL 2006);
- a seabird monitoring program should be implemented to collect data on seabird abundance in the area;
- ship operations will adhere to Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78);
- gear compensation program for gear losses attributed to seismic survey activity;
- using standard pollution prevention policies and procedures;

- avoidance of sensitive times and areas for selected periods and times to minimize potential effects to sensitive species; and
- a fisheries liaison officer, or similar, to maintain communication with fishers in the area of seismic activity.

5.2 Drill Mud Discharges Associated with Exploration and Production Activities

The environmental effects associated with drill muds and cuttings are depositional effects (habitat smothering, creation of piles, extent of disposition); toxicity associated with chemical constituents of the muds; bioaccumulation (hydrocarbon and metal bioaccumulation by fish and potential of taint); and physical effects related to the effects of fines. Drill cuttings will fall within a few metres with the associated fines being spread over a wider area dependant upon site-specific oceanographic cuttings. Because the drill muds and cuttings fall to the bottom, benthic organisms are primarily the group of organisms impacted.

5.2.1 Invertebrates

The effect of exploratory drilling waste released near the surface upon sensitive species will depend on physical parameters like water depths, currents and particle size.

5.2.1.1 Water-based Muds and Cuttings

Invertebrate smothering is the primary concern associated with the discharge of WBMs and cuttings. While motile fish and shellfish will likely move away from the zone of influence of cuttings deposition, research has indicated that sessile invertebrates are likely to be smothered in areas where the cuttings are greater than 1 cm thick (Bakke et al. 1989). Bryozoans, barnacles, brittlestars, urchins and other sessile epifauna will likely be smothered within 50 m of a well, whereas most polychaetes, amphipods, clams and other burrowing infauna will likely be less affected as they can resurface from a covering of several centimetres. Since most sessile invertebrate species have short generation times, invertebrate communities are expected to recover within one year after drilling (Hurley and Ellis 2004; Neff 2005).

WBMs may not immediately settle to the substrate bottom but may remain in suspension in the water boundary layer. Any drill cuttings remaining in suspension will likely affect suspension feeders such as scallop. Sea scallop feeding, growth and reproduction may be affected by suspended WBMs at concentrations less than 10 mg/L (Cranford 2004). In addition, the fine particles of bentonite and barite found in drill mud can interfere with digestion and feeding of bivalve species (Barlow and Kingston 2001) such as scallops (Armsworthy et al. 2005).

Changes to water column sediment loading could affect corals through either a reduction in feeding or outright mortality (Cimberg et al. 1981, in Breeze et al. 1997). Increased particle loading could abrade the living coral tissue and kill coral polyps through excessive mucous production (Hecker et al. 1980, in Breeze et al. 1997).

The meiofauna and macrofauna effects studied by Montagna and Harper (1996) indicated that environmental effects were localized within 100 to 200 m from the platforms. The patterns of community change included increases in deposit-feeding polychaetes and nematodes indicating organic enrichment, while density declines of harpacticoid copepods and amphipods indicated toxicity. Crustaceans (especially amphipods and harpacticoid copepods) and echinoderms are sensitive to toxics whereas polychaetes, oligochaetes and nematodes (especially nonselective deposit feeders) are enhanced by organic enrichment (either from hydrocarbons or biologically produced materials falling from the platform structure). The percentage of gravid female harpacticoid copepods was greater and the percentage of juveniles was reduced within 50 m of the platforms. In addition, reproductive effort for female harpacticoids carrying eggs was reduced. These responses could be explained as sublethal physiological reactions of these organisms to stress related to exposure to toxicants.

Boudreau et al. (1999) conducted a study on the potential sub-lethal effects of WBM discharge on the Georges Bank. Boudreau et al. (1999) combined bioassay studies and a benthic boundary layer transport model to predict the effects of WBM constituents (bentonite and barite) on adult scallops. Model simulations indicated the potential for a reduction in growing days within the WBM plume. The study concluded that there was a potential for loss of growing days, which could result in reproductive loss. However, the overall effect on scallop populations could not be determined and it must be noted that these conclusions are based in part on model simulations.

Documented data from 20 case studies (Hurley and Ellis 2004) indicate that WBMs have pattern of detectable contaminants and biological effects. Using barium as a tracer, the zone of detection for both single and multiple wells found that background levels for barium were achieved at 1,000 to 3,000 m from the drill source. Increases in other trace metals (specifically arsenic, cadmium, chromium, copper, mercury, lead and zinc) were more spatially limited to 250 to 500 m of the drill site. However, these metals tend not to be in a bioavailable form and thus few biological effects are attributed to increases from metals discharges (CAPP 2001).

Biological effects are routinely detected at distances of 200 to 500 m from the well site and include alterations to benthic community structure as measured by changes in abundance, species, richness and diversity. The changes to benthic community structures have been primarily attributed to physical alterations in sediment texture including smothering as opposed to toxic effects (Hurley and Ellis 2004). The effects and area affected will be influenced by environmental variables such as depth, current, wave regimes and substrate type, as well as the nature and volume of the discharges, including cuttings size and location of outfall within the water column. Studies have indicated that benthic communities around single exploration wells returned to baseline conditions within one year after cessation of drilling.

Results of the White Rose Environmental Effects Monitoring Program indicate that maximum concentrations of $>C_{10}$-C_{21} hydrocarbons were located between 300 and 600 m from drill centres (each containing multiple well slots) and the median concentration of 22 mg/kg (within 1 km of the drill centres) fell to approximately 1 mg/kg within 5 km of the drill centres (Husky 2005). Barium concentrations were also elevated near the drill centres, but levels decreased with distance to a background level of 200 mg/kg within 2 km of the drill centres (Husky 2005).

As WBMs are virtually free of hydrocarbons and metals present are in a form that is not readily bioavailable, contamination is of minimal concern to the environment. The *Offshore Chemical Selection Guidelines* (NEB et al. 1999) control WBM additives by ensuring that the additives have the least risk to the environment. Metals from WBMs and drill cuttings have not been shown to cause biological effects (CAPP 2001; Hurley and Ellis 2004). WBMs do not cause tainting or contamination of fish.

5.2.1.2 Synthetic-based Muds and Cuttings

The increased risk of invertebrate and invertebrate habitat contamination is the primary concern associated with treated SBM deposition. SBMs stay closer to the well site and do not disperse as widely as WBMs. Thus, no additional mortality (smothering) of sessile benthic invertebrates is expected to occur due to the discharge of SBMs since the area will have been subjected to smothering from previous WBMs deposition.

The primary concern associated with the deposition of treated SBMs is the increased risk of invertebrate and invertebrate habitat contamination. SBMs are essentially non-toxic, require less quantity of mud (compared to WBM) for the same distance drilled, have the potential to biodegrade relatively rapidly and disperse less than WBMs. The C-NLOPB approves any SBM discharge and discharge of whole SBM is not permitted. Changes in species abundance and richness (and other potential biological effects associated with the use of SBMs) are typically within distances of 50 to 500 m from well sites; benthic communities typically recover within one year of well completion. Thus, the risk of invertebrate and invertebrate habitat contamination is likely minimal.

Hurley and Ellis (2004) reviewed 19 studies to assess environmental effects associated with SBM and found that the area of detection and scale of biological effects were more localized than for WBM. Biological effects were generally detected at distances of 50 to 500 m from well sites, with recovery of benthic communities occurring within one year of well completion. While the biological effects of SBM are localized, there is uncertainty regarding degradation processes of SBM (it can produce anoxic conditions in the sediment). Toxic effects on the benthic invertebrate community may include indirect chemical toxicity and toxic effects due to anoxia caused by organic loading and biodegradation (CAPP 2001). In areas with active hydrodynamic conditions, chemical toxicity may play a more important role in SBM impacts than biodegradation, as it will be more likely that cuttings will be spread out and will degrade aerobically (not resulting in significant anoxia). In areas with more quiescent hydrodynamic conditions, biodegradation and subsequent development of anoxic conditions may play more of a role in determining benthic effects than chemical toxicity.

The major conclusions of an examination of Norwegian field studies (Jensen et al. 1999) were:

- results from monitoring studies on fields where only SBMs and WBMs have been used found that discharges of cuttings associated with SBMs and WBMs have little or no effect on benthic fauna outside a radius of 250 m;
- increases in the density of individuals of tolerant indicator species can be found up to 1,000 m from some installations; and
- effects on benthic invertebrate communities from SBM cuttings discharges are rarely seen outside of 250 to 500 m.

Suspension feeders such as scallops are most likely to be affected by SBM discharge. Armsworthy et al. (2005) have demonstrated weigh loss of somatic and reproductive scallop tissues when exposed to ParaDrill IA at concentrations of 1.5 mg/L. The fine particles of bentonite and barite in drilling mud are most likely the cause of effects on scallop tissue growth. Hamoutene et al. (2004) exposed lobsters to the SBM (IPAR) over a 20-day period and concluded that there was little or no potential for negative effects. Laboratory studies were conducted to assess effects of synthetic drill mud fluid and drill mud cuttings on a range of marine fish. The laboratory studies found 96 to 100 percent survival for marine copepods and 83 to 100 percent survival for ctenophores (Payne 2001a; 2001b).

Several reports have examined the discharge of drill mud and cuttings associated with routine drilling on the Grand Banks (where there are multiple drilling activities) (Husky 2000; MMS 2000; CAPP 2001; NEB et al. 2002) and have concluded that single well exploration drilling has no significant environmental effect on the marine environment.

5.2.2 Fish

5.2.2.1 Water-Based Muds and Cuttings

Using barium as a tracer, the zone of detection for both single and multiple wells found that background levels for barium were achieved at 1,000 to 3,000 m from the drill source. Increases in other trace metals (specifically arsenic, cadmium, chromium, copper, mercury, lead and zinc) were more spatially limited to 250 to 500 m of the drill site. However, these metals tend not to be in a bioavailable form and thus few biological effects are attributed to increases from metals discharges (CAPP 2001). WBMs have not been shown to cause biological effects (Hurley and Ellis 2004; CAPP 2001). WBMs contain a greater volume of fine-grained material; therefore, it is likely that they will remain in the water column much longer than SBMs. However, concentrations of WBMs in the water column are low, with short exposure times so short, they are not expected to cause any acute or sublethal effects on pelagic species (Neff 1987). Cuttings and associated drill mud deposition is expected to elicit a startle response in motile fish resulting in these organisms moving away from the potential zone of influence. Tainting or contamination of fish species is not expected to be associated with WBMs.

5.2.2.2 Synthetic-Based Muds and Cuttings

Biological effects were generally detected at distances of 50 to 500 m from well sites; however, the effects were essentially limited to sessile benthic invertebrates. Cuttings and associated drill mud deposition is expected to elicit a startle response in motile fish, resulting in these organisms moving away from the potential zone of influence. A number of reports have examined the discharge of SBMs and cuttings associated with routine drilling (Husky 2000; MMS 2000; CAPP 2001; NEB et al. 2002) and have concluded that small-scale drilling has no significant environmental effect on the marine environment of the Grand Banks.

