# Revised Environmental Assessment Addendum of Multiklient Invest Labrador Offshore Seismic Program, 2018–2023

**Prepared by**

LIMITED
environmental research associates

**Prepared for**

## Multiklient Invest AS

&

## TGS-NOPEC Geophysical Company ASA

**April 2019**
**LGL Report No. FA0106B-02**

# Revised Environmental Assessment Addendum of Multiklient Invest Labrador Offshore Seismic Program, 2018–2023

**Prepared by**


**LGL Limited, environmental research associates**
P.O. Box 13248, Stn. A
St. John's, NL A1B 4A5


**Prepared for**

**Multiklient Invest AS**
Lilleakerveien 4C, P.O. Box 251
Lilleaker, 0216, Oslo, Norway

&

**TGS-NOPEC Geophysical Company ASA**
1051 Clay Road
Houston, Texas, 77043, USA


**April 2019**
**LGL Report No. FA0106B-02**

**Suggested format for citation:**

LGL Limited. 2019. Revised Environmental Assessment Addendum of Multiklient Invest Labrador Offshore Seismic Program, 2018–2023. LGL Rep. FA0106B-02. Rep. by LGL Limited, St. John's, NL for Multiklient Invest AS, Oslo, Norway, and TGS-NOPEC Geophysical Company ASA, Houston, Texas, USA. 31 p.

# TABLE OF CONTENTS

Page

*(This page intentionally left blank for double-sided printing)*

# Introduction

This document is a revised Addendum to the Environmental Assessment (EA) of Multiklient Invest (MKI) Labrador Offshore Seismic Program, 2018–2023. The original Addendum, which was submitted in January 2019, addressed comments on the EA as submitted by the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) to MKI on 15 October 2018. Comments on the original Addendum were received from Environment and Climate Change Canada (ECCC), the Department of Fisheries and Land Resources (DFLR), the Nunatsiavut Government (NG), the C-NLOPB, Fish, Food and Allied Workers (FFAW), and the Department of Fisheries and Oceans Canada (DFO). In March 2019, follow-up comments were made by the NG and FFAW, and a revised EA Addendum was submitted to address those comments. In early April 2019, one follow-up comment was made by the NG on the revised EA Addendum. This document includes MKI's response to the NG follow-up comment. Follow-up responses are highlighted using blue font.

# General Comments

## Environment and Climate Change Canada (ECCC)

**Comment:** The following updated ECCC-CWS documents should be used in place of the older Chardine protocol documents. These represent more effective and detailed guidance for dealing with stranded birds in the offshore environment.

> ***Response:*** *So noted. Replace the first sentence in the third-last paragraph of Section 5.9 with the following: "Any seabirds that become stranded on a vessel will be documented and captured, stabilized, released and/or sent to shore in accordance with* Procedures for Handling and Documenting Stranded Birds Encountered on Infrastructure Offshore Atlantic Canada *and its appendices (ECCC 2017b)."*

## Department of Fisheries and Land Resources (FLR)

**Comment:** The FFAW or GEAC are not identified in the consultation list. Both would have members carrying out fishing in the identify area, therefore we suggest they be included in stakeholder consultations.

> ***Response:*** As a reminder, the Labrador EA was originally part of a larger EA entitled "Environmental Assessment of Multiklient Invest Newfoundland and Labrador Offshore Seismic Program, 2017–2026" (LGL 2017), which included the offshore regions of Labrador and Newfoundland. The FFAW and GEAC were indeed consulted during the EA process for this original EA and the FFAW was consulted again regarding potential future seismic surveys planned for 2018 (which

did not include Labrador). MKI will consult with fisheries stakeholders, including FFAW and GEAC, on future Labrador EA Updates.

## Nunatsiavut Government (NG)

**Comment:** Despite the change in geographical scope, timeline, and number of assessed seismic activities per season, the Nunatsiavut Government notes that the majority of the assessment, including the exact wording of many of the sections, remains unchanged from the original EA. The lack of change is disconcerting considering the change in scope of the project, and therefore our concerns regarding cumulative effects and monitoring plans remain.

> ***Response:*** As directed by the C-NLOPB, MKI was asked to split the Project Area of the original EA (Environmental Assessment of Multiklient Invest Newfoundland and Labrador Offshore Seismic Program, 2017–2026; LGL 2017) along 52 degrees latitude and decrease the temporal scope from 10 years to 6 years. MKI's understanding is that this was in part to address stakeholder concerns (including those of the NG) regarding the large Project Area and temporal scope of the original EA. Much of the original EA text and analyses are indeed directly applicable to the Labrador EA and as such, major changes were not required throughout the document. MKI has provided additional text regarding the assessment of cumulative effects (see below).

**Comment:** The NG has previously requested an end to the practice of referencing previous EA studies, particularly of other areas (e.g. page 153 of Revised EA). It is understandable to want to minimize the length of an EA, however these sections could be included as an appendix, especially when being used to assess the effects of the project activities on the environment.

> ***Response:*** As stated in Section 5 of the Scoping Document prepared by the C-NLOPB for the original EA (C-NLOPB 2017), "*Program activities are proposed for the southern, eastern and northern portions of the Canada-Newfoundland and Labrador Offshore Area which has been studied in recent EAs and the Eastern Newfoundland & Labrador Offshore Area Strategic Environmental Assessment (August 2014) (Eastern SEA), the Southern Newfoundland Strategic Environmental Assessment (February 2010) (Southern SEA) and the Labrador Shelf Offshore Area Strategic Environmental Assessment (August 2008) (Labrador SEA). For the purposes of this assessment, the information provided in the three SEAs should support the EA to avoid unnecessary duplication of information. Appropriate references should be included in the EA*." Specific weblinks for the Labrador Shelf SEA and supporting EAs were provided as footnotes in Section 2.4.1 (p.13) of the current EA. Including these documents (or large portions of these documents) as appendices to the current EA would result in very large documents. MKI contends

that providing a link to readily available documents is an appropriate way for reviewers to access information.

**Comment:** The NG recommends an improved review of the use of Passive Acoustic Monitoring (PAM) for mitigation; currently there is no review of the performance of PAM in seismic mitigation in the Revised EA. If PAM is to be used, the NG recommends minimizing the amount of noise during times of high visibility for MMOs when turning the vessel, thereby allowing for better detection. Please show how the PAM results would be incorporated into the overall monitoring reports and to the larger EA initiatives such as the Labrador Shelf Offshore Area Strategic Environmental Assessment (Labrador Shelf SEA).

***Response:*** The Scoping Document issued by the C-NLOPB does not require a performance review of PAM. Such a review would not be within the scope of an EA document but would typically be required by and occur in conjunction with DFO and/or the C-NLOPB. MKI used a PAM system provided by Seiche which integrated PAMGUARD software on two of its seismic vessels (*Ramform Hyperion* and *Ramform Sterling*) in 2018. In addition, each of the two vessels had a dedicated and trained PAM operator. Details of the PAM system, the number/type of acoustic detections, and a review of the efficacy of the system will be provided in the EA mitigation and monitoring report. This report can be made available upon request. The EA mitigation and monitoring report will be provided to the C-NLOPB and if and how it becomes incorporated into the Labrador Shelf SEA is in the purview of the C-NLOPB.

**Follow-up Comment:** PAM is classified as a mitigation for seismic impacts. Any environmental assessment is expected to show why a specific mitigation will be effective and to what degree. Therefore it is important to include the results of the efficacy of the system in the EA. This is a good example of how monitoring programs can lead to improved practices.

Regarding the mitigation and monitoring reports, their incorporation into the SEA is the purview of the co-chairs of the Labrador Shelf SEA, the C-NLOPB and the Nunatsiavut Government. The quality of CEA practice can only be improved with effort and collaboration from proponents. It would be beneficial for monitoring programs to be spelled out in EAs instead of requiring a request from the regulator. Monitoring programs from project-based EAs are an important contributor to the strengthening of Strategic Environmental Assessments as well as to assessing their own project-based cumulative effects. It would be beneficial to work with regulators, other operators and industries and enable access to monitoring results so that other proponents may improve upon their environmental assessments as well.

***Response:*** As stated in the initial response, MKI has addressed the Scoping Document for the EA and followed regulatory requirements. The review of PAM results for the *Ramform Hyperion* and *Ramform Sterling,* which operated offshore

Newfoundland in 2018, is provided in the EA mitigation and monitoring report, which has been submitted to the C-NLOPB. MKI is willing to work with the C-NLOPB and other stakeholders to discuss how the results of monitoring reports can be better incorporated into EAs.

