OCEAN NOISE

State of the Scotian Shelf Report

AUTHOR(S):
Danny Walmsley
Environmental Sciences Program,
St Mary's University, Halifax, Nova Scotia

Jim Theriault
Defence R&D Canada Atlantic,
P.O. Box 1012, Dartmouth, N.S. Canada B2Y 3Z7

EDITOR IN CHIEF :
Jay Walmsley
Oceans and Coastal Management Division,
Fisheries and Oceans Canada
1 Challenger Dr
Dartmouth NS B2Y 4A2

The material in this document is co-published as:
MacLean M, Breeze H, Walmsley J and Corkum J (eds). 2013.
State of the Scotian Shelf Report. Can. Tech. Rep. Fish. Aquat. Sci. 3074.

First published June 2011

ISBN: 978-0-9869437-2-0

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1 ISSUE IN BRIEF

LINKAGES

This theme paper also links to the following theme papers:

>> At Risk Species

There is increasing international concern about the extent to which anthropogenic noise is impairing the quality of the marine environment for animals that make use of sound as a key sensory tool for survival issues such as prey detection, predator evasion, reproduction, communication, echolocation, and orientation (McCarthy 2004. IMO 2004; IUCN 2004, International Fund for Animal Welfare 2008; OSPAR Commission 2009; see **Figure 1**).

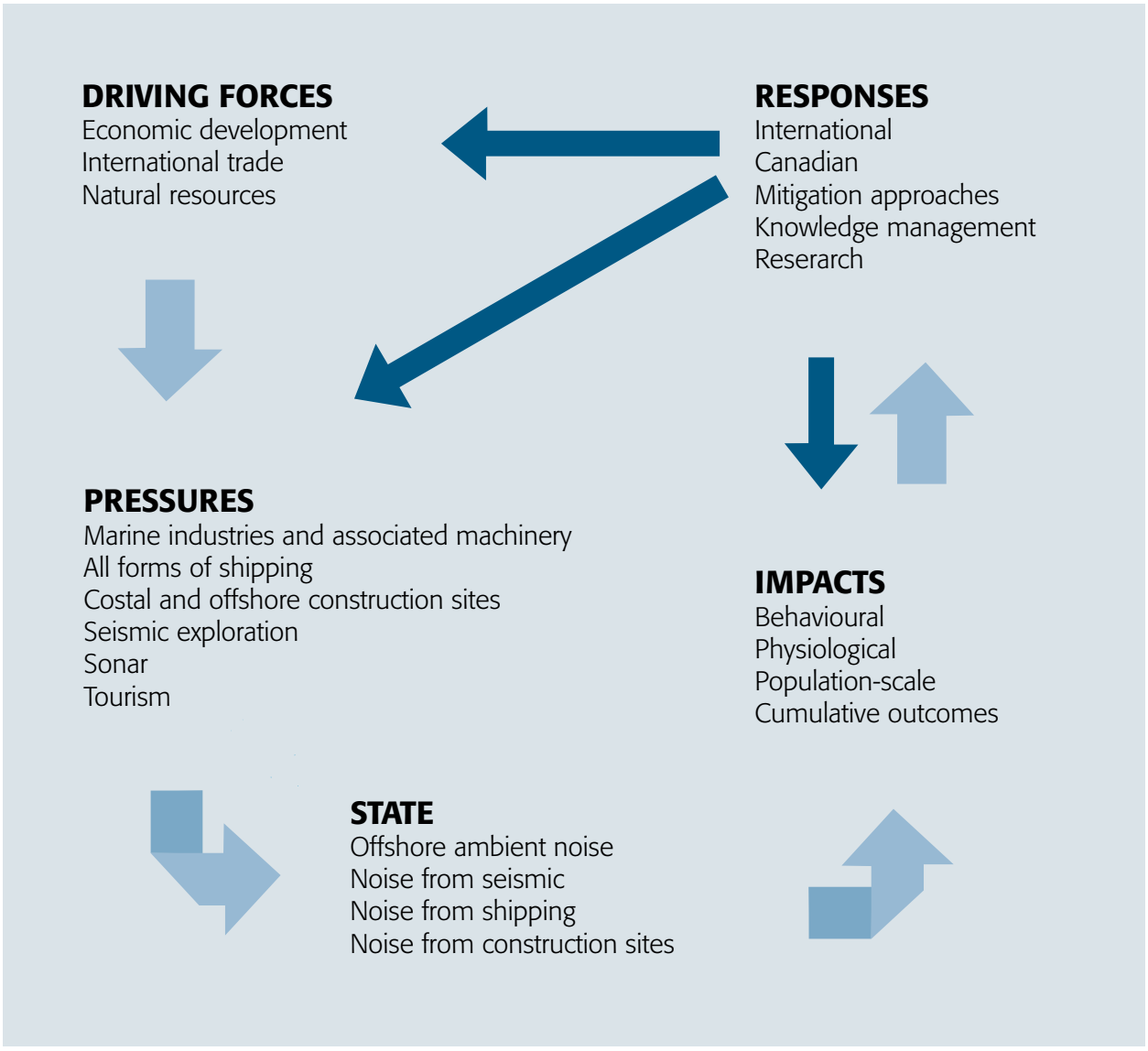

Figure 1: Driving forces, pressures, state, impacts and responses (DPSIR) for ocean noise on the Scotian Shelf. The DPSIR framework provides an overview of the relation between the environment and humans. According to this reporting framework, social and economic developments and natural conditions (driving forces) exert pressures on the environment and, as a consequence, the state of the environment changes. This leads to impacts on human health, ecosystems and natural resources, which may elicit a societal or government response that feeds back on all the other elements.

The Scotian Shelf is an active economic area and there are many sectors (e.g., shipping, commercial fishing, oil and gas, defence force, construction, marine scientifc research, and tourism) that contribute to ocean ambient noise on a constant or intermittent basis. Shipping, and its associated machinery, appears to be the major consistent contributor to low-frequency ambient noise on the Scotian Shelf as sound profiles in the offshore zone are indicative of high-density shipping (Zakarouskas et al. 1990; Pecknold et al. 2010). Studies indicate that, at frequencies dominated by shipping noise, background noise levels are up to 40 dB higher than noise levels generated by strong winds. Whilst there have been no definitive noise-impact research studies on the Scotian Shelf, comparable global literature indicates that there are numerous potential impacts that might adversely influence its resident and migratory marine animals. Depending on the species, and their proximity and length of exposure to various sound sources, the potential impacts on marine animals include, amongst others: mortality, physiological damage, behavioural changes, loss of hearing capabilities, masking, and area avoidance (DFO 2004; Worcester 2006; Payne et al. 2008). There are international governmental initiatives underway aimed at developing workable regulations and protocols to reduce noise in the marine environment. The main aspects which are being given attention include reductions in undesirable noise from shipping, seismic exploration, sonar, and tourist activities. Canadian regulations and policies are in place for seismic exploration, sonar, and whale watching on the Scotian Shelf (Theriault et al. 2005).

