Shipping and Seismic Exploration Noise in the Arctic Marine Soundscape: A look at Mitigation Measures for Cetaceans

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Abstract

Increasing levels of anthropogenic noise in the Arctic marine soundscape can have negative effects on cetaceans that have adapted to a relatively pristine acoustic environment and are unaccustomed to the loud, low frequency sounds associated with activities such as shipping and seismic surveys. This issue was explored first through a literature review on topics related to anthropogenic noise impacts on cetaceans in the Arctic. A detailed examination of three types of mitigation measures; operational, source-based and geographical measures, was then conducted. A review and analysis of the international, regional and national regulatory bodies and policies related to the management of anthropogenic noise impacts in the marine environment that could be applicable to the Arctic region was completed including a comparison of three seismic survey specific guidelines from Canada, the United States and the United Kingdom. Finally, recommendations on how management and mitigation policies could be improved at the international, regional and national level are provided. At the national level for example, after comparing the three seismic survey policies it was determined that Canada would benefit from a seismic survey policy specific to the Arctic region that would provide a detailed explanation of how source-based, operational and geographic mitigation measures are to be incorporated and utilized. Regionally it is recommended that the Arctic Council establishes minimum mitigation and management standards for all member states, creating a united effort to address this transboundary issue. At the international level anthropogenic noise and its effects on cetaceans in the marine soundscape is not widely recognized as a significant problem and therefore the most basic recommendation is that the various international bodies and organizations make an effort to include anthropogenic noise mitigation and management within any future policies, guidelines or recommendations. Generally, it is recommended that all mitigation or management policies and guidelines be based on scientifically informed decision making and the precautionary principle.

Keywords: anthropogenic noise; cetaceans; Canadian arctic; mitigation measures; policy; seismic; shipping

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Abbreviations

- ACAP - Arctic Contaminants Action Program
- AMAP - Arctic Monitoring and Assessment Programme
- AMSA - Arctic marine shipping agreement
- AMTP - Arctic Marine Tourism Project
- AOOGG - Arctic Offshore Oil and Gas Guidelines
- BOEM - Bureau of Ocean Energy Management
- CAFF - Conservation of Arctic Flora and Fauna
- COSEWIC - Committee on the Status of Endangered Wildlife in Canada
- dB - decibel
- DFO - Department of Fisheries and Oceans
- EC – Environment Canada
- Hz - Hertz
- IMO - International Maritime Organization
- IGO - Intergovernmental Organizations
- IOC – International Ocean Commission
- IUCN - International Union Conservation of Nature
- IWC - International Whaling Commission
- JNCC - Joint Nature Conservation Committee
- MMOs - Marine mammal observer
- MMPA – marine mammal protection act
- MPA - Marine protected areas
- NEB - National Energy Board
- NGO – Non-governmental Organization
- NOAA – National Oceanic and Atmospheric Administration
- NPC - Nunavut Planning Commission
- NTL – Notice to Lessees
- PAM - Passive acoustic monitoring
- PAME - Protection of the Arctic Marine Environment
- PTS - Permanent Threshold Shift
- SAR – Species at risk
- SARA - Species at Risk Act
- SOCP – The Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment
- SWGEC - Scientific Committee and the Standing Working Group on Environmental Concerns
- TTS - Temporary Threshold Shift
- UNCLOS - United Nations Convention on the Law of the Sea
- UNESCO - United Nations Educational, Scientific and Cultural Organization
- WGWAP – Western gray whale advisory panel

1. Introduction

Until recently, the Arctic and its extensive natural resources have remained fairly untouched by anthropogenic activity and industrial exploitation because of harsh weather conditions, brief summer seasons and geographical remoteness (AEPS, 1991; AMAP, 2015). Compared to the majority of the world's oceans, the unique ecosystem and marine soundscape of the Arctic Ocean have remained relatively pristine (Koivurova, 2008; Moore et al., 2012). In fact, the United Nations Educational, Scientific and Cultural Organization (UNESCO) IOC (International Oceanographic Commission) recently identified the Arctic and Antarctic Oceans as the only oceans in the world as "areas of very low human impact" (UNESCO IOC, 2010). However, it is widely accepted and understood that the Arctic ecosystem is facing significant changes due to climate change, affecting the land, marine environment, wildlife and the cultural livelihoods of the people who live there (AEPS, 1991; Reeves et al., 2014). These changes are intensified as the warming environment and melting sea ice increases accessibility to the Arctic; resulting in increased industry interest as it becomes more economically and logistically feasible for companies to develop the high north (AMSA, 2009; Huntington et al., 2012; Moore et al., 2012).

Over the last few decades, the Arctic Ocean has become recognized for its vast untapped resources and other economic opportunities, and industries such as oil and gas and shipping have become more common in the region (Angell & Parkins, 2011; Gavrilchuk & Lesage, 2014). Erratic development has resulted in inconsistencies in the management approaches and regulations established by different nations, governments and international regulatory bodies that govern the Arctic (Gavrilchuk & Lesage, 2014; Huntington et al., 2012; Williams et al., 2014). Even within Canada, regulation and management of industry activities varies across the three coastlines (Atlantic, Pacific and Arctic) and three territories (Yukon, Northwest Territory and Nunavut), resulting in a patchwork of policies from Territorial and Federal Governments, as well as various governmental bodies such as the National Energy Board (NEB) and the Department of Fisheries and Oceans (DFO), that are used to oversee activities in the Canadian Arctic (Cameron, Mageau & Smyth, 2008; Gavrilchuk & Lesage, 2014; NEB, 2015). Furthermore, Canadian policies and mitigation guidelines for offshore energy activities have been mainly focused on marine development projects occurring on the Atlantic coast, with less consideration given to their applicability for the Arctic region (Cameron et al., 2008; DFO, 2007; NEB, 2015). One human impact that is often inadequately addressed is how anthropogenic noise within the marine soundscape can impact marine species (Reeves et al., 2014). Noise is a form of pollution that can have detrimental effects on marine species, especially cetaceans who rely upon their sense of hearing for survival (Hastie, Donovan, Götz & Janik, 2014; Moore et al., 2012). The two largest contributors to anthropogenic noise in the Arctic are shipping activities and seismic surveys (Gavrilchuk & Lesage, 2014; Reeves et al., 2014).

Nunavut is seen as the last major undeveloped area within Canada as it has remained relatively untouched in comparison to the Western Canadian Arctic where industry development in the north has been concentrated for the past few decades (Gavrilchuk & Lesage, 2014). There is an opportunity within Canada, and specifically within Nunavut, to establish rigorous and precautionary management policies and mitigation guidelines for new industrial development initiatives to preserve this relatively pristine environment (AEPS, 1991; Koivurova, 2008).

For this paper, a literature review was conducted to examine sources of anthropogenic noise in the marine environment and its potential impacts on cetaceans in the Arctic (Section 2). A policy review and analysis was then performed to explore how anthropogenic noise in the marine environment is being managed and addressed at the international, regional and national level and to identify any major knowledge or policy gaps relevant to the unique challenges of the Arctic region (Section 3). Finally, recommendations on improving policies specific to anthropogenic noise in the Arctic marine environment and reducing potential effects on cetaceans through effective mitigation guidelines are provided (Section 4).

2. Literature Review

The purpose of this section is to review relevant information on anthropogenic noise, cetaceans and the Arctic marine soundscape to provide a more in-depth understanding of the current state of knowledge and research related to this topic.

2.1 Sound in the Arctic

To best understand the effects of anthropogenic noise on cetaceans, a basic understanding of sound is required. Sound can be defined as the "mechanical radiant energy that is transmitted by longitudinal pressure waves in a material medium (as air) and is the objective cause of hearing" (Merriam Webster, 2015).

Two basic concepts of sound especially relevant to the issue of anthropogenic noise and cetaceans are frequency (pitch) and amplitude (loudness). Frequency is based on the vibration rate of wave particles and is measured in Hertz (Hz) (Simmonds et al. 2004). Sounds are often described as being either of low or high frequency, which is often expressed as having either a low or high pitch (Dotinga & Oude Elferink, 2000; Simmonds et al., 2004). Humans can hear and process a limited range of frequencies (20-20,000 Hz), while the vocal and hearing range of cetaceans spans from <20 Hz to > 150 kHz (Dotinga & Oude Elferink 2000, Simmonds et al. 2004). Amplitude is the degree of change in particle displacement, and is measured in decibels (dB) (Simmonds et al. 2004). The amplitude of a sound can be difficult to measure and compare because decibels are based on a relative numerical scale and can be calculated in a variety of different ways (Chapman & Ellis 1998). A standard way to measure and state the amplitude of a sound underwater is ‘dB 1µPa’, which is based on a reference pressure of 1 micropascal (µPa) (Chapman & Ellis, 1998). Sometimes the amplitude of a sound will be expressed as ‘dB re. 1µPa @1m’ (Weir & Dolman, 2007) or just ‘dB re. 1µPa–m’ (Richardson & Würsig, 1997; Simmonds et al., 2004), and the ‘1m’ or ‘m’ denotes the measurement of a sound one metre from the sound source (Chapman & Elis, 1998). Amplitude can also be expressed as dB_{rms} (root mean square pressure level), dB_{cum} (cumulative pressure level) or dB_{peak} (peak pressure level) (NOAA, 2013). Cumulative pressure level is a measurement of “cumulative exposure over the duration of the activity”, while root mean square pressure level is “the square root of the average of the square of the pressure of the sound signal over a given duration” and peak pressure level is the “greatest absolute instantaneous sound pressure within a specified time interval” (NOAA, 2013). As a result, understanding local bathymetric and oceanographic conditions is valuable for predicting the sound transmission properties of an area (Moore et al., 2012).

Both frequency and amplitude affects how sound propagates through seawater, as louder sounds and lower frequencies tend to travel further and more efficiently through water (Tyack, 2008). The location of the sound source and oceanic variables such as depth, temperature, salinity, surface and bottom characteristics (including whether the sound is produced in coastal or deep waters, or if sea ice is present), all influence sound propagation (Diachok, 1976; Firestone & Jarvis, 2007; Jasny et al., 2005; Mansfield, 1983; Tollefsen & Sagen, 2014). Seasonal variability of ice cover makes the Arctic marine soundscape especially complex (AMSA, 2009). Diachok (1976) noted that when sound interacts with the ice-water interface it can be reflected or scattered differently than sound propagation in ice-free waters. Mansfield

(1983) identified ways that sound radiating from a vessel could be attenuated by sea ice including absorption by sea water and the ocean bottom, and reflection from both the ocean bottom and under-ice surface. These papers reveal that in ice-covered waters more sound is reflected by the sea-ice interface than absorbed, which often results in sound travelling much further than it would in non-ice-covered waters (Diachok, 1976; Mansfield, 1983). This is an important consideration for the management of anthropogenic noise in the Arctic, as it demonstrates the need for Arctic specific guidelines and approaches to account for the presence and effects of ice.

Numerous other factors affect the way sound is transmitted, received, produced and experienced. Identifying whether a sound is pulsed (single or multiple brief broadband transient sounds such as explosions or seismic airgun sounds) or non-pulse (intermittent or continuous but constant sounds such as vessel noise or drilling), and the time scale or duration of a sound are all essential to understanding the effects that sounds produced by humans can have on cetaceans and how they can be measured and mitigated (Nowacek & Tyack, 2008; Southall et al., 2008; Stocker, 2007).

It is important to note that even in the absence of anthropogenic noise, the oceans are not silent but naturally quite noisy. There are physical and environmental sources of sound from wind, waves, tectonic activity, as well as biological sources such as crustaceans, fish and mammals (Firestone & Jarvis, 2007; Moore et al., 2012; Simmonds et al., 2004). Additional noise occurs in the Arctic due to the melting, cracking and breaking of sea ice (Moore et al., 2012). However, marine mammals have evolved with these natural ocean sounds and have not yet adapted to new and unfamiliar anthropogenic noises. Natural ocean sounds and anthropogenic noise must therefore be considered separately, as their effects on cetaceans are not comparable. Understanding this difference is important for the management and mitigation of anthropogenic noise in the Arctic marine soundscape (Dotinga & Oude Elferink, 2000; Heide-Jørgensen et al., 2013; Simard et al., 2010).

2.2 Cetaceans and Sound

As vision underwater is limited to tens of meters, hearing is the primary sense used by cetaceans because sound can be transmitted over hundreds to thousands of kilometers, especially at the low frequencies used by some whales (Agardy et al., 2007; Parks & Clark, 2008). Cetaceans rely upon sound for essential life functions such as communication, locating prey, avoiding predators, maintaining group cohesion and navigation (Moore & Huntington, 2008; Richardson & Würsig, 1997; Simmonds et al., 2004). Navigation using sound is of particular importance to Arctic cetaceans because of the added challenge of maneuvering around shifting sea ice, which can result in ice entrapment and possibly death (Heide-Jorgensen et al., 2013; NPC, 2012; QIA, 2012).

