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Review of the 2008 Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ACRONYMS AND ABBREVIATIONS

~	Approximately
μPa	microPascal
AEP	Auditory Evoked Potential
BAA	Bowhead Aggregation Area
BACI	Before-After-Control-Impact
BOEM	Bureau of Ocean Energy Management
BP	British Petroleum
BRAHSS	Behavioral Response of Australian Humpback Whales to Seismic Surveys
CBS	Canadian Beaufort Sea
CEAA	*Canadian Environmental Assessment Act*
C-NLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
CNSOPB	Canada-Nova Scotia Offshore Petroleum Board
CPA	Closest Point of Approach
CSAS	Canadian Science Advisory Secretariat
cum	cumulative
CV	Curriculum Vitae
dB	Decibel
DCE	Danish Centre for Environment (and Energy)
DEWHA	Australian Department of the Environment, Water, Heritage and the Arts
DFO	Department of Fisheries and Oceans Canada
DOC	New Zealand Department of Conservation
EA	Environmental Assessment
EIA	Environmental Impact Assessment
EIRB	Environmental Impact Review Board
EISC	Environmental Impact Screening Committee
EL	Exploration License
FLO	Fisheries Liaison Officer
GXT	GX Technology
HTC	Hunters and Trappers Committee
Hz	Hertz
IBAMA	Brazil Institute of Environment and Natural Resources
IFA	Inuvialuit Final Agreement
IGC	Inuvialuit Game Council

IR	Infrared
ISR	Inuvialuit Settlement Region
IUCN	International Union for Conservation of Nature and Natural Resources
JNCC	Joint Nature Conservation Committee
km	kilometre
kts	knots
L-DEO	Lamont–Doherty Earth Observatory
m	metre
min	minute(s)
MMIA	Marine Mammal Impact Assessment
MMMMP	Marine Mammal Mitigation and Monitoring Plan
MMO	Marine Mammal Observer
MMSO	Marine Mammal and Seabird Observer
MV	Marine Vibrator
N.Z.	New Zealand
NARW	North Atlantic Right Whale
NEB	National Energy Board
NL	Newfoundland and Labrador
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOPSEMA	The Australian National Offshore Petroleum Safety and Environmental Management Authority
NPD	Norwegian Petroleum Directorate
NS	Nova Scotia
OBR	Opercular Beat Rate
OCS	Outer Continental Shelf
PAM	Passive Acoustic Monitoring
PD	Project Description
PTS	Permanent Threshold Shift
RADAR	Radio Detection and Ranging
rms	root-mean-square
RU	Ramp-up
s	second
SAR	Species at Risk
SARA	*Species at Risk Act*

SEL	Sound Exposure Level
SOCP	The Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment
SPI	Shot Point Interval
SPL	Sound Pressure Level
SSV	Sound Source Verification
SZ	Safety Zone
TNMPA	Tarium Niryutait Marine Protected Area
TTS	Temporary Threshold Shift
U.K.	United Kingdom
U.S.	United States (of America)
UVC	Underwater Visual Census
VSP	Vertical Seismic Profiling

ABSTRACT

In 2008, Fisheries and Oceans Canada (DFO) published "The Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment" (SOCP). The implementation of the SOCP has become a requirement by government agencies responsible for regulating geophysical exploration using air sources (commonly referred to as "airguns") in Canada. The SOCP was, in large part, based on a 2004 peer-reviewed report "Review of Scientific Information on Impacts of Seismic Sound on Fish, Invertebrates, Marine Turtles and Marine Mammals" and an assessment by technical experts of the best available and internationally-recognized techniques to mitigate the effects of seismic sound in the marine environment at that time.

The objective of this document is to provide a literature overview and an analysis of the recent science (since the 2004 peer-reviewed report), related Canadian Science Advisory Secretariat (CSAS) processes, regional Canadian mitigation and monitoring practices, and relevant international guidelines and protocols to determine if the 2008 SOCP requires updates to protect marine species. Based on the analysis of this information, we provided 29 recommendations for changes to the 2008 SOCP, which addressed all components of the SOCP. These recommendations and the associated rationale were discussed at a CSAS meeting held in Halifax, Nova Scotia on 28–30 May 2019 and are included as an appendix to a DFO Science Advisory Report (DFO 2020).

1.0 INTRODUCTION

1.1 BACKGROUND

The effects of underwater sound on marine fauna, particularly the effects of seismic air source (commonly referred to as "airgun") sound on marine mammals, have garnered much attention for decades. In 2008, Fisheries and Oceans Canada (DFO) published "The Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment" (hereafter referred to as the 'SOCP'; DFO 2008 *in* Appendix A). The SOCP was developed by federal, provincial and joint federal/provincial authorities responsible for the regulation and management of marine seismic surveys in Canada and specifies the mitigation and monitoring requirements intended to minimize effects of air source sound on marine fauna. The SOCP was, in large part, based on the 2004 peer-reviewed report "Review of Scientific Information on Impacts of Seismic Sound on Fish, Invertebrates, Marine Turtles and Marine Mammals" (DFO 2004) and an assessment by technical experts (including the input of industry) of the best available and internationally-recognized techniques to mitigate the effects of seismic sound in the marine environment. Since the publication of the SOCP in 2008, new seismic-related scientific literature has become available, which in some jurisdictions has led to changes in monitoring and mitigation requirements. As such, it is important to review and analyze new science, guidelines and protocols to determine if the current mitigation measures in the SOCP are adequate, require refinement or updating, or if there are new measures that should be added. Ultimately, that is the overall objective of this Research Document (see Section 1.2 below for specific objectives).

The review and analysis in this Research Document was based upon a working paper (Moulton et al. unpubl.) prepared for a Canadian Science Advisory Secretariat (CSAS) meeting on the SOCP (held in Halifax, Nova Scotia (NS) from 28–30 May 2019). It considers feedback received by DFO scientists and other experts at the CSAS meeting on the working paper. There have been previous reports from the CSAS on the capacity of the SOCP to effectively protect marine fauna; of particular relevance is the 2014 CSAS meeting on "Review of Mitigation and Monitoring Measures for Seismic Survey Activities in and Near the Habitat of Cetacean Species at Risk" (DFO 2015). However, because CSAS meetings and reports on the SOCP to date have focused on specific elements or on specific fauna, certain key aspects (e.g., new protocols used in other jurisdictions, supplementary and proactive mitigation measures taken by proponents) have not yet been addressed in detail. Furthermore, despite multiple CSAS meetings that have identified areas that could be revised, the SOCP has not yet been formally updated. Building on the work done in previous CSAS meetings and especially the 2014 review, this report is intended to review the SOCP with an aim to identifying those mitigation measures that could be enhanced, added, or updated to improve the overall quality and application of mitigation measures in an updated SOCP.

1.2 OBJECTIVES

The objective of this Research Document is to provide a literature overview and an analysis of the recent science (since the 2004 CSAS review) and relevant guidelines and protocols to mitigate the potential effects of air source sound to determine if any of the current mitigation measures in the SOCP require updates, or if there are new measures that should be considered to protect the marine environment (i.e., marine mammals, sea turtles, fish, and invertebrates). The report provides recommendations regarding how this new information is or could be applied by providing examples, when possible, of recent best available and internationally recognized techniques to mitigate the effects of seismic sound in the marine environment.

1.3 APPROACH

The approach to this review involved the key steps listed below.

1. Provision of brief overviews of the SOCP and related-CSAS documents;
2. Identifying the regional differences in monitoring and mitigation of seismic surveys in Canada;
3. Provision of key scientific findings related to the effects of air source sound on marine mammals, sea turtles, fish, and invertebrates since 2004;
4. Provision of a summary of select international mitigation measures and monitoring requirements for air source sound;
5. Conducting a comparative review and analysis of the SOCP in consideration of (1) to (4); and
6. Provision of recommendations for updating the SOCP.

To assist the reader, we have maintained where possible the main mitigation and monitoring topics and their sequence as presented in the SOCP. It is important to note that this document is not intended to provide a detailed review of the scientific literature on the effects of seismic survey sound on marine fauna but to highlight key findings that may influence decisions around the SOCP.

To clarify, the scope of work is limited to seismic surveys (2-D, 3-D, and 4-D) and does not include vertical seismic profiling (VSP), borehole surveys, and geohazard surveys, which typically employ smaller numbers of air sources and other types of survey equipment. We also do not include other types of geophysical surveying technology like on-ice vibroseis (e.g., LGL Limited 2008a). Likewise, the scope of work does not include mitigation and monitoring practices for the potential effects of seismic surveys on commercial fisheries.

Twenty-nine recommendations were made for changes to the SOCP. These recommendations were included in the working paper prepared for the CSAS meeting and are provided in an appendix to the DFO Science Advisory Report (DFO 2020).

2.0 OVERVIEW OF THE SOCP

In Canada, there are three primary offshore areas that have in recent years been regularly explored for oil and gas opportunities via seismic surveys: offshore Newfoundland and Labrador (NL), offshore NS, and the Canadian Beaufort Sea (CBS). Prior to the publication of the SOCP, each of these three Canadian regions implemented mitigation and monitoring practices which were identified during environmental assessment (EA) processes. Since the publication of the SOCP in 2008, each region has adapted as a minimum the requirements in the SOCP (see Section 2.2 for a summary) through different regulatory agencies and permitting processes unique to the region (see Section 2.1). Likewise, there are regional differences in how the SOCP has been implemented and in mitigation and monitoring practices which have exceeded minimum requirements set out in the SOCP (see Section 3.2).

2.1 REGULATORY OVERVIEW

Currently, the SOCP applies to all seismic surveys in Canadian marine waters which will employ an air source array (see Item 1 in the SOCP). It does not apply to ice-covered marine waters and lakes or the non-estuarine portions of rivers (Item 2 in the SOCP).

There are three lead regulatory agencies in Canada that regulate seismic surveys conducted for oil and gas exploration and which administer the SOCP: Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB), Canada-Nova Scotia Offshore Petroleum Board (CNSOPB), and the National Energy Board (NEB). All three agencies require implementation of, and compliance with, the SOCP. For seismic surveys conducted for any other purposes (e.g., hydroacoustic mapping by a government agency, academic research of glaciation events), DFO applies or requires use of the SOCP (DFO 2007). Additionally, DFO (as well as other federal agencies) provide science and management advice for EAs of seismic surveys under the purview of the C-NLOPB, CNSOPB, and NEB and in some cases actively contributes to the design of monitoring and mitigation programs for seismic surveys. Relevant Canadian legislation that governs marine species and sound in the marine environment includes the *Fisheries Act*, *Species at Risk Act* (SARA), and *Oceans Act*.

2.1.1 Canada-Newfoundland and Labrador Offshore Petroleum Board

The C-NLOPB regulates the oil and gas industry offshore NL on behalf of the Government of Canada and the provincial government. An EA is required before a Geophysical Program Authorization can be issued and to allow the C-NLOPB to fulfil its responsibilities under § 138 (1)(b) of the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Act* and § 134(1)(b) of the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act* (Accord Acts). The C-NLOPB has included the SOCP in their Geophysical, Geological, Environmental and Geotechnical Program Guidelines (2018); indicating operators should implement the mitigations listed in the SOCP. The required Geophysical Program Authorization to conduct a seismic survey stipulates that the Operator shall implement, or cause to be implemented, the mitigation measures outlined in any EA. Several mitigation measures regularly implemented offshore NL exceed the minimum requirements outlined in the SOCP.

2.1.2 Canada-Nova Scotia Offshore Petroleum Board

The CNSOPB regulates the oil and gas industry offshore NS on behalf of the Government of Canada (i.e., Natural Resources Canada) and the provincial government (Nova Scotia Department of Energy and Mines). As in NL, an EA is required before a Geophysical Work Authorization can be issued under paragraph 142(1) (b) of the *Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act*. The CNSOPB recognizes and requires implementation of the SOCP through their EA approval process to ensure mitigation measures are implemented. The required Geophysical Work Authorization to conduct a seismic survey stipulates that the Operator shall implement the mitigation measures and commitments outlined in the EA respecting its geophysical activities. Several mitigation measures regularly implemented offshore NS exceed the minimum requirements outlined in the SOCP.

2.1.3 National Energy Board

Seismic survey activity is regulated through the NEB under the *Canada Oil and Gas Operation Act* and the associated Canada Oil and Gas Geophysical Operations Regulations. The NEB's regulatory jurisdiction of oil and gas activities apply to offshore areas of the Northwest Territories, Nunavut, Yukon, British Columbia, the Bay of Fundy, Hudson Bay, James Bay, and portions of the Gulf of St. Lawrence. Companies that propose to conduct marine seismic activities in these areas must apply to the NEB for a Geophysical Operation Authorization. According to the NEB, applications for authorization should identify the mitigation measures and provide rationale for any that include modifications or variations to those in the SOCP. These requirements are intended to complement existing EA processes, including those defined in settled land claims such as the Inuvialuit Final Agreement (IFA) for the CBS.

Canadian Beaufort Sea

The Environmental Impact Screening Committee (EISC) is an advisory committee responsible for screening all proposed projects planned on Crown land or waters in the Inuvialuit Settlement Region (ISR), which includes the CBS. When a screening occurs, the EISC's responsibilities are set out in clause 11(17) of the IFA. Should the EISC determine that the project may have a "significant negative impact", the Project Description (PD; i.e., the environmental assessment document) will be referred to the Environmental Impact Review Board (EIRB) or other equivalent environmental review process for a public assessment and review pursuant to clause 11(19, 20, 29).

The NEB is the governmental authority competent to authorize the development within the meaning of the IFA. The NEB is also required to consider environmental impacts under its jurisdiction to approve the development under the *Canada Oil and Gas Operation Act* and applicable regulations. The revised *Canadian Environmental Assessment Act*, 2012 (CEAA 2012) came into force on 6 July 2012. The "Regulations Designating Physical Activities" lists physical activities that require an environmental assessment under the new Act. Marine seismic surveys are not included on the list, thus do not currently require an environmental assessment under CEAA 2012[1]. Prior to CEAA 2012, a screening level EA was required under CEAA.

The NEB's primary role since CEAA 2012 is the review and issuance of the Geophysical Operation Authorization, including the regulation of the safety aspects of the Project. In addition, the NEB[2] may submit information requests on the EISC PD.

2.2 OVERVIEW OF THE SOCP

The SOCP is divided into mitigation measures for planning and operational mitigation and monitoring requirements. It also includes provisions that allow for the implementation of additional mitigation measures and/or modifications to existing planning and operational measures should the need be identified during the EA process.

2.2.1 Planning Seismic Surveys

The SOCP outlines specific minimum mitigation measures to be undertaken during the planning phase of a seismic survey (Items 3–5 in the SOCP). Although not explicitly stated in this section of the SOCP, many of the planning mitigation measures highlighted below would be identified during the EA process for a seismic survey. This would involve input from DFO, other appropriate regulatory agencies, and stakeholders.

- **Air Source Array Specifications**: Seismic proponents must use the minimum amount of acoustic energy, minimize the horizontal propagation of acoustic energy, and minimize the amount of energy at frequencies above those needed for the purpose of the seismic survey (Item 3).

[1] In August 2019, CEAA 2012 was repealed and the *Impact Assessment Act* came into effect.

[2] In August 2019, the *Canadian Energy Regulator* (CER) *Act* came into effect which replaces the National Energy Board Act.

- **Significant Population-level Adverse Effects**: on any marine species should be avoided (Item 4).
- **Individual SARA Schedule 1 Marine Mammal and Sea Turtle:** listed as endangered or threatened should not be displaced during breeding, feeding, and nursing nor diverted from known migration routes (Item 5a,b). Likewise, significant adverse effects on these individuals should be avoided (Item 4).
- **Groups of Marine Mammals**: should not be displaced during breeding, feeding, and nursing nor diverted from known migration corridors if it is known there are no alternate areas available or that by using alternate areas those marine mammals would incur significant adverse effects (Item 5d,e).
- **Aggregations of Spawning Fish**: should not be dispersed from a known spawning area (Item 5c).
- **Aggregations of Migrating Fish**: should not be diverted from known migration routes if it is known there are no alternate routes available or that by using alternate routes the aggregations of fish would incur significant adverse effects (Item 5e).

2.2.2 Operational Mitigation Measures and Monitoring

Safety Zone and Start-up

The SOCP establishes a minimum safety zone (SZ), which serves as the basis for monitoring by Marine Mammal Observers (MMOs) for marine mammals and sea turtles and associated mitigation measures.

- **Establishment of the SZ**: a SZ of at least 500 m (radius) as measured from the center of the air source array should be established (Item 6a).
- **Visual Monitoring of the SZ**: should be conducted by a qualified MMO for the entire 30 minutes preceding the start of the air source array(s) (Item 6bi) and at all other times the air source(s) meet a threshold requirement for an environmental assessment under the *Canadian Environmental Assessment Act* (Item 6bii).
- **Delay of Air Source Array Ramp-up**: if the air source(s) have been inactive for more than 30 minutes, air sources can only be activated if the MMO has not visually detected for at least 30 minutes a cetacean or sea turtle; a SARA Schedule 1 marine mammal (endangered or threatened); or any other marine mammal that has been identified through the EA process as a species for which there could be significant adverse effects.
- **Ramp-up**: the air source array should be gradually ramped up over a minimum of 20 minutes preferably starting with the smallest air source and the gradual addition of other air sources until full volume is reached (Item 7b).

Shut-down of Air Source Array(s)

If the MMO detects a SARA Schedule 1 marine mammal or sea turtle (listed as endangered or threatened; Item 8a) or any other marine mammal or sea turtle that has been identified through the EA process as a species for which there could be significant adverse effects, the air source array(s) must be shut down immediately (Item 8b).

Line Changes and Maintenance Shut-downs

During line changes, the operator has the option of shutting down all air sources or operating a single air source (Item 9). If the operator does use a single air source during line changes, the safety zone must be monitored visually and shut downs implemented as outlined in Item 8 of the

SOCP. The SOCP states that ramp-up procedures (Item 7 of SOCP) are not required when transitioning from single air source use to seismic surveying.

Operations in Low Visibility

The SOCP requires use of cetacean detection technology (such as Passive Acoustic Monitoring, PAM) during the 30-minute pre-ramp-up watch when the SZ is not fully visible and when the seismic survey area occurs in Critical Habitat[3] for a vocalizing cetacean listed as endangered or threatened on Schedule 1 of SARA. Cetacean detection technology would also be required in areas where a vocalizing cetacean is expected to be encountered if that species, as predicted during the EA process, may incur significant adverse effects.

The SOCP states that if cetacean detection technology like PAM is used during the pre-ramp-up watch then any identified vocal signature or other recognition criteria must be assumed to be those that would trigger a shut down of the air sources. Likewise, if the cetacean detection technology cannot determine that a cetacean(s) is outside of the SZ, the ramp-up cannot commence until the non-identified cetacean vocalization has not been detected for at least 30 minutes.

2.2.3 Additional Mitigation Measures and Modifications

The SOCP has provisions which allow for the implementation of additional mitigation measures and/or modifications to existing mitigation measures should the need be identified during the EA process. More specifically, this section of the SOCP is intended to address:

- potential chronic or cumulative adverse effects of: multiple air source arrays operating concurrently, and seismic surveys being conducted in combination with other activities that may adversely affect marine environmental quality;
- variations in sound propagation (presumably cases of high variation although the SOCP is not explicit) in the water column;
- significantly higher or lower than average sound levels from the air source array(s); and
- species for which there is concern.

Any such measures must achieve equivalent or greater level of protection than existing measures in the SOCP and if alternate technologies or methods are proposed they should be evaluated in the EA process.

Finally, the SOCP requires that if a single air source is used and the ramping up from an individual air source element to multiple elements is not applicable, the sound should be introduced gradually whenever technically feasible.

3.0 SCIENCE ADVICE AND SUPPLEMENTAL GUIDANCE AND APPROACHES USED IN CANADA

As noted previously, since the publication of the SOCP in 2008, DFO has periodically examined the capacity of the SOCP to effectively mitigate the effects of seismic surveys on marine fauna, including species at risk. The key recommendations and findings from these processes are considered here. Appendix B provides a citation list of the CSAS and associated reports

[3] Critical Habitat is the habitat that is necessary for the survival or recovery of an endangered, threatened or extirpated species as listed on Schedule 1 of SARA and that is identified as the species' critical habitat in a recovery strategy or in an action plan for the species.

identified by DFO that relate to the SOCP. We focus on documents directly relevant to the objectives of this report and which were published after the SOCP (i.e., post 2008; see Section 3.1).

The SOCP provides guidance on minimum monitoring and mitigation requirements for seismic surveys in marine waters. Different regions within Canada, have modified and/or enhanced mitigation and monitoring measures, which are important to review and consider in the analysis presented in this report. A summary for offshore NL, offshore NS, and the CBS is provided in Section 3.2.

3.1 PREVIOUS CSAS DOCUMENTS RELATED TO SEISMIC SURVEYS

Since the publication of the SOCP, DFO has undertaken three primary initiatives designed to ascertain if mitigation measures and monitoring in the SOCP were protecting marine fauna:

1. In 2008, DFO undertook literature reviews focusing on publications (since 2004) of the effects of air source sound on fish/invertebrates (Payne et al. 2008) and marine mammals (Abgrall et al. 2008). These documents were used as the basis for a National Science Workshop in 2008 (DFO 2010a). Additionally, Harwood et al. (2008) and Nichol and Ford (2008) provided working papers with emphasis on mitigation of seismic sound for marine mammals. The overall objective of the workshop was to determine if the CSAS Habitat Status Report "Review of the Scientific Information on the Impacts of Seismic Sound on Fish, Invertebrates, Marine Turtles and Marine Mammals" (DFO 2004) required updating. It was concluded that modifications to the Habitat Status Report were not required at the time because any changes in past advice would be minor. We have not reviewed these documents because key scientific literature since 2004 is summarized in Section 4.0.
2. Resulting from (1) was a directive to examine the efficacy of the operational mitigation measures for marine mammals in the SOCP relative to environmental conditions. A National Workshop was held with several publications prepared in advance, namely Harwood et al. (2009), Joynt and Harwood (2009), Lawson (2009), Moulton et al. (2009), Nichol (2009), and Simard (2009). The key recommendations stemming from the workshop and supporting publications were captured in the Science Advisory Report "Guidance Related to the Efficacy of Measures Used to Mitigate Potential Impacts of Seismic Sound on Marine Mammals" (DFO 2010b). Key recommendations from this guidance document are summarized in Section 3.1.1.
3. DFO also examined the efficacy of the SOCP in meeting SARA requirements for cetaceans with respect to avoiding SARA-prohibited impacts of killing, harm and harassment of individuals listed as endangered or threatened and the destruction of their Critical Habitat. A CSAS meeting was held in March 2014 with the findings summarized in the Science Advisory Report "Review of Mitigation and Monitoring Measures for Seismic Survey Activities in and Near the Habitat of Species at Risk" (DFO 2015). The Moors-Murphy and Theriault (2017) report, which analyzed seismic survey mitigation and monitoring measures relative to cetacean species at risk, is of particular relevance and is summarized in Section 3.1.2.

3.1.1 Efficacy of the SOCP - Recommendations from DFO Science Advisory Report (DFO 2010b)

Based on the DFO Science Advisory Report (DFO 2010b), the recommendations outlined below were made.

Planning Seismic Surveys

Magnitude and frequency characteristics of the air source array should be modelled to minimize the seismic source output but yet achieve the geophysical objectives of the seismic survey. Additionally, the report noted that good planning should avoid or reduce impacts on life functions of marine mammals. When data gaps about life functions exist, minimizing effects can be achieved by avoiding concentrations of marine mammals, spatially and temporally.

Operational Mitigation Measures and Monitoring

Safety Zone

Sound propagation models should be used to establish safety zones for marine mammals during the planning stage of a seismic survey where applicable. The acoustic thresholds that DFO recommends as the basis for the SZ were not defined.

MMOs

- MMO training and qualifications should be standardized.
- Number of MMOs on watch simultaneously should be maximized, subject to operational logistics.
- A maximum shift length and total duty time per day should be set.
- Specify that when MMOs are on duty that is their sole task.
- Clearly establish that the MMO can determine when environmental conditions affect their ability to effectively conduct monitoring.
- MMOs should be positioned at the highest safe lookout with no obstruction to 360 degrees visibility around the vessel.
- High-quality optical equipment is required.
- Data recording and reporting should be standardized with MMO data sets archived in a central location that can be accessed by interested parties.

Passive Acoustic Monitoring

- A PAM array should possess the capability of detecting a wide range of frequency and characteristics of marine mammal vocalizations.
- To reduce the influence of anthropogenic noise (i.e., ship and air source sound) on a PAM system, tow the PAM array from a guard vessel at a long distance away from the seismic source vessel; use directional receivers and signal processing; use surface-linked fixed or drifting receivers at distances away from the seismic sound source.
- Localization of vocalizations in relation to the safety zone could be improved by towing two hydrophone arrays from the seismic vessel.
- Standard procedures and guidelines are required which include definitions of roles and responsibilities of the PAM Operator.
- The experience level of PAM Operators is crucial. There is currently a very limited pool of experienced people, especially locally.
- Capacity could be increased by training and standardization of equipment, set-ups and user interfaces (especially for mobile PAM deployment).

Ramp-up

- To the extent practical in the planning stages of a seismic survey, establish predetermined, project-specific incremental increase of sound source level.
- Establish whether the safety zone during ramp-up must be the same size as that during operations. If the safety zone is >500 m, the pre-ramp-up watch exclusion zone must be a minimum of 500 m but does not have to be of the same size as the full air source array volume safety zone.
- Conduct a detailed investigation of how duration and position of pre-ramp-up watch should be linked to ramp-up and the speed of the vessel as well as water depth (deeper diving and/or longer diving species).
- Periodic efforts are needed to consolidate MMO data. These data should be reviewed and used to update/change operational guidelines and standards (i.e., ramp up) in conjunction with regulatory framework reviews.
- The detection of pinnipeds within the SZ during pre-ramp-up watch should result in a ramp-up delay.

3.1.2 Cetacean Species at Risk - Recommendations from DFO Research Document (Moors-Murphy and Theriault 2017)

The objectives of the Moors-Murphy and Theriault (2017) review were to determine if the mitigation measures in the SOCP are likely to prevent SARA-prohibited impacts on listed cetaceans, to identify data gaps and associated issues, and to recommend additional or modified mitigation measures that should be considered. In summary, based on a review of key scientific findings and in consideration of the efficacy of mitigation measures, it was concluded that while most mitigation measures in the SOCP decrease the likelihood of SARA-prohibited impacts[4], most measures do not adequately address potential effects beyond the SZ (i.e., behavioural responses and changes in Critical Habitat). The following recommendations for operational mitigation measures were made:

- The SZ should be the most precautionary of a 500 m radius or a radius determined using sound propagation models based on best available data and science for a pre-determined acoustic threshold (which was not established). The SZ radius should be verified (sound source verification, SSV) with field measurements.
- Use of combined monitoring tools should be designed to maximize the probability of detecting SARA-listed species. A combination of tools (not limited to MMOs and PAM) may be required to achieve the desired target probabilities of detection (which were not established).
- In areas overlapping the distribution of deep-diving SARA-listed cetaceans, the pre-ramp-up watch should be a minimum of 60 minutes vs. current 30-minute duration.
- Immediate shutdown of the air source array should occur when a marine mammal or sea turtle (listed as endangered/threatened on SARA Schedule 1) detection occurs within the SZ or is about to enter the SZ. This would apply for any monitoring tools (i.e., MMO, PAM, or other).

[4] SARA prohibits the killing, harming, harassing, capturing, or taking of endangered or threatened individuals, or the destruction of their Critical Habitat.

- The air source array should only be shut down completely during line changes or operational maintenance if the SZ can be effectively monitored, otherwise a single air source should be operated or operations should be delayed until the SZ can be effectively monitored.
- A single air source should only be used during line changes if the SZ cannot be effectively monitored.
- Ramp up should occur after a single air source has been operated between seismic survey lines.

Also, recommendations were made regarding the planning aspects of the SOCP; notably:

- The spatial and temporal scope of seismic surveys should be minimized to the extent possible to avoid identified Critical Habitat of threatened or endangered cetaceans, when such species are expected in the area.
- Seismic surveys should be planned to avoid harm and harassment of individuals and destruction of Critical Habitat of threatened and endangered marine mammals.
- Pre-seismic survey studies should be conducted for SARA-listed species if the seismic survey area overlaps the distributional range of a SARA-listed species and finer-scale distributional patterns are not well known. These studies would assess for the occurrence of species and increase the understanding of the likelihood of displacing or diverting individuals.

3.2 SUPPLEMENTAL GUIDANCE AND APPROACHES USED IN CANADA

Each of the three regions in Canada where seismic surveys have occurred in recent years have implemented additional and enhanced mitigation measures that were deemed to be more protective than the minimum requirements in the SOCP. Regional modifications of mitigation measures for seismic surveys offshore NL, offshore NS, and in the CBS are overviewed in Sections 3.2.1–3.2.3, respectively, and summarized in Table 1. The review presented here focuses on seismic surveys conducted for oil and gas exploration purposes.

