Environmental Assessment of Seitel's East Coast Offshore Seismic Program, 2016–2025 Addendum

Prepared by

LGL LIMITED
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Prepared for

SEITEL

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INTRODUCTION

This Addendum document contains responses to comments provided by reviewers of the Environmental Assessment of Seitel's East Coast Offshore Seismic Program, 2016–2025, as well as responses to comments provided by reviewers of the initial version of the EA Addendum.

GENERAL COMMENTS

Fish, Food and Allied Workers (FFAW/Unifor)

General Comment #1: The timing of the activity coincides with the highest harvesting activity of our Membership.

> ***Response:*** Seitel concurs with the FFAW/Unifor that the timing of Seitel's proposed geophysical activities coincides with the time of highest harvesting activity by the FFAW/Unifor membership.

General Comment #2: The correct convention for the areas would be NAFO Divisions 3KLMNOPs and 4Vs, not 3K, 3L, 3M, 3N, 3O, 3Ps and 4Vs. There are multiple cases of this error in Section 4.3 Fisheries.

> ***Response:*** Seitel notes the correct convention for naming NAFO Divisions.

Nunatsiavut Government (NG)

The Nunatsiavut Government fundamentally disagrees with the length of the environmental assessment. The 10-year EA presents many problems which require clarification from the proponent.

General Comment #1: Within the 10-year authorization what are the opportunities for adaptive mitigation based on new information and technology? What reporting requirements exist in order to ensure adaptive and effective mitigation over the 10-year time period with regards to fisheries impacts, marine mammal impacts, and impacts to Inuit subsistence activities? What power does the C-NLOPB or its stakeholders have to encourage the use of new techniques that are developed during the length of the program? For example, the Pacific and Western Arctic jurisdictions of Canada have used Section 13 of the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (Statement of Practice) to establish mitigations based on received levels of sound within the marine environment. This action was instituted because the minimum 500 m was modelled and found to be insufficient to prevent harm to marine mammals in certain project areas.

> ***Response:*** There will be full opportunity for adaptive mitigation during the 10-year program. Seitel will be required to prepare an EA Update document prior to commencing activities in any given year. The Update document will include new relevant information that was unavailable during preparation of the previous program document(s). If there are any new techniques developed during the 10-year period that may help to further mitigate environmental effects, they will be investigated and incorporated into the program if deemed useful.

NG Reply to Seitel Response: These comments were raised to bring forth the lack of impetus to improve mitigation once a 10-year authorization was approved. It was not answered.

Question: Specifically, how will new technology and mitigation practices be assessed? On an annual basis? Through literature searches?

Seitel Response to NG Reply: Seitel contends that its response to the NG's original general comment did provide an adequate answer regarding adaptive mitigation. EA Updates that will be prepared during the 10-year scope of the Project will include any relevant new information not provided in the EA, the EA Addendum and prior EA Updates. Should new information regarding improved mitigation measures become available during the 10-year scope, it will be included in the EA Updates. It is also in the best interests of Seitel to investigate and perhaps implement better mitigation measures.

General Comment #2: The cumulative effects impact assessment does not incorporate climate change and the subsequent impacts to the marine environment and associated VECs. As this is a 10-year environmental assessment, the impacts of climate change should be included in the assessment. In 2010, the Canadian Environmental Assessment Agency published a guidance document called Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners (https://www.ceaa-acee.gc.ca/default.asp?lang=En&n=A41F45C5-1&offset=1&toc=show). This guidance document clearly outlines the importance of incorporating possible climate change impacts into the cumulative effects assessment. As a designated responsible authority under the Canada Environmental Assessment Act, the C-NLOPB is responsible to ensure proponents are following best practices not only in their operations but also in their environmental assessment practices.

Response: Seitel agrees that climate change is indeed a potential contributing factor to cumulative effects. From the perspective of greenhouse gases, atmospheric emission levels from the marine vessels and other relevant equipment that would be used during Seitel's exploration program are considerably less than those associated with drilling operations. Regardless of this fact, there will be atmospheric emissions produced during the Seitel program. The Canadian Environmental Assessment Agency's guidance document regarding the incorporation of climate change considerations in environmental assessment is of limited value in this case, primarily because a utile method of conducting assessment of cumulative effects has not yet been devised. Duinker et al. (2012), in their review of work to date on the scientific dimensions of cumulative effects assessment (CEA), concluded that it is particularly difficult to properly implement CEA in project-specific EAs. They made several recommendations regarding revisions to guidance materials for science in CEA, including the following:

- A much richer and nuanced conceptual framework for a cumulative effect is required in order to describe how effects become cumulative;
- Clearer guidance regarding CEA analytical methods is required; and
- Better definitions of thresholds, without which it is really impossible to judge the significance of cumulative effects.

Duinker et al. (2012) concluded by saying that lack of competent CEA impairs our ability to determine the degree to which particular activities jeopardize the sustainability of Valued Environmental Components (VECs), and that improvements in CEA practice are desperately needed.

NG Reply to Seitel Response: The proponent has focused on the emissions caused by their own project; however climate change should also be assessed based on the changes to the marine environment and by the cumulative effects of other foreseeable projects. The evaluation of cumulative effects involves evaluating the past, present, and future impacts of the project (CEAA, 2012, Ross, 1998) not evaluating the cumulative impacts on an annual basis.

Question: Please provide the precedent or reference for the practice of assessing cumulative effects on an annual basis (outside of the C-NLOPB or the C-NSOPB). Also, please discuss how changes to the marine environment and other future projects will be incorporated into a cumulative effects assessment.

The NG reiterates its prior comment: "As an extension of the above, the amendment fails to properly address cumulative impacts. Proper cumulative impact assessments are required to fully assess the additive or multiplicative effects of potential projects. Therefore, forgoing assessment with the reasoning that the number of active projects is unknown, as stated on page 13 of the Amendment is unacceptable EA practice. The proponent should clearly state and assess the maximum number of potential projects within the extended temporal scope of their program. Although the NG prefers EAs with annual or bi-annual timelines, the annual EA Update process should only be used to update a robust cumulative impact assessment as more concrete information becomes available."

> ***Seitel Response to NG Reply:*** Seitel contends that its response to the NG's original general comment regarding cumulative effects assessment did provide an adequate answer. As Duinker et al. (2012) indicated, there currently is not a well-developed approach to cumulative effects assessment, particularly in the marine environment. The cumulative effects assessment approach used by Seitel in its EA has been an acceptable one to the C-NLOPB for numerous recent seismic EAs that received positive determinations. Seitel also notes that seismic surveying in not a trigger under *CEAA (2012).* Therefore, guidance for cumulative effects assessment was provided by the Scoping Document issued by the C-NLOPB, not by guidelines issued by the Canadian Environmental Assessment Agency.

General Comment #3: Paragraph 19(1)(a) of CEAA 2012 specifies that a project EA must take into account environmental effects, including cumulative environmental effects that are likely to result from the designated project in combination with other physical activities that have been or will be carried out. This environmental assessment does not clearly state the proponent's scenario with which they are assessing their own cumulative effects of a 10-year program. The proponent states that the maximum possible combinations within each year are 2D and 2D or 2D and 3D; therefore section 5.8 should detail a scenario that includes one of these combinations each year for 10 years to assess cumulative effects.

> ***Response:*** As indicated in § 5.8 of the EA, the EA has assessed cumulative effects within the Project and the residual effects described in § 5.0 include any potential cumulative effects resulting from the Seitel activities. The cumulative effects discussed in the EA that consider other activities outside of Seitel's activities pertain to 2016 only. It isn't possible to realistically consider cumulative effects for the entire 10-year period. The annual EA Updates will consider the cumulative effects in subsequent years. As indicated in the response to the NG General Comment #2, improvements in CEA practice are desperately needed.

NG Reply to Seitel Response: Since the proponent has stated that for them it is "not possible to realistically consider cumulative effects for the entire 10-year period," it is the opinion of the NG that this project enters an annual or bi-annual review of the EA for the 10 year period.

However, it is possible to assess long-term cumulative effects based on the estimates of their own activities provided by the proponent (either 2D&2D or 2D&3D each year) in their project description and the list of known proponents and their activities on the C-NLOPB website.

More documentation and guidance is available for cumulative effects assessment than is referenced in the proponent's response. Duiker et al. (2012) is a valuable review on the state of CEA guidance, however further work has emerged, specifically with reference to the Canadian Environmental Assessment Act of 2012. For example, the Technical Guidance for Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012 provides specific examples of setting past and future temporal boundaries, among other references to methodology. Duiker et al. (2012) also provides clear steps towards improved CEA, such as the use of GIS to map long-term planning for large areas. It may also be of assistance to review the cumulative effects assessments of projects that have a similar timeframe and have been able to perform a cumulative effects assessment (i.e. mines, pipelines, etc.).

Bidstrup et al., (2016), Noble, (2015) and Duiker et al. (2012) all emphasize the importance of Strategic Environmental Assessment to the assessment of cumulative effects. The Technical Guidance for CEA Effects under the CEAA 2012 also states that "Mitigation, monitoring and effects management are recommended (e.g., as part of an Environmental Protection Plan). These measures may also be required at a regional scale (possibly requiring the involvement of other stakeholders) to address broader concerns regarding effects on VECs."

Monitoring programs from project-based EAs are therefore an important contributor to the strengthening of Strategic Environmental Assessments as well as to assessing project-based cumulative effects.

Question: Without a monitoring program at least based within their own project, how will the proponent assess total project effects and overall cumulative effects? How will the project impacts to *SARA* species be monitored and assessed against the EA's impact predictions?

> ***Seitel Response to NG Reply:*** Seitel contends that its response to the NG's original general comment regarding cumulative effects assessment did provide an adequate answer. The cumulative effects assessment approach used by Seitel in its EA has been an acceptable one to the C-NLOPB for numerous recent seismic EAs that received positive determinations. Seitel also notes that seismic surveying in not a trigger under *CEAA (2012).* Therefore, guidance for cumulative effects assessment was provided by the Scoping Document issued by the C-NLOPB, not by guidelines issued by the Canadian Environmental Assessment Agency.

General Comment #4: The maintenance of adequate separation of seismic projects is insufficient to reach a conclusion of "not significant" impacts to VECs. The concept of avoiding overlapping sound does not assess the impacts of diverted migration patterns or movements from multiple seismic projects, nor does it assess the impacts of multiple exposure events to VECs. Section 5.8.3 should detail the references and studies used to conclude that "any cumulative effects… will be additive (not multiplicative or synergistic) and predicted to be not significant."

> ***Response:*** According to Appendix 2: Types of Cumulative Effects of CEAA's Technical Guidance for Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment* Act (*CEAA*), although the cumulative effects of habitat loss, for example, can be considered to be additive, the cumulative effects on the species using the habitat may be synergistic (CEAA website; accessed May 2016). Therefore, the last sentence of the first paragraph on page 194 in § 5.8.3 of the EA should be changed from "Any cumulative effects (i.e., disturbance), if they occur, will be additive (not multiplicative or synergistic) and predicted to be not significant" to "Any cumulative effects are predicted to be not significant".

NG Reply to Seitel Response: The proponent's answer did not acknowledge the question. Please provide these references.

Question: Section 5.8.3 should *detail the references and studies* used to conclude that "any cumulative effects... will be additive (not multiplicative or synergistic) and predicted to be not significant." Please provide these references.

> ***Seitel Response to NG Reply:*** Seitel contends that its response to the NG's original general comment regarding cumulative effects did provide an adequate answer. Seitel indicated that the last sentence of the first paragraph on page 194 in § 5.8.3 of the EA should be changed from "Any cumulative effects (i.e., disturbance), if they occur, will be additive (not multiplicative or synergistic) and predicted to be not significant" to "Any cumulative effects are predicted to be not significant". Seitel also indicated that the text regarding additive and synergistic effects and how they apply to habitat and the biota using the habitat was based on language on the Canadian Environmental Assessment Agency website. The Canadian Environmental Assessment Agency did not cite any references.

General Comment #5: In addition, a 10-year environmental assessment should assess the impacts to the marine environment over 10 years. Section 5.8.3 of the environmental assessment has only assessed the potential for "cumulative effects with other seismic programs proposed for 2016 (e.g., WesternGeco, MKI, Statoil, GXT). If the proponent is applying for a 10-year project, the environmental assessment should be able to properly assess cumulative effects over that time span by assessing the certain and probable projects over that time period – otherwise each project should reduce the scope to an assessable timeframe; likely resulting in each seismic project being treated as an annual or bi-annual project with separate environmental assessments.

> ***Response:*** It isn't possible to assess cumulative effects for the entire 10-year period. The annual EA Updates will consider the cumulative effects in their respective years. As indicated in the response to the NG General Comment #2, improvements in CEA practice are desperately needed.

General Comment #6: The Nunatsiavut Government also takes issue with the referencing of previous EA studies to validate or defend a position. Rather than providing evidence to support conclusions, the proponent has instead asked the reviewer to refer to past EAs that are not included in the document. This practice is done throughout the document (ex. 4.5.11, 5.5, 5.7.4.1, 5.7 etc.). This is poor EA practice and should be discouraged by the regulator.

> ***Response:*** The use of this approach is based on directives in the C-NLOPB's Final Scoping Document provided to the proponent on 21 December 2015.

General Comment #7: A major gap within the EA is the absence of a defined monitoring plan. A monitoring plan needs to be in place if they wish to provide new plans for each year. Clarification and details on the plan is requested from the proponent.

> ***Response:*** A stand-alone monitoring plan per se is not typically required for environmental assessments of proposed geophysical programs. Types of monitoring that are typically included in geophysical program EAs are the employment of marine mammal/seabird observers (MMOs/SBOs) to monitor marine mammals and seabirds in the general vicinity of operations, and employment of Fisheries Liaison Officers (FLOs) to monitor commercial fishing/fishing gear/fishing vessels in the general vicinity of operations. Field reports are prepared and submitted for all of these monitoring activities. Seitel also commits to maintaining open dialogue with the NG and to have a NG MMO on the vessel.

NG Reply to Seitel Response: The definition of environmental assessment as per the Canadian Environmental Assessment Agency includes "a follow-up program to verify the accuracy of the environmental assessment and the effectiveness of the mitigation measures" (CEAA 2016). Monitoring plans are a very common component of an EA's Environmental Protection Plan, especially when species at risk are present. Therefore, a monitoring program can and should be applied to this project. Sound source verification, marine mammal observers, and environmental monitors are common practice within seismic activities in North America.