SOUND IN THE MARINE ENVIRONMENT

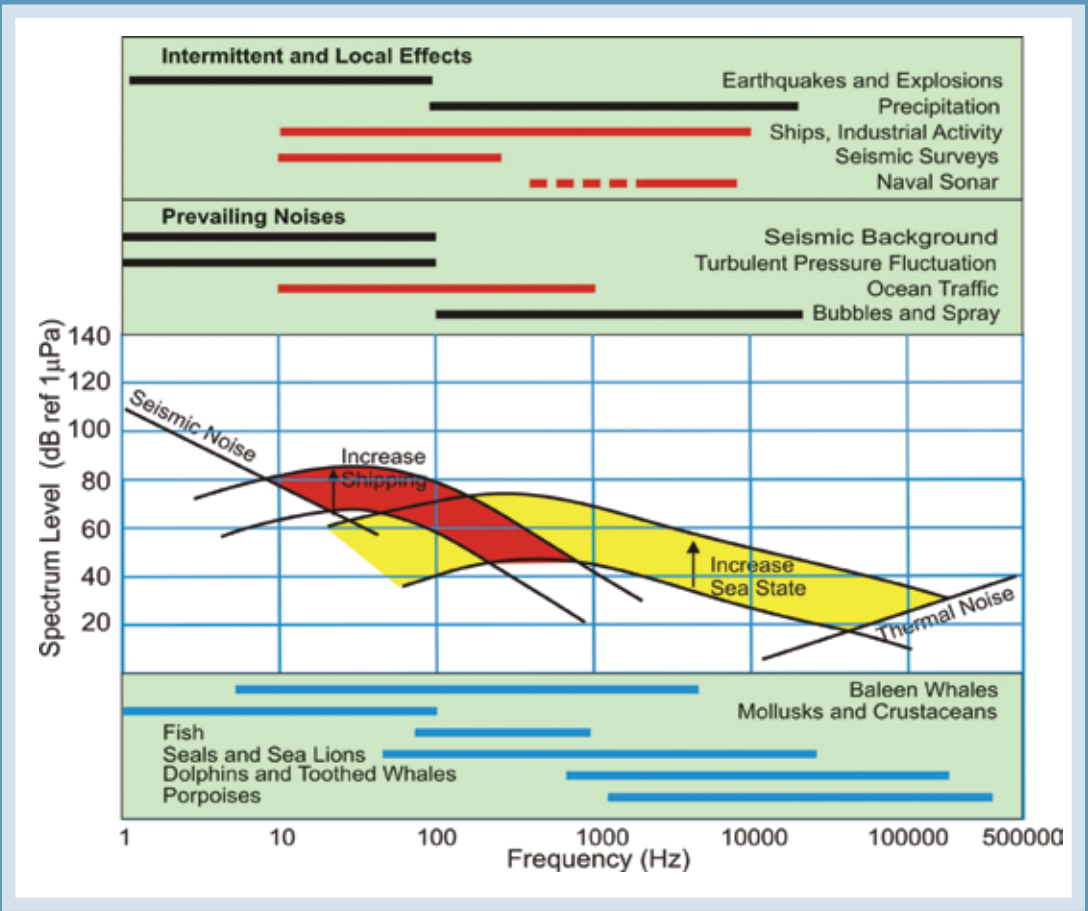

Figure 1: Typical ambient noise-frequency profiles for the marine environment (adapted from Wenz 1962 and the National Research Council 2003). Frequency bands associated with intermittent, prevailing and biological sources are indicated (red bars = anthropogenic; black bars = natural, and blue bars = biological).

Sound is produced by travelling waves or vibrations that occur at different frequencies and sound pressure or intensity is measured on a logarithmic scale (decibels, dB) (Chapman and Ellis 1998).

Sound in the marine environment is made up of a mixture of a variety of natural and anthropogenic sources (see **Figure 1**, National Research Council 2003). These contribute on a prevailing (constant), intermittent, or local basis. Prevailing sounds includes geological noise, noise from seismic surveys, distant ocean traffic, and sea surface bubbles and spray. Additionally, bioacoustic sound from crustaceans, fish, and mammals contributes over a wide frequency band. Episodal events and activities, such as earthquakes, nearby shipping, construction, wind, rain, seismic surveys (for Oil and Gas Exploration), and the use of active sonars by commercial and government sectors contribute at intermittent times in localized areas.

Noise is sometimes interpreted as being "unwanted sound" from anthropogenic sources, which being a form of energy, may be treated as a pollutant of the marine environment (Scott 2004).

2 DRIVING FORCES AND PRESSURES

2.1 ECONOMIC DEVELOPMENT

On the basis of data for the period 1950 to 1998, Frisk (2007) has demonstrated that there is a significant relationship between the increase in global gross domestic product (GDP) and the increase in ocean noise, thereby accentuating the importance of economic activity as the main driver of anthropogenic noise in ocean areas throughout the world. The Scotian Shelf represents a highly-developed and active area marine with numerous economic sectors making use of its geographic position and natural resources (DFO 2005). The area is an important contributor to the economy of Canada and Nova Scotia with the main marine industries comprising commercial fisheries, aquaculture, fish processing, oil and gas (exploration, development, and production), water transportation and support activities, tourism, marine construction, shipbuilding and boat building, and government services including research and defence (Gardner Pinfold 2009). All of these sectors use various forms of technology that emit noise into the ocean environment, and there are a wide variety of activities, each with its own characteristic mobility, timing, frequency, duration and intensity (**Table 1**). The Atlantic-facing seaboard of Nova Scotia is more than 500 km long and has numerous nodes of economic development (ports, bays, and small-craft harbours), which each have specific, and differing, sound sources linked to them. The development and economic sustainability of all of these sectors is a prime strategic objective of the region (Nova Scotia Department of Economic and Rural Development 2009), hence ensuring the perpetual presence of numerous sources and fluctuating levels of anthropogenic noise in most areas of the Scotian Shelf.

