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REVIEW OF MITIGATION AND MONITORING MEASURES FOR SEISMIC SURVEY ACTIVITIES IN AND NEAR THE HABITAT OF CETACEAN SPECIES AT RISK

Photo credits: northern bottlenose whale (top left) taken by H. Moors-Murphy, blue whale (top right) taken by Whitehead Lab Dalhousie University, North Atlantic right whales (bottom) taken by C. Gomez.

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

Context:

The potential impacts of sounds produced by seismic airgun arrays during seismic surveys are of concern for cetaceans. Since the establishment of the Species at Risk Act *(SARA) in 2002, the number of exploratory seismic surveys conducted in Canadian waters by the Offshore Petroleum Industry has been increasing. When conducting seismic surveys in Canadian waters, mitigation measures to reduce possible negative impacts of seismic survey operations on marine mammals, including cetacean species at risk, are required. Since 2008, the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (SOCP) has been used to guide the minimum standard mitigation measures required for seismic operations in Canadian non-ice covered marine waters. However, the effectiveness of these mitigation measures for avoiding the SARA-prohibited impacts of killing, harm and harassment of individuals of threatened and endangered species and destruction of their critical habitat is not known. Oil and gas exploration and mapping activities in areas frequented by SARA-listed cetaceans has thus led to the need to evaluate the ability of the SOCP to meet SARA requirements and determine if modified or additional mitigation measures are needed to avoid SARA-prohibited impacts.*

This Science Advisory Report summarizes the results of the March 25-27, 2014 "Review of Mitigation and Monitoring Measures for Seismic Survey Activities in and near the Habitat of Cetacean Species at Risk". Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Canada

SUMMARY

- Oil and gas exploration and mapping activities in areas frequented by cetacean species listed under the *Species at Risk Act* (SARA) has led to a need to review the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (SOCP) and evaluate its effectiveness for avoiding SARA-prohibited impacts (killing, “harm” and “harassment” of individuals and “destruction” of critical habitat) on SARA-listed cetaceans.
- Building on previous advice, the potential effects on SARA-listed cetaceans of seismic airgun sounds produced during seismic surveys were examined to identify potential consequences and pathways of effects linked to killing, “harm” and “harassment” of individuals and “destruction” of critical habitat (using the most recent definitions of these terms available) (Table 1).
- Possible sound exposure metrics that could be used to determine quantitative thresholds for avoiding SARA-prohibited impacts were discussed (Table 2). Potential sound exposure metrics do exist for a number of potential effects such as auditory physiological effects, changes in vocalization patterns, hampered passive acoustic detection of prey, predators and conspecifics, and hampered avoidance of anthropogenic threats. In most cases; however, standardized descriptors of these metrics used by the wider scientific community do not exist.
- Single independent thresholds to avoid SARA-prohibited impacts could not be determined at this time as little information is available on quantitative linkages between sound exposure and response metrics for cetaceans. Permanent (PTS) and temporary hearing threshold shifts (TTS) could potentially be used to establish thresholds for avoiding physiological effects resulting in the killing, “harm” and “harassment” of individuals, but these would only in-part address SARA-prohibited impacts and additional thresholds would be needed for potential effects on behavior and ecology. Further research and analyses are required to relate sound exposure metrics to quantitative thresholds for the various physiological, behavioral and ecosystem effects caused by exposure to seismic surveys that could result in SARA-prohibited impacts.
- Given the uncertainties that remain around thresholds for avoiding SARA-prohibited impacts, implementation of precautionary and reliable risk-reducing mitigation measures is likely to be the most effective approach for minimizing potential negative impacts on SARA-listed cetaceans. Thus, despite the inability to recommend quantitative thresholds, the mitigation measures of the SOCP were reviewed in a precautionary manner in reference to reducing/avoiding SARA-prohibited impacts on SARA-listed cetaceans using the Scotian Shelf population of northern bottlenose whales, North Atlantic right whales and Atlantic blue whales as case studies.
- It was concluded that most of the mitigation measures of the SOCP likely reduce the potential negative impacts of seismic airgun sounds on individuals, but to varying degrees and with some caveats (Table 3). For example, effectiveness may be limited by the availability of information on distribution, abundance and behavior of a species, or by the specific manner in which the mitigation measure is conducted. Implementation of the multiple measures of the SOCP as a whole is likely to be more effective than any one measure on its own, and the SOCP provides flexibility for enhancing mitigation measures to meet SARA requirements as it states that operators may be required to put in place additional or modified mitigation measures for species of concern.

- The SOCP focuses on reducing significant adverse effects on individuals and populations mainly through efforts to reduce potential physical injury to animals in close proximity of airgun arrays, but does not provide specific mitigation measures for reducing impacts that may occur at greater ranges from the sound source (i.e., beyond the safety zone) or for reducing impacts on habitat. Planning seismic surveys to avoid significant adverse effects or to avoid displacing/diverting listed marine mammals are considered the only measures within the SOCP that address preventing the potential “harm” or “harassment” of individuals beyond the established safety zone or “destruction” of critical habitat.
- 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.
- The safety zone radius should be the most conservative of either 500 meters or a radius determined using propagation models based on the best available data and science for a pre-determined acoustic threshold (which has yet to be established), taking into account to the extent possible the species, environment and sound source context, and which should be validated with field measurements.
- To effectively monitor a safety zone for cetaceans, seismic survey activities and cetacean detection methods should be designed to maximize the likelihood of detecting SARA-listed cetaceans to achieve a target probability of detection within the safety zone consistent with SARA requirements (which has yet to be established). Enhanced real-time monitoring methods/technologies such as extended pre ramp-up observation periods, limiting seismic survey operations to good visibility conditions, having an adequate number of experienced and qualified Marine Mammal Observers (MMOs) searching, use of additional monitoring platforms, enhancing visual observations with passive acoustic monitoring (PAM) efforts and/or other monitoring technologies should be considered. A combination of detection methods/technologies may be required to achieve the target probability of detection.
- The effectiveness of ramp-up procedures or reduction of the airgun array to a single source element as a mitigation measure during seismic surveys is not fully understood, though some modeling and behavioral response studies are currently being conducted to investigate effectiveness.
- To comply with SARA by avoiding SARA-prohibited impacts, research efforts to increase our understanding of distribution and abundance over time, the behavioral and physiological responses of cetaceans to seismic airgun sounds, and the consequences of such responses on the habitat use, health, reproduction, survival and recovery of impacted species are required. This will be especially important in areas where seismic surveys overlap the distribution of SARA-listed cetaceans. Such studies have been and continue to be conducted by the international science community and are important for increasing our knowledge of the extent of the impacts of seismic surveys on cetaceans. To be most relevant for effective management, this research should be focused on risk or harm reduction rather than full knowledge of the basic biology behind impacts, which could take many years build a complete understanding of and thus delay useful mitigation measures.

