



## REVIEW OF THE STATEMENT OF CANADIAN PRACTICE WITH RESPECT TO THE MITIGATION OF SEISMIC SOUND IN THE MARINE ENVIRONMENT



Figure 1. Department of Fisheries and Oceans' (DFO) six administrative regions.

### Context:

Noise produced from air source arrays during offshore exploration activities (by industry, academic, or government researchers) can have negative impacts on marine wildlife. The 2008 Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (SOCP) specifies the minimum standard mitigation requirements that must be met during the planning and conduct of seismic survey operations in non-ice covered Canadian waters to minimize potential negative impacts on marine wildlife. When it was created, it was recommended that the SOCP be reviewed annually and updated as additional scientific information, new technologies, and improved industry practices become available.

DFO's Oceans Management Directorate asked DFO Science Sector to conduct a scientific peer-review meeting and develop science advice that can be used to potentially update the mitigation measures in the SOCP. Since 2008, there have been advances in the knowledge of impacts of underwater noise on marine species as well as industry standards and best practices. In light of new information and practices, a comprehensive review of the current mitigation measures in the SOCP is warranted. This review aimed to identify if and what modifications and/or additional mitigation measures should be considered for a potential update to the SOCP, existing knowledge gaps, and if there remain potential risks to marine wildlife from noise produced during seismic surveys that are not addressed by the current or suggested modified/additional mitigation measures. Potential impacts of seismic sound in

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*general on marine life, but particularly on marine mammals were addressed, and domestic and international best practices were considered.*

*This Science Advisory Report is from the May 28-30, 2019 National Peer Review Meeting on the Review of the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada \(DFO\) Science Advisory Schedule](#) as they become available.*

## **SUMMARY**

- A scientific review of the measures in the 2008 Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (SOCP) was conducted to inform a potential update to the SOCP.
- Based on new scientific information and industry best practices, and following the review of 29 recommendations in the working paper, participants agreed that there is sufficient new information to support an update to the measures in the SOCP.
- Potential modifications and additions to the SOCP that should be considered, if/when an update to the SOCP occurs, are described in Table 1 and relate to:
  - Additional protection(s) for critical and important habitat for marine mammals and sea turtles
  - Protocols for enhancing marine mammal and sea turtle impact mitigation and monitoring
  - Acoustic modelling to determine the appropriate size of the safety zone and in-field verification to validate zone size
  - More specific guidance and protocols for marine mammal observers (MMO) and passive acoustic monitoring (PAM)
  - Data collection, data sharing, and reporting requirements
- Participant expertise was not sufficient to recommend specific mitigation measures for fish, invertebrates, and plankton.
- Several major knowledge gaps and uncertainties were identified including:
  - Knowledge of the temporal and spatial distribution of many marine species
  - Appropriate thresholds that may be used to establish the size of safety zones, and applicability in Canadian waters
  - Potential impacts of noise from air source arrays on many species
  - Cumulative effects of anthropogenic sound
  - Efficacy of some mitigation measures (e.g. PAM)Further research and monitoring, and the incorporation of Indigenous and local knowledge could reduce these uncertainties.
- Meeting participants identified potential risks to marine life from sounds produced during geotechnical surveying activities that are not currently addressed in the SOCP or by the working paper recommendations. These include:
  - Potential impacts outside and near the safety zone (e.g., behavioural, masking, stress responses)
  - Potential impacts resulting from seismic surveys in or near ice covered waters
  - Potential impacts from the use of alternative geotechnical surveying equipment other than compressed air sources

## **INTRODUCTION**

Seismic surveys and pile-driving for coastal and offshore installations produce impulsive anthropogenic sounds in the marine environment. Seismic surveys are carried out by the oil and gas industry, government agencies (e.g., mapping of continental shelves), and academia. Interest in offshore oil and gas exploration and development in Canadian waters from the offshore petroleum industry continues. One environmental concern for seismic survey operations is the addition of impulsive noise into the marine environment. Noise produced from compressed air source (often referred to as airgun) arrays used during seismic surveys can potentially have negative impacts on marine fauna. Modern seismic surveys are carried out with measures in place to reduce potential adverse impacts on the environment.

The potential impacts of underwater anthropogenic noise sources, including noise produced during seismic surveys, are most commonly studied and documented for marine mammals, though more research on fish and invertebrates is emerging. Potential direct and indirect impacts from noise produced from air source arrays on marine mammals include: auditory physiological effects (e.g., temporary (TTS) and permanent threshold shifts (PTS)), behavioural effects (e.g., changes in migration path, dive and respiratory patterns, displacement from foraging areas), systemic physiological effects (e.g., acute and chronic stress responses), and ecological effects (e.g., hampered detection and interpretation of conspecifics, predators, prey, and habitat features). Should these impacts occur, they can potentially lead to both, negative individual and population-level effects. However, the potential indirect impact of seismic sound on long-term responses such as reproduction, health and survival remains a considerable knowledge gap. Understanding of the potential impacts of seismic sound on marine fish, turtles, and invertebrates is more limited, partially as a result of the challenges associated with measuring noise particle motion important to some of these species, and the interpretation of results from controlled laboratory studies.

Because of the potential negative impacts of noise on marine fauna, seismic survey operations are required to adhere to guidelines that aim to reduce potential negative impacts of seismic noise on marine life. Based on peer-reviewed advice by technical experts (DFO, 2004), the 2008 Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (SOCP) was developed by federal and provincial authorities. The SOCP provides the minimum standard mitigation requirements for seismic survey operations in non-ice covered Canadian waters to minimize potential negative population-level impacts on marine fauna, specifically marine mammals, fish, invertebrates, and turtles (DFO, 2008).

Since the SOCPs original publication in 2008, there have been substantial advances in the knowledge of potential impacts of underwater noise on marine fauna, as well as industry standard best practices. Further, a number of Science Advisory Reports (SAR) and associated Research Documents assessing the efficacy of the mitigation measures in the SOCP have been generated (e.g., DFO 2010, DFO 2015).

As outlined in the Terms of Reference, participants were asked to address the following questions with respect to the potential impacts of seismic surveys (using air source arrays) in Canada, on marine mammals, fish, invertebrates, and sea turtles, and mitigation of these impacts:

1. Which of the existing mitigation measures for seismic exploration activities listed in the SOCP should be updated? If revisions to an existing mitigation measure are required, what changes are recommended?

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2. Are there other technically feasible mitigation measures that should be added to the SOCP? If additional mitigation measures are required, what additions are recommended?
3. If updates or additions are recommended but not possible at this time due to knowledge gaps, what are the knowledge gaps that need to be addressed and can meeting participants make recommendations as to how can they be addressed?
4. Are there potential risks to marine species from sounds produced during seismic exploration activities that are not currently addressed in the SOCP, or by the recommended revisions or additions to the SOCP?

## **ASSESSMENT**

### **Recommendations for modifications/additions to existing mitigation measures**

Prior to the meeting, a working paper was produced that provided a literature review (2004–2019) and analysis of recent published guidance documents and scientific information (including guidelines, protocols, and science advice) applicable to the development of mitigation measures in the SOCP (Moulton et al., unpublished<sup>1</sup>). This literature review, gap identification, and analysis was intended to build upon previous DFO science advice (e.g., DFO 2004, DFO 2010, DFO 2015), and other domestic and international best practices. Based on the analysis, 29 recommendations for modifying the mitigation measures within the SOCP to better reduce the potential impacts of seismic sound on marine mammals, fish, invertebrates, and sea turtles were provided to DFO for consideration, and were used to focus the meeting discussion (Table 1). Participants used the information and analysis provided in the working paper, information presented at the meeting, as well as their own expertise to discuss the 29 recommendations based on scientific support. The advice here is not meant to replace the current SOCP, but to recommend modifications and supplemental mitigation measures to enhance the effectiveness of the SOCP. A summary of the level of support, modifications, and knowledge gaps associated with the 29 recommendations is available in Table 1.