Laboratory studies were conducted to assess effects of synthetic drill mud fluid and drill mud cuttings (formulations used for Grand Banks oil and gas operations) on a range of marine fish. The laboratory studies found 88 percent survival rates for capelin larvae and 100 percent survival for yellowtail flounder (Payne 2001a; 2001b). Toxicity studies conducted by Payne et al. (2001a) using American plaice on Hibernia drill cuttings found no acute toxicity in juvenile American plaice exposed for 30 days to Hibernia cuttings, approximating hydrocarbon concentrations typically found 200 to 500 m from rigs in the North Sea.

5.2.3 Commercial Fisheries

Cuttings and associated drill mud deposition which includes water-based muds (see Section 5.2.2.1) and synthetic-based mud (see Section 5.2.2.2) may elicit a startle response in fish resulting in these organisms moving away from the potential zone of influence. The zone of influence is expected to be within the safety zone around the platform in which fishing activities are prohibited. Tainting or contamination of fish species is not expected to be associated with cutting and drill mud depositions (Husky 2000; CAPP 2001).

5.2.4 Marine Birds

The discharge of WBMs and/or SBMs and cuttings and associated drill muds will have negligible environmental effects on birds. Cuttings fall to the seafloor and, therefore, there is little chance of interaction with birds on the surface.

5.2.5 Marine Mammals and Sea Turtles

Drilling activities are unlikely to produce concentrations of heavy metals in muds and cuttings that are harmful to marine mammals (Neff et al. 1980, in Hinwood et al. 1994).

5.2.6 Species at Risk

The marine mammal species at risk that could occur in the SEA Area include the blue whale, beluga whale, North Atlantic right whale and fin whale. The leatherback turtle could also occur in the SEA Area. Marine-associated birds species at risk that could occur in the SEA Area are the Piping Plover. Fish species at risk that could occur in the SEA Area are the northern and spotted wolffish.

As noted in Section 5.2, benthic invertebrates are the primary group of organisms subject to environmental effects associated with drill muds and cuttings. Biological effects associated with drill muds and cuttings are not normally found beyond 500 m from drilling platforms (Hurley and Ellis 204) and as such, there will be limited interaction between drilling muds and cuttings and marine mammals and marine-associated species at risk. Deposition of drill muds and cuttings as well as potential environmental effect should be examined in greater detail in project-specific environmental assessments.

Because wolffish are bottom-dwelling species, there is the potential that drill muds and cuttings could have an effect on wolffish.

5.2.7 Sensitive Areas

Drill cuttings and associated muds (both WBMs and SBMs) have the potential to cause localized environmental effects around the well site to approximately 50 to 500 m, depending upon the type of cuttings and associated mud discharged (WBMs or SBMs). There may sensitive areas that are habitat for species that may be adversely affected by the discharge of drill cuttings and muds such as coral and scallops. It is anticipated that effects to those species may occur within 50 to 500 m of the well site. Special mitigation strategies may be required for such areas.

5.2.8 Mitigations

The mitigation measures to reduce or eliminate potential adverse effects of the drill mud WBMs-based drilling muds whenever feasible include but are not limited to;

- the use of WBMs whenever possible;
- treatment and disposition of drill cuttings and associated muds as per requirements of the OWTG (NEB et al. 2002);
- SBMs will be recycled, reused and ultimately disposed of on-shore;

- for exploration drilling, special mitigation strategies (e.g., zero discharge) may be required for areas identified as sensitive to drill cuttings and discharges (e.g., coral and scallop habitat). Other mitigative strategies may be identified at the project-specific environmental assessment stage;
- screening and selection of chemicals used for drilling;
- waste management plan for the storage, handling and disposal of waste generated offshore;
- use of best available technologies whenever feasible; and
- the timing and locations of planned Project activities will be provided to fishers who may be operating in the vicinity of the SEA Area via a Canadian Coast Guard "Notice to Mariners" and a CBC Radio Fisheries Broadcast "Notice to Fishers".

5.3 Routine Discharges (including Air Emissions)

They are a variety of routine discharges associated with offshore exploration and production activities, including cement slurries, BOP fluid, produced water, air emissions, storage displacement water, bilge and ballast water, deck drainage, cooling water, sewage and food wastes. Produced water discharges are anticipated to be the largest volume of discharges associated with production activities. Produced water tends to be primarily associated with production activities but it is possible to encountered limited quantities of produced water during exploration activities.

Deck drainage from a seismic vessel or drilling platform would result in the discharge of limited amounts of hydrocarbons; however, they are not generally associated with surface slicks. Bilge water is seawater that may seep or flow into the structure from various points in the offshore installation. Ballast water is water used to maintain the stability of an offshore facility. Vessels will adhere to Annex I of the *International Convention for the Prevention of Pollution from Ships* (MARPOL 73/78) and drilling platforms treat any oil-containing water period to discharge in adherence with the OWTG (NEB et al. 2002). Deck drainage, ballast water and bilge water are expected to have minimal environmental effects (when treated in accordance with OWTG (NEB et al. 2002) and would be localized immediately adjacent the discharge point. The discussion of produced water effects will capture any potential environmental effects that may have been associated with the hydrocarbons entrained with deck drainage, ballast and bilge water.

BOP fluid (routine safety testing) is typically a glycol-water mixture with low toxicity.

Estimates of grey water and black water discharges are associated with the drill platform. Waste water discharge is treated and tested for compliance with OWTG (NEB et al. 2002). Organic matter associated with discharges will disperse quickly in an open ocean environment and be quickly degraded by bacteria.

A low volume of non-chlorinated seawater will be used as cooling water and will result in a small area of thermal effects.

Storage displacement water is used to ensure equilibrium in the oil storage system and is limited to production activities on specific production facilities (i.e., GBS). As oil is produced and flows into the storage cells, storage displacement water is forced out via a buffer system and, as oil is offloaded from the storage cells, storage displacement water flows naturally back into the storage cells. Storage displacement water that is discharged should be treated to reduce its oil concentration to 15 mg/L or less in accordance with OWTG (NEB et al. 2002). The discussion of produced water effects will capture any potential environmental effects that may have been associated with the hydrocarbons entrained with storage displacement water. The environmental effects of storage displacement water are expected to be minimal and localized to immediately adjacent the discharge point.

Atmospheric emissions will be released from the drilling rig during exploration drilling. Operators will be required to conduct regular maintenance to ensure equipment operates as efficiently as possible. Therefore, emissions of potentially harmful materials will be small and will rapidly disperse to undetectable levels.

Produced water would only be encountered during exploration drilling during well-testing procedures. The amount encountered is very small compared to production activities. If any produced water is encountered, it is typically treated and disposed offshore or atomized in the flare. Produced water will be the main discharge associated with production activities. Produced water must be treated to reduce its oil content to compliance with the current OWTG (NEB et al. 2002), which require produced water to be treated to 30 mg/L oil in discharged produced water. Once produced water is treated to OTWG specifications, the produced water will be discharged overboard. Produced water environmental effects are discussed in detail in the following sections.

Dispersion modeling studies for produced water predict a rapid dilution in the range of 30- to 100-fold within the first tens of metres of the discharge point, followed by slower dilution rates (Terrens and Tait 1993; Brandsma and Smith 1996; Neff 2002). The factors that influence the actual plume dynamics upon discharge are discharge rates, ambient current speed, tidal factors, wind-driven surface current, turbulent mixing regimes, water column stratification, water depth, density of the plume, chemical composition and discharge pipe diameter. Field validation studies of produced water discharge dispersion have verified that dilution is rapid (Neff 2002). A summary of these studies is presented in Table 5.3.

Table 5.3 Produced Water Field Validation Data

Study	Method	Conclusion
Continental Shelf Associates 1993	radium 226	426-fold dilution at 5 m 1,065-fold dilution at 50 m
Smith et al. 1994	dye tracer	100-fold dilution at 10 m 1,000-fold dilution at 103 m
Somerville et al. 1987	dye tracer	100-fold dilution at 50 m 2,800-fold dilution at 1,000 m
Brooks et al. 1980	benzene	150,000-fold dilution at discharge
Terrens and Tait 1996	BTEX/PAHs	Varied depending upon fractions Ranged from 2,000- to 53,000-fold dilution
Holdway and Heggie 1998	benzene and toluene	10,000-fold dilution at 1,000 m
Rabalais et al. 1991; 1992	Barium	Elevated levels found in sediment out to 1,000 m of discharge
US Department of Energy 1997	benzene	Various fields: 41- to 260-fold dilution at 5 m 150- to 3,400-fold dilution at 100 m 4,900- to undetectable at 2,000 m
Source: as reported in Neff 2002.		

5.3.1 Invertebrates

Research has indicated that crustaceans are usually more sensitive to produced water effects than fish (Neff 1987; Terrens and Tait 1993; Jacobs and Marquenie 1991), with mysiids appearing to be as sensitive as or more sensitive than other species. Given the rapid rate of dilution and dispersion of most produced waters upon discharge to the receiving waters, most produced waters would be expected to minimally affect the receiving environment.

Cranford et al. (1998) examined the effect of produced water from Cohasset/Panuke on early life stages of lobster and sea scallop. The lobster larvae data were highly variable, with a 96-hour LC50 of 0.9 percent in experiments conducted with fed larvae. The authors noted cannibalism occurred among the larvae and warned that the resulting data should be interpreted with caution. The 96-hour LC50 for sea scallop larvae was 20.8 percent. Fertilization success of scallop eggs during 48-hour exposures of eggs and sperm to produced water was statistically significantly affected at produced water concentrations greater than 1 percent.

The most sensitive organisms generally do not show effects at concentrations below approximately 1 percent produced water and then only after exposure times of 48 hours or more. Produced water discharges are subject to rapid dilution factors within the 10 m of the discharge point that toxic effects are expected only immediately adjacent the discharge point.

5.3.2 Fish

The two primary components of produced water that are of environmental concern are the aromatic hydrocarbons (or the BTEX fraction of TPH analyses) and PAHs. BTEX is soluble in seawater and highly toxic to marine organisms. However, there is minimal exposure risk to marine organisms given the rapid loss due to evaporation, adsorption and sedimentation, biodegradation and photolysis (Johnsen et al. 2004). PAHs are less soluble but more persistent in the environment (Holdway and Heggie 2000) and the associated toxicity to marine organisms are primarily related to benzene and naphthalene fractions (Brand et al. 1989, in Holdway and Heggie 2000).

Naphthalene fractions are rapidly degraded in the water column (Johnsen et al. 2004). Low-molecular weight PAHs are the dominant fraction of produced water; these fractions degrade more readily than the high-molecular PAH fractions, which generally have a more specific toxicological nature, potentially interacting with cellular protein and DNA (Neff 2002; Johnsen at al. 2004). However, their concentrations in a produced water plume are very low due to the rapid dilution following discharge and are rarely at levels high enough to cause toxic effects in marine plants and animals (Neff 2002; Johnsen et al. 2004).

The produced water will be warmer and less dense than the receiving water. Some zooplankton and fish larvae may experience thermal shock in the immediate vicinity of the outfall. Produced water could affect water quality slightly downstream of the release point and affect plankton.