3.2.1 Offshore Newfoundland and Labrador

Since the SOCP was published, seismic surveying offshore Newfoundland has occurred each year, sometimes with multiple, concurrent surveys within a given year. The following is a list of mitigation measures, most of which are operational in nature, that have been regularly implemented for seismic surveys conducted by the oil and gas industry that exceed or are more specific than the minimum requirements included in the SOCP.

- No air source(s) activation was permitted outside of the Project Area identified during the EA process regulated by the C-NLOPB.
- The SZ includes the 500 m zone (i.e., radius) around the centre of the air sources. For some seismic surveys, the SZ also included a 500 m zone centered on the location of the MMO on the bridge of the seismic source vessel. If the MMO believes that there is a reasonable chance an animal seen 500 m ahead of or to the sides of the vessel will subsequently fall within 500 m of the air sources, then the appropriate mitigation measures would be implemented.
- The standard ramp-up period used has typically been 30 minutes vs. the minimum 20 minutes in the SOCP.

- Ramp-up is to be delayed if any marine mammal or sea turtle is detected within or approaching the SZ vs. just cetaceans and sea turtles as currently stipulated in the SOCP.
- Ramp-up procedures should be implemented when the air source(s) have been off for 20 or more minutes.
- If a single air source is used during line changes a 30-minute ramp-up must occur before the start of the next survey line. However, the 30-minute pre-ramp-up watch is not required.
- Shut downs are to be implemented if a species considered endangered or threatened on SARA Schedule 1 as well as all sea turtles and all beaked whales are detected within or about to enter the SZ. Note that shut downs for all beaked whales has only occurred since 2017.
- PAM has only recently been used (in 2018 by one seismic operator) as a tool to monitor for cetaceans during periods of darkness and periods of poor visibility. The commitment to use PAM was made by the seismic operator during the EA process. Ramp-up was to be delayed if a cetacean vocalization was detected within the SZ during the 30-minute pre-ramp-up watch and a shutdown was to be implemented if a vocalizing cetacean was detected within the SZ. [As written in the SOCP, cetacean detection technology, such as PAM is only required during the pre-ramp-up watch if the seismic survey occurs in Critical Habitat for a cetacean (listed as endangered or threatened on Schedule 1) or in an area used by a cetacean where significant adverse effects were predicted in the EA process.]
- Concurrent seismic surveys are to maintain a minimum separation distance of 30 km. This minimum separation distance has been used since 2017, although the metric for separation is not data-based.

3.2.2 Offshore Nova Scotia

Since the SOCP was published, there have been two seismic surveys (both Wide Azimuth involving multiple seismic source vessels) conducted offshore NS: Shell in 2013 and British Petroleum (BP) in 2014 (LGL 2013, 2014). The following is a list of mitigation measures that were implemented for these two recent seismic surveys that exceed or are more specific than the minimum requirements included in the SOCP.

Planning Seismic Surveys

- No air source operations were permitted outside of the Project Area identified in the EA for the industry seismic survey. This included special mention of avoidance of the Haddock Box 5 in the BP EA.
- Although the Shell Project Area (which included their Exploration Licenses or ELs; water depth ranged from ~500 m to >4,000 m) did not overlap with North Atlantic Right Whale (NARW; *Eubalaena glacialis*) Critical Habitat (minimum separation distance was 41 km), it was acknowledged in the EA that there was still potential for disturbance effects on right whales in the Roseway Basin Critical Habitat from seismic sound. Shell committed to only acquire seismic data in survey areas closest to Roseway Basin within the July–September seasonal window when sound propagation into the shallower shelf waters of the Roseway Basin is much reduced relative to conducting seismic surveying in April, May, and June, when sound propagation was higher. Note that precautionary acoustic modelling results

[5] The Haddock Box is a 13,700 km^2 conservation area that occurs over the Emerald and Western Banks (DFO 2003). It serves as a spawning area for groundfish and is characterized by high benthic species richness and fish diversity.

predicted maximum sound levels of ~120–130 dB root mean square (rms) in the Roseway Basin Critical Habitat based on the air source array location within Shell's 2013 seismic survey area (LGL 2013).

Operational Mitigation Measures and Monitoring

Safety Zone and Start-up

- The SZ used for shutdowns was based on acoustic modelling of the air source array. Shell used a 1000 m SZ (based on the 180 dB rms criterion) and BP used a 600 m SZ (based on National Marine Fishing Service (NMFS) [NOAA 2013] TTS criterion for low- and mid-frequency cetaceans, i.e., ≥183 dB SEL).
- The duration of the pre-ramp-up watch was typically 30 minutes but was increased to 60 minutes if a beaked whale was detected inside the SZ.
- For Shell, ramp-up was to be delayed if cetaceans and sea turtles listed on Schedule 1 of SARA and all other baleen whales and sea turtle species occurred within the 1000 m SZ or if any other species of marine mammal (i.e., dolphins, seals) was detected within the 500 m SZ. For BP, ramp-up was delayed for all cetaceans and sea turtles detected within the 600 m SZ.
- Ramp-up delay was 30 minutes unless a beaked whale (Schedule 1 of SARA; which included northern bottlenose whales and Sowerby's beaked whales) was detected in the SZ during pre-ramp-up watch; in that case a 60-minute delay was required.
- Ramp-up duration was 20 minutes (BP) or 30 minutes (Shell).

Shut-down of Air source Array

- Shell considered shutdown species as cetaceans and sea turtles listed on Schedule 1 of SARA as well as all other baleen whales and sea turtle species. BP considered shutdown species as cetaceans and sea turtles on Schedule 1 of SARA and beaked and baleen whales which could not be identified to species.

Line Changes and Maintenance Shut-downs

- Air sources were shut down during line changes.

Operations in Low Visibility

- PAM was used to monitor for vocalizing marine mammals within the SZ during the pre-ramp-up watch period and during periods when the full SZ was not visible. Note that based on a CNSOPB and DFO audit, adjustments were made to the PAM setup to increase the likelihood of detecting and identifying low-frequency calls of blue and fin whales.

Since the Shell and BP seismic programs, the CNSOPB and DFO have collaborated on the preparation of draft enhanced mitigation guidance for seismic surveys for the Scotian Shelf population of northern bottlenose whales.

3.2.3 Canadian Beaufort Sea

The CBS provides important summering habitat for bowhead (*Balaena mysticetus*) and beluga whales (*Delphinapterus leucas*), and beluga whales are an important subsistence species for the Inuvialuit. As such, enhanced planning and operational mitigation measures have been implemented to minimize the effects of seismic surveys on bowhead and beluga whales and, indirectly, on subsistence hunting within the ISR for many years, including those before publication of the SOCP. Here we recognize mitigation and monitoring implemented in the CBS before, during, and after the SOCP was published. More specifically, we have focused on the 2008 mitigation and monitoring program implemented for GX Technology's (GXT's) 2008 2-D seismic survey (LGL 2008b; Harris et al. 2008; Harwood et al. 2009). The GXT 2008 mitigation and monitoring program is representative of those conducted in 2006, 2007, 2010, and 2012 by the same company (Holst et al. 2018). Of note, the mitigation strategy in the CBS was planned, implemented, and updated annually and exceeded in many ways the minimum requirements outlined in the SOCP.

Planning Seismic Surveys

In 2008, several spatial and temporal planning measures were implemented by GXT with guidance received from DFO as well as other regulatory agencies and local stakeholders, including EISC, Inuvialuit Game Council (IGC) and the Hunters and Trappers Committees (HTCs) of the ISR.

- Seismic data acquisition was planned so that no survey lines near the primary beluga harvesting areas would be acquired until the main part of the hunt was complete. The proponent communicated closely with the communities regarding the status of the hunt.
- Seismic surveys remained distant from the Beluga 1A Management Zones while the beluga hunt was active (i.e., ~19 km at the closest point of approach) and were timed so that it was well past the peak of the beluga hunting season, which is usually 90% complete by the third week of July. A 22 km distance from shore of all seismic lines was also put in place to avoid interference with any coastal resource harvesting activities. The Beluga 1A Management Zones, which comprise the Tarium Niryutait Marine Protected Area (TNMPA), are key beluga harvesting areas for Inuvialuit hunters.
- Bowhead whale aggregation areas (BAAs) were defined each season and required special mitigation measures (see Additional Mitigation Measures and Modifications below for details).

Operational Mitigation Measures and Monitoring

Safety Zone and Start-up

The size of the SZ was determined via acoustic modelling and subsequent SSV measurements were made in the field (during each seismic survey season). Water depth, bottom type, and array volume all influenced the size of the SZ, which were based on a sound level threshold of 180 dB re 1 μPa_{rms}. The 180-dB threshold was used for cetaceans as it was also used at the time by the U.S. NMFS (Southall et al. 2007). The size of the SZ for cetaceans varied, ranging from 500–2500 m depending on water depth and other physical parameters (Zykov et al. 2007; MacGillivray et al. 2008). A 190 dB rms-based SZ was used for polar bears (*Ursus maritimus*) swimming in the water. Note that ramp-ups were not delayed for seals.

During daylight hours, MMOs conducted watches at least 30 minutes prior to the start of a ramp-up. [Note that the air source array could not be ramped up from a complete shut down if the entire SZ was not visible, such as during darkness or fog.] If the air source(s) were silent for more than 20 minutes and a whale or swimming polar bear was sighted within or approaching the relevant SZ, air sources were not activated until the animal had left the SZ, or 30 minutes had passed, and the animal had not been re-sighted.

Air sources in the array were gradually ramped up over an approximate 30-minute period. Ramp-up after a shut down could not begin until either (1) the whale/polar bear was observed outside the SZ, or (2) no whales/polar bears had been seen within a 30-minute watch following the shutdown.

Shut-down of Air source Array

If a whale (or swimming polar bear) was seen within, or about to enter, the relevant SZ (see above), MMOs initiated a shutdown of the air source array. Shut downs were to be implemented for bowhead, beluga, and gray whales (*Eschrichtius robustus*), as well as polar bears, even though these species were not listed as Endangered or Threatened on Schedule 1 of SARA. Air sources were not shut down for seals.

Line Changes and Maintenance Shut-downs

Air sources were often shut down when transiting between seismic lines. Because the air source array could not be ramped up from a complete shut down if the entire SZ was not visible, the smallest air source in the array was activated when the resumption of seismic surveying was expected to occur during a period of poor visibility (e.g., darkness or fog).

Operations in Low Visibility

Air source operations were not permitted in identified BAAs during periods when the full SZ was not visible. PAM was not used in the CBS because the technology was still in the research and development stage, and deemed ineffective by regional stakeholders. The explicit intention was to maximize the number of MMOs onboard and therefore make the most efficient use of limited vessel berth space by maximizing the number of MMOs.

Additional Mitigation Measures and Modifications

Seismic surveying could not be conducted within known, inferred, or probable bowhead feeding areas (BAAs) during periods of darkness or when visibility was poor (i.e., the full SZ was not visible). To facilitate implementation of that mitigation measure, it was necessary to (1) define BAAs (i.e., what density of bowheads constitutes an aggregation), (2) document the real-time distribution of bowheads in these areas and the region, and (3) use the available distributional data to identify the location and spatial extent of the BAAs.

BAAs were defined each year that seismic surveying was to occur (see Figure 1 for an example). In 2008 (as well as 2007, 2009 and 2010), DFO conducted aerial surveys of much of the southern CBS to document the distribution of bowhead whales (with some of the funding provided by the seismic operator). The delineated BAAs were forwarded to MMOs aboard the seismic vessel during August. MMOs applied the BAA-specific mitigation measures when seismic acquisition occurred there (e.g., Harris et al. 2009; Joynt and Harwood 2009).

BAA-specific mitigation measures included:

- at least two MMOs on watch simultaneously during periods when air sources were active;
- no air source operations were permitted when, in the opinion of any MMO on duty, the full SZ was not visible (e.g., during fog or darkness); and
- the air source array was shut down if, in the opinion of any MMO on duty, the sea state was such that bowhead whales could not readily be detected in the SZ.

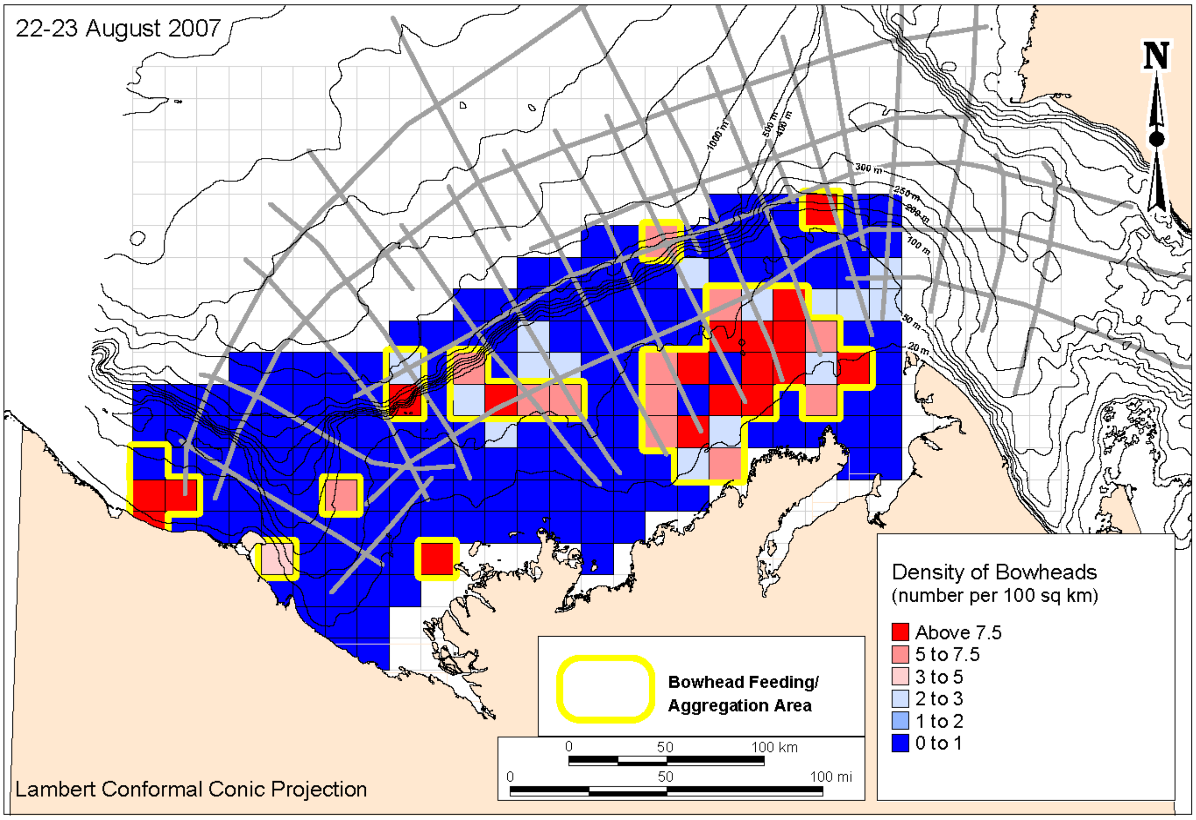

Figure 1. Example of bowhead aggregation/feeding areas for 2007, based on aerial surveys conducted by DFO on 22 and 23 August 2007 (LGL Limited 2008b). Grey lines depict GXT's planned seismic survey lines.

Table 1. Summary of mitigation and monitoring practices in Canada that exceed or are more specific than the minimum requirements included in the SOCP.

SOCP Component	Offshore Newfoundland and Labrador (2008-present)	Offshore Nova Scotia (based on 2013 and 2014)	Canadian Beaufort Sea (based on 2008)
Planning Seismic Surveys	No air source activation outside of the Project Area identified in the EA process.	No air source activation outside of the Project Area identified in the EA process. No air source testing or between line air source activation in the Haddock Box. Seismic surveying in areas closest to NARW Critical Habitat limited to periods when sound propagation was reduced. A Marine Mammal and Sea Turtle Mitigation and Monitoring Plan with regulatory approval from CNSOPB and DFO was required.	Spatial and temporal planning measures: Delay start of seismic surveys to avoid primary beluga subsistence harvest; Avoid Beluga 1A Management Areas while beluga hunt was active; Use of 22 km buffer from the coast to avoid coast resource harvesting activities; and Identification of BAAs, which required special mitigation measures (see below). A Marine Mammal Mitigation and Monitoring Plan (MMMMP), with DFO's approval (at the regional level), was required.

SOCP Component	Offshore Newfoundland and Labrador (2008-present)	Offshore Nova Scotia (based on 2013 and 2014)	Canadian Beaufort Sea (based on 2008)
Safety Zone and Start-up	SZ of 500 m radius from centre of air source array used. For some seismic surveys, the SZ also included a 500 m zone centred on the location of the MMO on the bridge of the seismic source vessel. Visual and acoustic (in 2018 by one seismic operator) monitoring of the SZ and adjacent waters for at least 30 minutes before ramp up (RU). RU delayed by minimum of 30 minutes for all marine mammals and sea turtles detected within SZ. RU delay duration increased to minimum of 60 minutes for all beaked whales detected within the SZ. RU over a period of 30 minutes.	SZ based on acoustic modelling using either >180 dB rms or >183 dB SEL as the threshold. SZ ranged from 600–1000 m. Visual and acoustic monitoring of the SZ and adjacent waters for cetaceans for at least 30 minutes before RU. RU delayed by minimum of 30 minutes for all cetaceans and sea turtles detected within SZ. *Or* RU delayed by minimum 30 minutes for dolphins and seals detected within a 500 m SZ. RU delay duration was increased to minimum of 60 minutes for beaked whales (SARA Schedule 1). RU over a period of 20 minutes to 30 minutes. DFO reviewed summary information about MMO qualifications in their advice to the CNSOPB during the regulatory review process.	SZ based on acoustic modelling using 180 dB rms as the threshold. SZ ranged from 500–2500 m. Visual monitoring of the SZ and adjacent waters for cetaceans and polar bears for at least 30 minutes before RU. RU delayed by minimum of 30 minutes if cetacean or polar bear (swimming) seen inside or approaching SZ. RU over a period of 30 min. 4 MMOs on source vessel, 2 MMOs on support vessel.

SOCP Component	Offshore Newfoundland and Labrador (2008-present)	Offshore Nova Scotia (based on 2013 and 2014)	Canadian Beaufort Sea (based on 2008)
Shut-down of Air Source Array(s)	Immediate shut down any time a SARA-Schedule 1 marine mammal (endangered, threatened), any sea turtle species, or any beaked whale is detected within the SZ.	Immediate shut-down any time a SARA-Schedule 1 marine mammal (endangered, threatened and special concern) or sea turtle is detected within the SZ. Variability in other shut down situations: All baleen whales, All sea turtles, Unidentified baleen whales, Unidentified beaked whales.	Immediate shut-down any time a whale or swimming polar bear is visually observed within or approaching the SZ. Any shut-down due to a whale or polar bear (swimming) visual sighting within the SZ must be followed by a 30-minute all-clear period and then a standard, full RU.
Line Changes and Maintenance Shut-downs	No air source operations outside of Project Area identified in the EA. RU implemented after periods of single air source use during line changes.	No air source operations outside of Project Area identified in the EA. Air sources shut down during line changes.	Air sources typically shutdown during line changes unless start-up was expected to occur during a period of poor visibility; in that case, a single air source (smallest volume) was activated.
Operations in Low Visibility	Up until 2018, PAM was not used. PAM has been used during periods when full SZ is not visible and during pre-RU watch, so far only in 2018[6].	PAM was used during periods of poor visibility (i.e., when the SZ was not entirely visible). Use of a longer hydrophone array was required to increase detection probability of low–frequency calls by baleen whales, namely blue and fin whales.	Air source operations were not permitted in identified BAAs when the full SZ was not visible.

[6] PAM has since been used in 2019 by a seismic operator offshore NL.

SOCP Component	Offshore Newfoundland and Labrador (2008-present)	Offshore Nova Scotia (based on 2013 and 2014)	Canadian Beaufort Sea (based on 2008)
Additional Mitigation Measures and Modifications	To minimize the potential for cumulative effects, seismic surveys are to maintain a minimum separation distance of 30 km	Use of turtle guards on seismic streamer tail buoys to minimize risk of entanglement.	BAAs were identified via the use of aerial surveys. When operating in a BAA, it was required that: • at least two MMOs on watch simultaneously during seismic activity; • no seismic activity was permitted when the full SZ was not visible (e.g., during fog or darkness); and • the air source array was shut down if, in the opinion of the MMO(s) on duty, the sea state was such that bowhead whales could not readily be detected.

4.0 REVIEW OF KEY SCIENTIFIC FINDINGS SINCE 2004

The scientific literature on the effects of seismic survey sound on marine mammals, sea turtles, fishes, and invertebrates has been reviewed previously in support of SOCP development. Three notable reviews relative to the SOCP include DFO (2004), Abgrall et al. (2008), and Payne et al. (2008). In the subsections below, we generally focus on key scientific findings since 2004, which are directly relevant to management measures in the SOCP.

4.1 MARINE MAMMALS

Our review of the scientific literature on marine mammals and related seismic studies indicate that there have been close to 300 publications since 2004. Key findings relative to the SOCP, based on professional judgement, are presented below. Additionally, DFO specifically requested that information on marine mammal response to seismic surveys conducted in-ice be included.

4.1.1 Hearing Impairment and Physical Effects

Of most relevance to this report, given that the implementation of shut downs (and ramp-up delays) for marine mammals detected within a SZ is intended to minimize the likelihood of hearing impairment, is the recent U.S. NMFS guidance document on acoustic thresholds for onset of Permanent and Temporary Threshold Shifts (PTS, TTS) in marine mammal hearing (NMFS 2016, 2018). Some background information and a review of NMFS (2016, 2018) are provided below. It is important to note that Canada has not formally adopted any thresholds for hearing impairment in marine mammals (or other marine fauna).

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. TTS has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed in Southall et al. 2007, 2019; Finneran 2015). However, there has been no specific documentation or studies of TTS, or permanent hearing damage, i.e., PTS, in free-ranging marine mammals exposed to sequences of air source pulses during realistic field conditions. Such experiments are very difficult to undertake, particularly for large cetaceans. Up until summer 2016, the NMFS policy regarding exposure of marine mammals to high-level sounds was that cetaceans and pinnipeds should not be exposed to impulsive sounds ≥180 and 190 dB re 1 μPa_{rms}, respectively (NMFS 1995, 2000). However, those criteria were established before there was any information about the minimum received levels of sounds necessary to cause auditory impairment in marine mammals. The 180 and 190 dB re 1 μPa_{rms} levels were not considered to be the levels above which TTS might occur. Rather, they were the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. Since that time, Southall et al. (2007) made recommendations for different science-based sound exposure criteria for marine mammals and frequency-weighting procedures. Those recommendations were never formally adopted by the NMFS for use in regulatory processes or during mitigation programs associated with seismic surveys.

In July 2016, NMFS released new technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016), taking at least some of the Southall et al. (2007) recommendations into account, as well as those presented by Finneran (2016). The new guidance revised thresholds for PTS onset (injury) for marine mammal species. The new noise exposure criteria for marine mammals account for the newly-available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive (e.g., frequency weightings for various groups of marine mammals, allowing for their functional bandwidths), and other relevant factors. For impulsive sounds, such as air source pulses, the new guidance incorporates marine mammal auditory weighting functions, and dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}). The onset of PTS is assumed to be 15 dB or 6 dB higher than TTS when considering SEL_{cum} and SPL_{flat}, respectively. Different thresholds have been provided for the various hearing groups, including low-frequency cetaceans (e.g., baleen whales), mid-frequency cetaceans (e.g., most delphinids and beaked whales), high-frequency cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater, and otariids underwater (Table 2). These thresholds are currently used as the basis in establishing the safety (shut-down) radii for seismic surveys conducted under U.S. jurisdiction; NMFS (2016, 2018) indicates that the largest distance of the dual criteria (SEL_{cum} or Peak SPL_{flat}) should be used as the safety radius. It should be recognized that there are a number of limitations and uncertainties associated with these injury criteria (Southall et al. 2007). Low or moderate degrees of TTS, up to at least 30 dB of elevation of the threshold, are not considered an injury (Southall et al. 2007; Le Prell 2012); beyond that level, TTS may grade into PTS (Le Prell 2012).

Table 2. Permanent Threshold Shift (PTS) onset thresholds for various marine mammal hearing groups (NMFS 2016, 2018)[a]. Also shown are the corresponding TTS thresholds.

Hearing Group	**Low-frequency Cetacean**	**Mid-frequency Cetacean**	**High-frequency Cetacean**	**Phocid Pinnipeds Underwater**	**Otariid Pinnipeds [b] Underwater**
PTS					
SEL_{cum} Threshold (dB)	183	185	155	185	203
Peak SPL_{flat} Threshold (dB)	219	230	202	218	232
TTS					
SEL_{cum} Threshold (dB)	168	170	140	170	188
Peak SPL_{flat} Threshold (dB)	213	224	196	212	226

[a] Since release of the new technical guidance by NMFS (2016, 2018), Southall et al. (2019) provided updated scientific recommendations regarding noise exposure criteria for hearing effects. The PTS-onset threshold values remain unchanged relative to those presented by NMFS (2016, 2018) and Finneran (2016), but include all marine mammals and a re-classification of hearing groups.

[b] In addition to otariids, walruses, polar bears, and sea otters are considered in this group.

TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises, and a sound must be stronger in order to be heard. It is a temporary phenomenon, and (especially when mild) is not considered to represent physical damage or “injury” (Southall et al. 2007; Le Prell 2012). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. However, research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Kujawa and Liberman 2009; Liberman 2016). These findings have raised some doubts as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015, 2016).

To provide context, the predicted ranges to PTS onset thresholds (based on NMFS 2018) for a recently modelled air source array (5085 in^3; source level of 235 dB re 1 μPa_{rms}) offshore Newfoundland were less than the current 500 m minimum SZ distance in the SOCP (Zykov 2018). Two sites (500 m and 1180 m water depth) were modelled at the Sackville Spur area (i.e., north of Flemish Pass) for two different times of year. Estimated sound levels from the air source array (5085 in^3) were above SPL_{peak} injury thresholds (PTS onset) for most marine mammal groups within 40 m of the array. Sound levels were predicted to decrease to below the SPL_{peak} injury threshold for cetaceans with high-frequency hearing slightly farther away (i.e., within 190 m of the air source array). Considering the SEL_{cum} metric for injury, once again, most marine mammals would have to occur and remain within close range of the air source array, <40 m to approximately 160 m, to in theory incur auditory injury (PTS). This also assumes that marine mammals occur within these distances of the air source array for a 24-hour period; this is considered an unlikely scenario particularly for a moving sound source. Likewise, acoustic modelling of five different air source arrays (ranging in volume from 4808–6420 in^3 and in source level from 235–247 dB re 1 μPa_{rms}) proposed to operate on the U.S. Mid- and South-Atlantic Outer Continental Shelf (OCS) predicted that the PTS-onset threshold for various marine mammal groups generally fell well within the 500 m radial isopleth on the basis of peak pressure (NOAA 2018). The exception was for high-frequency cetaceans and as such NMFS required a larger SZ (1500 m) for this marine mammal group.

Nowacek et al. (2013) stated that sufficient scientific data exist to conclude that seismic air sources have a low probability of directly harming most marine life, except at close range where physical injury can occur. Several aspects of the monitoring and mitigation measures that are now often implemented during seismic survey projects are designed to detect marine mammals occurring near the air source array, and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment. In addition, many cetaceans and (to a limited degree) pinnipeds show some avoidance of the area where received levels of air source sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves will reduce or (most likely) avoid the possibility of hearing impairment.

4.1.2 Behavioural Responses

Since 2004, there have been at least 139 new publications which present information on the behavioural effects of seismic survey sound on marine mammals. The new publications generally support previous findings about baleen whale, odontocete, and pinniped response to air source sound. Responses to air source sound by marine mammals, if any, depend on many factors, including species, current activity (e.g., migration vs. foraging), state of maturity, and experience (Southall et al. 2007; Weilgart 2007; Ellison et al. 2012). Most marine mammals (i.e., of those species with available data) exhibit at least localized avoidance of air source arrays with some species exhibiting avoidance at distances up to 20 to 30 km in certain situations (e.g., migrating bowhead whales; Miller et al. 1999; Richardson et al. 1999). Several studies have emphasized that if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Lusseau and Bejder 2007; Weilgart 2007; New et al. 2013; Nowacek et al. 2015; Forney et al. 2017); this has not been demonstrated for seismic surveys but there have been few, if any, studies that have directly examined this question with respect to air source sounds. Of note, the current NMFS threshold for Level B harassment (behaviour) from pulsed sound is 160 dB re 1µPa_{rms}, although this criterion is also expected to be revised in the future (Scholik-Schlomer 2015). Although this criterion has not been adopted formally in Canada (nor have any other behavioural criteria), it is used regularly in EAs of seismic surveys in Canada as a guide for predicting behavioural responses of marine mammals. As behavioural responses, including those to air source sound, are highly context-specific and not consistently associated with received levels, some authors have made recommendations on different approaches to assess behavioural responses (e.g., Gomez et al. 2016; Harris et al. 2017). For example, Gomez et al. (2016) recommended a dichotomous (response/no response) approach that can represent a measure of impact in terms of habitat loss and degradation.

