6.0 BIOLOGICAL/ECOLOGICAL ENVIRONMENT

This section provides a description of the project-related activity/discharge and its interaction with the environment. Possible effects of the project activity/discharge are discussed in terms of key components of the environment (*i.e.,* Valued Environmental Components or VECs (referred to as essential resources and systems in assessments conducted by the MMS)). Information sources include recent environmental assessments as well as primary literature. This chapter focuses on possible effects to the biological and physical components of the environment.

6.1 Issues and Possible Effects

6.1.1 Presence of Structures

Several types of structures may be present during an oil and gas exploration phase. These include mobile offshore drilling units (MODUs) such as semi-submersible or jack-up rigs, drill ships, seismic vessels and support/supply vessels. During the developmental and production phases structures may include gravity based system (GBS) production platforms, floating production, storage and offloading units (FPSOs), and associated subsea structures such as anchors and chains, manifolds, christmas trees, well heads and pipelines.

6.1.1.1 Issues

The primary issues related to offshore structures during the developmental stage include:

- the establishment of safety zones around drilling units and other offshore structures;
- disruption of benthic habitat by subsea structures such as anchors, well heads and pipelines;
- the creation of refuges and artificial reefs for fish and marine mammals;
- the attraction of seabirds to lights and flares; and
- the effects of increased noise on fish, marine mammals and seabirds.

6.1.1.2 Possible Effects

On the east Coast of Canada, the C-NOPB has established the *Newfoundland Offshore Area Petroleum Production and Conservation Regulations* (C-NOPB 2001). Likewise the C-NSOPB has established similar regulations (C-NSOPB 2001). The regulations state that a 500 m safety zone at and under sea level must be established around all production installations and for 50 m around anchor patterns of production installations. Although the regulations state production installations, safety zones are also applied around exploratory drilling units. At the Terra Nova installation on Newfoundland's Grand Banks, four well heads extend for several kilometres from the centralized FPSO. A Fisheries Exclusion Zone (FEZ), totalling 13.8 km^2, has been established. Similarly, FEZs have been established around Hibernia (5.2 km^2) and White Rose (15.4 km^2). The primary concern relating to the establishment of FEZs is the loss of potential fisheries revenue.

6.1.2 Lights and Flares

During drilling and production, natural gas that is present in the oil-bearing reservoir must be released to the surface. The gas may be re-injected back into the reservoir to provide reservoir pressure and enhance oil recovery or it may be flared. Flaring is simply the process of burning off the excess gas in a manner similar to the function of a blowtorch.

Issues
The primary issues related to lights and flares are:

- the attraction of fish and squid;
- the attraction of night-flying or migrating seabirds to the lights and flare; and
- the incineration of birds.

Possible Effects
Although it is generally accepted that fish and squid are attracted to light sources (Hurley 1980), the effects on fish and squid populations are generally considered negligible (Husky Oil 2001b). Light from vessels and flares does not propagate for substantial distances underwater and any attraction would thus be localized to the immediate area surrounding the light source.

One concern related to birds and offshore facilities is that night-flying seabirds and other migrating bird species will be attracted from great distances to lights or flares on offshore installations. Birds that are attracted may experience mortality through strikes against infrastructure or incineration in the flare. Birds may also become disoriented by lights, particularly during overcast or foggy conditions, and fly continuously around them consuming energy and delaying foraging or migration (Avery *et al.* 1978; Bourne 1979; Sage 1979; Wood 1999 (in Husky Oil 2000)).

Bird attraction to offshore platforms has been noted by numerous observers and researchers in the North Sea, Bering Sea and, more recently, on the Grand Banks. Tasker *et al.* (1986) noted higher densities of birds within 500 m of a platform than in the surrounding waters. Following establishment of a platform in the Bering Sea, bird densities were six to seven times higher than densities previously observed in the area of the platform (Baird 1990). Wiese and Montevecchi (2000) also noted a similar pattern in that seabird concentrations around offshore oil platforms on the Grand Banks were 19 to 38 times higher than on survey transects leading to the platforms. As well, there have been numerous observations made and some studies conducted, on bird attraction to land based facilities such as lighthouses, television towers, and skyscrapers.
During surveys of bird attraction to a flare on an offshore platform in the North Sea, it was noted that seabirds (mainly Fulmars (*Fulmarius glacialis*) and gulls (*Larus* spp.)) were attracted to the surface of the sea directly below the flare at night and appeared to be feeding on the surface. However, only one bird was observed flying up near the flame during the five-week observation period (Hope-Jones 1980). During the survey period, no bird mortality was observed from the flare, thus indicating that it is possible for large numbers of birds to be attracted to flares without mortality occurring (Hope-Jones 1980). Other North Sea installations have reported mortality from gas flares, however, the numbers are

usually low (Sage 1979; Hope-Jones 1980).

Weather conditions and the magnitude of bird movements are significant factors influencing bird mortality from strikes at tower structures (Crawford 1981). Moisture droplets in the air during conditions of drizzle and fog refract the light and greatly increase the illuminated area thus enhancing the attraction (Wiese *et al.* 2001). These conditions occur frequently at offshore installations on the Grand Banks. Hope-Jones (1980) also noted during observations from an offshore platform in the North Sea, that attraction of landbird migrants (mostly thrushes) to a gas flare occurred more often during misty weather. Of 16 incidents where birds were positively attracted to the flare, 14 occurred during misty or rainy weather.

6.1.3 Discharges

One project-related activity that is of concern to regulators is discharges from an offshore oil and gas platform, most importantly, the deposition of drill cuttings and the dispersion of produced water. Other discharges include ballast water, cooling water, sanitary and domestic waste, and deck drainage. In Atlantic Canada, discharge into the marine environment is governed by the Offshore Waste Treatment Guidelines (NEB, C-NOPB and 1996) (see Section 2.3.1 for differences in application of the guidelines by the C-NSOPB and C-NOPB).

In a recent EIS (MMS 2001a), the MMS identified discharges, including drill fluids, produced water and other discharges as an issue (although not a major issue). It should be noted that it is assumed that the drilling and operational discharges from this Alaskan project would be disposed of on site in a permitted disposal well. If any over the side discharges are permitted (via a National Pollution Discharge Elimination System), it would only apply to marine discharge of treated sanitary and domestic wastewater (MMS 2001a). Other jurisdictions (such as the Pacific Outer Continental Shelf Region and Gulf of Mexico Outer Continental Shelf Region) and elsewhere (such as Western Australia), permit over-the-side discharge of WBM drill cuttings and, in some cases, cleaned/treated (*i.e.,* oil-free) SBM drill cuttings (MMS 2000; 2001b; URS 2001).

6.1.3.1 Drill Cuttings

Drilling muds (refer to Section 5.3.8) are a critical and interrelated part of the drilling operation. The drill muds transport cuttings from the well. Cuttings (or waste rock) are by-products of the drilling process and must be conveyed from the wellbore. In the design of the well trajectory, consideration will be given to the total volumes of drill cuttings generated and the type of drilling fluid used (oil-based, water-based, low-toxicity mineral oil-based or synthetic based). A development would make the attempt to use the most environmentally acceptable fluid that meets the technical criteria of the fluid selection (e.g., direction drilling versus horizontal drilling). Currently, the industry discharges both WBM or SBM drill cuttings over the side, as well as re-injecting OBM drill cuttings into a permitted disposal well.

Issues
The primary issues related to the discharge and deposition of drill cuttings include:

- deposition (smothering habitat, creation of piles, extent of deposition);
- toxicity (based on the chemical constituents of the mud and the fluid and including heavy metals); and
- bioaccumulation (*i.e.,* uptake of hydrocarbons by fish and the perception of taint).

Possible Effects
In shallow areas, the release of drill cuttings may settle on the seabed, affecting the benthic infauna (the focus of most studies, as they are relatively immobile communities; some are pollution tolerant and others, pollution sensitive) in the vicinity of the well. In addition, the drill cuttings may be transported over larger areas, depending on currents and storm events.

While the release of both WBM and SBM drill cuttings can cause potential effects on the environment, there are differences in the level and extent of the various effects. For example, as the WBM drill cuttings are finer than SBM drill cuttings, they have a tendency to spread further in the water column before settling to the sea floor, thus potentially smothering a larger areal extent. While the SBM drill cuttings settle sooner (and have a low solubility in water), they can create piles on the sea floor, thus potentially concentrating any toxic affects of the drill cuttings, or increasing the organic enrichment or the seabed. However, heavy metals in drill cuttings are unlikely to accumulate to levels (or in bioavailable forms) harmful to marine mammals (Hinwood *et al.* 1994 in Husky Oil 2000) or seabirds (Gallagher *et al.* 1999; Husky Oil 2000).

Dose response studies on fish demonstrated that sediments contaminated with cuttings containing a synthetic-cased fluid had a very low acute toxicity potential (Payne *et al.* 2001a; 2001b). However, sublethal effects have been observed in flounder that have had chronic exposure to petroleum-contaminated sediment containing 1 ppm aromatic hydrocarbons (Payne *et al.* 1988).

While bioaccumulation of oil in fish tissue (and subsequent tainting of fish flesh) was identified as a potential issue with the use of oil-based drill cuttings (GESAMP 1993), drill cuttings discharged over the side are either water-based or synthetic-based. A review of the chemicals used in one type of synthetic-based fluid concluded that fish flesh would not become tainted (Kiceniuk 1999).
Another issue with discharge of drill cuttings is the creation of cuttings piles and recovery of benthic communities. North Sea data indicate that biological effects and contamination from single wells may not last beyond one winter storm season (GESAMP 1993). Synthetic-based drill cuttings are biodegradable; the time required for a pile degrade is dependent upon surrounding conditions such as water temperature, bottom currents and aerobic versus anaerobic conditions. Monitoring studies have shown that synthetic-based cuttings have little or no affect on benthic communities outside a radius of 250 m; there is a great variation in diversity of the benthic communities outside 250 to 500 m from

offshore installations and effects from drill cuttings discharge are difficult to isolate from natural variation (Jensen *et al.* 1999).

If sediment transport occurs in an area of offshore development, resuspension of drill cuttings by waves and currents, and subsequent deposition, may occur (Husky Oil 2001a).

A study of individual exploration drill sites in the Florida Keys concluded that with the application of modern technology and anti-dumping regulations, exploratory wells could probably be drilled without leaving a trace (Dunstan *et al.* 1991). This conclusion was also supported by an examination of three exploration wells drilled in the Hibernia field that indicated only slight accumulations of drilling materials (NORDCO 1983).

The Offshore Waste Treatment Guidelines currently permit over the side discharge of water-based and synthetic-based drill cuttings, however, offshore developers usually must investigate other disposal options, either on a life cycle cost-benefit basis or a risk analysis basis (Husky Oil 2001b), among others. Disposal options other than over the side of the platform include:

- cuttings re-injection; and
- ship to shore (which has its own on-land alternatives, such as thermal desorption, landfarming, landfilling, *etc*.).

Refer to Section 2.3.1 for the current disposal option preferences of the C-NSOPB and C-NOPB (and parenthetically, the North Sea and Gulf of Mexico).

6.1.3.2 Produced Water

One product from drilling a well is the formation water, which is released as produced water. Production water is initially 100 percent formation water but will eventually become mixed with seawater when the injection water (treated seawater injected to maintain formation pressure) breaks through to the producing well. Produced water can contain hydrocarbons, dissolved mineral salts, sulphur, barium, iron, small amounts of heavy metals and strontium (a naturally occurring radioactive material) and can range in pH from neutral to acidic (Rose and Ward 1981; Thomas *et al.* 1984; Mobil 1985). Due to the high reservoir temperature (110ºC), the temperature of produced water is approximately 60ºC (Husky Oil 2000b).

While water production starts in the first year of operation, the maximum daily amount of produced water usually occurs well into the operating life of a development (e.g., the peak rate of produced water during the White Rose development is not expected to occur until eight or nine years of operation (Husky Oil 2001a)). Produced water must be treated prior to discharge to meet the Offshore Waste Treatment Guidelines total hydrocarbon concentration of 40 mg/L or less averaged over a 30-day period.

Issues

The primary issues related to the discharge and dispersion of produced water are the:

- oil content within the plume (potentially resulting in fish taint and oiled seabirds); and
- temperature of the plume (potentially lethal to some life stages of fish).