**Comment:** The NG notes that the proponent has not included its own separate project (Multiklient Invest AS Newfoundland Offshore Seismic Program, 2018-2023) in the cumulative effects assessment. The NG suggests that the cumulative effects assessment be reviewed again, as the text has not been changed from the original EA, despite changes to the temporal and spatial scope and the project activities. The NG notes that despite the change in their own project to up to four seismic operations per season, there is little to no change to the impact assessment or the mitigations. For example, Table 5.17 regarding disturbance to marine animals, including species at risk, has not been altered to incorporate these changes. It is expected that increased communications would be a required mitigation. In addition, any impacts of multiple seismic operations in sensitive areas would warrant further impact assessment and mitigations such as spatial or temporal avoidance. With a low to medium level of certainty regarding the effects prediction of "not significant," the NG recommends the proponent make further efforts to reassess the effects assessment and to mitigate impacts by using best practices. Our original comments suggested that the spatial and temporal scope should be limited to the point where the proponent was able to properly assess cumulative effects. This remains our comment. The NG's concerns remain centred on the proponent's stated inability to properly assess cumulative effects. In addition, the proponent continues to repeat one statement from an academic paper (Duinker et al. 2012) to justify their current perspective that cumulative effects assessment is flawed and therefore could not be done. The text in the Revised EA remains almost exactly the same as in the original EA, leading us to question the quality of the re-assessment. The NG's letter from Sept. 15, 2016 (General Comment 3) provided key references to assist with the proper assessment of cumulative effects. This remains our comment.

***Response:*** The following project "Multiklient Invest Newfoundland Offshore Seismic Program, 2018–2023" should be added to the list of projects considered in the cumulative effects assessment. Regardless, the MKI EA for Labrador, did consider the potential of three concurrent 3D surveys and a 2D survey being conducted by MKI. In reality, this concurrent survey scenario will most certainly not occur offshore Labrador. MKI will likely only conduct one seismic survey per year offshore Labrador, particularly given the shorter survey window (with limited potential for a 2D and 3D seismic survey occurring at the same time). However, there is potential for other operators to conduct seismic surveys offshore Labrador and for seismic survey sound from areas south of and particularly adjacent to the southern boundary of the Labrador EA Project Area to cumulatively affect VECs that occur offshore Labrador. Given the EA process in place, MKI still contends that a more representative cumulative effects assessment is best captured in annual EA Updates when the details of seismic surveying (number of surveys, location, and timing) in a given year will be known. MKI suggests that the following text should be inserted as a new section of the EA.

**"Section 5.8.4 Consideration of Combined Activities**

*The primary concern associated with seismic surveys in combination with other projects or activities in the Study Area and adjacent waters is the effects of underwater sound on VECs. The cumulative effects of airgun sound from simultaneous seismic surveys on fish and fish habitat, fisheries, seabirds, marine mammals, sea turtles, species at risk and sensitive areas are predicted to be not significant. However, there are uncertainties regarding these predictions, particularly including the effects of masking and disturbance on marine mammals, and the effects of disturbance on marine invertebrates and fishes from sound produced during multiple seismic surveys. Note that possible disturbance effects on marine invertebrates and fishes might not only impact key life history components but also commercial fisheries and science surveys. However, disturbance effects on fisheries are more readily mitigated primarily through communication and temporal and spatial avoidance of seismic surveys from fishing activity. The uncertainties with the effects of underwater sound increase with the number of seismic surveys and additional sources of underwater sound in the area (e.g., commercial shipping, fishing vessels, and oil developments). Sound from vessels and sound associated with offshore production and drilling are generally continuous (vs. pulsed sound from airguns) and at much lower sound levels. There is little potential for hearing impairment or physical effects on VECs associated with underwater sound from vessels and offshore oil production. Any avoidance of vessels and offshore oil developments (on the Grand Banks) by VECs, including species at risk, is likely to be localized and temporary and is unlikely to contribute to cumulative effects on marine fauna occurring offshore Labrador.*

*As discussed previously, negative effects (auditory, physical, and behavioural) on key sensitive VECs, such as marine mammals, appear unlikely beyond a localized area from the sound source. A data gap in the assessment of three concurrent 3-D seismic programs as well as a single 2-D seismic survey is how marine mammals will respond behaviourally to sound from airgun pulses that may be received from multiple directions, variable intervals, and differing sound levels. Also, it is quite possible that the duration of exposures above a given sound level will increase (Wisniewska et al. 2014; Ellison et al. 2016). According to Nowacek et al. (2015), cumulative impacts have a high potential of disturbing marine mammals, especially those with limited ability to disperse. To the best of our knowledge, the marine mammal monitoring report prepared for Chevron's 2005 seismic program in Orphan Basin provides the only available analysis of disturbance effects on marine* *mammals from seismic surveys that occurred concurrently in Atlantic Canada (Moulton et al. 2006).*

*During the 2005 Chevron seismic program, there was a 12-week period when the M/V* Geco Diamond *and M/V* Western Patriot *conducted 3-D seismic surveys simultaneously in the Orphan Basin. The two vessels, which operated 5085 $in^3$ and 3000 $in^3$ arrays, were typically separated by distances of 50 km but were occasionally as close as 35 km during seismic operations (Moulton et al. 2006). Baleen whales, toothed whales, and dolphins were regularly sighted by MMOs on both seismic vessels during periods with and without airgun activity. Based on observations from the seismic vessels, for baleen whales (humpback, fin, sei, minke whales combined), there were no statistically significant differences in sighting rates (number of sightings/hour) nor radial distances (closest point of approach, CPA) during periods with vs. without airgun activity. Baleen whales were more likely to be observed swimming away from the seismic vessel during periods when the airguns were active vs. inactive. Similar results were observed for toothed whales (sperm whale, northern bottlenose whale, and Sowerby's beaked whale combined). Dolphins (long-finned pilot whale, Atlantic white-sided dolphin, striped dolphin, and bottlenose dolphin) were seen significantly farther from the seismic vessels during periods with (mean CPA= 807 m) vs. without airgun activity (mean CPA= 652 m). However, there were no statistically significant differences in sighting rates or types of behaviour recorded by MMOs. It is noteworthy (albeit one must acknowledge caveats, particularly that this was not a systematic study) that in 2004, Chevron undertook a single 3-D seismic survey in Orphan Basin (SR/V* Veritas Vantage*, 4450 $in^3$ array) and very similar marine mammal monitoring results, including sighting rates, were found relative to 2005 (Moulton et al. 2005, 2006).*

*All MKI seismic programs will use mitigation measures including ramp-ups, delayed startups, and shut-downs of the airgun arrays as well as spatial separation between concurrent seismic surveys (minimum of 30 km). MKI will use Passive Acoustic Monitoring (PAM) to assist with marine mammal detection during periods of poor visibility. In addition, there will be increased communication to ensure minimum separation distances between concurrent seismic surveys are maintained. Seismic programs and other ocean users (commercial shipping, fishing, oil developments) will also have to maintain an appropriate separation distance for safe operations. Marine mammal response (including species at risk) to commercial shipping noise is expected to be localized and temporary especially for vessels maintaining a constant course and speed, which is typical for transiting commercial vessels. Marine invertebrate and fish response to commercial shipping noise is also expected to be localized and temporary, especially given the much lower sound levels associated with commercial shipping. Thus, while some animals* *may receive sound from multiple seismic programs and other vessels in the region, the current prediction is that no significant residual effects will result from exposure to underwater sound. The level of confidence associated with this prediction is rated as low to medium given the scientific data gaps*."

The reference to Duinker et al. (2012) was intended to highlight the inherent problems with conducting a cumulative effects assessment. The references provided by the NG in response to the Seitel seismic EA (i.e., the letter from the NG dated September 2016) actually support conclusions made by Duinker et al. (2012). Bidstrup et al. (2016) state that cumulative effects assessment is lacking quality in impact assessments throughout the world. They indicated that more resources, data, collaboration, leadership and legislation can facilitate better cumulative effects assessment. Noble (2015) point out that current research on cumulative effects is focused largely on the development of frameworks and methodologies to advance cumulative effects assessment and management from individual projects to broader regional scales, and on the development of science and tools for assessing and monitoring cumulative effects. Noble (2015) added that interdisciplinary approaches and sustained funding are required to ensure that scholarly research continues to shape cumulative effects practice in the future.

**Follow-up Comment**: A cumulative effects assessment, by its nature, should encompass the entire temporal and spatial scope of the project as well as the effects of other known and foreseeable activities, such as those mentioned by the proponent in the above statement. The proponent has claimed to have assessed cumulative effects throughout the Revised EA (July 31, 2018, p. 194), however it only assesses the impacts of its own project on the VECs in the majority of the document. The minimal cumulative effects assessment lists the known and foreseeable activities, but does not quantify their impacts, nor assess the impacts together. Each of the activities' impacts are only assessed with the project activities, not with each other in a cumulative manner.

CEA best practices often include the creation of a table outlining effects of each component of the known and foreseeable projects on the VECs identified in the EA, the causes of that effect, the cumulative effect, and indicators that can monitor the effect(s). The low quality of this type of assessment in Section 5.8 calls into question the quality of monitoring and assessment that the proponent is suggesting can be done on an annual basis. For example, Section 5.8.2, Marine Transportation devotes only four sentences to its assessment. As this project expects to assess a 6-year time span, an assessment of whether or not shipping routes may see an increase or decrease in traffic, as well as any mention of the impacts of shipping on specific VECs would be appropriate. This information should be combined with the impacts of known and foreseeable projects to estimate cumulative impacts on each of the VECs. As of now, it is unclear how assessments such as Section 5.8.2 could lead to a robust monitoring of cumulative effects.