Laboratory-based studies indicated a correlation between fish reproduction effects and oil dispersed in water above 0.4 mg/L, with DNA adducts and PAH metabolites (biomarkers) responses observed at 0.1 mg/L oil dispersed in water (Bechmann et al. 2004). Ferraro and Fossi (2004) conducted laboratory experiments using produced water and found a indication of multi-function oxygenase (MFO) activities in relatively low concentrations of PAHs (and their bile metabolites), which suggested a potential role to toxicants other than PAHs. Expanding the study to the field, Ferraro and Fossi (2004) concluded that the studied platform was not particularly affecting biomarker responses, as MFO activities were found at different sites throughout the SEA Area. Studies have found that PAHs may cause adverse biological effects due to bioaccumulation in shallow, near shore oil and gas platforms; however, there is little bioaccumulation in marine organisms due to produced water discharged from deepwater offshore oil production platforms (Neff 2002).

Concentrations of phenols (and alkylated phenols) in produced water declines rapidly due to dilution, evaporation and bio- and photo-degradation with distance from a discharge point (Neff 2002). The solubility of phenols is very low in sea water, with concentrations often below detection limits; however, concern remains about their potential to disrupt reproduction when the degree of alkylation is increased (Johnsen et al. 2004). Laboratory-based studies on uptake of alkylated phenols in fish species have indicated that there is uptake in fish within 100 to 1,000 m of a discharge point, located primarily in the gastro-intestinal tract; and that the fish excreted the alkylated phenols (and all other associated compounds) via bile to background levels within 24 to 48 hours (Sundt and Baussant 2003).

5.3.3 Commercial Fisheries

Routine discharges including air emissions have the potential to affect commercial fisheries as a result of the potential for physical effects on commercial fisheries, including hydrocarbon and metal bioaccumulation and taint. The results of the 2004 White Rose Environmental Effects Monitoring Program (Husky 2005) concluded that metal and hydrocarbon body burdens for American plaice and snow crab were unaffected by project activity; there was no evidence of taint and health incidences for American plaice were similar between the White Rose Study Area and reference areas.

Therefore, routine discharges are expected to have minimal environmental effects on commercial fisheries. There is ongoing research conducted by DFO and others on the effects of produced water in the marine environment.

5.3.4 Marine Birds

Seabirds that are attracted to offshore production platforms may be exposed to the intermittent presence of oil sheens in the water. Sheens are thin films of organic materials typically less than 1 mm thick (Taft et al. 1995) that occur when oil droplets trapped in the produced water rise to the surface without breaking up. Oil sheen is defined as a thin film of oil, usually less than 0.002 mm thick on the water surface (Fingas 2001). Sheens contain a small amount of organic material per unit area of surface water. Sheens emanating from weathered crude were sampled in Alaska and were found to contain PAH concentrations ranging from non-detectable to 18.4 µg/L (Neff et al. 1990). Taft et al. (1995) reported that 15 ml of oil could form a rainbow sheen of approximately 50-m^2 surface area.

Since nesting burrows are located on land, vulnerability of Leach's Storm-Petrel (to marine anthropogenic disturbances) would be primarily during the non-breeding season and during oceanic feeding trips during incubation and rearing of young.

Factors affecting the concentration of dispersed oil in produced water and the likelihood of sheen occurrence include oil density, interfacial tension between oil and water phases, type and efficiency of chemical treatment and type, size, and efficiency of the physical separation equipment (Ali et al. 1999). Soluble organics and treatment chemicals in produced water decrease the interfacial tension between oil and water.

On calm water, produced water sheen can form at 25 ppm and nearly all offshore installations usually have faint but visible streaks of sheen extending for hundreds of metres downwind of them, even when their water treatment plants are the best available (New Logic Research n.d.). Sheens are typically short-lived due to natural weathering processes (Neff 1990). The high surface to volume ratios that characterize sheens, contribute to relatively rapid volatilization, dissolution, and dispersion of sheen components.

Seabirds that are attracted to offshore production platforms may be exposed to sheens. Sheens are thin films of organic materials typically less than 1 mm thick (Taft et al. 1995). Oil sheen is defined as a thin film of oil, usually less than 0.002 mm thick on the water surface (Fingas 2001). The discharge of produced water may cause sheening on surface waters in ideal weather conditions.

Potential effects to wildlife exposed to sheens are external contamination and irritation of the skin, eyes and gastrointestinal tract, depending upon the nature, thickness and persistence of the sheen. Adverse effects of oil on birds include hypothermia, loss of buoyancy and mortality (Neff 1990; Neff et al. 1990).

The Environmental Studies Research Fund has sponsored an independent literature review study regarding the potential effects of the sheens on seabirds. This study will also identify data gaps and propose a plan to address these gaps. The report should be completed by 2007.

5.3.5 Marine Mammals

Potential effects of routine discharges on marine mammals are the potential contamination of marine mammals and their food sources as a result of discharges.

As discussed in section 5.3.3 Commercial Fisheries, the results of the Whiterose Environmental Effects Monitoring Program (Husky 2005) found that American Plaice and Snow Crab were not contaminated as a result of project activity.

Therefore, routine discharges are expected to have minimal environmental effects on marine mammals.

5.3.6 Species at Risk

The marine mammal species at risk that could occur in the SEA Area include the blue whale beluga whale, North Atlantic right whale and fin whale. The leatherback turtle could also occur in the SEA Area. Marine-associated birds species at risk that could occur in the SEA Area are the Piping Plover and Harlequin Duck. Fish species at risk that could occur in the SEA Area are the northern and spotted wolffish.

Produced water effects are not expected to interact with the Piping Plover under most scenarios. However, in the unlikely scenario that a production platform is situated in estuarine waters with low flows and flushing rates, there is a possibility for produced water effects to occur in near-shore sediments. The effects of produced water discharges in estuarine systems may include toxicity to various organisms, the reduction of invertebrate abundance and diversity (Rabalais et al. 1991). Although this would not necessarily directly affect the Piping Plover, food sources of the Piping Plover could be affected.

5.3.7 Sensitive Areas

As noted in section 5.3.7, in the unlikely scenario that a production platform is situated in estuarine waters there is a possibility for produced water effects to occur in near shore sediments resulting in reduced invertebrate abundance and diversity. Although the likelihood of this scenario occurring is remote, it is considered for completeness.

5.3.8 Mitigations

Mitigations for routine discharges associated with exploration and production activities include but are not limited to:

- adherence to OWTG (NEB et al. 2002) limits on discharges;
- screening and selection of chemicals used for drilling;

- sanitary and food waste will be discharged below the water surface once it has been macerated to a particle size of 6 mm or less (NEB et al. 2002);
- design and implementation of a waste management plan that would serves as the controlling document for the storage, handling and disposal of waste generated during the drilling program;
- use of best available technologies and environmental criteria in selecting equipment and chemicals whenever feasible;
- use of Marine Mammal and Seabird Observer program;
- bird salvage permit requirements;
- protection measures for air emissions, bilge and ballast discharges, deck drainage, drilling discharges, sewage and grey water, hazardous and non-hazardous waste management, handling of helifuel, transfer of fuel, bulk drilling fluids and liquid wastes between vessels and rig, chemical management and spills;
- communication with fishing industry/other marine users regarding drilling activities (e.g., vessel, safety zone); and
- gear compensation program.

5.4 Existing Anthropogenic Disturbances in the Sydney Basin

The only known anthropogenic disturbance to the benthic invertebrate community in the SEA Area is commercial fishing by trawler. Trawling occurs in the SEA Area. Atlantic cod and redfish are harvested using stern otter trawls. Iceland and sea scallops are harvested with scallop dredges. The severity of the impact of trawling depends on its intensity/frequency, the habitat type and the organisms present (Kulka and Pitcher 2001). These conditions are site-specific and may range from long term alteration of hard coral habitat to temporary disruption of a low-diversity soft bottom habitat. Modelling exercises conducted by Hiddink et al. (2006) showed that the initial effect of the first trawl pass was large. Increasing trawling intensity in areas where trawling activity was already high had a smaller additive effect on benthic biomass (Hiddink et al. 2006).

5.5 Accidental Events

The worst case accidental event scenario would be from an oil spill associated with an exploration well blowout. Effects of large spills are typically predicted to be greater in enclosed seas and coastal zones than in the open ocean (Patin 1999, in Hurley and Ellis 2004).

Many of the early studies related to the effects of oil on the environment focused on the toxicity of individual compounds to marine organisms (Anderson 1979). The results from these types of studies indicated that the acute toxicity of individual hydrocarbons is largely related to their water solubility. The acute toxicity of a specific oil type is the result of the additive toxicity of individual compounds, especially aromatic compounds. Narcotic effects of individual petroleum compounds are an important component of acute toxicity and are related to low molecular weight volatile compounds (Donkin et al. 1990). Sublethal effects following acute or chronic exposure to petroleum hydrocarbons include disruption in energetic processes, interference with biosynthetic processes and structural development and direct toxic effects on developmental and reproductive stages (Capuzzo et al. 1988).

Weathering processes are extremely important in altering the toxicity of an oil spill. Neff et al. (2000) demonstrated rapid loss of monocyclic aromatic hydrocarbons (BTEX compounds) from evaporation and a reduction of acute toxicity of the water-accommodated fraction (WAF) with loss of these compounds. With weathering processes and loss of the monoaromatic compounds, the PAHs become more important contributors to the toxicity of weathered oils. Other factors that may contribute to alterations in toxicity include photodegradation and photoactivation (Garrett et al. 1998; Boese et al. 1999; Mallakin et al. 1999; Little et al. 2000).

Data gathered from several oil spills (1970s and 1980s) demonstrated that the medium and higher molecular weight aromatic compounds, such as the alkylated phenanthrenes and alkylated dibenzothiophenes, are among the most persistent compounds in both animal tissues and sediments (Capuzzo 1987). Impairment of feeding mechanisms, growth rates, development rates, energetics, reproductive output, recruitment rates and increased susceptibility to disease and other histopathological disorders are some examples of the types of sublethal effects that may occur with exposure to petroleum hydrocarbons (Capuzzo 1987). Early developmental stages can be especially vulnerable to hydrocarbon exposure, and recruitment failure in chronically contaminated habitats may be related to direct toxic effects of hydrocarbon contaminated sediments (Krebs and Burns 1977; Sanders et al. 1980; Elmgren et al. 1983).

5.5.1 Invertebrates

The effects of a fuel spill on invertebrate and invertebrate habitat will be determined by factors such as weather, time of year, type of habitat, species and life history stage. Hydrocarbons will be longest lasting in near-shore sheltered habitats of fine-grained substrates if the spill reaches the shoreline. Concentrations of hydrocarbons can be detectable for several years in the sediments if they are not physically or biologically disturbed (Sanders et al. 1990). Low levels of hydrocarbons in the substrate can have sub-lethal effects on nearby invertebrates. Oil spilled in near shore waters can become incorporated into near shore and intertidal sediments, where it can remain toxic and may affect benthic animals for years after the spill (Sanders et al. 1990).