#### **Spatial and temporal planning considerations**

The purpose of the SOCP is to attempt to prevent, avoid, or mitigate any potential negative impacts to marine fauna from noise produced from seismic surveys using air source arrays. To achieve this, the primary prevention measure in the SOCP should be spatial and temporal planning to avoid the conduct of seismic surveys in times and areas that are critical for the survival and reproduction of marine fauna.

Habitat protection for marine species potentially impacted by seismic surveys is not prescribed or captured explicitly in the existing SOCP. Consistent with current legislation (e.g., Species at Risk Act (SARA)), avoiding spatial and/or temporal overlap with identified critical habitat for SARA-listed marine mammals should be included in the SOCP. The acoustic environment is considered a feature of the critical habitat of listed marine mammal species, and protection of these critical habitat features is vital for survival. However, not all known important habitats have been officially designated as critical habitat for many listed species. For example, limiting the SOCP to protect only critical habitat would not protect populations such as the North Atlantic

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<sup>1</sup> Moulton, V.D., A. d'Entremont, and J.R. Christian. (unpublished). Review of the Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment. DFO Can. Sci. Advis. Sec. Working Paper.

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Right Whale (NARW) that spend time in the Gulf of St. Lawrence, outside of its currently designated critical habitat in Roseway Basin (off southwestern Nova Scotia).

Avoiding spatial and/or temporal overlap of important habitats should not be limited only to SARA-listed species. Important habitat has been identified for species not listed on Schedule 1 of the SARA, which includes Arctic species such as the bowhead, beluga and narwhal, and such habitats should also be avoided. These and other cetaceans as well as pinnipeds are key ecological and subsistence species in the Canadian Arctic, and at present are not afforded the same level of protection under the SOCP as SARA-listed species.

It is recommended that an updated SOCP include wording that requires spatial and/or temporal avoidance of other important marine mammal (for both SARA-listed and non-listed species) habitats (e.g., habitats used for mating, feeding, breeding, resting). Outlining the definitions, procedures and expectations for avoiding spatial and temporal overlap are vital to the successful implementation of this recommendation. The level of avoidance was not quantified by participants, but it was recognized that it should be defined within the SOCP.

Currently, the SOCP provides protection for sea turtles and prohibits their displacement. In addition to avoiding marine mammal critical and/or important habitat, avoiding spatial and/or temporal overlap with sea turtle critical habitat should be considered for addition to the SOCP. However, there are limited scientific studies on sea turtle hearing and of the potential impacts of seismic sound on sea turtles. Additional scientific studies on the impact of noise on sea turtles, and further delineation of sea turtle critical habitat and determination of areas and/or times of peak use is required to better understand potential impacts of seismic sound on sea turtles

Areas identified by Indigenous groups as important for subsistence harvesting of marine species (i.e., marine mammals and fish) should be spatially and/or temporally avoided before or during harvesting. Seismic operations prior to or during harvesting in some areas could result in important species (e.g. beluga whales) avoiding these areas during what would normally be the preferred harvesting season. Further research on the impact of seismic noise on marine fauna (e.g., marine mammals and fish) is recommended to expand our understanding of how subsistence harvesting is impacted by seismic surveys.

Since noise produced by seismic surveys propagates long distances, it is important to generate acoustic propagation models for the air source array sounds produced to understand the received sound levels expected at various ranges from the survey activities including what levels that could occur in nearby important habitats. A buffer zone from which seismic survey activities should be excluded should be established around defined important habitats to account for this noise propagation, if warranted. The buffer zone should be determined by acoustic propagation modelling and the best available information on acoustic thresholds.

Airgun(s) should not be activated in any areas outside of the identified Project Area for the seismic survey to minimize the area and number of marine species exposed to seismic noise.

**Pre-survey research and planning**

Prior to the start of a seismic survey, a Marine Mammal (and Sea Turtle) Mitigation and Monitoring Plan (hereafter referred to as the “Plan”) should be provided to the appropriate regulatory authority for acceptance. This Plan should include the following minimum key components: detailed mitigation measure procedures, monitoring requirements and planned Marine Mammal Observer (MMO) and/or Passive Acoustic Monitoring (PAM) Operator schedules (e.g., the number of MMOs and/or PAM Operators per vessel and shift hours), MMO and/or PAM Operator duties, data collection protocols, communication procedures with vessel crew for implementing mitigation measures, specifications of required monitoring equipment

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(e.g., reticle binoculars, PAM hardware and software) and instructions for its use, reporting and data sharing requirements, and descriptions of MMO and PAM Operators' experience and qualifications.

In cases when there is little specific knowledge of distribution, but marine mammals (including Schedule 1 SARA-listed species and other marine mammals identified during the Environmental Assessment (EA) process) are known or expected to occur, marine mammal surveys should be conducted prior to any seismic survey activities taking place. These surveys would inform species occurrence, help fill knowledge gaps associated with the likelihood of displacing or diverting marine mammals from key habitat, and help inform appropriate mitigation measures. Surveys should also be considered for other potentially impacted marine species (e.g., important fish spawning areas), prior to the start of seismic survey activities.

**Safety and pre-clearance zone**

The SOCP requires all seismic surveys to establish and monitor a "safety zone" (SZ) to mitigate potential impacts that may be strongest in proximity to the air source array. The existing SOCP states that the SZ should extend a minimum of 500 m from the centre of the airgun array(s). Participants recommended that the minimum SZ distance is based on the most precautionary estimate of either 500 m or a distance determined by acoustic modelling of noise transmission conditions in the seismic survey area using the best available data. Modelling should be required given advances made in acoustic modelling since publication of the original SOCP, and an increase in knowledge on differences in sound propagation in different environmental contexts. The modelled SZ should also be validated in the field. However, specific and universal validation methods and considerations were not recommended by participants. The centre of the SZ should be defined (array-based), however the specific point (i.e., centre vs. perimeter of the airgun array(s)) may be trivial as the difference is normally a matter of several metres.

There remain knowledge gaps associated with determining the appropriate size of a SZ depending on the sensitivity and hearing of the species which may occur in the zone of influence. Though thresholds have been developed in other jurisdictions (e.g., for PTS and TTS: NMFS, 2018), the applicability of these thresholds in the Canadian context is unclear due to regional differences in species presence and environmental context. Also, the intention of the SZ (e.g., to avoid PTS, TTS, or Harm and Harassment as defined by the SARA, or disturbance/behavioural impacts, etc.) should be clarified in the SOCP; however, participants did not make recommendations on what the intention of the SZ should be.

In addition to a SZ, a pre-clearance zone (i.e., pre-ramp-up watch zone) that is larger than the SZ should be established to increase the likelihood of detecting marine species approaching the array. However, there is currently no scientific justification for a specific pre-clearance radius for all seismic surveys. Similar to the SZ, the pre-clearance zone radius should be based on acoustic modelling using the best available data. Visual surveys of the MMOs during the period of pre-clearance should be focused ahead of the vessel to where the vessel will be when ramp-up procedures begin. During the pre-ramp-up watch of the pre-clearance zone, if any marine mammal or sea turtle is detected within or entering the zone, ramp-up should be delayed by a minimum 30 minutes since the last detection. Sharks should also be considered for inclusion on the pre-clearance list, however further research is required to determine potential impacts on sharks from seismic surveys and detection probability. This list would allow the SOCP to be more inclusive, and serve as an additional precautionary measure for marine species that are difficult to identify in the field. If deep-diving species (e.g., beaked whale, sperm whale, Kogia species) are detected within the pre-clearance zone, ramp-up should be delayed by a minimum of 60 minutes since the last detection, to account for extended dive cycles of deep-diving

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species in case they remain in the project area. In addition, the pre-ramp-up 'watch' should begin a minimum of 30 minutes before start-up in waters <200 m depth and a minimum of 60 minutes before start-up in waters >200 m depth in areas where deep-diving marine mammals are expected to occur.