***Response***: As discussed in the initial response, the EA did assess potential cumulative effects of multiple concurrent seismic surveys and did consider other human activities including fishing and marine shipping. Emphasis in the EA was placed on potential concurrent seismic surveys because relative to other human activities considered offshore Labrador, the sound from multiple seismic surveys over the temporal scope of the EA, has the potential to affect most VECs. The response to NG's original comment did provide additional consideration of potential cumulative effects from marine transportation. Shipping traffic levels offshore Labrador are considered low (see review in the Labrador SEA; C-NLOPB 2008[1]) and MKI (as well as other seismic operators) take steps to avoid close approach to other vessels. As such, while some animals may receive sound from multiple seismic programs and other vessels offshore Labrador, the current prediction is that no significant residual effects will result from exposure to underwater sound.

**Follow-up Comment**: The NG is not disputing the conclusions of the cited literature. However, none of the authors argue against completing a quality cumulative effects assessment. Cumulative effects assessments are not required to be perfect – they are carried out to manage uncertainty over the entire project. Therefore the argument of performing a CEA annually is not tenable. CEA practice does not require the exact future projects to be known; only those that are known and reasonably foreseeable should be assessed. This assessment would then provide an estimated baseline of impacts that could be compared to annual monitoring programs and data.

***Response***: A cumulative effects assessment has been conducted, with emphasis on potential future geophysical activity offshore Labrador. MKI will provide a more representative cumulative effects assessment in its annual EA Updates when the details of seismic surveying (number of surveys, location, and timing) in a given year will be known. The EA Update will also include and consider any updated information on human activity offshore Labrador. The EA Update will be used to confirm that the proposed project activities in a given year, including consideration of other human activities (i.e., cumulative effects), falls within the scope of the original EA.

**Comment:** The proponent continues to rely on the annual EA Update process to assess cumulative effects, which is not an appropriate practice within cumulative effects assessment. As we have stated in our previous letters on this project, the cumulative effects assessment should be completed prior to the start of the larger project, and adapted as necessary in the EA Updates. The 10-page 2018 EA Update for MKI's Newfoundland seismic project does not contain any details of monitoring as well as how that monitoring fits into any project-level monitoring program or strategic environmental assessment.

---

[1] C-NLOPB (Canada-Newfoundland and Labrador Offshore Petroleum Board). 2008. Labrador Shelf Offshore Area Strategic Environmental Assessment. Report by Sikumiut Environmental Management Ltd., St. John's, NL for the C-NLOPB, St. John's, NL. 519 p. + appendices.

***Response:*** As noted above, given the EA process in place, MKI contends that a more representative assessment of cumulative effects would occur on an annual basis (in EA Updates) because the actual details of seismic survey activity (number of surveys, location, timing) are not known years in advance. Monitoring and mitigation measures are consistent across seismic programs that are undertaken by MKI, regardless if there is one seismic survey or two or more surveys. The exception is that concurrent seismic programs maintain a minimum spatial separation of 30 km (as stated in several sections of the EA). In addition, enhanced communication between seismic surveys as well as with relevant stakeholders (e.g., fisheries, shipping) is also required. More specifically, to mitigate potential interactions between other primary ocean users, MKI's seismic and escort vessels constantly monitor fishing and shipping activity and communicate with other vessels to ensure that appropriate separation distances are maintained for safe operations. The EA mitigation and monitoring report is provided to the C-NLOPB and if and how it becomes incorporated into the Labrador Shelf SEA is in the purview of the C-NLOPB. MKI has recently learned that EA mitigation and monitoring reports for seismic programs are now available upon request from the C-NLOPB. In future EA Updates, relevant information in these reports will be included.

**Comment:** The proponent reviews the sound exposure criteria for marine fish, mammals and sea turtles to determine the effects and significance of seismic noise. Therefore, if sound exposure levels are being used to assess effects and significance, it is logical that they should be used for mitigation. The NG suggests that the proponent model the soundscape in the project area to ensure that their proposed 500m radius for marine mammals and sea turtles is covering the latest sound exposure criteria that they use in their assessment to determine the effects of seismic noise. This is an example of an opportunity to contribute to the adoption of best practices, as the proponent has stated its desire to do so in the revised EA. This information will also improve our understanding of the Labrador offshore environment.

***Response:*** MKI, like other proponents employing the use of airgun(s), are required to follow *The Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment* (SOCP) as outlined in the Geophysical, Geological, Environmental and Geotechnical Program Guidelines (C-NLOPB 2017). Although the SOCP requires the use of a 500 m safety zone, it does not provide the rationale for the selection of this distance (see Moulton et al. (2009) for a review of the efficacy of the SOCP). In recent years, acoustic modelling of airgun arrays has been undertaken for several EAs of seismic surveys offshore Nova Scotia (e.g., LGL 2013, 2014a). Modelling results have shown that the acoustic threshold (based on peak pressure) for Permanent Threshold Shift (PTS) is predicted to occur at distances less than 500 m (typically on the order of 10s of metres). Similarly, the distance from the airgun array where the cumulative

SEL threshold (based on 24 hours of energy accumulation for a stationary receiver) has also been predicted to be less than 500 m for most marine mammal hearing groups. The exception is typically for high-frequency cetaceans, which include the harbour porpoise offshore Newfoundland and Labrador. It is important to note that the U.S. National Marine Fisheries Service (NMFS 2016, 2018) underwater threshold (SEL) for onset of PTS assumes that marine mammals would have to stay within the threshold distance for 24 hours to "accumulate" enough sound energy to result in hearing impairment. This is an unlikely scenario given the mobile nature of marine mammals (including harbour porpoise) and that most cetaceans exhibit at least localized avoidance of airgun array sound as well as vessels.

**Comment:** The EA mitigation and monitoring report submitted to the C-NLOPB within 6 months of each's season should contain methods that will enable data to feed into longer term EA planning, such as the EA Updates and that of the Labrador SEA.

***Response:*** Historically, monitoring and mitigation reports have included detailed methods and analyses comparing marine mammal sighting rates and distances between periods with and without airguns. This has allowed for data compilation within and across marine mammal (and sea turtle) monitoring programs which permitted for more robust analyses (e.g., Moulton and Holst 2010). This information has been used in EAs to predict effects. The C-NLOPB currently requires proponents to include a description of monitoring and mitigation measures implemented during the seismic program and an assessment of the efficacy of these measures. MKI will adhere to C-NLOPB requirements and it is our understanding that the EA mitigation and monitoring reports are available upon request from the C-NLOPB. If and how it becomes incorporated into the Labrador Shelf SEA is in the purview of the C-NLOPB. In future EA Updates, relevant information from the EA mitigation and monitoring reports will be included.

**Follow-up Comment**: On page 7, the proponent references an assessment of shipping traffic levels from the Labrador Shelf SEA. As this document was created in 2008 and is stated to cover only up to 10 years from its publication, it would be beneficial to reassess the impact of shipping traffic from more recent shipping data, especially if this project is expected to extend to 2023.

**Response**: Shipping activity in the Project Area occurs primarily during the ice-free months, typically June–November. Seasonal marine traffic consists of local transport and coastal ferries to/from Labrador ports, oil tanker and sea-lift cargo supply vessels servicing the eastern Canadian Arctic, bulk carrier transits to/from Voisey's Bay, fishing vessels, ecotourism cruise ships, and seismic vessels. Year-round marine traffic through the Labrador Sea is mainly comprised of offshore commercial factory-freezer trawlers and freighters transiting between Greenland and eastern North American ports, and shipping of concentrated ore from mining operations in Voisey's Bay (C-NLOPB 2008). Data obtained from Canadian Coast

Guard, Marine Traffic and Communication Services, identified 624 and 608 vessel trips through the Labrador SEA area in 2006 and 2007, respectively. Information from the Coast Guard was provided with caveats however, in that it only recorded activities of vessels of 500 gross tonnage or greater, and of these, it could not provide a complete listing of vessels that travelled non-stop through the Labrador SEA area (C-NLOPB 2008).

More accurate assessments of regional marine traffic has been facilitated by the ubiquitous use of AIS transponders by vessels and technological advances in data storage, processing capabilities and online commercial service providers over the past decade. Figures 1 and 2 show cumulative marine traffic density that transited through the Project Area for calendar years 2016 and 2017, respectively. Source data to generate maritime routes for all vessel traffic was obtained from marine AIS tracking information archived and processed by marinetraffic.com. Publicly available density maps are color-coded to indicate concentrated maritime activity/traffic routes. Online visualizations are dynamic and based on unique vessel transits through a variable grid-cell size based on chosen zoom-level of a worldwide interactive map. Figures 1 and 2 are presented with similar scale for ease of comparison; vessel routes ranging from 1 to >800 per 23 $km^2$ grid-cell. Figure outputs were centered on the Labrador Sea, georeferenced (ArcGIS), and 'The Zone' and Project and Study Area boundaries were overlain to provide spatial context relative to the MKI Labrador offshore seismic program.