> ***Seitel Response to NG Reply:*** Seitel contends that its response to the NG's original general comment regarding a follow-up program and a monitoring plan did provide an adequate answer. Seitel notes that seismic surveying in not a trigger under *CEAA (2012).* Therefore, guidance for the environmental assessment of a proposed seismic program was provided by the Scoping Document issued by the C-NLOPB, not by guidelines issued by the Canadian Environmental Assessment Agency.

General Comment #8: The Nunatsiavut Government recommends that sound source verification be conducted in advance of project commencement (within a week prior to project start date), as is common practice in other Canadian jurisdiction. Verified sough propagation and modeling would ensure that seismic sound stays contained within the project area, including outside of the 'the Zone', and ensures that it does not exceed disturbance levels. Results of verification should be sent to regulators and relevant stakeholders immediately.

> ***Response:*** The requirement of underwater sound propagation modelling was not indicated in the Final Scoping Document provided to the proponent by the C-NLOPB on 21 December 2015.

General Comment #9: The EA states that DFO has not adopted any noise exposure criteria. With regards to the issue of preventing temporary threshold shift (TTS) and behavioral disturbance, the Western Arctic and Pacific Regions of DFO Canada have recommended precautionary noise exposure criteria within their advice provided to the National Energy Board. In the Western Arctic, criteria are based on 180 dB to avoid temporary threshold shift. It should be noted that seismic operations were successful in gaining their data when applying the mitigation recommended by DFO Western Arctic. In the Pacific Region, a safety zone is required to be modelled to correspond to 160 decibels is established to avoid behavioural disturbance (CSAS, 2014). This approach is based on Section 13 of the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment that allows for incorporation of new mitigation measures based on sound variation in the environment as well as cumulative effects.

Response: While some case-by-case recommendations have been made by DFO for noise exposure criteria, currently there are no nationally-adopted noise exposure criteria. The EA proposes to use the protocols currently approved for use in offshore Newfoundland and Labrador. It should also be noted that the 180 dB re 1 μPa_{rms} criterion to avoid temporary threshold shift (TTS) was established before there was any available information regarding the minimum received levels of sounds necessary to cause TTS in marine mammals. The requirement of underwater sound propagation modelling was not indicated in the Final Scoping Document (C-NLOPB 2015) provided to the proponent by the C-NLOPB on 21 December 2015.

NG Reply to Seitel Response: The exposure criteria for DFO Western Arctic and DFO Pacific (clearly not nationally set criteria) were determined through Southall et al., 2007 and through the application of evolving mitigation based on environmental assessment monitoring plans. The academic studies of temporary threshold shift (TTS) and disturbance in marine mammals has evolved to assess specific groups and species. For example, Tougard, Wright, and Madsen (2015) found even lower TTS thresholds for smaller odontocete species at 100dB. The NG recommends the use of these types of studies within the EA.

With regards to *SARA* species, it is important to feed information both to a monitoring plan for the proponent, but also to the strategic environmental assessment of the area. It is important to reiterate that the 500m safety zone is a minimum requirement, and that the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment encourages updates to mitigation with new scientific information. The Statement's supporting document is from 2004 and cites major gaps in knowledge regarding offshore *SARA* species.

Question: The NG requests that the proponent outline the work on TTS and disturbance criteria since 2004 and justify (with references) why the 500m radius remains adequate in their opinion.

The reasoning that the sound source verification is not necessary because it was not included in the scoping document is not consistent with the proponent's statement in Comment 1 that they will evaluate how they can improve mitigation and the incorporation of new techniques each year.

Seitel Response to NG Reply: Seitel contends that its response to the NG's original general comment regarding exposure thresholds for marine mammals. As indicated in a previous response to a NG comment regarding adaptive mitigation, Seitel is completely open to new information regarding mitigation measures, and would abide by a change in the required radius of a safety zone for marine mammals and sea turtles. At this time, a 500 m radius safety zone is required during seismic surveying in Newfoundland and Labrador waters.

General Comment #10: Considering the high number of potential projects in the area over the 10-year span of this EA, a precautionary approach to seismic mitigation for cetaceans and sea turtles is recommended. 500 m is stated as a minimum in Section 2.2 of this environmental assessment. It is recommended that sound propagation modelling should be done to assess the potential impacts to marine life throughout the project area. It should be noted that the Statement of Practice is based on a 2004 CSAS document that outlines the large data gaps and potential consequences in seismic mitigation. It states that "risks of these consequences are poorly quantified, often unknown, and likely to be variable with both conditions of the environment and of the organisms exposed to the sounds."

Response: The requirement of underwater sound propagation modelling was not indicated in the Final Scoping Document (C-NLOPB 2015) provided to the proponent by the C-NLOPB on 21 December 2015.

General Comment #11: With regards to the consultations in the appendices, please explain why specific recommendations regarding scallops and bivalves were not specifically included in mitigation and monitoring measures as encouraged by Ocean Choice International.

Response: The comment regarding the Arctic surf clam and the potential effects on them due to exposure to seismic airgun sound was made by Clearwater Seafoods. The references regarding bivalves and underwater sound were not directly cited in the EA because of the EA format stipulated by the C-NLOPB in its Final Scoping Document (i.e., cross referencing of related SEAs and EAs). However, the concerns expressed by Clearwater Seafoods were addressed.

The study of particular concern to Clearwater Seafoods is that authored by Aguilar de Soto et al. (2013). They conducted laboratory experimentation with larvae of the New Zealand scallop (*Pecten novaezelandiae*), exposing them to recordings of seismic pulses every 3 seconds at a distance of 5-10 cm from the sound source. The length of time of exposure is not clearly stated in the article. Exposure commenced within an hour of fertilization and larvae were sampled at seven intervals between 24 and 90 hours after fertilization. If the pulses occurred every 3 seconds for the entire 90 hour period, then the number of exposure pulses ranged from 28,800 (24 hours post-fertilization) to 108,000 (90 hours post-fertilization). Considering that results were collected in a tank not specifically designed for this type of experimentation, and that the number of close range exposures did not accurately reflect exposure conditions in the natural environment during seismic operations, the prediction that the residual effects of exposure to seismic sound on Arctic Surf Clams will be *not significant* remains valid.

SPECIFIC COMMENTS

Canada – Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB)

Specific Comment #1: § 1.0 Introduction, page 1 – the *Canada-Newfoundland Atlantic Accord Implementation Act* is incorrectly reference. It should be *Canada-Newfoundland and Labrador Atlantic Accord Implementation Act*. Please correct accordingly.

Response: "*Canada-Newfoundland Atlantic Accord Implementation Act*" in § 1.0 - Introduction should be revised to read "*Canada-Newfoundland and Labrador Atlantic Accord Implementation Act*".

Specific Comment #2: § 1.1 Relevant Legislation and Regulatory Approvals, page 1, first bullet – the *Canada-Newfoundland Atlantic Accord Implementation Act* is incorrectly referenced. It should be *Canada-Newfoundland and Labrador Atlantic Accord Implementation Act*. Please correct accordingly.

Response: Change "*Canada-Newfoundland Atlantic Accord Implementation Act*" in § 1.1 - Relevant Legislation and Regulatory Approvals to "*Canada-Newfoundland and Labrador Atlantic Accord Implementation Act*".

Specific Comment #3: § 2.2 Project Overview, page 6 –The maximum amount of 2D, 3D and/or 4D to be collected annually between 2017 and 2025 should be identified and included in the effects assessment.

Response: The maximum annual amounts of 2D and 3D seismic surveying between 2017 and 2025 are 30,000 km and 10,000 km^2, respectively.

Specific Comment #4: § 2.2.6 Seismic Energy Source Parameters, page 7 – The project description indicated a total volume of an airgun array ranging from 3,000-6,000 in^3 and the project was scoped as this range, but the EA Report has the upper limit as 8,000 in^3. Please clarify.

Response: During the period between submissions of the Project Description and the EA, Seitel decided it was necessary to increase the maximum value of total airgun volume. The official maximum value is 8,000 in^3.

C-NLOPB Reply to Seitel Response: Please confirm that the EA included the effects assessment of airgun arrays up to 8,000 in3.

NG Reply to Seitel Response to C-NLOPB Comment: The shifting of the gun size from a maximum of 6000 in3 to 8000 in3 is significant and should be reassessed within the EA.

Seitel Response to C-NLOPB and NG Replies: Seitel changes its official maximum air gun array volume to 6,000 in^3.

Specific Comment #5: § 2.2.7 Seismic Streamers, page 7 – Please identify the maximum streamer length and depth range in 2017-2025 for all proposed programs.

Response: The maximum streamer length and streamer deployment depth during 2017-2025 surveying are 16 km and 9-25 m, respectively.

Specific Comment #6: § 2.2.8 Ocean Bottom Nodes, page 8 – More information is required on the use of Ocean Bottom Nodes (PBNs) (e.g. maximum length of time on sea bottom), including effects assessment of this activity.

Response: Seitel proposes to use Ocean Bottom Nodes (OBNs) in conjunction with towed streamers for some of its seismic surveys during 2017-2025. The OBNs contain a single hydrophone and 3 geophones configured for multi-component acquisition and are not linked to one another via a cabled system. Each wireless OBN will have a footprint ranging between 0.20-0.25 m^2. These units are completely autonomous to operate on the seabed until retrieved and will be left unattended at any particular location for 30-40 days. Typically, about 1,000 OBNs are deployed in a 2D or 3D grid configuration on the sea bottom at any one time. Individual OBNs are typically spaced about 400 m apart. Therefore, the approximate area of an OBN grid will range from 125 to 155 km^2. The supply vessel will also serve as the platform for ROV operations. The OBNs can be deployed and retrieved by either Remotely Operated Vehicle (ROV) or rope.

The potential effects of the use of OBNs on the Fish and Fish Habitat VEC were assessed in the EA, specifically in § 5.7.4.2. Tables 5.2, 5.3 and 5.4 as well as text in this subsection refer to the assessment of OBN use.

The use of ocean bottom nodes (OBNs) will also potentially interact with the Fisheries VEC, specifically the fisheries that employ gear that make contact with the ocean bottom. Tables 5.5-5.7 of § 5.7.4.2 of the EA should also include rows specific to OBNs under the category '**Vessel/Equipment Presence'**. Given the small area of an OBN grid relative to the area of the entire Project Area and ongoing communication with commercial fishers and industry/DFO researchers, OBN use is predicted to have residual effects on the Fisheries VEC that are *negligible* to *low* in magnitude for a duration of *1-12 months* over a geographic area of *101-1,000* km^2. Based on these criteria ratings, the *reversible* residual effects of OBN use on the Fisheries VEC are predicted to be *not significant*. The level of confidence associated with this prediction is *high*.

Specific Comment #7: § 2.2.9 Gravity and Magnetic Surveys, page 8 – Although the potential to conduct gravity and magnetic surveys is identified here, they do not appear to have been included in the effects assessment.

Response: Gravity and magnetic surveys were indeed assessed in the EA. Interactions with the gravity and magnetic survey activity was indicated for the Marine-associated Bird VEC (Table 5.8), the Marine Mammal/Sea Turtle VEC (Table 5.11), and the Species at Risk VEC (Table 5.16). All assessment tables associated with these three VECs include the gravity/magnetic survey activity. The assessment summary table (Table 5.20 in § 5.10) also considers the gravity/magnetic survey activity.

Specific Comment #8: § 2.2.11 Waste Management, page 9 – Although it is stated that Seitel will follow MARPOL 73/78 Annex IV and Annex V for waste management, the effects assessment of this activity states that ".....garbage will be brought ashore". Please confirm the proposed approach to waste management.

Response: Any garbage generated will be collected and separated into items that are either dischargeable to the sea, non-dischargeable to the sea or reusable according to MARPOL 73/78 Annex IV and Annex V.

Specific Comment #9: § 2.3 Mitigation and Monitoring, page 10 – Will the fisheries compensation program be submitted with the application to conduct a geophysical program? Is there a fisheries compensation program already developed?

Response: A compensation program which is consistent with C-NLOPB guidelines and past practices will be made available by Seitel This program covers any damage to fishing gear or vessels caused by the survey vessel or survey gear, and includes the value of any harvest lost as a direct result of incident.

Specific Comment #10: § 2.4.1 Environmental Features, Figure 2.2, page 11 – The figure does not show Seitel's Project Area.

Response: For the purposes of Figure 2.2, there is no need to show the Seitel Project Area. Therefore, the figure caption should be changed to "Location of Seitel's Study Area Relative to Study Areas Associated with Relevant SEAs and EAs."

Specific Comment #11: § 2.5 Consultations, page 13, first two bullets – The results of consultation sessions with Labrador stakeholders should be provided.

Response: The report related to consultations conducted in Labrador is contained in Appendix 1 of this Addendum.

Specific Comment #12: § 2.7 Environmental Monitoring, page 14 – there seems to be a lot of description for the MMOs, see comment above with respect to § 2.2 Project Overview, and very little with respect to seabird observations. Both MMOs and SBOs are required and to add additional responsibilities to MMOs, dealing with seabird observations and stranded bird handling, may appear to be diminishing the importance of both observation programs. The C-NLOPB recommends there be a dedicated MMO and a dedicated Seabird Observer (SBO).

Response: With respect to LGL protocol, seabird observations are conducted 10 to 15 times daily, each observation period lasting 10 minutes. The seabird observations are conducted by an experienced MMO, during which time a second experienced MMO is observing for marine mammals and sea turtles. Therefore, marine mammal and sea turtle observations are continuous throughout the daytime period.

Specific Comment #13: § 5.9 Mitigation Measures and Follow-up, 2nd para, line 4, page 195 – Please see Section II of the Geophysical, Geological, Environmental and Geotechnical Program Guidelines (C-NLOPB 2012). It does not state that only "contacts with fishing gear with any identifiable markings" will be reported to the C-NLOPB. It states that "any incidents of contact with fishing gear" will be reported to the C-NLOPB.

Response: Seitel agrees that the text in question "Any contacts with fishing gear with any identifiable markings…" should be revised to read as follows: "Any incidents of contact with fishing gear…".

Specific Comment #14: § 5.9 Mitigation Measures and Follow-up, Table 5.19, page 196 – Please identify the proposed mitigation measure for the use of ocean bottom nodes in sensitive areas.