Table 1: Characteristics of some noise sources that are associated with various marine industry sector activities on the Scotian Shelf (selected from Simmonds et al. 2004; Wyatt 2008)

ACTIVITY/SOURCE	ECONOMIC SECTOR FREQUENCY (KHZ)	DOMINANT (dB re 1µPa-m)	SOURCE LEVEL	CHARACTERISTICS
650cc jet ski	Recreation/tourism	0.8-50.0	75-125	Intermittent movement in estuaries/ bays/surf zone/inshore
7m outboard	Recreation/tourism/aquaculture	0.63	152	Intermittent movement in estuaries/ bays/surf zone/inshore
Fishing boat	Fisheries/aquaculture	0.25-1.0	151	Intermittent movement offshore and inshore
Fishing trawler	Fisheries	0.1	158	Intermittent movement in offshore/ inshore/bays/estuaries/harbours
Tug	Support for transportation	1.0	170	Occasionally in all zones
Tanker	Transportation	0.06	180	Constant movement in offshore shipping lanes and ports
Container ship	Transportation	0.008	181	Constant movement in offshore shipping lanes and ports
Freighter	Transportation	0.041	172	Constant movement in offshore shipping lanes and ports
Airgun array	Oil and gas	0.01-0.10	255	Occasionally only by permit and localized in specified exploration areas
Naval Sonar	Defence	2-8	225	Intermittent in offshore
Depth sounder	Fisheries, defence, oil and gas, transportation	3	200	In association with shipping
Bottom profilers	Fisheries, defence, oil and gas, transportation	1-10	215	In association with shipping
Side scan	Fisheries, defence, oil and gas, transportation	60-300	225	In association with shipping
Acoustic deterrent devices	Aquaculture	10-25	205	localized inshore, embayments, estuaries
Dredging	Oil and gas, construction	broadband	131	Construction sites
Impact pile driving	Oil and gas, construction	0.010-0.12	190	Periodic and localized in areas of marine construction
Assorted motors, pumps, generators,	All sectors	-	-	Associated with construction sites, oil rigs and shipping
Aircraft – fixed wing and helicopters		All sectors		Associated with construction sites, oil rigs and shipping

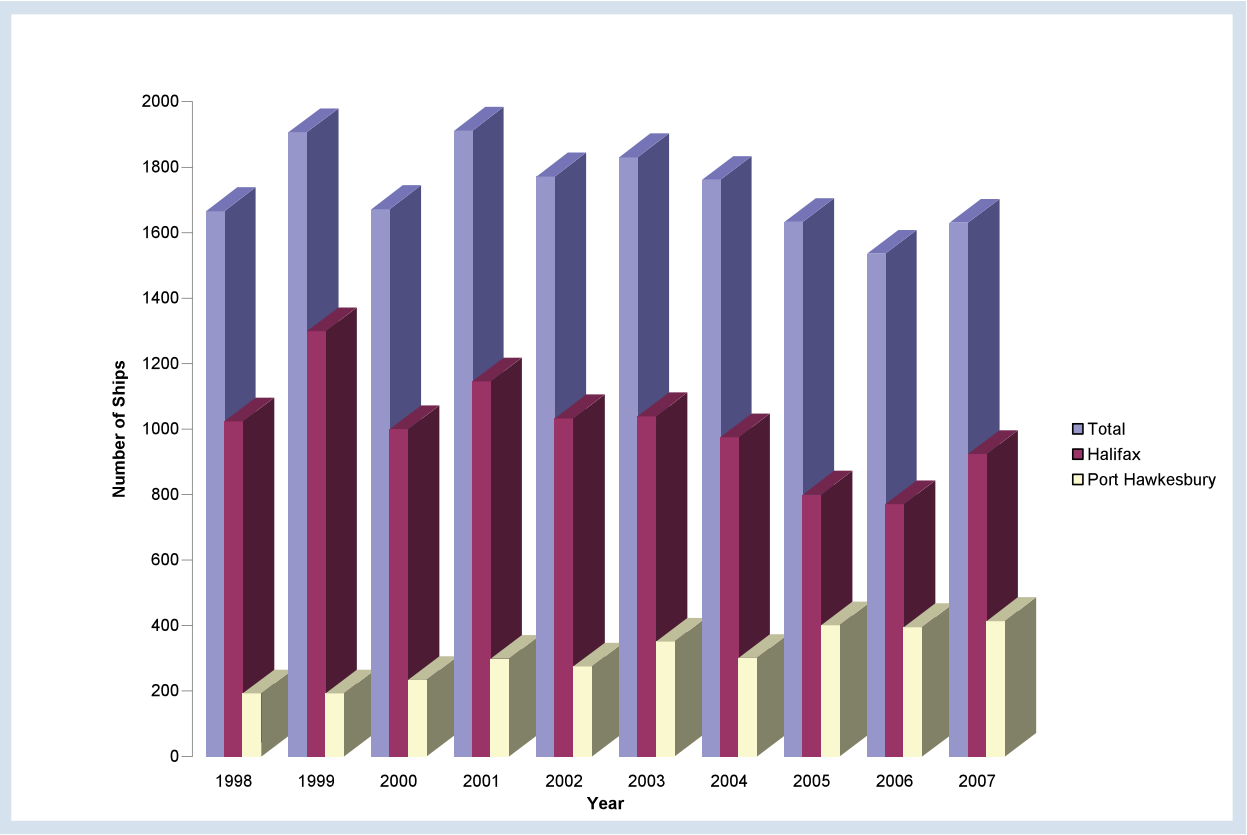

Figure 2: International shipping movements into ports of Nova Scotia for the period 1998 to 2007 (data obtained from Statistics Canada) showing annual total to all Nova Scotian ports, and trends for Halifax and Port Hawkesbury.

The following sections describe in more detail two of the main contributors of noise on the Scotian Shelf: shipping and oil and gas. Although there are other sources of noise, for example from military operations, these are minor and infrequent.

2.2 SHIPPING

Shipping traffic is considered to be one of the main anthropogenic drivers of marine ecosystem change and the northwest Atlantic Ocean, part of which incorporates the Scotian Shelf, contains some of the busiest sea routes in the world (Halpern et al. 2008). There are main shipping lanes traversing the Scotian Shelf in a north-south direction (DFO 2005) and several ports in Nova Scotia receive international shipping, including Sydney, Port Hawkesbury, Halifax, Shelburne and Hantsport. Nova Scotia has about 247 small craft harbours that cater to vessels that are involved in commercial fishing in ocean waters surrounding the province. There are no published reviews on the trends or exact numbers of shipping traffic traversing the Scotian Shelf, but figures for international ships making use of Nova Scotian ports show a regular pattern of between 1,600 and 2,000 large vessels per annum, of which the majority enter Halifax or Port Hawkesbury (**Figure 2**).

Pelot and Wootton (2004) report that merchant traffic (bulk, tanker, cargo) in the Halifax Sea Search and Rescue area (HSSR) remains relatively constant over the course of the year, but that commercial fishing and cruise ships are heavily seasonal. During 2001 there were 346,348 fishing vessel trips recorded inside the HSSR, indicating a heavy usage of the area by commercial fishing interests.