Participants acknowledged that there are regional differences that may hinder the implementation of the pre-clearance list of species. For example, in the Arctic some marine species (e.g., seals, walrus, polar bears) have been known to follow ships. The above list should remain flexible to account for the availability of new scientific information, species identified during the EA process, and regional differences.

**Ramp-up of air source array(s)**

Although the goal of ramp-up is to convince marine species to leave the area using lower-level exposures before the main seismic survey begins, ramp-up duration should be minimized to reduce unjustified and excessive noise energy released into the environment.

In addition to a minimum ramp-up duration of 20 minutes (as stated in the existing SOCP), the ramp-up of air source array(s) should include a maximum duration. However, the appropriate maximum duration may vary depending on the number of vessels and the array size. There is currently no scientific evidence available to support a standardized ramp-up duration for all seismic surveys.

Participants also suggested that ramp-up may be beneficial when sound source(s) have been inactive or reduced to a single source for a certain period of time during line changes or maintenance shut-downs, which is not currently required in the SOCP. If the array has only been reduced to an active single source for a short period of time, such a ramp-up may not be required. The length of inactivity and single source activity before a ramp-up is required should be defined, however participants found no scientific evidence to support any standardized time period at this time. Several factors should be taken into account to inform the duration of the period of inactivity including vessel speed, and movement of the vessel into areas where animals were not previously exposed.

Irrespective of ramp-up duration, the SZ should be continuously monitored throughout any period when there is an interruption in airgun use. Also, specific ramp-up procedures (e.g., consistent increase in levels, stepped increase approach) should be clearly outlined. Ramp-up procedures should be included as an additional precautionary measure in the attempt to alert marine species before the seismic survey begins, however further research and testing are required to determine mitigation efficacy and the appropriate ramp-up duration.

**Shut-down of air source array(s)**

In addition to a marine mammal or sea turtle listed as endangered or threatened on Schedule 1 of SARA as stated in the existing SOCP, the following animals are also recommended as "shut-down" species when judged to be in or entering the SZ: all sea turtles, all beaked whales, all baleen whales, harbour porpoise (*Phocoena phocoena*) and Kogia species. The inclusion of polar bears detected in the water, sea turtles, and all sharks listed on Schedule 1 of SARA should also be considered, however the impact of seismic sound as well as the detection probability of turtles and sharks is uncertain and requires further scientific research and review. Like the pre-clearance list, the shut-down list should remain flexible to include species that are not listed under SARA that are potentially adversely impacted by seismic sound. Updates may also be warranted based on newly available information on animal distribution and sensitivity to seismic sound. It is acknowledged that the list of "shut-down" species may not be reflected in

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the list of “pre-clearance” species and will depend on the different sensitivities and responses to seismic surveys.

It was recommended that the SOCP be modified to specify that the array should only be shut-down completely during line changes or operational maintenance if the full SZ can be fully monitored before ramping back up so that animals entering the SZ can still be detected. If the SZ cannot be fully monitored before ramping back up, the array should be reduced to a single airgun (smallest in volume) to deter animals from entering the area. However, in some cases line changes and operational maintenance may occur over extensive durations (many hours), in which case it may be more appropriate to shut off all airguns to reduce the amount of noise energy being put into the environment. As well, weather in certain regions can often make visual surveys challenging (e.g., Atlantic Canada), and using a single airgun for extended periods of time may not be the most effective mitigation measure. This mitigation measure thus should not preclude a complete shut down of all airguns as the ultimate objective of a shut-down is to reduce exposure of marine animals to airgun noise.

Due to the challenges of determining the exact distance of an animal relative to the SZ, the SOCP should be modified to require a shut-down of the array for animals “within and/or entering the SZ”.

**Passive Acoustic Monitoring and Marine Mammal Observers**

The SOCP should provide clear guidance on the minimum acceptable qualifications and experience level for a MMO and/or PAM Operator to increase probability of accurate detection and identification of marine mammals. Prior to a seismic survey, documentation demonstrating that the MMO(s) and/or PAM Operator(s) have adequate and appropriate qualifications (including both field experience and knowledge) should be provided and reviewed. In addition to marine mammals, MMO(s) should also be proficient in identifying sea turtles and sharks. Moreover, specifications of the PAM system (both hardware and software) should be provided to the regulatory agency to ensure adequate PAM system and operator capabilities to detect marine mammal vocalizations is in place. There are several international guidelines that could help inform minimum requirements (e.g. DOC (Ed), 2016a).

In addition to visual monitoring, PAM should be employed during the pre-ramp-up watch and throughout the duration of the seismic survey (i.e., not only during periods of low visibility). Concurrent PAM and visual monitoring will increase the probability of detection of marine mammal species. However, the efficacy of PAM and visual monitoring for the detection of a given species still needs to be considered. For example, beaked whales are not easily detectable visually as they spend long periods of time underwater and due to their cryptic behaviour at the surface, but they frequently vocalize and can often be detected by using PAM even when they are not visible at the surface. Conversely, many baleen whales (such as the bowhead whale) are not as reliably or easily detected using PAM because they vocalize less often and because noise from the ship and seismic source overlap the frequency of their calls. Furthermore, if it is determined that a species cannot be reliably detected in the SZ during all periods that the seismic survey is operating, then additional mitigation measures are needed to reduce exposing animals to harmful noise levels (e.g., only operating in periods of good visibility if PAM is not a reliable means of detecting a species). The efficacy of the use of PAM alone and in combination with visual observation requires further research.

PAM information should continue to be used to implement a ramp-up delay or shut-down, in addition to visual monitoring by a MMO. If a marine mammal cannot be localized with a reasonable degree of accuracy using PAM (which may often be the case), the marine mammal



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should be assumed to be within or entering the SZ, and a ramp-up delay or shut-down must be implemented. Similarly, if a marine mammal is observed within or entering the SZ by a MMO, a ramp-up delay or shut-down must be implemented.

**Cumulative effects**

Participants were undecided if a minimum spatial and temporal separation distance between seismic surveys in the same region should be established to minimize potential cumulative noise exposure to marine fauna. Concurrent surveys in the same area may produce a complicated sound field with the potential to impact animals in unpredictable ways further away from the area. Currently there is no scientific evidence to support or refute a separation distance larger than standard industry practice for concurrent seismic surveys (17.5 km). Measuring and assessing potential cumulative effects both spatially and temporally remains a critical knowledge gap. Once the effects of cumulative noise are better understood, modelling may help to determine, on a case-by-case basis, the necessary spatial separation distance for concurrent surveys to minimize the noise energy within a given area and the necessary temporal separation for consecutive surveys, if any.

It is important to note that potential cumulative effects may also occur from noise produced from other anthropogenic activities (e.g., fishing, shipping). If during the EA process there is a low level of certainty for predictions of cumulative effects from multiple concurrent or consecutive seismic surveys, and/or other stressors, additional mitigation measures and monitoring should be required.

**Data collection and management**

To help address vital data gaps on the impacts of seismic surveys on marine animals, standardized data and metadata should be collected throughout the seismic survey and submitted to the appropriate regulatory authority. These data should include information on marine fauna and their behaviour, environmental conditions, monitoring efforts, seismic survey activity, and implementation of mitigation measures. It is important to note that the availability of raw and unprocessed data are essential to allow for accurate and meaningful data analyses and interpretation in the future, rather than a summary of data in a report. A comprehensive technical report on the environmental monitoring procedures and results should also be submitted to the appropriate regulatory authority. The report should include observational and environmental data that are collected and available from the surveys, beyond standard MMO and PAM data (e.g., animal behaviour, animal size, sighting conditions, airgun activity). Guidelines for standardized data collection, management and reporting should be developed and included in the SOCP.

**General comments**

It is important that the terminology in the SOCP should be clear and defined, and be consistent with existing legislation including land claims agreements. For example, the term “significant adverse effect” (found in mitigation measures 4,5,7,8, and 11 in the existing SOCP) should be defined or removed from the SOCP. Other terms that should be defined, if used, include “avoidance”, “peak use” and “to the extent possible”. It is also important that the SOCP be clear and simple for users to implement. Seismic operators, and experienced MMO(s) and PAM Operators, among other stakeholders, should be engaged in the writing and review process.