Response: As indicated in Table 5.3 regarding the Fish and Fish Habitat VEC, the mitigations associated with the deployment of OBNs include a relatively small footprint and a short deployment time. These two mitigations also apply to the Sensitive Areas VEC, depending on the primary characteristics of the 'sensitive area'. For example, if occurrence of corals is a primary reason for an area being categorized as 'sensitive', then the proponent will have to conduct sea bottom surveys prior to deploying any OBNs.

Fisheries and Oceans Canada (DFO)

Specific Comment #1: § 2.2.8 Ocean Bottom Nodes, page 8 – This section notes that the proponent plans to use cable less Ocean Bottom Nodes (OBNs) in conjunction with towed streamers during surveys planned for 2017–2025. From that description it is assumed that OBNs will not be deployed during surveys planned for 2016, this should be confirmed. It should also be noted that details relative to the OBNs sites (e.g. coordinates, benthic habitat substrates, water depth, presence of important benthic habitat features (e.g. sponge/corals, invertebrates species)) and description of potential impacts and mitigations of potential impacts of OBN deployment on benthic habitat will be provided in annual project EA Updates.

> ***Response:*** Seitel will not be deploying OBNs in its Project Area in 2016. If and when Seitel decides to use OBNs, physical and biological characteristics of the deployment area as well as descriptions of potential impacts and associated mitigations will be provided in the EA Update for that particular year.

Specific Comment #2: § 4.2 Fish and Fish Habitat VEC, page 42 - regarding the last sentence in this section "*….data gaps identified in the two SEAs are also discussed….*" the two SEAs should be identified as there are three SEAs referenced in this section.

> ***Response:*** The last sentence of the first paragraph of § 4.2 - Fish and Fish Habitat VEC should be changed from "Fish and fish habitat data gaps identified in the two SEAs are also discussed in terms of current status" to "Fish and fish habitat data gaps identified in the three SEAs are also discussed in terms of current status".

Specific Comment #3: § 4.2.2 Fish – Northern Shrimp 2nd sentence 1st paragraph, page 55 - the reference to "*…..snow crab…..*" in this sentence should be removed and replaced with "...northern shrimp…"

> ***Response:*** The reference to 'snow crab' in § 4.2.2 Fish – Northern Shrimp should be revised to 'northern shrimp'.

Specific Comment #4: §Section 4.2.3 Fish and Fish Habitat Data Gaps Identified in Relevant SEAs, page 61 - regarding the last sentence in this section *"Any new information that has been made available since the two SEAs were completed…"* there are three SEAs referenced in this section, as such the last sentence be amended to make reference to "*…three SEAs….*". Based on Section 5.2.2 of the Project EA Scoping Document it is not clear if (or how) the project EA has *"…described the relevance of such data gaps in the conduct of the EA"* this should be clarified.

> ***Response:*** The last sentence of § 4.2.3 - Fish and Fish Habitat Data Gaps Identified in Relevant SEAs should be changed from "Any new information that has been made available since the two SEAs were completed is noted throughout § 4.2" to "Any new information that has been made available since the three SEAs were completed is noted throughout § 4.2".

DFO Reply to Seitel Response: This comment was a two part comment while part 1 of the comment has been addressed the second part - "Based on Section 5.2.2 of the Project EA Scoping Document it is not clear if (or how) the project EA has …"described the relevance of such data gaps in the conduct of the EA this should be clarified" – has not been clarified or addressed.

> ***Seitel Response to DFO Reply:*** As per Section 5.2.2 of the Final Scoping Document provided by the C-NLOPB, Seitel has reviewed the data gaps indicated in the three SEAs 'vis a vis marine fish/fish habitat, species at risk, sensitive areas, and marine fisheries'. Seitel concludes that these data gaps still exist. More information related to the data gaps is available now but not in

sufficient quantity to entirely fill the data gaps. The filling these data gaps would most certainly increase the certainty of residual effects significance predictions in the EA.

Specific Comment #5: § 4.3.4 Traditional and Aboriginal Fisheries, page 61 – there are a number of sentences (e.g., 3rd sentence 1st paragraph, 1st sentence 2nd paragraph and 3rd sentence 4th paragraph) that incorrectly reference "….*DFO, Resource Management and Aboriginal Affairs*……" These sentences should be amended to refer to "…*DFO, Resource Management and Aboriginal Fisheries*….."

Response: All references to "DFO, Resource Management and Aboriginal Affairs" in § 4.3.4 - Traditional and Aboriginal Fisheries should be changed to "DFO, Resource Management and Aboriginal Fisheries".

Specific Comment #6: §Section 4.5.1 Marine Mammals, page 123 - Regarding Table 4.17, appropriate population names should be included for those species noted as being listed under *SARA* or by COSEWIC.

Response: Seitel notes that population names for those species with status under *SARA* and/or COSEWIC were not included in Table 4.17. This was a conscious decision to avoid overcrowding text in the table. Note that the 'populations' are discussed in the individual species' accounts. The population names in question are as follow:

Humpback whale – Western North Atlantic population;
Sei whale – Atlantic population;
Fin whale – Atlantic population;
Blue whale – Atlantic population;
Northern bottlenose whale – Scotian Shelf population; Davis Strait-Baffin Bay-Labrador Sea population;
Beluga whale – Ungava Bay population; Eastern Hudson Bay population;
Killer whale – Northwest Atlantic/Eastern Arctic population; and
Harbour porpoise – Northwest Atlantic population.

Specific Comment #7: § 4.6 Species at Risk, page 135 - regarding the last sentence in this section "*Relevant data gaps identified in the two SEAs are also discussed…"* there are three SEAs referenced in this section, as such the last sentence should be amended to make reference to "…*three SEAs*….". or the two referenced SEAs should be identified in the sentence accordingly.

Response: The last sentence of the first paragraph of § 4.6 – Species at Risk should be changed from "Relevant data gaps identified in the two SEAs are also discussed in terms of current status" to "Relevant data gaps identified in the three SEAs are also discussed in terms of current status".

Specific Comment #8: § 4.7 Sensitive Areas, page 142 – This section should be amended to include reference to the approximately 60 km^2 Gilbert Bay Marine Protected Area (MPA) located on the southeast coast of Labrador in NAFO Subdivision 2J which was formally designated in 2005 to conserve and protect Gilbert Bay cod and its habitat.

Response: The Gilbert Bay MPA is located about 300 km from Happy Valley-Goose Bay on Labrador's southeast coast. The bay is 20 km long, has <100 m water depth, and has two narrow outlets to the open ocean, one at Williams Harbour Run and the other at Winard Tickle. This results in Gilbert Bay's semi-isolation from the Labrador Sea. Delineation of the Gilbert Bay MPA is based on the annual migration of the Gilbert Bay cod (DFO website; accessed May 2016).

The following figure (Figure 1) is a revised version of Figure 4.32 in the EA. It includes the Gilbert Bay MPA.

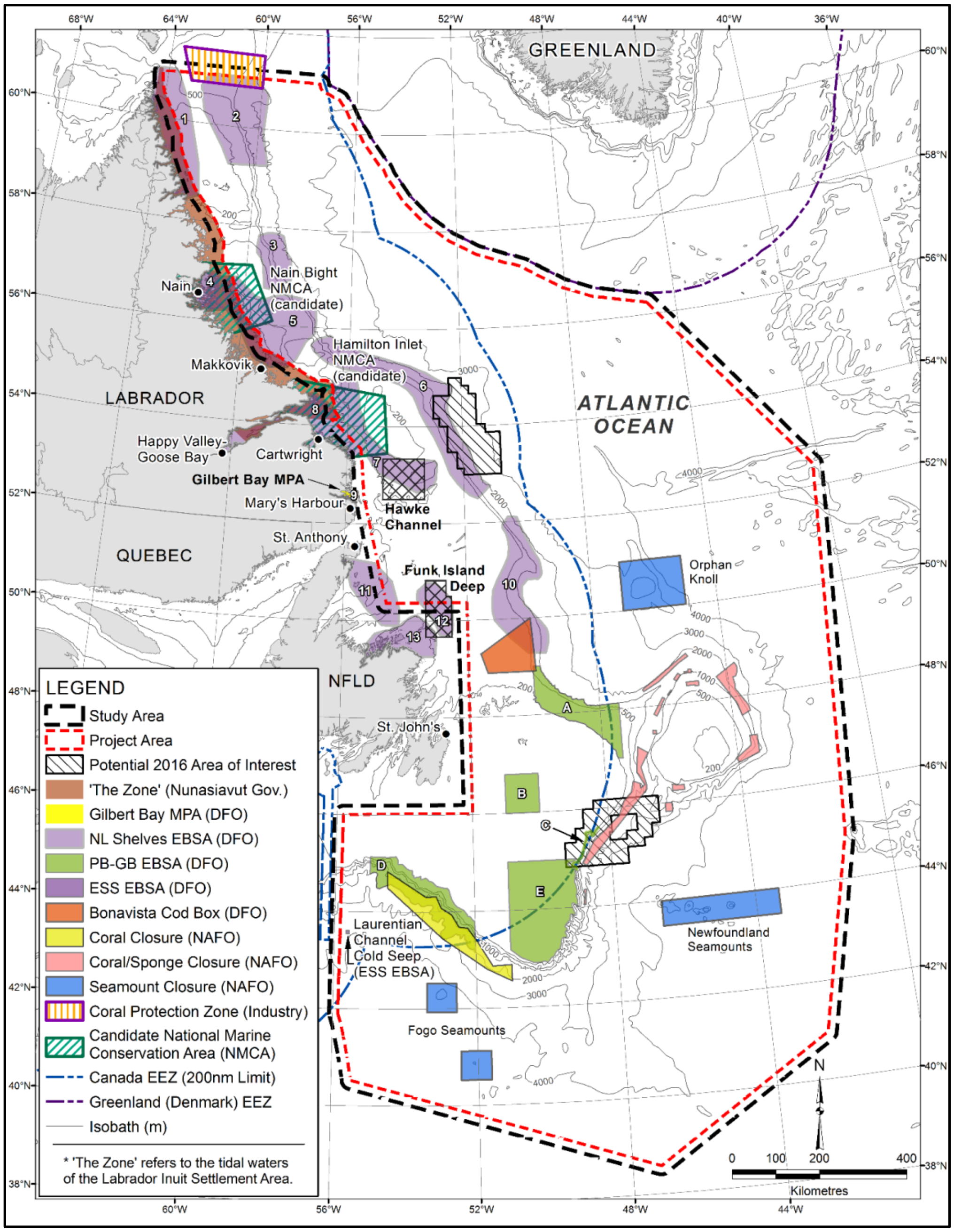

Figure 1. Locations of Sensitive Areas that Overlap the Seitel Study Area.

Specific Comment #9: § 5.5 Mitigation Measures, page 149 – the 4th bullet should also include reference to the *Species at Risk Act*. This section should also note that the *Marine Mammal Regulations (MMR)* under the *Fisheries Act* is currently undergoing amendment. While public consultation on proposed amendments have only just recently ended it should be noted that Schedule 11 of the proposed amended *MMR* provide approach distances for marine mammals based on species, vehicle (vessel, aircraft, etc.), area and timing. Given that the proposed seismic survey(s) are scheduled to run from 2016 to 2025 it is recommended that the proponent be aware of any potential implications that may arise if any proposed amendments to *MMR* are accepted during the timeframe covered by the proposed survey program.

> ***Response:*** The addition of a reference to the *Species at Risk Act* and indication of ongoing amendment of the Marine Mammal Regulations under the *Fisheries Act* are noted by Seitel. The program will comply with all regulations and future amendments.

Specific Comment #10: § 5.7.4 Fish and Fish Habitat VEC, page 154 – as described in Section 2.2.8 the proponent has noted plans to deploy up to 10,000 OBNs within survey areas in conjunction with the deployment of hydrophone streamers. The OBNs will be placed on the sea floor in as yet unknown or unspecified locations. To indicate in the 2nd sentence of this section that *"The seismic program will not result in any direct physical disturbance of the bottom substrate"* is not entirely accurate and not in keeping with information presented in Table 5.2 and Vessel/Equipment Presence (page 159). This sentence should be amended accordingly.

> ***Response:*** The sentence *"The seismic program will not result in any direct physical disturbance of the bottom substrate"* in § 5.7.4 - Fish and Fish Habitat VEC should be removed from the text.

Specific Comment #11: § 5.7.4.1 Sound, pages 156-157 – The 2nd sentence 5th paragraph (page 156) which notes that "*Available experimental data suggest that there may be physical impacts on the fertilized eggs of snow crab and on the egg, larval, juvenile and adult stages of cod at very close range*" requires an appropriate reference. The 1st sentence 2nd paragraph (page 157) which notes that "*Snow crab, thought to be sensitive to the particle motion component of sound only...*" requires an appropriate reference and since this is the first mention of particle motion a definition / description should be provided. The 1st sentence 4th paragraph (page 157) which notes that "*The physical effects of exposure to sound with frequencies >500 HZ are negligible, based on the available information from the scientific literature*." requires an appropriate reference.

> ***Response:*** The statements and associated references, and the definition of particle motions are provided below.
>
> "*Available experimental data suggest that there may be physical impacts on the fertilized eggs of snow crab and on the egg, larval, juvenile and adult stages of cod at very close range*" (Booman et al. 1996; Christian et al. 2003; Sierra-Flores et al. 2015).
>
> "*Snow crab, thought to be sensitive to the particle motion component of sound only*" (Popper et al. 2001).
>
> Particle motion is the component of underwater acoustic stimuli generated partly by hydrodynamic flow near the acoustic stimulus source and partly by the oscillations associated with the sound pressure waves as they propagate from the acoustic source as a cyclic compression and rarefaction of water molecules (Higgs et al. 2006).
>
> "*The physical effects of exposure to sound with frequencies >500 HZ are negligible, based on the available information from the scientific literature*." This statement is based on several studies in the literature. Most fishes and invertebrates appear to be most sensitive to very low frequency

sound (i.e., <500 Hz). Under natural conditions, the physical effects of exposure to anthropogenic sound with frequencies <500 Hz appear to be *negligible*. Even less physical effect has been observed after exposure to the higher frequency sound.