Within the MKI Labrador offshore Project Area, marine traffic density is concentrated in the southwestern corner at the confluence of marine routes between the Strait of Belle Isle and the eastern coastline of the Great Northern Peninsula of Newfoundland. Localized concentrations (orange/red clusters; >40 vessel routes per 23 $km^2$ grid-cell) adhere strongly to commercial catch (0.1x0.1 decimal degree) grid data for both 2016 and 2017. Specifically, northern shrimp catch effort at depths between 200 and 500 m in the northern half (*i.e.*, NAFO divisions 2H, 2G, 2G/0B) and southwest corner (2J) of the Project Area; Greenland halibut fishery along the Labrador Shelf (2J); and snow crab fishery locations at the southwestern extent of the Project Area (2J). Overall, shipping traffic levels through the Project Area are considered low, particularly in areas distant from coastal shipping routes. Shipping data from 2016 and 2017 confirm the conclusions made in the Labrador SEA (C-NLOPB 2008). Behavioural responses to periodic ship transits by marine mammals are expected to be short-term and localized. MKI (as well as other seismic operators) take steps to avoid close approach to other vessels. As such, while some animals may receive sound from a seismic program(s) and other vessels offshore Labrador, the current prediction is that no significant residual cumulative effects will result from exposure to underwater sound.

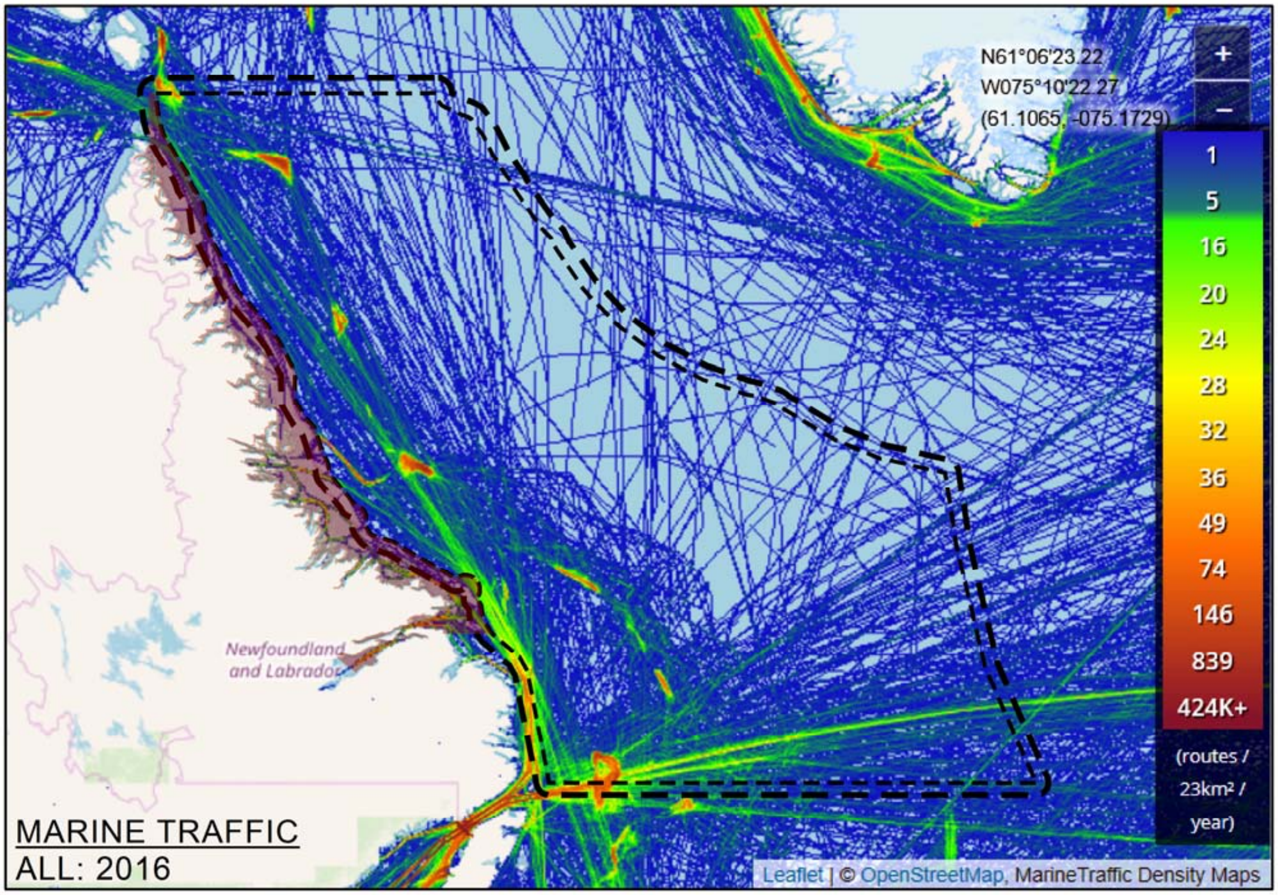


Figure 1. Marine shipping traffic density (routes per 23 $km^2$ grid cell) in 2016 in the MKI Project and Study Areas (depicted with small and large dashed lines, respectively).

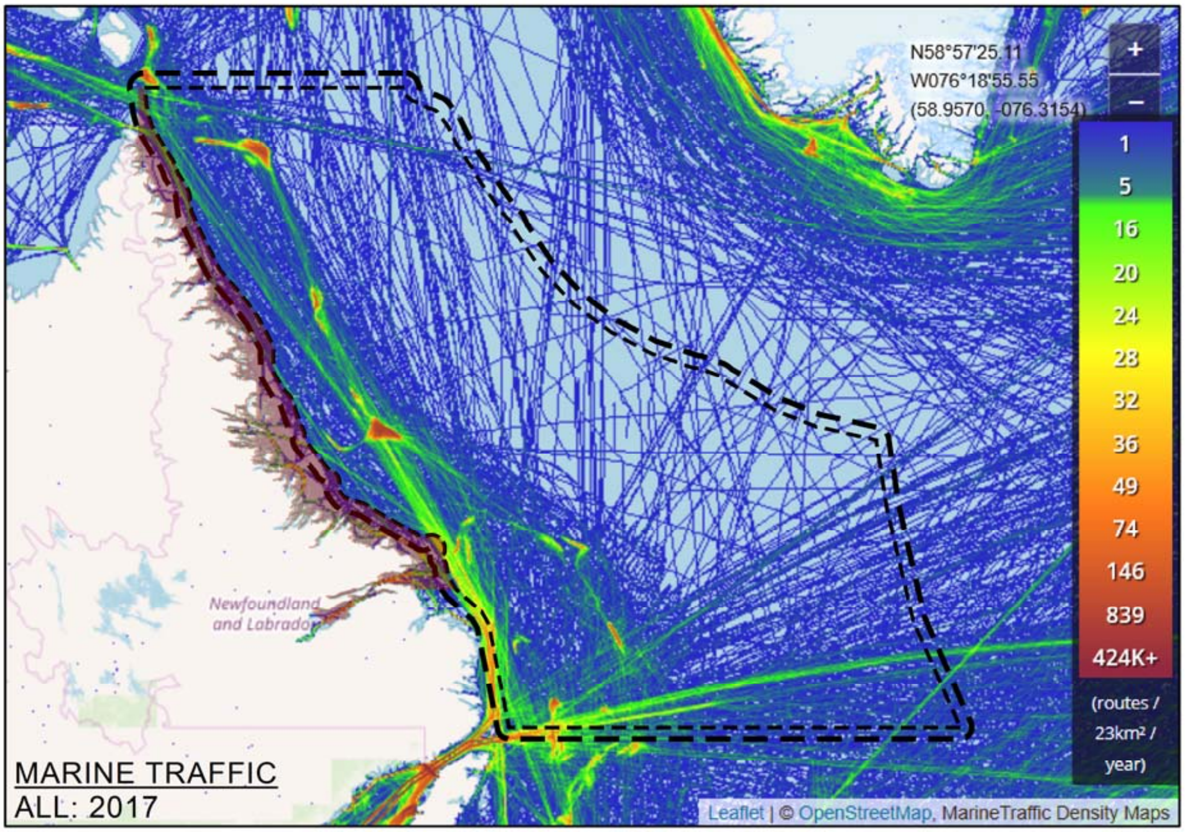


Figure 2. Marine shipping traffic density (routes per 23 $km^2$ grid cell) in 2017 in the MKI Project and Study Areas (depicted with small and large dashed lines, respectively).

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

**Comment:** The C-NLOPB concurs with the NG on the issue of cumulative effects. A more robust assessment of possible cumulative effects is required which includes MKI's Newfoundland Offshore Seismic Program.

> ***Response:*** See responses to the NG's comments above.

## Fish, Food and Allied Workers (FFAW)

**Comment:** From information presented in this EA it does not appear as the proponent has a true understanding of the current fishing industry off the Labrador coast. This is concerning if the proponent is to work with the fishing industry in the coming years to avoid potential conflicts between the two industries.