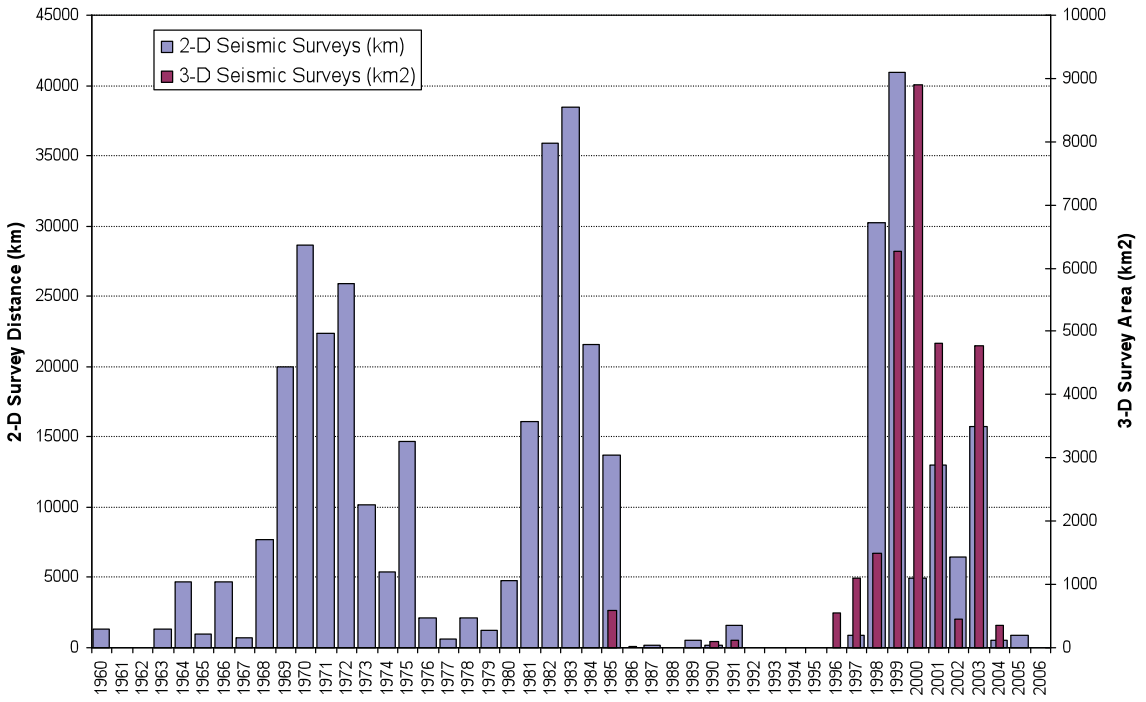

Figure 3: Seismic surveys undertaken on the Scotian Shelf from 1960 to 2006 (Source: Canada Nova Scotia Offshore Petroleum Board, CNSOPB, http://www.cnsopb.ns.ca/reflection_seismic.php).

Each vessel constitutes a moving source of sound that contributes to both background and local noise as it moves through an area. In general large ships create noise that covers a distance greater than approximately 50-80 km, and the noise fades into background levels as the ship passes. Oil tankers have been estimated to have an average area of ensonification at the 120 dB level of about 2,000 km^2 (Hatch et al. 2009).

2.3 OIL AND GAS EXPLORATION

A large portion of the Scotian Shelf has been designated for oil and gas exploration and development, and there are currently several areas that are under license with active extraction taking place centred on the Sable Island area (see Nova Scotia Department of Energy 2010). The oil and gas offshore industry creates numerous potential sources of noise that are generated on an impulsive, transient, or permanent basis (Wyatt 2008). Exploration-related seismic surveys represent one of the highest source levels (**Figure 3**, Walmsley 2007). Since 1960, there have been about 400,955 km of 2-D seismic and 29,512 km^2 of 3-D seismic shot on the Scotian Shelf and slope. This has occurred intermittently, with the majority of the activity taking place between the periods 1968-1975, 1980-1985 and 1996-2003. No commercial seismic surveys have occurred on the Scotian Shelf since 2005, although there have been geological research surveys on the Shelf and commercial surveys in areas adjacent to the Shelf (e.g., 3 D seismic survey during summer of 2010 in the Laurentian Channel north of the shelf).

3 STATUS AND TRENDS

3.1 AMBIENT NOISE

Ambient noise is defined by the National Research Council (2003) as "the overall background noise caused by all sources such that the contribution from a single specific source is not identifiable". It represents the background noise typical of the location and depth where the measurements are taken after identifiable, occasional noise sources are accounted for. Although there is a lot of data that has been collected on the Scotian Shelf over the years, there has not been any formal program on long-term monitoring of ambient noise on the Scotian Shelf, nor any analysis which reports on long-term changes at fixed sites or depths. There are however several reported studies over the last 50 years that allow for the general ambient noise characteristics of the Scotian Shelf to be defined.

Dataset for 1959/1960

Piggott (1964) investigated the relationship between noise levels and wind speed over an annual period and reported that there was a strong relationship between sea-noise spectrum levels (8.4 – 3100 Hz) and the logarithm of wind speed at an unspecified shallow water site (2 nm offshore at 40 - 50 m) on the Scotian Shelf. He also demonstrated that there were seasonal differences with higher ambient noise being encountered in winter months. The intermittent influence of shipping noise at the station was noted and possibly represented up to 30% of data in summer and 60% in winter.

Dataset for 1972/1985

Zakarauskas et al. (1990), collected data (30 – 900 Hz) at several sites during cruises between 1972 and 1985, and used an analysis approach that averaged transect data at mid-depth levels in the water column to give representative ambient noise profiles of the Scotian Shelf. They reported that ambient noise levels for frequencies of 150 Hz and above were the same as those given by Piggott (1964), but that at

lower frequencies the noise levels were up to 15 dB higher. This difference was attributed to three possible reasons: 1) propagation characteristics in inshore shallow waters, 2) position of hydrophones, and 3) higher shipping density. Zakarauskas et al. (1990) report that there was high variability of ambient noise on the Scotian Shelf and attributed this to shipping noise and propagation of ship noise from longer distances. They also reported that higher ambient noise during winter was related to improved propagation of shipping noise. They concluded that ambient noise profiles on the Scotian Shelf are representative of high shipping density.

Dataset for 1998

Desharnais and Collison (2001) investigated four sites on the Scotian Shelf with monthly sampling using four sonar buoys for each site over a period of one year. The values are high over all frequencies, and the variation and higher levels are likely associated with specific temporal and geographic factors.

Dataset for 2002

Hutt and Vachon (2004) obtained ambient noise profiles (10-1000Hz) on the Sable Bank in June 2002, and reported that measurements indicated that a ship noise parameter of 88 dB was appropriate for modelling purposes because there were 41 ships in the vicinity, corresponding to a moderate to high shipping density.