Specific Comment #12: § 5.7.4.1 Sound (Fish and Fish Habitat VEC) (page 154-157) – this section should include a short summary discussion (similar in detail to that provided for physical effects) of the potential behavioural effects in fish in relation to seismic sound (*e.g.* startle response; change in swim speed, depth and direction; schooling; reproduction; recruitment; feeding) that are reported in literature including among others - Popper and Hawkins 2012 Advances in Experimental Medicine and Biology Vol 730 - and other project EAs and applicable SEAs. This will also provide support to the linkage to the discussion on effects of seismic sound on Fisheries VEC presented in Section 5.7.5.1 of the EA Report.

> ***Response:*** Studies suggest that effects on fish behaviour due to exposure to airgun sound are temporary in nature, and that response thresholds for various demersal and pelagic species are quite variable. Numerous studies have reported startle/alarm responses by fish (Pearson et al. 1992; Fewtrell and McCauley 2012). Pearson et al. (1992) also reported observations of localized distributional shifts, tightening of schools, and random movement and orientation. Løkkeborg et al. (2012) reported differences between species in terms of catchability after being exposed to seismic sound. They observed higher catches in gill nets but lower catches on baited hooks, possibly resulting from increased random movement by the fish causing a higher incidence of fish being caught up in gill nets but a lower incidence of fish targeting baited hooks. There is some thought that the degree of behavioural response by fishes to exposure to anthropogenic sounds such as seismic airgun sound depends on what natural behaviour the fish is exhibiting at the time of exposure. For example, fish exhibiting reproductive and/or feeding behaviour may have a higher response threshold to anthropogenic sound than fish exhibiting migratory behaviour. More study is obviously required to test this hypothesis. A more comprehensive discussion regarding the behavioural effects of exposure to seismic sound on fishes is contained in the appendices of recently completed seismic EAs (e.g., LGL 2015a,b).

DFO Reply to Seitel Response: The response is acceptable, however, rather than refer readers to an appendix in another seismic project EA for a "…more comprehensive discussion…" it is felt that the discussion should be provided (as an appendix) within the Seitel EA.

> ***Seitel Response to DFO Reply:*** Seitel has appended a literature review of the potential behavioural effects of exposure to seismic sound on fishes (see Appendix 2).

Specific Comment #13: § 5.7.4.2 Vessel/Equipment Presence, page 159 – Although OBN use is predicted to have negligible / non-significant impacts on fish and fish habitat VECs it is felt (see above comment on Section 2.2.8) that subsequent annual project EA Updates should provide details relative to OBNs deployment (e.g. site coordinates, benthic habitat / substrate, water depth, presence of important benthic habitat features (e.g. sponge/corals, invertebrates species)) and any associated updated description of potential impacts and mitigations of potential impacts of OBN deployment on fish, fish habitat and sensitive areas. It should be clarified (either here or later in Section 5.7.9 Sensitive Areas VEC page 192) whether OBNs will be placed in sensitive marine areas and to what extent such placement is in keeping with regulations, accepted practices, restrictions and/or guidelines which may be in place governing activity within NAFO coral closure areas and/or other marine sensitive areas.

> ***Response:*** Seitel will not be deploying OBNs in its Project Area in 2016. If and when Seitel decides to use OBNs, physical and biological characteristics of the deployment area as well as descriptions of potential impacts and associated mitigations will be provided in the EA Update for that particular year. As indicated in Table 5.3 regarding the Fish and Fish Habitat VEC, the mitigations associated with the deployment of OBNs include a relatively small footprint and a short deployment time. These two mitigations also apply to the Sensitive Areas VEC, depending on the primary characteristics of the 'sensitive area'. For example, if occurrence of corals is a primary reason for an area being categorized as 'sensitive', then the proponent will have to conduct sea bottom surveys prior to deploying any OBNs.

DFO Reply to Seitel Response: This comment was also a two part comment and while the response clarifies whether OBNs will be placed in sensitive marine areas, the response does not clarify the second part of the comment that being "…and to what extent such placement is in keeping with regulations, accepted practices, restrictions and/or guidelines which may be in place governing activity within NAFO coral closure areas and/or other marine sensitive areas…"

> ***Seitel Response to DFO Reply:*** Seitel has contacted both NAFO in Dartmouth, NS and DFO in St. John's, NL. NAFO indicated that should Seitel plan to deploy OBNs in any of its Vulnerable Marine Ecosystem (VME) closure areas, then NAFO should be informed of the intention. While NAFO does not have the authority to prohibit Seitel from deploying OBNs in any of the VME closure areas, it would like to know some details of the operation. As for the deployment of OBNs in Marine Protected Areas (MPAs), Areas of Interest (AOIs) and Ecologically and Biologically Significant Areas (EBSAs), Seitel will have to complete an application to do so within established MPAs. DFO will review the application and provide a decision. There are not any legal requirements associated with the deployment of OBNs in either EBSAs or AOIs. However, DFO would still like to be informed should Seitel intend to make deployments in EBSAs and AOIs.

C-NLOPB Reply to Seitel Response: If the proponent plans to use OBNs in conjunction with towed streamers during surveys planned for 2017 – 2025 then the potential impacts of this activity should be included in the EA. The purpose of an EA Update is not to provide an assessment of potential impacts of new activities but to confirm that the proposed program activities fall within the scope of the previously assessed program and to validate EA predictions.

> ***Seitel Response to DFO Reply:*** Seitel confirms that the potential impacts of OBN use in conjunction with towed streamers during surveys planned for 2017 – 2025 have been assessed in the EA. Seitel notes that an EA Update is not meant to provide an assessment of potential impacts of new activities but rather to confirm that the proposed program activities fall within the scope of the previously assessed program and to validate EA predictions.

Specific Comment #14: § 5.7.7.1 Sound, Marine Mammals and Sea Turtle VEC, pages 174 and 175 – with respect to the discussion of Masking while it is safe to say (see 2nd sentence on page 175) that "*Based on past and current reviewed research, the potential for masking of marine mammal calls and/or important environmental cues is considered low….*" It is felt that this section should provide a short summary (similar to that provided on pages 175 and 176 for Disturbance, Hearing Impairment and Non Auditory Physical Effects) of some of the potential effects on masking that are provided within among others Erbe *et al* 2015 and Guan *et al* 2015.

Response: The following text provides a summary of the potential effects of masking.

"Masking is the obscuring of sounds of interest by interfering sounds, generally at similar frequencies. Introduced underwater sound will, through masking, reduce the effective communication distance of a marine mammal species if the frequency of the source is close to that used as a signal by the marine mammal, and if the anthropogenic sound is present for a significant fraction of the time (Richardson et al. 1995; Clark et al. 2009). Conversely, if little or no overlap occurs between the introduced sound and the frequencies used by the species, communication is not expected to be disrupted. Also, if the introduced sound is present only infrequently, communication is not expected to be disrupted much if at all. The biological repercussions of a loss of communication space, to the extent that this occurs, are unknown.

The duty cycle of airguns is low; the airgun sounds are pulsed, with relatively quiet periods between pulses. In most situations, strong airgun sound will only be received for a brief period (<1 s), with these sound pulses being separated by at least several seconds of relative silence, and longer in the case of deep-penetration surveys or refraction surveys.

Although masking effects of pulsed sounds on marine mammal calls and other natural sounds are expected to be limited, there are few specific studies on this. Some whales continue calling in the presence of seismic pulses and whale calls often can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999a,b; Nieukirk et al. 2004, 2012; Smultea et al. 2004; Holst et al. 2005a,b, 2006, 2011; Dunn and Hernandez 2009; Broker et al. 2013; Cerchio et al. 2014). However, some of these studies found evidence of reduced calling (or at least reduced call detection rates) in the presence of seismic pulses (Clark and Gagnon 2006; Blackwell et al. 2013). Di Iorio and Clark (2010) found that blue whales in the St. Lawrence Estuary increased their call rates during operations by a lower-energy seismic source. There is some evidence that fin whale song notes recorded in the Mediterranean had lower bandwidths during periods with versus without airgun sounds (Castellote et al. 2012).

Among the odontocetes, there has been one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994). However, more recent studies of sperm whales found that they continued calling in the presence of seismic pulses (Madsen et al. 2002; Tyack et al. 2003; Smultea et al. 2004; Holst et al. 2006, 2011; Jochens et al. 2008). Dolphins and porpoises are also commonly heard calling while airguns are operating (Gordon et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b, 2011; Potter et al. 2007). Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocetes, given the intermittent nature of seismic pulses plus the fact that sounds important to them are predominantly at much higher frequencies than are the dominant components of airgun sounds.

Pinnipeds have best hearing sensitivity and/or produce most of their sounds at frequencies higher than the dominant components of airgun sound, but there is some overlap in the frequencies of the airgun pulses and the calls. However, the intermittent nature of airgun pulses presumably reduces the potential for masking.

Some cetaceans are known to increase the source levels of their calls in the presence of elevated sound levels, shift their peak frequencies in response to strong sound signals, or otherwise modify their vocal behaviour in response to increased noise (Dahlheim 1987; Au 1993; reviewed in Richardson et al. 1995:233*ff*, 364*ff*; also Lesage et al. 1999; Terhune 1999; Nieukirk et al. 2005; Scheifele et al. 2005; Parks et al. 2007a,b, 2009, 2011; Hanser et al. 2009; Holt et al. 2009; Di Iorio and Clark 2010; McKenna 2011; Castellote et al. 2012; Melcón et al. 2012; Risch et al. 2012; Tyack and Janik 2013). It is not known how often these types of responses occur upon exposure to airgun sounds."

Specific Comment #15: § 5.7.7.1 Sound (Marine Mammals and Sea Turtle VEC) Hearing Impairment, page 176 – Regarding the 2nd sentence of the 4th paragraph examples of the "*Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals and sea turtles occurring near the airgun array*" should be provided either here or more likely in the discussion of project mitigations and monitoring (Sections 5.5 and 5.9). If monitoring other than visual monitoring of the 500 m safety zone is planned then the EA Report (e.g. Sections 5.5 and/or 5.9) should specify same and a linkage provided in the above noted 4th paragraph.

Response: Only visual monitoring is planned. The aspects of the monitoring and mitigation plan include the use of trained and experienced MMOs, the use of the ship's bridge for MMOs from which to conduct observations (i.e., good sight lines all around the vessel), and the use of reticle binoculars and other distance estimators to accurately estimate the location of the animal with respect to the safety zone.

Specific Comment #16: § 5.9 Mitigation Measures and Follow up, pages 195-197 – the 3rd and 4th sentences of the 1st paragraph on page 197 note that *"...observers will watch for marine mammals and sea turtles when the air gun array is active .."and* that *"…the array will be shut down whenever endangered and/or threatened marine mammals or sea turtles are sighted within the safety zone"*. That being said it is not clear what measures will be employed to monitor for *SARA* listed endangered and/or threatened mammals and sea turtles during periods of darkness and/or low visibility. This should be clarified accordingly.

Response: No additional measures are employed during these periods.

Nunatsiavut Government (NG)

Specific Comment #1: § 5.1.1.1 Seitel's Consultation Approach, page 144 - The language regarding consultation in this section is unclear. The section states that Seitel will consult with stakeholders after the survey is permitted, but also states that before permitting that there will be discussions regarding issues and concerns, communications, and mitigations. Please clarify the difference between the 'consultation meetings' and the meetings prior to the permitting process. In addition, please clarify what will be reported to the stakeholders within the follow-up communications after each project is completed. Please clarify how a monitoring plan will be developed and incorporated into this reporting prior to the approval of the environmental assessment.

Response: As stated in § 5.1.1.1 of the EA, Seitel's approach to consultation on marine seismic projects is to consult with relevant agencies, stakeholders and rights-holders (e.g., beneficiaries) before onset and during the seismic program, preferably through face-to-face meetings. Seitel has completed its 'before project onset' consultations and reports are appended to both the EA (in Newfoundland) and this Addendum document (in Labrador). Seitel will also communicate aspects of the program during its implementation, including but not limited to, marine mammal observation reports, sea bird counts, information related to commercial fishing, operational plans and activities.

A stand-alone monitoring plan per se is not typically required for environmental assessments of proposed geophysical programs. Types of monitoring that are typically included in geophysical program EAs are the employment of marine mammal/seabird observers (MMOs/SBOs) to monitor marine mammals and seabirds in the general vicinity of operations, and employment of Fisheries Laison Officers (FLOs) to monitor commercial fishing/fishing gear/fishing vessels in the general vicinity of operations. Field reports are prepared and submitted for all of these monitoring activities.

Specific Comment #2: § 5.5 Mitigation Measures, pages 149 and 150 - this section states that the mitigation measures will "be adhered to during each survey year, with necessary adjustments based on monitoring and follow-up." It is common practice to provide the environmental and mitigation monitoring plan within the environmental assessment. This is not included. Please clarify the type of monitoring plans that will be included prior to the approval of the environmental assessment and the consultation that will occur prior to the completion of the monitoring plans.

Response: A stand-alone monitoring plan per se is not typically required for environmental assessments of proposed geophysical programs. Types of monitoring that are typically included in geophysical program EAs are the employment of marine mammal/seabird observers (MMOs/SBOs) to monitor marine mammals and seabirds in the general vicinity of operations, and employment of Fisheries Liaison Officers (FLOs) to monitor commercial fishing/fishing gear/fishing vessels in the general vicinity of operations. Field reports are prepared and submitted for all of these monitoring activities.

There will be full opportunity for adaptive mitigation during the 10-year program. Seitel will be required to prepare an EA Update document prior to commencing activities in any given year. The Update document will include new relevant information that was unavailable during preparation of the previous program document(s). If there are any new techniques developed during the 10-year period that may help to further mitigate environmental effects, they will be investigated and incorporated into the program if deemed useful.

Specific Comment #3: § 5.7.7.1 Sound, pages 173 to 184 - this section should distinguish between difference classes within species (e.g. cow calf pairs) as well as providing references with regards to the conclusions of only localized and short-term effects for cetaceans and marine turtles. The Strategic Environmental Assessment for the Labrador Shelf Offshore Area states that there is limited information regarding cetaceans and marine turtles in the assessment area, leading to data constraints and uncertainty of impacts.

Response: The amount of available information does not enable the assessment to distinguish between social contexts within species (e.g., cow-calf pairing vs single animal). References for conclusions presented are provided in previous SEAs and EAs that are referenced in the current EA. As requested in the Scoping Document, only new information is cited in the EA. The uncertainty of the impact is reflected in the *medium* levels of confidence attributed to certain project activities (see Tables 5.12 and 5.15).