- Explicitly designed research studies will be necessary to evaluate the efficacy of mitigation measures that have been implemented during seismic surveys for reducing the impacts of seismic airgun sounds on SARA-listed cetaceans. Such studies will need to be designed with rigorous data collection protocols and sufficient statistical power and sensitivity to allow for detection and quantitative analysis of potential negative effects at ranges from the sound source where SARA-prohibited impacts may occur, including beyond the defined safety zone.

INTRODUCTION

The Offshore Petroleum Industry has a growing interest in oil and gas development in Canadian waters, particularly off eastern Canada. Since the establishment of the *Species at Risk Act* (SARA) in 2002, the number of Exploration Licenses issued and seismic surveys conducted in land parcels off Nova Scotia and Newfoundland has been increasing, and the most recent Call for Bids for land parcels off Nova Scotia included identified critical habitat of endangered Scotian Shelf northern bottlenose whales. Underwater noise, particularly loud sounds, can negatively impact cetaceans through a number of mechanisms and is considered a potential threat to individuals and populations. Concerns have thus been raised about the potential impacts of oil and gas exploration and mapping activities on SARA-listed cetaceans, especially sounds produced by seismic airgun arrays during seismic surveys.

Section 32 of the SARA prohibits the killing, “harm”, and “harassment” of individuals of threatened and endangered species and Section 58 prohibits the “destruction” of specific areas identified as their critical habitat (SARA 2002). Provided that specific criteria can be met; however, SARA allows activities that would otherwise be prohibited under the Act to proceed through the issuance of permits or agreements under Sections 73 and 74. SARA also allows exceptions for otherwise prohibited activities as outlined in Section 83 (SARA 2002).

Mitigation measures are required for seismic survey operations occurring in Canadian waters to reduce potential negative effects on marine mammals, including SARA-listed cetaceans. Since 2008, the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (SOCP) has been used to guide the minimum mitigation measures required for seismic operations occurring in all non-ice covered marine waters in Canada (DFO 2008). However, it is questionable if the generic recommendations provided in the SOCP are adequate to avoid SARA-prohibited impacts on SARA-listed cetaceans. Project specific Environmental Assessments (EA), which are reviewed by offshore petroleum industry regulators, Fisheries and Oceans, Environment Canada, and other stakeholders, are conducted prior to seismic survey activities occurring in Canadian waters to determine if proposed mitigation measures are sufficient and to identify any additional measures needed. Member companies of the Canadian Association of Petroleum Producers and their seismic contractors have often put into place additional mitigation measures identified during the EA process to further reduce the impacts of seismic survey activities on vulnerable species and sensitive marine areas.

There is currently little guidance on what additional mitigation measures should be considered to ensure that SARA-prohibited impacts on SARA-listed cetaceans are avoided. Increased interest in oil and gas exploration and mapping in areas with geophysical potential that overlap areas frequented by SARA-listed cetaceans has led to the need to evaluate the ability of the SOCP to avoid SARA-prohibited impacts, and to determine any additional or modified mitigation measures needed.

The Canadian Science Advisory Secretariat hosted a meeting on March 25-27, 2014 to:

(a) examine potential sound exposure metrics and thresholds that could be used to avoid impacts (killing, "harm" and "harassment") to individuals of SARA-listed cetaceans and "destruction" of their critical habitat, as required under SARA;
(b) determine efficacy of the SOCP in meeting SARA requirements for protecting individuals and their critical habitat; and,
(c) identify modifications to the SOCP or additional mitigation and monitoring measures that could be used to meet SARA requirements.

These mitigation measures were reviewed using the Scotian Shelf population of northern bottlenose whales (*Hyperoodon ampullatus*), North Atlantic right whales (*Eubalaena glacialis*) and Atlantic blue whales (*Balaenoptera musculus*) as case studies during the discussions relevant to (b) and (c).

ANALYSIS

Sound Exposure Metrics and Thresholds for Cetaceans

DFO Science Sector was requested to identify sound exposure metrics and thresholds for seismic survey activities that could be used to avoid SARA-prohibited impacts on SARA-listed cetaceans. Theriault and Moors-Murphy (unpublished[1]) provide further information and discussion on the material presented in this section.

Determining appropriate sound exposure metrics and associated thresholds to avoid SARA-prohibited impacts requires an understanding of the criteria that must be met through establishing such thresholds. For example, to establish an acoustic-based threshold for seismic survey activities to prevent "harm" to individuals, an understanding of what is "harm" (in the context of SARA), as well as the how the characteristics of sound relate to potential effects/responses that would constitute "harm" and thus need to be avoided, is necessary before an appropriate sound exposure metric can be chosen.

The most recent definitions for the SARA terms "harm", "harassment", and "destruction" of critical habitat are:

- Harm is "the adverse result of an activity where single or multiple events reduce the fitness (e.g., survival, reproduction, movement) of individuals" (DFO 2013).
- Harassment is "any act or series of acts which tend to disturb, alarm, or molest an individual or population, which by means of its frequency and magnitude results in changes to normal behavior(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" (most recent definition provided by DFO SARA Program, modified from the DFO (2009) definition of "harass" to incorporate results of recent supreme court decisions – see Provincial Court of British Columbia 2012).
- Destruction of critical habitat is "determined on a case by case basis. Destruction would result if part of the critical habitat were degraded, either permanently or temporarily such that it would not serve its function when needed by the species. Destruction may result

[1] Theriault, J. and Moors-Murphy, H.B. (unpublished). Species at Risk criteria and seismic survey noise thresholds for cetaceans. DFO Can. Sci. Advis. Sec. Working Paper.

from a single or multiple activities at one point in time or from the cumulative effects of one or more activities over time" (EC 2009).[2]

The potential effects (responses) of seismic airgun sounds on marine mammals were previously assessed by DFO (2004). These potential effects, with some modifications and additions, were hypothetically linked to the SARA-prohibited impacts "kill", "harm", "harass" and "destroy" (critical habitat) as defined above, by identifying direct and indirect impacts/consequences of each potential effect/response (Table 1). When available, scientific evidence supporting identified linkages (though not necessarily for seismic sound specifically) are provided in Table 1.

A review of sound exposure metrics associated with each potential effect/response that could potentially be used to establish thresholds to meet SARA requirements was conducted (Table 2). Substantial scientific knowledge gaps made it difficult to determine appropriate sound exposure metrics for non-auditory physiological effects, changes in dive and respiratory patterns, displacement and migratory diversion, changes in social behavior, changes in time budget, changes in cognitive processes and hampered use of critical habitat/reduced occupancy. It was determined that sound exposure metrics do exist (in that measurements that can be linked to the effect/response and the technology for making such measurements exist) for auditory physiological effects, changes in vocalization patterns, hampered passive acoustic detection of prey, predators and conspecifics, and hampered avoidance of anthropogenic threats (Table 2). However, in most cases, there are currently no standardized descriptors of these metrics used by the wider scientific community and it was not possible to determine a quantitative threshold for the potential effect/response in relation to SARA-prohibited impacts as they are currently defined without further research (e.g., behavioral response studies) as the amount of data available is limited. Threshold levels are also likely to be species and context specific, making the selection of appropriate thresholds even more challenging.