Baleen Whales

Baleen whales generally tend to avoid operating air sources, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to air source pulses at distances beyond a few kilometers, even though the sound levels from air source pulses remain well above ambient noise levels out to much longer distances. However, studies done since the late 1990s of migrating humpback and migrating bowhead whales show reactions, including avoidance, that sometimes extend to greater distances than documented earlier. Avoidance distances often exceed the distances at which boat-based observers can see whales, so observations from the source vessel can be biased. Observations over broader areas may be needed to determine the range of potential effects of some large-source seismic surveys where effects on cetaceans may extend to considerable distances (Bain and Williams 2006; Moore and Angliss 2006). Longer-range observations, when required, can sometimes be obtained via systematic aerial surveys or aircraft-based observations of behaviour (e.g., Miller et al. 2005;

Yazvenko et al. 2007a,b) or by use of observers on one or more support vessels operating in coordination with the seismic vessel (e.g., Smultea et al. 2004; Johnson et al. 2007). However, the presence of other vessels near the source vessel can, at least at times, reduce sightability of cetaceans from the source vessel (Beland et al. 2009), thus complicating interpretation of sighting data.

Some baleen whales show considerable tolerance of seismic pulses. However, when the pulses are strong enough, avoidance or other behavioural changes become evident. Because responsiveness is variable and the responses become less obvious with diminishing received sound level, it has been difficult to determine the maximum distance (or minimum received sound level) at which reactions to seismic become evident and, hence, how many whales are affected. Responsiveness depends on the situation (Richardson et al. 1995; Ellison et al. 2012).

Of the behavioural studies examining response of mysticetes to seismic surveys undertaken since 2004, the multi-year Behavioral Response of Australian Humpback Whales to Seismic Surveys (BRAHSS) provides a comprehensive design and analysis of migrating humpback whale response to seismic survey sound (e.g., Cato et al. 2013). The BRAHSS study was conducted on humpback whales off both the east and west coasts of Australia during their southward migrations in September and October of 2010–2014. The experimental design was relatively sophisticated with both treatment and control groups, a pre-trial statistical power analysis, a range of sound exposures, and a four-stage ramp-up design (Cato et al. 2013). The experimental design progressed from using a single air source (20 in^3) in 2010 to a fully operational commercial seismic array including a ramp-up procedure in 2014. Dunlop et al. (2015) reported that humpback whales responded to the vessel operating the single air source by decreasing their dive time and speed of southward migration; however, the same responses were obtained during control trials without an active air source, suggesting that humpbacks responded to the source vessel rather than the air source itself. A ramp-up was not superior to triggering humpbacks to move away from the vessel compared with a constant source at a higher level of 140 in^3, although an increase in distance from the air source array was noted for both sound sources (Dunlop et al. 2016a). Avoidance was also shown when no air sources were operational, indicating that the presence of the vessel itself had an effect on the response (Dunlop et al. 2016a,b). Overall, the results showed that humpbacks were more likely to avoid active air sources (of 20 and 140 in^3) within 3 km and at received levels of at least 140 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017a). Responses to ramp up and use of a 3130 in^3 array elicited greater behavioural changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Humpbacks reduced their southbound migration or deviated from their path, thereby avoiding the active array, when they were within 4 km of the active large air source, where received levels were >130 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017b, 2018). These results are consistent with earlier studies (e.g., McCauley et al. 2000). However, some individuals did not show avoidance behaviours even at levels as high as 160 to 170 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2018). Also, even in cases where there is no conspicuous avoidance or change in activity upon exposure to sound pulses from distant seismic operations, there are sometimes subtle changes in behaviour (e.g., surfacing–respiration–dive cycles) that are only evident through detailed statistical analysis (e.g., Richardson et al. 1986; Gailey et al. 2007).

Results from Moulton and Holst (2010) showed that, during operations with a single air source and during ramp up, blue whales were seen significantly farther from the vessel compared with periods without air source operations. Since start-up of a single air source is equivalent to the start of a ramp up, this suggests that baleen whales will begin to move away during the initial stages of a ramp-up. However, there is likely to be variation (i.e., species, context) in baleen whale response to ramp up.

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. Castellote et al. (2012) reported that fin whales avoided their potential winter ground for an extended period of time (at least 10 days) after seismic operations in the Mediterranean Sea had ceased. However, gray whales have continued to migrate annually along the west coast of North America despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A *in* Malme et al. 1984; Richardson et al. 1995), and there has been a substantial increase in the population over recent decades (Allen and Angliss 2013). The western Pacific gray whale population did not seem affected by a seismic survey in its feeding ground during a prior year (Johnson et al. 2007). Similarly, bowhead whales have continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years, and their numbers have increased notably (Allen and Angliss 2013). Bowheads also have been observed over periods of days or weeks in their summer foraging habitat in areas ensonified repeatedly by sound from seismic air source pulses (Harris et al. 2007). However, it is generally not known whether the same individual bowheads were involved in these repeated observations (within and between years) in repeatedly ensonified areas.

Pirotta et al. (2018) used a dynamic state model of behaviour and physiology to assess the consequences of disturbance (e.g., seismic surveys) on whales (in this case, blue whales). They found that the impact of localized, acute disturbance (e.g., seismic surveys) depended on the whale's behavioural response, with whales that remained in the affected area having a greater risk of reduced reproductive success than whales that avoided the disturbance. Chronic, but weaker disturbance (e.g., vessel traffic) appeared to have less effect on reproductive success. Nonetheless, in the absence of some unusual circumstances, the history of coexistence between seismic surveys and baleen whales suggests that brief exposures to sound pulses from any single seismic survey are unlikely to result in prolonged disturbance effects.

Odontocetes

Dolphins and porpoises are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bow riding). However, some studies near the U.K., Newfoundland, and Angola, in the Gulf of Mexico, and off Central America have shown localized avoidance (Holst et al. 2005a, 2006; Stone and Tasker 2006; Weir 2008; Barkaszi et al. 2009; Holst 2009; Richardson et al. 2009; Moulton and Holst 2010; Stone 2015). The beluga whale is a species that (at least at times) shows long-distance avoidance of seismic vessels. Aerial surveys conducted in the southeastern Beaufort Sea in summer found that sighting rates of belugas were significantly lower at distances 10–20 km compared with 20–30 km from an operating air source array (Miller et al. 2005). The low number of beluga sightings by MMOs on the vessel seemed to confirm there was a strong avoidance response to the 2250 in^3 air source array. More recent seismic monitoring studies in the same area have confirmed that the apparent displacement effect on belugas extended farther than has been shown for other small odontocetes exposed to air source pulses (e.g., Harris et al. 2007). In contrast, recent studies show little evidence of conspicuous reactions by sperm whales to air source pulses, contrary to earlier indications (Gordon et al. 2006; Stone and Tasker 2006; Winsor and Mate 2006; Jochens et al. 2008; Weir 2008; Barkaszi et al. 2009; Miller et al. 2009; Moulton and Holst 2010; Stone 2015).

There are almost no specific data on responses of beaked whales to seismic surveys, but given their response to vessels it is likely that most if not all species show avoidance. Observations from seismic vessels off the U.K. from 1994–2010 indicated that detection rates of beaked whales were significantly higher when air sources were not operating vs. when a large array was in operation; however, sample sizes were small (Stone 2015). Detections (acoustic or visual) of northern bottlenose whales have been made from seismic vessels during recent seismic surveys in the Northwest Atlantic during periods with and without air source operations (Moulton and Miller 2005; Potter et al. 2007; Moulton and Holst 2010). Similarly, other visual and acoustic studies indicated that some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (Laurinolli and Cochrane 2005; Simard et al. 2005).

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

Pinnipeds

Visual monitoring from seismic vessels has shown only slight (if any) avoidance of air sources or changes in behaviour by pinnipeds (Miller et al. 2005; Funk et al. 2010; Hannay et al. 2011; Stone 2015). These studies show that many pinnipeds do not avoid the area within a few hundred metres of an operating air source array. However, based on the studies with large sample size, observations from a separate monitoring vessel, or radio telemetry, it is apparent that some phocid seals do show localized avoidance of operating air sources (e.g., Thompson et al. 1998). The limited nature of this tendency for avoidance is a concern. It suggests that one cannot rely on pinnipeds to move away, or to move very far away, before received levels of sound from an approaching seismic survey vessel approach those that may cause hearing impairment.

Marine Mammals in Ice-covered Water

There is limited information available for marine mammal response to seismic surveys conducted in ice-covered waters. Marine mammal monitoring conducted for 2-D seismic surveying during 2009–2011 through ice-covered waters off northeast Greenland provides some limited information (Jones et al. 2009; Lang and Mactavish 2011; Mactavish and Lang 2011). In areas with heavy ice, pinnipeds (hooded, harp, bearded, and ringed seals; walrus) and polar bears were regularly seen on the ice and sightings rates and distances as documented by MMOs did not differ substantially during periods with versus without air source activity. In areas with less ice concentration, cetaceans (blue, fin, sei, minke, and northern bottlenose whales) were seen in small numbers. There were no clear indications that cetaceans were affected by air source operations. Overall, the small number of cetacean sightings (especially during non-seismic periods) warrants caution in drawing conclusions about whether marine mammal movement and initial behaviour indicated avoidance of air source operations. For pinnipeds, many individuals were first observed on ice and the behaviour they exhibited may have been in response to the visual cues of the seismic vessel and attending icebreaker and/or the in-air sound versus air source sound.

4.1.3 Masking

Masking is the obscuring of sounds of interest by interfering sounds, generally at similar frequencies. Introduced underwater sound will, through masking, reduce the effective communication distance of a marine mammal species if the frequency of the source is close to that used as a signal by the marine mammal, and if the anthropogenic sound is present for a significant fraction of the time (Clark et al. 2009; Jensen et al. 2009; Gervaise et al. 2012; Hatch et al. 2012; Rice et al. 2014; Erbe et al. 2016; Tenessen and Parks 2016; Jones et al. 2017; Putland et al. 2017; Cholewiak et al. 2018; Dunlop 2018). Conversely, if little or no overlap occurs between the introduced sound and the frequencies used by the species, communication is not expected to be disrupted. Also, if the introduced sound is present only infrequently, communication is not expected to be disrupted much, if at all. In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter et al. 2013, 2016; Finneran and Branstetter 2013; Sills et al. 2017). The biological repercussions of a loss of communication space, to the extent that this occurs, are unknown.

The duty cycle of air sources is low; the air source sounds are pulsed, with relatively quiet periods between pulses. In most situations, strong air source sound will only be received for a brief period (<1 s), with these sound pulses being separated by at least several seconds of relative silence, and longer in the case of deep-penetration surveys or refraction surveys. A single air source array would cause strong masking when propagation conditions are such that sound from each air source pulse reverberates strongly and persists for much or all of the interval up to the next air source pulse (e.g., Simard et al. 2005; Clark and Gagnon 2006). Situations with prolonged strong reverberation have been considered infrequent, but there are increased indications that this may be more of a concern for marine mammals than previously thought, particularly in consideration of multiple, concurrent seismic surveys. It is common for reverberation to cause some lesser degree of elevation of the background level between air source pulses (e.g., Gedamke 2011; Guerra et al. 2011, 2016; Klinck et al. 2012; Guan et al. 2015), and this weaker reverberation presumably reduces the detection range of calls and other natural sounds to some degree. Guerra et al. (2016) reported that ambient noise levels between seismic pulses were elevated as a result of reverberation at ranges of 50 km from the seismic source. Based on measurements in deep water of the Southern Ocean, Gedamke (2011) estimated that the slight elevation of background levels during intervals between pulses reduced blue and fin whale communication space by as much as 36 to 51% when a seismic survey was operating 450–2800 km away. Based on preliminary modelling, Wittekind et al. (2016) reported that air source sounds may reduce the communication range of blue and fin whales 2000 km from the seismic source. Nieukirk et al. (2012) and Blackwell et al. (2013) noted the potential for masking effects from seismic surveys on large whales.

Although masking effects of pulsed sounds on marine mammal calls and other natural sounds are expected to be limited, there are few specific studies on this. Some whales continue calling in the presence of seismic pulses and whale calls often can be heard between the seismic pulses (e.g., Nieukirk et al. 2004, 2012; Smultea et al. 2004; Holst et al. 2005a,b, 2006, 2011; Dunn and Hernandez 2009; Thode et al. 2012; Bröker et al. 2013; Cerchio et al. 2014; Sciacca et al. 2016). However, some of these studies found evidence of reduced calling (or at least reduced call detection rates) in the presence of seismic pulses. One report indicates that calling fin whales distributed in a part of the North Atlantic went silent for an extended period starting soon after the onset of a seismic survey in the area (Clark and Gagnon 2006). It is not clear from that paper whether the whales ceased calling because of masking, or whether this was a behavioural response not directly involving masking. Also, bowhead whales in the Beaufort Sea apparently decrease their calling rates in response to seismic operations, although movement out of the area also contributes to the lower call detection rate (Blackwell et al. 2013, 2015). In contrast, Di Iorio and Clark (2010) found that blue whales in the St. Lawrence Estuary increased their call rates during operations by a lower-energy seismic source. The sparker used during the study emitted frequencies of 30–450 Hz with a relatively low source level of 193 dB re 1 $\mu Pa_{pk\text{-}pk}$. There is some evidence that fin whale song notes recorded in the Mediterranean had lower bandwidths during periods with versus without air source sounds (Castellote et al. 2012).

Recent studies of sperm whales found that they continued calling in the presence of seismic pulses (Smultea et al. 2004; Holst et al. 2006, 2011; Jochens et al. 2008; Nieukirk et al. 2012). Madsen et al. (2006) noted that air source sounds would not be expected to cause significant masking of sperm whale calls given the intermittent nature of air source pulses. [However, some limited masking would be expected due to reverberation effects, as noted above.] Dolphins and porpoises are also commonly heard calling while air sources are operating (Gordon et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b, 2011; Potter et al. 2007). Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocetes, given the intermittent nature of seismic pulses plus the fact that sounds important to them are predominantly at much higher frequencies than are the dominant components of air source sounds.

Pinnipeds, sirenians and sea otters have the best hearing sensitivity and/or produce most of their sounds at frequencies higher than the dominant components of air source sound, but there is some overlap in the frequencies of air source pulses and their calls. Sills et al. (2017) reported that recorded air source sounds at 1 km from the source may have masked the detection of low-frequency sounds by ringed and spotted seals completely at the onset (initial 200 ms) of the air source pulse when signal amplitude is variable. Ghoul and Reichmuth (2016) reported that sea otter hearing is most sensitive underwater at 8–16 kHz; though, their hearing is not specialized to detect sounds in background noise. However, the intermittent nature of air source pulses presumably reduces the potential for masking.

Some cetaceans are known to increase the source levels of their calls, shift their peak frequencies, or otherwise modify their vocal behaviour in response to increased noise (Nieukirk et al. 2005; Scheifele et al. 2005; Parks et al. 2007, 2009, 2011, 2012, 2016a,b; Hanser et al. 2009; Holt et al. 2009; Di Iorio and Clark 2010; McKenna 2011; Castellote et al. 2012; Melcón et al. 2012; Risch et al. 2012; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Blackwell et al. 2015, 2017; Papale et al. 2015; Bittencourt et al. 2016; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Robertson et al. 2017; Fornet et al. 2018; Tsujii et al. 2018). However, Holt et al. (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals. Ultimately, the potential biological "costs" of these changes in vocalizations are unknown. Marine mammals do have mechanisms that enhance the detectability of signals in the presence of sound, including spatial release, comodulation masking release, as well as the within valley (or "dip") listening strategy (see Erbe et al. 2016 for a review).

4.1.4 Other Physical Effects

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur include stress[7], neurological effects, gas bubble formation and related organ or tissue damage resulting from a change in dive behaviour in response to acoustic exposure. Very little is known about the potential for seismic survey sounds (or other types of strong

[7] Physiological stress response in marine mammals is complicated and poorly understood. Several variables which can be measured in blubber, blood and feces can serve as indicators of stress level in marine mammals, including cortisol, adrenocorticotropic hormone, and aldosterone (see Champagne et al. 2018).

underwater sounds) to cause non-auditory physiological effects in marine mammals and there have been no new directed studies on this topic since 2004. Such effects, if they occur at all, would presumably be primarily limited to short distances and to activities that extend over a prolonged period. The available data do not allow identification of a specific exposure level above which non-auditory effects can be expected (Southall et al. 2007), or any meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in these ways.

4.1.5 Mortality and Strandings

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys. Ten cases of strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings (Castellote and Llorens 2016). The three cases of beaked whale strandings coincident with seismic surveys and strandings near naval exercises involving use of mid-frequency sonar suggest a need for caution in conducting seismic surveys in areas occupied by beaked whales until more is known about effects of seismic surveys on those species (Hildebrand 2005; Castellote and Llorens 2016). Seismic pulses and mid-frequency sonar signals are quite different, and some mechanisms by which sonar sounds have been hypothesized to affect beaked whales are unlikely to apply to air source pulses. Sounds produced by air source arrays are broadband impulses with most of the energy below 1 kHz. Typical naval mid-frequency sonars emit non-impulse sounds at frequencies of 2–10 kHz, generally with a relatively narrow bandwidth at any one time (though the frequency may change over time). Thus, it is not appropriate to assume that the effects of seismic surveys on beaked whales or other species would be the same as the apparent effects of naval sonar. One of the hypothesized mechanisms by which naval sonars lead to strandings might, in theory, also apply to seismic surveys: If the strong sounds sometimes cause deep-diving species to alter their surfacing–dive cycles in a way that causes bubble formation in tissue, that hypothesized mechanism might apply to seismic surveys as well as mid-frequency naval sonars. However, there is no specific evidence of this upon exposure to air source pulses.

4.2 SEA TURTLES

There have been far fewer studies on the effects of air source sound (or indeed any type of sound) on sea turtles relative to marine mammals, and little is known about the sound levels that will or will not elicit various types of behavioural responses (Nelms et al. 2016). As a reminder, the limited available data indicate that the frequency range of best hearing sensitivity of sea turtles extends from ~100–700 Hz (Bartol and Ketten 2006; Ketten and Bartol 2006; Yudhana et al. 2010a,b; Martin et al. 2012; Piniak et al. 2012a,b; 2016; Lavender et al. 2014), which overlaps substantially with the dominant frequencies produced by air source pulses. Given that, plus the high energy levels of air source pulses, we can conclude that sea turtles hear air source sounds. It has been hypothesized that sea turtles may be at reduced risk to air source sound exposure because they typically spend much time near the water surface. Received levels of low-frequency underwater sounds diminish close to the surface because of pressure-release and interference phenomena that occur at and near the surface (Urick 1983; Richardson et al. 1995; Potter et al. 2007).

Since 2004, data on sea turtle behaviour near air source operations have been collected during marine mammal and sea turtle monitoring and mitigation programs associated with various seismic operations around the world. The general finding is that some sea turtles exhibit behavioural changes and/or avoidance within a localized area around an operating seismic survey vessel, although turtles have also been seen within 100 m of an operating air source array during vessel-based surveys (see Holst et al. 2006; Weir 2007; Holst and Smultea 2008; DeRuiter and Doukara 2012).

For example, during six large-source (3050–8760 in^3) and small-source (75–1350 in^3) surveys conducted by the Lamont–Doherty Earth Observatory (L-DEO) during 2003–2005, the mean closest point of approach (CPA) for turtles was closer during non-seismic than seismic periods: 139 m vs. 228 m and 120 m vs. 285 m, respectively (Holst et al. 2006). During a large-source L-DEO seismic survey off the Pacific coast of Central America in 2008, the turtle sighting rate during non-seismic periods was seven times greater than that during seismic periods (Holst and Smultea 2008). In addition, distances of turtles seen from the seismic vessel were significantly farther from the air source array when it was operating (mean 159 m, n = 77) than when the air sources were off (mean 118 m, n = 69; Mann-Whitney U test, $P<0.001$) (Holst and Smultea 2008). During another L-DEO survey in the Eastern Tropical Pacific in 2008, the turtle sighting rate during non-seismic periods was 1.5 times greater than that during seismic periods; however, turtles tended to be seen closer to the air source array when it was operating, but this difference was not statistically significant (Hauser et al. 2008).

Weir (2007) reported on the behaviour of sea turtles near seismic exploration operations off Angola, West Africa. A total of 240 sea turtles were seen during 676 h of vessel-based monitoring, mainly for associated marine mammal mitigation measures. Air source arrays with total volumes of 5085 and 3147 in^3 were used at different times during the seismic program. Sea turtles tended to be seen slightly closer to the seismic source, and at sighting rates twice as high, during non-seismic vs. seismic periods (Weir 2007). However, there was no significant difference in the median distance of turtle sightings from the array during non-seismic vs. seismic periods, with means of 743 m (n = 112) and 779 m (n = 57). DeRuiter and Doukara (2012) observed that small numbers of basking loggerhead sea turtles (n = 6 of 86 turtles of whose behaviour was observed) exhibited an apparent startle response immediately following an air source pulse. Diving turtles (49 of 86 individuals) were observed at distances from the center of the air source array ranging from 50–839 m. The estimated sound level at the median distance of 130 m was 191 dB re 1 μPa (peak). These observations were made during ~150 h of vessel-based monitoring from a seismic vessel actively operating an air source array (2440 in^3) off Algeria—there was no corresponding observation effort during periods when the air source array was inactive (DeRuiter and Doukara 2012).

Off northeastern Brazil, 46 sea turtles were seen during 2028 h of vessel-based monitoring of seismic exploration using 4–8 GI air sources between June 2002 and August 2003 (Parente et al. 2006). Although slightly more sea turtles were sighted during non-seismic (0.075 turtles per hour) than seismic periods (0.054 turtles per hour), the sighting rates were not statistically significant. Detailed behavioural data during seismic operations were lacking (Parente et al. 2006). De Gurjão et al. (2005) suggested that sea turtles may have shown some avoidance around a seismic survey off Bahia State, Brazil, during January to May 2002.

Few studies have directly investigated hearing or sound-induced hearing loss in sea turtles (Nelms et al. 2016). There are very few data on temporary hearing loss and no data on permanent hearing loss or injury in sea turtles exposed to air source pulses. Although some information is available about effects of exposure to sounds from a single air source on captive sea turtles, the long-term acoustic effects (if any) of a full-scale marine seismic operation on free-ranging sea turtles are unknown. For impulsive sound such as those from air sources, the U.S. Navy (2017) proposed PTS thresholds of 204 dB SEL_{cum} and 232 dB_{peak}.

Although it is possible that exposure to air source sounds may cause mortality or mortal injuries in sea turtles close to the source, this has not been demonstrated and seems unlikely (Popper et al. 2014), especially since they appear to be highly resistant to explosives (Ketten et al. 2005 *in* Popper et al. 2014). Nonetheless, Popper et al. (2014) proposed mortality/mortal injury criteria for seismic air sources of 210 dB SEL_{cum} or >207 dB $_{peak}$; however, these criteria were largely based on impacts of pile-driving sound on fish.

Entanglement of turtles in seismic gear and vessel strikes during seismic survey operations are also possible but do not seem to be common. Geophysical companies routinely employ turtle excluder devises to minimize the risk of entanglement. The greatest effects are likely to occur if seismic operations occur in or near areas where turtles concentrate, and at seasons when turtles are concentrated there. However, there are no specific data that demonstrate the consequences of such seismic operations to sea turtles.

4.3 FISHES AND INVERTEBRATES

Since the original literature review that was conducted for the SOCP in 2004, there have been some noteworthy advances in the understanding of the potential effects of exposure to seismic sound on marine invertebrates and fishes. The following sections summarize the key additions to the scientific literature since 2004.

Despite the new information acquired since 2004, data required to recommend changes/additions to the SOCP as it applies to marine invertebrates and fishes are still lacking. Many of the invertebrate and fish studies discussed below are not representative of exposures of these animals to seismic source sound under natural conditions. However, given the lack of scientific study of this topic under natural conditions, the studies have been included in this document. The current mitigation measures of avoidance of spawning areas and migration corridors remain somewhat impractical given the lack of empirical data needed to describe the spatial and temporal aspects of important spawning areas and migration corridors. While there are data related to locations of spawning areas and migration corridors for some invertebrate and fish species, many of these data were collected some time ago before recently observed changes to the marine environment (e.g., water temperature, currents).

4.3.1 Studies Applicable to Both Marine Invertebrates and Fishes

More scientific focus has recently been applied to the particle motion component of underwater sound, including seismic air source sound, in terms of how it affects marine invertebrates and the best ways to measure it during experimentation (see Nedelec et al. 2016; Roberts et al. 2016; Roberts and Elliott 2017; Popper and Hawkins 2018). However, research on this is in its infancy and far less is known about how this component of underwater sound interacts with marine invertebrates and fishes, particularly from the perspective of effects of particle motion on these biota types.

Hawkins et al. (2015) identified the principal data gaps in understanding the effects of underwater sound on marine invertebrates and fishes, thereby providing a solid guide for future study. Priorities for research as determined through gap analysis are as follows:

- Describing soundscapes;
- Describing how invertebrates and fishes detect particle motion (e.g., variation in mechanism, sensitivity to particle motion, measurable effects of exposure to particle motion for both water-borne and substrate-borne particle motion);
- Describing practical mitigation measures; and
- Describing received sound in a consistent manner (e.g., metrics).

There has been publication of numerous review papers related to the potential impacts of seismic surveys on marine invertebrates and fishes, and how best to study these effects (e.g., Carroll et al. 2017; Hawkins and Popper 2016). Some of the primary recommendations provided in these review papers include the following:

- An integrated multidisciplinary approach to manipulative (i.e., laboratory or controlled field mesocosm) and in situ studies would be the most effective way to establish impact thresholds in the context of realistic exposure levels (Carroll et al. 2017);
- Development and application of procedures for screening and assigning priorities to invertebrate and fish species that may be especially vulnerable to exposure to seismic sound, including those which play important roles in local ecosystems (Hawkins and Popper 2016);
- Development of valid and appropriate sound exposure criteria specific to invertebrates and fishes which will allow regulators to set limits to seismic sound levels that are permissible under certain conditions (Hawkins and Popper 2016);
- Consideration of the actual physical, physiological and behavioural responses of individual and groups of invertebrates and fishes, especially in terms of those changes that may affect individual fitness and health. Distinctions should be made between short-term, transient changes from which animals typically recover quickly, and those that have lasting effects on individuals; and
- Development of mitigation approaches to reduce seismic sound source levels for sound pressure, particle motion, and substrate vibration that are directed at invertebrates and fishes rather than application of approaches (e.g., ramp-up) that were developed for, and are more applicable to, marine mammals.

4.3.2 Marine Invertebrate Studies

In a recent study, McCauley et al. (2017) conducted an experiment whereby they exposed zooplankton off the coast (shallow water) of Tasmania to a 150 in^3 air source. Observations from the study indicate that seismic surveys may have a greater effect on zooplankton communities than previously understood. Treatment samples of zooplankton exposed to the air source exhibited an increase of two to three-fold mortality versus the control group and impacts on zooplankton were observed as far as 1.2 km away from the air source. However, the sample size and number of replications was relatively small since the study occurred over just two days, so may be confounded by small sample size. Additional sampling is required in order to determine the full extent of the impact that air source sound has on zooplankton mortality.

A companion study completed by Richardson et al. (2017) attempted to model the impact of an air source survey on zooplankton over a larger temporal and spatial scale than what was originally considered by McCauley et al. (2017). In total, the modeled survey area was 80 km × 36 km, with a water depth range of 300–800 m. Air source impact was considered for a 35-day period. Modeling results indicate that significant impacts to zooplankton would most likely occur only at a local scale (i.e., within the 2.5 km linear survey area), with less of an impact on a larger spatial scale, contradictory to results obtained by McCauley et al. (2017). Richardson et al. (2017) attributes potential avoidance behaviour of the zooplankton as a possible reason why McCauley et al. (2017) observed such a marked decrease in zooplankton abundance during their study. Note that the plankton biomass recovered to about 95% of its original level within two to six days of the end of the exposure. No large-scale effects were detected.

Of note, the U.S. Bureau of Ocean Energy Management (BOEM) are planning a follow-up study of the effects of seismic sound on zooplankton that is planned in deeper waters offshore the U.S. east coast or in the Gulf of Mexico.

Other recent studies of invertebrates and seismic sound are summarized below.

Morris et al. (2018) conducted a two-year (2015-2016) BACI study examining the effects of 2-D seismic exploration on catch rates of snow crab (*Chionoecetes opilio*) along the eastern continental slope of the Grand Banks of Newfoundland (Lilly Canyon and Carson Canyon). The air source array used during both years of the study was operated from a commercial seismic exploration vessel. The array had a total volume of 4880 in^3, with an operational pressure of 2000 psi, a horizontal zero-to-peak SPL of 251 dB re 1 μPa @ 1 m, and a source SEL of 229 dB re 1 $\mu Pa^2 \cdot s$ @ 1m. The closest that the seismic source came within the vicinity of the sound recorders of the study area was 1,465 m in 2015, while it passed within only 100 m of the sound recorders in 2016. Overall, the findings of the study indicated that the sound from the commercial seismic survey did not significantly reduce snow crab catch rates in the short-term (i.e., days) or longer term (i.e., weeks) in which the study took place. For this particular study, the authors concluded that while the inherent variability of the catch per unit effort data limited the statistical power of the study, results suggest that if there are fishery-related effects of exposure to seismic sound on snow crab, they are smaller than changes related to natural spatial and temporal variation.