Marine mammals, and in particular cetaceans, are quite gifted at both generating and detecting sounds with their vocal range varying by sub-order and species (Moore et al., 2012; Simmonds et al. 2014; Southall et al., 2008). Toothed whales and dolphins (odontocetes) are able to produce moderate to very high frequency sounds in the 1-150 kHz range (Dotinga & Oude Elferink, 2000; Firestone & Jarvis, 2007; Richardson & Würsig, 1997). Baleen whales (mysticetes) produce intense, low frequency sounds usually below 1 kHz, generally ranging from 25 Hz - 25 kHz (Dotinga & Oude Elferink, 2000; Richardson & Würsig, 1997; Southall et al., 2008).

2.3 Arctic Cetaceans

The Canadian Arctic is home to three resident cetacean species, the bowhead whale (*Balaena mysticetus*), narwhal (*Monodon monoceros*) and beluga (*Delphinapterus leucas*) (Moore & Huntington, 2008; Reeves et al., 2014; Richardson & Würsig, 1997; Simmonds et al., 2004), as well as a few seasonal species including the fin whale (*Balaenoptera physalus*) (Simon et al., 2010), killer whale (*Orcinus orca*) (Westdel et al., 2013), humpback whale (*Megaptera novaeangliae*), minke whale (*Balaenoptera acutorostrata*) and gray whales (*Eschrichtius robustus*) (Moore & Huntington, 2008). The bowhead, beluga and narwhal are considered to be endemic to the Arctic region and as these cetacean species are found within waters of Nunavut, they are the focus of this paper (NPC, 2012; QIA, 2012; Reeves et al., 2014).

The beluga whale has a large range throughout Arctic and sub-Arctic waters of the northern hemisphere, with four distinct and independently managed populations occurring within waters of Nunavut (NPC, 2012; QIA, 2012): the Cumberland Sound, Eastern Hudson’s Bay, Eastern High Arctic/Baffin Bay and Western Hudson’s Bay populations (DFO, 2014; NEB, 2011; NPC, 2012). Currently, the Species at Risk Act (SARA) and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), have identified the Cumberland Sound Beluga population as threatened and the Eastern Hudson’s Bay population as endangered (COSEWIC, 2011; DFO, 2014; NEB, 2011). Beluga whales are known to have high site fidelity and seasonally return to the same areas every year, making it easier to track their migration patterns and major changes in behaviour, and therefore better inform management and mitigation strategies (NPC, 2012; QIA, 2012). This is particularly important for any coastal development that may overlap their summer range in shallow coastal waters, where they could be heavily affected by noisy development and human presence (NPC, 2012). The beluga whale is one of the most vocal marine mammals, with a wide range of calls in the 250 Hz to 13 kHz frequency range including communication calls such as whistles, yelps and growls to echolocation clicks that assist in foraging and navigation (Mansfield, 1983; Southall et al., 2008).

There are two populations of narwhal in the Canadian Arctic; the Baffin Bay and Hudson Bay populations, both found within the waters of Nunavut (NPC, 2012). Both populations have been identified as special concern by SARA and COSEWIC (DFO, 2014; NEB, 2011), in part, due to the “uncertainty in population numbers, trends, life history parameters and levels of sustainable hunting” (COSEWIC, 2011; NPC 2012). Narwhal also display high site fidelity, and are known to follow strict migration schedules, which puts them at high risk to anthropogenic noise and activities but is also advantageous for identifying important high-use areas for mitigation and management planning (Heide-Jorgensen et al., 2013; QIA, 2012). Canadian narwhal populations are concentrated within Baffin Bay and the surrounding waters, but in the summer months they tend to join the Hudson Bay populations within the internal waters of the Nunavut archipelago (DFO, 2010; Heide-Jorgensen et al., 2013). As a member of the odontocete family, narwhal are considered to be a mid to high-frequency vocalizing species with their communication calls and echolocation clicks range from 300 Hz to 150 kHz (Heide-Jorgensen et al., 2013; Mansfield, 1983).

Both the Hudson Bay/Foxe Bay and Davis Strait/Baffin Bay populations of bowhead whales in Nunavut have been classified as special concern by SARA and COSEWIC (COSEWIC, 2011, DFO, 2014; NEB, 2011). They are the only resident mysticete species in the Arctic region, with distinct Pacific and Atlantic populations (Moore & Gulland, 2014). Bowhead whales do not use echolocation, but produce two main types of calls generally ranging from 20

Hz to 2 kHz, with the simple moans occurring between 25-2000 Hz, and complex moans more concentrated in the 50-600 Hz range (Mansfield, 1983; NPC, 2012).

2.4 Sources of Anthropogenic Noise in the Arctic

One of the biggest challenges of studying and managing anthropogenic noise, is the wide range of human activities that produce underwater noise, whether deliberately or incidentally (Dotinga & Oude Elferink, 2000; Firestone & Jarvis, 2007; Romano et al., 2004; Simmonds et al., 2014). Not only are there numerous sources of anthropogenic sound, but the responses to, effects of, and mitigation options available vary substantially between types of noise (Moore et al., 2012; Richardson & Würsig, 1997). This section focuses on shipping and seismic surveys as they are currently the activities of most concern in the Arctic.

2.4.1 Shipping

Shipping is arguably the most harmful and disruptive anthropogenic noise in the world's oceans due to the sheer volume of vessels in the water (Hastie et al., 2014; Jasny, 2005; Moore et al., 2012; Simmonds et al., 2004). In the Arctic Ocean, commercial ships, tourist cruise ships, research vessels, military vessels, fishing fleets, recreational boats and ice breakers operate in the area throughout the year (Erbe, 1999; Huntington, 2009; Jasny, 2005; Simmonds et al., 2004; UNESCO IOC, 2010). As the Arctic becomes more accessible, the presence of ships is predicted to increase substantially, especially if the Northwest Passage becomes a viable option for shipping (Cosens & Dueck, 1993; UNESCO IOC, 2010). Additionally, increased presence of vessels requires the use of icebreakers to extend the shipping season beyond the ice-free summer months, which are noisier than typical vessels as breaking through sea ice is an incredibly loud activity (Erbe & Farmer, 2000; Mansfield, 1983).

The term ‘shipping noise’ typically refers to larger vessels such as shipping containers, cruise ships, supertankers and ice breakers, which contribute the most to anthropogenic noise levels (Jasny, 2005; UNESCO IOC, 2010). The majority of shipping noise is produced by propellers and a process called cavitation that involves the formation and subsequent collapse of bubbles underwater (Jasny, 2005; Mansfield, 1983; MEPC, 2010; Simmonds et al., 2004). Additional noise is created from machinery and engines, hulls moving through the water, and the use of sonar or depth sounders (Simmonds et al., 2004). Generally, the amount of noise a ship produces depends on a number of factors including the size of the ship, its load, speed, type of engine, and mode of operation (Dotinga & Oude Elferink, 2000). Faster, heavier, larger boats contribute more noise than smaller, lighter, slower travelling vessels (AMSA, 2009; Dotinga & Oude Elferink, 2000; Jasny, 2005). Most shipping noise is in the low-frequency range, below 1 kHz, with a source level amplitude between 152-190 dB re 1µPa (Firestone & Jarvis, 2007; Merchant, Pirotta, Barton & Thompson, 2014; Simmonds et al., 2004). In contrast, small leisure crafts generate noise in the mid-frequency range from 1 kHz to 50 kHz (Merchant et al., 2014; Simmonds et al., 2004). Although, Mansfield (1983) argued that the noise created by icebreakers breaking ice is no louder or devastating than noise caused by natural ice movement, ridging or cracking, in 1992 the Arctic Marine Shipping Act (AMSA) maintained that “compared to other vessels, icebreakers produce louder and more variable sounds”. Loud, low-frequency noise produced by ships cause masking effects (see Section 2.4) by contributing to background noise in the marine soundscape (AMSA, 2009; Parsons, 2012).

2.4.2 Seismic Surveys

Seismic surveys are typically conducted on behalf of oil and gas companies who are looking for fossil fuel deposits within the sub-sea rock strata of the ocean floor. This is achieved through use of high intensity, low frequency sounds (Simmonds et al., 2004; Weir & Dolman, 2007). These sounds are emitted from airgun arrays, aimed at the ocean floor, reflect off subsurface geological features and are then captured by an array of hydrophones at the surface. Seismic surveys involve at least one ship towing an array of airguns, as well as an array of receiving hydrophones. More recently, larger surveys involving multiple ships are becoming commonplace (Dotinga & Oude Elferink, 2000; NEB, 2011; Parsons et al., 2009). Sounds produced by seismic airguns tend to be lower in frequency with most acoustic output in the 10-300 Hz range (Parsons et al., 2009; Simmonds et al., 2004). Amplitude of airgun sounds typically range from 220-248 dB re. 1µPa @ 1m (Richardson & Würsig, 1997; Weir & Dolman, 2007).

Seismic airgun noise is concerning because of the great distance these high amplitude, low frequency sounds can travel. The range at which seismic surveys can be heard depends on the type and size of the survey (or the number of arrays), which affects the amplitude of the noise produced (Parsons et al., 2009; Simmonds et al., 2004). Some studies cited seismic sounds being detected 3000-5000 km from the source (Heide-Jørgensen et al., 2013; Moore et al., 2012; Parsons et al., 2009; Richardson & Würsig, 1997; Simmonds et al., 2004; Weilgart, 2007). This demonstrates how loud the noise created by seismic surveys is, especially large scale surveys with multiple airgun arrays. The great distances to which these powerful sounds can travel increases their potential to impact cetaceans, especially in Arctic waters where sea ice may be present, which would propagate airgun sounds even further (see Section 2.1).

2.5 Effects of Noise on Cetaceans

Categorization of anthropogenic noise impacts on cetaceans differs throughout the literature. Most categories use similar principles and this paper has adopted a combination of impact categories inspired by Erbe (1999), Gordon et al. (2004), Jasny (2005), Richardson & Würsig (1997) and Simmonds et al. (2004). These are behavioural, physiological, masking, chronic and environmental effects. In addition to discussing some of the potential effects under each of these impact categories, some observations and reports on the effects of and reactions to noise by belugas, narwhal and bowhead whales is included in this section (for a more complete listing, please refer to DFO 2015). The general challenges of studying, interpreting and understanding the effects of noise on cetaceans are also discussed.

2.5.1. Impact Categories

The behavioural effects of anthropogenic noise on cetaceans is difficult to measure, monitor, and observe because of the general challenges in studying cetaceans, but also because it requires an understanding of what constitutes normal or typical behaviour. Some changes are more obvious such as cessation of vocalizations, while others are more subtle such as changes in breathing and diving patterns (Gordon et al., 2004; Jasny, 2005; Simmonds et al., 2004; Southall et al., 2008). Vocalization patterns are relatively easy to monitor as some species tend to either compensate for the noise by altering their calling behaviour, or in the case of bowhead whales and narwhal, tend to fall silent (Heide-Jorgensen et al., 2013; Jasny, 2005; Moore et al., 2012; Tyack, 2008). Another major behavioural change is noise disturbance causing habitat displacement, which can have detrimental effects on population viability if activities such as breeding, nursing or feeding are disrupted (Jasny, 2005; Nowacek & Tyack, 2008; Romano et al., 2004; Weilgart, 2008).

Physiological impacts due to loud or continuous anthropogenic noise exposure include stress, reduction in auditory sensitivity/capability, damage to body tissue and even death (Erbe & Farmer, 2000; Gordon et al., 2004; Simmonds et al., 2004). The most significant and obvious physiological impact is damage to the ear resulting in a reduction in hearing capabilities and auditory sensitivity. Hearing damage is typically described as either a temporary or permanent threshold shift (TTS and PTS) (Jasny, 2005; McQuinn et al., 2011). TTS is the temporary reversible change in auditory sensitivity caused by exposure to a loud noise, while PTS is irreversible tissue damage from either prolonged exposure and repetitive TTS damage or exposure to a single, shorter noise event at a very high amplitude (Kastak et al., 1991; Southall et al., 2008).

Depending on the frequency and intensity of the anthropogenic noise, it may mask (or cover-up/drown-out) biologically important sounds if they overlap with the frequency band used by a cetacean species (Gordon et al., 2004; Simmonds et al., 2004). This can have significant impacts on important biological activities and result in population-level effects if cetacean cannot detect, interpret and respond to important sounds (Erbe & Farmer, 2000; Firestone & Jarvis, 2007; Gordon et al., 2004; Tyack, 2008). Therefore, masking is a major problem in the marine soundscape as ambient noise levels continue to rise globally, and is of particular concern in the Arctic region where increasing human presence is changing a relatively pristine soundscape.