Specific Comment #4: § 5.7.8 Species at Risk VEC, pages 187 to 192 - An environmental assessment is meant to show the assessor the specifics behind conclusions of significant impacts. This section should clarify the ways that the "potential effects of activities associated with Seitel's proposed seismic program are not expected to contravene the prohibitions of *SARA* (§ 32(1), 33, 58(1))." There is no description of the prohibitions within *SARA* and how each will not be contravened.

> ***Response:*** Conclusions made in § 5.7.8 of the EA regarding the significance of effects of the proposed project activities on the Species at Risk VEC are based on the rationales provided earlier in the EA with respect to the Fish and Fish Habitat VEC, the Fisheries VEC, the Marine-associated Bird VEC and the Marine Mammal/Sea Turtle VEC. For all of these VECs, it was predicted that the residual effects on them as a result of the proposed project activities would be *not significant*. LGL concludes that the potential effects of activities associated with Seitel's proposed seismic program are predicted to not contravene the prohibitions of the *SARA* sections 32(1) [Killing, harming, etc., listed wildlife species], 33 [damage or destruction of residence], and 58(1) [Destruction of critical habitat].

Specific Comment #5: § 5.9 Mitigation Measures and Follow-up, pages 195 to 197 – this section outlines the mitigation measures in regards to a marine mammal or sea turtle occurrences within 500m of the array. Please clarify if 500 m will be used as a minimum standard as recommended by the Statement of Practice and cited in Section 2.2. Please also further define scenarios within marine mammal mitigation with regards to what happens in low visibility and outline the discretion that MMOs have within the shutdown process.

> ***Response:*** Five hundred metres will be used as a minimum standard. In accordance with other seismic monitoring programs offshore Newfoundland and Labrador, no additional measures apply during periods of low visibility. MMOs have full authority to declare a shutdown. Highly experienced MMOs are needed on seismic vessels in order to accurately identify marine mammals to the species level, be aware of the status of species and the associated shutdown requirements, and to accurately estimate the distance of 'shutdown' species from the vessel using the best available tools.

NG Reply to Seitel Response: The proponent states that 500m will be the minimum standard for a safety zone shut down.

Question: What other standards will be used for other situations? Will they be applied to high-probability habitat? A monitoring plan could assess the amount of time spent in high probability habitat in low visibility and aid in future planning to decrease potential impacts.

> ***Seitel Response to NG Reply:*** Seitel will use a 500 m radius safety zone during its seismic surveying in offshore Newfoundland and Labrador until it is told otherwise.

Specific Comment #6: § 5.9 Mitigation Measures and Follow-up, page 195 - "commits to ongoing communications with other operators with active seismic programs within the general vicinity of its seismic program to minimize the potential for cumulative effects on VECs." Please clarify how these reports will be incorporated into the monitoring program and reported within the post-season follow-up.

> ***Response:*** Seitel plans to conduct Simultaneous Operations (SIMOPS) with any ongoing geophysical and fishing/research surveys that may be conducted within the same area at the same

time as the seismic program. To establish a temporal and spatial separation plan, it is imperative that detailed temporal and spatial information regarding seismic and fishing/research surveying operations be exchanged between the various parties.

Fish, Food and Allied Workers (FFAW/Unifor)

Specific Comment #1: § 5.1.1.2 Program Consultations, page 146 - FFAW/Unifor should be used consistently.

> ***Response:*** Seitel notes that the abbreviation for Fish, Food and Allied Workers should consistently be FFAW/Unifor.

Specific Comment #2: § 5.7.4.1 Sound, pages 156-157 - "In the case of eggs and larvae, it is likely that the numbers negatively affected by exposure to seismic sound would be negligible when compared to those succumbing to natural mortality," is a very strong statement to make. It is noted that LGL identifies and acknowledges the data gaps existent in this base of knowledge and that "available experimental data suggest that there may be physical impacts on the fertilized eggs of snow crab and on the egg, larval, juvenile and adult stages of cod at very close range." Therefore, the former statement is problematic as a sound knowledge set to back the statement up is lacking. Likewise, stating that spatial and temporal avoidance of key life stages, as well as ramp-up procedures, should mitigate these effects is unsatisfactory when we do not know the effects of seismic activity on these species.

Similarly, the sentence that, "Limited data regarding physiological impacts on fish and invertebrates indicate that these impacts are both short-term and most obvious after exposure at close range," states the key issue – "limited data." Until a more thorough examination has been made and conclusions have been agreed upon we cannot be sure that effects are indeed short-term.

> ***Response:*** As is stated in the EA, the predictions made about the effects of seismic activities on VECs are based on what is currently available in the literature, both primary and grey, and on professional judgement. As is the case with all things scientific, there is never too much data. Every year there is more scientific evidence added to the databases related to the potential effects of exposure to seismic airgun sound on marine biota. Over time, the degree of certainty associated with the effects predictions will heighten as more and more data become available.

Specific Comment #3: § 5.7.5.1 Sound, page 163 - "While some of the behavioural effects studies report decreases in catch rates near seismic survey areas, there is some disagreement on the duration and geographical extent of the effect," highlights one of our key concerns with seismic activity in commercial fish harvesting areas. As there has not yet been agreement on the effects of seismic on catch rates we reiterate that activity should not occur when harvesting is taking place, nor during key research times.

> ***Response:*** Seitel notes the FFAW/Unifor stance that paucity of study data related to the behavioural effects of exposure to seismic sound on fishes should result in no seismic surveying activity during either harvesting or key research times.

Specific Comment #4: Appendix A, page A-2/A-3 - We would like to once again stand by our Membership in that the southernmost potential area for survey, including the Carson Canyon, are to be avoided by seismic activity as these are very important snow crab harvesting grounds. Members in attendance at consultation stressed that they will not allow seismic activity in these areas and we are supportive of this stance.

Response: Seitel notes that there was discussion about this particular area during consultations and that the FFAW/Unifor are against any seismic surveying activity in that area.

Specific Comment #5: Appendix A, page A-7 - Johan Joensen is incorrectly identified as Petroleum Industry Liaison. Robyn Lee was the Petroleum Industry Liaison at time of consultation, not Johan Joensen as identified.

Response: Seitel notes that Robyn Lee was the Petroleum Industry Liaison (PIL) at the time of consultation, not Johan Joensen.

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Appendix 1

Labrador Consultations Report

Labrador Industry and Agency Consultations for the Seitel Canada Ltd. (Seitel) East Coast Offshore Seismic Program, 2016-2025

As part of the environmental assessment of Seitel Canada Ltd.'s proposed 2016-2025 seismic program, consultations were undertaken with relevant Labrador government agencies, representatives of the fishing industry and other interest groups. The objectives of these consultations were to describe the proposed seismic program, identify any issues and concerns, and gather additional information relevant to the EA process.

A summarized description of the proposed program, including program location map, was sent to the relevant agencies and industry stakeholder groups in December 2015. They were asked to review this information, provide any comments on the proposed activities, and indicate whether or not they would like to meet to discuss the proposed program in more detail. Additional contacts were made in January and February 2016.

During the period of February 29-March 7, 2016, both face-to-face meetings and public information sessions were held in three Labrador communities: (1) Mary's Harbour; (2) Happy Valley-Goose Bay; and (3) Nain. Table 1 provides more information on these consultations.

Table 1. Labrador Consultations.

Date	Community	Type of Consultation	Consultee
February 29, 2016	Mary's Harbour	Face-to-Face	Labrador Fishermen's Union Shrimp Company Ltd. (LFUSCL)
February 29, 2016	Mary's Harbour	Public Information Session	Public
March 1, 2016	HV-GB	Face-to-Face	Torngat Secretariat
March 1, 2016	HV-GB	Face-to-Face	Torngat Joint Fisheries Board
March 2, 2016	Nain	Face-to-Face	Nunatsiavut Government
March 2, 2016	Nain	Public Information Session	Public
March 3, 2016	Nain	-	-
March 4, 2016	Nain	-	-
March 5, 2016	HV-GB	-	-
March 6, 2016	HV-GB	-	-
March 7, 2016	HV-GB	Face-to-Face	Innu Nation
March 7, 2016	HV-GB	Face-to-Face	NunatuKavut Community Council (NCC)
March 7, 2016	HV-GB	Public Information Session	Public

Issues and Concerns

Comments and responses received to date from various stakeholders are provided below.

Mary's Harbour

Labrador Fishermen's Union Shrimp Company Ltd. (LFUSCL)

LFUSCL's Fisheries Advisor attended the consultation meeting with Seitel. He expressed concern about the Hawke Channel DFO Fisheries Closure Area and Seitel confirmed that no seismic activity would occur in this area. The LFUSCL representative also expressed concern about the temporal overlap of seismic surveying and the snow crab fishery season. He indicated that the snow crab fishery season typically wraps up by the end of July. Seitel confirmed that they would attempt to avoid overlap with fisheries as much as possible through early planning and good communication, both prior to and throughout the seismic program. It was also noted that the Fisheries Liaison Officer (FLO) for the program should be from Labrador, at least for the portion of the program occurring offshore Labrador.

Public Information Session

Following a presentation by Seitel's representative, attending fishers had comments and questions.

One fisher asked how far offshore the program would be conducted. Seitel showed a figure of the Project Area proposed for 2016.

Another fisher raised the point that since there were older geophysical data gathered in the 1980s, would some of those data be available for Seitel's use? Seitel explained that the quality of the data associated with programs conducted in the 1980s had relatively poor resolution compared to those currently being collected.

Seitel stated that no seismic surveying would be conducted in the Hawke Channel DFO Fisheries Closure Area.

Fishers noted that they would like to have local people on the seismic vessel acting as FLO. Seitel confirmed that they would have a FLO on the vessel as requested by the Fish, Food and Allied Workers Union (FFAW-Unifor). It was indicated that local fishers should contact the FFAW-Unifor to express their interest in having local people serve as FLOs offshore Labrador.

One fisher indicated that while working on a trawler on the Grand Banks in either 2010 or 2011, a seismic program was being conducted and the shrimp disappeared that season. He also expressed concern about Greenland halibut (turbot) that is being fished in offshore Labrador in areas where water depths range from 500 to 600 m. Seitel acknowledged the concern and indicated that no scientific research to date has indicated that seismic activity is linked to reductions in shrimp catches.

Happy Valley-Goose Bay

Torngat Secretariat and Torngat Joint Fisheries Board

Following Seitel's presentation, representatives of the Torngat Secretariat and the Torngat Joint Fisheries Board offered several comments. In general, it was acknowledged that the program was similar to other recent seismic programs offshore Labrador. However, the Ocean Bottom Node (OBN) component is novel for the area and discussion subsequently focused on this technology. Additional questions/comments from the representatives and Seitel's responses are provided below:

Question: What are the dimensions of the OBNs?
Response: They are about 18 inches in diameter and 4 to 6 inches in height.

Question: Do they lose many OBNs?
Response: The loss of OBNs is not typical. Something would have to hook an OBN and drag it away.

Question: Would an OBN survey cover a smaller area than traditional seismic?
Response: Yes, OBN surveys are typically conducted after 2D and/or 3D surveys. The cost associated with an OBN survey is about three times the price of a regular seismic survey.

Question: What are the depth limitations of OBNs?
Response: The depth limitation of OBNs is 3,000 metres. At that depth, the battery life of a unit is about 45 days.

Question: Can Seitel schedule its OBN activities around fishing operations?
Response: Yes, it would be necessary in order to avoid losing OBNs.

Question: Is there any flexibility in the OBN survey scheduling? It is important for people to know when and where the survey is taking place.
Response: Yes, there is some flexibility. Seitel also noted that OBN surveys are usually concentrated on a smaller spatial footprint than typical seismic surveys, especially large-scale 2D seismic surveys.

Question: Does Seitel feel that there is more market interest here than out in western Canada right now?
Response: Yes, this is why we are proposing this program.

Question: Do you rent your vessels?
Response: Yes, Seitel rents the vessels for the survey period and does not plan to own any vessels at this time.

Question: Are the vessels you use specifically fitted for this type of work?
Response: Yes.

Question: Are clients using existing data to provide focus on potential OBN surveys?
Response: Yes.

Question: Will Seitel be using local people to serve as observers during the program?
Response: Yes, just as in other geophysical programs recently conducted offshore Labrador.

Innu Nation

Following Seitel's presentation, the Innu Nation representative expressed general concerns about the effects of seismic exploration on wildlife such as fish, seabirds and marine mammals. Seitel summarized the body of knowledge on the effects of seismic exploration on wildlife, as detailed in the EA.

NunatuKavut Community Council (NCC)

NCC representatives provided questions and comments on the program. The majority of comments were related to the environmental assessment process and how it relates to the C-NLOPB's Labrador Shelf Strategic Environmental Assessment (SEA), the role of consultations in the EA and SEA processes, and the potential impact of seismic exploration on local wildlife. There were also concerns regarding the number of seismic operators offshore Labrador and the potential for cumulative effects.

Additional questions/comments from the NCC representatives and Seitel's responses are provided below:

Comment: The consultation process was insufficient during the Labrador Shelf SEA process. The SEA did not protect the NCC's values and interest.

Comment: The NCC has a significant interest with coastal operation. The program Study Area extends to the shoreline of southeastern Labrador, unlike further north where "the Zone" is excluded".

Seitel suggested that the NCC provide them with either a digital GIS layer or a general outline of coastal areas that they consider sensitive to their membership. Seitel could then determine whether or not these areas overlap with planned survey areas and subsequently consider modifying plans to avoid certain coastal areas. This suggestion was also repeated to the NCC via email on March 14, 2016, following the face-to-face meeting. As of May 18, 2016, nothing in this regard has been provided to Seitel.

Comment: The NCC wants to deploy an observer on the seismic vessel to represent the NCC and protect local interests. The observer would then be able to return to the communities and report observations.

Comment: The NCC doesn't know what happens after a survey season ends. There has not been any provision of post-program feedback.

Seitel is interested in discussing the possibility of presenting some of the survey results after completion of a field season. Another possibility is that Seitel would provide the Marine Mammal Monitoring report directly to the NCC since the C-NLOPB does not make these mandatory reports available through their website.

Question: Could you drag the sound source closer to the seafloor in order to minimize sound in the water column?