Additional studies of the effects of exposure to seismic sound on American lobster (*Homarus americanus*) have been conducted (see Payne et al. 2007, 2015). In the pilot laboratory/controlled field experiments conducted by Payne et al. (2007), resultant received peak-to-peak SPLs using actual air sources ranged from 202–227 dB. The various endpoints investigated include survival, food consumption, turnover rate, serum protein level, serum enzyme level, serum calcium level, and histopathology of hepatopancreas. While no significant differences between treated and control lobsters were observed for survival and turnover rate, sub-lethal effects were observed with respect to feeding and serum biochemistry. Time between exposure and assessment of animals ranged from a few days to a few months. Payne et al. (2007) conducted a pilot laboratory study that investigated the effects of exposure to recorded seismic survey sound on lobster in terms of mortality, gross pathology, histopathology, serum biochemistry and feeding. Measured received SPLs were 180 dB peak-to-peak, 174 dB 0-peak, and 171 dB rms. Animals were processed within a few hours of the 8-hour exposure. No effect was observed for mortality rate, overt gross pathology, or feeding. A higher degree of epithelial vacuolation and tubular dilation was observed in the hepatopancreas tissue of treated lobsters compared to control lobsters. While there were no significant differences between treated and control lobsters in terms of serum biochemistry, there was a trend for decreased levels of protein and triglyceride in exposed animals. The potential significance of these observations on American lobster populations was not explained in any detail. The exposure circumstances in this study (e.g., exposure time, received sound levels) do not reflect what would happen in the natural environment during a seismic survey.

Day et al. (2016a,b) conducted a field study which exposed egg-bearing female spiny lobsters (*Jasus edwardsii*) to three different air source configurations (peak-to-peak source levels ranging from 209–212 dB re 1 μPa). Embryonic development of spiny lobster was assessed through the number, morphology, energy content, and competency of hatched larvae. It was determined that none of these variables were significantly different for the treatment larvae when compared to the control larvae (Day et al. 2016a,b). However, there were non-lethal effects, including changes in reflex behavior time and haemolymph chemistry, as well as apparent damage to statocysts (Day et al. 2016b). In addition to these results associated with lobsters, Day et al. (2017) reported that exposure to seismic sound was also found to significantly increase mortality in scallops (*Pecten fumatus*), especially over a chronic time scale (i.e., months post-exposure). The details of exposure in this study (e.g., exposure time, received sound levels) do not reflect what would happen in the natural environment during a seismic survey.

Fitzgibbon et al. (2017) also examined the impact of air gun exposure on spiny lobster through a companion study to the Day et al. (2016a,b, 2017) studies. The same study site, experimental treatment methodologies, and air source exposures were used for the lobsters in Fitzgibbon et al. (2017) as in Day et al. (2016a,b, 2017). The objectives of the study were to examine the haemolymph biochemistry and nutritional condition of groups of lobsters over a period of up to 365 days post air source exposure. Overall, no mortalities were observed across both the experimental and control groups; however, lobster total haemocyte count was determined to have decreased by 23% to 60% for all lobster groups up to 120 days post air source exposure in the experimental group when compared to the control group. A lower haemocyte count increases the risk of disease through a lower immunological response. Also, the only other haemolyph parameter that was determined to have been significantly affected by air gun exposure was the Brix index of haemolymph at 120 and 365 days post exposure in just one of the experiments involving egg-laden females.

While certain studies have suggested that some marine invertebrates are affected physically by exposure to air source sound, the degree of the suggested effects have been minimal. In addition, the suggested physical effects were observed when constrained marine invertebrates were exposed to air source sound at very close range, resulting in exposures unrepresentative of those that would occur under natural conditions. Behavioural effects of exposure to air source sound have also been observed in studies but in those studies, the marine invertebrates that exhibited the behavioural changes were constrained and unable to freely move away from the air source(s).

4.3.3 Marine Fish Studies

There have been a number of recent reviews of fish bioacoustics (including hearing) and the potential effects of exposure to various underwater sound types (Hawkins and Popper 2018a,b; Popper and Hawkins 2019; Popper et al. 2019).

Although not a direct study involving seismic sound, Casper and Mann (2009) conducted field hearing measurements of the Atlantic sharpnose shark (*Rhizoprionodon terraenovae*), to determine hearing thresholds. The auditory evoked potential (AEP) method was employed. The highest sensitivity to pulsed tones by the Atlantic sharpnose shark was observed at 20 Hz (range of frequencies tested was 20–1,000 Hz) with a particle acceleration level of 1.3 x 10 3 m/s^2. The work by Casper and Mann (2009) demonstrates that the Atlantic sharpnose shark's peak sensitivity to underwater pulsed sound is likely within the frequency range that characterizes seismic air source sound. This paper is of particular relevance given that some shark species are considered at-risk in Canada and that mitigation measures for seismic surveys (e.g., air source shut downs) could be implemented for sharks detected at the surface (see Sections 6.2.1 and 6.2.2).

Physical Effects

The relationship between sensory hair cell loss and hearing loss in fishes as well as the negative effects of hair cell loss and potential recovery of damaged hair cells due to anthropogenic noise was reviewed recently by Smith (2016) and Smith and Monroe (2016).

Andrews et al. (2014) conducted genetic analyses and examined the behavior of captive juvenile Atlantic salmon (*Salmo salar*) exposed to a 10 in^3 air source at a distance of 2 m every 10 s for approximately 10 min. In order to replicate a worse-case scenario within several hundred metres of a survey vessel, the average SPL was approximately 204 dB re 1µPa $_{p\text{-}p}$.

The received levels were measured using hydrophones placed directly in front of the cage. Behavioural observations of interest upon exposure included any changes in swimming direction/speed, reaction time to air source blasts, and net avoidance. The right and left inner ears of the fish were sampled for genetic analyses 16 h following exposure and compared to control, non-exposed fish. The fish exhibited an initial startle response, generally for the first three air source discharges, with little further activity for the remainder of the exposure. Increased swimming was observed for exposed fish, with rapid and erratic swimming activity during attempted capture (netting). Genetic analyses revealed numerous instances of up- or down-regulation for transcripts encoding oxygen transport, the glycolytic pathway, the Krebs cycle, and the electron transport chain, indicating both potentially damaged ear tissues as a result of exposure (e.g., ruptured cell membranes) and regeneration of ear tissues post-exposure (including auditory hair cells).

Sierra-Flores (2015) examined noise as a short-term stressor in Atlantic cod (*Gadus morhua*) using cortisol as a biomarker. An underwater omnidirectional loudspeaker suspended at the center of a fish tank and submerged at 0.5 m depth emitted noise in a linear sweep for 10 seconds with SPLs ranging from 104 to 110 dB re 1 μPa_{rms}. Results of the experiment show that plasma cortisol levels of fish increased rapidly with noise exposure, returning to baseline levels 20-40 minutes post-exposure. A second experiment examined the effects of long-term noise exposure on Atlantic cod spawning performance. Tanks were stocked with male and female cod and exposed daily to six noise events, each lasting one hour. The noise exposure had a total SPL of 133 dB re 1 µPa. Cod eggs were collected daily and measured for egg quality parameters as well as egg cortisol content. Total egg volume, floating fraction, egg diameter and egg weight did not appear to be negatively affected by noise exposure. However, fertilization rate and viable egg productivity were reduced by 40% and 50%, respectively, compared with the control group. Mean egg cortisol content was found to be 34% greater in the exposed group as compared to the control group. Elevated cortisol levels inhibit reproductive physiology for males and can result in a greater frequency of larval deformities for spawning females.

Radford et al. (2016) conducted experiments examining how repeated exposures of different sounds to European seabass (*Dicentrarchus labrax*) can reduce the fishes' response to that sound. The experimenters exposed postlarval seabass to playback recordings of impulsive seismic survey noise (SEL_{SS} 144 dB re 1 $\mu Pa^2 \cdot s$) in large indoor tanks containing underwater speakers. Their findings indicate that short term exposure of seismic noise increased the ventilation rate (i.e., opercular beat rate [OBR]) of seabass not previously exposed to seismic relative to seabass in controlled, ambient sound conditions. Fish that were reared in tanks that were repeatedly exposed to seismic sound over a 12-week period exhibited a reduced OBR response to that sound type, but fish exposed over the same time period to pile-driving noise displayed a reduced response to both seismic and pile-driving noise. An increased ventilation rate is indicative of greater stress in the seabass. The experimenters found no evidence for mortality or effects on growth of the seabass throughout the 12-week study period.

Popper et al. (2014) provide interim exposure guidelines of seismic air source sound levels (in dB) that could cause negative effects to fish of various hearing abilities as well as eggs and larvae. Some of the effects addressed include mortality, potential mortal injury, recoverable injury as well as TTS, masking, and behavioural changes (see Table 7.4 *in* Popper et al. 2014). Note that the thresholds provided for seismic air source sound are based primarily on results of studies involving pile driving so more study is required to develop directly relevant guidelines for seismic sound thresholds for fishes. There are important differences between the impulsive sounds generated by seismic air sources and pile driving. For example, the rise times associated with pile driving sound are shorter than those associated with seismic air source sound. Sound with shorter rise times can have greater adverse effects on receiving animals compared with longer rise times (Popper et al. 2014).

Fertilized capelin (*Mallotus villosus*) eggs and monkfish (*Lophius americanus*) larvae were exposed to seismic air source sound and subsequently examined and monitored for possible effects of the exposure (Payne et al. 2009). The laboratory exposure studies involved a single air source at a fixed distance. Approximate received SPLs measured in the capelin egg and monkfish larvae exposures were 199 to 205 dB re 1 μPa^{p-p} and 205 dB re 1 μPa^{p-p}, respectively. The capelin eggs were exposed to either 10 or 20 air source discharges, and the monkfish larvae were exposed to either 10 or 30 discharges. No statistical differences in mortality/morbidity between control and exposed subjects were found at 1 to 4 days post-exposure in any of the exposure trials for either the capelin eggs or the monkfish larvae. The exposure conditions used in this study are not representative of those associated with a seismic survey under natural conditions (e.g., study has longer exposure times and higher received sound levels). However, given the lack of significant mortality/morbidity effect on these eggs and larvae in the study, it is unlikely that there would be any effect on them during a seismic survey under natural conditions.

Behavioural Effects

Using omnidirectional sonar, researchers at the Norwegian Institute of Marine Research studied the real-time behaviour of herring schools exposed to a full-scale 3D seismic survey off Vesteralen, northern Norway (Peña et al. 2013). They found that throughout the study period, the herring swam slowly against the predominant northeast current, with a net displacement along with the current. The mean swimming speed after subtracting the drift velocities was 0.35 m/s, and the mean response speed in the direction away from the air source array was 0.22 m/s. No changes were observed in swimming speed, swimming direction, or school size that could be attributed to the seismic sound as the vessel approached from a distance of 27 km to 2 km over a 6 h period. The reason for lack of response to the seismic sound was interpreted as a combination of a strong motivation for feeding, a lack of suddenness of the air source stimulus, and an increased level of tolerance to the seismic sound.

The effects of seismic air sources on species richness and abundance of a coral reef fish community was studied in a before-after seismic survey study completed by Miller and Cripps (2013) on Scott Reef in Western Australia. A 2,055 in^3 dual air source array was used in the survey which exposed the reef to SEL_{cum} levels that were approximately 187 dB re 1 μPa^2 s. Underwater Visual Census (UVC) of the reef fish community was conducted via SCUBA at six locations on the reef. At each location fish were surveyed along several 50 m × 5 m transects, at a depth of 6–11 m. The results of the study reveal that there was no evidence of either direct or indirect mortality of reef fish from the seismic survey. Also, modelling of results that considered spatial, temporal, and observer variability showed no significant effect of the seismic survey on species richness and abundance of Pomacentridae or non-Pomacentridae fishes (the most common family of fishes on the reef). Also, the experimenters analyzed the six most abundant fish species on the reef to determine if the seismic survey had a noticeable effect on their abundances. They did not find a significant effect of the seismic survey on the abundance of each of the fish species.

Paxton et al. (2017) examined the effects of seismic sound on the distribution and behaviour of fish on a temperate reef during a seismic survey conducted on the inner continental shelf of North Carolina, U.S. Much of the survey occurred in deep water (>1000 m) off the continental shelf; however, the survey ended in shallower (<35m) inner continental waters. Two hydrophones were set up on two reefs 0.7 km and 6.5 km from the linear path of the seismic vessel to measure sound pressure levels while a video camera was set up on a third reef

7.9 km away from the seismic track. Using a spherical spreading sound model, received sound pressure levels were estimated to be between 202 to 230 dB re 1 µPa for the hydrophone closest to the seismic track. A series of short, 10 second video clips were recorded every 20 minutes by the video camera for a time period of three days before seismic and one day of seismic activity. It was determined that overall abundances of fish declined by up to 78% on this reef when undergoing seismic activity as opposed to the days when no seismic occurred. Only one fish was observed to exhibit a startle response to the air source pulses from the seismic survey. The authors claim that although the study contains limited data, it contributes evidence that normal fish use of reef ecosystems is reduced when exposed to seismic sound.

Løkkeborg et al. (2012) examined whether and how seismic sound affected the commercial fishery. They focused on the effects on catches of gillnets and longlines, predicting that since these two fishing methods work on different principles, behavioural responses to seismic sound would have different consequences for gillnet and longline fisheries. In addition, they also examined the effect of exposure to seismic sound on the density and distribution of fish in the ensonified area via an acoustic survey. The authors suggested that an increase in swimming activity as a result of exposure to seismic sound might explain why gillnet catches increased for Greenland halibut (*Reinhardtius hippoglossoides*) and redfish (*Sebastes norvegicus*), and longline catches decreased for Greenland halibut and haddock (*Melanogrammus aeglefinus*). Except for saithe (*Pollachius virens*), acoustic mapping of fish abundance did not suggest displacement from fishing grounds.

In summary, some studies have shown that various life stages of particular fish species can be physically affected by exposure to air source sound. In all of these cases, the fish subjects were subjected to exposures that would not likely occur under natural conditions. Studies that demonstrated physical effects on fishes typically involved either captive juvenile/adult subjects that were unable to move away from the sound source or passive ichthyoplankton that were located within a few metres of the sound source. The focus of study related to the potential effects of exposure to air source sound on fishes has shifted to behavioural effects, particularly those that could result in a decrease in catch rate of the fishes. Fishes will exhibit both subtle and more overt behavioural changes in response to air source sound and these effects appear to be quite variable both between and within species. Generally, the behavioural effects are localized and temporary, but can result in short-term effects on catch rates. Recent work in Norway suggests that, in the future, particular acoustic-biological models may be used in the design and planning of seismic surveys in order to minimize disturbance to fishing (Hovem et al. 2012).

4.4 DETECTION TECHNOLOGY

Of direct relevance to this report is a recent study comparing methods for monitoring marine mammals in periods of low visibility during seismic surveys (Verfuss et al. 2018). The study compared the weaknesses and strengths of PAM, RADAR, active sonar, and thermal infrared (IR) detectors. A key issue with PAM that has typically been used during seismic surveys is that it is difficult to detect low-frequency vocalizations like those produced by baleen whales. Flow noise, noise from the seismic vessel and its associated machinery (e.g., air sources, pingers, clanking chains) contribute to this issue. The relative performance of PAM is influenced by a number of factors including target species, environmental conditions, PAM equipment type, and how it is deployed, and the skill of the PAM operators. Verfuss et al. (2018) comment that "…PAM is not achieving its potential during typical seismic surveys". PAM hydrophones deployed from seismic source vessels are often deployed on short cables and towed close to the vessel where propeller and machinery noise compromise performance. The authors concluded that the detection ranges and probabilities achievable by PAM systems for small cetaceans and sperm whales should generally be useful in improving the monitoring required in most jurisdictions, provided the hydrophone systems were well deployed. However, they note that currently available ancillary PAM systems are often unable to provide adequate detection range information for small cetaceans. These systems would primarily be useful in detecting an animal and providing a bearing that could be relayed to the MMO on watch to assist with visual detection. The other detection technology (RADAR, active sonar and thermal IR) were generally considered in the earlier stages of development and use compared to PAM. Similarly, Smith et al. (in prep) concluded that the thermal IR system they tested for marine mammal detection required further study and refinement so that it could be effectively used as a complementary monitoring tool during seismic surveys.

5.0 INTERNATIONAL PRACTICES AND GUIDELINES

This section presents an overview of mitigation and monitoring requirements for marine seismic surveys under the jurisdiction of the U.S. (BOEM 2014, 2016; NOAA 2018), the United Kingdom (U.K.; JNCC 2017), Australia (DEWHA 2008), New Zealand (DOC 2013), Brazil (IBAMA 2018), Greenland (DCE 2015) and Norway (Norway undated; NPD 2017). A summary table is presented at the end of this section to facilitate the comparison of mitigation measures amongst the jurisdictions (Table 3). Additional details on each jurisdiction's requirements are provided in Appendix C.

In addition to the jurisdictions above, the International Union for Conservation of Nature and Natural Resources (IUCN) released a guidance document which focuses on the planning, environmental assessment, risk assessment and monitoring of marine geophysical surveys (Nowacek and Southall 2016). This includes planning and monitoring practices which have developed over recent years (and continue to evolve) for seismic surveys off Sakhalin Island. As the guidelines do not include specific operational mitigation, they will not be evaluated further. Additional information can be found on the IUCN website.

In November 2018, New Zealand passed legislation which bans new permits for offshore oil and gas exploration, although existing permits are preserved and are subject to the existing marine seismic code. This follows bans for future offshore oil and gas exploration off Belize, Costa Rica, Ireland, Denmark (inland waters only, does not include the North Sea or Greenland) and a gradual phase-out in France (Offshore Technology 2018). The New Zealand ban effectively ended initiatives commencing in 2015 to update its Code, which included a series of working papers and workshop proceedings.

This section and Appendix C examine guidance documents which are specific to seismic programs in each jurisdiction to enable a direct comparison with the SOCP. As is the case in Canada, additional mitigation measures may be required on a project by project or site basis through the country's environmental assessment and permitting processes, which are beyond the scope of this study.

Appendix C provides additional mitigation for VSP, wellsite surveys, and high-resolution surveys. This section focuses on seismic surveys (i.e., 2-D, 3-D, and 4-D).

5.1 PLANNING SEISMIC SURVEYS

Most jurisdictions include provisions that the seismic operator determine and avoid migration, breeding, calving, and important feeding areas for marine mammals (and sea turtles in the case of New Zealand and Brazil). This is typically included in either the seismic guidance documents and/or the guidance document refers to the country's environmental assessment and permitting processes. In most cases, this requirement is based on legislation each jurisdiction has passed to protect marine mammals. The guidance documents referenced in this section do not include specific enforcement provisions.

The Australian National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA 2018) published an Information Paper related to the environmental plans (EPs) for marine seismic surveys, which includes an environmental impact assessment (EIA). Although adapting advice included in the Information Paper is not a regulatory requirement, EPs must be accepted before any petroleum activity or greenhouse gas activity can occur in Commonwealth waters.

Norway's guidelines are focused on fish and fisheries, with little reference to marine mammals. The licensee, before conducting a seismic survey, must decide whether the survey could have been undertaken in a different place, at another time, or in a manner that would be better for fishers, without having significant practical or economic consequences for the licensee (NPD 2017). A common mitigating measure is for the operator to use the lowest practicable power level and in the case of the U.K., Brazil, and Greenland consider methods to reduce and/or buffer unnecessary high frequency noise. JNCC (2017), IBAMA (2018) and DCE (2015) do not define or provide thresholds or values for "high frequency noise".

To the best of our knowledge, other jurisdictions have not adapted new technology that could replace air sources, although new technologies are being investigated and tested for specific types of geology (e.g., BP's Wolfspar® Technology for oil and gas reserves with salt layers). In 2007, ExxonMobil initiated a Joint Industry Project to develop the next generation marine vibrator (MV) technology. The goal of the MV Joint Industry Project is to develop a commercially viable marine vibrator source that could be used for areas where a better seismic signature is needed, for marine seismic surveys in environmentally sensitive areas, and for an improved source for certain operational environments such as shallow water where conventional air source arrays perform sub-optimally. To date, prototypes have been developed to meet key array output specifications and are currently undergoing reliability testing (Mougenot et al. 2017). The Sound and Marine Life Joint Industry Programme (under the International Association of Oil and Gas Producers) recently funded an environmental assessment of MVs (vibroseis); however, the findings are not yet publicly available (Matthews et al. *in prep*.).

5.2 SAFETY ZONE AND START-UP

Safety zones (often referred to as Exclusion zones or Mitigation zones) differ depending on jurisdiction (see Table 3 for additional detail). The U.S., JNCC (U.K.) and Greenland (Denmark) call for a 500 m safety zone, although Exclusion zones were recently extended to 1 km for pre-start-up watch and 1.5 km for certain species of marine mammals in the Mid-Atlantic OCS area of the U.S. (NOAA 2018).

Australia also uses a 500 m shut down zone; however, they incorporate a 3 km "observation zone" and a 1–2 km (depending on the size of the array) "low power zone". "Whales" (see definition in Section 5.3 below) and their movements should be monitored in the observation zone to determine if they are approaching the low power zone. When a whale is about to enter the low power zone, the acoustic source should immediately be powered down to the lowest possible setting.

Brazil's recently updated monitoring guide calls for a 1000 m Exclusion zone. New Zealand uses Mitigation zones varying from 200 m to 1.5 km depending on the output of the array and the potential risk of adverse impacts (see Appendix C for further details).

Most jurisdictions have adopted a 30-minute period of visual monitoring prior to ramping up the air source arrays. Both Greenland and the U.K. have extended this requirement to 60 minutes for waters greater than 200 m depth to account for deeper diving cetaceans.

Ramp-up must be delayed in all jurisdictions until no marine mammals (or whales, and in some cases turtles) have been observed in the Exclusion or Mitigation zones for the prescribed period of time.

Ramp-up is typically from 20–40 minutes, commencing with the smallest air source and gradually activating additional air sources until the desired operating level of the array is obtained. Australia provides for a ramp-up of 30 minutes. Norway's "Resource Management Regulations" do not stipulate a particular timeframe, only that the audio source must be started up gradually to give fish and marine mammals the opportunity to leave the area around the survey (NPD 2017).

Visual observers must be suitably trained (see Appendix C for additional information on each country's observer qualifications) in the observation and identification of marine mammals. These requirements vary by country, ranging from completing a course approved by the appropriate regulatory agency (or by the JNCC in the U.K.) in most instances to holding a university degree in a relevant discipline for Brazil and the mid-Atlantic OCS. Some countries require third party observers while others may utilize crew members who have been trained as observers, or a combination of both third party and trained crew observers (see Appendix C for additional information).

The U.S. and Greenland require two observers to be on watch at all times and New Zealand requires two observers to be onboard, with a recommendation that they both be on watch for start-up. Greenland requires three observers on board and the U.K. and Australia require sufficient MMO personnel to perform their duties.

5.3 SHUT-DOWN OF AIR SOURCE ARRAY(S)

The U.S. and Australia require an immediate shut down when a "whale" enters an Exclusion or shut down zone. Both countries define "whales" as all species of baleen whales, all species of beaked whales, and larger toothed whales. Dolphins do not fall under the definition of "whale" in either country (see Appendix C for a list of species for each country).

New Zealand and Brazil require an immediate shut down when any marine mammal (or sea turtle in the case of Brazil) enters the Exclusion or Mitigation Zone. Greenland requires that air source operations be reduced to the smallest air source. The U.K. does not require a shutdown of the air sources when marine mammals are detected within the Mitigation zone while the air sources are active, either during the soft-start procedure or at full power (JNCC 2017).

Shut-downs due to a whale or marine mammal sighting within the Exclusion or Mitigation zones are typically followed by an all-clear observation period and a standard, full ramp-up.

5.4 LINE CHANGES AND MAINTENANCE SHUT-DOWNS

The seven jurisdictions differ in their requirements for line changes and maintenance shut-downs. The U.S. allows operators in the Gulf of Mexico to maintain a "minimum source level" of 160 dB re 1 μPa-m (rms) for all turns between transect lines and unscheduled maintenance of the air source array that requires the shut-down of the array. Use of a single air source as a mitigation source during extended line turns is not allowed in the mid-Atlantic OCS (NOAA 2018). The acoustic source must be deactivated when not acquiring data or preparing to acquire, except as necessary for testing (NOAA 2018).

The U.K. allows air source activation only if power is reduced to 180 in^3 (or as close as is practically feasible) at standard pressure.

Australia requires air source arrays to be at the lowest possible setting. Operators are strongly encouraged in New Zealand to shut down at the end of a line although the use of acoustic sources for mitigation purposes during line turns is allowed, provided that the power output of the acoustic source is reduced to levels that limit ensonification of the Mitigation zone boundary.

Brazil provides for two scenarios: maximum power can be maintained if the line change is less than 20 minutes duration. For line changes greater than 20 minutes, the air source arrays must be shut down at the end of each line and restarted according to the normal observer (30 min) and ramp-up procedures. The use of a “mitigation gun” or single air source is prohibited.

Greenland also offers two scenarios: if a line change is expected to exceed one hour, air source firing must be terminated at the end of the line and a full pre-shooting search and ramp-up undertaken before the next line. If a line change is expected to be shorter than one hour, the array can be operated at a lower output or with the mitigation gun.

Countries such as the U.K. provide detailed mitigation on testing of air sources or unplanned breaks in data acquisition. This is summarized in Appendix C. In general, most jurisdictions will not require ramp up when the arrays are shut down for less than a prescribed period of time (20 minutes in the U.S. and Brazil, 10 minutes in the U.K., 5 minutes in Greenland) and certain conditions are met. Australian requirements are based on the results of MMO observations while New Zealand lists a series of criteria based on array size and power.

5.5 OPERATIONS IN LOW VISIBILITY

Although PAM is only “strongly encouraged”, the U.S. will not permit ramp-up in poor visibility in the Gulf of Mexico using only visual observers. NOAA (2018) requires the use of PAM during all air source surveys in the U.S. mid- and south-Atlantic OCS area. Although not mandatory in the U.K., PAM should be used during periods when visual mitigation is not possible (e.g. darkness, low visibility).

Larger acoustic sources cannot be activated during night-time hours or poor sighting conditions off New Zealand unless PAM has been carried out by a qualified PAM operator. PAM must also be used to augment observer capacities during periods of darkness, poor visibility or sea state above 3 off Greenland.

Soft start can commence in Australian waters provided that there have not been three or more whale instigated shut-downs during the preceding 24-hour period; or the vessel (and/or a spotter vessel or aircraft) has been in the vicinity (~10 km) for at least 2 hours (under good visibility conditions) within the preceding 24 hour period and no whales have been sighted. The use of PAM should be considered by the proponent operating in areas where the likelihood of encountering whales is moderate to high.

Conversely, for Brazil, PAM is mandatory 24 hours a day throughout the seismic operation.

Appendix C provides additional information on the recommended number of PAM operators and what steps must be followed if the PAM system malfunctions during periods of poor visibility.

5.6 ADDITIONAL MITIGATION MEASURES AND MODIFICATIONS

Many jurisdictions have begun to include additional mitigation for the cumulative effects of multiple seismic programs. A 40-km geographic separation distance (which is not data-based) may be required between simultaneously operating seismic surveys within the mid- and south-Atlantic OCS. The use of this mitigation measure will be evaluated on a case-by-case basis

(BOEM 2014). Note that this measure was not implemented by NOAA in their approval of five 2-D seismic surveys in December 2018 (NOAA 2018).

The JNCC guidelines state that if dual source arrays are to be operated simultaneously, the Mitigation Zone required to encompass the entire array (e.g., based on the centre point between the two arrays) must be estimated. For Australia, additional environmental assessment of potential impacts may be necessary if multiple seismic sources (e.g., two vessels on one project or multiple, adjacent projects) are to be operated in the same general area. DEWHA (2008) does not define “same general area” but includes a requirement that the proponent should liaise with government and industry bodies to ensure that surveys do not unnecessarily coincide or overlap.

In the case of overlapping seismic surveys off Brazil, special operating arrangements may be proposed, as well as the adoption of additional mitigation measures and monitoring which may include the denial of a license (IBAMA 2018).

Greenland requires that the total sound exposure level (across all air source pulses and all concurrent surveys, including those from different seismic operators and activities in the area) per 24 hours must be predicted through a noise propagation model in the environmental assessment and measured at representative locations during the seismic survey. New Zealand requires sound transmission loss modelling where activities are planned in Areas of Ecological Importance or Marine Mammal Sanctuaries (see Appendix C for modelling requirements).

Australia requires that for surveys being undertaken in the broad vicinity of known breeding or resting areas, a buffer (exclusion) zone should be established to ensure that operating survey vessels do not enter the vicinity where whales may be present. Where available, scientific evidence and/or acoustic propagation modelling should be used to determine and justify the buffer zone.