Chronic effects on cetaceans are impacts resulting from long-term exposure to anthropogenic sounds, and can vary depending on occurrence, proximity, frequency and amplitude of the sounds to which they are exposed (McQuinn et al., 2011). Less attention has focused on chronic exposure and effects, as they require long-term study. Potential effects from chronic exposure include increased stress levels, habitat abandonment, masking and TTS or PTS

(Firestone & Jarvis, 2007; Weilgart, 2007). Habituation, adaptation, sensitization, and tolerance are all reactions cetaceans may have in response to chronic noise exposure (Gordon et al., 2004; Simmonds et al., 2004; Weilgart, 2007).

The indirect effects of anthropogenic noise on cetaceans include reduction in habitat quality through changing background noise levels. Protecting habitat is recognized as “one of the most effective means currently available for reducing the impacts of anthropogenic noise on marine mammals” (Williams et al., 2014). Gordon et al. (2004) highlighted how a reduction in prey availability can be related to habitat quality and therefore preserving habitat by reducing anthropogenic noise can also protect prey species abundance.

2.5.2. Observed Impacts on Arctic Cetaceans

A significant amount of research has focused on reactions of beluga whales to noise disturbance. There is a wide range of reported reactions from beluga whales to noise ranging from tolerance to extreme sensitivity (NPC, 2012; Richardson & Würsig, 1997). Part of this variance in reactions could be attributed to misinterpretation of data, lack of ability to track minute changes in behaviour, or reliance on the interpretation of models.

Simmonds et al. (2004) discussed how predictions made by propagation models proved to be inaccurate when belugas reacted to noises at distances much farther than were predicted by modelling. Acoustic data from belugas in captivity predicted that they could not hear a vessel approaching from over 20 km away (assuming a threshold of 104 dB re 1μPa at 1 kHz) (Simmonds et al., 2004), which has been proven inaccurate by a number of sources (Richardson & Würsig, 1997; UNESCO IOC, 2010). Jasny (2005) found that in the Arctic belugas move more than 50 miles away from vessel noise to escape the noise, and Richardson and Würsig (1997) noted that belugas reacted strongly to icebreakers within 35-50 km. In addition to displacement, these last two studies also reported behavioural changes such as changing call patterns, increased use of alarm calls, changed diving patterns, and rapid, erratic swimming away from the sound source (Jasny, 2005; NPC, 2012; Richardson & Würsig, 1997). It has been observed that belugas seem more sensitive to noise when near sea ice (Richardson & Würsig, 1997).

Narwhal are particularly sensitive to human disturbance. They are known to be easily disturbed by approaching boats and quite nervous around anthropogenic noise producing activities (Heide-Jorgensen et al., 2013). Although their reactions can vary, Jasny (2005) and the Nunavut Planning Commission (NPC) (2012) report that narwhal are unique from many other cetacean species because of their tendency to freeze in place and fall silent when confronted with noise or approached by vessels. It is also believed that they experience long-term displacement due to the presence of shipping vessels and anthropogenic noise, even at relatively low received sound levels (94–105 dB re 1 µPa; 20–1000 Hz) (Heide-Jorgensen et al., 2013). This is concerning because if anthropogenic noise causes narwhal to alter their migratory paths, they are put at risk of ice entrapment, or being confined to sub-optimal winter feeding areas (Heide-Jorgensen et al., 2013).

Much like the narwhal and beluga, reactions of bowhead whales to anthropogenic noise vary depending on the situation (Blackwell et al., 2015; Richardson & Würsig, 1997). Some studies reveal a lack of response by bowhead whales to anthropogenic noise; however, there is reason to believe that subtle responses are occurring, whether they are noticed or not (Richardson & Würsig, 1997). Obvious examples of avoidance or displacement cannot be the only measures used to reveal the negative effects of anthropogenic noise on bowhead whales, because slight changes such as shorter, shallow dives and altered respiration rates are still examples of behavioural change even if they have not yet been studied or confirmed (Gordon et al., 2004; Mansfield, 1983; Richardson & Würsig, 1997; Weilgart, 2007). Moore et al. (2012) expressed the concerns over the variability, lack of response and conflicting opinions, with the statement "there is still no consensus on whether, how, or to what extent marine seismic survey activities negatively affect the whales". Additional examples of behavioural disturbance include changes in calling patterns and social interactions. Blackwell et al. (2015) found that bowhead whales decreased their calling rates when in the vicinity of human made noise, especially when seismic surveys were being conducted nearby; and postulated that by falling silent, they reduce communications and can become separated.

2.5.3. General Challenges

A major issue in studying the effects of anthropogenic noise on cetaceans is the substantial uncertainty that exists. There is a tendency for noise impacts to be situation specific, with many variables influencing each individual case. This further complicates the study of the possible effects of anthropogenic noise on cetaceans. It is important to understand that research on a single individual animal, cannot be extrapolated to apply to the entire pod or species of cetaceans because they are generally not representative of the entire population or species (Weilgart, 2007). Additionally, auditory information obtained from studying cetaceans in captivity should not be used to influence policy on free-ranging animals because their situations are radically different. Living in captivity significantly affects the animal and they are not representative of their wild counterparts who have not been exposed to such concentrated levels of human presence and sound (Weilgart, 2007).

2.6 Mitigation Measures for Reducing Anthropogenic Noise Impacts

Having a general understanding the various types of mitigation approaches that exist to reduce the negative effects of anthropogenic noise on cetaceans, is critical for determining which measures are the most effective and realistic. To differentiate between the various approaches this section is divided into three categories: operational measures, source-based measures and geographical-based measures.

2.6.1. Operational

Operational mitigation measures are modifications to normal operating procedures of various activities to reduce or avoid environmental impacts. Some measures are more proactive in nature, such as regulating vessel speed or reducing the amplitude of sounds emitted, but most are more reactive (Simmonds et al., 2004; Simmonds et al., 2014). For example, many guidelines or regulations existing for seismic surveys could be considered reactive because activities proceed with normal operating procedure until a cetacean is sighted, and only then are a series of mitigation measures triggered (Erbe & Farmer, 2000; Dotinga & Oude Elferink, 2000; Jasny, 2005). The operational measures typically used for noise-producing activities such as seismic surveys and military sonar include ramp-up or soft-starts, shut-offs, establishment of safety zones, and thresholds for safety zones all of which require marine mammal observers (MMOs) and/or passive acoustic monitoring (PAM) (BOEM, 2012a; DFO 2007; JNCC, 2004). There is a general need to strengthen and standardize these mitigation measures and to critically evaluate their effectiveness (ASOC, 2005; Dolman, 2007).

Ramp-up or soft-starts are the gradual increase in sound level (e.g. of airgun sonar sounds) over a designated amount of time, so cetaceans have ample warning and time to leave the area before sound levels peak (Weir & Dolman, 2007). Though ramp-up makes sense theoretically, the effectiveness of this measure has never been proven (Jasny, 2007; Simmonds et al., 2014; Weilgart, 2007; Weir & Dolman, 2007).

An operational shut-down is an example of a reactive mitigation measure, where, specifically for seismic surveys, airguns are stopped as soon as cetaceans are spotted or detected within the safety zone (Weir & Dolman, 2007). How long the seismic surveys are halted generally ranges from 5-30 minutes, and some guidelines require a soft-start before resuming activities (Weir & Dolman, 2007). There is controversy and debate over the length of time activities must be halted to monitor the cetacean's movement, as well as the need to ramp-up before resuming operations, but overall this method is effective if detection rates are high (Weilgart, 2007; Weir & Dolman, 2007).

The safety zone is a pre-determined area around the noise source (e.g. the airgun array) where the amplitude and intensity of the noise is strongest and therefore could significantly impact any present cetaceans (e.g. cause physical damage). This area is closely monitored as the presence of cetaceans or any species of concern within the safety zone typically initiates a shut-down or reduction of power. MMOs and PAM are utilized to monitor the safety zone and report any sightings of cetaceans around or within the designated zone (Jasny, 2005; Weilgart, 2007). In theory this is a straightforward, intuitive mitigation measure; however, like the soft-start, there are uncertainties in the effectiveness of this method due to how the safety zone radius' is determined as well as how it is monitored an enforced. The safety zone radius may be set as a specific distance/range, or may be based on a threshold amplitude level for injury and harm (e.g., PTS/TTS – see Tables 3 and 4). Many policies have adopted safety zones at standardized distances or ranges, rather than a threshold amplitude level (Weir & Dolman, 2007), which many critics consider to be inadequate as these distances often seem obscure and do not take into account the specific sound source or propagation effects that will vary by region (Jasny, 2005; Weir & Dolman, 2007)

PTS and TTS thresholds are sometimes used to establish safety zone radius, providing a source specific mitigation plan. However, thresholds are primarily based on research done on captive bottlenose dolphins and belugas that has been extrapolated and applied to all other cetacean species (Southall et al., 2008; Weilgart, 2007). The science used to support these mitigation thresholds is questionable and needs further investigation (Compton, Goodwin, Handy & Abbott, 2008; Southall et al., 2008; Weilgart, 2007). In terms of monitoring the safety zone, detection rates of locating cetaceans, either visually or acoustically, are consistently low due to issues such as poor visibility (due to fog, high winds or low light), cetacean behaviours such as long, deep dives or a lack of adequate training or experience by the MMOs and PAM personnel (Heide-Jorgensen et al., 2013; Weir & Dolman, 2007). Guidelines that dictate the requirements for MMOs vary greatly by both region and activity, and influence the effectiveness of visual monitoring (Weir & Dolman, 2007). PAM can be used to supplement visual observations and provide an additional method of tracking cetaceans, but there are challenges specific to acoustic monitoring as well – for example, some cetacean species fall silent in the presence of vessels and anthropogenic noise and therefore cannot be acoustically monitored and tracked (Richardson & Würsig, 1997). There is value in using combined visual and acoustic monitoring techniques to increase detection rates and thereby improve management effectiveness (Weir & Dolman, 2007).

2.6.2 Source-Based

Source-based mitigation measures target the actual source of the sound and attempt to reduce or eliminate noise, either through reducing the overall noise levels or by reducing noise propagation (Jasny, 2005; Simmonds et al., 2014). Source-based mitigation is often viewed as the most effective method to reduce the negative effects of noise on cetaceans because it is easier to research and develop new technologies that reduce noise at the source, rather than modify operational measures which require a better understanding of both the auditory and behavioural thresholds for the species of concern (Simmonds et al., 2014; Weilgart, 2007). Simmonds et al. (2014) argues strongly that “limiting noise input reduces impacts on all vulnerable species, whereas spatial and temporal restrictions will only protect species with consistent and predictable distribution patterns” which requires detailed knowledge of the fine-scale distribution of species of concern).

To reduce noise at the source, the development and implementation of new quieter technologies is the main recommendation (Simmonds et al., 2014). For many human activities that contribute significant levels of anthropogenic noise into the marine soundscape, there exists alternative designs and technologies, but lack of awareness, lack of pressure to change and high economic costs are some of the barriers limiting the implementation of these alternatives (ASOC, 2005; Dolman, 2007; Simmonds et al., 2014; Weilgart, 2007).

There is great potential for source-based quieting of vessels because available noise-quieting technologies already exist and there is incentive to improve vessel efficiency as it also tends to reduce noise outputs (Jasny, 2005). For example, as propeller cavitation is the largest source of noise from vessels, by modifying the existing propellers or by fitting new propellers with a more efficient design, hydro-acoustic noise produced by a vessel can be reduced while increasing propulsive efficiency (MEPC, 2010).

Construction, whether on coastal or offshore projects, is an incredibly noisy and disruptive activity, and therefore efforts are being made to discover and implement new technologies or approaches to reduce construction noise (Jefferson, Hung & Würsig, 2009). A method used to reduce noise from construction activities such as pile driving or dredging, is a bubble curtain (Jefferson et al., 2009; Würsig, Greene & Jefferson, 2000). The bubble curtain surrounds the sound source and the release of bubbles creates a curtain like effect and greatly reduces the noise being propagated into the oceans (Jefferson et al., 2009; Würsig et al., 2000). Currently, bubble curtains are only useful for human activities that are relatively stationary and has not yet been adapted to mobile activities such as seismic surveys (Jefferson et al., 2009). Würsig et al. (2000) found that bubble curtains were able to lower noise levels within a 1km radius of the noise source, and reduced noise in the 400-800 Hz frequency range. This noise-quieting system obviously has great potential as a source-based mitigation measure and should be recommended in anthropogenic noise policies because of its effectiveness in reducing noise impacts from stationary sources of anthropogenic noise.

There has also been a significant development in technologies to replace seismic survey airguns called marine vibroseis because of its low peak amplitude, slow rise time and compared to airguns produces or emits less energy over 100 Hz (ASOC, 2005; Dolman, 2007; Simmonds et al., 2014; Weir & Dolman 2007). Further research needs to be done on this alternative technology before it is ready to replace airgun arrays, but with additional development has the potential to change the way seismic surveys are conducted in the future (Simmonds et al., 2014).