Chronic toxicity of petroleum hydrocarbons after an oil spill is associated with the persistent fractions of oil and individual responses of different species to specific compounds. Alterations in bioenergetics and growth of bivalve molluscs following exposure to petroleum hydrocarbons appear to be related to tissue burdens of specific aromatic compounds (Gilfillan et al. 1977; Widdows et al. 1982, 1987; Donkin et al. 1990). Widdows et al. (1982) demonstrated a negative correlation between cellular and physiological stress indices (lysosomal properties and scope for growth) and tissue concentrations of aromatic hydrocarbons with long-term exposure of *Mytilus edulis* to low concentrations of North Sea crude oil. Recovery of mussels following long term exposure to low concentrations of diesel oil coincided with depuration of aromatic hydrocarbons (Widdows et al. 1987). Donkin et al. (1990) suggested that reductions in scope for growth in *Mytilus edulis* were related to the accumulation of two- and three-ring aromatic hydrocarbons, as these compounds induced a narcotizing effect on ciliary feeding mechanisms.

Krebs and Burns (1977) observed long term reductions in recruitment and over-wintering mortality in the fiddler crab (*Uca pugnax)* for seven years following the spill of No. 2 fuel oil from the barge *Florida*. Recovery of crab populations correlated with the disappearance of naphthalenes and alkylated naphthalenes from contaminated sediments. Ho et al. (1999) compared the toxicity to the amphipod *Ampelisca abdita* and chemistry of spilled No. 2 fuel oil in subtidal sediment samples for nine months following the spill from the barge *North Cape*. Toxicity to the amphipods decreased as the PAH concentration in sediments decreased over the first six months post-spill.

In addition to possible histopathological damage, sublethal toxic effects of contaminants in marine organisms include impairment of physiological processes and as such may alter the energy available for growth and reproduction (Capuzzo 1987; Capuzzo et al. 1988). Chronic exposure to chemical contaminants can result in alterations in reproductive and developmental potential of populations of marine organisms, resulting in possible changes in population structure and dynamics.

Spills that reach the shallow subtidal and intertidal environments may result in the mortality of sessile invertebrates or they may suffer sub-lethal effects. Eggs and larvae are more subject to harmful physiological effects from a fuel spill because they cannot actively avoid the spill and they have not developed any detoxification mechanisms. Effects can include morphological malfunctions, genetic damage, reduced growth or localized mortality of eggs and larvae (LGL 2005b).

American lobster larvae had a 24-h LC50 of 0.1 ppm to Venezuelan crude oil (Wells 1972). Larvae exposed to 0.1 ppm of South Louisiana crude oil swam and fed actively while those exposed to 1 ppm were lethargic (Forns 1977). Anderson et al. (1974) tested a variety of crude and refined oils and found that post-larval brown shrimp (*Penaeus aztecus*) were less sensitive than adult invertebrate species. Moulting larvae appear to be more sensitive to oil than intermoult larvae (Mecklenburg et al. 1977).

Oil weathers, loses buoyancy and eventually sinks. It can associate with particulate matter suspended in the water and eventually sink, thereby affecting the benthic invertebrate community (Elmgren et al. 1983). A second route of oil to the benthic communities is the transport of oil or contaminated particles from nearby oiled beaches. The most sensitive organisms in the benthic communities appear to be the crustaceans. Major effects on the crustacean fauna have been documented with most oil spills (Elmgren et al. 1980; Sanders et al. 1980; Dauvin and Gentil 1990; Jewett et al. 1999). As a result of the 1996 *North Cape* oil spill, (over 800,000 gallons of home heating oil) millions of American lobsters were killed and their death were attributed to the toxic effects of oil (McCay 2001).

5.5.2 Fish

A hydrocarbon spill can affect local abundance and availability of phytoplankton and zooplankton to fish but fish are not expected to remain within the area affected by the spill. If zooplankton survives exposure, accumulated hydrocarbons would be depurated within a few days after exposure has ended (Trudel 1985). If fish eat contaminated zooplankton they will accumulate hydrocarbons themselves, but fish are also able to metabolize hydrocarbons and there is no potential for biomagnification.

All fish and shellfish past the egg and larval stage should likely actively avoid a hydrocarbon spill by swimming away (Irwin 1998). The effect of a localized spill on egg and larval survival would be undetectable from the high rate of natural mortality. Recruitment to a population would not be affected unless more than 50 percent of the larvae in a large portion of the spawning area were lost (Rice 1985). When the survival of herring larvae was reduced by 58 percent as a result of the *Exxon Valdez* spill, no effect was detected at the population level (Hose et al. 1996).

Reported physiological effects of oil on fish have included abnormal gill function (Sanders et al. 1981), increased liver enzyme activity (Koning 1987; Payne et al. 1987), decreased growth (Moles and Norcross 1998), organ damage (Rice 1985) and increased disease or parasites loads (Brown et al. 1973; Carls et al. 1998; Marty et al. 1999). Fish may suffer effects that range from direct physical effects (e.g., coating of gills and suffocation) to more subtle physiological and behavioural effects when exposed to oil. Actual effects depend on a variety of factors such as the amount and type of oil, environmental conditions, species and life stage, lifestyle, fish condition, degree of confinement of experimental subjects, and others. Laboratory toxicity studies found that pelagic fish are more sensitive (LC50s of 1 to 3 ppm) than either benthic (LC50s of 3 to 8 ppm) or intertidal fish species (LC50s of >8 ppm) (Rice et al. 1979).

Juvenile and adult fish in shallow/enclosed areas could be more susceptible to impact from oil spills in that the oil might be more persistent in these areas. Therefore, exposure of the fish to the oil could potentially be of longer duration. At the same time, juvenile and adult finfish are mobile and can avoid the contaminated areas. Less mobile invertebrates could not so easily avoid the oil. Contamination of shoreline habitats that are particularly important to fish with specific habitat requirements could potentially result in more adverse effects on the fish.

Several studies have demonstrated the potential for oil residuals on beach sediments to have significant toxic effects on fish eggs and embryos. Heintz et al. (1999) reported embryo mortality of pink salmon with laboratory exposure to aqueous total PAH concentrations as low as 1 ppb total PAH derived from artificially weathered Alaska North Slope crude oil. This is consistent with the field observations of Bue et al. (1998) of embryo mortality of pink salmon in streams traversing oiled beaches following the spill from the *Exxon Valdez*. 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), with eggs and larvae exposed to high concentrations of oil may exhibit morphological malformations, genetic damage, and reduced growth. Damage to embryos may not be apparent until the larvae hatch. For example, although Atlantic cod eggs were observed to survive oiling, the hatched larvae were deformed and unable to swim (Kühnhold 1974). Atlantic herring larvae exposed to oil have exhibited behavioural abnormalities such as initial increased swimming activity followed by low activity, narcosis, and death (Kühnhold 1972).

5.5.3 Commercial Fisheries

While the physical effects on fish from a spill may not necessarily be significant, the economic affects resulting from the prevention or impediment of a fisher's ability to access fishing grounds (because of areas temporarily excluded during the spill or spill clean-up), damage to fishing gear (through oiling) or resulted in a negative effect on the marketability of fish products (because of market perception resulting in lower prices, even without organic or organoleptic evidence of tainting) may be considerable. An interruption could result in an economic effect because of reduced catches, or extra costs associated with having to relocate harvesting effort. Effects due to market perceptions of poor product quality are more difficult to predict, since the actual (physical) effects of the spill might have little to do with these perceptions, thus the perceived taint of fish has had negative effects on economic returns from fisheries. Areas around oil spills and blowouts have been closed without any evidence of taint. For example, during the 1984 blowout at the *Uniacke* well site near Sable Island, a no-fishing zone was established. Taste tests on cod, halibut and haddock sampled in the area did not indicate taint (Zitko et al. 1984). Similarly, during the *Kurdistan* oil spill in 1979, inspection officers rejected lobster with any traces of external oil and no proof of internal contamination (Tidmarsh et al. 1986). After the *Torry Canyon* spill in 1967, shellfish prices and sales declined dramatically, even though much of the shellfish catch was from other waters (LGL et al. 2000).

Damage to fishing vessels and gear can also result from small spills (less than 50 bbl) and materials lost from seismic vessels or drill rigs. Given the fisheries in the SEA Area, damage would be most likely to occur to gear or vessels fishing for Atlantic cod, snow crab, Iceland scallop, redfish, Atlantic halibut and skate. However, damages are expected to occur infrequently. The C-LNOPB reported that on average, there are two fishing gear conflicts per year from seismic activities in the Newfoundland and Labrador Offshore Area (JWEL 2003).

5.5.4 Marine Birds

5.5.4.1 Oil Spills

Birds are affected by direct contact with oil and most birds that come in contact with an oil spill subsequently die (Frink and White 1990; Fry 1990). From EMAP (2006) data, it appears that there are significant numbers and concentrations of birds within the SEA Area. Therefore, any oil spill or blowout could cause at least some and, at worst, extensive bird mortality. There is no clear correlation between the size of an oil spill and numbers of seabirds killed (Burger 1993). The density of birds in a spill area, wind velocity and direction, wave action and distance to shore may have a greater bearing on mortality than size of the spill (Burger 1993). There seems to be differing scientific evidence whether that oil pollution has major long-term effects on bird productivity or population dynamics. Some studies have suggested that oil pollution is unlikely to have major long-term effects on bird productivity or population dynamics (Clark 1984; Butler et al. 1998; Boersma et al. 1995; Wiens 1995) while others suggest the opposite (Piatt et al. 1990; Walton et al. 1997). There is no conclusive evidence that oil spills have either caused marked reductions in bird populations or have changed community structure at a large scale (Leighton 1995).

However, it is clear that aquatic and marine species of birds are most vulnerable and most often affected by exposure to marine oil spills. Diving species such as Black Guillemots, murres, Atlantic Puffins, Dovekies, eiders, Oldsquaws, scoters, Red-breasted Mergansers, and loons are considered to be the most susceptible to the immediate effects of surface slicks (Leighton et al. 1985; Chardine 1995; Wiese and Ryan 1999; 2003). Alcids often have the highest oiling rate of seabirds recovered from beaches along the south and east coasts of the Avalon Peninsula, Newfoundland showing an annual increase over a 13-yr period (2.7 percent) in the proportion of oiled birds (Wiese and Ryan 1999; 2003). Seabirds spend most of their lives at the air-water or land-water interfaces where floating oil accumulates (Wiens 1995), increasing their chances of becoming oiled. Marine birds must frequently pass through the water's surface and, as such, when oil is present, they may become fouled. The presence of oil on the feathers of a seabird can destroy the waterproofing and insulating characteristics of the feathers and lead to death from hypothermia. The external exposure results in matting of the feathers, which effectively destroys the thermal insulation and buoyancy provided by the air trapped by the feathers. Consequently, oiled birds are likely to suffer from hypothermia and/or drown (Clark 1984; Hartung 1995). Most seabird losses occur during the initial phase of oil spills when large numbers of birds are exposed to floating oil (Hartung 1995). Birds living in coldwater environments are most likely to succumb to hypothermia (Hartung 1995).