Possible Effects

Of the toxic components found in produced water, polycyclic aromatic hydrocarbons (PAHs) are the most persistent and the probable cause of any biological effects associated with produced water (the other toxic compounds evaporate quickly and pose only a very localized threat to marine organisms) (Black *et al.* 1994). PAHs pose the greatest bioaccumulation effect to sessile organisms, such as mussels, with lower concentrations found in crustaceans and lowest in the more highly mobile fish (Neff and Sauer 1996).

Most produced water does not appear to be acutely toxic (Krause *et al.* 1992 in Husky Oil 2000), and is unlikely at a dilution of 25-fold, which will occur near the discharge point (Hodgins and Hodgins 1998). Sessile organisms are most likely to be exposed to the chronic effects of produced water (including accumulation of oil). Sublethal effects have been recorded (Rabalais *et al.* 1992; Raimondi and Schmitt 1992; Krause *et al.* 1992; Din and Abu 1992; Osenburg *et al.* 1992), especially for larval stages of benthic organisms (considered more sensitive to oil pollution than older life stages of invertebrates), as have lowered species diversity and numbers of individuals of benthic invertebrates (Mulino *et al.* 1996). It should be noted that most of the studies were conducted in shallow water or in relation to shallow water situations, and these results may not be transferable to deeper waters in the offshore area (Husky Oil 2000).

Husky Oil (2000) predicted that due to the narrow, snakelike produced water plume that was predicted to occur (through modelling (Hodgins and Hodgins 2000)) on the Grand Banks, and the diluting effect of the Grand Banks, there would be no significant effect on the thermoregulatory capability of seabirds. Those conditions (calm sea state conditions) when an oily sheen could form on the water surface (where seabirds could come in to contact with oil) will rarely occur (probability of less than 1 percent) (Husky Oil 2001a).

The heated produced water should cool to ambient water temperatures within 50 m or less around a production site (Husky Oil 2000), however, some zooplankton and fish larvae (among the most sensitive life stages) in the immediate vicinity of the produced water outfall may be subjected to thermal shock. It should also be noted that the high temperatures may prevent some fouling organisms (such as sessile epibenthic plants and animals) from colonizing some parts of the structure, which helps mitigate the effects of biofouling on a project (Husky 2000).

6.1.3.3 Other Discharges

Ballast Water

Ballast water is seawater used by vessels to provide stability and maneuverability. Generally, seawater is provided to the ballast tanks by a combination of flooding from the sea through valves in the tanks and from the firemain. There are several types of ballast water, as defined by the US Uniform National Discharge Standards, clean ballast, compensated fuel ballast and dirty ballast. Clean ballast water is stored in dedicated ballast tanks and generally does not come into contact with oily substances. Compensated fuel ballast is seawater that replaces fuel as the fuel is used, thereby aiding a ship's stability. The tanks are always full of fuel and/or seawater. Seawater is forced out of the tank during refuelling. Dirty ballast is seawater that is pumped into and out of empty fuel tanks on an emergency basis on some vessels to increase vessel stability. The seawater mixes with residual fuel to produce dirty ballast (UNDS 2001).

Issues

The primary issues related to the discharge of ballast water include:

- release of oily water; and
- introduction of exotic species.

Possible Effects

On floating drill rigs and supply boats, only clean ballast is used. If oil is suspected to have entered a clean ballast system, then under Canada's pollution prevention regulations, which prevent the discharge of oil or pollutant substances into waters under Canadian jurisdiction, water must be tested and treated the ensure that oil concentrations are less than the Offshore Waste Treatment Guidelines of 15 mg/L (NEB, C-NOPB and C-NSOPB 1996).

The effects of ballast water on the environment are generally not related to the release of hydrocarbons, but rather to the introduction of exotic species entrained in the ballast water. Ballast water taken in foreign ports is dumped at the destination port when cargo is loaded and often includes exotic species of plankton, invertebrates and fish. To reduce the entrainment of exotic species, which are generally associated with coastal waters, voluntary guidelines suggest that ocean going vessels originating beyond the limits of the continental shelves replace their ballast with oceanic water when water depths exceed 2,000 m. For vessels not leaving the continental shelves, ballast water should be replaced when water depths exceed 300 m (TC 2001).

MODUs, however, represent a different situation. They remain in one area for extended periods of time and large assemblages of fauna and flora often attach to the subsurface structures, as well as entering ballast tanks. Since they are usually towed slowly from one location to another and may not travel beyond the continental shelves, replacing ballast water while under tow may help reduce the number of exotic organisms being transferred. A recent report by the Australian Department of Industry, Science and Resources indicates that heavily fouled vessels may carry up to 5 kg of material per square metre, or 60 tonnes on average-sized vessels. MODUs may carry greater amounts (Walter 1995 in ISR 2001). Frequent application of antifouling agents may help reduce the transfer of exotic organisms.

Cooling Water

Cooling water is used by vessels and rigs to remove heat from various systems. Seawater is drawn from the ocean either directly, via a hull connection (sea chest), or indirectly, via the firemain pump and passed through a heat exchanger. The seawater is then discharged back into the ocean, usually below the waterline (UNDS 2001). On drilling rigs, cooling water is used for equipment such as top-drives and draw-works.

Seawater is drawn into a closed loop system of heat exchangers and does not contact oily substances. Initially, the water is deoxygenated and sterilized by electrolysis, which releases chlorine from the salt solution (ISR 2001). Concentrations of chlorine are usually less than 2 mg/L (Husky Oil 2000). The temperature of discharged cooling water may be 20 to 30ºC above ambient temperature.

Issues

The primary issues relating to the release of cooling water are:

- the release of chlorinated water into the environment; and
- the increase in water temperature.

Possible Effects

No guidelines currently exist for maximum allowable discharge levels of chlorinated cooling water. However, since cooling water is discharged from a drilling unit's lower deck, much of the chlorine is lost by vaporization during the fall between the deck and the sea surface (ISR 2001). The effects of elevated water temperatures on the environment from discharged cooling water have yet to be ascertained, but any potential effects are generally considered negligible due to the relatively small volumes discharged.

Sanitary and Domestic Waste

Grey water is sink, shower or laundry water, whereas black water is sewage water. On a typical MODU containing 100 personnel, approximately 40 m^3 and 19 m^3 of grey and black water are released daily, respectively (Mobil 1985).

Sanitary and food wastes are permitted for disposal at sea, however, under the Offshore Waste

Treatment Guidelines (NEB, C-NOPB and C-NSOPB 1996), all food wastes must be macerated and reduced to a particle size of 6 mm or less. Degradation of organic waste by bacteria and other small marine organisms is rapid and any effects on the environment from such wastes are generally considered negligible.

All other domestic waste, such as paper, cardboard, plastic or packaging, is not permitted for disposal at sea and must be transported to shore for recycling or disposal.

Issues
The primary issues related to the discharge of sanitary and domestic waste is the attraction of seabirds to disposed food waste.

Possible Effects
While it is generally accepted that gulls and other species of seabirds are attracted to and follow vessels, the effects on birds due to intermittently disposed food wastes are generally considered negligible.

Deck Drainage

Deck drainage is water that reaches the deck of offshore installations through precipitation, sea spray or from routine operations such as washdown and fire drills. Under the Offshore Waste Treatment Guidelines (NEB, C-NOPB and C-NSOPB 1996), the deck drainage system must be completely separate from those systems that collect waste from machinery spaces since machinery space drainage is more likely to come into contact with hydrocarbons. All deck drainage from machinery spaces is routed to skimmers for treatment before discharging. Only water containing 15 mg/L or less of hydrocarbons can be discharged. All deck drainage from non-machinery spaces is released overboard. The effects of deck drainage on the environment are generally considered of low magnitude and of small geographic extent (Husky Oil 2000).

6.1.4 Vessel Traffic

Oil rigs and platforms frequently require support services from dedicated supply vessels. In addition to ferrying personnel, the primary tasks for supply vessels include cargo and bulk re-supply, anchor and mooring chain handling, environmental monitoring, oil spill response, standby service, search and rescue and emergency evacuation (Husky Oil 2000). In the Newfoundland offshore, supply vessels are also used to deflect icebergs away from drilling structures.

Issues
The primary issues related to increased vessel traffic include:

- increased noise and the effects on fish, marine mammals and birds;
- discharge of oily substances and the effects on the environment;

- disruption of migration routed for marine mammals;
- the attraction of seabirds to vessel lighting; and
- illegal discharge of oily bilge water.

Possible Effects

The effects of increased vessel traffic on fish are primarily related to oily discharges and increased noise. As discussed in the previous section, oily discharges from vessels are regulated under the Offshore Waste Treatment Guidelines (NEB, C-NOPB and C-NSOPB 1996) and no vessel may discharge fluids containing more than 15 mg/L of hydrocarbons. The overall effects of oily discharges on fish from vessels are generally considered negligible. Noise in the marine environment is complex and affects different fish species to varying degrees.

Vessel traffic could potentially affect seabirds through vessel lighting (see Section 6.1.2), oily discharges (see Section 6.1.3) and noise. Noise and disturbance from ships are unlikely to affect birds in areas where there is a history of fishing activity and cargo vessel movement. Birds have adapted to vessel traffic and some species, particularly gulls and northern fulmar, are attracted to ships and often stay with them for extended periods (Duffy and Schneider 1984; Brown 1986 cited in Husky Oil 2000). There is a potential for passing ships to disturb seabird colonies, however, prudent seamanship would generally ensure that vessels remain far enough from bird colonies to prevent disturbance.

6.1.5 Atmospheric Emissions

There are four sources of atmospheric emissions generated during exploratory and delineation drilling (Husky Oil 2000):

- burning of well fluids during production tests and well clean-ups (burner boom emissions);
- combustion products (nitrogen oxides (NO_x), sulphur oxides (SO_x), carbon monoxide (CO), carbon dioxide (CO_2), particulate matter (PM) and unburned hydrocarbons) from engines, generators, heating exhausts, cranes, turbines, helicopters and support vessels;
- mud, degassing and other mudroom exhausts; and
- fugitive emissions.

During the production phase of an oil and gas operation, various other atmospheric emissions are generated including (Husky Oil 2000):

- volatile organic compounds (VOC) from storage tank breathing and filling losses;
- combustion products (nitrogen oxides (NO_x), sulphur oxides (SO_x), carbon monoxide (CO), carbon dioxide (CO_2), particulate matter (PM) and unburned hydrocarbons) from engines, generators, heating exhausts, cranes, turbines, helicopters and support vessels;
- combustion products (gases) used as an inerting blanket gas in the tanks; and
- flaring operations during well testing or in production upset conditions that emit combustion

products.

Issues

The primary issues related to atmospheric emissions include:

- global warming due to greenhouse gases in the environment; and
- degradation of air quality.

Possible Effects

Global warming due to the release of greenhouse gases was the main focus of the Kyoto Summit in Japan in December 1997. One hundred and sixty countries participated in the summit, which delivered a protocol after 10 days of discussion. The primary aim of the Kyoto Protocol is to reduce greenhouse gas emissions globally by 5.97 percent by 2012. Canada must reduce its greenhouse gas emissions by 6 percent (the Kyoto Protocol was revisited in 2001)(EC 2001). Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), water vapour (H_2O) and chlorofluorocarbons (CFCs). The emissions of primary concern produced by offshore oil and gas installations are nitrogen oxides (NO_x) and reactive organic compounds (ROCs). ROCs or reactive hydrocarbons can react with other chemicals in the presence of sunlight to form ozone and smog and are considered toxic.

Atmospheric emissions from offshore oil and gas installations vary widely according to the project phase and equipment used. A recent study by the MMS (2001b) identified the types and quantity of atmospheric emissions generated by a typical mobile offshore drilling unit, the SEDCO 712, during an exploration and delineation drilling phase. Other sources of emissions measured in the MMS (2001b) study include vessel traffic and helicopters. Daily emissions from a SEDCO 712 MODU and its support equipment operating in Bonito, California are provided in Table 6.1.