While the EA provides notes on consultations with the fishing industry it references a fleet meeting with crab harvesters in 3L. These harvesters do not fish crab in 2J where the work is being proposed. Site specific consultations in Labrador were conducted two years prior to the proposed work. It should be noted that there are harvesters from other areas of the province who can fish for shrimp and turbot in the study area. Additional consultation is recommended.

> ***Response:*** MKI held consultations in Labrador in early 2017. No seismic surveys were planned offshore Labrador in 2018 and as such MKI did not pursue specific consultations with stakeholders for Labrador seismic surveys in 2018. MKI will undertake consultations with stakeholders with fishing interests offshore Labrador each active seismic season. Details will be provided in subsequent EA Updates.

**Comment:** The catch data (2010-2015) presented in this document is very outdated. While it is understood that this data can be challenging to acquire there is room in the commentary for updates from industry players to ensure the information is relevant. For example, there is indeed a commercial cod fishery in 2J which uses various gear types including hand lines and gillnets. The "inshore fleet" generally comprises fishing vessels up to 65 feet in length. Generally, vessels greater than 35 feet fish for crab (not less than 35 feet as the document states). Turbot is fished using both trawls (primarily the offshore fleet of vessels greater than 100 feet) and gillnets (inshore fleet). There is no current directed fishery for grenadier or witch flounder in the Labrador offshore. These species would be incidental by-catch from one of the three main fisheries (crab, turbot and shrimp). The shrimp fishery is indeed the most valuable fishery in the region but there is more potential conflict with fixed gear crab pots and turbot gillnets from an operational side. (It is recommended that the Shrimp Fishing Areas be mapped along with NAFO divisions when portraying shrimp catch data).

> ***Response:*** The 2010–2015 commercial catch data were the most up-to-date available data at the time of writing the EA. DFO experienced a backlog fulfilling requests since fall 2017, and as a result more recent data (i.e., 2016 catch) were not available from DFO until fall 2018. DFO catch data from 2017 are not yet available for request. All conclusions drawn within the EA were based on available substantiated data from DFO, although MKI acknowledges the information provided in the above comment. MKI regularly meets with the FFAW and can certainly include suitable information provided by the FFAW in future EA Updates. MKI will consider mapping Shrimp Fishing Areas when portraying shrimp catch data in future EA Updates.

**Comment:** The collaborative DFO-industry post season crab survey has undergone changes in terms of the location and number of survey stations in recent years. The survey footprint has been increased with stations shifting from densely sampled regions to cover a broader Snow Crab habitat range. Fixed stations will remain the same for five years while random stations will change every year. A review of the data will be conducted every year by DFO, FFAW/Unifor and fish harvesters. The changes to the post-season crab survey are not accurately reflected in the document.

***Response:*** Of most relevance here is that MKI has and will continue to as stated in the EA "… *coordinate with DFO, St. John's, and the FFAW|Unifor to avoid any potential conflicts with either survey vessels that may be operating in the area or survey stations in the area (e.g., Industry-DFO-FFAW|Unifor Collaborative Post-Season Trap Survey for Snow Crab).*" References to the above changes noted by FFAW were not found on the DFO or FFAW websites as of 25 October 2018. However, MKI is aware of these changes and will for future EA Updates seek official documentation reflecting the above changes in the collaborative DFO-Industry post season crab survey in order to accurately reflect the changes in future EA Update(s).

**Comment:** FFAW/Unifor continues to raise objection to the presented "7 day/30 km temporal/spatial avoidance protocol" mitigation measure presented for the post-season crab survey. It continues to be FFAW/Unifor's position that seismic work should NOT be conducted in the vicinity of survey stations until they have been sampled for the year. This post-season crab survey continues to be vital to the fishing industry as it informs decision making with regards to quotas for coming years. Our members rely on this survey to be completed each year, without interruption or potential effects from outside variables. It is understood that seismic planning around the survey stations is challenging.

***Response:*** DFO, the collaborator with the FFAW/Unifor on the post-season snow crab survey, has never indicated that seismic work should not be conducted in the vicinity of the survey stations until sampling has been completed for that particular year. Results of a recent study conducted on the Grand Banks and led by a DFO research scientist (Morris et al. 2018) did not support the contention that seismic activity negatively affects catch rates in shorter term (i.e., within days) or longer time frames (weeks). While they did indicate that the inherent variability of CPUE data limited the statistical power of the study, the results also suggested that if seismic effects on snow crab harvests do exist, they are smaller than changes related to natural spatial and temporal variation. MKI has maintained a continuous communication with the FFAW/Unifor during seismic surveys conducted in recent years in order to minimize any potential effect of exposure to seismic sound on snow crab behavior. This cooperative effort shown by MKI and the FFAW/Unifor has been very successful.

**Comment:** The area being proposed is large in scope. It is difficult to comment on the impacts to the fishing industry without knowing more spatial and temporal specific plans of proposed survey programs. It is imperative that there is a effective flow of information between the fishing and seismic industries several months prior to the start of the seismic season such that early engagement can occur and plans can be adapted, if necessary.

> ***Response:*** Although the Project Area has a large spatial scope, seismic surveys in a given year offshore Labrador will not be. MKI anticipates that within a given season, it will likely only conduct one seismic survey (with limited potential to conduct a 2D and 3D seismic survey in the same year). MKI is committed to minimizing potential effects on fisheries from its project activities and will effectively communicate with the fishing industry in advance of the seismic season as well as during and after the seismic season.

**Comment:** It is critical that effective and regular communication ensue with the fishing industry throughout the EA lifespan so that the seismic company is kept apprised of ongoing developments within our dynamic fishing industry.

> ***Response:*** Agreed. MKI has always taken the approach to communicate regularly with the fishing industry and this practice will continue during the EA lifespan.

**Follow-up Comment:** The FFAW-Unifor looks forward to direct consultation on any planned annual seismic program in Labrador going forward. It is important to reiterate that there are harvesters throughout Newfoundland and Labrador who fish in the study area (i.e., not just harvesters living in Labrador). Therefore, depending on the area of interest, additional consultation may be warranted.

> ***Response:*** MKI will continue to consult with FFAW-Unifor for seismic programs offshore Labrador (and Newfoundland).

## SPECIFIC COMMENTS

### Fisheries and Oceans Canada (DFO)

**Comment: Figure 2.3, page 14** - The location of the Seitel Canada East Coast Study Area is not clear; the figure should be revised accordingly.

> ***Response:*** The northern portion of the Seitel Canada East Coast Study Area includes a multi-shared boundary, rendering it difficult to clarify without obscuring the MKI Study Area boundary, which should be the focus. Add the following statement onto the end of the figure caption: *"The MKI Study Area is nested within the northern and western extents of the Seitel Study Area."*

**Comment: Section 4.2.1.2 Benthic Invertebrates, pages 44-45** - Very few references are provided in this section. If additional references are available, they should be noted.

> ***Response:*** One or more references were provided within each paragraph in the abovementioned Section 4.2.1.2, as information supplementing that within the

supporting Labrador Shelf SEA and project-relevant EAs. Additional references relative to the Study Area will be incorporated into EA Updates as they become available.

**Comment: Figure 4.21, page 84** - Catch locations outside the community of Cartwright (as indicated on page 51) are not evident; the figure should be revised accordingly.

***Response:*** Revise the second paragraph within the American Plaice subsection on page 51 to the following: *"There is limited commercial fishery data for catches of American plaice within the Study Area. During May–November 2015, American plaice were harvested in the southern region of the Study Area, within water depths between 500 m and 1,000 m (see Figure 4.21 in § 4.3.3.2)."* The catch locations indicated within Figure 4.21 are accurate.

**Comment: Section 4.2.1 Principal Macro-invertebrates and Fishes Commercially Harvested Macroinvertebrates, pages 48-50** - Information on pink shrimp should also be provided given its commercial harvest within the Study Area (see 4.3.2 Regional NAFO Fisheries, sentence 2, paragraph 1, page 57).

***Response:*** Although pink shrimp were indicated as relatively prevalent within the NAFO dataset for NAFO Divisions at least partially within the Study Area, this species was not captured within the Study Area-specific DFO catch data during 2010–2015. As such, it is likely that the pink shrimp reported within the NAFO dataset occurred beyond the Study Area bounds. Background information within the Macroinvertebrates section (pages 48–50) reflects those species observed within the Study Area as per the DFO datasets.

**Comment: Section 4.2.2.2 Other Fishes of Note, Anadromous Fishes, page 53** - Updated references should be provided in this section.

***Response:*** Atlantic salmon occurring in four Labrador rivers were assessed in 2017 (DFO 2018). One of these was English River, one of four scheduled salmon rivers in Salmon Fishing Area (SFA) 1. Total returns to English River were ~3% lower than the previous 6-year mean, despite a 41% increase in large salmon returns. Three of the 16 scheduled salmon rivers in SFA2 were also assessed in 2017: Sand Hill River, Muddy Bay Brook (Dykes River), and Southwest Brook (tributary of Paradise River). All three rivers had total returns of small and large salmon in 2017 that were lower than the previous 6-year mean. The estimated Labrador indigenous and subsistence fisheries harvest in 2017 was inferred from logbook returns to be 13,600, ~4% less than the previous six-year mean (DFO 2018). Genetic analysis of salmon harvested in Labrador fisheries during 2006–2016 indicated that the majority were of Labrador origin (95–99%). Marine survival continues to be considered the major factor limiting the abundance of Atlantic salmon within the Newfoundland and Labrador region (DFO 2018).