As stated in the existing SOCP, the mitigation measures should apply to all seismic surveys across Canadian marine waters as a minimum standard. However, regional differences (e.g., offshore Newfoundland vs. offshore Nova Scotia vs. Arctic waters) must be considered. For example, marine species present in the surveyed area, noise propagation, and seismic

operation logistics differs among regions. Participants agreed that while an updated SOCP could bring higher protection level and consistency across regions, it should also provide flexibility to allow regulators to manage according to regional specificities. It was noted that improvements to the SOCP could draw from guidelines and supporting documents in other jurisdictions, including those not reviewed in the working paper. For example, extensive discussions over the New Zealand equivalent of the SOCP were undertaken in the 2015-2017 period, much of which is contained within published reports (DOC (Ed), 2016b). A thorough review of such material may help advise and streamline any efforts to revise the SOCP.

### **Knowledge gaps, sources of uncertainty, and research recommendations**

There remain several knowledge gaps on the potential impacts of seismic source sounds on marine fauna and the effectiveness of mitigation measures. Although many mitigation measures in the SOCP are deemed to be at least somewhat effective at reducing potential negative effects on marine fauna (e.g., SARA-listed cetaceans; DFO, 2015), several research areas were identified to address data and knowledge gaps associated with the potential impacts of seismic sound and to develop more precise and effective mitigation measures. These research areas include:

- Continue increasing our understanding of the behavioural, physical, and physiological impacts of seismic sound on marine species. The sensitivity of many species to noise and how potential changes in behavior could affect their biological fitness is unclear. Studies should be designed and conducted in a realistic setting (i.e. non-caged) to investigate both direct (near and far-field) and indirect (long-term) effects/responses of marine fauna to seismic surveys and other forms of anthropogenic noise at both the individual and population level.
- Continue conducting research to improve our knowledge of the distribution and abundance of marine fauna potentially impacted by seismic survey activities. For spatial and/or temporal avoidance measures to be effectively defined and implemented, knowledge of species distribution, specifically in areas of interest for oil and gas exploration, is essential. Knowledge of species distribution will also help with the delineation of important habitats. Some data gaps associated with distribution may be addressed through the collection of visual sighting and acoustic data collection by MMO(s) and PAM Operators. These data should subsequently be shared and made nationally accessible to scientists, managers, and regulators to assist with future scientific studies and development of effective mitigation measures.
- Understanding how particle motion impacts marine species. Seismic surveys can generate particle motion in the direct vicinity of the array as well as over greater ranges through the substrate, which may affect certain fish and invertebrate species. Based on participant expertise, we were not able to conclude whether species with a potential sensitivity to particle motion should be included in the SOCP (e.g., inclusion of sharks on the pre-clearance and shut-down lists).
- Determining the appropriate threshold to use for defining the size of pre-clearance zones and SZs, as well as the intent of those zones (e.g., to avoid TTS, PTS, behavioural impacts, etc.). For many marine species, there is a lack of scientific evidence for selection of the appropriate noise level thresholds which cause any of PTS, TTS, behavioural responses or other impacts due to seismic noise. Though thresholds have been developed in other jurisdictions (e.g., for PTS and TTS: NMFS, 2018), the applicability of these thresholds in the Canadian context is unclear due to regional

differences (e.g., species presence, environmental context etc.). The size of pre-clearance and SZs should not be set at a fixed distance, but should be determined based on noise propagation models specific to the target seismic survey area using the best available scientific data and information for determination of the appropriate threshold. The size of these modelled zones ultimately used in the mitigation plan will depend on the species present and the noise sensitivity of those species, and selected level of protection.

- Continue evaluating the efficacy of mitigation measures described in the SOCP including PAM vs. visual observation for detecting different marine species impacted by seismic surveys, as well as the use of ramp-up, acknowledging also that other detection and mitigation technologies are becoming available. The extent of mitigation efficacy is challenging to measure. Comparability and efficacy of detection methods under a range of conditions and habitats should be investigated. In some cases, other detection technologies (e.g., infrared cameras) may be required during periods of low visibility to ensure a reasonable probability of detection; however, more research and testing is required to develop these technologies to the point where they can be reliably used. The effectiveness of using ramp-up as a mitigation measure to displace animals prior to a seismic survey is unclear and likely depends on animal behaviour and responsiveness to noise, and the type of ramp-up procedure. Further research and monitoring are needed to reduce any uncertainty and develop more precise mitigation measures. In addition to well designed scientific studies, data collected by well-trained and experienced MMOs and PAM Operators could help inform efficacy through providing information on such things as: distance at which certain species are detected, number of detections, headings, behaviour before, during, and after seismic surveys, aural and visual detection probability for certain species, typical closest point of approach for each species, and behaviors before/after ramp-up.
- Understanding potential spatio-temporal cumulative effects of seismic sound, including concurrent and/or consecutive surveys. For example, it is unknown whether there is a difference in level of impact between having multiple seismic surveys in a small area or spread out over a large area. Likewise, it is unknown whether it is better to have higher noise levels for a shorter period of time, or to extend a lower level of noise over a longer time period. Further research is also required on the potential spatio-temporal cumulative effects of other potential noise sources used at the same time as conventional arrays and/or other non-conventional seismic surveys (e.g., multibeam echosounders, marine vibroseis), as well as potential impacts that may occur as a result of cumulative and synergistic impacts from other non-noise anthropogenic stressors (e.g., climate change, bycatch, overfishing).

Many of the recommendations and knowledge gaps identified here are consistent with the conclusions of DFO (2015), which reviews the SOCP with respect to the habitat of cetacean Species at Risk.

### **Potential risks to marine fauna not addressed in the SOCP**

Despite mitigation measures outlined in the existing SOCP, and in a revised/updated SOCP, there remain potential risks to marine fauna that cannot be addressed by current management measures due to knowledge gaps. Potential risks to marine fauna that are not addressed in the existing SOCP or the recommended revisions/additions to the SOCP include:

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- Potential far-field sub-lethal impacts that may occur from exposures to seismic survey noise outside the SZ, such as the impacts of masking, changes in habitat use, behavior and communication, health, and reproduction. Long-term studies (at both the individual and population-level) are necessary to determine links between seismic sound and long-term impacts.
- Potential impacts of seismic sound on sea turtles, marine fish and marine invertebrates. In the existing and recommended/modified mitigation measures, the impacts to animals other than marine mammals are not fully addressed. Although information on the impacts of noise on fish and invertebrates exist in the literature, participants ultimately concluded that given their expertise and the current available knowledgebase, recommendations for modifications to existing or recommended mitigation measures could not be made at this time for fish, invertebrates, and plankton.
- Potential impacts of seismic sound on marine species that may occur as a result of seismic surveys in or near ice-covered waters. Although seismic surveys do not generally occur in ice-covered waters in Canada currently, future surveys of this kind in the Canadian Arctic may expose marine fauna to novel noises and create unexpected injuries and/or behavioural responses compared to animals in the open ocean. For example, in an attempt to avoid areas exposed to seismic sound, it is possible that seismic surveys may cause animals to get trapped in ice during migration (Heide-Jørgensen et al., 2013). Also, sound propagation is substantially different under sea ice compared to the open ocean and additional modelling is needed to determine whether extra precautionary mitigation measures should be implemented (e.g., a larger SZ) or whether seismic surveys are too unsafe to proceed in this environment. In the event that the SOCP covers ice-covered waters in the future, more research is required on the potential impacts and differences compared to the open ocean.
- Potential impacts from the use of alternative geotechnical surveying equipment other than compressed air sources (i.e. non-conventional surveys such as multibeam echosounders). The existing SOCP establishes minimum standards for seismic surveys that use air source arrays.