2.6.3. Geographical

Geographical mitigation measures include spatio-temporal approaches to reducing the effects of anthropogenic noise on cetaceans, such as the use of marine protected areas (MPAs), buffer zones and careful planning of routes and the location of activities (ASOC, 2005; Dolman, 2007; Simmonds et al., 2004). This requires substantial data on and detailed knowledge of the species of concern to inform the mapping of important habitat areas that may overlap with anthropogenic activities (Agardy et al., 2007). Being able to link what species will be where and at what time or season, is the most critical information needed to implement spatio-temporal restrictions or designations (Agardy et al., 2007; Jefferson et al., 2009; Williams et al., 2014). Geographical mitigation measures and restrictions are similar to source-based mitigation measures in that they both benefit more than the species to which the operational measures are restricted.

There is enough information to implement some spatio-temporal restrictions for Arctic cetacean species, but additional research providing detailed distribution and range information will improve the effectiveness of such measures (Agardy et al., 2007; Jefferson et al., 2009; Williams et al., 2014). This information could then be used to inform vessel route planning to avoid biologically important areas, and areas with a high risk of affecting cetaceans (Simmonds et al., 2004).

In addition to carefully planned routes, identifying areas of critical habitat and designating them as MPAs, (whether seasonally or permanent), is one of the most effective mitigation measures available to protect cetaceans and their critical habitat from cumulative effects of anthropogenic noise and other human stressors (Dolman, 2007; Simmonds et al., 2014; Weilgart, 2007). As MPAs can include or require buffer zones and limit levels of noise within their borders, this provides a safe zone for cetaceans and greatly reduces the negative effects of anthropogenic noise. The success of limiting anthropogenic noise in the MPA can be difficult to identify, implement, monitor and enforce because of the challenges in protecting an area without obvious borders, in remote areas, with limited resources and due to variability in sound propagation, noise frequency and amplitude.

3. Policy Analysis

The two objectives of this section were to first review policies related to the mitigation of anthropogenic noise impacts on cetaceans at the international and regional level (with a focus on Arctic and northern nations) to compare common strengths and weaknesses, gaps in coverage, and identify any major limitations to their success. Secondly, a comparative analysis of three national policies specific to the mitigation of seismic noise impacts on cetaceans (an issue of great concern in the Arctic) were reviewed to compare mitigation measures used, determine the more effective mitigation approaches and identify common issues or gaps. These analyses will be used to provide recommendations on the ideal mitigation and management policy on the effects of anthropogenic noise on cetaceans in the Arctic marine environment, at the international, regional and national level (Section 4)

3.1. Policies Relevant to the Management of Anthropogenic Noise in the Arctic

Due to the large scale of this topic, the number of organizations and governmental bodies that are involved at the international, regional and national levels, all with their own programs, guidelines and regulations, only a few select policies were used in this paper. These policies were chosen for a variety of reasons ranging from their relevance to the topic, accessibility of information and to provide a representative analysis. This means that many important policies, guidelines and organizations were excluded from this paper, and that this paper does not present a complete list and analysis of relevant policies. However, the chosen policies provide insight into the variety that exist at all levels, through different management approaches and with a range of objectives, power and effectiveness.

3.1.1 International

Three of the most relevant international organizations with policies applicable to anthropogenic noise impacts on Arctic cetaceans are the UNCLOS (United Nations Convention on the Law of the Sea), IMO (International Maritime Organization) and the IWC (International Whaling Commission). These international bodies represent a variety of interests but all have good member state participation or a globally representative membership (ASOC, 2005; Firestone & Jarvis, 2007; Moore et al., 2012; WWF, 2013). Regulation and management of anthropogenic noise has become a high profile issue about which these large international institutions and organizations are concerned (Scott, 2007).

3.1.1.1. United Nations Convention on the Law of the Sea

The UNCLOS is a "comprehensive regime of law and order in the world's oceans and seas establishing rules governing all uses of the oceans and their resources" (UNCLOS, 2013). This is an incredibly valuable tool because it is based on the premise that issues affecting our oceans are entirely transboundary and interrelated, therefore requiring a holistic and comprehensive management approach to cover and include the wide range of activities, maritime concerns and problems (UNCLOS, 2013). It is also important because UNCLOS includes the protection and preservation of the marine environment, and more specifically, marine pollution, as outlined in Article 1 (UNCLOS, 2013). This is a critical section, because the definition for pollution of the marine environment used by UNCLOS, includes "the introduction by man, directly or indirectly, of substances *or energy* into the marine environment" (UNCLOS, 2013, emphasis my own), which means that sound, a form of energy, is included. This is significant because it means that all the provisions and articles specific to the prevention, reduction and control of marine pollution are applicable to anthropogenic noise (Dotinga & Oude Elferink, 2000; Firestone & Jarvis, 2007; UNCLOS, 2013; Weilgart, 2007). The UNCLOS definition of marine pollution is precedent setting, and should be used to inform all similar documents and policies on their definition of marine pollution. UNCLOS is applicable to the topic of anthropogenic noise in the Arctic marine soundscape and cetaceans through three main articles: Article 234 - Ice-Covered Areas, Article 64 – Highly Migratory Species and 65 – Marine Mammals (UNCLOS, 2013).

3.1.1.2. International Maritime Organization

The International Maritime Organization (IMO) is the United Nations agency responsible for overseeing international shipping, safety, security and environmental concerns, by adopting treaties that are then signed and ratified by the national governments of member states (IMO, 2015; Williams et al., 2014; WWF, 2013). The IMO is a highly valuable organization because it addresses vessel noise and considers this issue to be a problem requiring policy guidance at the international and national level (Dotinga & Oude Elferink, 2000; IMO, 2015; Scott, 2007). Within the IMO, there is a Marine Environmental Protection Committee (MEPC) that have recently been working in collaboration with the United States on a draft document tentatively titled “Guidelines for the Reduction of Underwater Noise from Commercial Shipping” to address shipping noise pollution (Bahtiatian, 2015; IMO, 2008; Papastavrou, 2014). Until now, noise pollution has largely been neglected by the IMO, as only other forms of pollution were addressed by MEPC and the International Convention for the Prevention of Pollution of Ships, known as MARPOL (IMO, 2002). In 2002, the IMO adopted guidelines specific to the Arctic region and the unique challenges of shipping in ice-covered waters with the document “Guidelines for Ships Operating in Arctic Ice-Covered Waters” (IMO, 2002). Although these guidelines are specific to the Arctic region and ice-covered waters, and they do mention pollution throughout the document, they are quite general and do not include specific mitigation for noise pollution or cetaceans. The IMO is an example of an organization that could benefit from adopting the

UNCLOS definition of marine pollution to ensure that anthropogenic noise and its effects on cetaceans is sufficiently addressed.

3.1.1.3. International Whaling Commission

The International Whaling Commission (IWC) encompasses a wide range of threats to cetaceans beyond their original focus on whaling and are respected for their scientific research and contributions to the general understanding of cetaceans and anthropogenic threats (IWC, 2015). The Scientific Committee and the Standing Working Group on Environmental Concerns (SWGEC) have considered noise pollution as being of major concern to cetaceans since at least 1996 (Dotinga & Oude Elferink, 2000; Firestone & Jarvis, 2007; Simmonds et al., 2014). Originally their focus was on whale watching as a major contributor of anthropogenic noise impacting cetaceans, but in recent years they have broadened their research to include large-scale sound sources with larger impacts, such as military sonar and seismic surveys (ASOC, 2005; Dotinga & Oude Elferink, 2000; Firestone & Jarvis, 2007; IWC, 2015). The IWC Scientific Committee have recommended and encouraged geographic time/area closures, source-based ship quieting mitigation measures and further research into mapping cetacean soundscapes and habitats (IWC, 2015; Simmonds et al., 2014; UN, 2015). Although the IWC does not have any official policies or guidelines of their own, they do support significant and important research initiatives and are well-respected and involved in initiatives and work of other organizations (IWC, 2015; UN, 2015). For example, the IWC was involved in the Western Gray Whale Advisory Panel (WGWAP), which is an assemblage of independent scientists offering scientific advice and recommendations to Sakhalin Energy on their seismic survey operational plans and mitigation measures (IWC, 2015).

3.1.1.4. Policy Discussion

Table 1 summarizes the comparison between these three international organizations reviewed above, specifically noting the major differences between them as they vary in scale, goals and outputs. It is clear that the IWC is very different from the UNCLOS and IMO because they do not produce any guidelines, regulations or policies, but rather make mitigation suggestions based on scientific findings (IWC, 2015). However, it is interesting to note that although UNCLOS does include noise pollution, no specific mitigation measures are included for any forms of pollution (UNCLOS, 2013). Similarly, the IMO makes general references to pollution prevention within their Guidelines for Ships Operating in Arctic Ice-Covered Waters, but no specific mitigation measures are identified (IMO, 2002). Neither the IMO or UNCLOS specifically address anthropogenic noise and its effects on cetaceans in the Arctic marine soundscape (IMO, 2002; IMO, 2015; UNCLOS, 2013). While international organizations such as the IWC are identifying anthropogenic noise as a major concern within oceans, with potentially detrimental effects on cetaceans, the IMO and UNCLOS have been slow to actually implement noise specific guidelines, articles, treaties or policies (IWC, 2015). Overall, it would be advantageous if anthropogenic noise was formally acknowledged at the international level because of the trickle-down effect it would have on policies and guidelines regionally and nationally. Currently it is a stretch to say that UNCLOS has recognized noise as a major concern, but it does fall under their current definition of pollution and within some articles, which could lead to a more formal representation within the Law of the Sea. If UNCLOS provided this, then it would only benefit other organizations or bodies such as the IMO to encourage them to continue the discussion on anthropogenic noise and provide strategies for member states to utilize and follow. It would also provide some recognition to international bodies such as the IWC on the research they have done, their findings and recommendations.

3.1.2. Regional – the Arctic Council

The Arctic Council is a high level intergovernmental forum that was formally established in 1996 through The Ottawa Declaration, with the aim to promote cooperation, coordination and interaction among the Arctic States (AMSA, 2009), which includes Canada, Denmark, Finland, Iceland, the USA, Sweden, Norway and Russia (AMSA, 2009). Issues pertaining specifically to Arctic issues, such as indigenous communities, sustainable development, climate change and environmental protection, are the focus of the Arctic Council, and they have created a number of working groups to target specific issues. These include the Conservation of Arctic Flora and Fauna (CAFF), the Arctic Monitoring and Assessment Programme (AMAP), the Arctic Contaminants Action Program and the Protection of the Arctic Marine Environment (PAME) (AMAP, 2015; AMSA, 2009; PAME, 2009).

Although AMAP was established in 1991 with the main goal of monitoring pollutants and assessing their impacts on the Arctic region, as of 2015 energy or noise pollution is not included in their criteria (AMAP, 2015). Instead they focus on four classes of pollutants which are persistent organic pollutants (POPs), chemicals of emerging concern, heavy metals and radioactivity (AMAP, 2015). This presents a huge gap in the management and mitigation of anthropogenic noise pollution in the Arctic marine soundscape, as the main regional body does not include noise pollution within their definition of pollutants. The Arctic Council and AMAP should follow the lead of UNCLOS and widen their definition of pollution to include energy pollution (UNCLOS, 2013).

PAME is very relevant to the topic of how to manage and mitigate the effects of anthropogenic noise on cetaceans in the Arctic because of their mandate to "address policy and non-emergency pollution prevention" which includes "coordinated action programs and guidelines" (AMSA, 2009; PAME, 2009). The Arctic Marine Shipping Assessment (AMSA) is an example of a guideline made by PAME in 2009, which looked at the history of marine transport in the Arctic, the governing body's involved, environmental considerations and impacts, future scenarios and available infrastructure, and then made a series of recommendations based on those findings (AMSA, 2009). The document does make reference to anthropogenic vessel noise but does not offer any specific recommendations to mitigate the effects on cetaceans in the Arctic marine soundscape (AMSA, 2009). In the governance section, the AMSA discusses some of the international bodies that they work with and under, such as the IMO and their 'Guidelines for Ships Operating in Arctic Ice-covered waters" document (AMSA, 2009). However, as previously discussed, this document itself does not have specific mitigation to offer in terms of anthropogenic noise pollution (IMO, 2002).

PAME also has Arctic Offshore Oil and Gas Guidelines (AOOGG) (PAME, 2009) which encourages the use of the best current standards and practices during the planning, exploration, development, production and decommissioning phases of oil and gas development practices (PAME, 2009). Although they identify some recommended practices and responsible regulations, such as environmental monitoring and appropriate operating practices, they also stress that these guidelines are non-binding and entirely voluntary (PAME, 2009). The AOOGG states that the effects of all sources of noise, including seismic, vessels, drillships and ice-breaking equipment need to be assessed for their potential impacts on marine mammals and other marine animals, but does not describe how that should be done. The guidelines discuss the importance of establishing monitoring standards and practices for all phases of oil and gas activities, including seismic exploration and make some general suggestions such as the importance of long-term monitoring, baseline surveys and considering local indigenous populations. However, it also emphasizes how specific requirements for monitoring "should be defined in each country's legal and regulatory framework" (PAME, 2009). This emphasizes the need for international and regional bodies to create minimum standards to ensure consistency between nations in the level and quality of management and mitigation being implemented and enforced.