It was determined that data currently exist that could potentially be used to help establish quantitative thresholds for auditory physiological effects (Table 2). Permanent hearing threshold shift (PTS)-based thresholds could likely be used for physiological effects resulting in killing of individuals and temporary hearing threshold shift (TTS)-based thresholds could likely be used for physiological effects resulting in "harassment" of individuals, but it was not clear if thresholds for physiological effects resulting in "harm" should be based on PTS or TTS. While PTS is used by other countries as a threshold for physical injury (e.g., NOAA 2013), the most recent definition of "harm" is not limited to physical injury and repetitive TTS could meet the SARA criteria for "harm" (Table 1). Further discussion is needed to determine if the thresholds for physiological effects resulting in "harm" should be PTS or TTS-based. A review of Southall et al. (2007), NOAA (2013) and any new scientific literature on PTS/TTS would likely provide the information needed to determine the most appropriate sound exposure metrics and associated thresholds for avoidance of physiological effects resulting in killing, "harm" and "harassment" of individuals. It is likely that several metrics and associated thresholds will be established for both PTS or TTS (for example, see Southall et al. 2007 and NOAA 2013).

[2] Because marine mammals utilize both the passive reception and active transmission of sounds, the ambient background noise levels of their habitat can enhance or reduce its suitability for these activities (DFO 2009). Activities that alter the acoustic environment of the critical habitat of threatened and endangered cetacean species could result in destruction of critical habitat if its functions (e.g., providing foraging opportunities, supporting critical life history processes such as socializing, mating, giving birth to and rearing young) are either temporarily or permanently unavailable or compromised when needed. For example, if sounds produced during seismic surveys were to increase background noise within critical habitat known to be important foraging grounds for an at-risk species to levels at which individuals are no longer able to effectively forage (thus preventing them from accessing food within their critical habitat), then destruction of critical habitat would be considered to have occurred. It is therefore possible for sound-producing anthropogenic activities to alter the acoustic environment of the critical habitat of SARA-listed cetaceans to the extent that destruction of critical habitat occurs (DFO 2009).

Change/reduction in potential communication space was suggested as a metric that could be used to establish a quantitative threshold for changes in vocalization patterns, hampered passive acoustic detection of prey, predators and conspecifics, and hampered avoidance of anthropogenic threats (Table 2), but again, quantitative thresholds could not be established due to limited available information.

It is important to note that because multiple potential effects/responses could be linked to any one of the SARA-prohibited impacts (Table 1) determining single independent acoustic thresholds for kill, "harm", "harass" or "destroy" becomes difficult, as the metric chosen for any one threshold would need to be relevant for addressing a broad range of physiological, behavioral and ecological effects. Alternatively, it may be more appropriate to establish several thresholds that must be met to address the broad range of potential effects. For example, to prevent "harm" to individuals, it may be necessary to establish a threshold to address physiological effects (e.g., PTS/TTS), a threshold to address behavioral effects (e.g., change in vocalization rates) and a threshold to address ecological effects (e.g., change/reduction in potential communication space). Determining the potential effects/responses and associated sound exposure metrics most relevant for addressing each SARA-prohibited impact will require further discussion.

Because of the significant knowledge gaps that exist on the effects of seismic airgun sounds on marine mammals in general and specifically on SARA-listed cetaceans, it is difficult to determine the appropriate metrics and associated thresholds for avoiding SARA-prohibited impacts. Increasing our understanding of the behavioral and physiological responses of cetaceans to seismic airgun sounds, and the consequences of such responses on the habitat use, health, reproduction, survival and recovery of impacted individuals remains a key research topic in the field of marine mammals and noise worldwide. Continued international efforts in the development of innovative technologies and rigorously designed scientific studies will be required to address these knowledge gaps. To be most relevant for management, this research should be primarily focused on risk or harm reduction rather than what the precise responses and impacts are in all contexts—a task that will take many years.

Efficacy of the SOCP for SARA-Listed Cetaceans

Advice on whether the application of the current mitigation measures outlined in the SOCP would avoid SARA-prohibited impacts on SARA-listed cetaceans was sought from DFO Science Sector. Given the remaining knowledge gaps and uncertainties around acoustic impacts and sound exposure metrics and thresholds for meeting SARA requirements, implementation of precautionary and reliable risk-reducing mitigation measures is likely be the most effective approach for minimizing potential negative impacts on SARA-listed cetaceans. Thus, although quantitative thresholds to meet SARA requirements could not be determined, the mitigation measures of the SOCP were reviewed in a precautionary manner to determine if the current measures outlined in the SOCP are likely to meet SARA requirements and to identify potential gaps or issues. Scotian Shelf population of northern bottlenose whales, North Atlantic right whales and Atlantic blue whales were used as case studies during this review. Moors-Murphy and Theriault (unpublished[3]) provide further information and discussion around the material discussed in this section.

It was concluded that most mitigation measures in the SOCP (specifically, SOCP Sections 3-6, 7(a), 8, 9(a), 10(a), and 11-14) could reduce potential SARA-prohibited impacts, but to varying degrees of effectiveness (Table 3). It was recognized that the combination of the multiple

[3] Moors-Murphy, H. and Theriault, J.A. (unpublished). Review of mitigation measures for cetacean Species at Risk during seismic survey operations. DFO Can. Sci. Advis. Sec. Working Paper.

measures outlined in the SOCP as a whole is more effective than any one measure on its own. The SOCP also states that operators may be required to put in place additional or modified mitigation measures for species of concern (SOCP Section 13), and thus provides flexibility for enhancing mitigation measures to meet SARA requirements.

The majority of the mitigation measures in the SOCP (e.g., establishment and monitoring of a safety zone, ramp-up procedures, shut-down of the airgun array, reducing the airgun array to a single source element during line changes and maintenance shut-downs) are most relevant for reducing physical injury to marine mammals in close proximity to the seismic survey vessel and airgun array. The SOCP is therefore most relevant for reducing potential killing of and to some extent "harm" to SARA-listed cetaceans. The ability of the SOCP to address potential "harm" or "harassment" of individuals that may occur at greater ranges from the sound source (i.e., beyond the safety zone), or "destruction" of critical habitat, is limited. The most relevant mitigation measures within the SOCP for addressing 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 on listed marine mammal species (SOCP Section 4) and to avoid displacing or diverting listed marine mammal species (SOCP Section 5).