Oiled birds that escape death from hypothermia and/or drowning often seek refuge ashore where they engage in abnormally excessive preening in an attempt to rid their feathers of the oil (Hunt 1957, in Hartung 1995). The preening leads to the ingestion of significant quantities of oil that, although partially absorbed (McEwan and Whitehead 1980) can cause lethal effects. Noted effects on Common Murres and Thick-billed Murres oiled off Newfoundland's south coast include emaciation, renal tubular degeneration, necrosis of the duodenum and liver, anemia and electrolytic imbalance (Khan and Ryan 1991).

Nesting seabirds may transfer oil from their plumage and feet to their eggs (Albers and Szaro 1978). It has been demonstrated that small quantities of oil (1 to 20 µL) on eggs produce developmental defects and mortality in avian embryos of many species (Albers 1977; Albers and Szaro 1978; Hoffmann 1978, 1979a; Macko and King 1980; Parnell et al. 1984; Harfenist et al. 1990). The resultant hatching and fledging success of young appears to be related to the type of oil (Hoffman 1979b; Albers and Gay 1982; Stubblefield et al. 1995) and the timing of exposure during incubation. Embryos are most sensitive to oil during the first half of incubation (Albers 1977; Leighton 1995).

Breeding birds that ingest oil generally exhibit a decrease in fertilization (Holmes et al. 1978), egg laying and hatching (Hartung 1965; Ainley et al. 1981), chick growth (Szaro et al. 1978) and survival (Vangilder and Peterle 1980; Trivelpiece et al. 1984). Similar effects on ducklings occur when they ingest oil directly (Miller et al. 1978; Peakall et al. 1980; Szaro et al. 1981). Oil spills can also cause indirect reproductive failure. Abandonment of nesting burrows by oiled adult Leach's Storm-Petrels may have contributed to reproductive failure in that population (Butler et al. 1998).

Seabirds that ingest oil or oil-contaminated prey may lead to immuno-suppression and Heinz-body hemolytic anemia, which compromises the ability of the blood to carry oxygen (Leighton et al. 1983; Fry and Addiego 1987). This effect persists long after the birds appear to have recovered from exposure (Fry and Addiego 1987). Diminished oxygen transport capacity in the blood is a particular problem for species of birds that obtain their food by pursuing prey underwater. Effects may be exacerbated by stress resulting from handling during cleaning (Briggs et al. 1996). Sublethal effects of oil on seabirds include reduced reproductive success, and physiological impairment, including increased vulnerability to stress (Briggs et al. 1996).

The other waterfowl species of concern in the SEA Area is the Common Eider. Common Eiders are extremely sensitive to relatively small increases in adult mortality (Goudie et al. 2000). Chronic oil contamination remains a problem in areas near international shipping lanes, including southern Newfoundland (Canadian Coast Guard 1999). Like the Harlequin Duck, a spill could affect the Common Eider, which may be subjected to effects at any time of year (Common Eider breeds and winters in the SEA Area). Disturbances, such as oil spills to eiders during breeding season can affect breeding success.

Birds exposed to oil are also at risk of starvation (Hartung 1995). Oiled Common Eiders deplete all of their fat reserves and much of their muscle protein (Gorman and Milne 1970). The energy demands tend to be higher as a result of the fact that the metabolic rate of oiled birds increases to compensate for the heat loss caused by the reduced insulating capacity of their plumage. This can expedite starvation (Hartung 1967; McEwan and Koelink 1973).

Oil spill modelling (for surface and subsurface spills during drilling) will need to be conducted for each proposed exploration project to determine the trajectories of lost product during winter and summer. However, simple hypothetical spill scenarios indicate that product may reach shore from a near-shore location within half a day under strong gale or storm force wind conditions to perhaps 24 to 36 hours for a range of wind and current conditions. For locations farther afield, spilled oil is anticipated to reach shore within four days or longer.

Timing and spill location, not spill volume, are the primary factors that influence bird mortality rates (Wiese et al. 2001). Other factors such as type of oil spilled, volume, time of year and sea conditions will also influence the level of oiling, if birds are in the area of the spill. If birds are in the vicinity of an oil spill, then the potential effect could be considerable. One critical factor is the likelihood of oil reaching the coastline, especially the beaches used by Piping Plover.

If the spill occurs when birds are aggregated during breeding or migration, the environmental effect will be much greater than if they are widely dispersed at sea. It is likely that the cumulative effect of numerous “small” spills and chronic pollution has had a greater effect on seabird populations than the rarer large spills. A small spill around seabird habitat with large breeding populations may have a disproportionately large impact. An example of this occurred when an estimated 30,000 oiled seabirds washed up along the coasts of the Skagerrak following a small release of oil from one or two ships (Mead and Baillie 1981). At the other extreme, the wreck of the *Amoco Cadiz* off the coast of Brittany, France, resulted in the release of 230,000 tonnes of crude oil into coastal waters and the death of less than 5,000 birds (Hope-Jones et al. 1978).

5.5.4.2 Attraction to Lights/Flares

Storm-Petrels and other night flying birds could be attracted to vessel lighting or flares, which could potentially result in disorientation (especially during periods of drizzle and fog (Wiese et al. 2001)) and collision with the vessel lights, flares or infrastructure. Attraction could also result in continuous circling around the lights, using energy and delaying foraging or migration (Avery et al. 1978, in Husky Oil 2000; Bourne 1979, in Husky Oil 2000; Sage 1979, in Husky Oil 2000; Wood 1999, in Husky Oil 2000) or being burned in flares (Wiese et al. 2001). Vessel lighting is essential since operations occur on a 24-hour basis and flaring should be limited to a short period during well testing.

Storm-Petrels (with nocturnal feeding habits) and other night flyers would also be attracted to lighting or flares on a drilling platform (which is also a 24-hour operation), as the platform would likely be the largest and more intensely lit structure in the area.

5.5.5 Marine Mammals

5.5.5.1 Oil Spills

Whales are not considered at high risk to the effects of oil exposure. However, whales present in the area could suffer sublethal effects through oiling of mucous membranes or the eyes if they swim through a slick (Geraci 1990). These effects are reversible and would not cause permanent damage to the animals. There is a possibility that the baleen of whales could be contaminated with oil, thereby reducing filtration efficiency (Geraci 1990).

Any accidental spills of diesel fuel or lube oil from seismic vessels or other vessels associated with exploratory activities could, depending on the timing, location, and environmental conditions of such an event, result in oiling of marine mammals and sea turtles. However, the nature of diesel fuel is such that it evaporates relatively quickly from the surface and does not persist in the environment for any length of time and the likelihood of such an event is extremely low (JWL 2006).

Marine mammals and sea turtles can be affected by an oil spill if they come in direct contact with oil, but most marine mammals have been observed avoiding or attempting to avoid spill areas. Oil slicks will disperse more slowly in winter that in summer. However, the process would still be relatively slow in summer due to emulsion formation and high viscosities. Oil will settle on the sea surface in the unlikely event of a spill from above or below the sea’s surface, where it could potentially come in contact with marine mammals in the area. Direct exposure of marine mammals and sea turtle to oil should be brief, if it occurs at all.

Lutcavage et al. (1995) studied the effect of oil on loggerheads in a controlled setting. They suggest that all post-hatch life stages are vulnerable to oil affects and tar ingestion because sea turtles show no avoidance behavior when they encounter an oil slick. Turtles indiscriminately eat anything that registers as being an appropriate size for food, including tar balls. Such was the case with a juvenile loggerhead stranded in Gran Canaria, Spain, which had an esophageal defect that trapped tar balls, plastics, and fishing line in its digestive system (National Oceanic and Atmospheric Administration (NOAA) 2003).

Sea turtles' diving behavior also puts them at risk (NOAA 2003). Adults inhaling large volumes of air before diving and continually resurface in an oil spill may experience both extended physical exposure to the oil and prolonged exposure to petroleum vapors. Anecdotal accounts of dead or impaired green turtles found with tar balls in their mouths were summarized by Witham (1978). Three turtles found dead after the *Ixtoc 1* blowout showed evidence of oil externally and in the mouth, esophagus and small intestine, although there was no evidence of lesions in the gastrointestinal tract, trachea, or lungs (Hall et al. 1983). However, chemical analysis of tissue showed a chronic exposure to and selective accumulation of hydrocarbons. Hall et al. (1983) believed prolonged exposure to oil may have caused the poor body condition of the animals by disrupting feeding.

Lutcavage et al. (1995) studied the physiological and clinicopathological effects of oil on loggerhead sea turtles approximately 15 to 18 months old. They showed that the turtles' major physiological systems are adversely affected by both chronic and acute exposures (96-hour exposure to a 0.05-cm layer of South Louisiana crude oil versus 0.5 cm for 48 hours). The skin of exposed turtles, particularly the soft pliable areas of the neck and flippers, sloughed off in layers. This continued for one to two weeks into the recovery period. Histological examination of the damaged skin showed proliferation of inflamed, abnormal, and dead cells. Recovery from the sloughing skin and mucosa took up to 21 days, increasing the turtle's susceptibility to infection.

Frazier (1980, in NOAA 2003) suggested that olfactory impairment from chemical contamination could represent a substantial indirect effect in sea turtles, since a keen sense of smell plays an important role in navigation and orientation. Frazier (1980, in NOAA 2003) noted that masking olfactory cues may not harm a turtle outright, but impairing its ability to properly orient itself can result in a population effect (NOAA 2003).

The Lutcavage et al. (1995) study provided qualitative evidence that oil exposure affects the balancing of salt and water. Extended salt gland dysfunction would affect the turtle's health by altering internal salt and water homeostasis. In two experimentally oiled turtles, the salt glands effectively shut down for several days, although the turtles eventually recovered after the exposure was discontinued. The salt glands did not appear to be blocked so it appeared that the impact was toxic, rather than physical.

Kemp's ridley and loggerhead turtles feed primarily on crustaceans and mollusks, which bioaccumulate petroleum hydrocarbons (NOAA 2003). Thus Kemp's ridley and loggerhead turtles may be at greater risk of exposure by ingesting food than leatherback turtles which feed primarily on coelenterates.

5.5.5.2 Collisions

Whales and other marine mammals are vulnerable to ship collisions. A common denominator is most of marine mammal-vessel collisions occur near the surface where acoustical reflection and propagation can limited the ability of marine mammals to hear and locate approaching vessels (Gerstein et al. 2005). Marine mammal abilities to detect and locate approaching ships may be affected by downward refraction in negative temperature gradients; Lloyd mirror effect; spreading less from stern to bow for large ships;

acoustical shadowing and masking of approaching vessel noise from ambient noise and other anthropogenic noise sources. Thus the confluence of a variety of acoustical factors pose significant challenges for marine mammals to detect and locate approaching vessels. Of the eleven species known to have been subject to vessel collision, fin whales are struck the most frequently; right whales, humpback whales, sperm whales and gray whales are also commonly struck (Laist et al. 2001). The most severe and lethal injuries are caused by ships 80 m or larger and vessels travelling 26 km/hr (14 knots) or greater.

Information on vessel traffic within the SEA Area is provided within Section 5.6.4. Marine traffic in general is considered to be a threat to the northern right whale because of behaviours such as feeding, nursing and mating (Laist et al. 2001). All these behaviours occur at the surface and as such the right whale may be less attentive to surrounding activity and noise. Right whales, bowhead whales, gray whales, humpback whales and sperm whales are the slowest swimming whales and as such, may render them more vulnerable to vessel collisions.