New Zealand requires additional mitigation requirements when arriving on location for the first time. These are presented in Appendix C.

Norway requires a Fishery Expert when it is necessary for fishing operations in the area. Greenland requires a Fisheries liaison officer (FLO) to be on board “when appropriate”.

Table 3. Summary of mitigation and monitoring requirements for seismic surveys in select international jurisdictions.

SOCP Component	USA – Gulf of Mexico (BOEM 2016), Mid-Atlantic (BOEM 2014; NOAA 2018)	United Kingdom (JNCC 2017)	Australia (DEWHA 2008)	New Zealand (DOC 2013)	Brazil (IBAMA 2018)	Greenland (DCE 2015)	Norway (undated)
Planning Seismic Surveys	Reduce potential conflicts with sensitive species. Seasonal closures for areas of Critical Habitat, seasonal management areas or other protected areas (for example to protect NARW). Additional mitigation measures if warranted.	Lowest practicable power levels and seek/consider methods to reduce and/or buffer unnecessary high frequency noise. Determine what marine mammal species are likely to be present in the survey areas. Plan surveys to avoid areas/periods of high abundance and key seasons.	Seismic surveys should not be planned in areas where and when whales are likely to be breeding, calving, resting, feeding, or migrating. If proposed, these surveys and associated mitigation measures may require further assessment. EPs must be accepted before any petroleum activity can occur in Commonwealth waters.	Marine Mammal Impact Assessment (MMIA). Lowest practicable power levels for the acoustic source array. Avoid or mitigate negative effects on other key species (such as turtles, penguins and seabirds) or habitats.	Avoid marine mammals and turtles during reproduction, feeding, mating, or migration. Coordinate activity with overlapping seismic programs. Minimize the horizontal and high frequency emission of acoustic energy. Invest in technologies that reduce noise emissions.	Lowest practicable power levels. Reduce and/or baffle unnecessary high frequency noise. Determine marine mammal species in the survey area; seasonal or habitat considerations, for example migration, breeding, calving, or pupping. Contact fishing and hunting associations.	The licensee must decide whether the survey could have been undertaken in a different place, at another time, or in a manner that would be better for fishers.
Safety Zone and Start-up	500-m Exclusion Zone. Mid-Atlantic: 1 km for watch prior to ramp-up, 500 m most other cases. 1.5 km for right whales, cow/calf pairs, beaked whales or 6 or more whales in the mid-Atlantic OCS.	500-m Mitigation Zone. Pre-shooting search of 30 min for waters < 200 m deep; 60 min for depths > 200 m.	Surveys whereby received sound exposure level for each shot will not exceed 160 dB re 1µPa^2·s, for 95% of seismic shots at 1 km: *Observation* zone (monitoring): 3+ km.	Mitigation Zones vary from 200 m to 1.5 km depending on the output of the array and the potential risk of adverse impacts.	RU can only begin after 30 min have passed without the detection of marine mammals or turtles within a 1000 m Exclusion Zone. RU over a minimum of 20 min and a	500-m Exclusion Zone. 30-min pre-shooting search, extended to 60 min for waters >200 m.	When seismic surveys are started, sound source must be started up gradually to give fish and marine mammals the opportunity to leave the area around the survey.

SOCP Component	USA – Gulf of Mexico (BOEM 2016), Mid-Atlantic (BOEM 2014; NOAA 2018)	United Kingdom (JNCC 2017)	Australia (DEWHA 2008)	New Zealand (DOC 2013)	Brazil (IBAMA 2018)	Greenland (DCE 2015)	Norway (undated)
	Visually monitor the Exclusion Zone and adjacent waters for marine mammals and sea turtles for at least 30 min before RU. RU over a period of at least 20 min, but no longer than 40 min. Gulf of Mexico: Observers must have completed a protected species observer training program. Trained third party observers or trained crew members. Mid-Atlantic: Independent observers holding a bachelor's degree. At least two trained visual observers will be required on watch aboard seismic vessels at	RU delayed by a minimum of 20 min if marine mammals inside Mitigation Zone. RU over a minimum of 20 min and a maximum of 40 min. Shorter duration for air source volume <180 in^3. MMO must have undertaken formal training on a JNCC recognized course plus have 20 weeks of experience.	*Low power* zone (power down): 1 km. *Shut-down* zone: 500 m. All other surveys: *Observation* zone: 3+ km *Low power* zone: 2 km. *Shut-down* zone: 500 m. Observations undertaken by a suitably trained crew member for at least 30 min before the commencement of the 30-min RU.	RU of at least 20 min and no more than 40 min. Visual watch over the Mitigation Zone for at least 30 min, and at least 10 min for fur seals. Two qualified MMOs on board and at least one maintaining watch. Two PAM operators on board for larger "Level 1" arrays with at least one PAM operator monitoring for marine mammals.	maximum of 40 min. Each team of Onboard Observers is formed by at least three professionals, so that at least two are in simultaneous observation throughout the daytime period.	RU should not be significantly longer than 20 min. At least four trained Marine Mammal and Seabird Observers (MMSOs) including two certified PAM operators shall be on board the seismic vessel. Two MMSOs observing when shooting.	Fishery expert on board when fishing operations are in the area. Fisheries expert completed an approved course and have been an active fisherman.

SOCP Component	USA – Gulf of Mexico (BOEM 2016), Mid-Atlantic (BOEM 2014; NOAA 2018)	United Kingdom (JNCC 2017)	Australia (DEWHA 2008)	New Zealand (DOC 2013)	Brazil (IBAMA 2018)	Greenland (DCE 2015)	Norway (undated)
	all times during daylight hours.						
Shut-down of Air Source Array(s)	Immediate shut-down any time a whale is observed within the Exclusion Zone. Any shut-down due to a whale(s) sighting within the Exclusion Zone must be followed by a 30-min all-clear period and then a standard, full ramp-up.	No requirement to stop firing if marine mammals are detected within the Mitigation Zone whilst the air sources are firing, either during the soft-start procedure or when at full power.	If a whale is sighted within or is about to enter the *Low power* zone, the acoustic source should be powered down to the lowest possible setting. If a whale is sighted or is about to enter the *Shut-down* zone, the acoustic source should be shut down completely.	Delay the start of operations or shut down an active survey if a marine mammal is sighted within the Mitigation Zone.	Shutting down of air source arrays is the priority mitigation procedure and should be performed when marine mammals or turtles are detected within the 1000 m Exclusion Zone.	If marine mammals are within the Exclusion zone whilst the air sources are at full power or during RU, firing must be reduced to the smallest air source (*mitigation gun*). Full power may be regained as soon as the animals are outside the 500 m Exclusion Zone.	
Line Changes and Maintenance Shut-downs	A minimum source level of of 160 dB re 1 μPa-m (rms) can be used for line changes and unscheduled unavoidable maintenance of the air source array. A full RU will not be required. Periods of air source silence not exceeding 20 min in duration will not require RU for the resumption of	No equipment testing outside the licensed area. If line changes are expected to take longer than 40 min, firing is to be terminated at the end of the survey line. Pre-search and full RU to be undertaken. If line changes are completed within 40 min, air source	Operators should power down to the lowest possible setting. If the array is completely shut down or reduced to low power (e.g., for operational reasons or during line turns), observations for whales should continue. RU procedure initiated if no whales have been observed.	Operators are strongly encouraged to shut down at the end of a line and reactivate the acoustic source with RU procedures and pre-start observations. The use of acoustic sources for mitigation purposes during line turns is allowed with conditions.	RU and the 30-min watch must be adopted if the air sources have been silent for more than 5 min. Visual monitoring should be carried out regardless of whether or not the ship is firing the air guns, for example, during line changes, in case of problems with the sound sources or during navigation	20-min RU required for testing all air sources at full power. RU is not required to test a single air source at low power. The air sources should be fired at lower power first when testing multiple air sources. If a line change is expected to exceed one hour, air source firing shall be termi-nated at the end of the line and a full	

SOCP Component	USA – Gulf of Mexico (BOEM 2016), Mid-Atlantic (BOEM 2014; NOAA 2018)	United Kingdom (JNCC 2017)	Australia (DEWHA 2008)	New Zealand (DOC 2013)	Brazil (IBAMA 2018)	Greenland (DCE 2015)	Norway (undated)
	seismic operations if: (1) visual surveys are continued throughout the silent period (requiring daylight and reasonable sighting conditions), and (2) no whales, other marine mammals, or sea turtles are observed in the Exclusion Zone. Mid-Atlantic: Single air source as a ‘‘mitigation” source during extended line turns is not allowed. The acoustic source must be deactivated when not acquiring data or preparing to acquire data except as necessary for testing.	firing can continue during the line change **only** if power is reduced to 180 in^3 or less at standard pressure and the Shot Point Interval (SPI) is increased, not to exceed 5 min. If the air sources can be restarted and data acquisition resumed in less than 10 min, there is no requirement for a RU provided no marine mammal(s) have been detected in the Mitigation Zone during the breakdown period.		Seismic source tests with a maximum combined source capacity of <2.49 litres or 150 in^3 do not require RU procedures and can be undertaken following relevant pre-start observations.	between port and the seismic acquisition area. Line change <20 min, the shots should not be interrupted. Line change >20 min, the air source arrays must be shut down at the end of each line and restarted according to the normal observer (30 min) and RU (minimum 20 min) procedures. It is prohibited to use a mitigation gun or single air source.	pre-shooting search and 20-min RU prior to the next line. If line change is expected to be shorter than one hour, the array shall be operated at a lower output or with a mitigation gun.	
Operations in Low Visibility	RU can only begin after dark or in conditions that prohibit visual inspection (e.g., darkness, fog, rain) of the Exclusion Zone with the use	Where practical, operations should be timed to commence during daylight hours to ensure that visual mitigation by MMOs can be undertaken.	RU commenced provided that there have not been 3 or more whale instigated shut-downs during the preceding 24-hr period; or the	Level 1 (larger) acoustic sources cannot be activated during night-time hours or poor sighting conditions unless PAM has been carried out by	PAM is mandatory 24 hr a day throughout the seismic operation. At least 3, preferably 4 PAM	PAM will be used to augment observer capacities during periods of darkness, poor visibility or sea state above 3.	

SOCP Component	USA – Gulf of Mexico (BOEM 2016), Mid-Atlantic (BOEM 2014; NOAA 2018)	United Kingdom (JNCC 2017)	Australia (DEWHA 2008)	New Zealand (DOC 2013)	Brazil (IBAMA 2018)	Greenland (DCE 2015)	Norway (undated)
	of PAM by an observer proficient in its use. PAM required during all air source surveys in the Mid-Atlantic OCS area.	PAM should be used during periods when visual mitigation is not possible (e.g., darkness, low visibility).	vessel (and/or a spotter vessel or aircraft) has been in the vicinity (~10 km) for at least 2 hours (under good visibility conditions) within the preceding 24-hr period and no whales have been sighted. The use of PAM should be considered in areas where the likelihood of encountering whales is moderate to high	a qualified PAM operator for at least 30 min before activation. Due to the limited detection range of PAM for ultra-high frequency cetaceans (<300 m), any such detections will require an immediate shutdown.	operators on board the vessel to maintain a 24-hr operation. At least two should have proven experience as a PAM operator on seismic vessels. Visual observations during periods of low visibility during daylight hours should continue, even if PAM is operational	The use of PAMGuard or a similar tool is encouraged by the DCE.	
Additional Mitigation Measures and Modifications	A 40-km geographic separation distance **may** be required between simultaneously operating seismic surveys within the mid- and south-Atlantic OCS. Reduce speed to 10 kts or less while transiting areas	Where two or more vessels are operating in adjacent areas and take turns to shoot to avoid causing seismic interference, the guidelines apply on all vessels involved. If dual source arrays are to be used, particularly if they are to be	Further EA of potential impacts may be necessary if multiple seismic sources (e.g. two vessels on one project or multiple, adjacent projects) are to be operated in the same general area. For surveys being undertaken in the broad vicinity of	No person can use explosives as an acoustic source. Where activities are planned in Areas of Ecological Importance or Marine Mammal Sanctuaries, sound transmission loss modelling will be incorporated into the MMIA and	In the case of overlapping seismic surveys, special operating arrangements may be proposed, as well as the adoption of additional mitigation measures and monitoring which may include the denial of a license.	Predictive noise propagation model in the Environmental Impact Assessment (EIA). For cumulative effects, the total sound exposure level (across all air source pulses and all concurrent surveys and activities in the area) per 24 hr.	

SOCP Component	USA – Gulf of Mexico (BOEM 2016), Mid-Atlantic (BOEM 2014; NOAA 2018)	United Kingdom (JNCC 2017)	Australia (DEWHA 2008)	New Zealand (DOC 2013)	Brazil (IBAMA 2018)	Greenland (DCE 2015)	Norway (undated)
	frequented by NARW. Mitigation measures are outlined for borehole surveys. Extended Exclusion zones in the Cook Inlet Alaska (if EA is approved).	operated simultaneously, the mitigation zone required to encompass the entire array (e.g. based on the centre point between the two arrays) must be estimated. Mitigation provided for electromagnetic and multi-beam bathymetry surveys.	known breeding or resting areas, a buffer zone should be established to ensure that operating survey vessels do not enter the vicinity where whales may be present.	ground-truthed during the course of the survey. Additional mitigation for entering an area for the first time at night. Consider use of turtle guards to prevent entanglement.	In the case of a multiple vessel wide azimuth survey, the observers and PAM operators should be on all source vessel(s).	Actual sound exposure within the modelled area measured at representative locations during the seismic survey. FLO on board when appropriate.	

6.0 REVIEW AND ANALYSIS OF SOCP

Based on the information presented above in Sections 3–5 and supporting appendices, we identify key shortcomings in the different components of the SOCP and highlight where other jurisdictions have adapted different or additional mitigation and monitoring practices.

6.1 PLANNING SEISMIC SURVEYS

6.1.1 Item 3 (a)-(c): Air Source Array Specifications

Air source arrays are designed to transmit primarily low-frequency sounds downward through the seafloor, and the amount of sound transmitted in near-horizontal directions is considerably reduced. Nonetheless, they also emit sounds that travel horizontally toward non-geophysical target areas and can contain significant energy above the frequencies that air source arrays are designed to emit for geophysical purposes (DeRuiter et al. 2006; Madsen et al. 2006; Tyack et al. 2006). The SOCP states that a seismic survey should be planned to minimize the amount of energy, horizontal sound propagation, and use of sound at frequencies not necessary for surveying. It is assumed that this is intended to include measures beyond those incorporated into the standard industry design of an air source array. Based on this assumption, this item in the SOCP has not been practically implemented or verified for seismic surveys in Canada. In reality, each seismic operator generally has standard air source arrays that have a fixed volume, operating pressure, and layout, which cannot be practically modified. There are lower power air source alternatives to standard air source arrays that exist but have not yet been implemented for seismic surveys in Canadian waters; consideration should be given to use of these lower power alternatives during the planning phase as their development continues.

Despite this, four of the seven international jurisdictions reviewed for this report have similar provisions in their seismic mitigation guidelines (see Table 3). Greenland requires seismic proponents to demonstrate via acoustic modelling of the sound source that the lowest practical energy levels are used and that high-frequency sounds are minimized. However, an expert panel convened by BOEM determined that it was not reasonable or practical to develop metrics to determine if the lowest practical source level of an air source array was being used (Appendix L in BOEM 2017).

This review includes consideration of new technologies that may replace air source(s) like the eSource™ and marine vibrator. Marine vibrators produce sound energy signals that are typically an order of magnitude, or more, longer than the sound energy pulses from air sources. Since the energy is emitted over a longer time period, for a given amount of energy emitted into the water, the vibroseis array produces a lower peak pressure level than an air source array. Marine vibrators also differ from air sources in terms of the control over the emitted sound frequencies. Because of the inherent control over the vibrating mechanism, the output signal from a vibrator has an important decrease in source level with increasing frequency. This can be as much as 50–100 dB per decade, at frequencies above those useful for seismic surveying (~5–100 Hz). The only energy emitted at frequencies above the selected maximum is created by the spurious harmonic resonance of the vibrator. In comparison, air sources emit significant harmonic frequency sound energy above the nominal frequencies useful for seismic surveying. These higher frequencies, which are not useful for seismic surveying, have levels that typically decrease by only about 30 dB per decade at frequencies above 200 Hz (Spence 2009). A previous assessment of marine vibrators concluded that most of the risks of future geophysical exploration could be reduced by using marine vibrators instead of air sources (LGL and MAI 2011). Marine vibrators could reduce the safety radii for injury, but might increase the potential for masking effects, although acoustic modelling indicates that SELs from marine vibrators are reduced at long range compared to air sources (Duncan et al. 2017). As noted earlier, to date, prototypes of marine vibrators have been developed to meet key array output specifications and are currently undergoing reliability testing (e.g., Mougenot et al. 2017). Likewise the eSource™ is still considered in the development stage. Although new technologies are being investigated as a potential geophysical survey source, it is premature to include these specific technologies in the SOCP. Regardless, consideration should be given to use of these air source alternatives during the planning phase as their development continues.

6.1.2 Item 4: Avoidance of Significant Adverse Effects

It is unclear in the SOCP what is considered a significant adverse effect on a SARA-listed individual and on a population for other marine species as this term is not defined in the SOCP. The reader has to assume this is in reference to a determination made during an EA process. Also, marine fish species listed on Schedule 1 of SARA are not included in Item 4 of the SOCP.

In general, international jurisdictions do not include EA type terminology (i.e., significant adverse effect) in their mitigation guidelines. They focus on avoidance of key areas and times for marine fauna.

6.1.3 Item 5: Avoidance of Key Areas and Times

In many offshore areas of Canada, lack of seasonal, georeferenced baseline data on the distribution of mammals, sea turtles, and fishes precludes the implementation of the mitigation measures listed in Item 5 of the SOCP. The SOCP does not have provisions to deal with these data gaps, to allow this measure to be effectively implemented. Also, it is unclear how a group of marine mammals is defined. This section of the SOCP also does not include specific mention of invertebrates.

Planning seismic surveys to avoid spatial and temporal overlap with areas where SARA-listed cetaceans are anticipated to be present is considered the most effective mitigation measure to reduce impacts on individuals and their critical habitat, but is dependent upon adequate information on distribution and abundance. In many cases, research effort is needed prior to seismic survey activities to sufficiently determine species occurrence so that spatial and temporal avoidance measures can be effectively applied. Furthermore, avoidance of spatial and temporal overlap may not always be possible as seismic surveys are usually limited to a specific area of interest and year-round resident species cannot be avoided.

Most international jurisdictions include provisions to avoid migration, breeding, calving, and important feeding areas for marine mammals and in some cases sea turtles, again assuming these are known. Like Canada, most jurisdictions do not include provisions for seismic surveys in areas where specific marine mammal migration, breeding, calving, and important feeding areas are unknown. However, in Australia, seismic proponents may be required to conduct pre-seismic survey research to identify whale concentration areas (e.g., foraging areas and migratory paths). In the U.S., seismic surveying is not permitted in NARW Critical Habitat during periods when whales are there to breed and nurse calves. Also, sound levels from seismic surveys are not to exceed 160 dB rms (current NMFS behavioural threshold for impulsive sound) at the boundaries of the right whale Critical Habitat. Critical sea turtle nesting habitat must be avoided in Florida during the active nesting period.

6.1.4 Other Planning Practices

Certain international jurisdictions (e.g., U.S. and Greenland) require a marine mammal monitoring and mitigation plan that is reviewed and approved by the regulator. These monitoring and mitigation plans detail observational, mitigation, and reporting procedures for MMOs and in some cases for PAM equipment and PAM Operators. The plans are generally provided and reviewed with vessel and seismic crew to ensure mitigation measures are clearly communicated and that appropriate mechanisms are in place for implementation. As noted earlier (see Table 1), seismic surveys for oil and gas exploration offshore NS and in the CBS require an approved marine mammal monitoring and mitigation plan.

6.2 OPERATIONAL MITIGATION MEASURES AND MONITORING

As a reminder, a detailed review of the efficacy of the operational measures in the SOCP was prepared 10 years ago (Moulton et al. 2009) and in most cases is still quite relevant in assisting with identifying the shortcomings of the SOCP. A general short coming of the SOCP is that the majority of operational mitigation measures focus on marine mammals (and to a lesser extent sea turtles) with minimal consideration of seismic survey sound (sound pressure and particle motion components) effects on fishes and invertebrates.

6.2.1 Safety Zone and Start-up

This component of the SOCP includes several key features that require consideration including the size of the SZ, MMO (and/or PAM Operator) qualifications, pre-ramp-up watch, and ramp-up procedures.

Item 6a: Establishment of a Safety Zone

In light of the new NMFS guidelines (NMFS 2016, 2018) and the updated hearing effect recommendations by Southall et al. (2019), which considered best available scientific information, the current minimum 500 m SZ around air source arrays is likely sufficient to minimize exposure to air source pulses which may result in permanent auditory damage to most marine mammal species. It may not be sufficient to minimize temporary hearing impairment in marine mammals. It is recognized that there are data gaps which influence the certainty around hearing effect thresholds (see below) including those for non-marine mammal species (i.e., sea turtles).

A 500 m SZ (or shut down zone) around the air source arrays is used for marine mammals (and in some cases sea turtles) in several international jurisdictions namely the U.S. Gulf of Mexico, U.K., Australia, and Greenland. Brazil uses a 1000 m SZ and some jurisdictions use larger SZ in certain circumstances (for pre-ramp-up watches, species at risk, high-frequency hearing specialists, cow/calf pairs, and beaked whales).

Within Canada, the minimum 500 m SZ has been used offshore NL, whereas in the CBS and offshore NS, acoustic modelling of air source arrays have been undertaken with SZ ranging from 500 m–2500 m and 600 m–1000 m, respectively. A key decision for the SOCP is whether the SZ is intended to minimize the risk of marine mammals potentially incurring auditory injury (PTS) or whether the SZ is also intended to minimize the risk of marine mammals incurring potential temporary hearing impairment (TTS). This decision would, in part, require consideration of applicable legislation including the SARA and the *Fisheries Act*, which is beyond the scope of work for this report.

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

- the limited knowledge about sound-induced hearing damage in marine mammals, particularly baleen whales and pinnipeds;

- the seemingly greater susceptibility of certain species (e.g., harbour porpoise and harbour seal) to TTS and presumably also PTS; and
- the lack of knowledge about TTS and PTS thresholds in many species, including various species closely related to the harbour porpoise and harbour seal.

Furthermore, much remains unknown about cumulative effects of exposure from multiple, concurrent seismic surveys on hearing in marine mammals (as well as other species).

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

Item 6b: Use of Qualified MMO to Conduct Visual Watches

The SOCP requires that a qualified MMO conduct visual monitoring prior to a ramp-up and during periods when air sources are active. There are several shortcomings with this aspect of the SOCP; it does not provide clear direction on: (1) what constitutes a qualified MMO (and PAM Operator) including any necessary training, (2) the number of MMOs required, and (3) the rest period schedule. An MMO is defined in the SOCP as an individual who is trained in identifying species of marine mammals and turtles that are expected to be present in the seismic survey area. Several studies have demonstrated that experienced MMOs relative to inexperienced MMOs have higher marine mammal sighting rates and increased ability to correctly identify animals to species level (Barlow et al. 2006; Stone 2015; Smith et al. *in prep*.). Relative to requirements in several international jurisdictions, which in many cases, list training, experience, and educational requirements, the SOCP is inadequate. Several international jurisdictions also require approval of a MMO's Curriculum Vitae (CV) by a regulatory agency prior to the start of a seismic survey.

Several international jurisdictions require that two MMOs conduct visual watches concurrently during pre-ramp-up watch and during periods when air source(s) are active. It has been demonstrated that two MMOs detect significantly more marine mammals than a single MMO (e.g., Moulton and Lawson 2002; Holst et al. 2018).

Currently, the SOCP requires a minimum 30-minute pre-ramp-up watch. This may not afford adequate time to allow for certain species of marine mammals to surface from deep dives and hence, to make them available at surface for detection by MMOs (Moulton et al. 2009; Moors-Murphy and Theriault 2017). Several international jurisdictions have increased the pre-ramp-up watch to 60 minutes in areas with water depths >200 m to account for longer dive durations of deep-diving species like beaked and sperm whales.

Item 7a: Delay of Ramp Up

The SOCP requires that ramp-up should be delayed if during the pre-ramp-up watch a cetacean, sea turtle, marine mammal listed as endangered or threatened on Schedule 1 of SARA, or a marine mammal identified during the EA process for which a significant adverse effect was predicted is detected within the SZ. Although this may be protective of many species of marine fauna, it neglects to include pinnipeds (other than those which may be listed on Schedule 1 of SARA), and marine fishes considered at risk and which can be detected at the surface (e.g., white shark, *Carcharodon carcharias*). Most international jurisdictions require ramp-up delays for all marine mammal species and in some cases, all sea turtles.

Item 7b: Ramp-up Procedures

The SOCP requires a minimum 20-minute ramp-up duration but does not set a maximum duration. Most international jurisdictions require a minimum ramp-up duration of 30 minutes or a ramp-up duration range of 20–40 minutes. It is important to set a maximum ramp-up duration as seismic proponents will often start the ramp-up procedure well in advance of the start of a survey line (LGL, unpublished data), resulting in unnecessary sound emissions.

The SOCP sets out a general procedure for ramp-up, highlighting a “preference” to start with the smallest air source (in terms of energy output). This is generally in line with the international jurisdictions reviewed for this report, although most jurisdictions state that a ramp-up “must” start with the smallest air source.

The efficacy of the ramp-up procedure was reviewed in Moulton et al. (2009), which included consideration of a step-wise incremental increase in sound level per unit time as a ramp-up procedure. Ramp-up has become a standard mitigation procedure and, in the absence of much specific evidence of efficacy, is viewed primarily as a common-sense measure. To the best of our knowledge, there have been no comprehensive studies of the effectiveness of ramp-up.

6.2.2 Shut-down of Air Source Array(s)

As a reminder, the primary intent of implementing shut downs of the air source(s) is to minimize the risk of marine fauna from incurring auditory injury and/or impairment.

Item 8a: Shut-downs for SARA Schedule 1 Marine Mammals and Sea Turtles

This requirement, as currently stated in the SOCP, is not in line with best available scientific information and best practice implemented in other jurisdictions. In fact, seismic proponents in Canada have expanded the list of marine mammal and sea turtle shut down species to account for this shortcoming (see Table 3). The U.S. and Australia require an immediate shut down when a “whale” enters the SZ. Both countries define “whales” as all species of baleen whales, all species of beaked whales, and larger toothed whales. Dolphins do not fall under the definition of “whale” in either country. New Zealand and Brazil require an immediate shut down when any marine mammal enters the SZ.

Another potential shortcoming of the SOCP is that marine fish species listed on Schedule 1 of SARA are not included here. This is particularly relevant for shark SAR, which can be periodically detected at the surface. However, as highlighted in Section 4.3.3, our understanding of the effects of underwater sound on sharks, and fish in general, is considered limited.

Item 8b: Shut-downs for Marine Mammals and Sea Turtles with Predicted Significant Adverse Effects

To the best of our knowledge, significant adverse negative effects on marine mammals and sea turtles (and fishes/invertebrates) have not been predicted for seismic surveys in Canada during numerous EAs. This leads one to question the utility of this Item of the SOCP. Other jurisdictions do not directly link shut-down species to the EA process but take a broader, more inclusive approach as outlined above. Once again, it should be noted that marine fishes (and invertebrates) are not included in this Item.

6.2.3 Line Changes and Maintenance Shut-downs

Item 9: Air Source Use during Line Changes

A key shortcoming of this component of the SOCP is that there is no guidance as to what circumstances would warrant recommending shutting down air sources during line changes versus keeping one air source active. Also, the SOCP does not specify that if a single air source is operated during line changes then it should be the “smallest” air source (i.e., lowest volume) in the array.

The reviewed international jurisdictions differ in their requirements for line changes and maintenance shut-downs; several do not permit the use of a single air source during line changes. Those that do permit single air source use during line changes stipulate that the air source should be at a low power level or a single “mitigation” air source.

Item 10: Resumption of Seismic Surveying

The SOCP currently does not require that after a period of single air source use during line changes (or maintenance periods), the array must be gradually ramped up. Also, the SOCP does not specify how long the air sources can be shut down or operations can occur with a single air source before a ramp-up is required.

International jurisdictions which permit the use of a single air source during line changes generally require a gradual ramp-up of the array before seismic surveying resumes (Table 3, Appendix C). In general, most jurisdictions will not require ramp up when the arrays are shut down for less than a prescribed period of time (20 minutes in the U.S. and Brazil, 10 minutes in the U.K., and five minutes in Greenland) and certain conditions are met.