Response: No. The problem with towing the sound source at depth is that it's difficult to ensure that the sound source is at the desired position for each seismic pulse because of water currents at depth and the increased distance between the source and the vessel.

Question: What is the spatial footprint of a typical 3D seismic vessel? How far do the streamers go?

Response: Typically, the streamer footprint can be 1.5 km in width and 6-12 km in length.

Question: Can the seismic data be used for anything else than oil and gas exploration?

Response: Not really. The data that Seitel would collect in offshore Labrador would not serve any other purpose than assessing the suitability of the region for oil and gas exploration/exploitation.

Comment: We have some concerns about content in EAs and SEAs as it relates to impact on local wildlife, but mainly we have concerns with the assessment process. We want the process to respect our interest. The NCC would like to be involved in community consultations with its members as part of building relationships between its members and offshore operations.

Seitel offered to return after completion of a survey and discuss the program with the NCC and its members, perhaps at a yearly NCC meeting with its membership. On March 14, 2016, Seitel provided the NCC a link to EAs on the C-NLOPB website that included summaries of the impact of seismic activity on wildlife.

Comment: To increase participation at the public information sessions, Seitel should consider using the NCC boardroom for the meeting and have the NCC assistant help to inform its membership about the public information session.

Seitel will keep this in mind for future consultations in the area.

Comment: The NCC has research process protocols in place that might be of use. These protocols were developed in association with Memorial University of Newfoundland.

Seitel acknowledged that it would consider all applicable protocols for their program.

Comment: The NCC is building an opportunistic database for all wildlife, both terrestrial and aquatic.

Seitel expressed interest in having access to this database to include in the EA process, similar to what is currently done with the DFO opportunistic marine mammal sightings database.

Public Information Session

None of the HV-GB public attended the public meeting. Seitel was later contacted through LGL Limited by a town member who was not able to attend the public meeting and had a brief phone discussion about the program on March 22, 2016. An email was also sent to the town member on that date to provide a direct line of contact with Seitel for additional questions or concerns regarding the program. As of May 18, 2016, no additional comments have been received.

Nain

Nunatsiavut Government

Following Seitel's presentation, Nunatsiavut Government representatives asked questions and provided comments on the program. Most of the questions were related to the use of OBNs. There were also concerns expressed about the 10-year temporal scope of the EA. The concerns focused primarily on the uncertainties regarding future activity offshore Labrador during the 10-year period and the associated cumulative effects.

Additional questions/comments from the NG representatives and Seitel's responses are provided below:

Question: Would Seitel remain the Project Operator during the program or would the company hired to conduct the survey take on Project Operator responsibilities?
Response: Seitel will remain Project Operator during the program. It would hire a Project Management company to conduct the survey but the ultimate program operation and financing responsibilities would remain with Seitel.

Question: Have you selected a Project Management company to conduct the survey?
Response: Seitel has not yet finalized the selection but leading candidates include Seabird and SAE.

Question: What companies do you typically try to use?
Response: For Seitel's onshore operations in western Canada, all of its operations are run by Canadian companies.

Question: Who will do the hiring?
Response: For local employment, hiring will be done by Seitel in collaboration with the seismic Project Management company. For the vessel crew, the Project Management company typically has a crew that comes with the hired vessel.

Comment: If there are openings for specific positions on the vessels that require specialized training and "tickets", we would appreciate knowing as soon as possible so that local people are given the opportunity to obtain the required papers ahead of time and be eligible for the potential positions.
Response: Seitel will provide notice regarding potential job opportunities for the 2016 program as early as possible. The same will be done in subsequent years.

Comment: Inuit MMOs and Inuit FLOs should be on the same vessels as the biologist MMOs and the FFAW-Unifor FLOs. In the past, they were put on a chase vessel by themselves.
Response: Seitel agrees that all observers should be on the same boat as this is both a job opportunity and a training opportunity for some of the individuals selected.

Question: Is Seitel looking for a partner for the entire program or on an annual basis?
Response: Seitel hopes to have a partner for the entire program. The probability of finding a partner for 2016 is fairly low, given the current state of the oil and gas industry.

Question: If the program does go ahead in 2016, will it focus offshore Labrador or offshore Newfoundland?
Response: For 2016, it would likely be offshore Labrador. The interest for this sector is related to the upcoming 2018 bidding round.

Question: What is 4D seismic?
Response: It is 3D seismic surveying repeated at the same location at a different time. The "fourth dimension" refers to time.

Question: Have OBNs ever been used offshore Newfoundland and Labrador before?
Response: No.

Question: Where else have OBNs been used?
Response: Mainly in the South China Sea and offshore Africa.

Comment: Note that, in the past, some boats that worked exclusively in southern locations were not equipped to deal with the cold weather conditions offshore Labrador.

Question: The OBNs are downward-facing for data recording?
Response: Yes, the technique basically allows the cancellation of the noise of the water column which is present in 'standard' seismic surveying that tows streamers behind a vessel.

Question: How does Seitel deal with vibrations on the OBNs?
Response: By knowing the frequency of the vibrations, one can filter them out.

Question: Can the sound level on the seafloor be predicted?
Response: It could theoretically be modelled.

Question: Is the Geophysical Permit a one-time permit or does one have to apply for a permit every year?
Response: The permit is awarded following the EA evaluation process. Any changes to the program moving forward will require an amendment of the EA and corresponding approval process. It is also necessary to submit annual EA Updates prior to any surveying in any year following Year 1.

Question: It appears the EA only considers the impact assessment for the 2016 2D seismic program. Is that the case?

Response: The EA assesses the potential impacts of seismic surveying activities during the entire 10-year period.

Public Information Session

Other than the Director of Non-Renewable Resources for the Nunatsiavut Government and the hired interpreter, none of the Nain public attended the public information session.

Agency/Stakeholder Individuals Involved in the Consultations

The following Labrador agencies, managers and fishing industry participants were consulted during the preparation of Seitel's Environmental Assessment.

Labrador Fishermen's Union Shrimp Company Ltd. (LFUSCL)

Claude Rumbolt, Fisheries Advisor

Mary's Harbour (Public Meeting)

Seven participants at the Riverlodge Hotel meeting room.

Torngat Secretariat

Jamie Snook, Executive Director
Julie Whalen, Fisheries Research Program Director
Robyn Morris, Policy Analyst
Beverly White, Executive Assistant

Torngat Joint Fisheries Board

John Mercer, Chairperson
David Bonnell, Canadian Appointee
Alphonsus Pittman, Canadian Appointee
Eric Andersen, Nunatsiavut Appointee
Craig Taylor, Nunatsiavut Appointee

Nunatsiavut Government

Harry Borlase, Director Non-Renewable Resources
Rodd Laing, Research Manager

Nain (Public Meeting)

Attendees included only Harry Borlase of the Nunatsiavut Government and Wilson Jararuse, the hired interpreter for the public meeting at the Nunatsiavut Government Administration Building.

Innu Nation

Paula Reid, Environmental Advisor

NunatuKavut Community Council (NCC)

Todd Russell, President
George Russell, Environment and Resource Manager
Amy Hudson, Executive Assistant to the President

Town of Happy Valley-Goose Bay

No attendees at the Labrador Friendship Centre. One phone inquiry by a town member following the public meeting.

Appendix 2

Literature Review on the Potential Effects of Exposure to Seismic Airgun Sound on Fishes

Review of Potential Effects of Airgun Sounds on Fishes

The potential effects of seismic airgun sound on fishes has been studied for a variety of taxa that includes marine, freshwater, and anadromous species (reviewed by Fay and Popper 2000; Ladich and Popper 2004; Hastings and Popper 2005; Popper and Hastings 2009a,b; Popper et al. 2014; Kunc et al. 2016).

It is sometimes difficult to interpret studies on the effects of underwater sound on marine animals because authors often do not provide enough information, including received sound levels, source sound levels, and specific characteristics of the sound. Specific characteristics of the sound include units and references, whether the sound is continuous or impulsive, and its frequency range. Underwater sound pressure levels are typically reported as a number of decibels referenced to a reference level, usually 1 micro-Pascal (μPa). However, the sound pressure dB number can represent multiple types of measurements, including "zero to peak [0-p]", "peak to peak [p-p]", or 'averaged [rms]'. Sound exposure levels (SEL) may also be reported as dB. The SEL is the integration of all the acoustic energy contained within the duration of a single sound event. Unless precise measurement types are reported, it can be impossible to directly compare results from two or more independent studies. In addition to researchers presenting a proper and complete description of anthropogenic sound levels in sound impact studies, Hawkins and Popper (2016) outlined several other prerequisites that should be adhered to when evaluating the effects of anthropogenic sound on fishes, including: knowledge of background sound levels in the environment, prediction of the transmission of sound from different anthropogenic sources, and consideration of the effects that the sound may have on fishes at different locations from the sound source.

The information contained in the following sections reflects currently available material. Study methods are continuously developing to address some of the known shortcomings. Some of these shortcomings are addressed in a recently published paper by Hawkins et al. (2015). They identified a number of data gaps that require addressment in order to better understand the effects of exposure to underwater sound from various sources, including seismic airguns, on fishes.

This appendix provides an overview of the acoustic capabilities of fishes as well as information on the potential effects of exposure to seismic airgun sound on these animals.

Acoustic Capabilities

Sensory systems, like those that allow for hearing, provide information about an animal's physical, biological and social environments. Extensive work has been done to understand the structures, mechanisms, and functions of animal sensory systems in aquatic environments (Atema et al. 1988; Kapoor and Hara 2001; Collin and Marshall 2003). All fish species have hearing and skin-based mechanosensory systems (inner ear and lateral line systems, respectively) that provide information about their surroundings (Fay and Popper 2000). Fay (2009) and some others refer to the ambient sounds to which fishes are exposed as 'underwater soundscapes'. Anthropogenic sounds can potentially have important negative consequences for fish survival and reproduction if they disrupt an individual's ability to sense its soundscape, which often tells of predation risk, prey items, or mating opportunities. Potential negative effects include masking of key environmental sounds or social signals, displacement of fish from their habitat, or interference with sensory orientation and navigation.

Fish hearing via the inner ear is typically restricted to low frequencies. As with other vertebrates, fish hearing involves a mechanism whereby the beds of hair cells (Howard et al. 1988; Hudspeth and Markin 1994) located in the inner ear are mechanically affected and cause a neural discharge (Popper and Fay 1999). At least two major pathways for sound transmittance between sound source and the inner ear have been identified for fishes. The most primitive pathway involves direct transmission to the inner ear's otolith, a calcium carbonate mass enveloped by sensory hairs. The inertial difference between the dense otolith and the less-dense inner ear causes the otolith to stimulate the surrounding sensory hair cells. This motion differential is interpreted by the central nervous system as sound.

The second transmission pathway between sound source and the inner ear of fishes is via the swim bladder, a gas-filled structure that is much less dense than the rest of the fish's body. The swim bladder, being more compressible and expandable than either water or fish tissue, will differentially contract and expand relative to the rest of the fish in a sound field. The pulsating swim bladder transmits this mechanical disturbance directly to the inner ear (discussed below). Such a secondary source of sound detection may be more or less effective at stimulating the inner ear depending on the amplitude and frequency of the pulsation, and the distance and mechanical coupling between the swim bladder and the inner ear (Popper and Fay 1993).

A recent paper by Popper and Fay (2011) discusses the designation of fishes based on sound detection capabilities. They suggest that the designations 'hearing specialist' and 'hearing generalist' no longer be used for fishes because of their vague and sometimes contradictory definitions, and that there is instead a range of hearing capabilities across species that is more like a continuum, presumably based on the relative contributions of pressure to the overall hearing capabilities of a species.

According to Popper and Fay (2011), one end of this continuum is represented by fishes that only detect particle displacement because they lack pressure-sensitive gas bubbles (e.g., swim bladder). These species include elasmobranchs (e.g., sharks) and jawless fishes, and some teleosts including flatfishes. Fishes at this end of the continuum are typically capable of detecting sound frequencies less than 1,500 Hz (e.g., Casper et al. 2003: Casper and Mann 2006, 2007, 2009).

The other end of the fish hearing continuum is represented by fishes with highly specialized otophysic connections between pressure receptive organs, such as the swim bladder, and the inner ear. These fishes include some squirrelfish, mormyrids, herrings, and otophysan fishes (freshwater fishes with Weberian apparatus, an articulated series of small bones that extend from the swim bladder to the inner ear). Rather than being limited to 1.5 kHz or less in hearing, these fishes can typically hear up to several kHz. One group of fish in the anadromous herring sub-family Alosinae (shads and menhaden) can detect sounds to well over 180 kHz (Mann et al. 1997, 1998, 2001). This may be the widest hearing range of any vertebrate that has been studied to date. While the specific reason for this very high frequency hearing is not totally clear, there is strong evidence that this capability evolved for the detection of the ultrasonic sounds produced by echolocating dolphins to enable the fish to detect, and avoid, predation (Mann et al. 1997; Plachta and Popper 2003).

All other fishes have hearing capabilities that fall somewhere between these two extremes of the continuum. Some have unconnected swim bladders located relatively far from the inner ear (e.g., salmonids, tuna) while others have unconnected swim bladders located relatively close to the inner ear (e.g., Atlantic cod, *Gadus morhua*). There has also been the suggestion that Atlantic cod can detect 38 kHz (Astrup and Møhl 1993). However, the general consensus was that this was not hearing with the ear, but probably the fish responding to exceedingly high pressure signals of the 38-kHz source through some other receptor in the skin, such as touch receptors (Astrup and Møhl 1998).

It is important to recognize that the swim bladder itself is not a sensory end organ, but rather an intermediate part of the sound pathway between sound source and the inner ear of some fishes. The inner ear of fishes is ultimately the organ that translates the particle displacement component into neural signals for the brain to interpret as sound.

A third mechanosensory pathway found in most bony fishes and elasmobranchs (i.e., cartilaginous fishes) involves the lateral line system. It too relies on sensitivity to water particle displacement. The basic sensory unit of the lateral line system is the neuromast, a bundle of sensory and supporting cells whose projecting cilia, similar to those in the ears, are encased in a gelatinous cap. Neuromasts detect distorted sound waves in the immediate vicinity of fishes. Generally, fishes use the lateral line system to detect the particle displacement component of low frequency acoustic signals (up to 160 to 200 Hz) over a distance of one to two body lengths. The lateral line is used in conjunction with other sensory systems, including hearing (Sand 1981; Coombs and Montgomery 1999).