In areas of special concern, measures to reduce vessel speed below 26 km/hr (14 knots) may be beneficial (Laist et al. 2001), as data would suggest the most severe and lethal injuries are caused by vessels travelling at greater than 26 km/hr (14 knots). Seismic vessels typically travel at speeds of 7.4 to 9.3 km/h (4 to 5 knots), emitting seismic shots during operation.

5.5.6 Species at Risk

The marine mammal species at risk that could occur in the SEA Area include the blue whale, beluga whale, North Atlantic right whale and fin whale. The leatherback turtle could also occur in the SEA Area. Marine-associated birds species at risk that could occur in the SEA Area are the endangered Piping Plover and the Harlequin Duck (Special Concern). Fish species at risk that could occur in the SEA Area are the northern, spotted and Atlantic wolffish.

5.5.6.1 Oil Spills

Although oil spills are rare events, they have the potential to cause significant environmental effects. The SARA species most likely to be affected is the Piping Plover. Pairs of the Piping Plover nest on coastal beaches in the SEA Area so there is the potential for effects of accidental events on coastal bird habitats and sensitive areas, particularly the identified IBAs and critical habitat sites identified for the Piping Plover. Sandy beaches are rare on the coast of Newfoundland and Piping Plover are vulnerable to oil washed ashore as well human disturbance (Lock et al. 1994). Terns are less vulnerable to oil, but spill clean-up activities may disturb nesting terns and cause nesting failure (Lock et al. 1994).

Harlequin Ducks overwinter within and migrate through the SEA Area and would be at risk in the event of an oil spill. The greatest threat to Harlequin Duck populations is oil spills (CWS website), as was shown with the *Exxon Valdez* spill in 1989. Oil accumulated in intertidal zones where Harlequins foraged. Galt et al. (1991) and Lanctot et al. (1999) found that slow emigration rates hindered population recovery over the long-term. A spot of oil, the size of a one dollar coin, is enough to kill a seabird. The oil mats the bird's feathers, which become water-logged and the bird slowly freezes to death. When a Harlequin Duck or other bird preens its oiled feathers and ingests the oil, it may be poisoned (CWS website). One oil spill or a ship flushing their bilge or slop tanks may have an effect on a wintering flock on the south coast of Newfoundland. During the moulting period in early fall (Palmer 1976), Harlequins are particularly susceptible to disturbance and oil pollution because of their inability to fly (they lose almost all their flight feathers at once).

5.5.6.2 Vessel Collisions

As noted in Section 5.5.5.2, marine mammals are vulnerable to vessel collisions. For small marine mammal populations, vessel collisions may pose a substantial threat (Laist et al. 2001). Injuries on stranded ship-struck marine mammals suggest that large vessels are the principal source of injury with most marine mammals not observed prior to the collision or at the last moment. Their collision avoidance strategies may be ineffective for large vessels with limited maneuver ability. Laist et al. (2001) data suggest that vessel speed reduction in areas of high use marine mammal habitat may reduce the impact on vessel collisions. However, Gerstein et al. (2005) indicate that vessel speed reduction without compensating for acoustical consequences may in actuality increase risk of collisions suggesting that "blanket reduction" of vessel speed may be counter-productive to marine mammal protection.

The most significant threats to fin whales are vessel collision and fishery gear entanglement.

The potential effects of known vessel traffic routes in the SEA Area to species at risk (especially the Northern right whale, which has been proven to be vulnerable to vessel collision) will be addressed at the project-specific environmental assessment stage.

5.5.7 Sensitive Areas

The coastal bird habitats located on the southern Newfoundland Coast are sensitive areas that may be affected in the event of an oil spill or blowout. Studies of oil effects on sea grass (e.g., *Thalassia* sp., *Halophila* sp., *Zostera* sp.) are limited to short and long term effects from particular oil spills. Little evaluation of chronic or acute damage from laboratory studies exists. Eelgrass meadows in the tidal zone are generally directly exposed to oil and die-off in the first year of an oil spill. After the initial mortality in the first year, long-term effects of eelgrass are mixed. Long term (>5 years) effects at the *Exxon Valdez* spill were inferred by decreased mean density of shoots and flowering shoots in the oiled area. Biomass, however, was the same between oiled and non-oiled areas (Dean et al. 1998).

Oil spills are known to cause potential long term damage to salt marsh ecosystems (Duke et al. 1997; Mille et al. 1998). The vegetation and the structure that salt marshes provide may be affected, sediments may be contaminated and ecosystem functions may be impaired with regard to utilization by organisms, including important fisheries species and stabilization of sediments. The rate of degradation of the oil in the sediments is influenced by the sediment type, oxygen content and bacterial community of the sediment, availability and level of nutrients in the sediments and at the oil/sediment interface and the depth to which the oil has penetrated. Oiling effects may be limited when the oil exposure is minimal, the vegetative structure is not impacted and residual oil levels are minimal or rapidly weathered. Oiling effects are particularly great when oil coats the vegetation or is incorporated deeply in the sediments beneath the vegetation.

Densities of animals in salt marshes may be reduced by acute, short-term toxic effects of crude oil that sharply increase mortality rates (McDonald et al. 1991; Nance 1991; Widbom and Oviatt 1994), or cause avoidance by mobile organisms (Moles et al. 1994). Oil may persist in marsh sediments for many years (DeLaune et al. 1990; Teal et al. 1992) and may continue to affect habitat use.

Although not a considered a sensitive habitat, the common organisms found on rocky intertidal shores (F*ucus*, mussels, periwinkles, starfish and barnacle) are also susceptible to the toxic effects of oil (Chan 1977; Stekoll et al. 1993). Recovery of these components can be quite substantial within a year or two, or nearly complete. However, in the *Exxon Valdez* spill, the aggressive washing of the intertidal rock shores resulted in loss of a considerable amount of silt from the rock interstices and the bivalve fauna has not been fully re-established and may not be until these sediments have been replenished by natural processes (Driskell et al. 1996).

The spatial scale of the affected sand or mud shoreline area will determine the rebound of the affected area. An example of this is the effect of the *Amoco Cadiz* oil spill on benthic crustaceans. Failure to recover in some subtidal habitats was due to the fractionated distribution pattern of favored habitat by some species of amphipods (Dauvin and Gentil 1990). The populations were able to recover; densities on the impacted site returned to pre-spill levels within 15 years (Dauvin 1998).

Oil production may adversely affect the tourism/recreational potential of the south coast region, primarily in the event of an accidental spill. Tourism and recreation on the south coast could be adversely affected by a fuel or oil spill, depending on the severity of the incident. If a spill were to occur, marine mammals, fish and birds could be negatively affected. This would have negative consequences for whale-watching, recreational fishing and bird-watching in the area. Activities such as kayaking and diving would also be affected by any degradation of the area's marine environment and may represent public safety concerns. Any perceived degradation, real or imagined, would lessen the appeal of the region as a destination for eco-travelers.

5.5.8 Mitigations

5.5.8.1 Oil Spills

Given the proximity of potential drilling activities to coastal areas and identified sensitive areas, oil spill response capabilities will be critical. The increased probability of oil reaching shore or any of the identified offshore sensitive areas further necessitates that operators be prepared with an oil spill response strategy. The most effective planning tool for minimizing the effects of oil spills is oil spill prevention and preparedness.

Mitigations in the event of an oil spill include but are not limited to:

- design and Implementation of an Oil Spill Response Plan to be approved by the C-NLOPB;
- emphasis on spill prevention through a combination of education, procedures and policies;
- maintenance of spill response capabilities (trained personnel, absorbents, containment and cleanup systems) on the drill rigs and/or supply vessels;
- preparation to implement shoreline protection measures and clean-up in event of an accidental event;
- fishery compensation programs for damaged gear and market losses, associated with damage; and
- training and education of personnel.

5.5.8.2 Vessel Collisions

Although there is a conflict opinions regarding the effectiveness of speed reduction and marine mammal vessel collisions (Section 5.5.6.2), the limited data suggests that vessels speeds below 26 km/hr (14 knots) may be beneficial in reducing marine mammal vessel collisions (Laist et al. 2001). The speed of typical seismic vessel (7.4 to 9.3 km/h or 4 to 5 knots) operation may assist in the avoidance of marine mammal collisions.

The general lack of basic information regarding types of ships involved with marine mammal collisions, speed during collision, collision location, marine mammal behaviour prior to collision, and other factors have hampered the development of mitigation factors and must be considered a data gap.

5.6 Cumulative Environmental Effects

Individual exploration projects and related activities can result in environmental effects that are not necessarily mutually exclusive of each other, but can act cumulatively. An early analysis of the environmental effects of policies, plans and programs is facilitated by an SEA, resulting in the identification of cumulative environmental effects that could occur (Bonnell and Storey 2000). The overall environmental consequences of exploration and production activities that result from policies, plans and programs (FEARO 1992) can often only be identified at the strategic level.

An important step in undertaking a cumulative effects assessment is the identification of other actions whose effects will likely act in combination with those of the proposed activities under review to bring about cumulative effects. CEAA requires that only activities that have been or will be conducted be considered. The degree of certainty that the activity will proceed must therefore be considered (CEA Agency 1999). The other activities considered for offshore exploration and production activities included those that are ongoing or likely to proceed (as specified by CEA Agency 1994). The cumulative effects of the proposed offshore exploration and production activities within the SEA Area may include cumulative effects in combination from interactions with:

- marine transportation;
- fishing activities;
- tourism and recreation activities; and
- other proposed exploration and production activities (as per C-NLOPB registry) within and adjacent to the SEA Area.

5.6.1 Call for Bids Associated with this Strategic Environmental Assessment

There is currently a call for bids for three parcels in the SEA Area. Typical exploration activities associated with an Exploration License include a seismic survey, geohazard survey (in advance of siting a drilling platform) and exploration and/or delineation drilling. Specific details on the nature, spatial and temporal distribution of potential exploration and production activities in the SEA Area are not currently available. In the future, additional parcels may become available within the SEA Area, thereby adding additional potential exploration and production activities within the SEA Area.

Based on previous experience, it is anticipated that at least one exploration well and two to three delineation wells could be drilled per license (parcel), resulting in up to 12 well drilled on the three parcels over the nine-year lease agreement.

It is unlikely that more than one seismic vessel would be available at any one time. Therefore, it is likely that seismic surveys would be conducted consecutively on the three licenses, not concurrently. Likewise, the availability of drilling platforms likely precludes more than one drilling platform working in the SEA Area at one time. It is likely that any wells would be drilled sequentially in the parcels.

5.6.2 Exploration and Production Activities

While there are no exploration and production activities occurring within the SEA Area, there have been/are exploration activities occurring in adjacent (Laurentian Sub-basin and Western Newfoundland and Labrador) Offshore Areas. In addition, there is the possibility for exploration and production activities to occur within areas adjacent to Newfoundland and Labrador water, off the coast of Nova Scotia.