Table 6.1 Daily Emissions from a SEDCO 712 and its Support Equipment

Drilling Operation	NO_x (lb/day)	CO (lb/day)	VOC (lb/day)	SO_2 (lb/day)	PM_{10} (lb/day)
Drilling	506.32	67.75	2.85	11.41	22.11
Cranes	23.70	9.21	0.11	0.42	2.65
Flares	70.00	24.50	4.48	2.87	3.50
Total	**600.01**	101.46	**7.44**	**14.70**	**28.26**
Vessels *	241.56	5.78	27.56	97.33	101.33
Helicopter **	12.44	1.78	1.60	32.08	14.26
Overall Total	**854.01**	**109.02**	**36.60**	**144.11**	**143.85**

Source: Modified from MMS 2001b

* Assumes 110 ft crew boat making 8 trips/month, 110 ft supply boat making 12 trips/month.

** Assumes one flight daily.

Air emissions from oil related activities offshore have generally been considered negligible in several of Canada's East Coast oil projects (Husky Oil 2001; Petro-Canada 1995; SOEP 1997) since they are rapidly dispersed to undetectable levels.

6.1.6 Helicopter Traffic

Helicopters are routinely used to carry personnel, equipment and supplies between shore and offshore installations. On the East Coast of Canada, over 25,000 personnel are ferried by helicopter annually to offshore installations (CHI 2001).

Issues

The primary issue related to increased helicopter traffic include the effects of increased noise on fish, marine mammals and birds.

Possible Effects

The effects of helicopter noise on fish generally are considered negligible since sound does not transmit well between air and water. Richardson *et al.* (1995) determined that the frequency of a Eurocopter Super Puma (the helicopter currently being used in the Newfoundland offshore oil industry) flying at 300 m altitude generates frequencies of 20 and 50 Hz. Noise levels detected at the sea surface were 105-110 dB re 1μPa^{-1}, whereas noise levels detected at 3 to 18m depth were 65-70 dB re 1μPa^{-1}. In comparison, wind (<1.8 km/h) generates a noise level of 60 dB re 1μPa^{-1}.

Marine mammals are generally more tolerant of fixed sound sources such as drilling rigs rather than mobile sources of noise such as ships or helicopters. Pinnipeds (seals) are most sensitive to aircraft when they are hauled out for pupping or moulting (Richardson *et al.* 1995). Commonwealth guidelines have been established for aerial observations of marine mammals, which restrict an aircraft from approaching within 300 m of a marine mammal (EA 1999 in ISR 2001). Helicopter flight routes should be selected to minimize or eliminate flights over known haul out areas. Baleen whales, such as minke, right whales and bowhead whales, have been observed changing their swimming behaviour when aircraft have flown at altitudes between 150 to 300 m (Leatherwood *et al.* 1982; Watkins and Moore 1983; Payne *et al.* 1983; Richardson *et al.* 1985a; 1985b). Similarly some toothed whales have also been known to dive or swim away (see Petro-Canada 1995).

Helicopter noise can potentially disturb nesting seabirds at colonies, although seabird reactions to helicopters and other aircraft are complex and depend on a number of factors including species, previous exposure levels, and the location, altitude and number of flights (Hunt 1985 cited in MMS 2001a). Similar to their response to vessel traffic, seabirds may also habituate to air traffic over time. Identification of breeding colonies in an area of helicopter activity and maintenance of minimum altitudes and exclusion zones should mitigate the adverse effects of this activity. Effects to seabirds offshore would be negligible, as aircraft would likely be flying at an altitude and speed that would make any effects to offshore seabirds negligible. Similarly, birds that spend time near offshore installations would become habituated to helicopter traffic (MMS 2001b).

6.1.7 Noise

Noise is generated from operation of the platform and vessel and helicopter traffic, and is discussed in the respective sections (Sections 6.1.4 and 6.1.6).

6.1.8 Seismic Surveys

Seismic surveys are an integral part of offshore oil and gas exploration and are used to determine the existence of potential hydrocarbon deposits buried deep below the ocean's bottom. Specialized vessels tow airgun arrays and hydrophone streamers, which trail the vessel for several kilometres. Airgun arrays consist of small cylinders (10 to 100 cu. in) pressurized to approximately 2000 psi (JNCC 2001) and towed approximately 50 m behind a seismic vessel. Air, which is discharged from the airguns every 6 to 10 seconds with a duration of 10 to 30 milliseconds (ISR 2001), generates a large downward pressure pulse with a frequency between 10 to 300 Hz (JNCC 2001). The high-energy pulse travels through the subsea strata and the reflections are subsequently detected by the hydrophone streamers, which are towed at depths between 5 and 12 m.

Issues

The primary environmental concerns relating to seismic surveys are:

- the effects of seismic surveys on catch rates of commercially important fish species; and
- the effects of high energy pressure pulses on
  - early life stages of fish,
  - swim bladder resonance and ear damage in fish,
  - marine mammal auditory systems, and
  - marine mammal behaviour.

Potential Effects

A study by the Norwegian Institute for Marine Research assessed the effects of seismic surveys on the catch and catch availability of commercially important species of fish such as cod and haddock (Engås *et al.* 1993). Fishing trials using trawls and longlines were conducted several days before, during and after seismic shooting to determine fish distribution and abundance estimates. The overall conclusion of the study was that seismic shooting affected fish distributions in the immediate vicinity and at the edge of the study area, 18-20 nautical miles either side of the shooting area. Trawl catches were reduced by 70 percent in the seismic shooting area and averaged 50 percent over the entire study area, whereas longline catches declined by 44 percent in the shooting area, with no decline observed at the study area perimeter. Acoustic mapping suggested that the fish reacted by swimming away from noise generated by the airguns. The study did not ascertain the duration of effects on fish; however, catch rates remained low for a period of five days after cessation of shooting. It was also suggested that the period of time required to attain normal catch rates following shooting varies with season, locality, duration of shooting, availability of food and whether fish are migrating.

Few studies have addressed the effects of seismic exploration on ichthyoplankton, or fish eggs and larval fish. Kostyuchenko (1971; cited in ISR 2001) noted that mortality may occur but only in close proximity (approximately 1 to 10 m) to an operating airgun. The Georges Bank Review Panel heard that studies on the potential physical effects of fish and fish larvae are few and not comprehensive enough to provide statistical power, but there was general agreement that within 6 m of an air gun, there were mortalities among eggs and larvae and damage to fish with swim bladders, but there is no significant physical effect beyond the 6 m zone (NRCan and NSPD 1999). There are numerous studies, however, on the physiological effects of seismic exploration on adult fish. Several studies address the effects on fish's swim bladders - air-filled bladders found in most fish, which are primarily used for buoyancy control (for review see McCauley *et al.* 2000). Swim bladders resonate, and the larger the swim bladder, the lower the frequency to which it can resonate. A swim bladder of a large cod is known to resonate at a frequency of approximately 600 Hz (Hawkins 1977; Løvik and Hovem 1979), whereas the swim bladders of smaller fish resonate at higher frequencies. Since seismic testing produces high-energy sound waves below 150 Hz, the effects on swim bladders would be considered slight. However, swim bladder damage and mortality has been observed in adult fish in close proximity (approximately 1.5 to 6 m) to airguns (MMS 2001b).

Low frequency, high-energy sound waves generated by seismic airgun can also affect marine mammals, which depend on low frequency sound waves for communication. The auditory systems of marine mammals are well developed for detecting low frequency sound over many kilometres. Baleen whales, such as grey, right, humpback and fin whales, communicate at frequencies below 3 Hz (JNCC 2001). Toothed whales, such as killer whales, pilot whales, dolphins and porpoises, use much higher frequencies to communicate and their sensitivity to sounds below 1,000 Hz (1 kHz) is poor. A dolphin produces sound with frequencies above 4.8 kHz for communication and may produce frequencies up to 200 kHz for echolocation. Thus, the auditory systems of toothed whales are much less susceptible to the sounds generated by seismic airguns than baleen whales (JNCC 2001).

Comprehensive reviews on the effects of noise on marine mammals were prepared by Richardson *et al.* (1995) and McCauley *et al.* (2000). They conclude that temporary or permanent damage to auditory structures could result if an animal was within 100 m of an airgun array, and that the most likely effects of seismic surveys on marine mammals are to their swimming and feeding behavior. Noise from seismic activity can be heard by whales as far as 50 to 100 km from the source, but avoidance and other disturbance behaviors occur between 5 to 15 km (NRCan and NSPD 1999). Field observations indicated that baleen whales alter their swimming behavior at distance of 5 to 8 km or more (MMS 2001b). Recently, the Joint Nature Conservation Committee (JNCC) in the UK has established guidelines for reducing the impacts of seismic exploration on marine mammals (JNCC 2001). The guidelines suggest that before commencing seismic surveys, the JNCC be contacted for information relating to marine mammal population in the survey area, and that qualified marine mammal observers be placed on seismic vessels during surveys. In addition, the JNCC suggests that visual checks of the survey area be conducted immediately prior to airgun deployment to ensure no mammals are present within a 500 m radius. Slow build-up of power to the lowest practicable power level would provide sufficient time for mammals to vacate the immediate vicinity.

A summary of effects from air gun operations on whales, sea turtles and fish is presented in Table 6.2 (modified from URS 2001).

Table 6.2 Summary of Effects from Air Gun Operations on Whales, Sea Turtles and Fish

Air Gun Level (dB re 1 µPa rms)	Species	Effects	Source
160	Grey Whale	General stand-off range*	Malme *et al.* 1985
150-180	Grey and Bowhead Whales	General stand-off range	Richardson *et al.* 1995
157-164	Humpback Whale	Stand-off range for migrating humpbacks	McCauley *et al.* 2000
140	Humpback Whale	Resting pods with cows in key habitat type begin avoidance	McCauley *et al.* 2000
143	Humpback Whale	Resting pods with cows in key habitat type stand-off range	McCauley *et al.* 2000
179	Humpback Whale	Maximum level tolerated by investigating, probably male, humpbacks to single air gun	McCauley *et al.* 2000
175-176	Loggerhead Turtle	Avoidance	O'Hara 1990
166	Green and Loggerhead Turtles	Noticeable increase in swimming behaviour	McCauley *et al.* 2000
175	Green and Loggerhead Turtles	Turtle behaviour becomes increasingly erratic	McCauley *et al.* 2000
149	Rockfish (*Sebastes* spp.)	Subtle behaviour changes commence	Pearson *et al.* 1992
168	Rockfish	Alarm response	Pearson *et al.* 1992
>171	Fish Ear Model	Rapid increase in hearing stimulus begins	McCauley *et al.* 2000
182-195	Fish (*Pelates sexlineatus*)	Persistent C-turn startle	McCauley *et al.* 2000
200-205	Selected Rockfish Species	C-turn startle responses elicited	Pearson *et al.* 1992
183-207	Various Wild Finfish	C-turn startle response	Warde *et al.* 9n press
Level not determined	Fish (*Chrysophrys auratus*)	Preliminary evidence of pathological damage to hearing systems of contrained fish	McCauley *et al.* 2000
146-195	Finfish	No significant physiological stress increase	McCauley *et al.* 2000

Source: Modified from URS 2001

* General stand-off range relates to the distance these animals will remain from a vessel towing an operating air gun.

Given the ongoing concern on the potential effects of seismic activity during oil and gas exploration, a workshop was held in 2000 to discuss priorities for research on the effects of seismic activity on the East

Coast fishery. Recommendations that resulted from the workshop included (LGL and Griffiths Muecke Associates 2001):

- highest priority, the study of seismic effects on shellfish (especially crab and lobster);
- an ad hoc study of seismic effects on catch rate of cod during coincident seismic activity;
- seismic effects on hearing structures (and hearing ability) in swordfish and tuna;
- duration and extent of seismic effects on cod and redfish catches;
- behavioural and sublethal effects of seismic activity on fish; and
- behavioural study of seismic effects on spawning.

6.1.9 Oil Spills [Accidental Events]

There are five size classifications for oil spills, the top three of which are cumulative (*i.e.,* includes the smaller sized spills) (Husky 2000a):

- extremely large spills - >150,000 barrels;
- very large spills - >10,000 barrels;
- large spills - >1,000 barrels;
- medium spills – 50 to 999 barrels; and
- small spills – 1 to 49.9 barrels.

The five potential sources of an oil spill from exploration activities include (WAEPA 1997 in URS 2001):

- burning-off during production testing;
- refuelling incident;
- diesel storage on rig;
- rupture of fuel tank on tender/supply vessel; and
- blowout (loss of well control due to encounter with unexpected high reservoir pressure).