Under PAME, the Arctic Council has also introduced the Framework for a Pan-Arctic Network of MPAs with the aim of improving the management of these valued ecological areas of major cultural significance (PAME, 2015). By establishing MPAs or other area-based conservation measures throughout the Arctic region the use of geographical or time-area mitigation measures can be more easily applied. Some of the important features they list as needing or requiring protection and management that are particularly relevant to anthropogenic noise in the Arctic marine soundscape include, "critical habitat of endangered and threatened species", "areas important for migratory species" and "areas of high species and/or habitat diversity" (PAME, 2015).

The Arctic Council has significant potential to address and mitigate the effects of anthropogenic noise on cetaceans in the Arctic through the establishment of detailed guidelines specific to this issue, and by encouraging all member states to adopt these recommendations into legislation. The Arctic Council is able to take on a larger role, with a more focused emphasis on the issue of anthropogenic noise than any international bodies such as UNCLOS and the IMO because of their smaller management area and small number of member states. This is advantageous because it allows them to follow the recommendations of these international bodies, but to then add additional measures that are especially beneficial and relevant to the Arctic region. There is also the opportunity for collaboration between the various bodies and groups within the Arctic Council and the IMO or IWC for research initiatives and management projects.

3.1.3. National

3.1.3.1. Canada

Within Canada, Environment Canada has lead responsibility over the SARA, with the exception of when aquatic species are involved and jurisdiction then shifts to the Department of Fisheries and Oceans (DFO) (DFO, 2014). The SARA was officially enacted in 2004 when "it became illegal to kill, harm, harass, capture, or take any endangered or threatened species protected under the Species at Risk Act" (DFO, 2014). It is also illegal under the SARA to destroy the critical habitat of species at risk (SAR) and the SARA can impose certain restrictions, limitations and conditions on development and construction projects to protect and preserve the habitat of these endangered or threatened species (DFO, 2014). Any activity which negatively affects an area of critical habitat and therefore reduces the ability of a SAR to recover or survive is considered destructive, and this includes noise disturbance in critical habitat areas when the background noise is dramatically altered (DFO, 2015b; EC, 2004). Unfortunately, no areas of critical habitat have been officially recognized within the Canadian Arctic, although some important feeding, breeding and nursing areas, and major migration routes for bowhead, beluga and narwhal are known. The lack of designated critical habitat in the Arctic is a major limitation in the regulation of anthropogenic noise for these at risk species, despite the obvious benefits and significance to the species from being designated by the SARA. If critical habitats are identified for endangered and threatened populations (e.g., the Cumberland Sound and Eastern Hudson's Bay beluga populations), noise produced by shipping and seismic survey activities in the Arctic that alter the critical habitat in such a way that the population can no longer access/use it, will be prohibited under the SARA. There are exceptions to this law, but these activities require approval from the Minister of Fisheries and Oceans to proceed and typically include stipulations (DFO, 2014).

Also falling under the jurisdiction of DFO, is the Marine Mammal Regulations (MMR) under the Fisheries Act (DFO, 2015a). The MMR applies to “the management and control of (a) fishing for marine mammals and related activities in Canada or in Canadian fisheries waters”, and specifically addresses the hunting of beluga, narwhal and bowhead whales in the Arctic, as they are the only cetacean species hunted in Canada (DFO, 2015a). Under the MMR Prohibitions, it is illegal for people to disturb, attempt to kill or fish for a marine mammal unless they are authorized to under the MMR, or are qualified and capable of doing so to ensure humane and ethical practices are upheld (DFO, 2015a). Although relevant to the management of Arctic cetaceans, it is less applicable overall to the management of anthropogenic noise and its effects on cetaceans than the SARA or policies such as the Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment (SOCP) (see Section 3.3.1).

3.1.3.2. United States of America

Within the USA, there are two main acts that are applicable to the effects of anthropogenic noise on cetaceans: the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA) (Moore et al., 2012). The MMPA has protected marine mammals since 1972 by prohibiting the harassment, capture or killing of any marine mammal, while the ESA, established in 1973, specifically protects threatened or endangered species (NOAA, n.d.-a) The SARA and MMR in Canada are comparable to the ESA and the MMPA in the United States.

The USA has identified specific sound exposure level thresholds for injury (PTS conservatively based on TTS, also referred to as Level A harassment), and behavioural disturbance (referred to as Level B harassment) for impulsive and non-pulse noise in the “Interim Sound Threshold Guidance”, provided in Table 2 (NOAA, n.d.-b). Newly proposed thresholds for PTS and TTS meant to replace these interim thresholds for Level A harassment are based on the most recent and best available science for specific marine mammals hearing groups and both impulsive and non-pulse sounds in the (Draft)” Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammals: Underwater Acoustic Threshold Levels for Onset of Permanent and Temporary Threshold Shifts” document (Table 3; NOAA, 2013; NOAA, 2015). Until NOAA finalizes this new guideline, the conservative thresholds from the Interim guide are used to reduce disturbance, injury and death to cetaceans from anthropogenic noise in the marine environment through permit conditions and limitations (NOAA, n.d.-b; NOAA, 2013; NOAA, 2015). These thresholds are used in MMPA and ESA permits and authorizations such as the ‘Incidental Harassment Authorization’ which identifies the level (see Table 2) of incidental marine mammal harassment an activity (such as military sonar or training exercises, seismic surveys, construction or research) is allowed and includes a series of conditions that must be followed (Golde, 2013). A safety or exclusion zone is calculated based off of the sound exposure threshold levels, creating a geographical and operational mitigation measure specific to the particular scenario, thus requiring companies to take into account the effects of anthropogenic noise (Golde, 2013). These PTS thresholds also have been used to determine a more conservative safety zone radius for some seismic surveys occurring in Canadian waters, including the Beaufort Sea, in recent years (DFO PS, 2015)

3.2. Policies Related to Reducing Seismic Noise Impacts in the Arctic

Seismic survey policies will receive additional attention in this section of the policy analysis because unlike other sources of anthropogenic noise (such as shipping), several countries have established policies consisting of specific mitigation measures to reduce the impacts of seismic airgun noise on marine mammals. Seismic survey policies from Canada, as well as the UK and the USA are examined and compared.

3.2.1. Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment

The Canadian policy that focuses exclusively on the issue of managing and mitigating the effects of anthropogenic noise in the marine soundscape on marine life, is the Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment (SOCP) established in 2007 (Table 5) (DFO, 2007). Although the SOCP offers some guidelines to mitigate the effects of seismic surveys on marine mammals, there are concerns over the effectiveness of this policy. Research done by DFO (2015) states that “the ability of the SOCP to address potential “harm” or “harassment” of individuals that may occur at greater ranges from the sound source, or “destruction” of critical habitat, is limited” (DFO, 2015b). Williams et al. (2014) also argued that there are serious limitations to the SOCP in its ability to protect endangered species and critical habitat, and that the SARA could benefit from “clearly defined limits to the level of noise that defines ‘destruction’ of ‘critical habitat’”.

Canada has yet to identify such thresholds for impacts on cetaceans, (or to establish any sound exposure thresholds for noise producing activities as the USA has done – see Table 2 and 3). DFO (2015b) did argue that identifying auditory and behavioural threshold levels cannot be done because too much uncertainty exists to confirm such a standard. This is a reasonable argument because there are large knowledge gaps in the understanding of how cetaceans react or respond to anthropogenic noise (e.g., see Section 2.4.2), but also reinforces the importance of the precautionary approach and strict, clearly outlined and all-encompassing mitigation measures.

Williams et al. (2014) discuss how the requirements and mitigation measures listed in the SOCP are quite generic and are (almost) entirely operational measures, without real reference to time-area or geographic mitigation measures (DFO, 2007; Williams et al., 2014). The only mitigation measure that could be considered as source-based mitigation is under the "Planning of Seismic Surveys" section, where it is stated that "Each seismic survey must be planned to a. use the minimum amount of energy necessary to achieve operational objectives" and "c. minimize the amount of energy at frequencies above those necessary for the purpose of the survey" (DFO, 2007). Similarly, the only section that includes geographic mitigation measures is also under the "Planning Seismic Surveys" section, where it addresses the importance of planning to avoid the displacement of marine mammals from breeding, nursing or feeding, and avoiding diverting migratory species from known migratory routes or corridors (DFO, 2007).

The requirements outlined in the SOCP are specified to be minimum standards, and it is explicitly stated within the SOCP that people or companies "may be required to put in place additional or modified environmental mitigation measures" according to the recommendations outlined in the project environmental assessment (DFO, 2007). Thus, the SOCP does provide flexibility to add in additional source-based and geographic mitigation measures or modified measures, but nowhere within the SOCP are the possible additional or modified mitigation measures listed Potential additional mitigation measures are outlined in the 'Review of Mitigation and Monitoring Measures for Seismic Survey Activities in and near the Habitat of Cetacean Species at Risk' (DFO, 2015b). The challenge of managing anthropogenic noise in the marine soundscape and its effects on cetaceans is that every case and situation is different and therefore, each project proposal must be considered individually (Williams et al., 2014). In this regard, having a generic, minimum standard of practice, with the option of additional measures to “achieve an equivalent or greater level of environmental protection” (DFO, 2007), is a respectable management plan. However, it needs to be combined with strict, clear and precautionary guidelines, with the alternative or additional measures explicitly stated and explained including what type of situations they may be used or applied, and what combinations of tactics should be used.

Another weakness of the SOCP is that it does not include any monitoring or enforcement strategies for ensuring compliance (Williams et al., 2014). As well, the SOCP does not provide enough detail for legitimate and consistent enforcement of the mitigation requirements for example, details about the number of MMOs required per ship, level of training, length of shifts or rules for adverse weather or nighttime are not provided (DFO, 2007). There is also a lack of scientific evidence or justification to support some measures; for example, it is not clear why a safety zone radius of 500 m is specified (DFO, 2007).

It has also been recognized that combinations of mitigation measures will be “more effective than any one measure on its own” (DFO, 2015b) and that redundancy is advantageous and beneficial.

While the National Energy Board (NEB) claims that the SOCP was “developed based on available scientific knowledge and can be considered to be the current best practice for minimizing potential adverse impacts of seismic activity” (NEB, 2015), many other sources argue otherwise (ASOC, 2005; Dolman, 2007; Jasny, 2005). The SOCP should be updated to match current scientific knowledge. There is currently a movement away from operational measures towards incorporating source-based and geographical mitigation measures into anthropogenic noise guidelines, which would all contribute to reducing the effects of noise on cetaceans.

One highly significant limitation of the SOCP in terms of its applicability to the Arctic is that it clearly states that the mitigation requirements only apply to non-ice covered marine waters in Canada (DFO, 2007). While it is not clear if this only includes areas with year-round ice presence or if winter ice presence, or areas of with seasonal pack ice, are also included, it is clear that this leaves a significant gap in mitigation requirements for the Arctic.

3.2.2. BOEM Notice to Lessees – Implementation of Seismic Survey Mitigation Measures and Protected Species Observer Program

The Bureau of Ocean Energy Management (BOEM) is the organization responsible for setting the specific criteria associated with lease agreements to extract oil and gas in the USA. The USA is different from Canada in that they do not have a single, specific guidance document for seismic survey operators to reference, but instead have regularly updated documents outlining mitigation requirements that apply to all lessees and operators (BOEM, 2012a). The first Notice to Lessees (NTL) providing seismic survey mitigation measures was implemented in 2002, updated in 2003, 2004, 2007 and most recently in 2012, as the NTL No. 2012-G02, ‘Implementation of Seismic Survey Mitigation Measures and Protected Species Observer Program’ (see Table 5) (BOEM, 2012a; BOEM, 2012b). One of the major strengths of this document, is that an updated version is released every few years, which allows new types of mitigation measures to be introduced or previous mitigation measures to be clarified (BOEM, 2012b). This is highly advantageous over documents such as the SOCP, which is more challenging to update, making it less effective and more likely to be out-dated.

3.2.3. JNCC – Guidelines for Minimising the Risk of Injury and Disturbance to Marine Mammals from Seismic Surveys

Within the United Kingdom, a statutory conservation agency, the Joint Nature Conservation Committee (JNCC) was responsible for creating a guideline for seismic survey operators "aimed at minimising the risk of acoustic disturbance to marine mammals" titled "JNCC Guidelines for Minimising the Risk of Injury and Disturbance to Marine Mammals from Seismic Surveys" (JNCC, 2004; Table 4 and 5). The JNCC Guidelines are quite comparable to the Canadian SOCP in that they both focus almost entirely on operational mitigation measures such as the soft-start, delay, MMOs and PAM, with the only real reference to source-based mitigation being the goal of "keeping noise levels at lowest practicable levels" (JNCC, 2004). The JNCC does; however, go into more detail than the Canadian SOCP, and state that they favour a precautionary approach (JNCC, 2004; Parsons et al., 2009). A major advantage of their guideline is that there is great detail about the MMO requirements including required courses, the number of MMOs required and a chart identifying the four main marine areas in the UK and their specific sensitivities, which affects the MMO requirements for that region (JNCC, 2004; see Table 4).