## **CONCLUSIONS**

It was concluded that there is sufficient new science and technical information since the publication of the original guidelines to support an update to the 2008 Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (SOCP).

Participants were asked to recommend modifications to the existing mitigation measures listed in the SOCP, and recommend other technically feasible mitigation measure that should be added to the SOCP. The recommendations for modifications and additions, based on a review of 29 recommendations in the working paper, are provided above and summarized in Table 1. It is important to note that not all possible mitigation measures that could potentially be added to the SOCP are provided in the recommendations here. As well, participant expertise was not sufficient to recommend specific mitigation measures for fish, invertebrates, and plankton.

Some updates or additions to the existing SOCP were recommended but had knowledge gaps. Participants identified research areas to address data and knowledge gaps associated with the potential impacts of seismic sound and to develop more precise and effective mitigation measures. Knowledge gaps associated with the existing SOCP, and recommended modifications and additions are provided above and summarized in Table 1. These knowledge

gaps are related to increasing our understanding of: the impacts of seismic sound on marine species, the distribution and abundance of marine species, how particle motion impacts marine species, the appropriate threshold to use for defining the size of pre-clearance zones and SZs, the efficacy of mitigation measures for seismic sound, and the potential spatio-temporal cumulative effects of seismic sound and other stressors.

There remain potential risks to marine species from sounds produced during seismic exploration activities that are not currently addressed in the existing SOCP, or by the revisions and additions to the SOCP recommended here. These potential risks are related to: potential far-field sub-lethal impacts that may occur from exposures to seismic survey noise outside the SZ, potential impacts on sea turtles, marine fish and marine invertebrates, potential impacts on marine species that may occur as a result of seismic surveys in or near ice-covered waters, and potential impacts from the use of alternative geotechnical surveying equipment other than compressed air sources.

Given the knowledge gaps associated with the impacts of seismic sound and the effectiveness of mitigation measures outlined in the SOCP, as well as potential risks to marine species not covered in the SOCP, it was concluded that the application of a precautionary approach to mitigation is the most effective way to avoid some potential negative impacts. Foremost, avoiding spatial and/or temporal overlap of the acoustic footprint of seismic surveys with potentially impacted marine fauna and their critical and important habitats is recommended as the most effective form of mitigation.

## **OTHER CONSIDERATIONS**

Participants acknowledged that Indigenous Knowledge about marine ecosystems, the effect of noise on these ecosystems, and other issues relevant to the science advice presented here, must be considered equally with scientific and technical knowledge.

During an update of the SOCP, collaboration with many stakeholders including Regulators, the Oil & Gas Industry, MMOs, PAM Operators, Fishing Industry, Scientific Researchers, the Geological and Geophysical Industry, and Environmental Groups is also essential to ensure precise, practical, and effective mitigation measures.

Management measures to prevent or mitigate all potential impacts on marine fauna from seismic surveys may not be feasible, especially when considering the large spatial scale over which noise from seismic surveys can travel. Investigating the use of quieter alternative survey technologies (e.g., marine vibrators) may be a more practical approach to reduce potential negative impacts and increase mitigation effectiveness. The SOCP should thus not be worded to preclude their use.

## **SOURCES OF INFORMATION**

This Science Advisory Report is from the May 28-30, 2019 National Peer Review Meeting on the Review of the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada \(DFO\) Science Advisory Schedule](#) as they become available.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2013. COSEWIC assessment and status report on the North Atlantic Right Whale *Eubalaena glacialis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 58 p.

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- DFO. 2015. [Review of Mitigation and Monitoring Measures for Seismic Survey Activities in and near the Habitat of Cetacean Species at Risk](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/005.
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APPENDIX

Table 1. Assessment of recommendations provided by Moulton et al. (unpublished) to update the existing SOCP, including the working paper rationale provided by the authors, scientific support for the recommendation by participants, proposed modifications to the recommendation by participants, and known knowledge gaps associated with the recommendation. Refer to the research document for a literature review (2004–present) and analysis of recent published scientific information (including guidelines, protocols, and science advice) applicable to the development of mitigation measures in the SOCP (Moulton et al., unpublished). The grey sections include the existing mitigation measures found in the original SOCP.

<p><b>Existing SOCP: Application</b></p> <ol style="list-style-type: none"> <li>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).</li> <li>2. The mitigation measures set out in this Statement do not apply to seismic surveys conducted:             <ol style="list-style-type: none"> <li>a. on ice-covered marine waters; or</li> <li>b. in lakes or the non-estuarine portions of rivers.</li> </ol> </li> </ol>					
<p><b>Existing SOCP: Section 1. Planning Seismic Surveys</b></p> <ol style="list-style-type: none"> <li>3. Each seismic survey must be planned to             <ol style="list-style-type: none"> <li>a. use the minimum amount of energy necessary to achieve operational objectives;</li> <li>b. minimize the proportion of the energy that propagates horizontally; and</li> <li>c. minimize the amount of energy at frequencies above those necessary for the purpose of the survey.</li> </ol> </li> <li>4. All seismic surveys must be planned to avoid:             <ol style="list-style-type: none"> <li>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</li> <li>b. a significant adverse population-level effect for any other marine species.</li> </ol> </li> <li>5. Each seismic survey must be planned to avoid:             <ol style="list-style-type: none"> <li>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;</li> <li>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;</li> <li>c. dispersing aggregations of spawning fish from a known spawning area;</li> <li>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</li> <li>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.</li> </ol> </li> </ol>					
No.	Working paper recommendations and rationale	How does this recommendation relate to the original SOCP mitigation measures?	Is there scientific support for the recommendation?	Does this recommendation require any modifications?	Are there knowledge gaps associated with the recommendation?
1	<p>Airgun(s) should not be activated in areas outside of the identified Project Area for the seismic survey assessed during the EA process.</p> <p><i>Rationale: This is a prudent and precautionary practice as it serves to minimize airgun sound in the marine environment, including potentially sensitive areas that may have fallen outside of the area considered during the EA process. This has already become a standard requirement by the C-NLOPB and CNSOPB.</i></p>	New	Yes	No	No