The most common spills that might occur during the exploration phase of an offshore oil and gas development are small spills (equivalent 1 to 49 barrels). The exploration phase is least likely to have larger spills unless associated with blowouts (Table 6.3).

While small spills can occur during routine drilling and production activities, this section will focus on larger spills that result from an accidental event during development/production (Table 6.4).

Table 6.3 Important Exploration Well Statistics from World-Wide, Gulf of Mexico, Offshore Norway North Sea and UK North Sea

Location	Statistic	Source
Exploration Wells Drilled World-Wide, 1955-1980	11,737	Gulf 1981
Approximate Exploration Wells Drilled World-Wide To 1988	20,000	Sharples *et al.* 1989
Blowouts During Exploration Drilling World-Wide (Including Shallow Gas Blowouts), 1955-1980	96	Gulf 1981
Blowouts During Exploration Drilling World-Wide (Including Shallow Gas Blowouts), 1980-1996	81	E&P Forum 1996
Exploration Wells Drilled, US Gulf of Mexico, 1955-1980	4,794	Gulf 1981
Blowouts During Exploration Drilling (Including Shallow Gas Blowouts), US Gulf of Mexico ,1955-1980	30	Gulf 1981
Exploratory Drilling Blowouts, US Outer Continental Shelf, 1971-1995	49	MMS 1997a
Exploration And Appraisal Wells Drilled Norwegian Offshore, 1966-1980	939	NPD 1999
Exploration Wells Drilled UK North Sea, 1964-1980	838	Gulf 1981
Exploration And Appraisal Wells Drilled UK North Sea, 1988-1997	1,694	Meltzer 1998
Exploration Wells Drilled North Sea UK And Norwegian Combined, 1980-1992	2,315	E&P Forum 1996
Exploration Drilling Blowouts North Sea UK And Norwegian Combined, 1980-1992	16	E&P Forum 1996

Source: Husky Oil 2000

Table 6.4 Important Development/Production Well Statistics from World-Wide, Gulf of Mexico, Offshore Norway North Sea and UK North Sea

Location	Statistic	Source
Development Wells Drilled World-Wide, 1955-1980	24,896	Gulf 1991
Approximate Development/Production Wells Drilled World-Wide To 1988	51,000	Sharples *et al.* 1989
Blowouts During Development Drilling (Including Shallow Gas Blowouts), 1955-1980	66	Gulf 1981
Other Blowouts (During Production, Workovers, etc.), 1955-1980	52	Gulf 19981
Blowouts During Development Drilling (Including Shallow Gas Blowouts), 1980-1996	51	E&P Forum 1996
Other Blowouts (During Production, Workovers, etc.), 1980-1996	73	E&P Forum 1996
Development Wells Drilled In US Gulf of Mexico, 1955-1980	12,390	Gulf 1981
Blowouts During Development Drilling (Including Shallow Gas Blowouts), US Gulf of Mexico, 1955-1980	36	Gulf 1981
Production And Workover Blowouts, US Gulf of Mexico, 1955-1980	32	Gulf 1981
Development Drilling Blowouts, US Outer Continental Shelf, 1971-1995	45	MMS 1997a
Production, Workover And Completion Blowouts, US Outer Continental Shelf, 1971-1995	57	MMS 1997a
Development Wells Drilled, Norwegian Offshore, 1966-1998	1,501	NPD 1999
Development Wells Drilled, UK North Sea, 1964-1980	721	Gulf 1981
Development Wells Drilled, UK North Sea, 1988-1997	3,932	Meltzer 1998
Development Wells Drilled, North Sea UK And Norwegian Combined, 1980-1992	2,389	E&P Forum 1996
Development Drilling Blowouts, North Sea UK And Norwegian Combined, 1980-1992	4	E&P Forum 1996

Source: Husky 2000a

The two types of accidental events that could occur during drilling and operation of an offshore oil and gas platform are oil-well blowouts (continuous spills lasting hours, days or weeks which discharges large volumes of crude oil into the surrounding waters and petroleum gas into the atmosphere) and "batch spills" (instantaneous or short-duration discharges of oil from accidents occurring where the oil is stored or when transferring to offloading vessels) (Husky Oil 2000).

Issues

The major issues associated with an accidental release of oil includes:

- ingestion -- bioaccumulation through the food chain, resulting in lethal and sublethal effects;
- insulation – inability to thermoregulate, resulting in higher energy costs and potentially starvation (primarily seabirds and furred marine mammals);
- irritation – resulting in increased sensitivity to skin lesions/parasitism (primarily fish and marine mammals);
- taint (fisheries);
- buoyancy (seabirds); and
- persistence – if oil reaches land or the seabed, future storm events or land/substrate disturbance can free trapped pockets of oil and re-release them into the environment.

Possible Effects

The short-term effects of oil spills are generally well understood. Depending on the location, time of year, and exposure of animals and/or fish , short-term effects range from sub-lethal (e.g., pelagic fish) to mortality (e.g., seabirds). The longer-term effects (often behavioural and physiological) can last months to years (depending on species, exposure time, spill type). Generally, the recovery time of affected animal populations range from fast (months) (e.g., recolonization by plants and benthic organisms) to slow (years) (e.g., according to some sources regarding seabird colonies).

Fish and Fish Habitat

The effects of oil spills on fish and fish habitat have been studied extensively (see, for example, Armstrong *et al.* 1995 and Rice *et al.* 1996 for recent comprehensive reviews). Oil spills can result in mortality (Berdugo *et al.* 1979; Foy 1982; Trudel 1985), shortened life span and total egg production (Berdugo *et al.* 1979), inhibited or modified feeding behaviour (Berman and Heinle 1980) of zooplankton (a common prey species for many fish, birds and mammals). While oil spilled nearshore can become captured in pockets and be affect benthic fauna for years after a spill (Sanders *et al.* 1990; MMS 2001a), oil from a deepwater offshore spill water will not come in contact with the substrate (Husky 2000a).

Both lethal and sublethal effects of kelp beds (and other marine plants) have been observed, and are a primarily a result of surface oil slicks and soil entrapped in the substrate, However, marine plants can recolonize and recover within a few years (Duncan *et al.* 1993 and van Tamelen and Stekoll 1993 in

MMS 2001a). Ironically, the clean-up of an oil spill can often delay the recolonization and recovery of marine plants, as cleaning an area treated with a high-pressure wash could have as large an effect as the oiling itself (Houghton *et al.* 1996 in MMS 2001a).

Invertebrate (e.g., crustaceans such as lobster) eggs and larvae oil sensitivity varies with species, life history stage and oil type and concentration (Husky Oil 2000). Oil exposure may result in reduced feeding and growth rate and increased oxygen consumption in invertebrate larvae (Johns and Pechenik 1980). Fish eggs and larvae are the life stage most sensitive to effects of oil (up to 10 times as sensitive as adults (Moore and Dwyer 1974; MMS 2001a)) as they cannot easily avoid a spill or depurate toxins from their body and develop at or near the surface where exposure to oil is greatest (Rice 1985). Affected eggs and larvae generally exhibit morphological malformations (Kühnhold 1974; Hose *et al.* 1996; Norcross *et al.* 1996), behavioural abnormalities (Kühnhold 1972) genetic damage (Hose *et al.* 1996; Norcross *et al.* 1996; Marty *et al.* 1997) and reduced growth (Marty *et al.* 1997). With respect to pink salmon smolt (Husky Energy 2000a):

> "Ten-day exposure of large numbers of pink salmon smolt (Oncorhynchus gorbuscha) to the water-soluble fraction of crude oil (0.025 to 0.349 ppm) and their subsequent release to the Pacific Ocean did not result in a detectable effect on their survival to maturity compared to non-exposed fish (Birtwell *et al.* 1999). However, it should be noted that pink salmon may be more resistant to environmental disturbance than other species because pink salmon spend more time in the variable estuarine environment."

Adult fish are mobile and any potential effect from an oil spill is dependent on timing and location (Husky Oil 2000). This is especially true of pelagic fish (living within the water column). Benthic fish (living on or just above the seabed) may be at higher risk in shallow waters if oil reaches the sea bottom and becomes entrapped in the substrate. An oil spill can result in lethal (e.g., direct mortality from suffocation due to oil coating the gills or toxicological disruption of physiological processes) and sublethal (long-term physiological and behavioural) effects (Husky Oil 2000; MMS 2001a). Many fish species can detoxify and excrete harmful oil compounds (Koning 1987) and can also excrete oil through gills and in mucous secretions of the skin (Varanasi *et al.* 1978; Thomas and Rice 1981; 1982). However, heavier hydrocarbon fractions can accumulate in fish tissue, resulting in damage to the liver, gut, pancreas, vertebrae, stomach, brain and olfactory organs and physiological changes in heart rate, respiration, blood parameters and ion concentrations (Rice 1985 in Husky Oil 2000). Other physiological effects include reduced growth (Moles and Norcross 1998), increased viral infections (Carls *et al.* 1998) and lesions (Marty *et al.* 1999) (both found in Pacific herring), and changes in fish health (Moles and Norcross 1998). Behavioural changes in fish may include altered schooling behaviour (Gardner 1975), predator avoidance (Pearson *et al.* 1984) and feeding (Christiansen and George 1995). The most likely potential threat to individual salmon in the event of a large offshore oil spill is contact of the oil with migratory pathways (or spawning habitat, but this is unlikely, given that salmon spawn in headwaters of freshwater waterways) (MMS 2001a). To a lesser extent, salmon could also be affected by potential effects to lower trophic levels (*i.e.,* their food source) (MMS 2001a). In addition, while fish can avoid oil-contaminated water, they may choose not to if they need to migrate to a specific area (Husky Oil 2000):

One such study tested whether adult salmon returning to a home stream avoided a contaminated fish ladder and used and uncontaminated ladder instead. Salmon did avoid the contaminated ladder when concentrations of monoaromatic hydrocarbons approached acute toxic levels (Weber *et al.* 1981)

No conclusive evidence exists to suggest that oiled sites (such as the *Exxon Valdez* areas) posed a long-term hazard to fish embryo or larval survival (Kocan *et al.* 1996 in Husky Oil 2000). The *Exxon Valdez* spill did not significantly affect the larval distribution, settlement, fecundity, recruitment and growth of juvenile and subadult crab, pandalid shrimp, clams and scallops (Armstrong *et al.* 1995). A study on prey sources of juvenile salmon in Prince William Sound concluded that the *Exxon Valdez* spill did not reduce the availability of various prey, including zooplankton (Celewycz and Wertheimer 1996 in Husky 2000a).

Fisheries

The direct effect of an oil spill on the fisheries is fouling of fishing gear and vessels. The primary biological effect of an oil spill on the fisheries is the uptake of hydrocarbons into commercial fish species and tainting (or more importantly, the perception of tainting) of fish flesh. Tainting in marine organisms is defined as "a foreign flavour or odour in the organisms induced by conditions in the water to which the organisms are exposed" (GESAMP 1982), and the off-taste is considered a warning sign that degradation/spoilage of tissue is occurring, especially with regard to fish (Höfer 1998a; 1998b). The principal components of oil that cause taint (such as phenols, naphthenic acids, dibenzothiophenes, mercaptans, tetradecanes and methylkated naphthalenes) are water- and lipid-soluble and are, therefore, readily taken in and absorbed into fish tissue. Fish with high fat content (such as herring) are more susceptible to taint than those with a lower fat content (cod and haddock) (Sidwell 1981); shellfish have relatively low lipid content (Ackman 1976). Even if no tainting occurs, the public perception of tainted fish from an area in or near an oil spill can influence the economic stability of a fisheries, and prices and sales can decline dramatically, even if taint tastes indicate tainting had not occurred (Zitko *et al.* 1984; Tidmarsh *et al.* 1986).

Although fish kills have been reported after oil spills and blowouts, a decrease in fishery stocks has never been attributed to these events (Rice, 1985; Armstrong *et al.* 1995 in Husky Oil 2000).