3.2.4. Comparison of Seismic Survey Policies

As revealed in Table 5, Canada's SOCP appears to be a weaker policy when compared to the USA's BOEM and the UK's JNCC because of its lack of detail and explanation around the mitigation measures provided. The Canadian SOCP has yet to undergo any significant updates to the document, unlike the JNCC and BOEM, which have both undergone review and updates (BOEM, 2012a; DFO, 2007; JNCC, 2004). Overall the BOEM provides the most detail of all three documents (BOEM, 2012a).

The SOCP, BOEM and JNCC policies are generally comparable in terms of the standard operational mitigation measures that they all utilize such as the soft-start, safety zone, shut-down and MMOs, but it's the additional information offered in the BOEM that makes it stand out. Another example in the range of quality between these documents is that the SOCP does not require any reporting while the JNCC and BOEM require reporting on any marine mammal sightings, technical information (number of airgun arrays and vessels, firing interval, total volume, etc.) and general comments (BOEM, 2012a; DFO, 2007; JNCC, 2004). Although none of the policies explicitly include geographic or source-based mitigation measures, vague references to critical or sensitive habitats in the planning stages are made in the SOCP and BOEM, while the JNCC includes specific area sensitivities with corresponding MMO requirements (Table 4) (BOEM, 2012a; DFO, 2007; JNCC, 2004).

Specifically focusing on the SOCP and BOEM, both documents include many of the same elements within their policies and generally have similar mitigation measure approaches, but the BOEM is much more thorough and detailed than the SOCP. For example, both the SOCP and BOEM have the same basic requirements for safety zone ranges, soft-starts, shut-down and MMO, but for each of those measures, BOEM goes into additional detail that SOCP doesn't include (BOEM, 2012a; DFO, 2007). While the SOCP does mention the SARA, it does not provide detailed information, while the BOEM describes how the MMPA and ESA are included in the MMO training course (BOEM, 2012a). The BOEM also has auditory and behavioural thresholds (see Table 2 and 3) which inform the safety zone radius being monitored by the MMOs with a minimum range of 500m, while the SOCP has no thresholds and relies on the generic 500m safety zone range (BOEM, 2012a; DFO, 2007).

Details about MMO requirements are valuable for ensuring a standard level of quality in visual observation and Canada could benefit from adding additional MMO requirements like those included in the JNCC and BOEM policies (BOEM, 2012a; DFO, 2007; JNCC, 2004). The SOCP could also be modified to include geographical cetacean distribution and bathymetric information for the Arctic region and incorporate information about general regional sensitivities, similar to the JNCC table (Table 4). The regional sensitivities would need to be done at a much larger, broader scale due to the considerable difference in scale between the UK and Canada, but the general idea is still applicable. Canada could also obtain valuable information from requiring all seismic survey activities and MMOs to report on significant cetacean sightings and the subsequent response efforts, as the JNCC and BOEM require, to track distribution, ranges and responses (BOEM, 2012a; DFO, 2007; JNCC, 2004).

3. 3. Major Gaps Identified

The main limitation in the management and mitigation of anthropogenic noise impacts on cetaceans is that there is no comprehensive, all-encompassing international law, agreement or regulation specific to anthropogenic noise (Firestone & Jarvis, 2007; Jasny, 2005). This is problematic because anthropogenic noise in the marine soundscape is inherently a transboundary problem that crosses multiple jurisdictions and regions of the world's oceans, and impacts cetaceans that are often migratory species themselves (ASOC, 2005; Dotinga & Oude Elferink, 2000; Jasny, 2005; WWF, 2013). As this problem must be dealt with at the global level through international cooperation and coordination (ASOC, 2005; Firestone & Jarvis, 2007; Simmonds et al., 2014).

Currently, due to a lack of coordination between nations, there are major inconsistencies in the management and mitigation approaches being used. Implementing and enforcing an international law to oversee and guide the regulation of anthropogenic noise impacts on cetaceans will help ensure consistency in management practices and mitigation measures used (Weir & Dolman, 2007). Development of a standard international minimum best practice would ensure that all nations have the same basic level of management, mitigation and enforcement. Such a standard would allow for enhanced or additional mitigation measures to be utilized on a case-by-case basis or through national or regional guidelines or policies (Weir & Dolman, 2007).

Another issue with migration and management policies is that guidelines such as the SOCP or IMO treaties are entirely voluntary, and are not mandated by law unless a country chooses to ratify them into their legislation (Dotinga & Oude Elferink, 2000; Williams et al., 2014). Voluntary guidelines are still useful as they often hold significant weight and can be enforced through other channels (as seen in the policy review), but legally binding international regulations would be ideal.

4. Recommendations

There are two guiding principles that should be at the foundation for all management and mitigation policies for anthropogenic noise impacts on cetaceans in the Arctic marine soundscape: the precautionary principle and the use of policies informed by science (Williams et al., 2014). Based on the 1992 Rio Declaration on the Environment and Development the precautionary principle ensures that "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (Gillespie, 2007). This ensures that despite lack of scientific certainty and complexity of issues, it is better to proceed with caution and allow the development or activity to continue with precautionary restraints or limitations in place to reduce any potential detrimental effects (Gordon et al., 2004; Simmonds et al., 2004). Gillespie (2007) also stresses the importance of transparency in management and mitigation policies, to ensure accountability is maintained. This is especially important due to the challenges in monitoring and enforcing anthropogenic noise mitigation measures (Dotinga & Oude Elferink, 2000; Simmonds et al., 2004). As both the precautionary principle and science-based decision-making are critical to the management and mitigation of anthropogenic noise in the Arctic and are currently lacking in Canadian policies such as the SOCP, recommendations on how to best incorporate them into policies and guidelines at the national, regional and international level are made in the following sections (Figure 1).

4.1 Policy & Management

4.1.1. International

Collaboration and cooperation at the international level is essential for addressing the effects of anthropogenic noise on cetaceans in the Arctic. There is great interest and support from a variety of different organizations at both the international level (such as the IMO and IWC Scientific Committee), as well as at the regional level (like the Arctic Council). As discussed above, policies at the international level provide little guidance on specific mitigation measures for member states to follow, and as this is a transboundary issue, a minimum global standard of practice for noise-producing activities such as seismic or shipping, based on precautionary mitigation measures would be valuable (Reeves et al., 2014; Simmonds et al., 2014). The global minimum standard could address the issue of anthropogenic noise from all three mitigation approaches and consider how countries could easily, effectively and realistically incorporate source-based, operational and geographic measures. For example, minimum noise standards for all newly built shipping containers or military vessels or minimum standards and requirements for MMOs.

A major issue with mitigation and management policies related to transboundary issues and, in particular, the oceans, is that guidelines (such as the SOCP or IMO treaties) are entirely voluntary and not mandated by law, unless a country chooses to ratify them into their legislation (Dotinga & Oude Elferink, 2000; Williams et al., 2014). By also encouraging any international minimum standard to be enforced internationally, regionally and nationally, compliance would be improved (Compton et al., 2008; Jasny, 2005). It would also be advantageous to incorporate the precautionary principle and science-based decision-making into international policies as they set the global standard and must lead by example.

The IMO is a good example of an organization that has the power to encourage and assist in major changes that will benefit cetaceans and reduce the negative impacts of anthropogenic noise. By identifying 'Areas to be Avoided', encouraging quieter propellers or by enforcing speed restrictions, the IMO could have major influence on the use of operational, geographic and source-based mitigation measures for reducing shipping noise impacts worldwide (Agardy et al., 2007; Scott, 2007). This reinforces the importance of international collaboration and cooperation in handling mitigation measures to protect cetaceans from anthropogenic noise. As previously mentioned, they do have 'Guidelines for Ships Operating in Arctic Ice-Covered Waters', which acknowledges that there are unique challenges that vessels face when travelling through the Arctic, but this would also be a convenient document to address shipping noise and provide a few mitigation recommendations.

4.1.2. Regional

As the main regional body for the Arctic region, the Arctic Council should continue to develop policies and acts specific to the unique challenges of the region (AMSA, 2009). Creating a unified and consistent management plan with Arctic-specific mitigation measures to address anthropogenic noise would be valuable. Certain measures that are common in many noise mitigation policies would be included, but to address Arctic specific challenges and issues, such as ice, they could be made more precautious. For example, the safety zone for seismic surveys would be much larger than the average zone utilized in more southern regions, this would address both the extra sensitivity of Arctic cetaceans, but also the potential for any ice to propagate the noise much farther. Just as oil and gas spill policies are much stricter in the Arctic to compensate for uncertainty, remoteness and uncertainty, noise policies could do the same. Furthermore, including noise or energy pollution in the Arctic Council Action Plan to Eliminate Pollution (ACAP) within AMAP would be advantageous (AMAP, 2015; Dotinga & Oude Elferink, 2000; UNCLOS, 2013).

4.1.3. Canada

The primary recommendation for Canada is to use the precautionary principle and scientifically informed decision-making to guide policies related to reducing the effects of anthropogenic noise on cetaceans in the Arctic. Guidelines such as the SOCP would benefit from more conservative mitigation measures (especially in the Arctic region) such as increasing the safety zone radius to account for ice effects on noise propagation or requiring both MMOs and PAM to be monitoring at all times (Williams et al., 2014).

Incorporating all three types of mitigation measures (operational, source-based and geographic) into policies and guidelines would create strong, effective and precautionary management plans. More attention should also be given to species at risk and their critical habitat and recovery plans to ensure that any seismic survey or anthropogenic noise policies incorporate SARA requirements and guidelines. It would be beneficial to develop a geographical organization chart for shipping and seismic activities similar to the one provided in the JNCC seismic survey guidelines (JNCC, 2004; Table 4). This chart organizes the coastline into different regions, outlines the unique characteristics of each area, and then identifies the specific mitigation measures that should be used to accommodate any regional sensitivities (JNCC, 2004). This type of chart is useful because it provides accurate and detailed regional knowledge and makes it readily available to stakeholders and policy makers. There are a number of ways that the Arctic region could be divided, such as using the Large Marine Ecosystems (LME's) divisions (PAME LME, 2015), the Canadian Arctic bioregions divisions (DFO, 2011) or Parks Canada's National Marine Conservation Areas (Parks Canada, 2010). This Canadian Arctic regional chart could include critical information such as: identifying what endangered species are found in the area, at what time of year they occur there and for what purpose, if there are critical habitats or MPA's and typical seasonal ice conditions. Scientists and policy makers could use this kind of information to outline specific and accurate geographic time-area mitigation measures.

Geographic mitigation measures are applicable to a wide range of anthropogenic activities and are currently underutilized in anthropogenic noise mitigation policy. WWF (2013) states that MPAs are the best option for protecting marine life from the negative effects of anthropogenic noise, and that although there are a number of different ways to establish protected marine areas within Canada (including National Wildlife Areas, Marine Protected Areas and National Marine Conservation Areas) they all accomplish a similar goal (WWF, 2013). The establishment of protected marine areas within the Arctic with specific noise regulations would help preserve the critical, productive and sensitive marine habitats important to cetaceans (ASOC, 2005; Firestone & Jarvis, 2007). Additional knowledge of where beluga, narwhal and bowhead whales occur within the Canadian Arctic at different times of the year and their activities (breeding, nursing, feeding, etc.) would be beneficial in the designation of critical habitat and MPAs (Weir & Dolman, 2007). Although, it could be argued that to a certain extent, there is currently enough information on their behaviour such as whether they prefer shallow or deep waters, if they display high site fidelity, and their specific seasonal migrations to implement some areas of critical habitat or marine protected areas and it is political will that is lacking.

For activities such as seismic airgun mitigation, operational measures are the most commonly used measures, likely because they are easily implemented and enforced. Such measures do not require significant amounts of new research, investment in new technologies or upgrading of old systems and therefore are considered more cost effective by companies. Understandably, cost must be considered when creating or updating policies; but the risks associated with continuing to utilize less effective measures within their guidelines must be considered. Incorporating operational, source-based and geographic mitigation measures into policy development is the most effective and precautionary management option and will be discussed in the following sections within the context of shipping and seismic survey policies (see Figure 2 and 3).