The extent of information on distribution, abundance and behavior of a species, or the specific manner in which the mitigation measure is conducted, will impact the effectiveness of the mitigation measures applied to meet SARA requirements. For example, using marine mammal observers (MMOs) to monitor the safety zone (SOCP Sections 6 and 7) will only be effective for highly visible species during times of good visibility. In the case of beaked whales, Barlow and Gisiner (2006) found that even in the best of circumstances, using an adequate number of experienced observers with the best equipment and during good visibility during daylight hours, the probability of visually detecting small beaked whales directly in front of the ship when they were present and near the vessel was in the range of 20-50% at best. The probability of detection decreased to as little as 1-2% with inexperienced observers, and as sea state increased and visibility decreased (Barlow and Gisiner 2006). Similarly low detection rates would be expected for northern bottlenose whales, another deep-diving beaked whale species. Beaked whales, including northern bottlenose whales, can be detected using passive acoustic techniques (e.g., Moors 2012, Yack et al. 2013). Use of passive acoustic monitoring (PAM) or other detection technologies to monitor the safety zone during conditions of poor visibility (SOCP Section 11) is therefore expected to increase the ability to detect beaked whales in the safety zone in these conditions (an example of how the combination of mitigation measures outlined in the SOCP is more effective than any one measure on its own). Supplementing visual observations made by MMOs with concurrent PAM and/or other proven detection technologies, a measure not specifically outlined within the SOCP, would likely increase the ability to detect beaked whales within the safety zone not only during conditions of poor visibility, but in almost all circumstances (an example of how modified mitigation measures could enhance the effectiveness of the SOCP).

Gradual ramp-up procedures are required during seismic surveys (SOCP Sections 7(b) and 10(b)), but the effectiveness of this procedure as a mitigation measure is not fully understood. At least one airgun array modelling study has been conducted using threshold criteria proposed by Southall et al. (2007), which suggests that implementation of ramp-up procedures does not pose a significantly greater risk of physical injury to cetaceans(Hannay et al. 2010). Naval sonar modelling studies by Benda-Beckmann et al. (2013) indicate that ramp-up procedures of only a few minutes duration with relatively short pulses may reduce the risk of physical injury to cetaceans, especially as animal responsiveness to the sound signal increases (i.e., when lower sound-level thresholds elicit a response). At least one behavioral response study investigating the effectiveness of ramp-up on cetaceans is currently being conducted (Cato et al. 2013). The effectiveness of reducing the airgun array to a single source element during line changes or

operational maintenance rather than shutting down completely (SOCP Section 9(b)) is also not well understood. Since the effectiveness of these measures is unclear, their ability to avoid SARA-prohibited impacts is unknown (Table 3).

To fully evaluate the effectiveness of mitigation measures that have been implemented for reducing the impacts of seismic survey activities on SARA-listed cetaceans, it will be necessary to implement explicitly designed research studies with rigorous data collection protocols and adequate statistical power and sensitivity to allow for detection and quantitative analysis of potential SARA-prohibited impacts. This includes monitoring beyond the defined safety zone at ranges from the source where “harm”, “harassment” and “destruction” of critical habitat may occur so that even distant impacts can be detected if they do occur. Such environmental effects monitoring programs have previously been conducted during seismic surveys in Canadian waters (e.g., Lee et al. 2005).

Modified/Additional Mitigation Measures for SARA-Listed Cetaceans

DFO Science Sector was asked to identify potential modifications to the current SOCP or additional mitigation and monitoring measures that could be used to meet SARA requirements. Again, despite the inability to establish quantitative thresholds to avoid SARA-prohibited impacts, the mitigation measures of the SOCP were reviewed in a precautionary manner to provide advice on enhanced mitigation measures that could be put in place to reduce potential negative effects on SARA-listed cetaceans. The measures outlined in the SOCP were previously assessed by DFO (2010), who provided many recommendations for increasing the effectiveness of these mitigation measures that are still relevant to date. The following bullets provide a summary of more specific recommendations for modifications and/or additions to the measures currently outlined in the SOCP resulting from discussions during this meeting. These suggestions are also summarized in Table 3. The SOCP references in each bullet indicate to which sections of the SOCP the measure being discussed relates.

General:

- If it is determined that spatial and temporal avoidance measures cannot be employed, as is likely to happen when the distribution of year-round resident species overlap areas of interest for oil and gas exploration, source-based mitigation (e.g., the use of quieter technological alternatives) will be the most effective measure for reducing potential prohibited impacts on SARA-listed cetaceans and such measures should be used whenever feasible.
- The SOCP does not specifically address potential impacts on individuals that may occur at greater ranges from the seismic vessel and sound source or potential impacts on habitat. In addition to the mitigation measures currently outlined in the SOCP, measures specifically intended to avoid SARA-prohibited impacts on individuals that may occur at greater ranges from the sound source and to the critical habitat of SARA-listed cetaceans should be considered.

Planning:

- SOCP Section 3: In addition to planning seismic surveys to minimize the amount of energy in the water, the horizontal propagation of energy, and the frequency bandwidth of the seismic airgun sounds being produced, seismic surveys should also be planned to minimize the area surveyed and duration of the survey to the extent possible, with particular consideration given to avoiding identified critical habitat of threatened and endangered marine mammals when such species are expected to be present in the area.

- SOCP Section 4: In addition to avoiding significant adverse effects on individuals of threatened and endangered marine mammals, it should be specified that seismic surveys must be planned to avoid “harm” and “harassment” of individuals and “destruction" of critical habitat of threatened and endangered marine mammals.
- SOCP Section 5: Planning seismic surveys to avoid spatial and temporal overlap with SARA-listed cetaceans is considered to be the most effective mitigation for reducing negative impacts on SARA-listed cetaceans. However, avoidance of spatial and temporal overlap can only be successfully employed when there is flexibility in the exact location where and time when seismic surveys can occur or when species of concern are not resident year-round in the proposed area of interest. Quantifying the effectiveness of this measure requires adequate information on distribution and abundance to be available. When large knowledge gaps exist (which is currently the case for most cetacean species occurring in the Scotian Shelf region; Hurley 2013), further studies of abundance and distribution are required to inform spatial and temporal avoidance measures to enhance their effectiveness. If a seismic survey overlaps the distributional range of a SARA-listed cetacean but precise species-specific and relevant distribution patterns within the area of interest are not well known, then timely pre-survey studies at the appropriate temporal and spatial scales should be conducted prior to the survey to assess species occurrence and increase understanding of the likelihood of displacing or diverting individuals (e.g., Harwood et al. 2009).