DFO has not published a document regarding Labrador Arctic char since 2001. DFO (2001) was cited in the discussion about Arctic char in LGL (2014b).

**Comment: Section 4.3.3.1 Historical Fisheries, 1st sentence, page 58 -** Pink shrimp should also be noted based on Figure 4.2 (page 58).

***Response:*** Revise the first sentence on page 58, Section 4.3.3.1 Historical Fisheries, to the following: *"During recent years, northern and pink shrimps have comprised the majority of harvest within and/or adjacent to the Study Area beyond the EEZ, followed by Greenland halibut and, less so, by Atlantic cod."*

**Comment: Section 4.3.3.2 Study Area Catch Analysis, 2010-2015, Fishing Gear Used in the Study Area, paragraph 1, page 67** - There are some inconsistencies regarding the description of gears in the text and the list of gear types provided in Table 4.10 (page 69). Revision to text is recommended.

***Response:*** Revise the third- and second-last sentences in paragraph 1, Section 4.3.3.2, Fishing Gear Used in the Study Area (page 67) to the following: *"Shrimp trawls (mobile gear) and snow crab pots (fixed gear) accounted for ~85% and 7%, respectively, of the total catch weight of all species in the Study Area during 2010."*

**Comment: Section 4.3.8 Industry and DFO Science Surveys, 2nd sentence, paragraph 2, page 101** - Based on Table 4.13 (page 102), it appears that surveys within the Study Area are scheduled to commence on October 5. Text should be revised accordingly.

***Response:*** Revise the second sentence of paragraph 2, page 101, Section 4.3.8 to the following: *"Fall surveys within the Study Area are scheduled to commence 5 October and continue until 19 December."*

**Comment: Section 4.5.1.2 Baleen Whales (Mysticetes), Humpback Whale (Western North Atlantic Population), 3rd sentence, paragraph 1, page 117** - Information on the timing of sightings does not match Table 4.17 (pages 116-117). Reference to Table 4.17 could be removed here as well as other similar instances throughout the text.

***Response:*** For humpback whales and other cetaceans insert *"DFO sighting database, unpublished" in front of "Table 4.17; Figure 4.33". As such, text should read "(DFO sighting database, unpublished; Table 4.17; Figure 4.33)".*

**Comment: Section 4.5.1.4 Pinnipeds (True Seals (Phocids); sentence 1, paragraph 1 & sentence 1, paragraph 2, page 124)** - Timing of occurrence is inconsistent with Table 4.16 (page 115). Text should be revised accordingly.

***Response:*** Revise the sentences referred to in the above comment to the following, respectively:

*"Hooded seals are likely to be most common in the Study Area during winter to spring."*

*"Harp seals are prevalent within the Study Area winter to spring, particularly during late winter off northeast Newfoundland and southern Labrador where they congregate to breed and pup on the pack ice."*

**Comment:** When describing Species at Risk, the appropriate population name should be referenced:

- Atlantic population for Leatherback Sea Turtle - Section 4.5.2 Sea Turtles (paragraph 1, page 125); Section 4.6.2.3 Marine Mammals and Sea Turtles (sentence 1, paragraph 1, page 130);
- Atlantic population for Blue Whale - Section 4.6.1 Species at Risk within the Study Area (paragraph 1, page 127);
- Atlantic population for Fin Whale - Section 4.6.1 Species at Risk within the Study Area (paragraph 1, page 127);
- Northwest Atlantic/Eastern Arctic population for Killer Whale - Section 5.7.7.1 Sound (Toothed Whales, sentence 3, page 179); and
- Northwest Atlantic population for Harbour Porpoise - Section 5.7.7.1 Sound (Toothed Whales, sentence 3, page 179).

***Response:*** So noted. Population names were omitted from these sections in an effort to reduce duplication relative to information provided within Table 4.19. Revise the appropriate sections as per the bullet points in the above comments.

**Comment: Table 4.19, page 129** - Bowhead Whale (Eastern Canada - West Greenland population) should be included.

***Response:*** So noted. See the revised Table 4.19 below.

**Comment: Section 5.3.2.4 Regional Area, page 141** - The spatial limits of the "Regional Area" should be clarified.

***Response:*** As stated in the EA, the Regional Area is the area where cumulative effects are considered. MKI's seismic assessment included consideration of the offshore waters of Labrador, the Grand Banks (with emphasis on the eastern area), Northeast Newfoundland Slope area, and the Flemish Pass area.

**Comment: Section 5.5 Mitigation Measures, bullet iv, page 146** - Whale species described are inconsistent with Table 4.19 (page 129). Text should be revised accordingly. This comment also applies to Section 5.7.7.1 Sound (Toothed Whales, sentence 2, page 179) and Section 5.7.7.1 Sound (Baleen Whales, sentence 2, page 182).

***Response:*** Revise the text in question to *"The airgun source array(s) will be shut down immediately if a marine mammal or sea turtle with either endangered or threatened status on Schedule 1 of the SARA is detected within the safety zone. For the Study Area, this currently includes North Atlantic right whales, blue whales, beluga whales, leatherback sea turtles, and loggerhead sea turtles. Note that MKI also commits to implementing shut downs for all sea turtle species and all beaked whales, including northern bottlenose whale and Sowerby's beaked whale."* North Atlantic right whales have been included in the 'shut down' list given that there is some limited chance they may occur in the Project Area.

Text in Section 5.7.7.1 (Toothed Whales) should be revised to *"Species of most concern are those that are designated under SARA Schedule 1 and that may occur in and near the Project Area (i.e., beluga whales and Sowerby's beaked whales)."*

Text in Section 5.7.7.1 (Baleen Whales) should be revised to *"Species of most concern are those that are designated under SARA Schedule 1 and that may occur in and near the Project Area (i.e., namely blue whales and fin whales but also North Atlantic right whales in the event this critically endangered species occurs offshore Labrador)."*

## Table 4.19 *SARA*- and COSEWIC-listed Marine Species with Reasonable Likelihood of Occurrence in the Study Area.

| SPECIES | | *SARA*[a] | | | COSEWIC[b] | | |
|---|---|---|---|---|---|---|---|
| **Common Name** | **Scientific Name** | **Endangered** | **Threatened** | **Special Concern** | **Endangered** | **Threatened** | **Special Concern** |
| **Marine Fish** | | | | | | | |
| Northern Wolffish | *Anarhichas denticulatus* | | Schedule 1 | | | X | |
| Spotted Wolffish | *Anarhichas minor* | | Schedule 1 | | | X | |
| Atlantic Wolffish | *Anarhichas lupus* | | | Schedule 1 | | | X |
| Atlantic Cod | *Gadus morhua* | | | Schedule 3 | | | |
| Atlantic Cod (Newfoundland and Labrador population) | *G. morhua* | | | | X | | |
| Atlantic Bluefin Tuna | *Thunnus thynnus* | | | | X | | |
| Porbeagle Shark | *Lamna nasus* | | | | X | | |
| Roundnose Grenadier | *Coryphaenoides rupestris* | | | | X | | |
| Cusk | *Brosme brosme* | | | | X | | |
| Smooth Skate (Funk Island Deep population) | *Malacoraja senta* | | | | X | | |
| Winter Skate (Eastern Scotian Shelf-Newfoundland population) | *Leucoraja ocellata* | | | | X | | |
| Atlantic Salmon<br>(Anticosti Island population)<br>(Eastern Cape Breton population)<br>(Nova Scotia Southern Upland population)<br>(Outer Bay of Fundy population) | *Salmo salar* | | | | X | | |
| American Eel | *Anguilla rostrata* | | | | | X | |
| American Plaice (Newfoundland and Labrador population) | *Hippoglossoides platessoides* | | | | | X | |
| Atlantic Salmon<br>(South Newfoundland population) | *S. salar* | | | | | X | |
| Acadian Redfish (Atlantic population) | *Sebastes fasciatus* | | | | | X | |
| Deepwater Redfish (Northern population) | *S. mentella* | | | | | X | |
| White Hake (Atlantic and Northern Gulf of St. Lawrence population) | *Urophycis tenuis* | | | | | X | |
| Lumpfish | *Cyclopterus lumpus* | | | | | X | |
| Atlantic Salmon<br>(Quebec Eastern North Shore population)<br>(Quebec Western North Shore population)<br>(Inner St. Lawrence population)<br>(Gaspé-Southern Gulf of St. Lawrence population) | *S. salar* | | | | | | X |
| Shortfin Mako Shark (Atlantic population) | *Isurus oxyrinchus* | | | | | | X |
| Basking Shark (Atlantic population) | *Cetorhinus maximus* | | | | | | X |
| Spiny Dogfish (Atlantic population) | *Squalus acanthias* | | | | | | X |
| Roughhead Grenadier | *Macrourus berglax* | | | | | | X |
| Thorny Skate | *Amblyraja radiata* | | | | | | X |