4.1.3.1. Shipping

The ideal Canadian shipping policy would focus on source-based mitigation measures to reduce the negative impacts that shipping noise can have on the Arctic marine environment. Currently, Canada does not have their own Arctic specific shipping policy, but as members of the Arctic Council, they do have the guidance of the Arctic Marine Shipping Act (AMSA). Canada could benefit from combining the main principles and ideas from the AMSA with additional measures unique to the Canadian Arctic, to create a progressive policy to phase out old noisy equipment over a structured timeline (Stocker, 2007). One key component of a progressive policy is the recognition and acceptance that no policy is forever permanent, and it will require frequent reassessment and updating to keep up with new research and technology, emerging trends and political will. This will also require collaboration with the IMO and UNCLOS to add international authority to encourage compliance by foreign vessels (Scott, 2007). Generally speaking, the shipping industry is in favour of reducing noise pollution, in part because these changes often improve vessel efficiency and therefore reduce operating costs (Jasny, 2005; MEPC, 2010). However, their support is limited by the high costs of updating or replacing old, noisy parts (Jasny, 2005; MEPC, 2010).

Legislation should provide incentives to phase out noisy equipment on older vessels, while requiring new vessels to meet a targeted operational quietness (Stocker, 2007). As the main source of vessel noise is due to propeller cavitation, policies should first provide incentives to install propellers with improved design to reduce cavitation noise (MEPC, 2010). It is important to be realistic in the progressive legislation time line, as well as the feasibility and trade-offs in the quieting technologies being recommended or required by the policy (Reeves et al., 2014). But as these technologies do exist, and anthropogenic noise from shipping (especially from large cargo vessels) is considered to have negative impacts on cetaceans there is an urgent need to encourage vessel owners to make the necessary changes (Dolman, 2007).

The main operational mitigation measure relevant to shipping that should be included within a Canadian Arctic shipping policy is to reduce vessel speed through sensitive habitats because this greatly reduces the amount of noise the large cargo ships produce and can also reduce the number cetacean deaths due to ship-strikes (Laist, Knowlton & Pentleton, 2014; MEPC, 2010; Simmonds et al., 2014).

4.1.3.2. Seismic

The main recommendations regarding seismic activities in Canada is that the SOCP either needs to be updated to include measures for the Arctic and ice-covered waters, or a separate policy for the Arctic needs to be created. For example, the Canadian Territories could implement their own version of the SOCP specific to the unique challenges and requirements of the Arctic. The precautionary principle is not prevalent in the SOCP, and should be the guiding principle when discussing the risks of anthropogenic noise in the Arctic marine soundscape and how to best mitigate impacts. However, even if the creation of an Arctic specific SOCP is the main goal, improving or updating the current SOCP to at least match the standards of the USA and UK policies should be a priority.

Currently, the majority of mitigation measures included within the SOCP are operational guidelines, some of which are ineffective. This goes against both the precautionary principle and informed decision-making principle. To fully embrace the precautionary principle, the SOCP should also include geographical and source-based mitigation measures. As some of the short-comings of the SOCP have already been discussed in the Section 3.3, possible improvements will be discussed here.

Lack of detail is perhaps the most significant issue with the SOCP, especially for MMOs and PAM, both of which are critical to the success of operational mitigation. Canada should outline specific MMO guidelines and requirements similar to the JNCC and BOEM (see Table 5) to ensure high detection rates, fair working conditions and competent, knowledgeable staff. It would be valuable for Canada to create a course to educate and certify experienced MMOs as being qualified to work in the Arctic because of the unique knowledge required on the cetaceans and environmental conditions, including the presence of sea ice. Additionally, specific to the

Arctic Region, requiring a minimum number of MMOs to be trained local Inuit would be advantageous for making use of their local knowledge and in building relationships between seismic companies and local communities (Huntington et al., 2012). Furthermore, details such as the number of MMOs required, the length of their shifts, and rest periods, their level of experience and conditions they may work in, should all be explicitly stated. To account for the limitations of visual observation, PAM with appropriately trained and experienced personnel should be used at all times (ASOC, 2005). PAM is only useful if the cetaceans are vocalizing, but it does add some redundancy that satisfies the need for precautionary measures (Weir & Dolman, 2007). Conducting seismic surveys during hours of darkness or periods of low visibility should be avoided, and in the Arctic this is entirely possible as surveys are typically limited to the summer months when there is constant light (AMSA, 2009).

The effectiveness of the ramp-up operational mitigation procedure should be assessed. Due to the lack of scientific evidence that ramp-up of seismic airgun sounds cause cetaceans to leave the area, the potential impacts of using ramp-up and contributing unnecessary noise to the environment should be considered (Jasny, 2007; Simmonds et al., 2014; Weilgart, 2007). If the pre-seismic monitoring has been sufficient and adequate, there should not be any or many cetaceans in the area when activities commence and therefore ramp-up may be unnecessary.

As previously mentioned, the USA has identified two levels of auditory and behavioural thresholds (Table 2), and are currently working on a guideline with updated auditory thresholds specific to different types of marine mammals (Table 3). Despite the scientific uncertainty that exists in identifying auditory and behavioural thresholds, if they are conservative, precautionary and used to extend the range of the safety zone radius, it could help reduce the effects of anthropogenic noise on cetaceans in the Arctic region and be incorporated into a Canadian Arctic seismic survey specific policy.

Knowing how to best mitigate the effects of anthropogenic noise on cetaceans is challenging. By providing detailed explanations of each measure, why they are being used, what science was used to support the effectiveness of each measure, and whether they reinforce the precautionary principle, would ensure transparency and operator accountability. This could be accomplished in part by also incorporating governance measures into policies which specifically outlines how the effectiveness of the guidelines will be monitored, evaluated and potentially improved.

4.2 Future Research

Attempting to identify behavioural and auditory thresholds has been a major area of focus, to varying and debatable levels of success, but would still be valuable information to obtain (Southall et al., 2008). This type of information is useful for setting operational guidelines such as the size and range of safety zones or how loud the airgun arrays can be before causing injury to cetaceans (DFO, 2015b). In addition to thresholds, basic information about cetacean biological habits and patterns such as migration, breeding, birthing, nursing and feeding would also be an important area to focus attention and resources. This type of information would be useful for improving geographic mitigation measures, and understanding how cetacean populations are affected by anthropogenic noise pollution (Parsons et al., 2009). While these represent two major gaps in knowledge, some researchers argue that more emphasis should be placed on source-based reduction of noise and generally reducing the amount of anthropogenic noise in the environment. Moving forward, research into source-based mitigation measures and alternative technologies to improve efficiency and reduce the production and propagation of unintentional noise, will also be critical.

It would also be beneficial to have a complete outline of what anthropogenic noise policies exist within all member states of the Arctic Council. This would allow for a more thorough and useful comparison and analysis of how the Council has guided or influenced policies and determine what measures would be reasonable to include within a regional minimum standard of mitigation measures and approaches.

Furthermore, a more extensive analysis of potential collaboration between Canada and international bodies to enforce joint initiatives such as areas to be avoided by vessels would be beneficial. As would a thorough examination of Canadian laws and programs through which additional legal pressure could be utilized, which would only strengthen the management and mitigation approaches used to reduce the negative effects of anthropogenic noise on cetaceans in the Arctic.

5. Conclusions

Anthropogenic noise in the marine environment and its possible effects on cetaceans in the Canadian Arctic is an important issue that will require a great deal of attention, research and collaboration amongst scientists and decision-makers at the international, regional and national level. It has proven that just identifying anthropogenic noise as a problem is not enough, and policies, regulations and guidelines with specific mitigation measures and management approaches are necessary to tackle this transboundary issue. This is a complex problem, with many stakeholders and significant scientific uncertainty, which is why informed decision making and the precautionary principle must guide all management and mitigation policies. There is great opportunity for Canada to create mitigation and management policies for reducing the effects of anthropogenic noise that is specific to the needs and challenges of the Arctic marine environment, specifically taking into consideration the relatively pristine marine soundscape, the endemic cetacean species and the presence of sea ice. The Nunavut territory in particular could benefit from such policies and guidelines, as they have largely been immune to development compared to the Yukon and the Northwest Territories and are now being targeted for industrial development. This could either be achieved by updating pre-existing policies such as the Canadian SOCP, to make them more appropriate for the Arctic environment and to generally improve the quality and effectiveness of the mitigation measures, or through the creation of a mitigation and management policy specific to anthropogenic noise in the Arctic. Either way, the success of such guidelines would be improved greatly if there was also coordination with, and support from the Arctic Council and international organizations such as the UNCLOS and IMO.

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7. Tables

Table 1. Comparative analysis of three major international bodies relevant to anthropogenic noise in the Arctic marine soundscape and its effects on cetaceans, the UNCLOS, IMO and IWC. (IMO 2002, IMO 2015, IWC 2015, UNCLOS 2013).

	UNCLOS	IMO	IWC
Member states (# of countries, significant non-member nations)	Over 160 nations have ratified UNCLOS, not ratified by the USA	Over 170 member states, 3 associate members, 76 Non-Governmental Organizations with consultative status and 64 Intergovernmental Organizations	Over 80 members, Canada has not been a member since 1982
Policies /guidelines relevant to anthropogenic noise impacts	Protection and Preservation of the Marine Environment Section 1. General Provisions Section 2. Global and Regional Cooperation Section 3. Technical Assistance Section 5. International Rules and National Legislation to Prevent, Reduce and Control Pollution of the Marine Environment	MARPOL - International Convention for the Prevention of Pollution of Ships MEPC - Marine Environmental Protection Committee	No policies or guidelines, but produce Science Advisory Committee Reports providing advice on reducing anthropogenic noise
Has a general anthropogenic noise policy?	No, but anthropogenic noise falls under “energy pollution”	Not yet, draft ‘Guidelines for the Reduction of Underwater Noise from Commercial Shipping’, currently in development	No
Has a seismic specific policy?	No	No	Contributed to guidelines for mitigation and monitoring of seismic surveys off Sakhalin Island (WGWAP)
Has a shipping specific policy?	No	Yes, all of their policies are shipping specific	Yes, they have reports about shipping concerns – ship strikes, pollution, vessel noise, etc.
Has a cetacean specific policy?	Yes, Part V Exclusive Economic Zone Article 64 Highly Migratory Species - Article 65 Marine mammals	No	Yes, all of their work is cetacean specific

Has an Arctic specific policy?	SECTION 8. ICE-COVERED AREAS Article 234 Ice-covered waters	Guidelines for Ships Operating in Arctic Ice-Covered Waters 2002	No
Major strengths of organization/ Policy	International, covers wide range of topics/ activities/concerns	Recognizes shipping as a huge contributor of anthropogenic noise, organization could facilitate the management and mitigation of shipping noise	Important scientific research at an international level, reports and advisory organization Cetacean specific, addresses anthropogenic noise
Major weaknesses of this organization/ Policy	Not completely legally binding, anthropogenic noise, seismic surveys and vessel noise are not explicitly stated or included	Policy specific to vessel noise pollution is still in development, not legally binding	Not legally binding, Canada isn't a member, No real policies or guidelines

Table 2. NOAA Fisheries current in-water acoustic thresholds (excluding tactical sonar and explosives) showing the behavioral thresholds and PTS injury thresholds that have been identified and utilized by NOAA (NOAA, n.d.-b)

NOAA Fisheries current in-water acoustic thresholds (excluding tactical sonar and explosives):		
Criterion	**Criterion Definition**	**Threshold**
Level A	PTS (injury) conservatively based on TTS	190 dB_{rms} for pinnipeds 180 dB_{rms} for cetaceans
Level B	Behavioral disruption for <u>impulsive</u> noise (e.g., impact pile driving)	160 dB_{rms}
Level B	Behavioral disruption for non-pulse noise (e.g., vibratory pile driving, drilling)	120* dB_{rms}

Table 3. “Summary of PTS onset dual metric acoustic threshold levels” table showing auditory threshold levels identified for different types of marine mammals from the NOAA Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammals draft document (NOAA 2013).

	PTS Onset Threshold Levels (Received Level)	
Hearing Group	**Impulsive**	**Non-impulsive**
Low-Frequency (LF) Cetaceans	230 dB_{peak} & 192 dB SEL_{cum}	230 dB_{peak} & 207 dB SEL_{cum}
Mid-Frequency (MF) Cetaceans	230 dB_{peak} & 187 dB SEL_{cum}	230 dB_{peak} & 199 dB SEL_{cum}
High-Frequency (HF) Cetaceans	202 dB_{peak} & 154 dB SEL_{cum}	202 dB_{peak} & 171 dB SEL_{cum}
Phocid Pinnipeds (Underwater)	230 dB_{peak} & 186 dB SEL_{cum}	230 dB_{peak} & 201 dB SEL_{cum}
Otariid Pinnipeds (Underwater)	230 dB_{peak} & 203 dB SEL_{cum}	230 dB_{peak} & 218 dB SEL_{cum}

*Dual metric acoustic threshold levels: Use whichever level (dB_{peak} or dB SEL_{cum}) exceeded first. All SEL_{cum} acoustic threshold levels (re: 1 μPa^2-s) incorporate marine mammal auditory weighting functions, while peak pressure thresholds should not be weighted. Note: Acoustic threshold levels for impulsive or non-impulsive sources are based on temporal characteristics at the source and not the receiver.