Safety Zone and Start-Up; and Operations in Low Visibility:

- SOCP Section 6(a): Rather than establishing the safety zone radius solely based on a fixed distance, the safety zone radius should be the most conservative of either 500 meters or a radius determined using propagation models based on the best available data and science for a pre-determined acoustic threshold (which has yet to be established), taking into account to the extent possible the species, environment and sound source context. Such models yield only approximate and often underestimated safety zone radii and should therefore be validated with field measurements (McQuinn and Carrier 2005). Establishing a threshold-based safety zone during seismic survey activities is an increasingly common practice. PTS is used by other countries as a threshold for physical injury (e.g., NOAA 2013). As discussed above, establishing a safety zone based on a PTS threshold would reduce the likelihood of physiological effects resulting in killing of individuals, but it is not clear if physiological effects resulting in “harm” to SARA-listed cetaceans would be avoided. A TTS-based threshold is likely to increase the size of the safety zone to beyond several kilometers, which would be difficult to monitor effectively using the methods traditionally employed during seismic surveys. As stated in the SOCP, the safety zone radius should be at least 500 meters - the radius of threshold-based safety zones, whether established based on PTS or TTS, often exceed this.
- SOCP Sections 6(b), 7(a) and 11: The probability of detecting all individuals that occur within the safety zone through use of MMOs and PAM will almost always be substantially less than 1.0 (i.e., less than 100% effective), especially in the case of beaked whales where probability of visual detection is extremely low. Rather, to ensure that the safety zone is effectively monitored, combined monitoring capabilities should be designed to maximize the probability of detecting SARA-listed cetaceans to achieve a target probability of detection (e.g., detection function estimate) within the safety zone consistent with SARA requirements (which has yet to be established). Further work will be needed to provide guidance on the probability of detection that can be achieved for each species and to clarify “effectively monitored” in the context of target probability of detection to meet SARA requirements. Enhanced real-time monitoring methods/technologies to meet a

specified target probability of detection may include (but are not limited to) extending the pre ramp-up observation period, limiting seismic operations to periods of good visibility, increasing the number of experienced and qualified MMOs searching at any one time, the use of additional monitoring platforms (e.g., additional vessels, aerial surveys), enhancing visual observations with the use of PAM detection, localization and classification methods and/or other monitoring technologies, etc. Multiple detection methods likely increase the probability detection as compared to any one measure on its own, thus a combination of detection methods/technologies may be required to achieve a target probability of detection.

- SOCP Sections 6 (b), 7(a), 12(b): To increase the probability of detecting deep-diving species, the pre start-up (or restart-up) observation period should be extended to a minimum of 60 minutes, and ideally should be determined based on the maximum duration of species-specific deep-dive cycles.
- SOCP Section 7(b): The effectiveness of ramp-up will depend on the nature and level of the animal's responsiveness, which may vary by individual, species and context. A detailed literature review and possibly additional field or modeling studies will be required to determine the effectiveness of this measure for avoiding SARA-prohibited impacts.

Shut-down of source array:

- SOCP Section 8: The immediate shutdown of the airgun array when a threatened or endangered marine mammal is detected within the safety zone, should apply when detection occurs by any monitoring method or technique used. Shutdown should also occur before the animal enters the safety zone if it is anticipated, by any monitoring technique, that the animal will enter the safety zone based on its movement patterns.

Line changes and maintenance shut-downs:

- SOCP Section 9(a): During line changes or operational maintenance the airgun array should be shut-down completely if the safety zone can be effectively monitored (i.e., the target probability of detection can be obtained) before ramping back up; otherwise, the airgun array should be reduced to a single source element or operations should be delayed until the safety zone can be effectively monitored.
- SOCP Section 9(b): During line changes or operational maintenance the airgun array should only be reduced to a single source element if the safety zone cannot be effectively monitored before ramping back up. The effectiveness of reducing the airgun array to a single source element during line changes or operational maintenance will depend on the nature and level of the animal's responsiveness, which may vary by species and context. A detailed literature review and possibly additional field or modeling studies will be required to determine the effectiveness of this measure for avoiding SARA-prohibited impacts.
- SOCP Section 10(b): Ramp-up should be conducted as appropriate, including when recommencing the survey after the airgun array has been reduced to a single source element.

Sources of Uncertainty

Single independent thresholds to meet the SARA requirements of avoiding killing, "harm" and "harassment" of individuals and "destruction" of their critical habitat could not be determined at this time. It was determined that PTS could likely be used to establish a threshold for avoiding physiological effects resulting in killing of individuals and TTS could likely be used to establish a threshold for avoiding physiological effects resulting in "harassment" of individuals, but it was

unclear if PTS or TTS-based thresholds should be used to avoid physiological effects resulting in "harm". PTS and TTS-based thresholds only in-part address the avoidance of SARA-prohibited impacts to individuals as these metrics are not appropriate for measuring behavioral and ecological effects that could potentially result in the killing, "harm", "harassment" of individuals. The significant knowledge gaps that remain on the effects of seismic airgun sounds on marine mammals and the broad definitions for the SARA terms "harm", "harass" and "destruction" of critical habitat make it challenging to determine the appropriate metrics and establish acoustic thresholds for avoiding SARA-prohibited impacts.

Because of the significant knowledge gaps that remain on the effects of seismic airgun sounds on marine mammals in general, and on SARA-listed cetaceans specifically, it is difficult to fully evaluate the effectiveness of the mitigation and monitoring measures in the SOCP for meeting SARA requirements. However, evaluating the sighting rates and the proportion of potentially impacted animals in the safety zone compared to outside it can be, and to some degree has been, accomplished with current knowledge. Recommended research/actions to address knowledge gaps relevant to establishing acoustic thresholds to meet SARA requirements and for evaluating the efficacy of the SOCP for avoiding SARA-prohibited impacts include:

- Determine which of PTS or TTS would be most appropriate for establishing thresholds for physiological effects that constitute "harm" of individuals under SARA. Conducting a critical review of the various PTS/TTS thresholds being used throughout the world, including an examination of differences in calculated range of effect for PTS/TTS may be useful for informing this discussion.
- Conduct a review of Southall et al. (2007), NOAA (2013) and additional new scientific literature on PTS/TTS in marine mammals to gather the information necessary to choose the most appropriate metrics for establishing quantitative thresholds for physiological effects resulting in killing, "harm" and "harassment" of individuals.
- Investigate how change/reduction in communication space relates to changes in vocalization patterns, hampered passive acoustic detection of prey, predators and conspecifics, and hampered avoidance of anthropogenic threats and determine the extent of change in communication space that would constitute "harm" and "harassment" of individuals or destruction of critical habitat.
- Continue to investigate possible metrics for establishing acoustic thresholds for non-auditory physiological effects, changes in dive and respiratory patterns, displacement and migratory diversion, changes in social behavior, changes in time budget, changes in cognitive processes and hampered use of critical habitat/reduced occupancy.
- Increase capacity to detect and respond to mortalities (including at-sea deaths) that coincide with seismic survey activities and to conduct necropsies on such animals in a timely manner, to increase the ability to detect and measure potential physiological effects (direct physical injury or mortality) resulting from seismic survey activities, if they do occur.
- Continue to conduct behavioral response and environmental monitoring studies to improve our understanding of the direct effects/responses that may occur during seismic survey operations. Such studies should be designed so that frequency and magnitude of response (i.e. effect on vital rates and population-level impacts) in relation to noise level and distance from the sound source can be assessed. Additionally, the linkages between direct effects/responses to long-term impacts on habitat use, health, reproduction, survival and recovery remain a significant knowledge gap requiring further investigation. The importance of designing and conducting long-term studies of the population-level and ecological impacts of seismic noise on cetaceans is emphasized. This research will help

develop the knowledge base required to determine acoustic thresholds to meet the SARA criteria for “harm”, “harassment” and “destruction” of critical habitat.