6.2.4 Operations in Low Visibility

Item 11: Use of Cetacean Detection Technology

As written in the SOCP, cetacean detection technology, such as PAM is only required during the pre-ramp-up watch if the seismic survey occurs in Critical Habitat for a cetacean (listed as endangered or threatened on Schedule 1) or in an area used by a cetacean where significant adverse effects were predicted in the EA process. [There have been no circumstances in which this specific requirement (i.e., seismic surveying in Critical Habitat or prediction of significant adverse effects on a cetacean during the EA process), as worded in the SOCP, has been triggered.] A serious shortcoming in the SOCP is the lack of provisions addressing the detection of marine mammals (and sea turtles) when the SZ is not visible; this is relevant to all offshore regions of Canada. As reviewed in Moulton et al. (2009), offshore NS and Newfoundland, a 500-m safety zone was fully visible on average only ~39% of the time (minimum 25%) in months during which seismic exploration commonly occurs. In the CBS, visibility is estimated to be restricted by a combination of: 25–60% due to darkness, 25–40% due to sea states/swell height, and 10% due to poor visibility associated with fog (Harwood and Joynt 2009). The result is that for substantial periods, without cetacean detection technology, shut downs and ramp-up delay mitigation measures are ineffective as they cannot be implemented.

In most international jurisdictions, air sources cannot be re-activated during periods when the full SZ is not visible and as a result PAM is typically employed and/or required. It is recognized that PAM can only be effective when marine mammals are vocalizing. Also, as highlighted in Section 4.4, there are limitations to PAM systems.

The SOCP does not provide any guidance on the minimum standards required for PAM hardware and software (including performance record) as well as training and experience level required for PAM Operators. A good example of best practice with regards to these topics is NOAA’s recent PAM requirements for the Mid-Atlantic OCS proposed seismic surveys (NOAA 2018), recognizing that these requirements have not yet been implemented in the field.

Other types of cetacean detection technologies (thermal IR, RADAR, and active sonar) are generally considered in the earlier stages of development and use compared to PAM (see Section 4.4), and as such are typically not used as a monitoring tool during seismic surveys. Additionally, each type of detection technology has limitations (e.g., thermal IR is ineffective in heavy fog).

Item 12: Unidentified Cetaceans

The SOCP requires that cetaceans not identified to species should be considered "shut down" species and that if a detected vocalization is not determined to fall outside of the SZ, it should be assumed to be within the SZ, and ramp up should not commence until 30 minutes have passed since the last detection. The provisions in this Item of the SOCP are considered quite precautionary. Both the U.S. and Greenland clearly leave it to the discretion of the PAM Operator to assess vocalizations and determine whether they occur within versus beyond the SZ. Conversely, New Zealand takes a similar approach to the SOCP.

6.2.5 Additional Mitigation Measures and Modifications

Items 13 and 14: Additional and Precautionary Mitigation Measures

These Items of the SOCP are sufficiently broad enough to allow regulators, stakeholders, and seismic proponents flexibility in adapting new mitigation measures or modifying existing measures to be more precautionary, including consideration of cumulative effects from concurrent seismic surveys. However, it is essential that appropriate regulatory agencies implement this aspect of the SOCP. Additional mitigation measures employed in the CBS for bowhead whales provide a good example of how this flexible feature of the SOCP can be effectively implemented (see Section 3.2.3).

Most international jurisdictions allow for additional, albeit typically non-specific, mitigation measures in certain circumstances including concurrent seismic surveys.

Item 15: Activating a Single Air Source

The requirement to gradually power up a single air source if it is the only sound source that will be used during surveying seems counterintuitive given that the activation of a single air source (at full power) is how the ramp up of an air source array starts. However, in New Zealand, for borehole seismic surveys, this is included as a potential mitigation measure.

6.3 OPERATIONS IN AND NEAR ICE-COVERED WATERS

Currently, the SOCP does not include consideration of seismic surveying in ice-covered waters. In Canada, conventional seismic surveying (i.e., 2-D, 3-D surveys) has not occurred through ice-covered waters. However, in the CBS 2-D seismic surveys have occurred in areas adjacent to ice (e.g., LGL et al. 2006; LGL and Canning & Pitt 2007; LGL 2008b). The primary mitigation measure which was adapted given the proximity of the surveys to ice was the implementation of shut downs for polar bears detected in the water (see Section 3.2.3 above).

Seismic surveying (2-D) through ice-covered waters has occurred off the northeast coast of Greenland (see for e.g., GXT 2009). Surveying in ice was possible because an icebreaker sailed ahead of the seismic source vessel. Additionally, specialized technology was used to submerge the hydrophone receiver cable. Mitigation and monitoring requirements were the same as those for seismic surveys conducted in open-water areas of Greenland; many of these requirements are included in the SOCP.

It is recognized that ice cover (see Richardson et al. 1995) and subsea permafrost can affect underwater sound propagation (see for e.g., Moulton and Richardson 2010). Potential variation in sound propagation could affect the size of the SZ used to mitigate effects on marine mammals, and there may be other concerns specific to operating in or near ice-covered waters that should be taken into consideration. The potential need to put in place additional or modified environmental mitigation measures as identified in the EA of the project is addressed in Item 13b of the SOCP.

The subject of seismic operations in or near ice-covered waters and whether it should be specifically included in the SOCP remains unclear, as there is minimal information regarding risks to marine mammals in or near ice-covered waters as well as potential mitigation strategies. However, one study has identified ice entrapment as a potential risk to marine mammals exposed to seismic survey sound (Heide-Jørgensen et al. 2013).

6.4 OTHERS

The scope of this review includes consideration of mitigation measures and monitoring for behavioural responses of marine fauna, namely marine mammals. As acknowledged by Moors-Murphy and Theriault (2017), the ability of the SOCP to address potential harm or harassment of individuals (i.e., behavioural responses[8]) of species at risk that may occur at greater ranges from the sound source (i.e., beyond the SZ) is limited. The only mitigation measures within the SOCP that currently address such impacts are those applied at the planning stage where it is specified that all seismic surveys must be planned to avoid significant adverse effects and to avoid displacing or diverting listed marine mammal species. There are currently no operational mitigation measures within the SOCP that specifically pertain to reducing potential behavioural effects or the impacts of masking on marine mammals (or sea turtles).

Based on LGL's experience, it is difficult for MMOs located on a seismic vessel to collect detailed behavioural data, whether at the time of an air source array shut down or even during most other periods. The combination of a limited time period available to observe a marine mammal as the seismic ship sails on (thus no extended behavioural observations), and the need to keep a constant watch of the SZ, means that MMOs can devote limited effort to recording observations (Holst et al. 2018). Furthermore, it is unclear what type of behavioural response by a marine mammal (or sea turtle) observed from a seismic vessel would trigger a mitigation measure in real-time. Likewise, the utility of placing MMOs on support vessels, which typically sail 1–2 km ahead of a seismic vessel is questionable. Based on a review of MMO data from the CBS, Holst et al. (2018) did not recommend placing MMOs on the support vessel because the monitoring results indicated that given the typical separation distance between the support and seismic vessels, the MMOs on the support vessel serve minimal purpose relative to monitoring and mitigation objectives.

At distances beyond those effectively monitored by MMOs aboard seismic vessels, aerial surveys and acoustic monitoring programs have been successfully used to document marine mammal response to seismic surveys. The intent of these types of monitoring programs is typically to validate predictions made during the EA process and/or to address data gaps. The need for follow-up monitoring for seismic surveys should be identified during the EA process and as such, is likely best captured in Item 13 of the SOCP. However, once again, we highlight that regulatory agencies should require implementation of this aspect of the SOCP as appropriate.

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[8] "Harm" is considered to be "*the adverse result of an activity where single or multiple events reduce the fitness (e.g., survival, reproduction, movement) of individuals*". "Harass" is considered to be "*any act or series of acts which tend to disturb, alarm, or molest an individual or population, which by means of frequency and magnitude results in changes to normal behaviour(s) that reduce an individual's ability to carry out one or more of its life processes which could jeopardize the survival or recovery of the species*" (see Moors-Murphy and Theriault 2017).

7.0 CONCLUSION

Based upon an overview of the scientific literature, international mitigation practices, and regional mitigation practices within Canada, it is evident that updates to the 2008 SOCP are required. This was also the consensus stemming from the CSAS meeting held in Halifax in May 2019. The analysis undertaken in advance of and during the CSAS meeting led to recommended changes in each component of the 2008 SOCP. These recommendations are included in a DFO Science Advisory Report (DFO 2020).

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APPENDIX A: STATEMENT OF CANADIAN PRACTICE WITH RESPECT TO THE MITIGATION OF SEISMIC SOUND IN THE MARINE ENVIRONMENT

CONTEXT

The Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment specifies the mitigation requirements that must be met during the planning and conduct of marine seismic surveys, in order to minimize impacts on life in the oceans. These requirements are set out as minimum standards, which will apply in all non-ice-covered marine waters in Canada. The Statement complements existing environmental assessment processes, including those set out in settled land claims. The current regulatory system will continue to address protection of the health and safety of offshore workers and ensure that seismic activities are respectful of interactions with other ocean users.

DEFINITIONS

- **Cetacean:** a whale, dolphin or porpoise.
- **Critical habitat:** the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species.
- **Marine Mammal Observer:** an individual trained to identify different species of marine mammals and turtles that may reasonably be expected to be present in the area where the seismic survey will take place.
- **Marine mammals:** all cetaceans and pinnipeds.
- **Passive Acoustic Monitoring:** a technology that may be used to detect the subsea presence of vocalizing cetaceans.
- **Pinniped:** a seal, sea lion or walrus.
- **Ramp-up:** the gradual increase in emitted sound levels from a seismic air source array by systematically turning on the full complement of an array’s air sources over a period of time.
- **Seismic air source:** an air source that is used to generate acoustic waves in a seismic survey.
- **Seismic air source array(s):** one or a series of devices designed to release compressed air into the water column in order to create an acoustical energy pulse to penetrate the seafloor.
- **Seismic survey:** a geophysical operation that uses a seismic air source to generate acoustic waves that propagate through the earth, are reflected from or refracted along subsurface layers of the earth and are subsequently recorded.
- **“Statement":** the Statement of Canadian Practice for the Mitigation of Seismic Sound in the Marine Environment.
- **Whale:** a cetacean that is not a dolphin or porpoise.

APPLICATION

1. Unless otherwise provided, the mitigation measures set out in this Statement apply to all seismic surveys planned to be conducted in Canadian marine waters and which propose to use an air source array(s).
2. The mitigation measures set out in this Statement do not apply to seismic surveys conducted:
   a. on ice-covered marine waters; or
   b. in lakes or the non-estuarine portions of rivers.

PLANNING SEISMIC SURVEYS

Mitigation Measures

3. Each seismic survey must be planned to
   a. use the minimum amount of energy necessary to achieve operational objectives;
   b. minimize the proportion of the energy that propagates horizontally; and
   c. minimize the amount of energy at frequencies above those necessary for the purpose of the survey.
4. All seismic surveys must be planned to avoid:
   a. a significant adverse effect for an individual marine mammal or sea turtle of a species listed as endangered or threatened on Schedule 1 of the *Species at Risk Act*; and
   b. a significant adverse population-level effect for any other marine species.
5. Each seismic survey must be planned to avoid:
   a. displacing an individual marine mammal or sea turtle of a species listed as endangered or threatened on Schedule 1 of the *Species at Risk Act* from breeding, feeding or nursing;
   b. diverting an individual migrating marine mammal or sea turtle of a species listed as endangered or threatened on Schedule 1 of the *Species at Risk Act* from a known migration route or corridor;
   c. dispersing aggregations of spawning fish from a known spawning area;
   d. displacing a group of breeding, feeding or nursing marine mammals, if it is known there are no alternate areas available to those marine mammals for those activities, or that if by using those alternate areas, those marine mammals would incur significant adverse effects; and
   e. diverting aggregations of fish or groups of marine mammals from known migration routes or corridors if it is known there are no alternate migration routes or corridors, or that if by using those alternate migration routes or corridors, the group of marine mammals or aggregations of fish would incur significant adverse effects.

SAFETY ZONE AND START-UP

Mitigation Measures

6. Each seismic survey must:
   a. establish a safety zone which is a circle with a radius of at least 500 metres as measured from the centre of the air source array(s); and
   b. for all times the safety zone is visible,
      i. a qualified Marine Mammal Observer must continuously observe the safety zone for a minimum period of 30 minutes prior to the start up of the air source array(s), and
      ii. maintain a regular watch of the safety zone at all other times if the proposed seismic survey is of a power that it would meet a threshold requirement for an assessment under the *Canadian Environmental Assessment Act*, regardless of whether the Act applies.
7. If the full extent of the safety zone is visible, before starting or restarting an air source array(s) after they have been shut down for more than 30 minutes, the following conditions and processes apply:
   a. none of the following have been observed by the Marine Mammal Observer within the safety zone for at least 30 minutes:
      i. a cetacean or sea turtle,
      ii. a marine mammal listed as endangered or threatened on Schedule 1 of the *Species at Risk Act*, or
      iii. based on the considerations set out in sub-section 4(b), any other marine mammal that has been identified in an environmental assessment process as a species for which there could be significant adverse effects; and
   b. a gradual ramp-up of the air source array(s) over a minimum of a 20 minute period beginning with the activation of a single source element of the air source array(s), preferably the smallest source element in terms of energy output and a gradual activation of additional source elements of the air source array(s) until the operating level is obtained.

SHUT DOWN OF AIR SOURCE ARRAY(S)

Mitigation Measures

8. The air source array(s) must be shut down immediately if any of the following is observed by the Marine Mammal Observer in the safety zone:
   a. a marine mammal or sea turtle listed as endangered or threatened on Schedule 1 of the *Species at Risk Act*; or
   b. based on the considerations set out in sub-section 4(b), any other marine mammal or sea turtle that has been identified in an environmental assessment process as a species for which there could be significant adverse effects.

LINE CHANGES AND MAINTENANCE SHUT-DOWNS

Mitigation Measures

9. When seismic surveying (data collection) ceases during line changes, for maintenance or for other operational reasons, the air source array(s) must be:
   a. shut down completely; or
   b. reduced to a single source element.
10. If the air source array(s) is reduced to a single source element as per subsection 9(b), then:
    a. visual monitoring of the safety zone as set out in section 6 and shut-down requirements as set out in section 8 must be maintained; but
    b. ramp-up procedures as set out in section 7 will not be required when seismic surveying resumes.

OPERATIONS IN LOW VISIBILITY

Mitigation Measures

11. Under the conditions set out in this section, cetacean detection technology, such as Passive Acoustic Monitoring, must be used prior to ramp-up for the same time period as for visual monitoring set out in section 6. Those conditions are as follows:
    a. the full extent of the safety zone is not visible; and
    b. the seismic survey is in an area that
       i. has been identified as critical habitat for a vocalizing cetacean listed as endangered or threatened on Schedule 1 of the *Species at Risk Act*, or
       ii. in keeping with the considerations set out in sub-section 4(b), has been identified through an environmental assessment process as an area where a vocalising cetacean is expected to be encountered if that vocalizing cetacean has been identified through the environmental assessment process as a species for which there could be significant adverse effects.
12. If Passive Acoustic Monitoring or similar cetacean detection technology is used in accordance with the provision of section 11, unless the species can be identified by vocal signature or other recognition criteria:
    a. all non-identified cetacean vocalizations must be assumed to be those of whales named in sections 8(a) or (b); and
    b. unless it can be determined that the cetacean(s) is outside the safety zone, the ramp-up must not commence until non-identified cetacean vocalizations have not been detected for a period of at least 30 minutes.

ADDITIONAL MITIGATIVE MEASURES AND MODIFICATIONS

Mitigation Measures

13. Persons wishing to conduct seismic surveys in Canadian marine waters may be required to put in place additional or modified environmental mitigation measures, including modifications to the area of the safety zone and/or other measures as identified in the environmental assessment of the project to address:

a. the potential for chronic or cumulative adverse environmental effects of

    i. multiple air source arrays (e.g., two vessels on one project; multiple projects), or

    ii. seismic surveys being carried out in combination with other activities adverse to marine environmental quality in the area affected by the proposed program or programs;

b. variations in sound propagation levels within the water column, including factors such as seabed, geomorphologic, and oceanographic characteristics that affect sound propagation;

c. sound levels from air source array(s) that are significantly lower or higher than average; and

d. species identified in an environmental assessment process for which there is concern, including those described in sub-section 4b).

14. Variations to some or all of the measures set out in this Statement may be allowed provided the alternate mitigation or precautionary measures will achieve an equivalent or greater level of environmental protection to address the matters outlined in sections 6 through 13 inclusive. Where alternative methods or technologies are proposed, they should be evaluated as part of the environmental assessment of the project.

15. Where a single source element is used and the ramping up from an individual air source element to multiple elements is not applicable, the sound should still be introduced gradually whenever technically feasible.

APPENDIX B: LIST OF CSAS AND RELATED DOCUMENTS PROVIDED BY DFO

SERIES	YEAR	PUBLICATION NUMBER	AUTHORS	TITLE	URL	REGION	DATE PUBLISHED
HSR	2003	2003/001	DFO-MPO	A Framework to Assist DFO Consideration of Requests for Review of Seismic Testing Proposals	http://waves-vagues.dfo-mpo.gc.ca/Library/281840.pdf	National Capital Region	
HSR	2004	2004/003	DFO-MPO	Potential Impacts of Seismic Energy on Snow Crab	http://waves-vagues.dfo-mpo.gc.ca/Library/283728.pdf	Gulf	10/21/2004
HSR	2004	2004/002	DFO-MPO	Review of Scientific Information on Impacts of Seismic Sound on Fish, Invertebrates, Marine Turtles and Marine Mammals	http://waves-vagues.dfo-mpo.gc.ca/Library/283727.pdf	National Capital Region	9/15/2004
PRO	2004	2004/045	DFO-MPO	Proceedings of the Peer Review on Potential Impacts of Seismic Energy on Snow Crab; September 29, 2004	http://waves-vagues.dfo-mpo.gc.ca/Library/315147.pdf	Maritimes	06/06/2005
PRO	2008	2008/032	DFO-MPO	National Science Workshop: Review of Scientific Information on the Impacts of Seismic Sound on Fish, Invertebrates, and Marine Mammals Workshop II, 2008; 26-27 March 2008	http://www.dfo-mpo.gc.ca/csas-sccs/publications/pro-cr/2008/2008_032-eng.htm	National Capital Region	05/04/2009
PRO	2009	2009/044	DFO-MPO	Proceedings of the National Workshop to Examine the Effectiveness of Measures Used to Mitigate Potential Impacts of Seismic Sound on Marine Mammals; May 12-13, 2009	http://www.dfo-mpo.gc.ca/csas-sccs/publications/pro-cr/2009/2009_044-eng.htm	National Capital Region	05/04/2010
PRO	2015	2015/033	DFO-MPO	Proceedings of the National Peer Review of Mitigation and Monitoring Measures for Seismic Survey Activities in and near the Habitat of Cetacean Species at Risk	http://www.dfo-mpo.gc.ca/csas-sccs/publications/pro-cr/2015/2015_033-eng.html	National Capital Region	7/17/2015

SERIES	YEAR	PUBLICATION NUMBER	AUTHORS	TITLE	URL	REGION	DATE PUBLISHED
RES	2004	2004/121	Lawson, J.W., McQuinn, I.H.	Review of the Potential Hydrophysical-related Issues in Canada, Risks to Marine Mammals, and Monitoring and Mitigation Strategies for Seismic Activities	http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2004/2004_121-eng.htm	Newfoundland & Labrador	4/28/2005
RES	2004	2004/122	Measures, L.N.	Marine mammals and "wildlife rehabilitation" programs	http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2004/2004_122-eng.htm	Quebec	04/01/2005
RES	2004	2004/125	Payne, J.F.	Potential Effect of Seismic Surveys on Fish Eggs, Larvae and Zooplankton	http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2004/2004_125-eng.htm	National Capital Region	4/20/2005
RES	2004	2004/126	Benhalima, K., Allain, R.J., Moriyasu, M., Claytor, R.R.	Effects of seismic and marine noise on invertebrates: A literature Review	http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2004/2004_126-eng.htm	Gulf	9/21/2005
RES	2004	2004/133	Lawson, J.W., Gosselin, J.-F.	Distribution and abundance indices of marine mammals in the Gully and two adjacent canyons of the Scotian Shelf before and during nearby hydrocarbon seismic exploration programmes in April and July 2003	http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2004/2004_133-eng.htm	Maritimes Quebec	9/22/2005
RES	2006	2006/092	Worcester, T.	Effects of Seismic Energy on Fish: A Literature Review	http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2006/2006_092-eng.htm	National Capital Region	7/17/2007
RES	2008	2008/060	Fancey, L., Andrews, C., White, D., Payne, J.F., Christian, J.	Potential Effects of Seismic Energy on Fish and Shellfish: An Update Since 2003	http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2008/2008_060-eng.htm	Newfoundland & Labrador	11/26/2008

SERIES	YEAR	PUBLICATION NUMBER	AUTHORS	TITLE	URL	REGION	DATE PUBLISHED
RES	2008	2008/087	Abgrall, P., Richardson, W.J., Moulton, V.D.	Updated Review of Scientific Information on Impacts of Seismic Survey Sound on Marine Mammals, 2004-present	http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2008/2008_087-eng.htm	National Capital Region	3/25/2009
RES	2009	2009/040	Joynt, A., Harwood, L.A., Pitt, R., Kennedy, D., Moore, S.	Spatial restrictions and temporal planning as measures to mitigate potential effects of seismic noise on cetaceans: a working example from the Canadian Beaufort Sea, 2007-2008	http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2009/2009_040-eng.htm	Central & Arctic	9/23/2009
RES	2009	2009/048	Joynt, A., Harwood, L.A.	Factors influencing the Effectiveness of Marine Mammal Observers on Seismic Vessels, with examples from the Canadian Beaufort Sea	http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2009/2009_048-eng.htm	Central & Arctic	9/23/2009
RES	2009	2009/068	Simard, Y.	Passive acoustic monitoring during seismic surveys	http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2009/2009_068-eng.htm	Quebec National Capital Region	11/03/2009
RES	2009	2009/060	Lawson, J.W.	The Use of Sound Propagation Models to Determine Safe Distances from A Seismic Sound Energy Source	http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2009/2009_060-eng.htm	Newfoundland & Labrador	01/05/2010
RES	2015	2015/078	Therriault, J.-C., Moors-Murphy, H.B.	Species at Risk criteria and seismic survey noise thresholds for cetaceans	http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2015/2015_078-eng.html	National Capital Region	12/18/2015
RES	2017	2017/008	Moors-Murphy, H.B., J.A. Theriault	Review of Mitigation Measures for Cetacean Species at Risk During Seismic Survey Operations	http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2017/2017_008-eng.html	Maritimes	5/18/2017
SAR	2010	2010/043	DFO-MPO	Guidance Related to the Efficacy of Measures Used to Mitigate Potential Impacts of Seismic Sound on Marine Mammals	http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2010/2010_043-eng.htm	National Capital Region	09/03/2010

SERIES	YEAR	PUBLICATION NUMBER	AUTHORS	TITLE	URL	REGION	DATE PUBLISHED
SAR	2015	2015/005	DFO-MPO	Review of Mitigation and Monitoring Measures for Seismic Survey Activities in and near the Habitat of Cetacean Species at Risk	http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2015/2015_005-eng.html	National Capital Region	2/13/2015
SR	2007	2007/011	DFO-MPO	Tekoil & Gas Corporation Port au Port Seismic Program Screening - Review of the EA report	http://waves-vagues.dfo-mpo.gc.ca/Library/329017.pdf	Quebec	6/27/2007

APPENDIX C: INTERNATIONAL PRACTICES AND GUIDELINES[9]

1.0 INTRODUCTION

This appendix presents a detailed review of mitigation and monitoring requirements for marine seismic surveys under the jurisdiction of the United States, the United Kingdom, Australia, New Zealand, Brazil, Greenland (Denmark) and Norway. Where available, we also present information on borehole and geohazard type surveys.

Note that New Zealand passed legislation in November 2018 which bans new permits for offshore oil and gas exploration, although existing permits are preserved and are subject to the existing marine seismic code. This follows bans for future offshore oil and gas exploration off Belize, Costa Rica, Ireland, Denmark (inland waters only, does not include the North Sea or Greenland), and a gradual phase-out in France (Offshore Technology 2018).

In addition to the jurisdictions above, the International Union for Conservation of Nature and Natural Resources (IUCN) has released a guidance document which focusses on the planning, environmental assessment, risk assessment and monitoring of marine geophysical surveys (Nowacek and Southall 2016). This includes planning and monitoring practices which have developed over recent years (and continue to evolve) for seismic surveys off Sakhalin Island. As the guidelines do not include specific operational mitigation, they will not be evaluated further. Additional information can be found on the IUCN website.

2.0 UNITED STATES

Seismic programs for the United States Outer Continental Shelf (OCS) are regulated by the Bureau of Ocean Energy and Management (BOEM). BOEM has jurisdiction over the OCS of four regions, Alaska, Atlantic, Pacific, and Gulf of Mexico. The primary source for this section will be BOEM's "Notice to Lessees and Operators on the Implementation of Seismic Survey Mitigation Measures and Protected Species Observer Program" (BOEM 2016). This document was developed for BOEM's Gulf of Mexico OCS region.

Additional mitigation measures for the mid-Atlantic OCS region have been extracted from either BOEM (2014) or NOAA (2018). Similar guidance documents were not readily available for the Alaskan OCS region although extended Exclusion zones were recommended in a recent environmental assessment for a proposed 3D seismic program in Alaska's Cook Inlet which at the time of writing was pending approval from BOEM (Hilcorp 2018).

The discussion below is taken from the Notice to Lessees BOEM (2016) unless otherwise referenced.

2.1 PLANNING SEISMIC SURVEYS

Planning to avoid important areas for marine mammals are included in the environmental assessment and permitting processes.

NMFS has designated critical habitat for the North Atlantic Right Whale (NARW) offshore the coast of southern Georgia and northern Florida (BOEM 2014). Airgun surveys within the designated area will be prohibited between November 1 and April 30, when right whales are

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present to breed and nurse calves (NOAA 2018). BOEM (2014) and NOAA (2018) provide details on other time-area restrictions off the mid-Atlantic states.

Survey operators will also be required to ensure that sound from surveys outside of NARW critical habitat, and other restricted areas does not exceed 160 dB at the boundaries of these areas - the limit currently advanced by NMFS as the threshold for assuring no disruption of marine mammal behavior (BOEM 2014).

To protect nesting sea turtles, which breed in large numbers at Archie Carr National Wildlife Refuge, airgun seismic surveys will be prohibited between May I and October 31 in a zone extending lo 5.9 miles offshore Brevard County, Florida (BOEM 2014).

2.2 SAFETY ZONE AND START-UP

"Exclusion zone" is defined as the area at and below the sea surface within a radius of 500 m surrounding the center of an airgun array (around the outer extent of the array(s) for the mid-Atlantic OCS) and the area within the immediate vicinity of the survey vessel. A 500 m buffer zone (essentially resulting in a 1 km Exclusion zone) has been added for the pre-clearance watch prior to ramping up for the mid-Atlantic OCS (NOAA 2018). A total of 500 m remains for ramp-up and operations at full power in that area (NOAA 2018).

There is one important exception to the above: NOAA (2018) requires a 1.5 km Exclusion zone upon sighting a NARW; or a baleen whale or sperm whale accompanied by a calf; or a beaked whale or *Kogia* spp; or upon visual observation of an aggregation (defined as six or more animals) of large whales of any species.

Operators must visually monitor the Exclusion zone and adjacent waters for the presence of any marine mammals and sea turtles for at least 30 minutes before initiating ramp-up procedures. If none are detected, ramp-up procedures may be initiated. Ramp-up procedures should be initiated by firing a single airgun. The preferred airgun to begin with should be the smallest airgun, in terms of energy output (dB) and volume (in^3). Ramp-up must be continued by gradually activating additional airguns over a period of at least 20 minutes, but no longer than 40 minutes, until the desired operating level of the airgun array is obtained.

All airguns should be immediately shut down at any time a whale is detected entering or within the Exclusion zone. "Whales" mean all marine mammals except dolphins and manatees in the Gulf of Mexico and specific genera of small dolphins; *Steno, Tursiops, Stenella, Delphinus, Lagenorhynchus,* and *Lagenodelphisg* in the mid-Atlantic (NOAA 2018). Seismic operations and ramp-up of airguns may only be recommenced when the Exclusion zone has been visually inspected for at least 30 minutes to ensure the absence of marine mammals and sea turtles.

Visual observers who have completed a protected species observer training program as described in BOEM (2016) are required on all seismic vessels conducting operations in water depths greater than 200 m (656 ft) throughout the Gulf of Mexico. Visual observers are required on all seismic vessels conducting operations in OCS water depths less than 200 meters (656 ft) in the Gulf of Mexico waters east of 88.0° W. longitude. At least two protected species visual observers will be required on watch aboard seismic vessels at all times during daylight hours (dawn to dusk) when seismic operations are being conducted, unless conditions (fog, rain, darkness) make sea surface observations impossible. If conditions deteriorate during daylight hours such that the sea surface observations are halted, visual observations must resume as soon as conditions permit.

Observer requirements vary by OCS region. For the Gulf of Mexico, operators may engage trained third-party observers, may utilize crew members who have been trained as observers, or may use a combination of both third party and trained crew observers (BOEM 2014). In the mid-Atlantic OCS, independent observers are employed by a third-party observer provider; vessel crew may not serve as observers. In addition, observers ("Protected Species Observers") require a bachelor's degree with a major in one of the natural sciences and a minimum of 30 semester hours or equivalent in the biological sciences and at least one undergraduate course in math or statistics (NOAA 2018).