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2	<p>Spatial and/or temporal avoidance of critical habitat for marine mammals.</p> <p><b>Rationale:</b> <i>This suggested recommendation is in line with international best practice and would serve to reduce or avoid SARA-prohibited impacts as identified in Moors-Murphy and Theriault (2017). Currently, in Atlantic Canada critical habitat has been designated for North Atlantic right whales (Roseway Basin and Grand Manan Basin; COSEWIC 2013; DFO 2014) and the Scotian Shelf population of northern bottlenose whales, Hyperoodon ampullatus (Gully, Shortland and Haldimand canyons; DFO 2016a). Critical habitat for marine mammals has not been designated in the CBS.</i></p>	Additional of Critical Habitat to existing protections (4 & 5)	Yes	<p>Include marine mammals that are not SARA-listed</p> <p>Include the avoidance of other known important habitats</p> <p>Require using acoustic propagation modelling to determine extent of habitat avoidance</p> <p>Require modelling of a buffer zone around important habitats</p> <p>Define 'avoidance'</p>	<p>Delineation of critical/important habitat for many marine mammals</p> <p>Definition of spatial and temporal avoidance</p> <p>Procedures for spatial and temporal avoidance</p>
3	<p>Spatial and/or temporal avoidance of sea turtle critical habitat (to the extent possible) during the period of peak use by sea turtles.</p> <p><b>Rationale :</b> <i>This suggested recommendation is considered precautionary, particularly since available information indicates that sea turtles are not as much affected by airgun sounds relative to marine mammals. International best practice requires avoidance of key nesting habitat and periods for sea turtles. Currently, three proposed areas have been identified as critical habitat for leatherback sea turtles (Dermochelys coriacea; DFO 2016b) in Atlantic Canada, one of which (Southwestern Scotian Slope) overlaps with awarded Exploration Licenses for oil and gas. In Atlantic Canada, leatherback sea turtle critical habitat has been proposed because it is considered important foraging habitat.</i></p>	Addition of Critical Habitat to existing protections (4 & 5)	Inconclusive	Define 'peak use', 'avoidance' and 'extent possible'	<p>Impacts of seismic sound on sea turtles and their habitat</p> <p>Sea turtle hearing thresholds</p> <p>Delineation of critical habitat for many sea turtles</p> <p>Definition of spatial and temporal avoidance</p> <p>Procedures for spatial and temporal avoidance</p>
4	<p>Spatial and/or temporal avoidance of areas identified by Indigenous groups as essential for the conduct of subsistence harvesting of marine species (i.e., marine mammals and fish) during peak periods of use.</p> <p><b>Rationale:</b> <i>As has been done in the CBS, it is important to recognize and minimize potential effects of seismic surveys on Indigenous subsistence harvesting of marine mammals and coastal fisheries. The specific mitigation measures are best identified during the EA process via stakeholder engagement and regulatory review.</i></p>	New	Yes	<p>Define whether 'peak use' refers to marine species or Indigenous groups</p> <p>Define 'avoidance'</p>	Impact of seismic sound on marine fish
5	<p>Either define significant adverse effect or remove it from the SOCP.</p> <p><b>Rationale:</b> <i>As noted in Section 6.1.2 of the working paper, it is unclear what is considered a significant adverse effect on a SARA-listed individual and on a population for other marine species. If a significant adverse effect is defined, then marine fish (and invertebrate) species listed on Schedule 1 of SARA should be added to Item 4 of the SOCP.</i></p>	Clarify existing wording (4 & 5)	Yes	Clarify the inclusion and mitigation of individual and/or population level impacts	No
6	<p>A Marine Mammal (and Sea Turtle) Mitigation and Monitoring Plan (i.e., Plan) should be provided to DFO (and other regulatory agencies as appropriate) for review and approval prior to start of a seismic survey program.</p> <p>We suggest including as a minimum the following key components in the Plan:</p> <ul style="list-style-type: none"> <li>• Detailed mitigation measure procedures;</li> <li>• Monitoring requirements and planned MMO and/or PAM Operator schedule, including specifying the number of MMOs and/or PAM Operators per vessel;</li> <li>• MMO and/or PAM Operator duties;</li> </ul>	New	Yes	<p>Include specific requirements for MMOs and PAM Operators in the measure (e.g., number, shift length, and PAM system required)</p> <p>Replace 'DFO' with 'appropriate regulatory authority'</p>	No

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	<ul style="list-style-type: none"> <li>Data collection protocols;</li> <li>Communication procedures with vessel crew for implementing mitigation measures;</li> <li>Specifications of required monitoring equipment (e.g., reticle binoculars, PAM hardware and software); and instructions for its use;</li> <li>Reporting requirements.</li> </ul> <p>The Plan contents should be standardized across Canadian regions to the extent possible.</p> <p><b>Rationale:</b> <i>Seismic proponents have been required to submit mitigation and monitoring plans for seismic surveys offshore Nova Scotia and the CBS. This has not been a requirement for offshore Newfoundland and Labrador. Standardized and detailed plans are considered best practice and would provide the basis for ensuring seismic operators/contractors, MMOs and/or PAM Operators have clear instructions on mitigation measures, monitoring procedures, data collection, and reporting requirements, and that an adequate plan is in place to meet regulatory requirements.</i></p>			Add data sharing requirements to appropriate regulatory authority	
7	<p>Provide clear guidance on minimum acceptable qualifications and experience level for a MMO and/or PAM Operator. Prior to a seismic survey, the regulatory agency should be provided with a CV of MMO(s) and/or PAM Operator(s) to ascertain whether qualifications are met. In addition to marine mammals, MMO(s) should also be able to identify sea turtles and sharks.</p> <p><b>Rationale:</b> <i>As noted previously, relative to several international jurisdictions which in many cases, list training, experience, and educational requirements, the SOCP is inadequate. Several international jurisdictions and some Canadian regions (e.g., Nova Scotia) have also required (at least in recent years) approval of a MMO's CV prior to the start of a seismic survey. It is important to have well-qualified and experienced MMOs and/or PAM Operators to properly implement the SOCP (see Section 6.2.1 of the working paper).</i></p>	New	Yes	<p>Include both field experience and knowledge as acceptable qualifications</p> <p>Define 'minimum acceptable qualifications and experience'</p>	The impact of seismic sound on sea turtles and sharks
8	<p>In areas where marine mammals listed on Schedule 1 of SARA are known or expected to concentrate and available information is insufficient to identify breeding, feeding, nursing areas or migration routes, pre-survey research at appropriate spatial and temporal scales should be conducted to assess species occurrence and increase the understanding of the likelihood of displacing or dispersing Schedule 1 marine mammals from key habitat.</p> <p><b>Rationale:</b> <i>This is considered a necessary measure particularly for SARA Schedule 1 marine mammal species (e.g., northern bottlenose whales) which may occur in a given area (e.g., Sackville Spur, Flemish Pass) year-round. The Australian Policy Statement for seismic surveys includes provisions for similar pre-survey research in areas where data gaps on migration, feeding, or other aggregation areas exist.</i></p>	Additional wording to fill pre-survey research gaps associated with measure 4 & 5	Yes	Include marine mammals that are not SARA-listed	No

**Existing SOCP: Section 2. Safety Zone and Start-up**

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,
    - b) 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
    - c) 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:

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	<p>b) a cetacean or sea turtle, c) a marine mammal listed as endangered or threatened on Schedule 1 of the Species at Risk Act, or d) 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</p> <p>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.</p>				
9	<p>To minimize the risk of marine mammals (and sea turtles) incurring auditory injury, establish a minimum SZ that extends 500 m from the outer perimeter of the airgun array(s).</p> <p><b>Rationale:</b> <i>The 500 m SZ is generally in line with shut down zones for the U.S., Australia, U.K. (only a ramp-up delay is required), and Greenland. 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 minimum 500 m SZ around airgun array(s) is considered adequate to minimize exposure to airgun sounds which may result in permanent auditory damage to most marine mammal species (and sea turtles). Basing the SZ on the outer perimeter of the airgun array(s) increases the SZ (relative to the centre of the airgun array(s)) and should make it easier for MMOs to implement.</i></p>	Replace existing wording in measure 6a	Yes	<p>The minimum safety zone distance should be based on the most conservative estimate of either 500 m or acoustic modelling using the best available data</p> <p>Include verification of modelled safety zone in-field</p>	Hearing thresholds and behavioural responses of many marine species
9.1	<p>If the intent of the SZ is to minimize the likelihood of marine mammals incurring temporary hearing impairment, acoustic modelling and possibly SSV of the airgun array should be considered for inclusion in the SOCP, with the safety zone boundary being adjusted upward if appropriate.</p>	New	Yes	Define the goal of a SZ (e.g., to avoid PTS, TTS, Harm, Harassment)	How TTS and PTS matches with definitions under SARA
10	<p>Establish a minimum pre-clearance zone (i.e., pre-ramp-up watch zone) that extends 1000 m from the outer perimeter of the airgun array(s).</p> <p><b>Rationale:</b> <i>The use of a larger "pre-ramp-up watch" zone is considered precautionary and provides marine fauna, including SAR, with increased opportunity to move away from the airgun array(s) before exposure to sound levels from the full array. This is intended to minimize the potential for PTS as well as temporary hearing impairment, and to limit the likelihood of potential severe behavioural responses to airgun activation at close range (NOAA 2018). Similar approaches are used in Brazil, New Zealand, Australia, and most recently for planned seismic surveys in the U.S. Mid-Atlantic OCS.</i></p>	New	Partial	<p>Remove the standardized distance of '1000 m'</p> <p>Pre-clearance zone should only be based on acoustic modelling using the best available data</p>	Hearing thresholds and behavioural responses of many marine species
11	<p>If <u>any</u> marine mammal, sea turtle, or shark is detected within the 1000 m pre-clearance zone, ramp-up should be delayed by a minimum 30 minutes since the last detection. If a beaked whale is detected within the pre-clearance zone, ramp-up should be delayed by a minimum of 60 minutes since the last detection.</p> <p><b>Rationale:</b> <i>This recommendation is considered precautionary, consistent with best practice in international jurisdictions, and reflective of best available scientific information. It also is in agreement with recommendations made during previous CSAS processes and reflects current regional practices in Canada.</i></p>	<p>New</p> <p>Additional of non-cetaceans, sharks to list in measure 7</p> <p>Extends the ramp-up delay to 60 minutes for beaked whales</p>	Yes	<p>Include other species identified in the EA process</p> <p>Include deep-diving species in deep water (E.g., sperm whales, Kogia)</p> <p>Remove 1000 m distance</p>	<p>Detection probability of sea turtles and sharks</p> <p>Impact of seismic sound on sea turtles and sharks</p>
12	<p>The pre-ramp-up 'watch' should begin a minimum of 30 minutes before start-up in waters &lt;200 m depth and a minimum of 60 minutes before start-up in waters &gt;200 m depth in areas where deep-diving marine mammals are expected to occur.</p> <p><b>Rationale:</b> <i>This recommendation is consistent with best practice in international jurisdictions and is considered precautionary for deep-diving marine mammals. It</i></p>	<p>New</p> <p>Extends pre-ramp-up water to 60 mins in deep water in measure 6b</p>	Yes	No	No