- Conduct studies to enhance our knowledge of the distribution and abundance of SARA-listed cetaceans, particularly in areas of interest for offshore oil and gas activities. Information on species occurrence is required to assess the extent of potential impacts of seismic survey activities on SARA-listed cetaceans and to enable spatial and temporal avoidance measures to effectively be applied. The scale of studies required may vary from strategically planned region-wide surveys to project-by-project data collection in specific areas of interest, depending on the current state of knowledge on species occurrence. Visual sightings and acoustic detection data obtained during seismic surveys and other industry operations (by MMOs or otherwise) may be useful for enhancing our collective understanding of the seasonal distribution of cetaceans and should be made available to develop this knowledge base. Development of a national sightings database easily accessible to managers, regulators and industry would provide a resource to collect, store and share data in common formats on marine mammal occurrence.
- Determine the appropriate threshold to be used for establishing the safety zone radius, rather than using a fixed distance of 500 meters.
- Determine a target probability of detection for each SARA-listed cetacean species of concern which seismic survey operators would be expected to achieve when operating in certain areas. A scientific literature review including an investigation of detection function estimates from research surveys and how different environmental factors (e.g., sea state, weather, visibility), human-related factors (e.g., experience, protocols used) and equipment (e.g., survey platform, binoculars) may influence detectability of a species would help inform this discussion. Developing a framework for evaluating how the various additional mitigation measures would influence the probability of detection would be useful for both regulators and operators when developing mitigation strategies.
- Design and implement effective monitoring programs with rigorous data collection protocols that allow for detection and quantitative analysis of potential negative impacts on SARA-listed cetaceans at ranges from the sound source where “harm”, “harassment” or “destruction” of critical habitat may occur, including beyond a defined safety zone.

Many of these identified knowledge gaps are consistent with the findings of Hurley (2013), who provides recommendations for research needed to address data gaps in the offshore Nova Scotia region pertaining to the impacts of seismic airgun sounds on marine mammals.

CONCLUSIONS AND ADVICE

Substantial scientific knowledge gaps on the effects of seismic airgun sounds on marine mammals make determining appropriate acoustic thresholds to avoid SARA-prohibited impacts difficult. Additionally, the current definitions provided for “harm”, “harassment” and “destruction” of critical habitat are fairly broad, which make it challenging to determine a single independent acoustic threshold to avoid any one of the SARA-prohibited impacts, as the metric chosen for any one threshold would need to be relevant for a broad range of potential effects/responses. Alternatively, a number of acoustic metrics could be established, all of which would have to be fulfilled to meet SARA requirements. Given the uncertainty around establishing acoustic thresholds for avoiding impacts prohibited by SARA, emphasis is placed on reducing potential impacts on cetacean species at risk through implementation of reliable and precautionary mitigation measures. It was concluded that most of the mitigation measures outlined in the SOCP contribute to reducing potential negative impacts on species at risk to some extent, but

with some caveats. Several additions/modifications to the mitigation measures currently outlined in the SOCP to meet SARA requirements were discussed and are provided above.

A number of research areas to address knowledge gaps relevant for establishing acoustic thresholds to meet SARA requirements and for evaluating the efficacy of the SOCP for avoiding SARA-prohibited impacts are provided above. It is particularly important to note that gaps in our knowledge of the distribution of SARA-listed cetacean species in some areas limit the effectiveness of spatial and temporal avoidance measures during the planning stages of seismic survey activities. Increasing knowledge of when and where species occur, as well as the nature of their activities in specific areas (i.e., feeding, mating, calving), through long-term monitoring programs in known areas of interest to the offshore petroleum industry should be a research priority. As well, to address knowledge gaps and better understand the impacts of seismic surveys on SARA-listed cetaceans, continued research efforts by the international science community aimed at increasing our understanding of the behavioral and physiological response of cetaceans to seismic airgun sounds, and the consequences of such responses on the habitat use, health, reproduction, survival and recovery of impacted individuals is needed. Finally, to fully evaluate the efficacy of the mitigation and monitoring measures implemented during seismic surveys for meeting SARA requirements, it will be necessary to design effective research programs with rigorous data collection protocols that allow for detection and quantitative analysis of potential negative impacts at ranges from the sound source where “harm”, “harassment” or “destruction” of critical habitat may occur, including beyond a defined safety zone.

As understanding and interpretation of SARA continues, revisiting the SOCP within the SARA context is recommended.

OTHER CONSIDERATIONS

When establishing management thresholds, the practicality of implementing any threshold should be carefully considered. Behavioral and ecological effects/responses that may constitute “harm” and “harassment” of individuals and destruction of critical habitat may occur at long ranges from the sound source and will require mitigation measures designed to effectively detect potential SARA-prohibited impacts at long range. As an example, preventing the hampering of passive acoustic detection of prey, predators and conspecifics (i.e., masking) at levels that may fit under the SARA definition of harassment could result in the establishment of threshold levels resulting in large mitigation zones (hundreds and even thousands of kilometers in range). The ability to actually mitigate potential impacts over such large zones will be highly limited. Source-based mitigation (quieting alternative technologies) may therefore represent a more practical mitigation tool.

SOURCES OF INFORMATION

This Science Advisory Report summarizes the results of the March 25-27, 2014 “Review of Mitigation and Monitoring Measures for Seismic Survey Activities in and near the Habitat of Cetacean Species at Risk". Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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APPENDIX: TABLES

Table 1. List of potential effects/responses (modified from DFO 2004) and potential impacts/consequences of seismic airgun sounds on marine mammal physiology, behavior and ecology, and SARA prohibited impact category to which they apply based on the most recent definitions. Examples of studies providing evidence of seismic airgun sounds causing a particular effect/response are provided. Under SARA prohibited impact categories, black circles indicate a direct link between the potential effect and SARA prohibited impact while grey circles indicate an indirect link between the potential effect and SARA prohibited impact.

Potential effects/responses	Direct potential impacts/consequences	Indirect potential impacts/consequences	Kill	Harm[4]	Harass[5]	Destroy[6]
Physiology						
Non-auditory physiological effects	Gaz emboli formation, organ/ tissue damage, neurological effects, increased stress hormones	Stranding/near-stranding/at-sea death, reduced socializing/foraging, malnutrition, reduced reproduction/survival	●	●	●	
Auditory physiological effects (*e.g.* TTS, PTS) (Finneran et al. 2002)	Loss of hearing	Reduced socializing/foraging, malnutrition, starvation, increased exposure to threats, reduced reproduction/survival	●	●	●	
Behavior						
Changes in dive and respiratory patterns (Jochens et al. 2006; Gailey et al. 2007)	Stranding/near-stranding, emboli formation, tissue damage, increased energetic cost, reduced socializing/foraging	Stranding/near-stranding/at-sea death, malnutrition, increased exposure to threats, reduced reproduction/survival	●	●	●	

[4] Based on following definition of harm: "the adverse result of an activity where single or multiple events reduce the fitness (e.g., survival, reproduction, movement) of individuals" (DFO 2013).