An exploration/delineation drilling program in the Laurentian Subbasin Offshore Area is currently undergoing a CEAA screening. The project proposes to drill up to seven exploration and delineation wells on five Exploration Licenses (1081, 1082, 1085, 1086 and 1087) up to the end of 2013. The Scoping Document was March 2, 2006; an environmental assessment has not yet been posted to the Public Registry (as of October 31, 2006).

Two companies have expressed interest in proposed seismic programs in the Western Newfoundland and Labrador Offshore Area. One is proposed for Exploration Licenses 1069 and 1097 and extends from the near-shore to the 200-m bathymetric isopleth. The other is proposed for the Port au Port Peninsula area and extends from onshore to the 50-m isploeth offshore. Both of these programs are presently undergoing a CEAA screening.

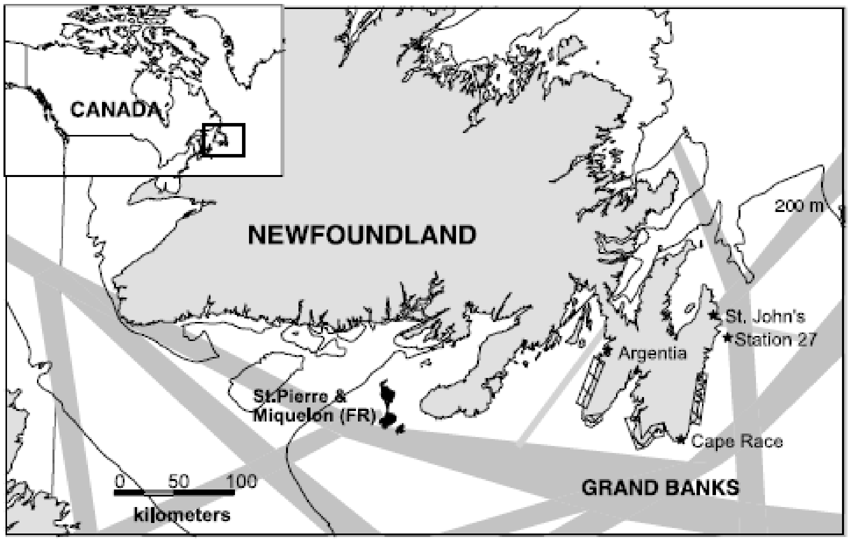
5.6.3 Commercial Fisheries

The domestic harvest within the SEA Area Unit Areas consists largely of groundfish, though other species (particularly scallops and herring are important in some Unit Areas. The principal species that comprise the commercial fisheries in the SEA Area are Atlantic cod, redfish, white hake, monkfish, herring, scallop (both Iceland and sea and snow crab, with emerging fisheries for waved (or rough) whelk and sea cucumber. Only one multi-species DFO science survey in the SEA Area (in 3Ps) is proposed for 2006 (Canning & Pitt 2006).

5.6.4 Marine Transportation

The SEA Area is in proximity to various shipping lanes so that any activities should be planned in recognition of the location and frequency of traffic. Major shipping routes pass over the middle and southern part of the region (Figure 5.3). The Marine Atlantic ferry from Sydney, Nova Scotia, to Port Aux Basques, Newfoundland and Labrador, crosses over the Western-most tip of the study region, and the ferry to Argentia passes over the southern-most part of the SEA Area (Marine Atlantic 2006). Commercial cruise lines increasingly frequent ports such as Sydney, Nova Scotia, Charlottetown, Prince Edward Island and Corner Brook and St. John's, Newfoundland and Labrador.

Figure 5.3 Shipping Routes in Vicinity of Strategic Environmental Assessment Area



Source: Wiese and Ryan 2003.
Note: Major shipping routes are greyed bars.

The Eastern Canada and Great Lakes trade route with Europe passes directly through the SEA Area (Figure 5.4). Oceanex cargo routes from St. John's and/or Halifax to Corner Brook or Montreal that cross the SEA Area are shown in Figure 5.5. There is also potential traffic from oil tanker traffic from the Newfoundland Transshipment Terminal and Come By Chance Oil Refinery in Placentia Bay or other locations sailing for central Canada refineries (Figure 5.6).

Figure 5.4 General Shipping Routes

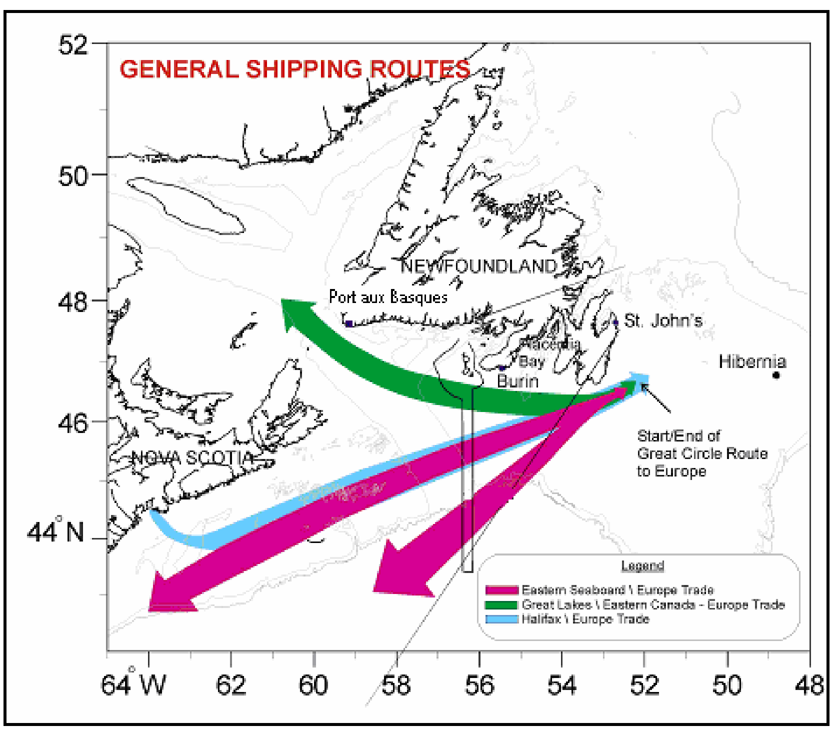


Figure 5.5 Cargo Vessels and Ferry Traffic

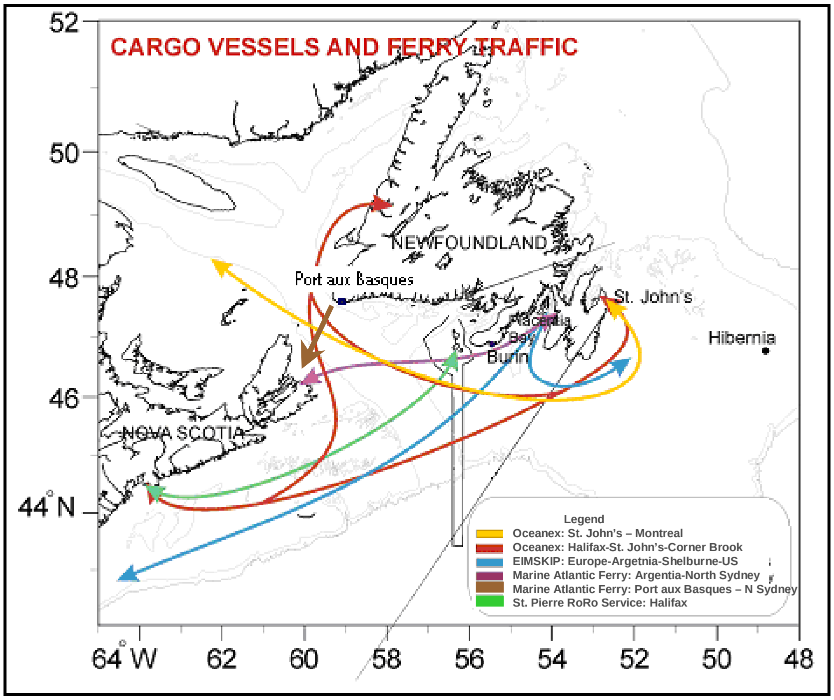
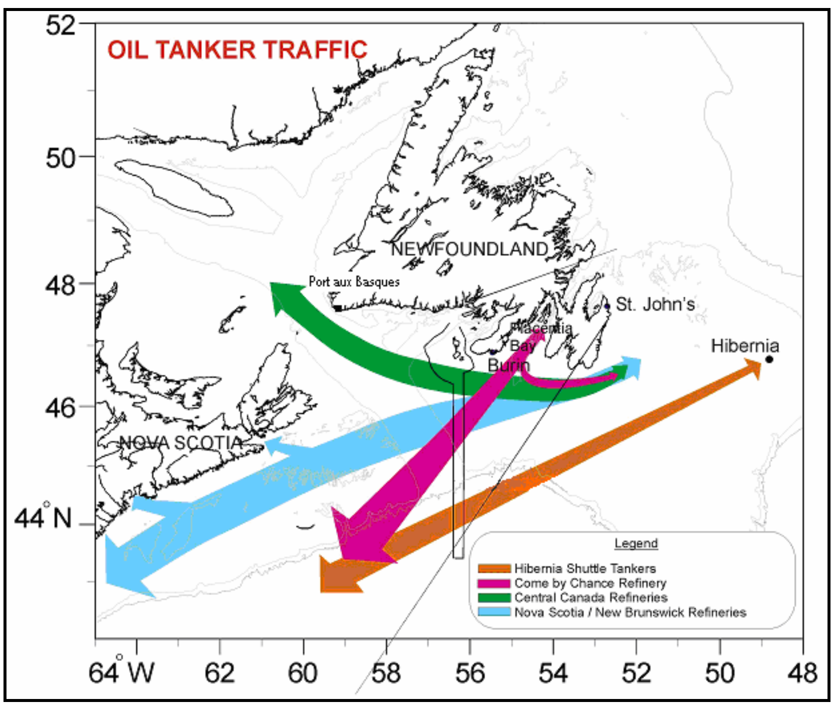


Figure 5.6 Oil Tanker Traffic



Transport Canada is presently undertaking an Environmental Risk Assessment Study of the South Coast of Newfoundland and Labrador. "Its purpose is to assess and quantify the risk facing the south coast of Newfoundland and Labrador over the next 10 years by the transportation of oil and oil products by commercial vessels. The study will provide Transport Canada with extremely valuable information for its role of governance of Canada's Marine Oil Spill Preparedness and Response Regime" (Transport Canada 2006).

The risk SEA Area of interest extends 92.6 km (50 nautical miles) offshore and runs from east of Cape St. Francis on the Avalon Peninsula south and around Cape Race, then west, encompassing Placentia and Fortune Bays and approaches, St. Pierre et Miquelon and as far as Cape Ray on the west coast.

Consequently, there will be a large overlap with the SEA Area both in terms of geography and in time interval (e.g., the next 10 years).

The information should ultimately be of strategic and practical benefit for stakeholders for the SEA Area. An initial phase of the work has been completed and a report is being drafted by Transport Canada (C. van Ginkel, pers. comm.).