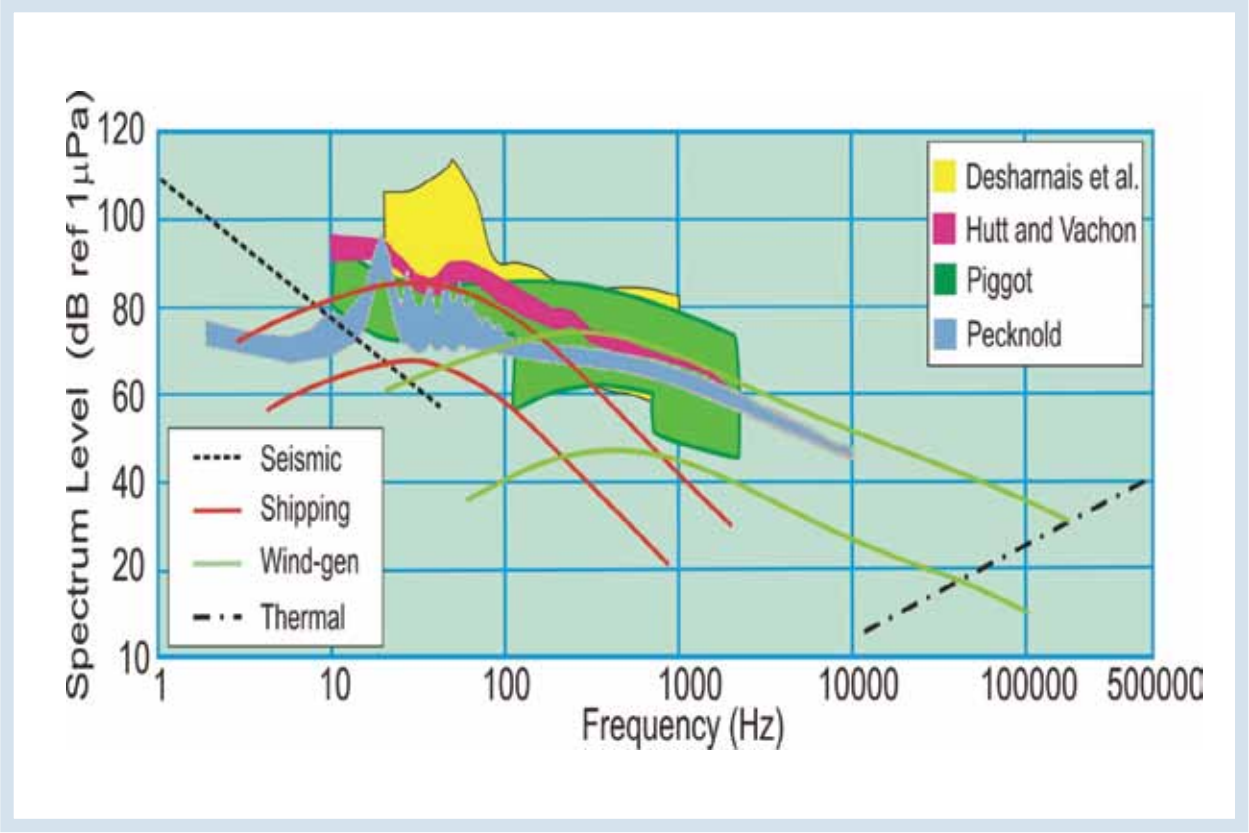

Figure 4: Spectrum-frequency profiles for datasets showing ambient noise at sites on the Scotian Shelf (Desharnais and Collison 2001; Hutt and Vachon 2003; Piggot 1964; and Pecknold 2010).

Dataset for 2009

A more recent study by Pecknold et al. (2010) using a small temporal data set, and focusing on wind generated noise, also confirmed the nature of ambient noise on the Scotian Shelf and its influence by high shipping activity.

A comparison of the spectrum-frequency profiles of these datasets is shown in **Figure 4**. This demonstrates their positions in accordance with curves of Wenz (1962) and the relative influence of shipping in all of datasets.

The studies undertaken have been limited, so that it is not possible to assess or predict any trends. The studies show that there is obviously considerable temporal and spatial variation, and that ambient noise is higher than that predicted for deep water by Wenz (1962). Wind and wave generated noise (> 100 Hz) is generally higher than that predicted for average sea state. At the frequencies dominated by shipping noise (10 - 100 Hz), the studies have shown ambient noise levels that are up to 10 000 times (40 dB) higher than noise levels generated by high winds.

3.2 INTERMITTENT AND LOCAL NOISE

There is limited published work available on measured noise from intermittent or local sources on the Scotian Shelf, although generic source level information is available for numerous intermittent and local sources (see Simmonds et al. 2004, Wyatt 2008, **Table 1**).

The acoustics of air-gun arrays for seismic surveys, with one of the highest source levels, have received attention in areas of the Scotian Shelf. Far field sound measurements were included as

part of a research investigation associated with a 3-D seismic survey near the Gully Marine Protected Area in 2003 (Lee et al. 2005). During this survey Austin and Carr (2005) showed that. :

- A maximum measured average peak sound level of 175 dB re µPa was received at 30 m water depth, and at a range of 2.6 km from the seismic array; and

- The measurements recorded in the Gully Marine Protected Area, at a range of approximately 55 km from the airgun array, had average received peaks of 143 and 136 dB re µPa at depths of 77 m and 180 m, respectively (see also McQuinn and Carrier 2005).

Seismic airgun noise has the capacity to propagate over large distances. Niukirk et al. (2004) report that noise from seismic exploration on the Scotian Shelf was recorded at a station on the mid-Atlantic Ridge 3,000 km away. As with prevailing noise, the ranges at which seismic surveys can be heard is highly variable and their influence is restricted to the period of operation.

Ocean floor morphology, ocean depth, temperature, salinity, and proximity to land are important modifying factors in determining the characteristics of noise distribution in the marine environment (Wenz, 1962, Piggott 1964; OSPAR Commission 2009). Because of this, sounds from industrial activities on the inshore part of the Scotian Shelf can be expected to be more varied, and different, to those of the offshore. Noise can be expected to be higher close to fixed developments and sites where there are numerous forms of mechanization (pumps, generators, motors, mobile rigs, aircraft etc.).