2.3 SHUT-DOWN OF AIR SOURCE ARRAY(S)

At any time a whale is observed within the Exclusion zone, whether due to the whale's movement, the vessel's movement, or because the whale surfaced inside the Exclusion zone, the observer will call for the immediate shut-down of the seismic operation (the vessel may continue on its course but all airgun discharges must cease).

When no marine mammals or sea turtles are sighted for at least a 30-minute period, ramp-up of the source array may begin. Any shut-down due to a whale(s) sighting within the Exclusion zone must be followed by a 30-minute all-clear period and then a standard, full ramp-up. Any shut-down for other reasons, including, but not limited to, mechanical or electronic failure, resulting in the cessation of the sound source for a period greater than 20 minutes, must also be followed by full ramp-up procedures.

2.4 LINE CHANGES AND MAINTENANCE SHUT-DOWNS

Operators in the Gulf of Mexico may reduce the source level of the airgun array, using the same shot interval as the seismic survey, to maintain a "minimum source level" of 160 dB re 1 μPa-m (rms) for the duration of certain activities. By maintaining the minimum source level, seismic survey operators will not be required to conduct the 30-minute visual clearance of the Exclusion zone before ramping back up to full output. Activities appropriate for maintaining the minimum source level are: (1) all turns between transect lines, when the full array is being used immediately prior to the turn and will be resumed immediately after the turn; and (2) unscheduled, unavoidable maintenance of the airgun array that requires the interruption of a survey to shut down the array. The survey should be resumed immediately after the repairs are completed.

There may be other occasions when this practice is appropriate but use of the minimum source level to avoid the 30-minute visual clearance of the Exclusion zone is only for events that occur during a survey using the full power array. The minimum sound source level is not to be used to allow a later ramp-up after dark or in conditions when ramp-up would not otherwise be allowed.

Use of a single airgun as a "mitigation source," e.g., during extended line turns, is not allowed in the mid-Atlantic OCS (NOAA 2018). The acoustic source must be deactivated when not acquiring data or preparing to acquire data in the mid-Atlantic OCS, except as necessary for testing (NOAA 2018).

Periods of airgun silence not exceeding 20 minutes in duration will not require ramp-up for the resumption of seismic operations if: (1) visual surveys are continued diligently throughout the silent period (requiring daylight and reasonable sighting conditions), and (2) no whales, other marine mammals, or sea turtles are observed in the Exclusion zone. If whales, other marine mammals, or sea turtles are observed in the Exclusion zone during the short silent period, resumption of seismic survey operations must be preceded by ramp-up.

2.5 OPERATIONS IN LOW VISIBILITY

Ramp-up cannot begin unless conditions allow the sea surface to be visually inspected for marine mammals and sea turtles for 30 minutes prior to commencement of ramp-up. Thus, ramp-up cannot begin after dark or in conditions that prohibit visual inspection (e.g., darkness, fog, rain) of the Exclusion zone.

BOEM (2016) "strongly encourages" operators to include PAM as part of their protected species observer program in the Gulf of Mexico. Monitoring for whales with a passive acoustic array by an observer proficient in its use will allow ramp-up and the subsequent start of a seismic survey during times of reduced visibility (e.g., darkness, fog, rain) when such ramp-up otherwise would not be permitted using only visual observers.

BOEM (2014) and NOAA (2018) require the use of PAM during all airgun surveys in the mid-Atlantic OCS area. NOAA (2018) emulates the protocol developed in New Zealand (DOC 2013) to address PAM malfunctions (see section B.4.5 below).

2.6 ADDITIONAL MITIGATION MEASURES AND MODIFICATIONS

Vessel operators, regardless of vessel size, must maintain a vigilant watch for all marine mammals and sea turtles to avoid strikes while in transit. Speed must be reduced to 10 knots or less when within designated time/area closures for NARWs or when mother/calf pairs, pods, or large groups of any cetaceans are observed nearby. While in transit, a minimum distance of 500 m must be kept from any NARW sighted, 100 m from other whale species listed under the *Endangered Species Act* (ESA), and 50 m from all other marine mammals and sea turtles (BOEM 2014) (NOAA 2018).

BOEM (2016) outlines the following mitigation for Borehole surveys:

- During daylight hours, when visual observations of the Exclusion zone are being performed as required, borehole seismic operations will not be required to ramp-up for shutdowns of 30 minutes or less in duration, as long as no whales, other marine mammals, or sea turtles are observed in the Exclusion zone during the shutdown. If a whale, other marine mammal, or sea turtle is sighted in the Exclusion zone during the shut-down, ramp-up is required and may begin only after visual surveys confirm that the Exclusion zone has been clear for 30 minutes.
- During nighttime or when conditions prohibit visual observation of the Exclusion zone, ramp-up will not be required for shutdowns of 20 minutes or less in duration. For borehole seismic surveys that utilize PAM during nighttime and periods of poor visibility, ramp-up is not required for shutdowns of 30 minutes or less.
- Nighttime or poor visibility ramp-up is allowed for borehole seismic surveys only when PAM systems are used to ensure that no whales are present in the Exclusion zone (as for all other seismic surveys). Operators are strongly encouraged to acquire the survey in daylight hours when possible.
- Protected species observers must be used during daylight hours and may be stationed either on the source boat or on the associated drilling rig or platform if a clear view of the sea surface in the Exclusion zone and adjacent waters is available.

A 200-m minimum Exclusion zone for marine mammals and sea turtles will be required for High Resolution Geophysical (HRG) surveys in the mid-Atlantic and South Atlantic OCS operating at 200 kHz or lower frequencies. Larger zones will be required if field observations or modeling indicate that sound pressure levels may exceed 180 decibels beyond 200 meters from the HRG survey activities (BOEM 2014).

Hilcorp Alaska LLC in their October 2018 Environmental Evaluation Document (Hilcorp 2018) has committed to the Exclusion zones and safety zones in Table 1 for their proposed program in the Cook Inlet. Beluga whales in the Cook Inlet are designated as critically endangered thus requiring a larger Exclusion zone. It should be noted that the approval of their program was still pending at the time of writing, therefore any legal requirements are yet to be provided by BOEM.

Table 4. Radii of Exclusion zone (EZ) and safety zone (SZ) for Hilcorp seismic program.

Exclusion Zone (m)					SZ Radius
Source	**Sea Otters**	**Beluga Whales**	**Harbor and Dall's Porpoises**	**All Other Marine Mammals**	**All Marine Mammals (Other Than Beluga Whales)**
40 in^3 airgun	50 m	500 m	50 m	50 m	500 m
2,010 in^3 airgun	180 m	7.33 km	1 km	500 m	7.33 km

Notes: The proposed EZ and SZ were based on a 2,010 in^3 airgun array and 40 in^3 mitigation airgun. The 3D seismic survey array has since been refined to be a 1,945 in^3 array and 40 in^3 mitigation airgun. The Environmental Evaluation Document does not refer to any acoustic modelling used in the determination these zones but includes a commitment to perform a sound source verification survey at the beginning of the 3D seismic survey program to verify the EZ and SZ. Source: Hillcorp (2018).

3.0 UNITED KINGDOM

The mitigation measures outlined in the "JNCC guidelines for minimizing the risk of injury to marine mammals from geophysical surveys" are designed to be used by all regulators who have jurisdiction over the United Kingdom Continental Shelf (UKCS) (JNCC 2017).

The focus of these guidelines is on marine mammals; however, they could be adapted to help reduce the risk of deliberate injury to other marine species by the relevant regulator. For example, other potentially sensitive species include marine turtles and several shark species which are UK priority marine species.

3.1 PLANNING SEISMIC SURVEYS

When planning a geophysical survey, the following should be considered (JNCC 2017):

- Use the lowest practicable power levels needed to achieve the survey objectives and seek/consider methods to reduce and/or buffer unnecessary high frequency noise produced.
- Airgun firing (including testing) must not exceed the planned maximum production volumes outlined in the consent or licence application.
- Determine what marine mammal species are likely to be present in the survey area, identify if the survey is to occur within or near an area of importance for marine mammals.
- When possible, plan surveys to avoid areas/periods of high abundance and key seasons.
- The standard radius of the Mitigation Zone referred to in these guidelines is 500 m**.** Any variation to this Mitigation Zone size can be proposed during the application process, but requires a clear rationale, potentially supported by noise propagation modelling and including consideration of how the standard mitigation measures could be applied to the proposed Mitigation Zone.
- Consider the direction of survey lines and distance to sensitive areas and coastline to reduce any potential for entrapment.

3.2 SAFETY ZONE AND START-UP

The standard radius of the Mitigation Zone is 500 m, estimated from the centre of the airgun array or noise source location.

The duration of the pre-shooting search is determined as follows:

- **Waters less than 200 m deep**: 30 minutes prior to the use of any airguns.
- **Waters greater than 200 m deep**: 60 minutes prior to the use of any airguns.

Visual monitoring is undertaken by a Marine Mammal Observer (MMO). It should be undertaken from the source vessel with the MMO located on a suitable platform enabling the best view of the Mitigation Zone and ahead of the vessel.

Both the MMO and PAM operative should ensure their efforts are concentrated on the mitigation periods, i.e., the pre-shooting search and soft-start time periods until the survey line has started and data acquisition has begun. The guidelines should not be interpreted to imply that MMO/PAM operatives should continue a visual/acoustic search during all available hours, unless specified as a survey consent or licence condition.

If marine mammals are detected within the Mitigation Zone during the pre-shooting search (visually or acoustically), the soft-start must be delayed until their passage, or the transit of the vessel results in them being outside of the Mitigation Zone. There must be a minimum of a 20-minute delay from the time of the last detection within the Mitigation Zone and the commencement of the soft-start, to allow animals unavailable for detection (i.e. not re-surfacing in that time) to have moved outside of the Mitigation Zone. A full soft-start must be undertaken after any delay due to the presence of marine mammals within the Mitigation Zone.

In situations where seal(s) are congregating around a fixed platform within a survey area, the soft-start should commence at a location at least 500 m from the platform.

The standard duration of a soft start is a minimum of 20 minutes and a maximum of 40 minutes from the start of the soft start to the commencement of a survey line.

One exception to these criteria is for surveys where the maximum airgun volume is <180 in^3, in which case:

- From the start of the soft-start until full operational power: minimum of 15 minutes;
- From the start of the soft-start until the start of the survey line: maximum of 25 minutes.

For a MMO to be classified as trained, the individual must have undertaken formal training on a JNCC recognized course plus have some experience of visually spotting marine mammals. An experienced MMO should have a minimum of 20 weeks' experience of implementing JNCC guidelines in UK waters over the previous ten years, and preferably within the previous five.

It is the operators' responsibility to employ sufficient MMO/PAM personnel to cover all mitigation periods, taking account the specific requirements and logistics of their survey, thus removing the potential for operative fatigue and meeting health and safety requirements. This is particularly important when working at northern latitudes (i.e. above 57°) during summer months and when planning 24-hour data acquisition.

3.3 SHUT-DOWN OF AIR SOURCE ARRAY(S)

If marine mammals are detected within the Mitigation Zone whilst the airguns are firing, either during the soft-start procedure or when at full power, there is no requirement to stop firing.

3.4 LINE CHANGES AND MAINTENANCE SHUT-DOWNS

Due to the longer pre-shooting search time required in deeper waters, pre-shooting searches can commence before the end of a preceding survey line (whilst the airguns are still firing) **IF** line changes will take less time than the pre-shooting search and soft-start combined (i.e., 80 mins).

If line changes (or geophone repositioning) are expected to take longer than 40 minutes, regardless of airgun volume:

- Firing is to be terminated at the end of the survey line (or during geophone repositioning);
- A pre-shooting search is to be undertaken during the scheduled line change (or geophone repositioning);
- The soft-start is to be delayed if marine mammals are seen within the Mitigation Zone during the pre-shooting search; and
- A full 20-minute soft-start is to be undertaken before the start of the next line or VSP data collection.

If line changes (or geophone repositioning) are expected to be completed within 40 minutes, regardless of airgun volume:

- Airgun firing can continue during the line change **only** if power is reduced to 180 in^3 (or as close as is practically feasible) at standard pressure. Airgun volumes of less than 180 cubic inches can continue to fire at their operational volume and pressure; **AND**
- The Shot Point Interval (SPI) is increased to provide a longer duration between shots, with the SPI not to exceed 5 minutes; **AND**
- The power is increased, and the SPI is decreased in uniform stages during the final 10 minutes of the line change (or geophone repositioning), prior to data collection re-commencing (i.e., a form of mini soft start).

If the above is not practical, and an alternative procedure has not been agreed with the Regulator, then airgun firing should be terminated and a pre-shooting search and soft-start implemented prior to the start of the next line.

No equipment testing should be undertaken outside the consented or licensed area (including any greater working area as defined in some applications).

The following guidance is provided to clarify when a soft-start is required for airgun testing:

- If the intention is to test a single airgun, a soft-start is not required.
- If the intention is to test multiple airguns, a soft-start is required. This should be carried out over a time period proportional to the number and/or volume of guns being tested and should not exceed 20 minutes in duration. Airguns should be tested in order of volume, smallest first.
- A pre-shooting search must be undertaken before any instances of airgun testing.

Unplanned breaks: This refers to instances where the airguns cease firing unexpectedly during data acquisition, e.g. a technical problem or breakdown. In such circumstances, it is imperative the MMO/PAM operatives begin to monitor the Mitigation Zone as quickly as possible after an unplanned break has occurred.

If the airguns can be restarted and data acquisition resumed in less than 10 minutes, there is no requirement for a soft-start and firing can recommence at the same power level as at prior to the break (or lower), provided no marine mammal(s) have been detected in the Mitigation Zone during the breakdown period.

If a marine mammal is detected in the Mitigation Zone during the breakdown period, the MMO/PAM operative will advise to delay recommencement of the airgun firing until their passage, or the transit of the vessel, results in the marine mammals being outside of the Mitigation Zone. There must be a minimum of a 20-minute delay from the time of the last detection within the Mitigation Zone and a soft-start must then be undertaken.

If it takes longer than 10 minutes to restart the airguns, a full pre-shooting search and soft-start should be carried out before the survey re-commences. If a MMO/PAM operative has been monitoring during the breakdown period, this time can contribute to the pre-shooting search time (30 or 60 minutes as appropriate).

If the breakdown occurs at night or during daylight conditions not conducive for a visual search, the Mitigation Zone should be monitored using PAM. If PAM is not available, the survey must be delayed until conditions are suitable for visual observations.

Planned breaks: If breaks in data acquisition other than during a line change are required (e.g. to avoid a structure), the same procedures for unplanned breaks can be applied. However, if the planned break will be for less than 10 minutes, the MMO/PAM operatives must begin monitoring 20 minutes prior to the planned break and continue for the duration of the break.

3.5 OPERATIONS IN LOW VISIBILITY

Where practical, operations should be timed to commence during daylight hours to ensure that visual mitigation by MMOs can be undertaken. Depending upon the nature of the survey and the consent or licence conditions, operations may have to be delayed until conditions change or improve, unless an alternative method to visual surveys, such as PAM, is available and can be deployed.

Where PAM is a condition of the consent or licence, it must be used if soft starts will occur during hours of darkness and during periods when day-time conditions are not conducive to visual surveys (e.g. fog).

Where PAM is not a condition of the consent or licence and day-time conditions are such that visual observations cannot be undertaken and no other form of monitoring is available, best practice would be to delay the initiation of soft starts and seismic shooting until conditions improve.

A minimum of one PAM operator is required when PAM equipment is to be deployed, with consideration of the survey specifics (including potential use during daylight hours) used to determine the total number of operators. PAM may be required to supplement visual surveys (in addition to use at night and periods of poor visibility) in areas of importance for marine mammals. Under such circumstances, the operator must ensure sufficient personnel are employed to allow for 24-hour PAM coverage (i.e., usually a minimum of two PAM operators).

It is not uncommon for individuals to conduct both the MMO and PAM roles during the same survey. This is acceptable under these guidelines, but it is essential that personnel are trained and competent in both roles.

3.6 ADDITIONAL MITIGATION MEASURES AND MODIFICATIONS

When vessels are time-sharing, i.e. where two or more vessels are operating in adjacent areas and take turns to shoot to avoid causing seismic interference, the guidelines apply on all vessels involved and clear communication channels are required to ensure effective mitigation.

If dual source arrays are to be used, particularly if they are to be operated simultaneously rather than in an alternative manner (e.g. flip flop mode), the Mitigation Zone required to encompass the entire array (e.g. based on the centre point between the two arrays) must be estimated. Any proposed alteration to the standard Mitigation Zone should be made clear in the survey application, *potentially* supported by noise propagation modelling.

High resolution data can be achieved either using airguns or electromagnetic sources. Sub-bottom profiling (SBP, e.g. pingers, sparkers, boomers and CHIRP systems), side-scan sonar and multi-beam echosounders all use electromagnetic sources. The JNCC will provide advice on a case-by-case basis based on the following:

Electromagnetic sources:

- Pre-shooting search of the Mitigation Zone and a delay in proceeding if a marine mammal is observed. Typically, a non-dedicated MMO can be used.
- Soft start – where practical, ramp up the power in a uniform manner. However, it is acknowledged that this is not possible for some SBP equipment (i.e. it is either on or off).

If several types of equipment are to be started sequentially or interchanged during the operation, only one pre-shooting search is required prior to the start of acoustic output, only if there are no gaps in data acquisition of greater than 10 minutes.

Some multi-beam systems used in deeper waters (>200 m) utilize frequencies (<100 kHz) at sound levels that may be of concern to cetacean species, both in relation to deliberate injury and disturbance offences. Mitigation requirements will be provided on a case by case basis

Multi-beam surveys in shallower waters (<200 m) are not subject to these requirements as it is thought the higher frequencies typically used fall outside the hearing frequencies of cetaceans and the sounds produced are likely to attenuate more quickly than the lower frequencies used in deeper waters. Mitigation is not required for multi-beam surveys in shallow waters.

4.0 AUSTRALIA

Australia's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Policy Statement 2.1 – Interaction between offshore seismic exploration and whales **(**Australia 2008) provide standards to minimise the risk of acoustic injury to whales in the vicinity of seismic survey operations. This Policy Statement has been written with the goal of minimising the likelihood of injury or hearing impairment of whales. Calculations are primarily based on received sound energy levels that are estimated to lead to a temporary threshold shift (TTS) in baleen whale hearing. "Whales**"** includes baleen whales and larger toothed whales, such as sperm whales, killer whales, false killer whales, pilot whales, and beaked whales. The Policy Statement does not apply to encounters with the smaller dolphins and porpoises.

4.1 PLANNING SEISMIC SURVEYS

Australia requires extensive planning documents outside of the DEWHA (2008) which is the focus of this section. The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA, the approximate version of DFO in Australia) has published an Information Paper related to the environmental plans (EPs) for marine seismic surveys, which includes an environmental impact assessment (EIA). Although applying the Information Paper is not a regulatory requirement, EPs are required under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Environment Regulations). Under these regulations, the EPs must be accepted before any petroleum activity or greenhouse gas activity can occur in Commonwealth waters.

Seismic surveys should not be planned in areas where and when whales are likely to be breeding, calving, resting, feeding or migrating. If proposed, these surveys and associated mitigation measures will need careful consideration and may require further assessment under the EPBC Act.

4.2 SAFETY ZONE AND START-UP

Mitigation measures aimed at preventing injury and minimising the risk (to whales) of biologically significant behavioral changes should be applied to ensure their protection. For proposed seismic surveys that can demonstrate through sound modelling or empirical measurements that the received sound exposure level for each shot will not likely exceed 160dB re 1μPa^2·s, for 95% of seismic shots at 1 km range, the following precaution zones are recommended:

- *Observation* zone: 3+ km horizontal radius from the acoustic source.
- *Low power* zone: 1 km horizontal radius from the acoustic source.
- *Shut-down* zone: 500 m horizontal radius from the acoustic source.

For all other proposed seismic surveys:

- *Observation* zone: 3+ km horizontal radius from the acoustic source.
- *Low power* zone: 2 km horizontal radius from the acoustic source.
- *Shut-down* zone: 500 m horizontal radius from the acoustic source.

In the *observation* zone whales and their movements should be monitored to determine whether they are approaching or entering the *low power* zone. When a whale is sighted within, or is about to enter, the *low power* zone, the acoustic source should immediately be powered down to the lowest possible setting. When a whale is sighted within, or is about to enter, the *shut-down* zone, the acoustic source must immediately be shut down completely.

During daylight hours, visual observations for the presence of whales should be undertaken by a suitably trained crew member for at least 30 minutes before the commencement of the Soft Start Procedure. Observations should, where visibility allows, extend to 3+ km (the *Observation* zone) from the vessel but with particular focus on the *Low power* and *Shut-down* zones around the acoustic source (see above). During these 30-minute observations, the observer should make observations around the whole of the vessel (360°) and towed array out to a 3km distance and, if possible, beyond 3 km.

If no whales have been sighted within the *Low power* and *Shut-down* zones during the pre-start-up procedure, the soft start procedure may commence. Soft start procedures should be used each time the acoustic sources are initiated, gradually increasing power over a 30-minute period. The full power operating level should be the minimum acoustic energy that is necessary to achieve the survey's objectives. During daylight hours, visual observations by trained crew should be maintained continuously during soft starts to identify any whales within the precaution zones.

If a whale is sighted within the 3 km *observation z*one during the soft start an additional trained crew member or MMO should also be brought to the bridge to continuously monitor the whale whilst in sight.

Soft start procedures should only resume after the whale has been observed to move outside the *Low power* zone, or when 30 minutes have lapsed since the last whale sighting.

During daylight hours, trained crew should undertake visual observations continuously during survey operations.

The organisation conducting the survey should ensure that there is sufficient trained crew to fulfil the basic mitigation requirements outlined in the Policy. The trained crew members must have proven experience in whale observation, distance estimation and reporting.

4.3 SHUT-DOWN OF AIR SOURCE ARRAY(S)

As presented above, if a whale is sighted within or is about to enter the *Low power* zone, the acoustic source should be powered down to the lowest possible setting. If a whale is sighted or is about to enter the *Shut-down* zone, the acoustic source should be shut down completely.

4.4 LINE CHANGES AND MAINTENANCE SHUT-DOWNS

Operators should power down the acoustic source to the lowest possible setting when not collecting data or undertaking soft start procedures (e.g. during line turns or when moving to another part of the survey area).

If the array is completely shut down or reduced to low power (e.g. for operational reasons or during line turns), observations for whales should continue. To restart the array the following procedures should take place:

- If no whales are sighted during the shut-down/low power period, then start-up may commence using the Soft Start Procedure.
- If whales are sighted during the shut-down/low power period, or if observations for whales ceased, then start-up should not begin until pre start-up visual observations have been conducted. Start-up may then commence using the Soft Start Procedure.

4.5 OPERATIONS IN LOW VISIBILITY

At night-time or at other times of low-visibility (when observations cannot extend to 3 km from the acoustic source, e.g. during fog or periods of high winds), start-up may be commenced according to the Soft-Start Procedure:

- provided that there have not been 3 or more whale instigated power-down or shut-down situations during the preceding 24-hour period; or
- if operations were not previously underway during the preceding 24 hours, the vessel (and/or a spotter vessel or aircraft) has been in the vicinity (approximately 10 km) of the proposed start up position for at least 2 hours (under good visibility conditions where observations can extend beyond 3 km) within the preceding 24 hour period, and no whales have been sighted.

During low visibility, where conditions allow, continuous observations to spot whales should be maintained with a particular focus on the *Low power* and *Shut-down* zones. If sightings of whales have been frequent or are higher than were anticipated during the planning of the survey, the proponent should contact the Department of the Environment, Water, Heritage and the Arts to discuss appropriate night-time provisions and whether additional management measures should be employed for day and/or night-time operations.

The use of PAM as a detection tool should be considered by the proponent operating in areas where the likelihood of encountering whales is moderate to high and, if deployed, details should be provided on their intended use as part of any referral under the EPBC Act. “Moderate to high" is defined as "spatially and/or temporally proximate to aggregation areas, migratory pathways and/or areas considered to provide biologically important habitat" (DEWHA 2008).

4.6 ADDITIONAL MITIGATION MEASURES AND MODIFICATIONS

Further environmental assessment of potential impacts may be necessary if multiple seismic sources (e.g. two vessels on one project or multiple, adjacent projects) are to be operated in the same general area. Where a seismic survey is proposed, the proponent should liaise with government and industry bodies to ensure that surveys do not unnecessarily coincide or overlap.

For seismic surveys operating in areas where the likelihood of encountering whales is moderate to high, the application of additional measures, to ensure that impacts and interference are avoided and/or minimised, are necessary. The following measures are recommended, however, application of all these measures may not be necessary, applicable or possible for all seismic survey operations:

- As the likelihood of encountering whales increases, the proponent should engage MMOs. MMOs should be trained and experienced in whale identification and behaviour, distance estimation, and be capable of making accurate identifications and observations of whales in Australian waters. The MMOs should assist other observers (e.g. trained crew) and be available to provide advice, should whales be encountered.
- For surveys in areas where whales are expected to be encountered, the proponent should include appropriate management measures to detect (or predict) whale presence and apply measures to reduce the likelihood of encounters. Possible measures include:
- Limiting initiation of soft start procedures to conditions that allow visual inspection of the precaution zone;
- Daylight spotter vessel or aircraft searches of the night-time survey area to determine if whales are present; and
- Pre survey research (including surveys) to detect and identify likely whale concentration areas, such as: peak migration paths and times, key feeding sites (e.g. shelf breaks, sea mounts and trenches), or other aggregation areas.

In some locations and circumstances, it may be advisable to apply increased distances for the instigation of power-down procedures from those above. For important habitats, such as feeding areas, when concentrations of food and whales are likely to occur, an increased *low power* zone (e.g. 3 km) may be appropriate to ensure that disturbance or displacement of whales does not occur. Such a measure may not need to apply for the whole of the survey (time and area) but may be advisable for particular specific locations (e.g. along the shelf edge where food sources are most likely to occur).

For surveys being undertaken in the broad vicinity of known breeding or resting areas, a buffer (exclusion) zone should be established to ensure that operating survey vessels do not enter the vicinity where whales may be present. The size of the buffer zone should be established on a precautionary basis. Where available, scientific evidence and/or acoustic propagation modelling should be used to determine and justify the buffer zone. The Policy Statement does not provide further information on how to conduct acoustic propagation modelling.

5.0 NEW ZEALAND

The New Zealand Department of Conservation (DOC) has developed the *2013 Code of conduct for minimising acoustic disturbance to marine mammals from seismic survey operations* (the

Code) (DOC 2013) and its Reference document to provide mitigation measures for minimizing acoustic disturbance of marine mammals during seismic surveys.

The Code includes differing mitigation depending on the size and output of the seismic source.

Level 1 survey means any marine seismic survey using an acoustic source with a total combined operational capacity exceeding 7 L/427 in^3.

Level 2 survey means any marine seismic survey using an acoustic source with a total combined operational capacity of between 2.50–6.99 L/151–426 in^3 capacity.

Level 3 survey means any marine seismic survey using low-energy, high-resolution electro-mechanical sources. These may include small seismic sources of less than 2.49 L/150 in^3 capacity, sparkers, pingers and boomers. Level 3 surveys are exempt from the provisions of the Code.

At the time of implementation, DOC committed to the Code being reviewed after three years. Accordingly, the review of the 2013 Code began in July 2015, with a request for feedback from numerous stakeholders (the Seismic Code Review Group; SCRG). In August 2015, this feedback was combined with that obtained during the three years since implementation.

New Zealand passed legislation in November 2018 which bans new permits for offshore oil and gas exploration, although existing permits are preserved and are subject to the existing marine seismic code. This follows bans for future offshore oil and gas exploration off Belize, Costa Rica, Ireland, Denmark (inland waters only, does not include the North Sea or Greenland) and a gradual phase-out in France (Offshore Technology 2018). This ban effectively ended initiatives to update the Code, which included a series of working papers and workshop proceedings. For example, Wright et al. (2016) summarized presentations and discussions on two main categories: performance standards for source techniques, and performance standards for mitigation techniques.

The following sections are excerpts from the Code (DOC 2013).

5.1 PLANNING SEISMIC SURVEYS

The fundamental component of the planning process for seismic surveys is the preparation of a Marine Mammal Impact Assessment (MMIA). Under normal circumstances marine seismic surveys will not be planned in any sensitive, ecologically important areas or during key biological periods where Species of Concern are likely to be breeding, calving, resting, feeding or migrating, or where risks are particularly evident such as in confined waters (for example, embayments or channels). However, where conducting surveys in such areas and seasons is demonstrated to be necessary and unavoidable, further measures may be required to minimize potential impacts. This can range up to the complete ban of all mining (including seismic surveys), fishing or harvesting of any kind in the Kaikoura whale sanctuary.

A core component of the planning process is for the proponent to determine the lowest practicable power levels for the acoustic source array that will achieve the geophysical objectives of the survey—and to limit operations to this maximum level. While the Code is primarily concerned with protection of marine mammals, proponents are strongly encouraged to adopt whatever means are available to avoid or mitigate negative effects on other key species (such as turtles, penguins and seabirds) or key habitats identified in the planning stage as being potentially impacted.