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	<i>also is in agreement with recommendations made during previous CSAS processes and reflects current regional practices in Canada.</i>				
13	During the pre-ramp-up 'watch', visual monitoring as well as PAM (and/or other cetacean detection technology) should be employed.  <b>Rationale:</b> <i>This recommendation is consistent with best practice in international jurisdictions and is considered precautionary and prudent. It also is in agreement with recommendations made during previous CSAS processes and reflects current regional practices in Atlantic Canada.</i>	New  Addition of PAM to measure 7	Yes	No	Efficacy of PAM and visual monitoring for detection of a given species  Efficacy of other detection technologies (e.g., infrared camera)
14	Ramp-up duration should be 20 minutes to 40 minutes.  <b>Rationale:</b> <i>This recommendation is consistent with best practice in international jurisdictions and is considered precautionary. It also is in alignment with current regional practices in Atlantic Canada.</i>	Modifying wording in measure 7b	Partial	Lower and upper bounds should be based on specifications of the seismic survey (e.g., vessel number, array size)  Define ramp-up procedure	Effectiveness of ramp-up as a mitigation measure  Correct ramp-up duration
15	A ramp-up is required when airgun(s) have been inactive for 10 or more minutes.  <b>Rationale:</b> <i>The SOCP needs to provide clarity on when a ramp-up is required. Most international jurisdictions will not require ramp-up when the airgun array(s) is 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 5 minutes in Greenland).</i>	Modifying wording in measure 7	No	Include requirement to monitor safety zone during inactivity of airguns	Effectiveness of ramp-up as a mitigation measure  Correct length of time before a ramp-up is required

**Existing SOCP: Section 3. Shut-down of Air Source Array(s)**

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.

No.	Working paper recommendations and rationale	How does this recommendation relate to the original SOCP mitigation measures?	Is there scientific support for the recommendation?	Does this recommendation require any modifications?	Are there knowledge gaps associated with the recommendation?
16	In addition to a marine mammal or sea turtle listed as endangered or threatened on Schedule 1 of SARA the following animals are also recommended as "shut down" species. <ul style="list-style-type: none"> <li>• Marine mammal or sea turtles listed as special concern on Schedule 1 of SARA.</li> <li>• All sea turtles</li> <li>• All beaked whales.</li> <li>• All baleen whales.</li> <li>• Sperm whales</li> <li>• Harbour porpoise and Kogia species</li> <li>• Polar bears detected in the water.</li> </ul> All sharks listed on Schedule 1 of SARA as either endangered or threatened  <b>Rationale:</b> <i>The addition of the shut-down species listed above is in line with international best practice, current science, and is considered prudent and precautionary. In several instances, seismic proponents and regional regulatory agencies in Canada already require additional shut down species (see Table 1 of the working paper). Sea turtles, beaked whales and even baleen whales can often be difficult to identify to species, particularly in poor visibility conditions; as such, this requirement is considered precautionary for SAR in the event of species misidentification or inability to identify to species level. During the EA process</i>	Modifying list in measure 8 to include other taxa	Yes	Include non-SARA-listed species	Impact of seismic sound on sea turtles and sharks

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	<i>consideration should also be given to those species about to be listed as at risk on Schedule 1 of SARA (e.g., porbeagle shark, Lamna nasus).</i>				
17	The SOCP should be revised to reflect that an airgun(s) shut down would be required if the species identified above are detected within the SZ or are detected about to enter the SZ.  <i>Rationale: This is considered precautionary and is in line with current practice in Canada, a recommendation by Moors-Murphy and Theriault (2017), and some international jurisdictions.</i>	Modifying wording in measure 8 to include shut down for species entering the SZ	Yes	Modify to say "within and/or entering the SZ"	No

**Existing SOCP: Section 4. Line Changes and Maintenance Shut-downs**

9. When seismic surveying (data collection) ceases during line changes, for maintenance or for other operational reasons, the air source array(s) must be:
- shut down completely; or
  - 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:
- 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
  - ramp-up procedures as set out in section 7 will not be required when seismic surveying resumes.

No.	Working paper recommendations and rationale	How does this recommendation relate to the original SOCP mitigation measures?	Is there scientific support for the recommendation?	Does this recommendation require any modifications?	Are there knowledge gaps associated with the recommendation?
18	During line changes or operational maintenance the airgun array should only be shut-down completely if the full SZ can be effectively monitored before ramping back up; otherwise, the airgun array should be reduced to a single airgun (smallest in volume) or operations should be delayed until the safety zone can be effectively monitored.  <i>Rationale: This recommendation provides clearer direction to seismic operators and is in agreement with a recommendation made by Moors-Murphy and Theriault (2017). It is uncertain which measure is more precautionary because marine mammal (and sea turtle) response to single airgun use is unknown for many species. This uncertainty no doubt contributes to the variability in international practice in airgun use during line changes and maintenance shut-downs.</i>	Replace existing wording in measure 9	Yes	Modify wording to ensure that a complete shut-down is not precluded  Modify wording to ensure that the objective is the reduction of noise input into the environment	Response of marine species to a single airgun
19	If a single airgun is used during line changes or maintenance shut-downs a ramp-up is required.  <i>Rationale: Ramp-up after a period of single airgun use has become standard practice in Canadian regions, is in agreement with a recommendation made by Moors-Murphy and Theriault (2017), and is in line with international best practice.</i>	Replace existing wording in 10b	Yes	Define ramp-up procedure	Effectiveness of ramp-up as a mitigation measure  Response of marine species to a single airgun
20	A ramp-up from a single airgun is not required if the single airgun has been active for 10 minutes or less.  <i>Rationale: The SOCP needs to provide clarity on when a ramp-up is required. Most international jurisdictions will not require ramp-up when the airgun array(s) is 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 5 minutes in Greenland).</i>	New	Partial	Remove 10 minutes	Correct length of time before a ramp-up is required  Response of marine species to a single airgun

**Existing SOCP: Section 5. Operations in Low Visibility**

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:
- the full extent of the safety zone is not visible; and
  - the seismic survey is in an area that