| SPECIES | | *SARA*[a] | | | COSEWIC[b] | | |
|---|---|---|---|---|---|---|---|
| **Common Name** | **Scientific Name** | **Endangered** | **Threatened** | **Special Concern** | **Endangered** | **Threatened** | **Special Concern** |
| **Marine-associated Birds** | | | | | | | |
| Ivory Gull | *Pagophila eburnea* | Schedule 1 | | | X | | |
| Red Knot *rufa* subspecies | *Calidris canutus rufa* | Schedule 1 | | | X | | |
| Buff-breasted Sandpiper | *Tryngites subruficollis* | | | Schedule 1 | | | X |
| Harlequin Duck (Eastern population) | *Histrionicus histrionicus* | | | Schedule 1 | | | X |
| Barrow's Goldeneye (Eastern population) | *Bucephala islandica* | | | Schedule 1 | | | X |
| Ross's Gull | *Rhodostethia rosea* | | Schedule 1 | | | X | |
| **Marine Mammals** | | | | | | | |
| Blue Whale (Atlantic population) | *Balaenoptera musculus* | Schedule 1 | | | X | | |
| Beluga Whale (St. Lawrence Estuary population) | *Delphinapterus leucas* | Schedule 1 | | | X | | |
| Beluga Whale (Cumberland Sound population) | *D. leucas* | | Schedule 1 | | | X | |
| Fin Whale (Atlantic population) | *B. physalus* | | | Schedule 1 | | | X |
| Sowerby's Beaked Whale | *Mesoplodon bidens* | | | Schedule 1 | | | X |
| Polar Bear | *Ursus maritimus* | | | Schedule 1 | | | X |
| Harbour Porpoise (Northwest Atlantic population) | *Phocoena phocoena* | | Schedule 2 | | | | X |
| Humpback Whale (Western North Atlantic population) | *Megaptera novaeangliae* | | | Schedule 3 | | | |
| Beluga Whale (Eastern Hudson Bay population) | *D. leucas* | | | | X | | |
| Beluga Whale (Ungava population) | *D. leucas* | | | | X | | |
| Beluga Whale (Eastern High Arctic-Baffin Bay population) | *D. leucas* | | | | | | X |
| Beluga Whale (Western Hudson Bay) | *D. leucas* | | | | | | X |
| Killer Whale (Northwest Atlantic/Eastern Arctic populations) | *Orcinus orca* | | | | | | X |
| Northern Bottlenose Whale (Davis Strait-Baffin Bay-Labrador Sea population) | *Hyperoodon ampullatus* | | | | | | X |
| Bowhead Whale (Eastern Canada-West Greenland population) | *Balaena mysticetus* | | | | | | **X** |
| Atlantic Walrus (Central/Low Arctic population) | *Odobenus rosmarus rosmarus* | | | | | | X |
| **Sea Turtles** | | | | | | | |
| Leatherback Sea Turtle (Atlantic population) | *Dermochelys coriacea* | Schedule 1 | | | X | | |
| Loggerhead Sea Turtle | *Caretta caretta* | Schedule 1 | | | X | | |

Source: [a]*SARA* website (http://www.sararegistry.gc.ca/sar/index/default_e.cfm), accessed May 2018; [b]COSEWIC website (https://www.canada.ca/en/environment-climate-change/services/committee-status-endangered-wildlife.html), accessed May 2018.

**Comment: Section 5.7.4.1 Sound, Sound Exposure Effects Assessment, page 152** - It is not clear why only Snow Crab and Atlantic Cod are noted in this section when other species are referenced in subsequent paragraphs (e.g., Behavioural Effects, pages 153-154). This section should be revised to clearly describe which information is incorporated in the effects assessment.

***Response:*** Replace existing text under the heading 'Sound Exposure Effects Assessment' (in Subsection 5.7.4.1, page 152) with the following:

*"It is not practical to asses in detail the potential effects of every type of sound on every species in the Study Area. The best approach in environmental assessment is to provide focus by selecting the sound source with the highest source sound level (i.e., seismic airgun array) and then assess exposure of invertebrates and fishes to this source by highlighting species that have been used in scientific studies and are most relevant to species occurring in the Study Area.*

*The primary factors considered in the assessment include the following: (1) distance between seismic airgun array and the invertebrate or fish life stage; (2) motility of the invertebrate or fish life stage; (3) the sensitivity of an invertebrate or fish life stage to the underwater sound components pressure and particle motion; and (4) the reproductive strategy of the invertebrate or fish.*

*Although the amount of research on the effects of exposure to airgun sound on marine invertebrates and fishes is constantly increasing, several key data gaps remain (Hawkins et al. 2015).*

*Potential interactions between the proposed Project activities and the Fish and Fish Habitat VEC are shown in Table 5.2."*

**Comment: Section 5.7.4.1 Sound, Physical and Physiological Effects, pages 152-153** - Examples of physical effects would be useful for clarity.

***Response:*** The following text provides some examples of physical effects of exposure to underwater sound on invertebrates and fishes observed during scientific study.

*"A study conducted in New Zealand involved the exposure of wild scallop larvae to recorded seismic pulses. Results indicated significant developmental delays from trocophore to D-veliger larval stage, with 46% of the larvae exhibiting body abnormalities. It was suggested that the malformations could be due to cumulative exposure (de Soto et al. 2013).*

*Day et al. (2016a,b, 2017) conducted a field study that involved the exposure of egg-bearing female spiny lobsters (Jasus edwardsi) to three different air gun configurations with corresponding maximum peak-to-peak source levels of 209, 210, and 212 dB re 1 µPa; and maximum cumulative SEL source levels of 192, 193, and 199 dB re 1 µPa$^2$ • s. Observed non-lethal effects included apparent damage to statocysts (Day et al. 2016b, 2017).*

*Evidence for airgun-induced damage to fish ears was collected 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 ~223 dB re 1 µPa • $m_{p\text{-}p}$, and the received SPLs ranged from 165 to 209 dB re 1 $\mu Pa_{p\text{-}p}$. 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).*

*Andrews et al. (2014) conducted genetic analyses on 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 received SPL was approximately 204 dB re 1µPa $_{p\text{-}p}$. The received levels were measured using hydrophones placed directly in front of the cage. 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. 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)."*

**Comment: Section 5.7.4.1 Sound, Behavioural Effects, pages 153-154** - Information pertaining to the behavioural effects for fish with different acoustic sensitivity would be useful.

***Response:*** The following text provides information pertaining to differing acoustic sensitivities among fishes and how these differing sensitivities affect behavioural effects of exposure to underwater sound.

*"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). This secondary transmission pathway 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 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).*

*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).*

*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. Generally, fishes use the lateral line system to detect the particle displacement component of low frequency acoustic signals (up to 160–200 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).*

*Behavioural effects of exposure to sound on fishes that are sensitive to the particle displacement component of sound only typically occur when the receiving animal is relatively close to the sound source. The propagation of particle displacement in the water column is less than that for sound pressure. Fishes that use a swim bladder in hearing (i.e., detect sound pressure) are typically able to detect sound at greater distances from the source than those that are able to detect particle displacement only. Note that demersal fishes lacking swim bladders may be able*

> *to detect particle displacement at greater distances from source than pelagic fishes lacking swim bladders due to various sound-associated shear waves that travel along the surface of and/or within the surficial sediment. Behavioural responses range from temporary startle responses to more long-term movement away from the sound source."*

**Comment: Table 5.3, page 157 -** Magnitude for Airgun Array should be 1-2 based on Assessment of Effects of Exposure to Sound (1st sentence 1, paragraph 1, page 156). Table 5.3 should be modified accordingly.

> ***Response:*** The magnitude rating for Airgun Array (2D, 3D and 4D) in Table 5.3 should be revised to from'0–2' to '1–2'.

**Comment: Table 5.4, page 158 -** Level of Confidence for Vessel Lights should be 2–3 based on Vessel Lights (last sentence, paragraph 1, page 156). Table 5.4 should be modified accordingly. This comment also applies to Table 5.20 (page 201).

> ***Response:*** The level of confidence ratings for 'Vessel Lights' in Tables 5.4 and should be revised from '3' to '2–3'.

**Comment: Section 5.7.7.1 Sound, Masking, 2nd last sentence, paragraph 1, page 173 -** References are recommended to justify the statement that the potential for masking is considered low.

> ***Response:*** The text in question is based on a review of the literature including many sources cited in Appendix 4 of LGL (2015a,b), which is cited throughout the EA. Please revise the text to *"However, based on past and current reviewed research, the potential for masking of marine mammal calls and/or important environmental cues from the proposed seismic program is considered low (see Section 1.4 in Appendix 4 of LGL [2015a,b])."*

**Comment: Section 5.7.7.1 Sound, Toothed Whales, last sentence, page 179 -** A reference should be provided for the use of 170 dB re 1 $\mu PA_{rms}$ a more realistic indicator of the isopleth within which disturbance is possible.