Seabirds

Seabirds are the group most at risk from marine oil spills and blowouts, and can experience immediate, short-term and long-term effects:

- immediate effects include external exposure when a bird lands or a diving bird surfaces or swimming bird swims into an oil slick, resulting in a loss of waterproofing, thermoregulatory capability (hypothermia) and buoyancy (drowning) due to matting of feathers (Clark 1984; Hartung 1995; Weisse 1999; MMS 2001a; Weisse *et al.* 2001);
- short-term effects include ingestion of oil from excessive preening/cleaning (of even slightly oiled feathers (Stout 1993)), resulting in lethal (McEwan and Whitehead 1980; Hughes *et al.* 1990; Khan and Ryan 1991; MMS 2001a) and sublethal (Hartung and Hunt 1966; Lawler *et al.* 1978; Holmes *et al.* 1979; Peakall *et al.* 1980; 1982; MMS 2001a) effects, including starvation due to increased energy needs to compensate for heat loss (Hartung 1967; 1995; McEwan and Koelink 1973);
- long-term effects include
  - transfer of oil from plumage and feet of nesting seabirds to eggs and its affects on embryos and hatching and fledging success (Albers 1977; 1978; Albers and Szaro 1978; Hoffmann 1978; 1979a; 1979b; Leighton *et al.* 1995; Macko and King 1980; Albers and Gay 1982; Parnell *et al.* 1984; Harfenist *et al.* 1990; Stubblefield *et al.* 1995),
  - direct ingestion of oil by breeding seabirds and ducklings can result in decreased fertilization, egg laying and hatching, and chick growth and survival (Hartung 1965; Holmes *et al.* 1978; Miller *et al.* 1978; Peakall *et al.* 1980; Vangilder and Peterle 1980; Ainley *et al.* 1981; Szaro *et al.* 1981; Trivelpiece *et al.* 1984), and
  - indirect reproductive failure due to nest and chick abandonment by patents (Butler *et al.* 1988; Eppley and Rubega 1990).

Opinion is divided on whether oil pollution produces major long-term effects on population dynamics or bird productivity (Clark 1984; Butler *et al.* 1988, Boersma *et al.* 1995 and Wiens 1995 suggest there are no long-term major effects, while Piatt *et al.* 1990 and Walton *et al.* 1997 indicate the opposite). There is no direct relationship between the volume of oil spilled and bird mortality, rather it is the timing and location of spills that influence mortality rates (Weise *et al.* 2001).

Marine Mammals

Marine mammals exhibit avoidance and behavioural effects (cetaceans and pinnipeds) (St. Aubin *et al.* 1985; Harvey and Dahlheim 1994; Lowry *et al.* 1994; Matkin *et al.* 1994; Spraker *et al.* 1994; Smultea and Würsig 1995, MMS 2001a), can experience oiling of external surfaces (especially fur of sea otters and fur seals) (Davis and Anderson 1976; Geraci and Smith 1976; Geraci 1990; Sergeant 1991; Lowry *et al.* 1994; Spraker *et al.* 1994; Williams *et al.* 1994; Levenson and Schusterman 1997; MMS 2001a), can digest and inhale oil (especially from cleaning oiled fur) (Geraci and Smith 1976; Engelhardt *et al.* 1977; Engelhardt 1985; Geraci 1990; Würsig 1990; Spraker *et al.* 1994; Bence and Burns 1995; MMS 2001a), experience fouling of baleen (cetaceans) (St. Aubin *et al.* 1984; Geraci 1990; MMS 2001a) and increased exposure from contaminated haulout sites (pinnipeds) (Boulva and McLaren 1979; Yochem *et al.* 1987).

Migrating grey whales were apparently not adversely affected by the *Santa Barbara* spill (Geraci 1990 in Husky 2000a). A review of various whale populations after the *Exxon Valdez* spill could find no evidence of effects on humpback whales in Prince William Sound (von Siegesar *et al.* 1994), and while there was a significant decrease in the size of a resident killer whale pod, no clear cause and effect relationship between the spill and decline could be established (Dahlheim and Matkin 1994).

Summary

The effects of oil on marine resources was summarized in an Australian study on the effects of exploration activities (URS 2001) and are provided for components relevant to the BC marine environment in Table 6.5.

Table 6.5 Summary of Effects of Oil on Marine Environment

Habitat/Population Type	**Exposure and Type of Effect**	**Sensitivity to Oil and Recovery Rates Following Exposure**
Intertidal Mud and Sand Flats	Areas supporting great variety of marine flora and fauna and often spawning or nursery grounds and fish and bird feeding areas. Susceptible to adverse effects	Dependent on the persistence of pockets of oil and the availability of recolonizing species, recovery rates can range from months to years
Birds (Breeding Areas)	Plumage may become matted with oil and oil may be ingested, resulting in mortalities	Birds are very sensitive and an exposed breeding population would likely be slow o recover
Seals and Sea Lion Haulout and Breeding Areas	While seals and sea lions may be able to avoid small surface slicks, the effect on adults and pups onshore may be severe	Haulout areas very sensitive to oiling, especially during and after pupping
Whales and Dolphins	Ability of whales and dolphins to move out of an affected area may minimize the effect	Unknown at sea, with possible high risk to calves during feeding
Reefs (non-coral)	The effects on associated flora and fauna may be sever if the reef is shallow, however, it is unlikely the oil will persist	Sensitivity dependent upon depth and exposure time to slick
Fish	While pelagic fish could avoid the affected area, mortality, tainting and birth defects could occur. The most sever effects could occur on breeding populations in confined waterways and to benthic life stages of fish and crustaceans that occur in areas of highly polluted substrate	Moderate sensitivity and moderate to rapid recovery rates
Benthic Communities	Species composition, abundance and distribution may be affected (thus potentially disturbing the ecological balance)	Mobile species will avoid a slick, non-mobile species may be more sensitive, however, surrounding areas will provide recruitment to aid recovery

Table 6.5 (Continued) Summary of Effects of Oil on Marine Environment

Habitat/Population Type	Exposure and Type of Effect	Sensitivity to Oil and Recovery Rates Following Exposure
Kelp Beds	It is unlikely that oil will persist on the kelp fronds or penetrate surrounding sediments, however, some contact burning may occur of the kelp is emergent	While intertidal algal beds may experience some damage, they quickly recover
Sandy Beaches	The effect could be severe on feeding and breeding wading birds and intertidal fauna	Recovery is dependent on the time required to clean the sandy beach – pockets oil can persist. Breeding populations affected by the spill can be slow to recover
Rocky Intertidal	Due to the usual conditions found in the rocky intertidal zone, the organisms in this habitat are hardy and probably fairly resistant to damage by oil. Some parts of the habitat could experience suffocation or loss of purchase due to surface slickness)	Doe to the environmental conditions usually found in this habitat, the area usually experiences a fast recovery and rapid recolonization.
Open Water	Surface dwelling/diving mammals and birds could be affected if they surface/div through an oil slick	Diving birds usually become oiled, however, most mammals can avoid open water slicks
Fishing	Fishing activities could be interrupted and their could be a public perception of taint of fish caught in or near an oil spill.	While there may be a public perception of taint, analytical data does not usually support actual contamination of flesh fish Effects usually short term.

Source: after AMOSC 1997 in URS 2001

6.2 Mitigation

The industry standard is to incorporate mitigation measures into the design of a program or development (both standard and project-specific) and can include additions to or changes in equipment, operational procedures, timing of activities or other measures. Mitigation includes environmental design, environmental protection strategies and mitigation specific to a particular component of the environment (e.g., seabirds) (Husky Oil 2000). Environmental protection planning incorporates the project-specific mitigation measures, which are built in to the standard activities. Environmental protection plans for each stage of a development (e.g., drilling, production, decommissioning) are usually a condition of approval (e.g., Terra Nova Decision 97.02 (C-NOPB 1997)) and must be addressed in at least a preliminary form in a DA, usually within the EIS.

Regulatory requirements also provide direction on the types of mitigation that can be incorporated into routine activities. For example, the following regulatory tools also enable the effects of drill cuttings and produced water discharge to the environment to be minimized:

- all chemicals which would be discharged into the offshore environment must undergo a screening process and be approved under the Offshore Chemical Selection Guidelines;

- use of low toxicity WBMs and SBMs during drilling;
- compliance with the Offshore Waste Treatment Guidelines (NEB, C-NOPB and C-NSOPB 1996);
- all projects must operate under permits, many of which have specific requirements for environmental compliance monitoring; and
- projects must undertake an environmental effects monitoring program (as discussed in Section 6.4) to provide feedback on potential environmental changes which have occurred since the onset of the development (including drilling).

Mitigation activities that may be incorporated into the routine activities of a project may include (Petro-Canada 1995; SOEP 1997; Husky Oil 2000):

- no blasting during underwater construction;
- recycling drill muds and returning muds to shore when no longer useful;
- treating drill cuttings and produced water (as per the Offshore Waste Treatment Guidelines) prior to discharge and/or re-injecting drill cuttings and produced water;
- treating other discharges such as deck drainage and ballast water (as per the Offshore Waste Treatment Guidelines) prior to discharge;
- having a waste management plan in place;
- having contingency plans in place for accidental events (such as oil spills)
- providing training, maintaining clean-up equipment inventory and practicing prevention (*i.e.,* "zero tolerance") to mitigate against an accidental event (oil spill);
- designing equipment to reduce the amount of fugitive atmospheric emissions;
- releasing stranded birds which may have been attracted to a platform;
- avoiding seabird colonies and concentrations of marine mammals during vessel transport;
- avoiding colonies and repeated overflights of bird concentrations during helicopter transport;
- maintaining steady course and vessel speed when possible;
- flying helicopters at minimum altitude of 600 m whenever possible; and
- removal of subsea equipment at abandonment.

The C-NSOPB has provided direction for mitigation and operating procedures for seismic activity during the exploration phase. In 1998, the C-NSOPB required that the following operating conditions be met to mitigate potential adverse environmental effects (C-NSOPB 1998):

- proponents must "ramp-up" the noise of the airgun array to warn marine mammals and to allow them to take evasive action before being exposed to the full array;
- proponents will avoid undertaking seismic operations in the DFO whale sanctuary on the Roseway Basin, from July through November, to avoid disturbance to the endangered northern right whale;
- proponents will not be permitted to undertake operations in the Gully, throughout the 1998 seismic

season, to allow the DFO and others time to develop a Gully Conservation Strategy;

- scheduling of seismic activities should be addressed, to the fullest extent possible, to minimize potential disturbance of vulnerable ecological resources as identified in the LGL class screening report;
- proponents must ensure, to the fullest extent practical, that oily and other liquid wastes are not discharged from the seismic vessel. Discharges of solid waste or persistent litter will not be permitted. Any spills of oil or other hazardous substances should be reported immediately to the C-NSOPB and the Canadian Coast Guard;
- proponents are encouraged to consult with the fishing industry to mitigate against any potential conflicts at sea with commercial fishing operations;
- to provide effective liaison with fishermen who may be in the vicinity of seismic programs, seismic operators are to include a qualified fisheries liaison observer, who ideally is also experienced in observing marine mammals and seabirds. The observer would meet with appropriate fisheries groups prior to commencing the seismic program, and would be onboard to further reduce the likelihood of conflicts at sea. The Seafood Producers Association of Nova Scotia (SPANS) can be contacted to arrange for a qualified observer. This requirement was to be reviewed after the 1998 season; and
- proponents should be aware of improvements in seismic technology, which may be requested by the C-NSOPB for future seismic exploration programs particularly in, or adjacent to, sensitive areas.

The current status of these mitigations/conditions is not known.

6.3 Environmental Management Systems

Many oil and gas companies (in fact, most industries) have adopted environmental management systems (EMS), which provide a policy driven down from the top leadership in a company (*i.e.,* endorsed by the Chief Executive Officer). An EMS policy (plus the programs and procedures that support it) assists a company to provide due diligence and responsibility in its stewardship of health, safety and the environment. Many EMS comply with the requirements of the ISO 14001 standard "Environmental Management Systems - Specifications with Guidance for Use".

An Environmental Management System (which has as its precursor environmental management plans, which are now components of an EMS) can include the following components (which are often a condition of project approval (C-NOPB 1997)):

- an environmental effects monitoring program (see Section 6.4);
- an environmental compliance plan (Section 6.3);
- a waste management plan (Section 6.3);
- a fishing industry agreements and compensation procedures plan;
- a chemical management plan (Section 6.3);

- phase-specific environmental protection plans; and
- a contingency plan for environmental emergencies (Section 6.3).