There has also been recent study of the auditory sensitivity of settlement-stage fishes. Using the auditory brainstem response (ABR) technique in the laboratory, Wright et al. (2010) concluded that larvae of coral reef species tested had significantly more sensitive hearing than the larvae of pelagic species tested. All reef fish larvae as well as the larvae of one of the pelagic species detected frequencies in the 100-2,000 Hz range. The larvae of the one other pelagic species did not detect frequencies higher than 800 Hz. The larvae of all six species exhibited best hearing at frequencies between 100 and 300 Hz. The results of Wright et al. (2010) suggested that settlement-stage larval reef fishes may be able to detect reef sounds at distances of 100s of metres. Other recent research also indicates that settlement-stage larvae of coral reef fishes may use sound as a cue to locate settlement sites (Tolimieri et al. 2004; Leis et al. 2003; Simpson et al. 2005; Leis and Locket 2005).

Potential Effects

Review papers on the effects of anthropogenic sources of underwater sound on fishes have been published recently (Popper 2009; Popper and Hastings 2009a,b; Fay and Popper 2012; Popper et al. 2014; Mann 2016). These papers consider various sources of anthropogenic sound, including seismic airguns. For the purposes of this review, only the effects of seismic airgun sound are considered. Note that many of the studies were conducted either in a laboratory or in the field using captive fish, and are therefore not representative of the natural scenario of fish being able to move away from the sound source.

There are three categories of potential effects of exposure to air gun sound on marine fishes: pathological, physiological, and behavioural. Pathological effects include lethal and sub-lethal injury to the animals, physiological effects include temporary primary and secondary stress responses, and behavioural effects refer to changes in exhibited behaviours (i.e., disturbance). For the purpose of this review, pathological and physiological effects are grouped as physical effects. The three categories should not be considered as independent of one another and are likely interrelated in complex ways.

Table 7.4 in Popper et al. (2014) provides guidelines of seismic airgun sound levels that could potentially cause negative effects to fishes of various hearing abilities and eggs and larvae. Some of the effects addressed include mortality, potential mortal injury, recoverable injury, temporary threshold shift (TTS), masking, and behavioural changes.

Marine Fishes

Physical Effects

Juveniles and Adults

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

(2016) and Smith and Monroe (2016). In addition to providing examples of previous studies related to various anthropogenic noise sources and their effects on fish sensory hair cells and recovery, they reviewed the following McCauley (2003) study on seismic air gun damage to fish ears.

Evidence for airgun-induced damage to fish ears (i.e., pathological effect) has been provided in studies using pink snapper *Pagrus auratus* as subjects (McCauley et al. 2000a,b, 2003). In these experiments, fish were caged and exposed to the sound of a single moving seismic airgun every 10 s over a period of 1 h and 41 min. The source SPL at 1 m was about 223 dB re 1 $\mu Pa \cdot m_{p\text{-}p}$, and the received SPLs ranged from 165 to 209 dB re 1 $\mu Pa_{p\text{-}p}$. The sound energy was highest over the 20–70 Hz frequency range. The pink snapper were exposed to more than 600 airgun discharges during the study. In some individual fish, the sensory epithelium of the inner ear sustained extensive damage as indicated by ablated hair cells. Damage was more extensive in fish examined 58 days post-exposure compared to those examined 18 h post-exposure. There was no evidence of repair or replacement of damaged sensory cells up to 58 days post-exposure. McCauley et al. (2000a,b, 2003) included the following caveats in the study reports: (1) fish were caged and unable to swim away from the seismic source, (2) only one species of fish was examined, (3) the impact on the ultimate survival of the fish is unclear, and (4) airgun exposure specifics required to cause the observed damage were not obtained (i.e., a few high SPL signals or the cumulative effect of many low to moderate SPL signals).

In another study, caged European sea bass (*Dicentrarchus labrax*) were exposed to multiple discharges from a moving seismic airgun array with a source SPL of about 256 dB re 1 $\mu Pa \cdot m_{0\text{-}p}$ (unspecified measure type) (Santulli et al. 1999). The airguns were discharged every 25 s during a 2-h period. The minimum distance between fish and seismic source was 180 m. The authors did not indicate any observed pathological injury to the sea bass. Blood was collected from both exposed fish (6 h post-exposure) and control fish (6 h pre-exposure) and subsequently analyzed for cortisol, glucose, and lactate levels. Stress can cause the levels of these chemicals to fluctuate. Levels of cortisol, glucose, and lactate were significantly higher in the sera of exposed fish compared to sera of control fish. The elevated levels of all three chemicals returned to pre-exposure levels within 72 h of exposure (Santulli et al. 1999).

Andrews et al. (2014) conducted genetic analyses and examined the behavior of captive juvenile Atlantic salmon (*Salmo salar*) exposed to a 10 in^3 airgun at a distance of 2 m every 10 s for approximately 10 min. In order to replicate a worse-case scenario within several hundred metres of a survey vessel, the average SPL was approximately 204 dB re 1$\mu Pa_{p\text{-}p}$. The received levels were measured using hydrophones placed directly in front of the cage. Behavioural observations of interest upon exposure included any changes in swimming direction/speed, reaction time to airgun blasts, and net avoidance. The right and left inner ears of the fish were sampled for genetic analyses 16 h following exposure and compared to control, non-exposed fish. The fish exhibited an initial startle response, generally for the first three airgun discharges, with little further activity for the remainder of the exposure. Increased swimming was observed for exposed fish, with rapid and erratic swimming activity during attempted capture (netting). Genetic analyses revealed numerous instances of up- or down-regulation for transcripts encoding oxygen transport, the glycolytic pathway, the Krebs cycle, and the electron transport chain, indicating both potentially damaged ear tissues as a result of exposure (e.g., ruptured cell membranes) and regeneration of ear tissues post-exposure (including auditory hair cells).

Eggs and Larvae

Fertilized capelin (*Mallotus villosus*) eggs and monkfish (*Lophius americanus*) larvae were exposed to seismic airgun sound and subsequently examined and monitored for possible effects of the exposure (Payne et al. 2009). The laboratory exposure studies involved a single airgun at a fixed distance. Approximate received SPLs measured in the capelin egg and monkfish larvae exposures were 199 to 205 dB re 1 $\mu Pa_{p\text{-}p}$ and 205 dB re 1 $\mu Pa_{p\text{-}p}$, respectively. The capelin eggs were exposed to either 10 or 20 airgun discharges, and the monkfish larvae were exposed to either 10 or 30 discharges. No statistical differences in mortality/morbidity between control and exposed subjects were found at 1 to 4 days post-exposure in any of the exposure trials for either the capelin eggs or the monkfish larvae.

In uncontrolled experiments, Kostyvchenko (1973) exposed the eggs of numerous fish species (anchovy, red mullet, crucian carp, blue runner) to various sound sources, including seismic airguns. With the seismic airgun discharge as close as 0.5 m from the eggs, over 75% of them survived the exposure. Egg survival rate increased to over 90% when placed 10 m from the airgun sound source. The range of received SPLs was about 215 to 233 dB re 1 $\mu Pa_{0\text{-}p}$.

Eggs, yolk sac larvae, post-yolk sac larvae, post-larvae, and fry of various commercially important fish species (cod, saithe, herring, turbot, and plaice) were exposed to received SPLs ranging from 220 to 242 dB re 1 µPa (unspecified measure type) (Booman et al. 1996). These received levels corresponded to exposure distances ranging from 0.75 to 6 m. The authors reported some cases of injury and mortality but most of these occurred as a result of exposures at very close range. The rigor of anatomical and pathological assessments was questionable.

Saetre and Ona (1996) applied a "worst-case scenario" mathematical model to investigate the effects of seismic sound on fish eggs and larvae. They concluded that mortality rates caused by exposure to seismic airgun sound are so low compared to the natural mortality that the impact of seismic surveying on recruitment to a fish stock must be regarded as insignificant.

Behavioural Effects

Studies described in this subsection suggest that effects on fish behaviour due to exposure to airgun sound are temporary in nature, and that response thresholds for various demersal and pelagic species are quite variable. Generally speaking, there are three different methods of studying the impacts of anthropogenic noise on fish behavior. These methods include: (1) captive indoor (indoor studies where fishes are maintained in tanks); (2) captive outdoor (outdoor studies where captive fish are restricted within a cage); and (3) free-range outdoor (outdoor studies on free-ranging fish that are located around the selected study area). The experimental control on these study methods is greatest for captive indoor, with control progressively diminishing in studies that gravitate more towards outdoor and free-ranging. The acoustic validity and behaviour validity in relation to real-life scenarios involving anthropogenic noise and fish behavior however are more robust for the outdoor study methods than the captive indoor method because they simulate more realistic interactions between anthropogenic sound sources and fishes (Slabbekoorn 2016).

The fish exposed to sound from a single airgun in the McCauley et al. studies (i.e., pink snapper and trevally *Pseudocaranx dentex*) also exhibited startle responses to short range start up and high-level airgun signals (i.e., with received SPLs of 182 to 195 dB re 1 μPa_{rms} (McCauley et al. 2000a,b; Fewtrell and McCauley 2012). Smaller fish were more likely to display a startle response. Responses were observed above received SPLs of 156 to 161 dB re 1 μPa_{rms}. The occurrence of both startle response (classic C-turn response) and alarm responses (e.g., darting movements, flash school expansion, fast swimming) decreased over time. Other observations included downward distributional shift that was restricted by the 10 m x 6 m x 3 m cages, increase in swimming speed, and the formation of denser aggregations. Fish behavior appeared to return to pre-exposure state 15–30 min after cessation of seismic firing.

A study by Pearson et al. (1992) also showed that behavioural effects were temporary in nature. They investigated the effects of seismic airgun sound on the behavior of captive rockfishes (*Sebastes* spp.) exposed to the sound of a single stationary airgun at a variety of distances. The airgun used in the study had a source SPL at 1 m of 223 dB re 1 $\mu Pa \cdot m_{0\text{-}p}$, and measured received SPLs ranged from 137 to 206 dB re 1 $\mu Pa_{0\text{-}p}$. The authors reported that rockfishes reacted to the airgun sounds by exhibiting varying degrees of startle and alarm responses, depending on the species of rockfish and the received SPL. Startle responses were observed at a minimum received SPL of 200 dB re 1 $\mu Pa_{0\text{-}p}$, and alarm responses occurred at a minimum received SPL of 177 dB re 1 $\mu Pa_{0\text{-}p}$. Other observed behavioral changes included the tightening of schools, downward distributional shift, and random movement and orientation. Some fishes ascended in the water column and commenced to mill (i.e., "eddy") at increased speed, while others descended to the bottom of the enclosure and remained motionless. Pre-exposure behavior was re-established from 20 to 60 min after cessation of seismic airgun discharge. Pearson et al. (1992) concluded that received SPL thresholds for overt rockfish behavioral response and more subtle rockfish behavioral response are 180 dB re 1 $\mu Pa_{0\text{-}p}$ and 161 dB re 1 $\mu Pa_{0\text{-}p}$, respectively.

Using an experimental hook and line fishery approach, Skalski et al. (1992) studied the potential effects of seismic airgun sound on the distribution and catchability of rockfishes. The source SPL of the single airgun used in the study was 223 dB re 1 $\mu Pa \cdot m_{0\text{-}p}$, and the received SPLs at the bases of the rockfish aggregations ranged from 186 to 191 dB re 1 $\mu Pa_{0\text{-}p}$. Characteristics of the fish aggregations were assessed using echosounders. During long-term stationary seismic airgun discharge, there was an overall downward shift in fish distribution. The authors also observed a significant decline in total catch of rockfishes during seismic discharge. It should be noted that this experimental approach was quite different from an actual seismic survey, in that duration of exposure was much longer.

Activity levels tend to return to normal within hours of exposure to airgun sound. Santulli et al. (1999) also used underwater video cameras to monitor fish response to seismic airgun discharge. Resultant video indicated slight startle responses by some of the sea bass when the seismic airgun array discharged as far as 2.5 km from the cage. The proportion of sea bass that exhibited startle response increased as the airgun sound source approached the cage. Once the seismic array was within 180 m of the cage, the sea bass were densely packed at the middle of the enclosure, exhibiting random orientation, and appearing more active than they had been under pre-exposure conditions. Normal behavior resumed about 2 h after airgun discharge nearest the fish (Santulli et al. 1999).

Boeger et al. (2006) observed coral reef fishes in field enclosures before, during and after exposure to seismic airgun sound. This Brazilian study used an array of eight airguns that was presented to the fishes as both a mobile sound source and a static sound source. Minimum distances between the sound source and the fish cage ranged from 0 to 7 m. Received sound levels were not reported, however neither mortality nor external damage to the fishes was observed in any of the experimental scenarios. Most of the airgun array discharges resulted in startle responses although these behavioral changes lessened with repeated exposures, suggesting habituation.

Chapman and Hawkins (1969) showed that after an hour of exposure to the airgun sound, whiting appeared to have habituated as indicated by their return to the pre-exposure depth range, despite the continuing airgun discharge. They investigated the reactions of free ranging whiting (silver hake), *Merluccius bilinearis*, to an intermittently discharging stationary airgun with a source SPL of 220 dB re 1 $\mu Pa \cdot m_{0\text{-}p}$. Received SPLs were estimated to be 178 dB re 1 $\mu Pa_{0\text{-}p}$. The whiting were monitored with an echosounder. Prior to any airgun discharge, the fish were located at a depth range of 25 to 55 m. In apparent response to the airgun sound, the fish descended, forming a compact layer at depths greater than 55 m. Airgun discharge ceased for a time and upon its resumption, the fish again descended to greater depths, indicating only temporary habituation.