Where Passive Acoustic Monitoring (PAM) is incorporated as a mitigation tool in the survey methodology, pre-survey planning should include input from the lead PAM operator, where possible, to ensure appropriate system specifications.

5.2 SAFETY ZONE AND STARTUP

The Code utilizes Mitigation Zones of varying extent, based on potential risk of adverse impacts.

Level 1 seismic programs must adhere to the following zones:

- *Species of Concern with calves within a mitigation zone of 1.5 km*
- *Species of Concern within a mitigation zone of 1 km*
- *Other Marine Mammals within a mitigation zone of 20*0 m

Level 2 seismic programs have the following zones:

- *Species of Concern with calves within a mitigation zone of 1 km*
- *Species of Concern within a mitigation zone of 600 m*
- *Other Marine Mammals within a mitigation zone of 200 m*

Level 1 or 2 acoustic sources will not be activated at any time except by soft start, unless the source is being reactivated after a single break in firing (not in response to a marine mammal observation within a Mitigation Zone) of less than 10 minutes immediately following normal operations at full power, and the qualified observers have not detected marine mammals in the relevant Mitigation Zones. This means a gradual increase of the source's power, starting with the lowest capacity gun, over a period of at least 20 minutes and no more than 40 minutes.

It is recognized that alternative acoustic source technologies may be used for borehole seismic surveys, and that soft start may not be possible in the same manner as a conventional marine seismic source array. Where possible, initial activation of the acoustic source must involve the gradual increase of the source's power over a period of at least 20 minutes and no more than 40 minutes.

A Level 1 sound source cannot be activated during daylight hours unless at least one qualified MMO has continuously made visual observations for the presence of marine mammals, and no marine mammals (other than fur seals) have been observed in the relevant Mitigation Zone for at least 30 minutes, and no fur seals have been observed in the relevant Mitigation Zones for at least 10 minutes. In addition, PAM for the presence of marine mammals has been carried out by a qualified PAM operator for at least 30 minutes before activation and no vocalizing cetaceans have been detected in the relevant Mitigation Zones.

For all Level 1 surveys the minimum qualified observer requirements are:

- At all times there will be at least two qualified MMOs on board, and
- At all times there will be at least two qualified PAM operators on board, and
- At all times while the acoustic source is in the water, at least one qualified MMO (during daylight hours) and at least one qualified PAM operator will maintain watches for marine mammals. So long as it does not cause health and safety issues, it is recommended that both qualified MMO are on watch during pre-start observations during daylight hours, or at any other key times where practical and possible.

Level 2 MMO requirements are similar to Level 1. PAM is not required for Level 2 surveys.

An MMO with adequate understanding of the PAM system in operation, while not required for visual observation duties, may provide temporary cover in place of a qualified PAM operator to ensure continuation of 24-hour monitoring.

To be a trained observer (either MMO or PAM), a person will have

- Successfully completed the respective marine mammal observation course or PAM operator course recognized by the DOC, or
- Demonstrated all required competencies through an assessment process consistent with DOC standards.

In addition to the above, the person will have logged a minimum of 12 weeks' relevant sea-time engaged in marine seismic survey operations in New Zealand continental waters, either as an MMO or PAM operator under the supervision of an appropriately qualified observer.

For Level 1 surveys, seismic survey vessel crew cannot be considered as qualified observers irrespective of training or experience. However, for Level 2 seismic survey vessels, crew trained and experienced as outlined above may function as qualified observers.

5.3 SHUT-DOWN OF AIR SOURCE ARRAY(S)

Any qualified observer on duty has the authority to delay the start of operations or shut down an active survey if a marine mammal is sighted within the appropriate Mitigation Zone.

5.4 LINE CHANGES AND MAINTENANCE SHUT-DOWNS

Seismic source tests will be subject to the relevant soft start procedures for each survey level, though the 20-minute minimum duration does not apply. Where possible, power should be built up gradually to the required test level at a rate not exceeding that of a normal soft start. Level 1 and 2 seismic source tests with a maximum combined source capacity of <2.49 L or 150 in^3 do not require soft start procedures and can be undertaken following relevant pre-start observations.

Acoustic source tests cannot be used for mitigation purposes, or to avoid implementation of soft start procedures.

Operators are strongly encouraged to reduce unnecessary marine noise, if possible and practical, by shutting down at the end of a line and reactivating the acoustic source according to the applicable soft start procedures and pre-start observations. The use of acoustic sources for mitigation purposes during line turns immediately following normal full power operations is allowed, providing that the power output of the acoustic source during line turns is reduced to levels that limit effective ensonification to the maximum Mitigation Zone boundary. Use of acoustic sources for mitigation purposes should only be used in exceptional circumstances where demonstrated by the proponent to be necessary. If mitigation acoustics are employed, they will be subject to the same shutdown provisions as normal seismic survey operations.

5.5 OPERATIONS IN LOW VISIBILITY

Level 1 acoustic sources cannot be activated during night-time hours or poor sighting conditions unless passive acoustic monitoring for the presence of marine mammals has been carried

out by a qualified PAM operator for at least 30 minutes before activation, and the qualified observer has not detected vocalizing cetaceans in the relevant Mitigation Zones.

If operating in an area where calves are expected to be present or have been observed during the survey, that vocalizing cetacean detections by PAM should be assumed to be emanating from a cow/calf pair. In this case the more stringent Mitigation Zone provisions should be applied, unless determined otherwise by the MMO during good sighting conditions.

If operating in an area where calves are expected to be present, vocalizing cetacean detections by PAM should be assumed to be emanating from a cow/calf pair. In this case the more stringent mitigation zone provisions should be applied, unless determined otherwise by the MMO. Due to the limited detection range of PAM technology for ultra-high frequency cetaceans (<300 m), any such bioacoustic detections will require an immediate shutdown of an active survey or will delay the start of operations, regardless of signal strength or whether distance or bearing from the acoustic source has been determined. Shutdown of an activated acoustic source will not be required if visual observations by a qualified MMO confirm that the acoustic detection was of a species of marine mammal not designated as a Species of Concern.

If the PAM system has malfunctioned or become damaged, operations may continue for 20 minutes without PAM while the PAM operator diagnoses the issue. If the diagnosis indicates that the PAM gear must be repaired to solve the problem, operations may continue for an additional 2 hours without PAM monitoring as long as all of the following conditions are met:

- It is daylight hours and the sea state is less than or equal to Beaufort 4;
- No marine mammals were detected solely by PAM in the relevant Mitigation Zones in the previous 2 hours;
- Two MMOs maintain watch at all times during operations when PAM is not operational;
- DOC is notified via email as soon as practicable with the time and location in which operations began without an active PAM system; and
- Operations with an active source, but without an active PAM system, do not exceed a cumulative total of 4 hours in any 24-hour period.

If PAM or other alternative technologies are incorporated to support marine mammal observations and are fully operational, Level 2 acoustic sources may be activated, and active surveys may proceed at night or during poor sighting conditions.

However, when observations are limited to MMOs for Level 2 survey operations, startup can be initiated, and active surveys may proceed at night or during poor sighting conditions only if:

- There have not been more than 3 marine mammal instigated shutdowns or delayed starts in the previous 24 hours of active survey operations in good sighting conditions, or
- If active survey operations were not conducted in the previous 24 hours, MMOs have undertaken observations within a radius of 20 nm of the proposed start-up position for at least the last 2 hours of good sighting conditions during the daylight hours preceding proposed operations and no marine mammals have been detected.

5.6 ADDITIONAL MITIGATION MEASURES AND MODIFICATIONS

No person can use explosives as an acoustic source in New Zealand continental waters.

Where activities are planned in Areas of Ecological Importance or Marine Mammal Sanctuaries, sound transmission loss modelling will be incorporated into the MMIA methodology and ground truthed during the course of the survey by appropriate means. Such modelling will indicate predicted sound levels within the various Mitigation Zones and potential impacts on species present. If sound levels are predicted to exceed either 171 dB re 1 μPa^2-s at distances corresponding to the relevant Mitigation Zones for Species of Concern or 186 dB re 1 μPa^2-s at 200 m, consideration will be given to either extending the radius of the mitigation zone or limiting acoustic source power accordingly.

In addition to the normal pre-start observation requirements outlined above, when arriving at a new location in the survey program for the first time, the initial acoustic source activation must not be undertaken at night or during poor sighting conditions unless either:

- MMOs have undertaken observations within 20 nautical miles of the planned start up position for at least the last 2 hours of good sighting conditions preceding proposed operations, and no marine mammals have been detected; or
- Where there have been less than 2 hours of good sighting conditions preceding proposed operations (within 20 nautical miles of the planned start up position), the source may be activated if:
    - PAM monitoring has been conducted for 2 hours immediately preceding proposed operations, and
    - Two MMOs have conducted visual monitoring in the 2 hours immediately preceding proposed operations, and
    - No Species of Concern have been sighted during visual monitoring or detected during acoustic monitoring in the relevant Mitigation Zones in the 2 hours immediately preceding proposed operations, and
    - No fur seals have been sighted during visual monitoring in the relevant Mitigation Zone in the 10 minutes immediately preceding proposed operations, and
    - No other marine mammals have been sighted during visual monitoring or detected during acoustic monitoring in the relevant Mitigation Zones in the 30 minutes immediately preceding proposed operations.

6.0 BRAZIL

Brazil's "Monitoring Guide for Monitoring Marine Biota During Seismic Data Acquisition Activities" (IBAMA 2005, 2018) was first released in 2005 and updated in October 2018. In addition to any temporary restriction areas identified as part of the licensing process, the document establishes procedures to mitigate potential impacts from the acquisition of seismic data on marine biota. The mitigation measures outlined in the guide are compulsory as conditions of a seismic survey license. IBAMA (Institute of Environment and Natural Resources) may require more restrictive procedures than those in the Guide. The discussion which follows has been adapted from an English translation of the original 2018 Portuguese Guide (IBAMA 2018).

6.1 PLANNING SEISMIC SURVEYS

The operation must be planned to avoid marine mammals and turtles during periods of reproduction, feeding, mating or migration. The proponent must also coordinate their activity with any other overlapping seismic programs. Airgun arrays should be planned to minimize the horizontal emission of acoustic energy and minimize noise emission at higher frequencies. Operators are encouraged to invest in technologies and operational alternatives that reduce noise to the marine environment. Pre-operational training of responsible crew members is mandatory.

6.2 SAFETY ZONE AND STARTUP

Ramp-up can only begin after 30 minutes have passed without the detection of marine mammals or turtles within a 1000 m Exclusion Zone from the center of the array. If animals are detected within the Exclusion Area during ramp-up the airguns must immediately be shut down until 30 minutes have passed without marine mammals or turtles being detected within the Exclusion Zone. At this point, a full ramp-up is required. Ramp-up and the 30-minute watch must be adopted if the airguns have been silent for more than 5 minutes. In case of interruptions of less than 5-minute duration, the activity can be resumed with the same power unless a marine mammal or turtle is detected in the Exclusion Area during this 5-minute interval. In this case, a new ramp-up procedure should be initiated.

Monitoring should be carried out simultaneously by at least two qualified observers regardless of whether the ship is firing the airguns.

Airguns must gradually be ramped-up over a minimum of 20 minutes and a maximum of 40 minutes. The gradual increase must be planned in order to reach full power as close to the start of the seismic line as possible.

Each team of Onboard Observers is formed by at least three professionals, so that at least two are in simultaneous observation throughout the daytime period (to divide the field of vision into two halves). The Guide provides details of equipment to be available to the observers, and instructions on how to conduct, document and submit their work. The latter includes shift lengths, rest periods, calibrating distances and plotting the location of any observed animals.

All Onboard Observers must have higher education in an area compatible with the function, such as biology, oceanography, fisheries engineering or veterinary medicine. Previous academic experience with marine mammals is desirable. At least two observers should have previous experience in marine biota observation on board seismic vessels for at least 100 days. At least two professionals from each team must be fluent in the language of the other crew members of the seismic vessel.

6.3 SHUT-DOWN OF AIR SOURCE ARRAY(S)

Shutting down of airgun arrays is the priority mitigation procedure and should be performed in any situation where mammals or turtles are detected within the 1000m Exclusion Zone. There should be no intermediate procedures that delay shutting down of the airguns.

6.4 LINE CHANGES AND MAINTENANCE SHUT-DOWNS

Shots outside the acquisition area are prohibited, with the exception of those necessary for line changes. Sound source tests at maximum power should preferably take place within the acquisition area. If testing of the sound sources is lower than full power, there is no need to restart the procedure with minimum power, but gradually increase the test power to full power.

Monitoring should be carried out simultaneously by at least two qualified observers regardless of whether or not the ship is firing the air guns including line changes, maintenance of the sound sources or during navigation between port and the seismic acquisition area.

The Guide provides for two-line change scenarios. If the line change is less than 20 minutes duration, the shots should not be interrupted, maintaining maximum power throughout the maneuver. In the event that the line change is greater than 20 minutes, the airgun arrays must be shut down at the end of each line and restarted according to the normal observer (30 minutes) and ramp up (minimum 20 minutes) procedures.

It is prohibited to use as an alternative mitigation mechanism or "night operation" a mitigation gun or single airgun.

6.5 OPERATIONS IN LOW VISIBILITY

Passive Acoustic Monitoring (PAM) is mandatory 24 hours a day throughout the seismic operation. The use of PAM was voluntary in 2005. Although IBAMA recognizes limitations with PAM, they consider that in coordinated with visual observation, PAM can significantly increase the effectiveness of mitigation of acoustic impact on marine mammals (IBAMA 2018). Brazil requires the operator to submit a PAM project or plan for approval as part of the licensing process. Two sections of the Guide cover basic requirements (including use of state-of-the-art equipment, number of receivers, positioning of the PAM array, PAM operator shifts and mechanism to reduce fatigue, recommended use of PAMGuard, record keeping).

There should be at least 3, preferably 4 PAM operators on board the vessel to maintain a 24-hour operation. At least two of these individuals should have proven experience as a PAM operator on seismic vessels.

The Guide provides for wind speed, weather and sea state thresholds that may limit the effectiveness of visual observations. In spite of these limitations, visual observations during daylight hours should continue, even if PAM is operational.

During the night, or if the vessel encounters a period of low visibility, seismic acquisition may continue for up to one hour along the current seismic line if the PAM system is temporarily out of order. The operation must be suspended after this period if the PAM system continues to malfunction and visibility has not improved due to darkness or adverse weather. If the PAM system malfunctions during periods of good visibility, seismic operations shall be permitted exclusively during the daytime with visual monitoring for a maximum period of 48 hours. At the end of this period, seismic activity should be discontinued until the PAM system becomes functional.

If visual observation becomes possible during the operation of a PAM system for a line start or test, it is not necessary to restart the 30-minute visual observation procedure. Simultaneous visual scanning should be made with PAM during the initial 30 minutes of scanning.

The Guide provides examples of what a PAM operator must consider if a marine mammal is detected but the distance from the array has not been determined.

6.6 ADDITIONAL MITIGATION MEASURES AND MODIFICATIONS

In the case of overlapping seismic surveys, special operating arrangements may be proposed, as well as the adoption of additional mitigation measures and monitoring which may include the denial of a license.

In the case of a multiple vessel wide azimuth survey, the observers and PAM operators should be on the source vessel. If the acquisition geometry employs more than one source at the same time, all source vessels should have observers and PAM systems.

Given that the Guide addresses both mitigation and monitoring, it provides several pages of detailed guidance on data collection and reporting (especially combining visual and PAM data).

There are no references to acoustic thresholds in the Guide.

7.0 GREENLAND

Greenland's "Offshore Seismic Surveys in Greenland. Guidelines to Best Practices, Environmental Impact Assessments and Environmental Mitigation Assessments" (DCE 2015) describes the practices that must be followed in Greenland waters in order to reduce impacts on marine mammals and fish and also provides guidance on the preparation of environmental assessments. The operator is required to submit an Environmental Impact Assessment if there is a risk of significant impacts. Acoustic modelling is required for all Environmental Impact Assessments of seismic programs. If the risk is identified as minor, the operator must submit an Environmental Mitigation Assessment.

The Guidelines designate, and illustrates on maps, two types of areas related to the occurrence of marine mammals: areas of concern and closed areas. *Areas of concern* are where specific sensitive species of seals, walrus and whales occur and where there is a risk of overlap with seismic surveys. If seismic surveys are planned to overlap with these areas in the season indicated on the map, specific regulations in order to protect these species from disturbance may be introduced, especially if new information on the abundance and occurrence of the particular marine mammals has been obtained. Such regulation may refer to mitigating actions such as line density, source level of the airgun array, temporary closure of areas, etc.

In the *closed areas* seismic surveys as a rule are not possible. However, limited seismic surveys can be allowed after specific application, including a detailed shooting program and proposal of impact studies on the marine mammal in question. Limited seismic survey means that only one company operates, that only a few and short lines are placed inside the protected area and that they are widely spaced (> 10 km).

7.1 PLANNING SEISMIC SURVEYS

Best Available Technique (BAT) and Best Environmental Practice (BEP) must be applied and used in order to minimize environmental impacts. When planning a seismic survey (DCE 2015):

- Choose the lowest practicable power levels to achieve the geophysical objectives of the survey.
- Seek methods to reduce and/or baffle unnecessary high frequency noise produced by the airguns and to increase the directionality of the airguns.
- Determine which marine mammal species are likely to be present in the survey area and assess if there are any seasonal or habitat considerations that need to be taken into account, for example periods of migration, breeding, calving or pupping.
- Obtain knowledge about other planned seismic surveys in nearby licensing areas in Greenland and Canada.

7.2 SAFETY ZONE AND STARTUP

Greenland has adopted the Exclusion Zone of 500 m from the centre of the array from the Canadian Statement of Practice (DEC 2015). A pre-shooting search must normally be conducted over a period of 30 minutes before commencement of any use of the airguns. The Marine Mammal and Seabird Observer (MMSO) shall make a visual assessment to determine if any marine mammals are within 500 meters of the centre of the airgun array. However, in deep waters (>200 m) the pre-shooting search must be extended to 60 minutes as deep diving species (e.g. sperm whale and beaked whales) are known to dive for longer than 30 minutes.

If marine mammals are detected (by the MMSO) within this zone during the pre-shooting search, the ramp-up of the seismic sources will be delayed until their passage, or the transit of the vessel results in the marine mammals being more than 500 m away from the source. In both cases, there will be a 20-minute delay from the time of the last sighting within 500 m of the source to the commencement of the ramp-up, in order to determine whether the animals have left the area.

If marine mammals are likely to be present in the area, seismic activities may as far as possible only be commenced during the hours of daylight when visual mitigation using MMSOs is possible. It is the MMSO who assesses whether visual mitigation is possible or not.

A ramp-up (from commencement of ramp-up to commencement of the line) should not be significantly longer than 20 minutes (for example, ramp-ups longer than 40 minutes are considered to be excessive). Once the ramp-up has been performed and the airguns are at full power the survey line must start immediately. Where possible, ramp-ups should be planned so that they commence within daylight hours.

Site surveys and Vertical Seismic Profiling (VSP) surveys shall apply both pre-shooting search and ramp-up procedure. Use of a 'mini-airgun' (single airgun with a volume of less than 10 cubic inches) does not require ramp-up however a pre-shooting search shall still be conducted before its use.

At least four trained Marine Mammal and Seabird Observers (MMSOs) including two certified PAM-operators shall be on board the seismic vessels operating in Greenland waters. MMSOs shall be trained in observation methodology and in mitigation of impacts on marine mammals. At least two shall be certified in operating the PAM-system, including trouble shooting the system. The MMSOs shall document skills in identification and registration of Greenland marine mammals and seabirds. Two MMSOs should be posted at the observation site when shooting.

The MMSOs have three tasks:

- Monitor the 500 m Exclusion Zone for marine mammals before start-up and during seismic surveys.
- Collect data on abundance and distribution of seabirds and marine mammals through systematic surveys.
- Operate the PAM-system, thus requiring that at least two of the MMSO's to be certified PAM-operators.

7.3 SHUT-DOWN OF AIR SOURCE ARRAY(S)

If marine mammals are detected within the Exclusion Zone (even when they are on ice, i.e., polar bears) whilst the airguns are firing at full power or during ramp-up, firing must be reduced to only the smallest airgun in the array (*mitigation gun*), which should prevent further approach of animals to the array. Full power may be regained as soon as the animals are outside the 500 m exclusion zone.

7.4 LINE CHANGES AND MAINTENANCE SHUT-DOWNS

If a line change is expected to *exceed one hour*, airgun firing shall be terminated at the end of the line and a full pre-shooting search and 20-minute ramp-up shall be undertaken before the next line. If line change is expected to be *shorter than one hour*, the array shall be operated at a lower output or with the mitigation gun and the MMSOs shall remain on watch. With small airguns (site surveys) the Shot Point Interval (SPI) may be increased to max. 5 minutes during the turn. If no marine mammals are present within the 500 m Exclusion Zone, the airguns can be restarted at full power at the start of the new seismic line. If a marine mammal is sighted, the vessel must wait until 20 minutes after the marine mammal has left the Exclusion Zone and subsequently ramped-up.

Airgun tests may be required before a survey commences, or to test damaged or misfiring guns following repair or to trial new arrays. If the intention is to test all airguns at full power, a 20-minute ramp-up is required. If the intention is to test a single airgun at low power, a ramp-up is not required. If the intention is to test a single airgun, or a number of guns on high power, the airgun or airguns should be fired at lower power first, and the power then increased to the level of the required test; this should be carried out over a time period proportional to the number of guns being tested and ideally not exceed 20 minutes in duration.

MMSOs must maintain a watch before any instances of gun testing.

If, for any reason, firing of the airguns has stopped and not restarted for at least 10 minutes, then a 20-minute ramp-up must be carried out. If no MMSO was on watch before the break, a pre-shooting search has to be carried out as well. Between 5 and 10 minutes the MMSO shall make a visual assessment for marine mammals (not a pre-shooting search, given that an MMSO was on duty immediately prior to the stop) within the 500 m Exclusion Zone. If a marine mammal is detected while the airguns are not firing the MMSO shall advise to delay commencement, as per the pre-shooting search and ramp-up procedures. If no marine mammals are present, then they can advise to commence firing the airguns. If the break is of less than 5 minutes, the airguns can start firing at full power immediately. If possible, the mitigation gun should remain firing when otherwise the entire array is shut down.

7.5 OPERATIONS IN LOW VISIBILITY

When visual observation is not conducive to mitigation (e.g. during periods of darkness, poor visibility or sea state above 3), PAM will be used to augment observer capacities. If PAM is used it is the responsibility of the PAM operator to assess any acoustic detections and determine if there are likely to be marine mammals in the water within 500 m of the source. If the PAM operator considers that marine mammals are present within the range, then the start of the operation shall be delayed as outlined above.

The use of PAMGuard or a similar tool is encouraged by the DCE.

7.6 ADDITIONAL MITIGATION MEASURES AND MODIFICATIONS

The Guidelines state that the assessment of impacts shall include cumulative impacts, including other seismic surveys (including those conducted by multiple seismic operators) in the same general area (simultaneously, previously and if possible, also in the future) and also other disturbing activities such as fishery.

A significant part of an EIA will be a predictive model of the expected noise propagation from the seismic activities. The model must be state of the art and build on updated valid environmental data collected in the focal area. The model must include a relevant number of sample positions at relevant distances from the seismic survey. The model must include frequencies up to at least 48 kHz at ranges up to 20 km and frequencies up to 20 kHz beyond 20 km. Noise levels to be presented in the model are peak-to-peak sound pressure levels referenced to 1μPa (peak-to-peak), rms sound pressure levels referenced to 1 μPa (rms measured over 90% of pulse duration), and in sound exposure levels referenced to 1 $\mu Pa^2 s$ per pulse. For assessment of cumulative effects, the total sound exposure level (across all airgun pulses and all concurrent surveys and activities in the area) per 24 hours shall be presented.

Actual sound exposure within the modelled area must be documented at selected and representative locations during the seismic survey. Monitoring can be conducted over the total or a substantial part of the survey period, by means of deployed autonomous data-loggers, or measurements can be obtained from a measuring vessel during a representative part of the survey.

Recordings must be made at several depths at each position, preferably down to the maximum depth utilized by species in the area, but at least to a depth below the sound speed minimum, as determined from the vertical sound speed profile. At least three recording ranges must be sampled and at least out to a distance of 50 km range from the survey area. Sound speed profiles must be obtained at each recording position, either directly or from synchronous measurements of depth, salinity and temperature (CTD-measurements).

Guidance related to fish and the fishery include a general recommendation of contacting the fishing and hunting association in advance of the program and bringing a fishery liaison officer (FLO) on board when appropriate. The Guidelines state that there are no current measures to protect spawning areas, although this may change for cod in the future.

8.0 NORWAY

"Implementation of seismic surveys on the Norwegian Continental Shelf" (Norway undated) is Norway's guidance document for undertaking seismic surveys on the Norwegian continental shelf. It is partly based on Chapter 2 of the "*Regulations relating to resource management in the petroleum activities (Resource Management Regulations)*".

The Norwegian Guide is exclusively dedicated to fish and fisheries, with no guidance on potential adverse effects on marine mammals.

Section 8 of the "Resource Management Regulations" stipulates "When seismic surveys are started, the audio source must be started up gradually to give fish and marine mammals the opportunity to leave the area around the survey."

8.1 MITIGATING POTENTIAL EFFECTS ON FISH

No restrictions are placed on seismic surveys out of consideration to injuries to fish eggs, larvae and fry. Restrictions on seismic activity have been implemented in areas with important spawning grounds and in areas when concentrated spawning migrations take place. Time and area restrictions are block specific and are stipulated in the individual licensing round announcements.

8.2 MITIGATING POTENTIAL EFFECTS ON FISHERIES

No later than five weeks prior to the start-up of survey activities, the licensee shall submit details of the survey to the Norwegian Petroleum Directorate, Directorate of Fisheries, Institute of Marine Research and Ministry of Defence.

The licensee, before conducting a seismic survey, must decide whether the survey could have been undertaken in a different place, at another time or in a manner that would be better for fishers, without having significant practical or economic consequences for the licensee. If licensees have not included such considerations and assessments in their planning, it could be difficult to assess whether the survey unnecessarily complicates or impedes other business interests. It is therefore important that licensees demonstrate and document that they have taken these factors into account in their planning.

The *Marine Resources Act* and the *Petroleum Act* and Regulations provide guidelines for the obligation on seismic vessels to yield and other factors such as maintaining a safe distance to fixed fishing gear and fishing vessels in fisheries. Escort vessels may not order fishing vessels to move out of the way of the seismic vessel, and that communication with the fishing vessels shall mainly take place via the seismic vessel.

Section 10-1, second paragraph, first sentence of the *Petroleum Act* reads:

"The petroleum activities must not unnecessarily or to an unreasonable extent impede or obstruct shipping, fishing, aviation or other activities, or cause damage or threat of damage to pipelines, cables or other subsea facilities. All reasonable precautions shall be taken to prevent damage to animal life and vegetation in the sea". This implies that the actors engaged in the petroleum industry must take other industries and users of the sea into account when they plan their activities.

If a licensee does not comply with the provisions of Section 10-1 of the Petroleum Act, it could provide a basis for the Government to intervene and suspend activities. Such injunctions to suspend activities are invasive and will have major economic consequences (Norway undated).

It cannot be expected that all seismic acquisitions only take place during periods of low fishing activity. Weather conditions and time constraints due, for instance, to spawning can imply that the licensee has a very limited amount of time to conduct the surveys, and thus must conduct the surveys even though there are substantial fishery activities in the area.

Section 5, first subsection of the Resource Management Regulations, reads:

"Vessels carrying out seismic surveys shall maintain a safe distance from vessels carrying out fishing activities and from fixed and floating fishing gear. Particular attention must be exercised when an accumulation of fishing vessels is observed."

The Petroleum Regulations stipulate that vessels carrying out seismic surveys must have a fishery expert on board when it is necessary for fishing operations in the area. The fishery expert shall preferably be involved prior to the survey, but no later than the kick-off meeting. At this meeting, the fishery expert should give a briefing on any expected fishery activities based on obtained information and information contained in the assessment from the Directorate of Fisheries. The expert shall obtain an overview of the vessels in the area and should well ahead of the start of acquisition contact fishing vessels that may be affected by the seismic surveys and hear their views and what their plans are. Based on this, the seismic acquisition can be adjusted and adapted to the benefit of both industries.

In some cases, the licensee collecting seismic data may elect to have two fishery experts on board. The advantage of this is that a fishery expert will then be present on the bridge at all times.

Those serving as fisheries expert must have completed and passed a test for an approved course. Those participating in the course must be proficient in Norwegian and English and be able to document that they, over the course of the last five years, have been active fishermen for at least twelve consecutive months. One must also document knowledge about fishery activities in the waters where the seismic vessel will be operating. A minimum of 1 year of experience as skipper/first officer is also required.

The fisheries expert must, every five years after passing the course, be able to document that, over the last five years, he/she has been an active fisher and/or fisheries expert for at least twelve consecutive months.

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