These plans are often controlled documents within corporate structure (*i.e.,* numbered documents are provided to specific responsible individuals and updated with clearly identified revisions). Examples within the Canadian oil and gas industry include Total Loss Management (TLM) National Standards (Petro-Canada 1997), and Health, Safety and Environment (HS&E) Loss Control Management Performance Standards (Husky Oil 1998). These systems are discussed as examples only.

The TLM National Standards (Petro-Canada 1997) state that TLM is "a method of efficiently grouping several functional management areas to help protect People, Facilities, Third Parties and the Environment". The National Standards address a wide range of corporate risk management issues, including those relating directly to environmental management. The National Standards include four areas to be managed, supported by six common elements.

The management areas are:

- health and safety and security;
- equipment integrity and reliability;
- contractor management; and
- environmental management.

The supporting common elements are:

- leadership;
- employee competency;
- audits and inspections;
- external relations;
- emergency preparedness; and
- event management.

The HS&E Loss Control Management Performance Standards (Husky Oil 1998 in Husky 2000) states that adherence to the standards will assist in meeting the following objectives (Husky Oil 2000):

- keeping Husky and contractor employees free from harm;
- ensuring that project facilities and operations are run in a manner that demonstrates to Husky employees, neighbours, regulators and the general public Husky's commitment to HS&E stewardship;
- managing the effects of Husky activities on the environment and the liabilities associated with those potential effects;

- managing risk to protect Husky from loss;
- ensuring clear expectations and appropriate consistency in the Husky's Loss Control Management program; and
- facilitating consistent company-wide application of the Husky Loss Control Management program.

6.4 Environmental Effects Monitoring

6.4.1 Program Design and Implementation

Environmental effects monitoring (EEM) has been a condition of project approval for all Atlantic Canada developments, and is conducted as a matter of routine in many other jurisdictions (see, for example, the Hibernia and Terra Nova Decision Reports (C-NOPB 1986; 1990; 1997)). The EEM programs used in Atlantic Canada are based on the design and experience of other jurisdictions, such as the North Sea and Gulf of Mexico. EEM is conducted to:

- test effects predictions made during the assessment process;
- assess the effectiveness of implemented mitigation; assess the status of the marine environment;
- detect changes in the marine environment; and
- provide an early warning of any undesirable change resulting from the effects of a development on the environment.

Prior to conducting an EEM program, a survey is usually conducted to establish a baseline against which future results may be compared. The goal of the design of a baseline program is to provide a foundation upon which to structure and design the future EEM programs. A design report is usually developed for the baseline survey and provided to regulatory agencies for comment (usually via a lead agency and including review and comment from supporting agencies, for example, the C-NOPB/C-NSOPB takes the lead in Atlantic Canada, with DFO and Environment Canada providing comment on the document).

A baseline survey usually covers a wide geographic area and is designed to incorporate as many potential future design changes as possible (e.g., change in glory hole location). It also includes at least one (but preferably two) reference areas. The reference areas should have the same type of substrate and community structures as in the immediate vicinity of the development, but be far enough away to avoid any influence from existing and future developments (usually a minimum of 20 km 'downstream' of the proposed development). Given the study requirements (*i.e.,* equipment), the biological and biophysical (*i.e.,* sediment) surveys are usually conducted separately. It is important that the biological cruise be conducted when the target monitoring species can be easily collected. Future survey cruises should be conducted during the same time period in successive years.

Prior to the onset of an EEM program, the EEM program is built on the baseline design and based on the final project design. Current Atlantic Canada EEMs are based on a radial design using the platform as the centre of the radial. Additional smaller redial components may be incorporated for those developments with more than one discharge point source (e.g., FPSO and drill centres), or the design may try to incorporate the drill centres along a radial arm. The EEM design is then made available to the regulatory agencies and the public (usually transmitted via open houses) for review and comment. Theoretically, the C-NOPB/C-NSOPB provides approval of the EEM design prior to the onset of the EEM program; however, that is not always the case, and an EEM program may proceed without that approval.

EEM is usually conducted during site development (*i.e.,* drilling) and during production, the timing of which is usually set by the regulatory agency. EEM programs are usually conducted annually for the first three years of production (Years One to Three), then regularly at a longer interval as agreed to with the C-NOPB/C-NSOPB (usually Years Five, Seven and Ten of production). There may also be a requirement for a post-production/abandonment EEM program.

6.4.2 Results of Atlantic Canada EEM Programs

At present, no Atlantic Canada EEM reports are publicly available. Results of baseline surveys of some of the programs were presented at a workshop held in 2000 and co-sponsored by the Sable Offshore Energy Environmental Effects Monitoring Advisory Group (SEEMAG) and the Bedford Institute of Oceanography. These are summarized here by program (Gordon *et al.* 2000):

- A seven-year mussel study essentially showed that taint and hydrocarbon uptake did occur in mussels at the Cohasset site (a decommissioned site), with the majority of effects limited to within 500 m of the discharges and hydrocarbon levels quickly returned to background when discharges ended (MacNeil and Full in Gordon *et al.* 2000).
- To date, Hibernia's operational discharges have not resulted in any major or minor effects outside of a predicted 500 m exclusion zone and hydrocarbons in the sediments decrease to background within 1,000 m from the platform (metals remained at baseline values or below their limits of quantitation) (Taylor in Gordon *et al.* 2001).
- The Sable EEM found visible drill cuttings piles within 70 m of the discharge pipe and elevated levels of total petroleum hydrocarbons and barium (a component of drill muds) were short-lived and generally found between 250 and 500 m from the platforms; dispersion or burial appeared to occur with six months. No taint was detected in sensory evaluations (Hurley in Gordon *et al.* 2000).
- Years One and Two EEM surveys were conducted for the Terra Nova EEM program in 200 and 2001, respectively; results are not yet available (Williams and Murdoch in Gordon *et al.* 2001).

It should be noted that the results of the Atlantic Canada EEM programs (which confirmed the effects predictions, which indicated effects would be within 500 m of the platforms) are similar to results from studies in other jurisdictions. For example, a review of environmental effects of exploration activities in Australia found that while "discharge of drill cuttings and associated fluids does have an effect on the character of the benthos and sediments, the effects are limited in extent to 100 to 200 m down current from the discharge point and the effects are not permanent, with recovery of the benthic character occurring within 6 to 12 months after the cessation of drilling" (URS 2001).

6.5 Cumulative Effects

Consideration of cumulative effects of proposed developments has become increasingly important in recent years. Federal legislation in Canada, the US, the UK, and other jurisdictions requires that cumulative effects be assessed prior to projects proceeding. Methods to assess cumulative effects have been developed and it is standard practice to assess cumulative effects of offshore oil and gas developments in Canada and the US, along with the standard project-specific effects.

The assessment of cumulative effects, or those effects that may result from several projects or activities in a defined geographic region over a defined period of time, is current standard practice for projects subject to *CEAA* (Section 16), and/or the British Columbia *Environmental Assessment Act* (Section 22 (j)). Subsection 16(1)(a) of *CEAA* requires that every environmental assessment must consider any cumulative environmental effects that are "*likely to result from the project in combination with other projects or activities that have been or will be carried out.*"

Methodological approaches and guidance have been developed by the Canadian Environmental Assessment Agency (the "CEA Agency"), and include the:

- *Responsible Authority's Guide* (CEA Agency 1994a);
- *Reference Guide for Addressing Cumulative Environmental Effects* (CEA Agency 1994b); and
- *Cumulative Effects Assessment Practitioners Guide* (Hegmann *et al.* 1999)

In conducting environmental assessment, proponents and practitioners must consider the likely cumulative effects of the project being assessed in combination with other projects or activities that have been or will be carried out. The guidance publications recommend a general methodological framework to assess cumulative effects:

- scoping;
- analysis of effects;
- identification of mitigation;
- evaluation of significance; and
- follow-up.

It is also standard practice in the United States to assess cumulative effects of offshore oil and gas projects pursuant to the *National Environmental Policy Act* and the Council on Environmental Quality's (CEQ) implementation regulations. There is provision in the United Kingdom, pursuant to the *Offshore Petroleum Production and Pipe-Lines (Assessment of Environmental Effects) Regulations*, SI No. 360, and in accordance with the UK's Environmental Statement/Pon 15 system, for cumulative effects to be considered in an environmental assessment.

6.5.1 Canadian East Coast Experience

6.5.1.1 Exploration Phase

Class Environmental Assessment for Seismic Exploration

The C-NSOPB conducted a Class Environmental Assessment for Seismic Exploration in the Scotian Shelf (C-NSOPB 1998). The intent of a class screening is to evaluate the potential environmental effects of a group of projects that are not expected to result in significant adverse environmental effects. Seismic exploration is generally transitory and does not introduce chemical contaminants into the marine environment. Therefore, the potential residual effects from seismic operations on the Scotian Shelf were considered to be insignificant provided appropriate mitigation measures are implemented (C-NOSPB 1998). The one caveat is the potential for significant cumulative effects if exploration eventually leads to several development proposals on the Scotian Shelf. The report indicated these potential cumulative effects should be addressed in more detail during the assessment of future development plan applications. The Class Environmental assessment used existing information and the C-NSOPB made the following conclusions (C-NSOPB 1998):

- the potential for adverse cumulative effects to occur, if effects threshold are exceeded, must be recognized;
- the effects thresholds have not been determined;
- cumulative effects are difficult to evaluate due to the speculative nature of offshore petroleum exploration;
- in addition to other documented activities, the C-NSOPB felt that cumulative effects could also result from: long-range atmospheric transport of contaminants, contaminant input from rivers and coastal land-based sources, the effect of fossil fuels on global warming, and growth-inducing potential of the identification of promising petroleum resource;
- authorization requests for future exploration activities must include an overview of potential cumulative effects. Development applications must be prepared to include a thorough evaluation of the potential cumulative effects of the project in question, in conjunction with past, present and reasonably foreseeable projects and stresses to the marine environment;
- the C-NSOPB recommended that a research proposal be developed, with potential funding from the Environmental Studies Research Fund (ESRF) to examine the effects of seismic shooting on larger toothed whales such as sperm and northern bottlenose whales, and on the commercial herring fishery; and
- the C-NSOPB recommended that effects thresholds be developed for important ecological indicators on the Scotian Shelf. Indicators could range from contaminant concentrations in water and

sediments to populations of endangered or threatened cetaceans on the Scotian Shelf.

Generic Environmental Assessment of Exploration Drilling off Nova Scotia

In 2000, the C-NSOPB and C-NOPB commissioned a generic environmental assessment for offshore exploration on the Scotian Shelf and the St. Pierre Bank (LGL 2000). The effects, including cumulative effects, of a typical exploration program (geophysical surveys, exploration drilling, well testing, delineation drilling), in combination with fishing, shipping, the Sable Offshore Energy Project (SOEP), and future projects, were assessed. The study focussed on the following Valued Environmental Components (VECs):

- fish larvae;
- fish and invertebrates;
- fisheries;
- marine mammals;
- marine birds;
- sea turtles; and
- special areas, including
  - fish nursery areas,
  - The Gully,
  - right whale habitat, and
  - Sable Island.

Potential cumulative effects were identified as:

- Noise and Disturbance - The study concluded that the incremental noise of supply vessels and drilling rigs "would not add significantly to existing ambient noise levels in the study area" (LGL 2000). Although noise from activities at several exploration wells would increase the number of site-specific areas exposed to increased noise levels, "…they would not add significantly to the overall noise on a regional level" (LGL 2000). Mitigative measures included the avoidance of seabird colonies, seal haul-out areas and whale sanctuaries by vessels and aircraft.
- Operational Discharges of Oil - The study concluded that operational discharges of oil from exploration activities would be negligible and would not add significantly to the current input of oil from other discharges (e.g., ships, river run-off, atmospheric deposition and natural seeps).
- Disruption of the Benthos - The study concluded that, although drilling operations would cause some disruption of the benthos through smothering with mud and cuttings and through effects of water-based muds to distances of a few hundred metres from the drill site, the small areas that would be affected would result "…in very small increases in the amount of bottom perturbations that already exists" due to trawling or dredging activities of commercial fishing vessels (LGL 2000). The study also concluded that there may be some minor, sub-lethal effects on deep-sea corals, but there would

unlikely be mortality because the drilling mud is well dispersed by the time it reaches the sea floor.