The SEL_{cum} could be exceeded in multitude of ways (i.e. varying exposure levels and durations, duty cycle). It is valuable for action proponents, if possible, to indicate under what conditions these acoustic threshold levels will be exceeded.

Note: In this Table, dB_{peak} is equivalent to the ANSI abbreviation of L_{pk} and SEL_{cum} is equivalent to the ANSI abbreviation of L_E (ANSI 2013)

Table 4. This table shows the level of detail that the JNCC Seismic Survey Guidelines provides regarding MMO requirements. This shows how the UK is divided into 3 coastal areas and specific information such as cetacean sensitivity and the corresponding responses or actions by MMOs is described in a clear and accessible way that is easy for seismic survey operators to follow (JNCC 2004)

Area	Sensitivity/MMO Requirement
Southern North Sea **Irish Sea Basin**	Cetacean sensitivities are generally low to moderate. Seismic surveys using large sources such as those for 2D or 3D seismic surveys may require a dedicated MMO. For all other surveys a dedicated MMO is usually not required however A watch should be kept for marine mammals before airgun start up (See section 2) • A report should still be submitted to the JNCC containing location, effort and sighting forms (See Section 2).
Central and Northern North Sea **St Georges Channel** **South West Approaches** **English Channel**	Cetacean sensitivities are highly variable. Requirements for MMOs are varied according to the energy source volume, energy source pressure level, sound frequency and survey location however the following guidance is available. Seismic surveys using large sources such as those for 2D or 3D seismic surveys will require a dedicated MMO. • All surveys requiring MMOs taking place between 1st April and 1st October north of 57° latitude will require two dedicated MMOs due to the longer daylight hours.
Moray Firth, **Cardigan Bay,** **West of Britain (includes all areas to the north and west of Shetland and to the west of Orkney and the Western Isles)**	Cetacean sensitivities are high Any seismic operation including site surveys will require dedicated experienced MMOs. • All surveys requiring MMOs taking place between 1st April and 1st October north of 57° latitude will require two dedicated MMOs due to the longer daylight hours.

Table 5. Comparative examination of Seismic Survey mitigation and management policies in Canada, the USA and the UK (BOEM 2012, DFO 2007, JNCC 2004)

	CAN SOCP	USA BOEM (JOINT NTL No. 2012-G02)	UK JNCC
Year enforced	2007	2002 – first version implemented (has subsequently been updated in 2003, 2004 2007 and most recently 2012)	1995 – JNCC developed guidelines for anthropogenic noise – have been reviewed and updated many times since then
Is it specific to seismic surveys?	Yes	Yes	Yes
Have auditory thresholds been identified?	No	Yes – See table 3	No
Have behavioural thresholds been identified?	No	Yes – See table 2	No
It is specific to cetaceans?	No – focus is instead on all marine mammals	No – focus is instead on all marine mammals	No – focus is instead on all marine mammals
Are endangered species or their critical habitat included or referenced?	Yes – the SARA is referenced, and specifically mentions threatened and endangered species	Yes – the MMPA and the ESA are reviewed in their training course and there is a protected species observer program, but measures specific to endangered species or critical habitat is not included	No – endangered species are not explicitly mentioned, but sensitive areas for breeding and calving are included – see Table 4
What type(s) of mitigation measures are used?	Mostly operational, vague references to source-based reduction and geographical	Operational measures such as exclusion zones, ramp-up procedures and visual observers, no real mention of source-based or geographical	Mostly operational, during the planning stage both geographic (See Table 4) and source-based are vaguely/quickly mentioned
Identified a safety zone range? What distance?	At least 500m	Yes – 500m, but each survey vessel must maintain its own unique exclusion zone	At least 500m

Uses soft-start/ramp-up mitigation measure?	Yes – minimum 20 minutes	Yes – minimum 20 minutes and maximum 40 minutes With 30 min visual monitoring prior to initiating ramp-up	Yes – minimum 20 minutes and maximum 40 minutes
Uses shut-down mitigation measure?	Yes – 30 minute waiting/observation period	Yes – 30 minute waiting/observation period	No - not explicitly stated
Allow surveying at night?	No	Only when PAM is available	No
Uses marine mammal observers? Are any specific details included?	Yes – does not state how many, etc.	Yes – “Visual Observers” – prerequisite course, number of hours, break length (max 4 consecutive hours on watch, min. 2 hour break, no more than 12 hours of watching within a 24 hr period)	Yes – prerequisite course, sensitive areas require an experienced cetacean biologist or an experienced MMO, 2 MMOs when daylight hours exceed 12 hrs/day
Uses passive acoustic monitoring (PAM)? Any specific details?	Yes	Yes – during periods of reduced visibility or for borehole seismic surveys, nighttime, PAM may be used	Yes – but only when the environmental assessment of their application requires it
Is reporting required?	No	Yes – observer effort report, survey report and sighting reports	Yes – survey and sighting reports

8. Figures

Figure 1. This figure summarizes some of the notable findings from the policy analysis at the international, regional and national levels, with the corresponding recommendations on how they could be improved or incorporated into a Canadian Arctic policy.

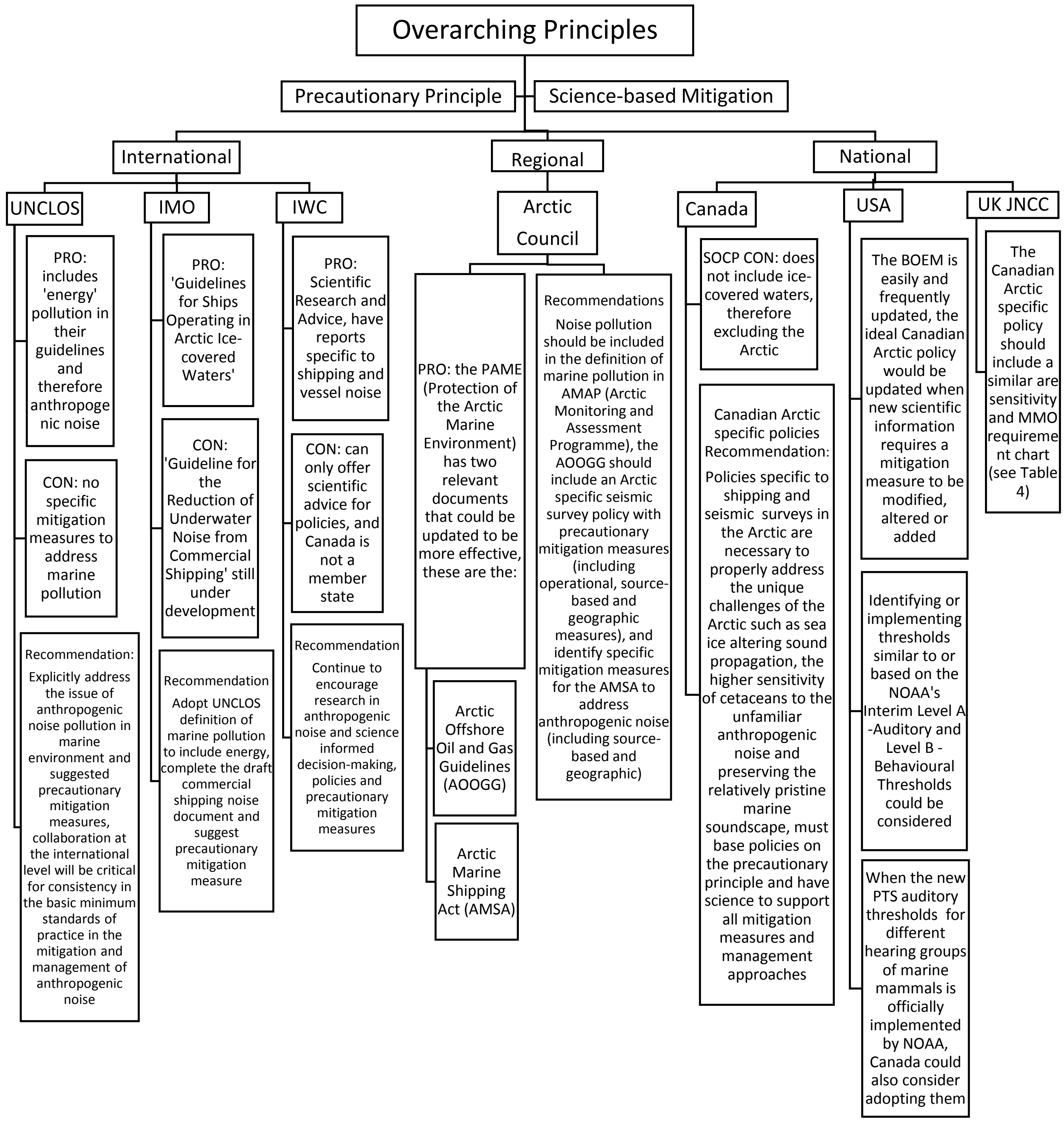

Figure 2. This figure summarizes the policy recommendations made in this paper, specific to seismic surveys mitigation measures in the Canadian Arctic.

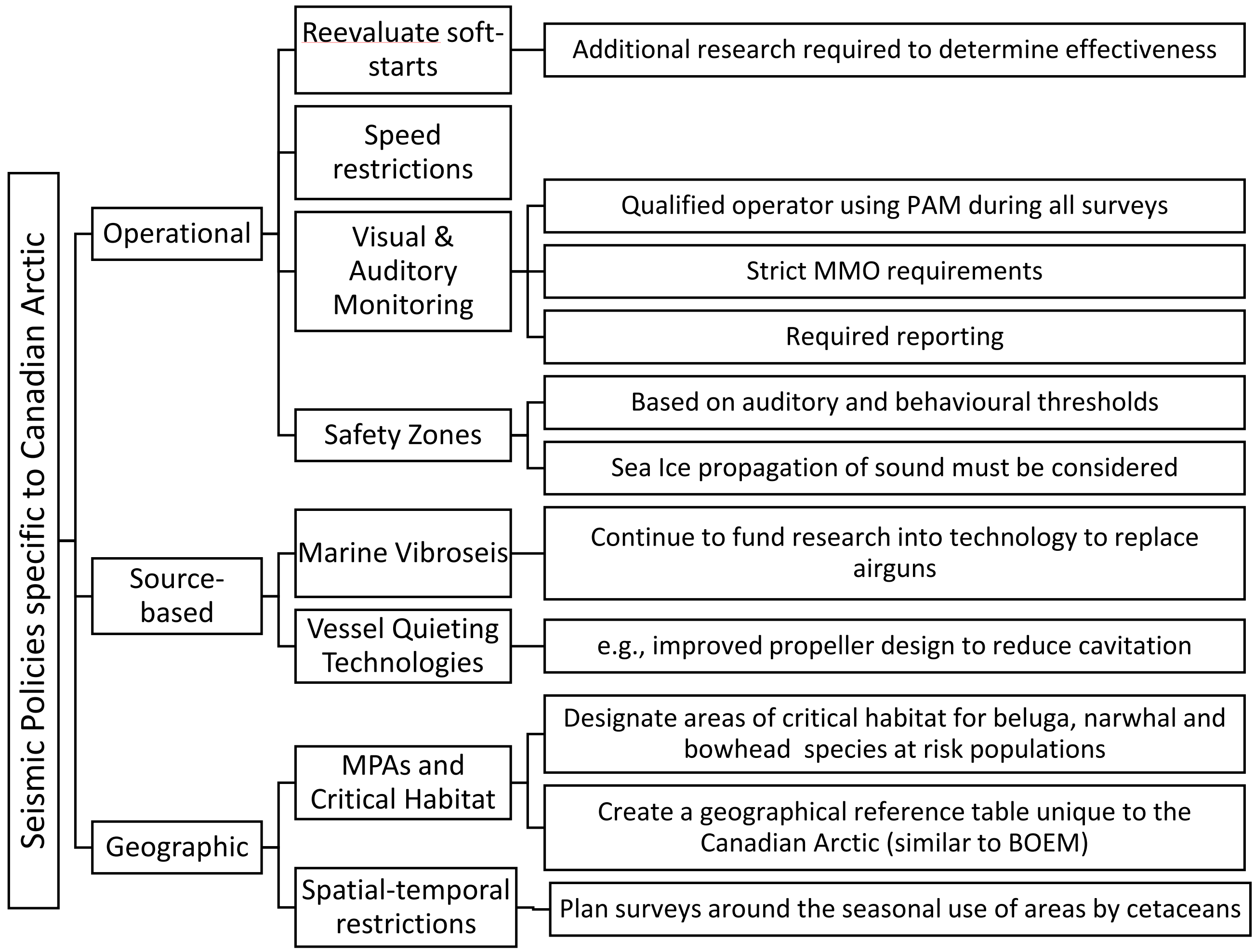

Figure 3. This figure summarizes the policy recommendations made in this paper, specific to shipping mitigation measures in the Canadian Arctic.