The cumulative effects of the increased traffic and noise on the behaviour and physiology of marine species and in particular marine mammals are difficult to quantity. The SEA Area, is currently subject to a variety of marine transportation that includes shipping vessel traffic, marine ferry operations, oil tanker traffic, military vessel operations and periodic commercial cruise vessel traffic. Information provided by Transport Canada's Environment Risk Assessment Study of the South Coast of Newfoundland and Labrador may assist during preparation of project specific environmental assessments and consideration of project specific effects related to marine transportation issues.

5.7 Tourism and Recreation

In 2005, there were an estimated 469,000 non-resident visits to Newfoundland and Labrador (an increase of 4.5 percent over 2004). These visits equated to tourism expenditures estimated at $336 million (an increase of 4.8 percent over 2004) (Newfoundland and Labrador Department of Tourism, Culture and Recreation (NLDTCR) 2006a). Despite the general increase in non-resident visits and expenditures, some regions reported lower than expected tourist visitation. These regional disparities have been attributed to a slow resident travel market, a decline in non-resident auto traffic and a recognized Canada-wide trend of increased travel to urban centres (NLDTCR 2006b). All are attributable, in whole or in part, to rising fuel prices.

This being said, the tourism industry is now playing a more important role in rural Newfoundland economies than it ever has before. On the southwest coast in particular, scenic, natural and cultural attractions translate into economic opportunities for the resident population and provide domestic, national and international travelers with world-class outdoor recreation activities. These activities (both commercial and private) include bird watching, whale watching, diving, kayaking, fishing and camping, as well as activities associated with cruise ship visitation and the area's cultural and archaeological attractions.

5.7.1 Whale Watching

Currently one boating operation, based in Burgeo, provides tourists with whale watching opportunities (NLDTCR n.d.). Whale watching is a proven attraction, is sustainable in perpetuity and is non-consumptive. Seven species of whale visit the offshore waters of the southwest coast, including pilot, blue, minke, fin, sperm, humpback and right whales BDDB (2003).

5.7.2 Bird Watching

Bird watching, like whale watching, is sustainable, non-consumptive and is a popular outdoor activity. The coastal area of the south coast, and particularly offshore islands such as the Ramea archipelago, provide habitat for water-associated birds (shorebirds, waterfowl, and seabirds) such as Atlantic Puffins, Common Eiders, Harlequin Ducks, Canada Geese, Leach's Storm-Petrels, cormorants, Piping Plovers, terns, murres and Kittiwakes. Rare bird species which have been observed include Eastern Bluebird (*Sialia sialis*), Wood Thrush (*Hylocichla mustelina*), Gray Catbird (*Dumetella carolinensis*), Tricolored Heron (*Egretta tricolor*) and Ross's Gull (*Rodostethia cosea*) (BDDB 2003).

Bird watching is a popular activity at Sandbanks Provincial Park, which hosts a nesting colony of Piping Plover. Visitation to Sandbanks Provincial Park increased 15 percent from 1,217 in 2004 to 1,403 in 2005 (NLDTCR 2006b). Bird watching is often done in conjunction with other outdoor activities, such as whale watching, hiking and kayaking.

5.7.3 Diving

Diving is an activity that does not typically attract large numbers of tourists, but serves a niche clientele. Currently, there is one diving operation in the area, based in Burgeo (NLDTCR n.d.). This service further diversifies the overall eco-tourism appeal of the region.

5.7.4 Sea Kayaking

Sea kayaking is a very popular activity on Newfoundland's south coast. Two operators offer sea kayaking tours in the region, one based in Ramea and the other in Burgeo (NLDTCR n.d.). The coast is popular for its scenic appeal, including its geomorphological features and its flora and fauna. There are also many sheltered coves and harbours, providing easy access to the land and suitable as camping sites on overnight trips. Aside from official operations, many kayakers enjoy the waters of the south coast independently, and are therefore never recorded in any tourism statistics. This is true of many of these outdoor recreation activities, especially with respect to the outdoor recreation participation of the resident population of the immediate area and of the Province as a whole.

5.7.5 Recreational Fishing

Fishing is deeply rooted in Newfoundland and Labrador culture and is a popular activity for tourists. Three species are targeted recreationally on Newfoundland's south coast: Atlantic salmon; sea-run trout (*Salvinus fontinalis*); and Atlantic cod. Grandy's River and Grey River are two of the most productive salmon rivers on the south coast and both draw anglers from around the province and around the world. Sea-run trout are also a favoured target species for anglers and are sought in brackish waters where rivers outflow into the sea.

5.7.6 Cruise Ships

The cruise ship industry in Newfoundland has grown from 17,700 passenger visits in 2004, with estimated expenditures of $1.3 million, to 25,600 passenger visits in 2005, with estimated expenditures of $1.9 million. There are four ports of call on Newfoundland's southwest coast: François; Ramea; La Poile; and Grand Bruit. In 2005, Ramea was visited three times and Grand Bruit once. La Poile and François were not visited in 2005 but in 2004 were visited once and three times, respectively (NLDTCR 2006a).

5.7.7 Prehistoric and Historic Resources

There are currently no registered historic sites on the southwest coast, but there are several sites of cultural and archaeological significance that may come to be recognized for their tourism and recreation potential. Among these are sites associated with European settlement and those of the aboriginal peoples who preceded them, including the Maritime Archaic, Dorset Paleo-Eskimo and Recent Indian.

5.7.8 Cumulative Environmental Effects Interactions

5.7.8.1 Exploration and Production Activities

Attempts should be made to avoid overlap with activities in other license areas, especially those in the Gulf of St. Lawrence.

The incremental amount of vessel traffic as a result of exploration and production activities in the SEA Area will be negligible compared to existing vessel traffic in the area. At current time there are no production activities within the SEA Area, or in offshore area in the Western Newfoundland and Labrador Offshore Area (there are land-based production activities located on the Port au Port Peninsula), Laurentian Sub-Basin Offshore Area and nearby Nova Scotia areas. The actual potential for cumulative effects associated with production activities will be based on a variety of factors including the location of the production, volume of the production, type of production platform and other factors intrinsic to the region of the future “potential” production platforms and will be examined in detail in project-specific environmental assessments.

Geophysical (seismic including 2-D, 3-D and VSP) activities will not overlap temporally or spatially, as this may interfere with data collection. However, it is possible that they could occur sequentially. There could result in an additive effect to marine mammals (i.e., humpbacks) and fish species (i.e., herring) that may be sensitive to noise generated during the seismic survey. There is also the potential for seismic surveys to be conducted in the Western Newfoundland and Labrador Offshore Area, Laurentian Sub-Basin Offshore area and Areas located in Nova Scotia water at the same time as in the SEA Area, which could sequentially subject migratory species to more than one seismic noise source.

Environmental assessments to date have concluded that the effects of individual seismic programs on marine animals (i.e., marine mammals, marine birds, sea turtles, fish, and invertebrates) are not significant given the proper implementation of mitigation measures (Davis et al. 1998) and that spatial and temporal overlap between different seismic programs can be readily minimized. Therefore seismic cumulative effects should be minimal. Nonetheless, individual seismic programs will require a site-specific environmental assessment pursuant to CEAA that will examine cumulative effects in detail, including background noise levels. Mitigations such as ramp-ups and avoidance of sensitive areas and times and following the C-NLOPB’s *Geophysical, Geological, Environmental and Geotechnical Program Guidelines, Newfoundland Offshore Area*, April 2004, ramp-up procedures should mitigate any potential cumulative effects to acceptable levels. Any proposed seismic program would require an authorization issued by the C-NLOPB, and as such are subject to an environmental assessment (C-NLOPB 2004) to address the potential environmental effects of seismic surveys in the SEA Area.

Based on previous experience, it is anticipated that at least one exploration well and two to three delineation wells could be drilled per license (parcel), resulting in up to 12 well drilled on the three parcels over the nine-year lease agreement.

It is unlikely that more than one seismic vessel would be available at any one time. Therefore, it is likely that seismic surveys would be conducted consecutively on the three licenses, not concurrently. Likewise, the availability of drilling platforms likely precludes more than one drilling platform working in the SEA Area at one time. It is likely that any wells would be drilled sequentially in the parcels.

Exploration/delineation drilling activities may overlap temporally or spatially between licenses, or with activities undertaken in the Western Newfoundland and Labrador Offshore Area, Laurentian Sub-Basin Offshore Area and areas located in Nova Scotia water at the same time as in the SEA Area. In addition, there will likely be support vessels and air support for production platforms in the SEA Area at any given time. With the exception of noise generation, the environmental effects per drilling platform, its support vessels and aircraft would likely be limited in geographic extent (typically within 50 to 1,000 m), duration (typically 40 to 60 days) and magnitude.

The offshore exploration and production activities will incrementally add to the underwater ambient noise levels in the SEA Area, but most likely will not measurably increase overall noise levels. The lack of noise measurement and modeling for the area is an existing data gap. The cumulative effects associated with incremental increases of underwater noise will be examined in project-specific environmental assessments for which there will be more information regarding other exploration and production activities within and adjacent to the SEA Area.

Marine bird distribution and abundance may be influenced by natural processes such as weather, food availability and oceanographic variation, as well as by human activities such as fishing, vessel traffic, large offshore structures and pollution (Wiese and Montevecchi 2000). Exploration and production activities, commercial fishing and marine transportation could result in cumulative effects on seabirds. Seabirds may also be affected by offshore exploration and production activities that occur outside the SEA Area, but within their migratory ranges. As well, changes in prey and predator populations may affect marine bird populations.

In addition, during certain periods and activities associated with exploration and production activities support vessels will be operating in the SEA Area. Vessel traffic may affect marine birds through vessel lighting, oily discharges and noise. Chronic routine discharges, such as deck drainage and ballast and accidental releases of hydrocarbons, can expose birds to oil. Chronic releases (including those from non-exploration and production activities) may be equally or more important to long-term population dynamics of seabirds. All routine drilling platform discharges will comply with the OWTG (NEB et al. 2002).

Offshore exploration and production activities have the potential to affect habitat for benthic invertebrates within approximately 50 m of the drill centre due to deposition of cuttings. Filter feeding organisms could be impacted (reduction in somatic and gonad tissue growth) by drill mud suspended in the benthic boundary layer up to 20 km from the drill centre. Behavioural effects induced by noise associated with the exploration and production activities (drilling, well abandonment and supply vessel support) could also result.

5.7.8.2 Commercial Fisheries

The potential exists for exploration and production activities to result in cumulative environmental effects with existing commercial fisheries activities. The establishment of safety zones around drilling platforms would be implemented as a mitigation measure. These effects would be addressed in project-specific environmental assessments.

Mitigative measures that could be applied during seismic operations include a Fisheries Liaison Officer, A Single Point of contact and an exclusion zone around the seismic vessel and airgun streamer. These would be addressed in more detail in a project-specific environmental assessment.

5.7.8.3 Shipping

The potential exists for support vessels to result in cumulative environmental effects with existing shipping in/through the SEA Area as discussed in Section 5.5.6.1. These effects would be addressed in a project-specific environmental assessment.

5.7.8.4 Tourism and Recreation

Exploration and production activities may result in cumulative environmental effects with tourism and recreation activities in the SEA Area, including activities such as hunting (marine birds). The specifics of these activities and potential effects will be considered during any project-specific environmental assessments.