- Garbage and Waste Materials - Garbage and waste materials will not be discharged to the marine environment, and therefore will not contribute to cumulative effects.
- Accidental Spills of Oil - The study examined potential cumulative effects of a blowout. The study concluded that in the unlikely event of a blowout, the effects would be limited to offshore waters, and that among the VECs, birds would be the most likely to be affected, although significant effects to seabird populations would not occur. Other activities currently occurring that result in seabird mortalities include operational discharges from ships, nearshore spills, capture in fishing gear, and hunting.

6.5.1.2 Development Phase

Cumulative effects of the production phase have been assessed for numerous developments and are contained in environmental assessment documents. With the exception of the Hibernia Oilfield EIS, which was completed in 1985, the environmental assessments of offshore oil and gas developments on Canada's East Coast have included consideration of cumulative effects. Cumulative effects have been assessed for: other oil and gas projects (including future projects); oil spills; commercial fishing; commercial shipping; climactic change; exploration activity; and marine bird hunting on: water quality; benthos; fish; fisheries; fish habitat; marine mammals; seabirds; and sea turtles.

The Sable Offshore Energy Project and the Maritimes and Northeast Pipeline Project (M&NP)

A Joint Public Review Panel was struck to review the two projects together (Sable Gas Projects Panel 1997). SOEP evaluated cumulative effects that could result from the project in combination with commercial fisheries, other oil and gas development (*i.e.,* Cohasset-Panuke), vessel traffic, aquaculture facilities (pipeline construction in the near shore area), industrial discharges, other industrial air emissions, and timber harvesting (on-land pipeline construction). Issues raised during the review focussed on the scope of activities that were assessed, with intervenors recommending that future potential developments on the Scotian Shelf be included and assessed. The Panel accepted SOEP's cumulative effects analysis (*i.e.,* not significant cumulative impacts, localized and controllable cumulative impacts), in consideration of the commitment to monitor environmental effects and to apply appropriate mitigations.

The M&NP project is an on-land pipeline and associated facilities for transporting natural gas product from the SOEP. The M&NP EIS assessed cumulative effects for numerous on-land VECs, focussing on: air quality, wildlife habitat, wildlife and freshwater fish. Other projects or activities that were considered included: timber harvesting, mining, roads and agriculture. The Panel accepted M&NP's cumulative effects analysis (*i.e.,* the Project is not likely to result in significant adverse cumulative environmental effects), in consideration of the commitment to monitor environmental effects and to apply appropriate mitigations.

Georges Bank Review Panel Report (NRCan and NSPD 1999)

In 1996, a three-member independent Panel was appointed to conduct a public review of potential environmental and socio-economic effects of exploration and drilling on the Canadian side of the Georges Bank. Public meetings, information sessions, community workshops and hearings were held in 1996, 1997, 1998 and 1999 respectively. An Environmental Impact Statement was not prepared for the hearings or meetings (thus, there was no definition of significance to apply to the participants description of potential "significant effects" that could result from ending the moratorium on Georges Bank). The report notes that, as a result, cumulative impacts were not discussed systematically. Participants included representatives of the fisheries sector, the petroleum industry, environmental groups, government departments and agencies, business organizations and companies, elected officials, scientists, consultants, academics and interested citizens. The cumulative effects resulting from the effects of exploration and drilling over a three to four year period and cumulative effects over a longer time scale were both examined. Different points of view were heard by the Panel, from those expressed by a representative of a petroleum company**,** who indicated that contaminants from one to three exploratory wells would be rapidly dispersed and would probably not overlap in time or space**,** to views of Environment Canada**,** who indicated that migrating seabirds would encounter offshore petroleum installations on Georges Bank, Sable Island Bank, and Grand Bank, with "…each constituting a separate and definite hazard". The report noted that some participants were concerned with other potential cumulative effects that could result from exploration activities in combination with fishing operations, marine traffic and land-based marine pollution. Some participants also noted concern with the potential adverse effects to fish stocks and Northern right whale. Some participants noted concerns with longer-term cumulative effects**,** including bioaccumulation of contaminants, formation and produced water, transportation of hydrocarbons by tanker or pipeline, greenhouse gas emissions, and natural gas and environmental illness. The Panel commented that "In the absence of any specific project proposal, precise quantification of impacts…would necessarily be theoretical or speculative". However, they continue: "…the review of cumulative impacts from exploration does include the possibility of development and production, and these cumulative effects in total could be much more significant than impacts from the initial stages of seismic and exploration drilling". The Panel concluded that "Cumulative effects of exploration include field development and production, which, should these occur, could have significant impacts on the biota and fisheries of Georges" (Note: "significant impact" is not described or defined in the report.)

The Terra Nova Development Project (Petro-Canada 1996)

The EIS concluded that the cumulative effects of development activities within the proposed project would result in minor (not significant) effects to water quality and benthos, minor (not significant) local effects to marine mammals (negligible effects to populations) due to noise, and negligible effects due to oily water discharges. The report concluded that the effects resulting from routine operations would be neither additive nor cumulative, and that effects resulting from oil spills would not be cumulative. The cumulative effects resulting from shipping associated with the project were assessed to be negligible. Although there is some discussion in the EIS with respect to cumulative effects to fish and the fishery, conclusions regarding the significance of such effects are not presented.

The Terra Nova Environmental Assessment Panel released its Report in August 1997, followed by the C-NOPB's Decision Document (C-NOPB 1997). The Panel acknowledged both the importance and challenges of conducting cumulative effects assessment, and made the following recommendations:

- a workshop be convened by the C-NOPB to examine the potential for cumulative effects associated with offshore petroleum development activities, and to develop approaches to monitor them;
- the C-NOPB identify factors necessary for monitoring cumulative effects, and design a plan for implementing a monitoring program;
- future EIS's be required explicitly to incorporate cumulative effects into consideration; and
- the cumulative effects workshop include a discussion of criteria for determining "significance".

The C-NOPB's Decision Document (C-NOPB 1997) acknowledges the importance and challenges of conducting cumulative effects assessment and accepted the recommendation to convene a Workshop. It also noted that the legislative requirement to include consideration of cumulative effects in any future EIS already exists. In its decision, the C-NOPB attached 23 conditions to Petro-Canada's Development Permit. Condition 23 relates to EEM and states (C-NOPB 1997):

> *(i)* *The Proponent submits its Environmental Effects Monitoring (EEM) program respecting the drilling and production phases of the Terra Nova project prior to commencing drilling operations*
>
> *(ii)* *The Proponent provide, during the design of its environmental effects monitoring program, opportunity for the general public to obtain input into, and review, the design.*

The Cumulative Effects Workshop which the Panel recommended and the C-NOPB accepted, was convened in May 2000.

White Rose Oilfield Development

The EIS assessed cumulative effects of project activities in combination with: other oil and gas projects, oil and gas exploration activities, commercial fishing, marine shipping and hunting activity (of marine birds) on fish and fish habitat, marine birds, marine mammals and sea turtles.

Issues such as discharge of oily drill cuttings, produced water, vessel noise, no fishing zone, the commercial fishery and marine transportation were assessed for fish and fish habitat. It was concluded that no effects or not significant cumulative effects would result to fish and fish habitat from routine operations in combination with other projects and activities. The cumulative effects of the White Rose Project in combination with hunting (seabirds) and the commercial fishery on marine birds was determined to be not significant; the cumulative effects of the White Rose Project in combination with vessel traffic on marine mammals was assessed to be not significant. The EIS indicates that Husky Oil (the Proponent for White Rose) was in consultation with other oil and gas operators on the Grand Banks to develop a regional EEM program.

The Commissioner's Report was released on September 26, 2001. The Report recommended that the C-NOPB and DFO work together to establish a regional/cumulative EEM program.

Strategic Environmental Assessment

The C-NSOPB prepared a Strategic Environmental Assessment (SEA), providing a draft for public comment in October of 2000 (C-NSOPB 2000). This report addresses potential cumulative effects of all phases of petroleum production, including exploration.

Although there are many unknowns, it was acknowledged that increased petroleum activity (also in combination with other users of the offshore) would result in greater stress to the marine environment. It was suggested that cumulative effects of increased activities on the Scotian Shelf and Slope, as well as the lack of baseline information, could be addressed either under initiatives under the *Oceans Act* or under funding sources such as the ESRF. It was recommended that ambient targets and thresholds for evaluating the potential significance of cumulative effects be developed, and these ambient criteria be used to identify trends in the total stress burden on marine ecosystems of the Scotian Shelf and slope.

It was noted that the DFO is planning to develop an integrated management plan for the eastern Scotian Shelf, and is in the early stages of identifying areas which may be considered as candidate marine protected areas.

With respect to the exploration phase, the C-NSOPB has a minimum six-week rule for proponents to communicate with fishers, and the placement of observers on seismic vessels to help minimize gear conflicts.

The SEA Report determined that "…cumulative impacts are a particular concern where they may encroach on identified valued areas, such as the Gully and Sable Island". The Gully Science Review found that available evidence suggested the Gully/Sable Island area is the most important habitat for both cetaceans and pinnipeds on the Scotian Shelf (Harrison and Fenton 1998). Increasing exploration and development in that vicinity, even if it does not directly encroach on Sable Island or the Gully, could have repercussions for the fauna that use the Gully and Sable Island area".

6.5.1.3 Overview of Cumulative Effects Workshop

In response to the Terra Nova Environmental Assessment Panel recommendation on the need to address cumulative effects of offshore oil and gas development, a workshop was held in May 2000 on Cumulative Environmental Effects Assessment and Monitoring on the Grand Banks and Scotian Shelf (Hatch and Griffiths Muecke 2000). Over sixty oil and gas industry, fishing industry, government, academic and non-government organization representatives attended. Several issues pertinent to cumulative effects assessment and monitoring were considered; the main conclusions of the workshop are outlined below.

Acceptable Approaches to Cumulative Effects Assessment and Management in the Offshore

- Long-term financial and human resources need to be dedicated to assess cumulative effects.
- A collaborative approach to monitoring cumulative effects should be established, headed up by DFO, or an independent body funded by government and oil and gas companies.
- A multi-stakeholder group should be organized to monitor cumulative effects.
- Cumulative effects should be managed through:
- Establishing marine protected areas and codes of practice;
- Improving fishing practices;
- Identifying traffic and safety zones; and
- Developing integrated management plans to manage seabed footprint changes.

Likelihood of Cumulative Effects

- Uncertainty should be acknowledged.
- Likelihood of impacts may be reduced through improved technology and regulatory regimes.
- Information from EEM should be integrated into resource management decisions and future impact predictions.

Spatial and Temporal Boundaries

- The appropriate selection of spatial and temporal boundaries is critical to determine cumulative effects.

Factors Necessary for Monitoring Potential Effects

- Cumulative effects monitoring should consider: the benthic environment; fish, eggs, and larvae; seabirds; marine mammals; and fisheries.
- The design of a cumulative EEM program should consider effects resulting from: contaminant loading; habitat change; habitat alienation; habitat fragmentation; and direct mortality.

Scientifically Credible Means of Determining "Significance" of Environmental Effects

- Significance of cumulative effects is difficult to determine.
- There are many species for which thresholds are unknown.
- A better knowledge of the duration and recovery time of cumulative effects is required.

Means by which Potential Cumulative Effects may be Monitored

- A consensus-driven approach was recommended.
- A monitoring program should build on existing knowledge.
- Long term reference stations should be established.
- Clear questions or hypotheses should be established.

The Way Forward

Generally, the workshop participants agreed that regional, cumulative effects monitoring is required on the Grand Banks and Scotian Shelf and that a multi-stakeholder body should be established to guide the development of a regional EEM program. It was also noted that communication is essential among all parties and that a sustained effort is required to move cumulative effects assessment forward on a sustained basis.

The central recommendation from the workshop was:

> *That, as soon as possible, C-NOPB and/or ESRF should write to DFO to a) convey the conclusion of the workshop, and b) request that DFO take the lead in convening one or more follow-up meetings involving representatives from all relevant stakeholder groups to discuss how cumulative effects assessment should be pursued on a regional basis.*

Current Status

To date, a regional effects monitoring program has not been established on the Grand Banks or Scotian Shelf.

6.5.2 American Experience

Cumulative effects have also been assessed by the Minerals Management Service (US Department of the Interior) for offshore oil and gas activities in American waters (Gulf of Mexico, Pacific Region, Alaskan Region, and Atlantic Region) (MMS 1997b; 2000; 2001a; 2001b).