[5] Based on following definition of harass: "any act or series of acts which tend to disturb, alarm, or molest an individual or population, which by means of its frequency and magnitude could reduce the likelihood of recovery or survival of the species by changing its normal behavior(s) and thus impacting a life history function" (unpublished report).

[6] Based on following definition of destruction of critical habitat: "if part of the critical habitat were degraded, either permanently or temporarily such that it would not serve its function when needed by the species" (EC 2009).

Potential effects/responses	Direct potential impacts/consequences	Indirect potential impacts/consequences	Kill	Harm[4]	Harass[5]	Destroy[6]
Displacement and migratory diversion (Richardson et al. 1986; Miller et al. 1999; Bain and Williams 2006; Moore and Angliss 2006)	Increased energetic cost, reduced socializing/foraging	Malnutrition, increased exposure to threats, reduced reproduction/survival	○	●	●	●
Changes in social behavior (*e.g.* hampered parental care and bonding, hampered breeding, etc.)	Reduced socializing/foraging	Calf mortality, reduced reproduction/ survival	○	○	●	●
Changes in vocalization patterns (*e.g.* hampered communication and echolocation) (Clark and Gagnon 2006; Di Lorio and Clark 2006; Castellote et al. 2012)	Reduced socializing/foraging	Malnutrition, reduced reproduction/survival	○	○	●	●
Changes in time budget (*e.g.* proportion of time spent performing various activities such as resting, foraging, socializing)	Increased energetic cost, reduced socializing/ foraging/resting	Malnutrition, increased exposure to threats, reduced reproduction/ survival	○	●	●	●
Changes in cognitive processes (*e.g.* distraction)	Reduced socializing/foraging	Malnutrition, increased exposure to threats, reduced reproduction/ survival	○	○	●	
Ecology						
Hampered passive acoustic detection of prey, predators, and conspecifics	Predator-related injury/mortality, reduced socializing/foraging	Malnutrition, increased exposure to threats, reduced reproduction/ survival	●	●	●	●
Hampered avoidance of anthropogenic threats (e.g., ship strikes, bycatch, etc)	Anthropogenic injury/mortality	Increased exposure to threats, reduced reproduction/ survival	●	●	●	
Hampered use of critical habitat/reduced occupancy	Reduced socializing/foraging	Reduced reproduction/ survival				●

Table 2. Summary of information available and knowledge gaps to be addressed in relevance to determining the appropriate sound exposure metrics that could be used to establish thresholds for each potential effect/response of seismic airgun sounds on cetaceans.

Potential effects/responses	Potential sound exposure metric(s)	Information available	Knowledge gaps
		Physiological effects	
Non-auditory physiological effects	None determined	May be related to changes in dive and respiratory patterns. Currently no evidence of emboli formation or hemorrhaging linked to seismic airgun sounds (DFO 2010). Increased stress hormone levels in cetaceans have been linked to increased vessel traffic and underwater noise levels (Rolland et al. 2012).	Probability of detecting physical injuries or at-sea deaths caused by seismic airgun sounds during offshore activities is low due to distance from shore, sinking carcasses and limited ability to respond to such incidents and perform necropsies in a timely manner. Currently no measurements of stress hormone levels in cetaceans during seismic surveys. Long-term impacts of increased stress hormone levels unknown but likely to include decreased immunity and fertility, as the stress response is highly conserved across species (Wright et al. 2007a,b).
Auditory physiological effects (*e.g.* TTS, PTS)	Metrics related to TTS, PTS (e.g., Sound Pressure Level,Sound Exposure Level (SEL), Cummulative SEL, Peak Ampllitude)	Some information on TTS available, less information available on PTS (e.g., Southall et al. 2007). A variety of metrics have been used for establishing quantitative TTS/PTS thresholds (NOAA 2000, Southall et al. 2007, NOAA 2013).	PTS generally not empirically measured but derived from TTS. Thresholds for TTS/PTS based on a small set of measurements from a limited number of species.
		Behavioral effects	
Changes in dive and respiratory patterns	None determined	Some studies show changes in dive behavior (e.g., fluke rate) and respiratory rate during seismic surveys (Abgrall et al. 2008).	Uncertainty in the most appropriate responses to measure (e.g., fluke rate, ascent/descent rate, dive duration, dive depth?) or how such responses relate to various sound exposure metrics. Responses variable and highly species/context specific, thresholds likely to be species dependent. Species-specific case studies examining frequency and magnitude of response needed. Long-term impacts of increased energetic costs unknown but can be estimated/calculated.

Potential effects/responses	Potential sound exposure metric(s)	Information available	Knowledge gaps
Displacement and migratory diversion	None determined	Some mysticete species known to move away from seismic activities (Miller et al. 1999, Moore and Angliss 2006), which likely have an energetic cost (Claridge 2013). However, in both, mysticete and odontocete species, the response is varied (Jochens et al. 2006; Miller et al. 2006; Smultea et al. 2004; Moulton and Miller 2005; Bain and Williams 2006; Harris et al. 2007; Holst et al. 2006; Stone and Tasker 2006; Weir 2008).	Uncertainty in the most appropriate responses to measure (e.g., changes in swim direction, speed?) or how such responses relate to various sound exposure metrics. Responses variable and highly species/context specific, thresholds likely to be species dependent. Species-specific case studies examining frequency and magnitude of response (i.e. effect on vital rates and population-level impacts) needed. Long-term impacts of increased energetic costs unknown but can be estimated/calculated.
Changes in social behavior (*e.g.* hampered parental care and bonding, hampered breeding, etc.)	None determined	May be related to displacement, changes in vocalization patterns, hampered passive acoustic detection of conspecifics. It has been noted that mothers with calves are more sensitive to (respond to lower levels of) to seismic airgun sounds (McCauley et al. 2000).	Relationship between displacement and hampered parental care unknown. Uncertainty in the most appropriate responses to measure or how such responses relate to various sound exposure metrics. Responses likely variable and highly species/context specific, thresholds are likely to be species dependent. Species-specific case studies examining frequency and magnitude of response needed. Long-term impacts of generally unknown.