4 IMPACTS

There are diverse animal groups (plankton, benthic and pelagic invertebrates, reptiles, fish and mammals) that make use of benthic and pelagic habitats on the Scotian Shelf (Breeze et al. 2002; Zwannenberg et al. 2005). Many of these groups have been shown to be sensitive to various forms of sound (DFO 2004a; Hawkins et al. 2008; OSPAR 2009). While there is an absence of verifiable experimental information on the impacts of sound on specific biota, which makes it extremely difficult to specify the exact impact of a particular sound type on any particular species in Canadian waters (DFO 2004a), there is a developing body of research synthesis which suggest there may be wider impacts of anthropogenic sound on marine organisms (DFO 2004a; Simmonds et al. 2004; Hawkins et al. 2008; IFAW 2008; OSPAR Commission 2009; see **Table 2**).

Table 2. Potential impacts of noise on major groups of marine animals that occur on the Scotian Shelf.

ANIMAL GROUP	POTENTIAL IMPACTS
Invertebrates	Wide range of possible impacts: extremely high levels of noise such as seismic may result in bruised organs and abnormal ovaries, smaller larvae, delayed development, soiled gills, altered feeding patterns, signs of stress in response to seismic noise (DFO 2004 a, b; Payne et al. 2009).
Fish	Wide range of possible effects: high levels of noise cause startle response, orientation problems, structural damage to swim bladders, ablated ear cells, internal bleeding, or blindness. Most damage occurs upon exposure within 5 m of the source. Temporary and/or permanent hearing loss, physiological changes as a result of stress, masking (DFO 2004a; Worcester 2006).
Reptiles	Wide range of effects: increased swimming speed, increased activity, change in swimming direction, and avoidance (DFO 2004a).
Mammals (whales, dolphins, seals)	Wide range of effects including: cessation of feeding, changes in behaviour, orientation, changes in socializing and vocalizing, avoidance, attraction, masking (see **Figure 6**), damage to ears (hearing threshold shift), stress, displacement from area, cumulative impacts, social disruption (Abgrall et al. 2008; DFO 2004a; Simmonds et al. 2004; Weilgart 2007). Sonar exposure has been associated with strandings and mortality in some beaked whale species.

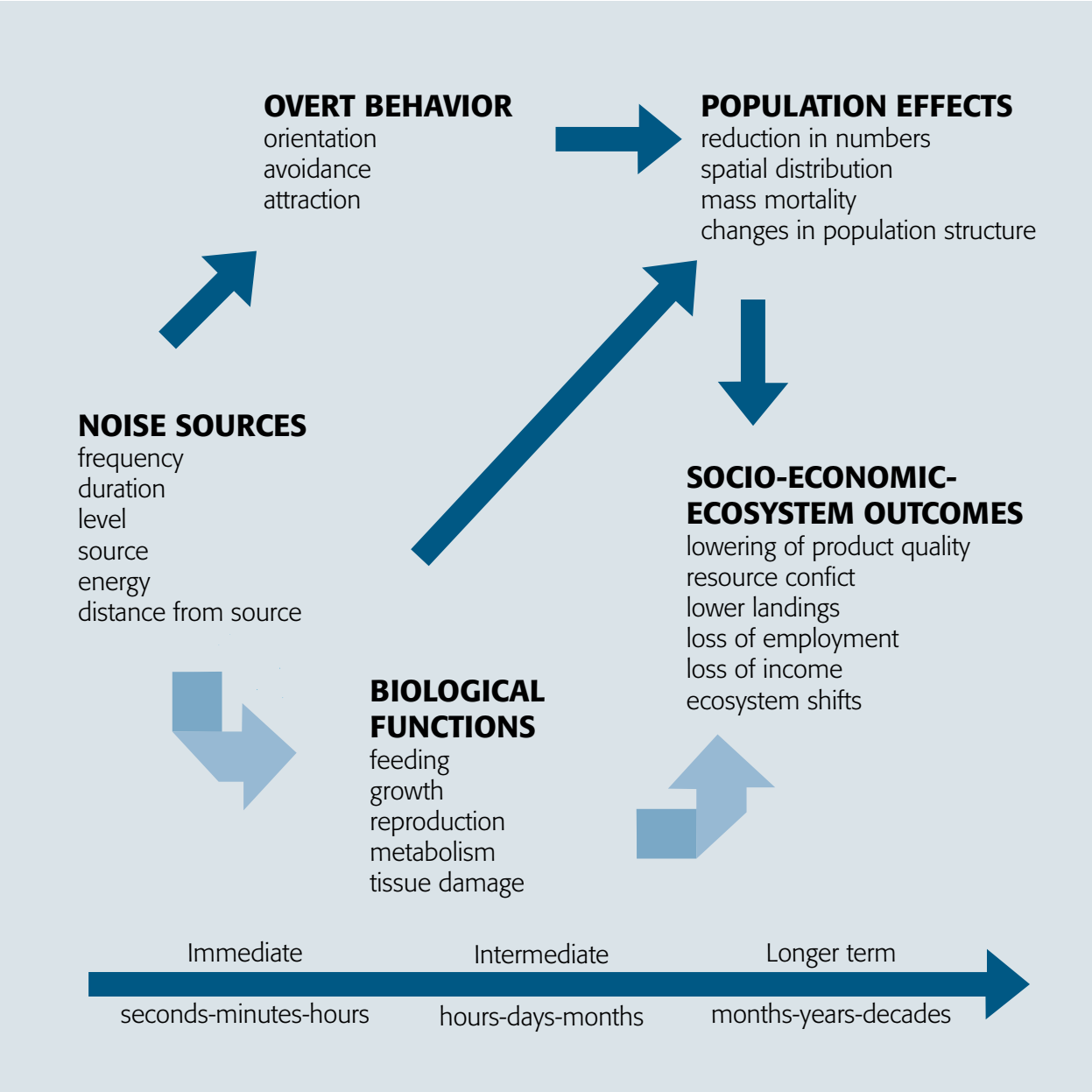

Figure 5: PCAD model to illustrate the impacts of noise at individual, population and ecosystem levels (Walmsley 2007; adapted from National Research Council 2005)

In the marine environment where senses such as vision, touch, smell and taste are limited in range, sound is an important sensory tool for many marine organisms (marine mammals, fish and some invertebrates) that have developed special mechanisms both for emitting and detecting underwater sound (Hawkins et al. 2008). Sound is important for detection of prey and predators, for echolocation and avoidance of obstacles, and for communication between individuals. It is, therefore, vital for survival of many individual animals through its role in directing movement, behaviour, feeding, reproduction, and avoidance of threats.