Generally, cumulative effects are assessed for any offshore oil and gas project in US Federal waters; at least one environmental assessment report considers cumulative effects to be a major issue (MMS 2001a). Consistent with the Canadian experience, cumulative effects are assessed for the project under consideration, in combination with other past, present and reasonably foreseeable projects that may occur concurrently in space or time (MMS 2000).

Cumulative effects of oil and gas exploration/development proposals, in combination with other activities such as on-going oil and gas activities, commercial fishing, marine shipping and tankering, coastal development, recreational fishing, and fibre cable installation have been assessed on environmental components such as air quality, water quality, benthic substrate, marine mammals, fish, threatened and endangered species, and protected areas. Several recent cumulative effects assessments for offshore oil and gas exploration/developments in US Federal waters are summarized in Appendix 8.

The MMS of the US Department of the Interior reported results from cumulative effects studies in the Gulf of Mexico Region, Pacific Region, Alaska Region, and Atlantic Region from 1992 to 1994 (MMS 1997). For the most part, the reported studies appear to investigate project-specific and site-specific effects, rather than regional, area-wide effects. However, the results are summarized here for reference. The report concludes that Outer Continental Shelf (OCS) activities (over 850 exploratory wells drilled; over 1,200 development wells drilled; over 1 billion barrels of crude oil and condensate produced; nearly 14 trillion cubic feet produced; approximately 681,000 short tons of salt produced; nearly 5.4 million short tons of sulfur produced; 367 OCS platforms installed; over 2,000 line miles of pipeline installed; 392 platforms removed; less than 7,425 barrels of crude oil and condensate spilled) caused only temporary, localized effects on most of the resources that were studied. The cumulative effects identified in the Gulf of Mexico Region were wetland loss, social effects and economic effects. Local onshore impacts were identified in the Pacific Region and social, cultural and subsistence effects were identified in the Alaska Region and Atlantic Region (MMS 1997). This summary of that report focuses on biophysical effects.

6.5.2.1 Gulf of Mexico Region

OCS Activities – 1992 to 1994

- 850 exploratory wells drilled;
- 1,197 production wells drilled;
- 363 OCS platforms installed;
- 391 OCS platforms removed;
- 2,040 miles of OCS pipeline installed; and
- 77 small OCS spills (1 to 999 barrels) resulted in a total oil spillage of 1,001 barrels and two large pipeline spills (1,000 barrels or more) resulted in a total oil spillage of 6,533 barrels.

Air Quality

Air emissions from routine OCS oil and natural gas operations, including nitrogen oxides, volatile organic compounds, sulfur dioxide, particulate matter and carbon monoxide are routinely monitored. The potential impacts of OCS-related emissions on ozone were also studied. It was found that the contribution of OCS-emission sources was less than 0.002 ppm during modelled exceedances of ozone concentrations in Houston/Galveston and Beaumont/Port Arthur, Texas. The MMS were in consultation with the EPA in 1997 to determine if existing regulatory requirements for OCS emission sources were adequate to prevent adverse effects on ozone non-attainment areas. Studies were also conducted on effects of OCS-emission sources on the Breton National Wildlife Refuge.

Drilling Discharges

A three-phase study was initiated in 1992 to investigate the biological communities, chemical contamination and biochemical responses of resident biota beneath three OCS platforms in the northwestern Gulf of Mexico. The study found:

- the platforms had little effect on the seawater that flowed past them;
- sediment texture was observed to be enriched with sand close to the platform. This sand appeared to be related to cuttings disposal;
- inorganic carbon generally increased near the platforms;
- no significant bioaccumulation of hydrocarbons was observed in invertebrates or in fish livers or stomachs for those organisms residing near the platforms;
- no significant bioaccumulation of metals in invertebrates or fish was associated with proximity to the platform;
- pore water within 100 m of the platform was found to be significantly toxic to test organisms. Toxicity appeared to be related to higher levels of metals;
- the abundance of meiofauna (e.g., copepods and nematodes) was consistently lower near platforms;
- macroinfauna abundance and species numbers (especially polychaetes) were greatest within 100 m of the platforms. The abundance and types of amphipods and foraminifera were lower near platforms;
- few observed effects on megafauna (e.g., crabs, shrimp, fish) could be directly attributed to proximity to platforms or contaminant exposure; and
- no discernible differences in enzyme activities were found in sampled fish.

Oil Spills

There were a total of 77 small and two large (greater than 1,000 barrels) OCS spills reported in the Gulf of Mexico from 1992 to 1994. Neither of the two large oil spills resulted in significant effects. Although one spill contacted shore, the effects were minimal. The other spill dissipated before it contacted land.

Chemosynthetic Communities

Effects to chemosynthtic communities are not significant, as drilling operations are not permitted in areas known to support chemosynthetic communities.

Removal of Structures

The primary issue associated with the removal of platforms is the potential injury to marine animals, particularly sea turtles or dolphins, due to explosives detonation. The enforcement of several mitigation measures has resulted in minimal effects to these animals.

Coastal Wetlands

The effects of constructed canals on coastal wetlands were studied; results varied from no impact to "diminished habitat function".

The effects of two separately occurring oil spills on marshes in Louisiana were monitored. The effects of a 300 barrel spill of crude oil in 1985 indicated that:

- a relatively low dosage of crude oil spilled into a coastal brackish marsh can have considerable negative short-term impact on marsh vegetation;
- vegetation in the study area appeared to fully recover within five years after the spill;
- the health of the recolonizing vegetation in oiled plots was found not to be significantly different than that measured in control plots;
- although the spill had a significant short-term impact on the marsh vegetation, analysis revealed that land loss rates in the oil-impacted marsh were consistent with other periods in the past; and
- in many cases, sediment addition, followed by planting or natural colonization, may greatly improve the long-term vegetative recovery success of oil-impacted marshes.

A 2,000-barrel spill occurred in 1992 during Hurricane Andrew. In this instance, natural processes were relied upon for recovery because bringing in additional clean-up equipment would have caused more damage to the marsh. Observers noted in overflights of the area in 1997 that "the marshes appeared healthy and that there were no long-term effects from the oil spill".

Studies were also conducted on the disposal of Normally Occurring Radioactive Material and marine debris on beaches.

6.5.2.2 Pacific Region

OCS Activities 1992-1994

- 50 development wells drilled;
- two production platforms brought online;
- one OCS structure removed; and
- 172 barrels of OCS crude oil and condensate spilled.

Air Quality

Air emissions from routine OCS oil and natural gas operations, including nitrogen oxides, volatile organic compounds, sulfur dioxide, particulate matter and carbon monoxide are routinely monitored. Air quality monitoring studies in the 1980's indicated that OCS emission sources contribute to ambient ozone levels in Santa Barbara and Ventura Counties. OCS emissions were compared to emissions in adjacent onshore jurisdictions; the OCS emissions were equal to approximately 8 and 2 percent, respectively, of the combined N0x and VOC emissions from Santa Barabara and Ventura Counties. They were equal to approximately 1 and 0.2 percent, respectively, of the total NO_X and VOC emissions from the South Coast Air Quality Management District. Pacific Region OCS operators installed various types of pollution control technologies and emission reduction measures to comply with new regulatory standards in the early 1990s.

Oil Spills

There were a total of 92 OCS spills reported in the Pacific Region from 1992 to 1994, including three that were greater than 1 barrel. There were no reports of adverse impacts from these spills, and no reports of oil-contacted marine animals (e.g., mammals, birds).

Drilling Discharges

A three-phase study was initiated in the 1980s to investigate the long-term cumulative effect of offshore drilling and production activities on the marine environment. In summary the study found:

- barium concentrations in bottom sediments increased up to 40 percent during periods of drilling;
- barium concentrations in suspended particulates increased up to 300 percent during periods of drilling;
- these increases were attributed to contributions of barite associated with drilling muds;
- over time, the levels of barium decreased to background levels in suspended particulates;
- over time, the levels of barium in bottom sediments decreased to slightly elevated over background levels due to the presence of residual barite particles.;

- decreased abundances for 4 of the 22 taxa surveyed were recorded (timing was not indicated). The study concluded the decreases were likely due to disruption of feeding, respiration and/or postlarval survivorship due to burial rather than responses to toxicity; and
- Phase III results (1991-1992) indicated:
  - there were no obvious residual effects on hard-bottom communities,
  - concentrations of chemical contaminants were at or near background concentrations for all those analyzed with the exception of a small residual amount of barium,
  - there were no residual impacts on the four taxa that had decreased abundances during Phase II, and
  - surface-generated waves did not cause re-suspension at deeper bottom depths (e.g., 138 m), but that transport and re-suspension is greater at shallower depths (e.g., 105 to 119 m).

Commercial Fisheries

OCS operators are required to conduct activities in a manner that would avoid undue interference with commercial fishing activities. In the event of fishing gear/vessel damage or loss, compensation can be filed through the Fisherman's Contingency Fund.

Observations which may have some relevance for OCS-activities included:

- there were distinct differences in the fish assemblages between a surveyed platform and near-by natural reefs. Mid-water rockfish were dominant at the platform, whereas bottom-associated species were not common;
- platform mariculture of mussels, oysters, scallops, and clams in the Santa Barbara channel has been successful; and
- exclusion zones (approximately 3 mi^2) established during the installation or removal of structures do not substantially increase the long-term or cumulative impacts on commercial fisheries. Communications of plans with local fishers and relevant agencies, and implementation of mitigation measures are conditions of approval.

An overview of the expansion of the Santa Ynez Unit was also conducted. A multi-stakeholder Offshore Oil and Gas Energy Resources Study was conducted to, in part, address the potential onshore effects of offshore oil and gas development.

6.5.2.3 Alaska Region

OCS Activities 1992-1994

- 20 geological and geophysical exploration permits issued; and
- four exploratory wells drilled.

Water Quality

Up to 12 oil and gas platforms had been discharging drilling muds, cuttings, formation waters and specialty chemicals (e.g., biocides) in Cook Inlet over a period of three decades. In response to expressed concerns, the MMS conducted a joint study of Cook Inlet with the University of Alaska to determine:

- the presence of hydrocarbons and trace metal contaminants in the water;
- the accumulation of contaminants in the sediment; and
- the effects of contamination levels on sensitive animal life stages.

Sampling sites were chosen in fine-grained bottom sediment bays, in the vicinity of production platforms in upper Cook Inlet, and in bays near processing and transportation facilities in northern lower Cook Inlet.

The physical chemical and bioassay results of the Cook Inlet Water Quality Study "…showed that Cook Inlet had very low environmental concentrations of hydrocarbons and that the sediments and water were generally free from toxic components. The results also showed no immediate evidence of heavy metal pollution in Cook Inlet".

Bowhead Whales

In the US, protection of the bowhead whale is required under the *Marine Mammal Protection Act* (1972) and the *Endangered Species Act* (1973). Site-specific effects of exploratory activities on bowhead whales must be monitored by industry for OCS leases in the Beaufort Sea Planning Area:

> "The lessee shall conduct a site-specific monitoring program during exploratory drilling activities to determine when bowhead whales are present in the vicinity of lease operations and the extent of behavioural effects on bowhead whales due to these activities."

MMS reviews the information an on annual basis with NMFS and the State of Alaska to determine whether existing mitigating measures adequately protect the whales from serious, irreparable, or immediate harm from oil exploration activities.

Broad-scale effects on the distribution, abundance, and behaviour of bowhead whales in the Beaufort sea are monitored each fall migration period. The surveys provide real-time data on the progress of migration and are used to limit OCS exploratory activities.

Aerial surveys in 1992, 1993, and 1994 indicated that bowhead whale fall migrations exhibited patterns found in previous years. A site-specific monitoring program at the Kuvlum area was also conducted in 1992 and 1993. Results from the 1992 program indicated that bowhead whales migrated north of an exploratory well in the Kuvlum #1 monitoring area; although ice conditions may have influenced the shift, industrial activity could not be eliminated as a source for the observed shift in distribution of bowhead whales. The 1993 program results indicated that bowhead whale distribution in the same area was within previously recorded fall migration distributions. The cause(s) of this local and temporary avoidance of some OCS exploration activities was not clear, and could have resulted from heavy ice conditions or industrial activity. The MMS "…found no evidence of serious, irreparable, or immediate harm to the bowhead whales from OCS-related activities during 1992-1994".