Hassel et al. (2003, 2004) studied the potential effects of exposure to airgun sound on the behavior of captive lesser sandeel, *Ammodytes marinus*, but their commercial fishery catch data were inconclusive with respect to behavioral effects. Depth of the study enclosure used to hold the sandeel was about 55 m. The moving airgun array had an estimated source SPL of 256 dB re 1 $\mu Pa \cdot m$ (unspecified measure type). Received SPLs were not measured. Exposures were conducted over a 3-day period in a 10 km × 10 km area with the cage at its center. The distance between airgun array and fish cage ranged from 55 m when the array was overhead to 7.5 km. No mortality attributable to exposure to the airgun sound was noted. Behavior of the fish was monitored using underwater video cameras, echosounders, and commercial fishery data collected close to the study area. The approach of the seismic vessel appeared to cause an increase in tail-beat frequency although the sandeels still appeared to swim calmly. During seismic airgun discharge, many fish exhibited startle responses, followed by flight from the immediate area. The frequency of occurrence of startle response seemed to increase as the operating seismic array moved closer to the fish. The sandeels stopped exhibiting the startle response once the airgun discharge ceased. The sandeel tended to remain higher in the water column during the airgun discharge, and none of them were observed burying themselves in the soft substrate.

Various species of demersal fishes, blue whiting, and some small pelagic fishes were exposed to a moving seismic airgun array with a source SPL of about 250 dB re 1 µPa · m (unspecified measure type) (Dalen and Knutsen 1986). Received SPLs estimated using the assumption of spherical spreading ranged from 200 to 210 dB re 1 µPa (unspecified measure type). Seismic sound exposures were conducted every 10 s during a one week period. The authors used echosounders and sonars to assess the pre- and post-exposure fish distributions. The acoustic mapping results indicated a significant decrease in abundance of demersal fish (36%) after airgun discharge but comparative trawl catches did not support this. Non-significant reductions in the abundances of blue whiting and small pelagic fish were also indicated by post-exposure acoustic mapping.

La Bella et al. (1996) studied the effects of exposure to seismic airgun sound on fish distribution using echosounder monitoring and changes in catch rate of hake by trawl, and clupeoids by gill netting. The seismic array used was composed of 16 airguns and had a source SPL of 256 dB re 1 µPa · $m_{0\text{-}p}$. The pulse interval was 25 s, and exposure durations ranged from 4.6 to 12 h. Horizontal distributions did not appear to change as a result of exposure to seismic discharge, but there was some indication of a downward shift in the vertical distribution. The catch rates during experimental fishing did not differ significantly between pre- and post-seismic fishing periods.

Wardle et al. (2001) used video and telemetry to make behavioral observations of marine fishes (primarily juvenile saithe, adult pollock, juvenile cod, and adult mackerel) inhabiting an inshore reef off Scotland before, during, and after exposure to discharges of a stationary airgun. The received SPLs ranged from about 195 to 218 dB re 1 $\mu Pa_{0\text{-}p}$. Pollock did not move away from the reef in response to the seismic airgun sound, and their diurnal rhythm did not appear to be affected. However, there was an indication of a slight effect on the long-term day-to-night movements of the pollock. Video camera observations indicated that fish exhibited startle responses ("C-starts") to all received levels. There were also indications of behavioral responses to visual stimuli. If the seismic source was visible to the fish, they fled from it. However, if the source was not visible to the fish, they often continued to move toward it.

The potential effects of exposure to seismic sound on fish abundance and distribution were also investigated by Slotte et al. (2004). Twelve days of seismic survey operations spread over a period of 1 month used a seismic airgun array with a source SPL of 222.6 dB re 1 µPa · $m_{p\text{-}p}$. The SPLs received by the fish were not measured. Acoustic surveys of the local distributions of various kinds of pelagic fish, including herring, blue whiting, and mesopelagic species, were conducted during the seismic surveys. There was no strong evidence of short-term horizontal distributional effects. With respect to vertical distribution, blue whiting and mesopelagics were distributed deeper (20 to 50 m) during the seismic survey compared to pre-exposure. The average densities of fish aggregations were lower within the seismic survey area, and fish abundances appeared to increase in accordance with increasing distance from the seismic survey area.

Peña et al. (2013) studied the real-time behavior of herring schools exposed to a full-scale 3D seismic survey off northern Norway using an omnidirectional fisheries sonar. The feeding herring were observed over a six-hour period as the seismic vessel and active airguns approached them from a distance of 27 km to a point 2 km away.

The received SEL increased from about 125 to 155 dB re 1 µPa^2 s during the vessel's approach. The investigators observed a lack of response by the herring and concluded that this observation was likely due to a combination of factors including a strong motivation for feeding, a lack of suddenness of the airgun stimulus, and an increased level of tolerance to the seismic sound.

Indirect Effects on Fisheries

The initial comprehensive experimentation on the effects of seismic airgun sound on catchability of fishes was conducted in the Barents Sea by Engås et al. (1993, 1996). They investigated the effects of seismic airgun sound on distributions, abundances, and catch rates of cod and haddock using acoustic mapping and experimental fishing with trawls and longlines. The maximum source SPL was about 248 dB re 1 µPa · m $_{0\text{-}p}$ based on back-calculations from measurements collected via a hydrophone at depth 80 m. No measurements of the received SPLs were made. Davis et al. (1998) estimated the received SPL at the sea bottom immediately below the array and at 18 km from the array to be 205 dB re 1 µPa$_{0\text{-}p}$ and 178 dB re 1 µPa$_{0\text{-}p}$, respectively. Engås et al. (1993, 1996) concluded that there were indications of distributional change during and immediately following the seismic airgun discharge (45 to 64% decrease in acoustic density according to sonar data). The lowest densities were observed within 9.3 km of the seismic discharge area. The authors indicated that trawl catches of both cod and haddock declined after the seismic operations. While longline catches of haddock also showed decline after seismic airgun discharge, those for cod increased.

Løkkeborg (1991), Løkkeborg and Soldal (1993), and Dalen and Knutsen (1986) also examined the effects of seismic airgun sound on demersal fish catches. Løkkeborg (1991) examined the effects on cod catches. The source SPL of the airgun array used in his study was 239 dB re 1 µPa · m (unspecified measure type), but received SPLs were not measured. Approximately 43 h of seismic airgun discharge occurred during an 11-day period, with a five-second interval between pulses. Catch rate decreases ranging from 55 to 80% within the seismic survey area were observed. This apparent effect persisted for at least 24 h within about 10 km of the survey area.

Løkkeborg et al. (2012) recently described a 2009 study of the effect of exposure to seismic sound on commercial fishes. Both gillnet and longline vessels fished for Greenland halibut, redfish, saithe and haddock for 12 days before the onset of seismic surveying, 38 days during seismic surveying, and 25 days after cessation of seismic surveying. Acoustic surveying was also conducted during these times. Gillnet catches of Greenland halibut and redfish increased during seismic operations and remained higher after cessation of seismic surveying than they had been before the onset of seismic surveying. Longline catches of Greenland halibut decreased during seismic operations but increased again after the seismic surveying was completed. Gillnet catches of saithe decreased during seismic operations and remained low during the 25 day period following the seismic surveying. Longline catches of haddock before and during seismic operations were not significantly different although catches did decline as the seismic vessel approached the fishing area. The haddock fishery was conducted in an area with lower esonification compared to the fishery areas of the other three species. Acoustic surveys showed that the saithe had partly left the area, while the distributional changes of the other three species were not observed. Løkkeborg et al. (2012) suggested that an increase in swimming activity as a result of exposure to seismic sound might explain why gillnet catches increased and longline catches decreased.

Skalski et al. (1992) used a 100-in^3 airgun with a source level of 223 dB re 1 µPa · m$_{0\text{-}p}$ to examine the potential effects of airgun sound on the catchability of rockfishes. The moving airgun was discharged along transects in the study fishing area, after which a fishing vessel deployed a set line, ran three echosounder transects, and then deployed two more set lines. Each fishing experiment lasted 1 h 25 min. Received SPLs at the base of the rockfish aggregations ranged from 186 to 191 dB re 1 µPa$_{0\text{-}p}$. The catch-per-unit-effort (CPUE) for rockfish declined on average by 52.4% when the airguns were operating. Skalski et al. (1992) suggested that the reduction in catch resulted from a change in behavior of the fishes. The fish schools descended towards the bottom and their swimming behavior changed during airgun discharge. Although fish dispersal was not observed, the authors hypothesized that it could have occurred at a different location with a different bottom type. Skalski et al. (1992) did not continue fishing after cessation of airgun discharge. They speculated that CPUE would quickly return to normal in the experimental area, because fish behavior appeared to normalize within minutes of cessation of airgun discharge. However, in an area where exposure to airgun sound might have caused the fish to disperse, the authors suggested that a lower CPUE might persist for a longer period.

Turnpenny et al. (1994) examined results of this study as well as the results of other studies on rockfish. They used rough estimations of received SPLs at catch locations and concluded that catchability is reduced when received SPLs exceed 160 to 180 dB re 1 $\mu Pa_{0\text{-}p}$. They also concluded that reaction thresholds of fishes lacking a swim bladder (e.g., flatfish) would likely be about 20 dB higher. Given the considerable variability in sound transmission loss between different geographic locations, the SPLs that were assumed in these studies were likely quite inaccurate.

Turnpenny and Nedwell (1994) also reported on the effects of seismic airgun discharge on inshore bass fisheries in shallow U.K. waters (5 to 30 m deep). The airgun array used had a source level of 250 dB re 1 $\mu Pa \cdot m_{0\text{-}p}$. Received levels in the fishing areas were estimated to be 163–191 dB re 1 $\mu Pa_{0\text{-}p}$. Using fish tagging and catch record methodologies, they concluded that there was not any distinguishable migration from the ensonified area, nor was there any reduction in bass catches on days when seismic airguns were discharged. The authors concluded that effects on fisheries would be smaller in shallow nearshore waters than in deep water because attenuation of sound is more rapid in shallow water.

European sea bass were exposed to sound from seismic airgun arrays with a source SPL of 262 dB re 1 $\mu Pa \cdot m_{0\text{-}p}$ (Pickett et al. 1994). The seismic survey was conducted over a period of 4 to 5 months. The study was intended to investigate the effects of seismic airgun discharge on inshore bass fisheries. Information was collected through a tag and release program, and from the logbooks of commercial fishermen. Most of the 152 recovered fish from the tagging program were caught within 10 km of the release site, and it was suggested that most of these bass did not leave the area for a prolonged period. With respect to the commercial fishery, no significant changes in catch rate were observed (Pickett et al. 1994).

Freshwater Fishes

Popper et al. (2005) tested the hearing sensitivity of three Mackenzie River fish species after exposure to five discharges from a seismic airgun. The mean received peak SPL was 205 to 209 dB re 1 µPa per discharge, and the approximate mean received SEL was 176 to 180 dB re 1 $\mu Pa^2 \cdot s$ per discharge. While the broad whitefish showed no Temporary Threshold Shift (TTS) as a result of the exposure, adult northern pike and lake chub exhibited TTSs of 10 to 15 dB, followed by complete recovery within 24 h of exposure. The same animals were also examined to determine whether there were observable effects on the sensory cells of the inner ear as a result of exposure to seismic sound (Song et al. 2008). No damage to the ears of the fishes was found, including those that exhibited TTS.

In another part of the same Mackenzie River project, Jorgenson and Gyselman (2009) investigated the behavioral responses of arctic riverine fishes to seismic airgun sound. They used hydroacoustic survey techniques to determine whether fish behavior upon exposure to airgun sound can either mitigate or enhance the potential impact of the sound. The study indicated that fish behavioral characteristics were generally unchanged by the exposure to airgun sound. The tracked fish did not exhibit herding behavior in front of the mobile airgun array and, therefore, were not exposed to sustained high sound levels.

Popper et al. (2013) recently conducted a study that examined the effects of exposure to seismic airgun sound on caged pallid sturgeon (*Scaphirhynchus albus*) and paddlefish (*Polyodon spathula*). The maximum received peak SPL in this study was 224 dB re 1 µPa. Results of the study indicated no mortality, either acute or after seven days post-exposure, and no statistical differences in effects on body tissues between exposed and control fish.

Anadromous Fishes

In uncontrolled experiments using a very small sample of different groups of young salmonids, including Arctic cisco, fish were caged and exposed to various types of sound. One sound type was either a single pulse or a series of four pulses 10 to 15 s apart of a 300-in^3 seismic airgun at 2000 to 2200 psi (Falk and Lawrence 1973). Swim bladder damage was reported but no mortality was observed when fish were exposed within 1 to 2 m of an airgun source with source level, as estimated by Turnpenny and Nedwell (1994), of ~230 dB re 1 µPa · m (unspecified measure).

Thomsen (2002) exposed rainbow trout and Atlantic salmon held in aquaculture enclosures to recordings of sounds from a small airgun array. Received SPLs were 142 to 186 dB re 1 $\mu Pa_{p\text{-}p}$. The fish were exposed to 124 pulses over a 3-day period. Only eight of the 124 pulses appeared to evoke behavioral reactions by the salmonids, but overall impacts were minimal. No fish mortality was observed during or immediately after exposure. The author reported no significant effects on cod and haddock catch rates, and the behavioral effects were hard to differentiate from normal behavior.

Weinhold and Weaver (1972, cited in Turnpenny et al. 1994) exposed caged coho salmon smolts to impulses from 330 and 660-in^3 airguns at distances ranging from 1 to 10 m, resulting in received levels estimated at ~214 to 216 dB (units not given). No lethal effects were observed.

It should be noted that, in a recent and comprehensive review, Hastings and Popper (2005) take issue with many of the authors cited above for problems with experimental design and execution, measurements, and interpretation. Hastings and Popper (2005) deal primarily with possible effects of pile-driving sounds (which, like airgun sounds, are impulsive and repetitive). However, that review provides an excellent and critical review of the impacts to fish from other underwater anthropogenic sounds.

Summary of Potential Effects of Airgun Sound on Fishes

Some studies have shown that various life stages of particular fish species can be physically affected by exposure to airgun sound. In all of these cases, the fish subjects were subjected to exposures that would not likely occur under natural conditions. Studies that demonstrated physical effects on fishes typically involved either captive juvenile/adult subjects that were unable to move away from the sound source or passive ichthyoplankton that were located within a few metres of the sound source. The focus of study related to the potential effects of exposure to airgun sound on fishes has shifted to behavioural effects, particularly those that could result in a decrease in catch rate of the fishes. Fishes will exhibit both subtle and more overt behavioural changes in response to airgun sound and these effects appear to be quite variable both between and within species. Generally, the behavioural effects are localized and temporary, but can result in short-term effect on catch rates.

Recent work in Norway suggests that, in the future, particular acoustic-biological models may be used in the design and planning of seismic surveys in order to minimize disturbance to fishing (Hovem et al. 2012).

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