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<p>b) 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</p> <p>c) 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.</p> <p>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:</p> <p>a. all non-identified cetacean vocalizations must be assumed to be those of whales named in sections 8(a) or (b); and</p> <p>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.</p>					
No.	Working paper recommendations and rationale	How does this recommendation relate to the original SOCP mitigation measures?	Is there scientific support for the recommendation?	Does this recommendation require any modifications?	Are there knowledge gaps associated with the recommendation?
21	<p>Cetacean detection technology (i.e., PAM) should be employed during the pre-ramp-up watch and during periods when the full SZ cannot be monitored visually while airgun(s) are active.</p> <p><b>Rationale:</b> <i>The use of PAM has become a standard practice in many international jurisdictions and in certain Canadian regions (notably offshore Nova Scotia). It is essential to have a means (albeit it is acknowledged that no marine mammal detection technology or even combination of technologies will detect all marine mammals) to detect cetaceans, particularly cetaceans considered at risk, during periods when the full SZ cannot be visually monitored. In Atlantic Canada, during summer months, the 500 m SZ was estimated to be visible during only 25–39% of the time (Moulton et al. 2009). It is recognized that other 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 of the working paper).</i></p>	Modifying existing wording in measure 11	Yes	<p>Remove ‘Cetacean detection technology’ and refer to ‘PAM’ directly, acknowledging that additional text clauses be needed for other emerging detection technologies.</p> <p>PAM should be employed at all times, not only during periods of low visibility when the full SZ cannot be monitored visually.</p>	Relative effectiveness of other detection technologies
22	<p>In the event of an acoustic detection during periods when airgun(s) are active, shut down must be implemented when the PAM Operator determines on the basis of professional judgement that the cetacean vocalization may be that of a shut-down species and that the species is likely within or about to enter the SZ.</p> <p><b>Rationale:</b> <i>For both Recommendation nos. 22 and 23, we suggest modifying the overly precautionous language in the SOCP (Item 12) to prevent unwarranted delays and shut downs. This is considered a prudent practice and is reflective of a current NMFS requirement for the Mid-Atlantic OCS (NOAA 2018). However, reliance on the professional judgement of a PAM Operator highlights the need to have experienced PAM Operators in place.</i></p>	New	No	PAM information should be used to implement a shut-down. If a marine mammal cannot be localized with a reasonable degree of accuracy using PAM (which may often be the case), the marine mammal should be assumed to be within or entering the SZ, and a shut-down must be implemented.	Efficacy of PAM for detection of a given species
23	<p>In the event of a marine mammal acoustic detection during the pre-ramp-up watch, ramp-up delay must be implemented when the PAM Operator determines on the basis of professional judgement that the marine mammal is likely within or about to enter the SZ.</p> <p><b>Rationale:</b> <i>See recommendation 22</i></p>	Modifying measure 12b	No	PAM information should be used to implement a ramp-up delay. If a marine mammal cannot be localized with a reasonable degree of accuracy using PAM (which may often be the case), the marine mammal should be assumed to be within or entering the SZ, and a ramp-up delay must be implemented.	Efficacy of PAM for detection of a given species
24	Specifications of the PAM system should be provided to DFO and other regulatory agencies (as appropriate) to demonstrate PAM system and operator	New	Yes	Replace ‘DFO’ with ‘appropriate regulatory authority’	No

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<p>capabilities to detect and localize cetacean vocalizations and to facilitate identification where feasible.</p> <p><b>Rationale:</b> Based on a review of PAM systems, Verfuss et al. (2018) note that PAM is not achieving its potential during typical seismic surveys given the type of hardware deployed and how it is deployed. The CNSOPB recognized this potential shortcoming and has required seismic operators to provide details of its PAM system for approval. Likewise, the U.S. NMFS has also required the provision of PAM specifications including most recently a detailed PAM system requirement list for seismic surveys in the Mid-Atlantic OCS (see NOAA 2018).</p>			<p>Add data sharing requirements with appropriate regulatory authority</p>	
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**Existing SOCP: Section 6. Additional Mitigation Measures and Modifications**

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

No.	Working paper recommendations and rationale	How does this recommendation relate to the original SOCP mitigation measures?	Is there scientific support for the recommendation?	Does this recommendation require any modifications?	Are there knowledge gaps associated with the recommendation?
25	<p>There should be a minimum separation distance between concurrent seismic surveys in the same region to minimize potential cumulative sound exposure on marine fauna. This separation distance should be based on best available science and should be clearly demonstrated during the EA process.</p> <p><b>Rationale:</b> The SOCP (Items 13 and 14) as currently written allows for additional mitigation measures and modifications to address potential effects on marine fauna as identified during the EA process. We recommend including some standard mitigation measures and monitoring requirements to address the potential for cumulative effects, particularly from concurrent seismic surveys in the same region, as well as the need to address key data gaps and uncertainties identified in the EA process.</p>	New	Partial	<p>Include the consideration of cumulative effects for consecutive surveys</p> <p>Include the consideration of cumulative effects from other anthropogenic noise stressors (e.g., shipping, fishing)</p>	<p>Measuring and assessing cumulative effects both spatially and temporally</p> <p>The minimum spatial and/or temporal separation distance between seismic surveys</p>
26	<p>If during the EA process there is a low level of certainty with cumulative effects predictions of seismic survey sound from multiple concurrent seismic surveys on marine fauna, additional mitigation measures and monitoring should be required. The details will be determined in consultation with regulatory agencies and/or local stakeholders.</p> <p><b>Rationale:</b> See recommendation 25</p>	Modifying existing wording in 13a	Yes	<p>Include the consideration of cumulative effects from other anthropogenic noise stressors (e.g., shipping, fishing)</p>	<p>Measuring and assessing cumulative effects both spatially and temporally</p>

**Existing SOCP: Section 7. Other**

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No.	Working paper recommendations and rationale	How does this recommendation relate to the original SOCP mitigation measures?	Is there scientific support for the recommendation?	Does this recommendation require any modifications?	Are there knowledge gaps associated with the recommendation?
27	<p>MMOs and PAM Operators should collect standardized data on marine fauna, environmental conditions, monitoring effort, seismic survey activity, and implementation of mitigation measures.</p> <p><b>Rationale:</b> <i>The collection of standardized data would allow for easier and more reliable consolidation of MMO and/or PAM Operator data. These consolidated data would permit data analysis across seismic monitoring programs, which would assist with detecting patterns and trends in marine fauna response to airgun sounds and provide information on the efficacy of mitigation measures (see for e.g., Moulton and Holst 2010; Stone 2015; Holst et al. 2018).</i></p>	New	Yes	Specify data collection protocol	No
28	<p>A comprehensive technical report on the environmental monitoring procedures and results should be prepared for each permitted seismic program, with review and approval by DFO and other regulatory agencies (as appropriate). DFO should define minimum standard reporting requirements and report structure. These technical reports should be made publically available and the findings should be taken into account in subsequent EAs.</p> <p><b>Rationale:</b> <i>As has been demonstrated in Canada and international jurisdictions, comprehensive technical reports provide valuable information that can be used to better predict effects of seismic surveys on marine fauna during the EA process and provide information on the efficacy of mitigation measures. This is particularly valuable when results are pooled across multiple seismic monitoring programs (e.g., Moulton and Holst 2010; Stone 2015; Holst et al. 2018).</i></p>	New	Yes	<p>Include all data that is collected and available from the surveys, beyond standard MMO and PAM data</p> <p>Define standardized guidelines</p> <p>Replace 'DFO' with 'appropriate regulatory authority'</p>	No
29	<p>Standardized monitoring data and metadata (see Recommendation No. 27) should be submitted to the appropriate regulatory agency and archived.</p> <p><b>Rationale:</b> <i>The archiving of standardized data has been recommended during a previous CSAS process (DFO 2010b) and will facilitate data analyses across combined seismic monitoring programs (see Rationale for Recommendation No. 27). Currently, the C-NLOPB and CNSOPB require that MMO data are submitted to them and the data are subsequently provided to DFO.</i></p>	NA	Yes	No	No



**THIS REPORT IS AVAILABLE FROM THE :**

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ISSN 1919-5087

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Correct Citation for this Publication:

DFO. 2020. Review of the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/005.

*Aussi disponible en français :*

*MPO. 2020. Examen de l'Énoncé des pratiques canadiennes d'atténuation des ondes sismiques en milieu marin. Secr. can. de consult. sci. du MPO, Avis sci. 2020/005.*