Potential effects/responses	Potential sound exposure metric(s)	Information available	Knowledge gaps
Changes in vocalization patterns (*e.g.* hampered communication and echolocation)	Metrics related to changes/reduction in communication space	May be related to hampered passive acoustic detection of conspecifics and prey. Changes in vocalization patterns (e.g., increased/decreased vocalization rates, changes in call frequency, source levels) linked to seismic airgun sounds have been documented in some species (Clark and Gagnon 2006; Di Iorio and Clark 2010; Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999a, 1999b; Nieukirk et al. 2004, 2012; Smultea et al. 2004; Holst et al. 2005a, 2005b, 2006, 2011; Dunn and Hernandez 2009; Cerchio et al. unpublished[7]). Evidence of reduced communication space and masking as a result of seismic sound production exists, particularly important for low-frequency vocalizers (Clark and Gagnon 2006, Di Iorio and Clark 2006). This was noted as an important area to investigate due to wide-ranging impacts.	Uncertainty in how such responses relate to various sound exposure metrics. Responses variable and highly species/context specific, thresholds likely to be species dependent. Species-specific case studies examining frequency and magnitude of response are needed. Long-term impacts of changes in vocalization patterns and communication space generally unknown.
Changes in time budget (*e.g.* proportion of time spent performing various activities such as resting, foraging, socializing)	None determined		Not known if this occurs.

[7] Cerchio, S., T. Collins, S., Strindberg, C. Bennett, and H. Rosenbaum. 2010 (unpublished). Humpback whale singing activity off northern Angola: an indication of the migratory cycle, breeding habitat and impact of seismic surveys on singer number in Breeding Stock B1. Unpublished report submitted to the International Whaling Commission, Cambridge, UK.

Potential effects/responses	Potential sound exposure metric(s)	Information available	Knowledge gaps
Changes in cognitive processes (*e.g.* distraction)	None determined	Changes in cognitive processes due to anthropogenic noise have been shown to occur in some fauna. They result in hampering efficient foraging (Purser and Radford 2011), increased predation risk (Chan et al. 2010), but have been considered in general decision making for marine mammals (Bateson 2011)	Not known if this occurs in marine mammals.
Ecosystem effects			
Hampered passive acoustic detection of prey, predators, and conspecifics	Metrics related to changes/reduction in communication space	May be related to auditory physiological effects. Because predators/prey make sound, some evidence that passive acoustic detection of predators/prey may be important for some species – e.g., beaked whale species have been observed responding to killer whale playbacks by leaving the vicinity (Tyack et al 2011).	Not known if baleen whales passively acoustically detect prey. Uncertainty in how such responses relate to various sound exposure metrics. Long-term impacts of changes in communication space generally unknown.
Hampered avoidance of anthropogenic threats (e.g., ship strikes, bycatch, etc)	Metrics related to changes/reduction in communication space	May be related to auditory physiological effects and hampered passive acoustic detection. Some evidence that hearing impaired species increases vulnerability to ship strikes and entanglement (DFO 2004, Abgrall et al. 2008).	Links between exposure to seismic airgun sounds and increased exposure to threats uncertain.
Hampered use of critical habitat/reduced occupancy	None determined	May be related to hampered passive acoustic detection.	Not known if this occurs.

Table 3. Review of mitigation and monitoring measures of the SOCP and their likely effectiveness/ability to avoid SARA-prohibited impacts when properly implemented ("avoid" = measure likely to help avoid prohibited impacts, "reduce" = measure likely to reduce likelihood but not altogether avoid prohibited impacts, "unknown" = effectiveness not known), and recommended modifications or additional mitigation measures to be considered.

Mitigation measure (from the SOCP)	Effectiveness	Recommendations for modifications/additions
Planning		
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.	reduce/avoid	Seismic surveys should also be planned to minimize the area surveyed and duration of the survey to the extent possible, with particular consideration given to avoiding identified critical habitat of threatened and endangered cetacean species when such species are expected to be present in the area.
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.	avoid	Seismic surveys should also be planned to avoid harm and harassment of individuals and destruction of critical habitat of threatened and endangered marine mammals.

Mitigation measure (from the SOCP)	Effectiveness	Recommendations for modifications/additions
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.	avoid	If a seismic survey area overlaps the distributional range of a SARA-listed species but finer-scale distribution patterns within the area of interest are not well known, then timely pre-survey studies at the appropriate temporal and spatial scales should be conducted prior to the survey to assess species occurrence and increase understanding of the likelihood of displacing or diverting individuals.

Mitigation measure (from the SOCP)	Effectiveness	Recommendations for modifications/additions
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 meters as measured from the center of the air source array(s); and for all times the safety zone is visible, 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 (b) 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.	reduce	(a) The safety zone radius should be the most conservative of 500 meters or a radius determined using propagation models based on the best available data and science for a pre-determined acoustic threshold (which has yet to be established), taking into account to the extent possible the species, environment and sound source context, and which should be validated with field measurements. (b) Combined monitoring capabilities should be designed to maximize the probability of detecting SARA-listed species to achieve a target probability of detection within the safety zone consistent with SARA requirements (which has yet to be established). A combination of detection methods/technologies (not limited to MMOs and PAM) may be required to achieve the target probability of detection. When operating in areas overlapping the distribution of deep-diving SARA-listed cetaceans, the pre start-up (or restart-up) observation period should be extended to a minimum of 60 minutes to increase the probability of detecting deep-diving species, and ideally should be determined based on the maximum duration of at least one deep-dive cycle.

Mitigation measure (from the SOCP)	Effectiveness	Recommendations for modifications/additions
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.	(a) reduce (b) unknown	(a) See 6(b) above. (b) Effectiveness is likely to be dependent on the nature and level of the animals' responsiveness, which may vary by species and context. A review of available literature and additional studies is required to fully understand effectiveness.
Shut-down of air source array		
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.	reduce	The immediate shutdown of the airgun array should apply when detection occurs within the safety zone by any monitoring method or technique used, and should also occur before the animal enters the safety zone if it is anticipated, by any monitoring technique, that the animal will enter the safety zone based on its movement pattern.

Mitigation measure (from the SOCP)	Effectiveness	Recommendations for modifications/additions
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: (a) shut down completely; or (b) reduced to a single source element.	(a) reduce (b) unknown	(a) During line changes or operational maintenance the airgun array should only be shut-down completely if the safety zone can be effectively monitored (i.e., the target probability of detection can be obtained) before ramping back up; otherwise, the air source array should be reduced to a single source element or operations should be delayed until the safety zone can be effectively monitored. (b) During line changes or operational maintenance the airgun array should only be reduced to a single source element if the safety zone cannot be effectively monitored before ramping back up. Effectiveness is likely to be dependent on the nature and level of the animals' responsiveness, which may vary by species and context. A review of available literature and additional studies is required to fully understand effectiveness.
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.	(a) reduce (b) unknown	(b) Ramp-up should be conducted as appropriate even when the airgun array is reduced to a single source element.

Mitigation measure (from the SOCP)	Effectiveness	Recommendations for modifications/additions
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: (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 vocalizing 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.	reduce	See 6(b) above.
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.	reduce	(b) See caveat about deep-diving species on 6(b) above.

Mitigation measure (from the SOCP)	Effectiveness	Recommendations for modifications/additions
Additional mitigation measures and modifications		
15. 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).	reduce	
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.	reduce	
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.	reduce	

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