The Population Consequences of Acoustic Disturbance (PCAD) model (National Research Council 2005), provides a general perspective of the wide range of potential impacts on marine organisms (**Figure 5**). Noise creates a risk of impacts involv-

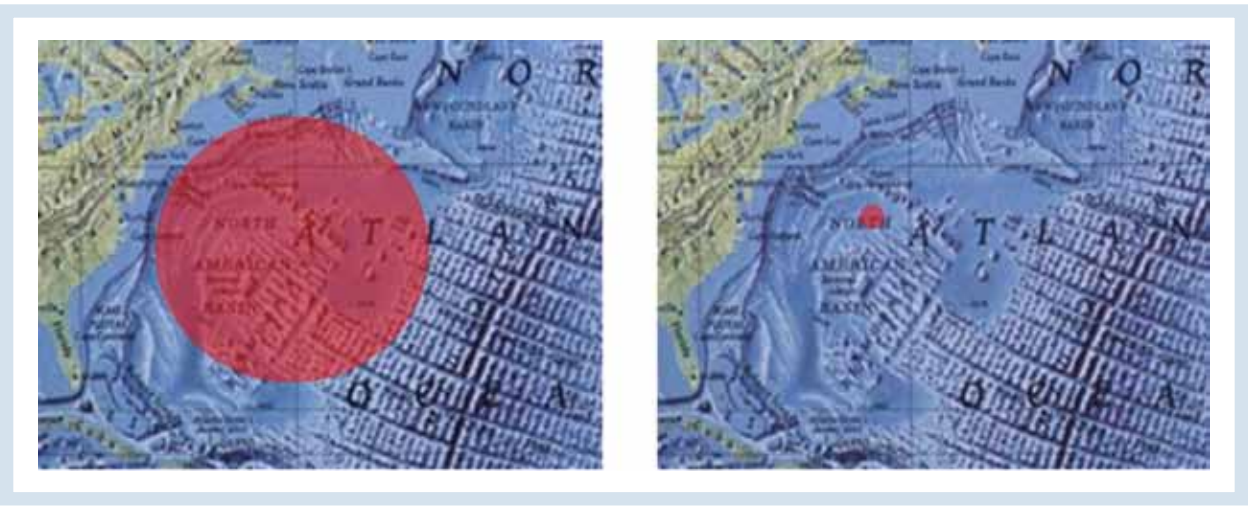

Figure 6: Expected reductions in blue whale communication ranges from the many hundreds of square kilometres possible prior to the advent of commercial shipping and other industrialized sounds (left) compared to the greatly reduced possible ranges for those same calls today (right). Figure courtesy of Christopher Clark, Cornell University based on historical and recent low frequency ambient noise and whale call measurements (from Wright 2008).

ing the behaviour and biological functions at both individual and population levels, and ultimately, at wider socio-economic and ecosystem scale levels. Richardson et al. (1995) cite a range of possible impacts (e.g., mortality, injury, behavioral changes, avoidance, attraction, and masking) with the level of impact related to many factors including amongst others: proximity of animals to the sound source, the nature of the sound source, environmental factors, the sound sensitivity and behavioral state of the organism, and the duration of exposure. The situation is complex as the groups and species all have different wavelength spectra to which they are sensitive, and therefore a source might have an impact on one species but not on others.

The potential impacts of seismic airgun noise, one of the loudest sources of noise on the Scotian Shelf, has received attention in Canada (DFO 2004a, b, Lee et al. 2005, Worcester 2006; Moriyasu et al. 2004; Payne et al. 2008). Studies indicate that there is a wide range of potential impacts, but they still require confirmatory research.

Animals on the Scotian Shelf are exposed to a wide range of intermittent and prevailing noises, and there is concern that long-term exposure within such an environment might lead to cumulative impacts, ultimately causing stress-related effects on the general condition of animals, making them prone to secondary indirect impacts (e.g., disease, loss of reproductive capability; Simmonds et al. 2004).

5 ACTIONS AND RESPONSES

Concern about noise as a detrimental environmental factor for marine mammals was raised as long ago as the 1970's (see Payne and Webb 1971). There is a growing opinion that noise in the marine environment is a priority issue which needs to be addressed at the global level (IUCN 2004; Scott 2004; International Maritime Organization (IMO) 2009, International Whaling Commission 2006, OSPAR Commission 2009). Because propagation of noise occurs over long distances in the marine environment, it is recognized that the management of noise will require an international collaborative effort (IMO 2009). A lack of research on the exact quantifiable impacts of noise has limited the development of regulations based on concrete scientific fact, and most of the current approaches are based on a "precautionary approach" aimed at reducing risks of certain types of potential impact (Theriault et al. 2005).

5.1 INTERNATIONAL RESPONSE

Although there is no specific international legislation for the regulation of noise in the sea, there is recognition that responsibility for addressing the situation lies within the mandate of the UN and its structures (IUCN 2004; IMO 2009). The United Nations Law of the Sea (UNLOS - http://www.un.org/Depts/los/index.htm) obliges parties to: *"take all measures that are necessary to prevent, reduce and control pollution of the marine environment from any source."* Pollution is broadly defined by UNLOS in Article 1(4) as: "[t]he introduction by man, directly or indirectly, of substances or energy into the marine environment". Based on this definition, anthropogenic noise, which is a form of energy, should be regarded as a pollutant (Scott 2004). However, noise does not yet feature on any of the international pollution regulations which are coordinated through *The International Convention for the Prevention of Pollution from Ships* (*MARPOL*- http://www.imo.org/conventions/contents.asp?doc_id=678&topic_id=258) under the IMO. This omission is in the process of being addressed, as evidenced by several actions and activities which have taken place in recent years. These have included:

- A resolution by the World Conservation Union (IUCN 2004) that recognizes that *"anthropogenic underwater noise, depending on source and intensity, is a form of pollution, comprised of energy, that can degrade habitat and have adverse effects on marine life ranging from disturbance to injury and mortality".* The resolution urged member governments that are parties to the UN to work through UNLOS, MARPOL and the IMO to develop mechanisms for the control of undersea noise (http://www.awionline.org/ht/a/GetDocumentAction/i/10132). The IUCN also called for assistance of IUCN members, Commissions and Council, to identify and implement measures to promote among governments the reduction of anthropogenic ocean noise, and to support and conduct further research into the effects and mitigation of anthropogenic ocean noise.

- Statements from the UN General Assembly (20 December 2006, and December 2009) that encourage further research, studies and consideration of the impacts of ocean noise on marine living resources, and request the UN structures to continue to compile peer-reviewed scientific studies (http://www.un.org/depts/los/general_assembly/noise/noise.htm).

- The establishment of a correspondence group by the Marine Environment Protection Committee (MEPC) of the IMO to investigate the adverse impact of ship noise on marine life. The correspondence group prepared a review

and report that was submitted to the MEPC in 2009 (IMO 2009). Work is continuing on the development of voluntary technical guidelines for ship quieting technologies.

- Concerns by the International Whaling Commission (IWC) about the cumulative impacts of noise on whales and the regular inclusion of anthropogenic sound as an agenda item on annual meetings of the IWC Scientific Committee (IWC 2006, IWC 2010). There has also been agreement for increased coordination and cooperation between the IWC and the IMO on the issue of anthropogenic noise. The main focus points for international management appear to be shipping noise, seismic exploration, use of sonar, and whale watching activities (IMO 2009, IWC 2010).

5.2 CANADIAN REGULATIONS AND POLICY

Canada is a member of the UN, and a signatory to both UNLOS and MARPOL, and has been a participant in the above-mentioned international activities. Some of the Canadian regulations and policies that are, or could be, applicable to the regulation of noise on the Scotian Shelf include (Theriault et al.2005):

- The *Species at Risk Act* is aimed at the legal protection of listed "at risk" species, and includes provision for management of critical habitats in which these species are found. There are currently 28 Scotian Shelf species that are listed by COSEWIC as being either extirpated, endangered, or of concern (http://www.sararegistry.gc.ca/). For many of these species noise is cited as being an issue of concern (see *At Risk Species* [hyperlink on web]).
- The *Canada Shipping Act* makes provision for the regulation of shipping in Canadian waters. Section 658 of Part XV of the Act relates to provisions for implementation of any MARPOL-related regulations.
- The *Canadian Environmental Protection Act* is designed to protect the ecological health of Canada, and prescribes activities to ensure environmental protection. The Act defines marine pollution as "the introduction by humans, directly or indirectly, of substances or energy into the sea."
- The Oceans Act defines the efforts that can be employed to protect resources and endangered species in offshore areas. The Act (sections 52.1) allows for the development related to marine environmental quality requirements and standards. An example is The Statement of Canadian Practice with respect to the *Mitigation of Seismic Sound in the Marine Environment*, which specifies the mitigation requirements that must be met during the planning and conduct of marine seismic surveys, in order to minimize impacts on life in the oceans (see http://www.dfo-mpo.gc.ca/oceans/management-gestion/integratedmanagement-gestionintegree/ seismic-sismique/statement-enonce-eng.asp).).
- The *Fisheries Act* contains several provisions that are relevant to noise. Section 35 states that "no person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat."; Section 7 states "no person shall disturb a marine mammal except when fishing."; and Section 32 of the Fisheries Act prohibits the destruction of fish by means other than fishing.
- The *Canadian Environmental Assessment Act* requires federal departments and agencies to assess the environmental impact of proposed projects and activities.

- *Canada–Nova Scotia Offshore Petroleum Resources Accord Implementation Act* contains Nova Scotia Offshore Area Petroleum Geophysical Operations Regulations (SOR/95-144) and applies to oil and gas activities. The Canada Nova Scotia Offshore Petroleum Board (CNSOPB; http://www.cnsopb.ns.ca/) is the agency responsible for regulations concerning seismic exploration activities in Nova Scotian waters. No petroleum development activity takes place offshore Nova Scotia without an environmental assessment. The convening of a public commission involving stakeholders in the assessment of potential impact of seismic exploration (http://www.cnsopb.ns.ca/pdfs/Report1upPublicComm.pdf) off Cape Breton is an example of this.

- Maritime Forces Atlantic issues Maritime Command Orders (MARCORDS) dealing with the use of sonar in association with marine mammals.

5.3 Knowledge Development and Research

There are numerous international and Canadian research organizations and agencies that are involved in the support of research and dissemination of information on the impacts of noise in marine waters. Some of these include:

- The Canadian Environmental Studies Research Funds (ESRF) sponsors projects designed to assist in the decision-making process related to oil and gas exploration and development (see- http://www.esrfunds.org/pubpub_e.php).

- The Offshore Energy Environmental Research Association (OEER) has a program on the impacts of seismic on invertebrates (http://www.offshoreenergyresearch.ca/Default.aspx?tabid=54).

- Petroleum Research Atlantic Canada (PRAC) is an organization that has provided funding support for seismic- related research in Atlantic Canada (http://pr-ac.ca/programs/).

- The DFO regularly carries out research projects and reviews on noise (DFO 2004, 2005, Worcester, 2006, Payne et al. 2008, Lawson 2009)

- Defence R&D Canada is an agency of the Canadian Department of National Defence that has been involved in numerous assessments of noise on the Scotian Shelf (http://www.drdc-rddc.gc.ca/index1-eng.asp).

- The United States, which has several agencies and actions underway (e.g,. The Marine Mammal Commission - http://mmc.gov/reports/workshop/; National Oceanic and Atmospheric Administration - http://www.nmfs.noaa.gov/pr/pdfs/acoustics/shipping_noise.pdf). An Interagency Task Force on Anthropogenic Sound and the Marine Environment has motivated a research plan for US federal agencies (Southall et al. 2009).

- The International Association of Oil and Gas Producers (http://www.soundandmarinelife.org/Site/index.html) has a E&P Sound and Marine Life Joint Industry Programme (JIP).

- Ongoing conferences and symposia that present and synthesize information on the effects of noise on aquatic life (see- http://www.aquaticnoise.org/).

- Numerous websites that present useful information on noise and its environmental impacts (e.g. http://www.acousticecology.org/aboutus.html , http://www.dosits.org/, http://www.noaa.gov/).

INDICATOR SUMMARY

INDICATOR	POLICY ISSUE	DPSIR	ASSESSMENT	TREND
Marine ship traffic	Noise impact from shipping	Pressure	Poor	/
Extent and frequency of seismic surveys	Noise impact from seismic surveys	Pressure	Fair	+
Ambient noise	Environmental quality	State	Poor	?
Airgun noise propagation	Environmental quality	State	Fair	?
List of potential impacts	Impact assessment	Impact	Poor	?
Applicable regulations	Policy and regulations	Response	Fair	/
List of knowledge development activities	Knowledge management and research	Response	Poor	/

Key:
Negative trend: -
Unclear or neutral trend: /
Positive trend: +
No assessment due to lack of data:?
* see more about the DPSIR framework at http://coinatlantic.ca/index.php/state-of-the-scotian-shelf/217

Data Confidence:
- Cited source levels are generic and not necessarily those that might be measured on the Scotian Shelf.
- Shipping traffic values are proxy indicators and do not reflect the overall dynamic shipping situation on the total area of the Scotian Shelf.
- Cited ambient noise levels only reflect the situation at a single point over a limited time period.

Data Gaps:
- No continuous record of ambient noise levels in critical habitats of the Scotian Shelf. Ocean bottom seismometers and Cornell pop-up acoustic recorders have been deployed in canyons and along the slope of the Soctian shelf and the data could be analyzed to gain a better understanding of ambient noise.
- No long-term monitoring or assessment of noise from fixed sites.
- No analysis of shipping patterns and ship types is readily available.
- No analysis of noise sources or noise budgets is available.
- Few conclusive studies of impacts on organisms have been undertaken.

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