> ***Response:*** The text in question is based on a review of the literature including many sources cited in Appendix 4 of LGL (2015a,b), which is cited throughout the EA. Please revise the text to *"However, there is no good scientific basis for using this 160 dB criterion for odontocetes, rather 170 dB re 1 $\mu Pa_{rms}$ is likely a more realistic indicator of the isopleth within which disturbance is possible, at least for delphinids (see Section 1.5.2 in Appendix 4 of LGL [2015a,b])."*

**Comment: Table 5.12, page 180 -** Duration for Helicopter should be 1-2 based on section 5.7.7.2 Helicopter Sound (sentence 2, page 187). Table 5.12 should be modified accordingly. This comment also applies to Table 5.14 (page 185).

> ***Response:*** The values for Duration in Tables 5.12 and 5.14 are correct (i.e., value of 1 which is a Duration of less than 1 month). However, text in Section 5.7.7.2 should be revised to "*As indicated in Tables 5.12 and 5.14, sound produced by helicopters associated with the proposed Project is predicted to have residual disturbance effects on marine mammals and sea turtles that are negligible to* low *in magnitude for a duration of* <1 month *over a geographic area of* <1 to 1–10 km$^2$."

**Comment: Section 5.9 Mitigation Measures and Follow-up, paragraph 3, page 199 -** Sentence 1 should specify 'marine mammal' instead of 'whale'.

> ***Response:*** Revise sentence 1, paragraph 3, page 199, Section 5.9 to the following: *"Mitigation measures designed to reduce the likelihood of effects on marine mammals and sea turtles will include ramp ups (during all periods of day and night), no initiation of airgun array if a marine mammal or sea turtle is detected 30 min prior to ramp up within 500 m safety zone of the energy source, and shutdown of the energy source if an endangered or threatened marine mammal or sea turtle is detected within the 500 m safety zone."*

## LITERATURE CITED


Andrews, C.D., J.F. Payne, and M.L. Rise. 2014. Identification of a gene set to evaluate the potential effects of loud sounds from seismic surveys on the ears of fishes: A study with Salmo salar. **J. Fish Biol.** 84: 1793-1819.

Bidstrup, M., L. Kørnøv, and M.R. Partidário. 2016. Cumulative effects in strategic environmental assessment: The influence of plan boundaries. **Environmental Impact Assessment Review** 57: 151–158.

Casper, B.M. and D.A. Mann. 2006. Evoked potential audiograms of the nurse shark (Ginglymostoma cirratum) and the yellow stingray (Urobatis jamaicensis). **Envir. Biol. Fish.** 76:101-108.

Casper, B.M. and D.A. Mann. 2007. The directional hearing abilities of two species of bamboo sharks. **J. Exp. Biol.** 210:505-511.

Casper, B.M. and D.A. Mann. 2009. Field hearing measurements of the Atlantic sharpnose shark Rhizoprionodon terraenovae. **J. Fish Biol**. 75:2768-2776.

Casper, B.M., P.S. Lobel and H.Y. Yan. 2003. The hearing sensitivity of the little skate, Raja erinacea: a comparison of two methods. **Envir. Biol. Fish.** 68:371-379.

C-NLOPB (Canada-Newfoundland and Labrador Offshore Petroleum Board). 2008. Labrador Shelf Offshore Area Strategic Environmental Assessment. Report by Sikumiut Environmental Management Ltd., St. John's, NL for the C-NLOPB, St. John's, NL. 519 p. + appendices.

C-NLOPB. 2017. Multiklient Invest AS Newfoundland and Labrador Offshore Seismic Program, 2017-2026 scoping document. 11 p.

Coombs, S. and J.C. Montgomery. 1999. The enigmatic lateral line system. p. 319-362 In: R.R. Fay and A.N. Popper (eds.), Comparative hearing: fish and amphibians. Springer Handbook of Auditory Research 11. Springer-Verlag, New York, NY. 438 p.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, and J.M. Semmens. 2016a. Seismic air gun exposure during early-stage embryonic development does not negatively affect spiny lobster Jasus edwardsii larvae (Decapoda: Palinuridae). Sci. Rep. 6, 22723.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, K. Hartmann, and J.M. Semmens. 2016b. Assessing the impact of marine seismic surveys on southeast Australian scallop and lobster fisheries. Fisheries Research & Development Corporation (FRDC). FRDC Project No 2012/008. 144 p.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, K. Hartmann, and J.M. Semmens. 2017 Exposure to seismic air gun signals causes physiological harm and alters behavior in the scallop Pecten fumatus. **P. NATL. ACAD. SCI. USA.** 114(40) 8537-8546.

de Soto, N.A., N. Delorme, J. Atkins, S. Howard, J. Williams, and M. Johnson. 2013. Anthropogenic noise causes body malformations and delays development in marine larvae. Presented at The Effects of Noise on Aquatic Life, Third International Conference: 11-16 August 2013, Budapest, Hungary.

DFO (Department of Fisheries and Oceans). 2001. North Labrador Arctic Charr. DFO Science Stock Status report D2-07 (2001).

DFO. 2018. Stock assessment of Newfoundland and Labrador Atlantic salmon – 2017. DFO Can. Sci. Advis. Rep. 2018/034. (Erratum: September 2018).

ECCC (Environment and Climate Change Canada). 2017b. Procedures for handling and documenting stranded birds encountered on infrastructure offshore Atlantic Canada. 17 p. + appendices.

Ellison, W.T., R. Racca, C.W. Clark, B. Streever, A.S. Frankel, E. Fleishman, R. Angliss, J. Berger, D. Ketten, M. Guerra, M. Leu, M. McKenna, T. Sformo, B. Southall, R. Suydam, and L. Thomas, 2016. Modeling the aggregated exposure and responses of bowhead whales *Balaena mysticetus* to multiple sources of anthropogenic underwater sound. Endang. Spec. Res. 30:95-108.

Hawkins, A.D., A.E. Pembroke, and A.N. Popper. 2015. Information gaps in understanding the effects of noise on fishes and invertebrates. Rev. Fish. Biol. Fisheries 25: 39-64.

Howard J, W.M. Roberts, and A.J. Hudspeth. 1988. Mechanoelectrical transduction by hair cells. **Annu. Rev. Biophys. Chem**. 17:99-124.

Hudspeth, A.J. and V.S. Markin. 1994. The ear's gears: mechanical transduction by hair cells. **Physics Today** 47(2):22-28.

LGL Limited (LGL). 2013. Environmental assessment of Shell Canada Ltd.'s Shelburne Basin 3-D Seismic Survey. LGL Rep. SA1175. Rep. by LGL Limited, St. John's, NL and Mahone Bay, NS, for Shell Canada Limited, Calgary, AB. 127 p + appendices.

LGL. 2014a. Environmental assessment of BP Exploration (Canada) Limited's Tangier 3-D Seismic Survey. BP Document NS-HS-REP-BP-01-000 and LGL Rep. SA1222. Rep. by LGL Limited, Mahone Bay, NS and St. John's, NL for BP Exploration Canada Limited, Calgary, AB. 177 p + appendices

LGL. 2014b. Environmental assessment MKI Labrador Sea seismic program. LGL Rep. SA1245. Rep. by LGL Limited, St. John's, NL, for Multi Klient Invest AS, Oslo, Norway, and TGS-NOPEC Geophysical Company ASA, Houston, TX. 241 p. + appendices.

LGL. 2015a. Environmental assessment of WesternGeco's Eastern Newfoundland Offshore Seismic Program, 2015-2024. LGL Rep. FA0035. Prepared by LGL Limited in association with Canning & Pitt Associates Inc., St. John's, NL for WesternGeco (Division of Schlumberger Canada Limited), Calgary, AB. 255 p. + appendices.

MarineTraffic – Global Ship Tracking Intelligence (www.marinetraffic.com). 2019. Worldwide Density Maps [Online]. Available at: https://www.marinetraffic.com/en/ais/home/centerx:-63.2/centery:56.7/zoom:5 (Accessed: 10 April 2019).

LGL. 2015b. Environmental assessment of WesternGeco's Southeastern Newfoundland Offshore Seismic Program, 2015-2024. LGL Rep. FA0034. Prepared by LGL Limited in associated with Canning & Pitt Associates Inc., St. John's, for WesternGeco (Division of Schlumberger Canada Limited), Calgary, AB. 283 p. + appendices.

LGL. 2017. Environmental Assessment of Multiklient Invest Newfoundland and Labrador Offshore Seismic Program, 2017–2026. LGL Rep. FA0106. Rep. by LGL Limited, St. John's, NL for Multiklient Invest AS, Oslo, Norway, and TGS-NOPEC Geophysical Company ASA, Houston, TX. 255 p. + Appendix

Mann, D.A., D.M. Higgs, W.N. Tavolga, M.J. Souza, and A.N. Popper. 2001. Ultrasound detection by clupeiform fishes. **J. Acoust. Soc. Am.** 109(6):3048-3054.

Mann, D.A., Z. Lu, and A.N. Popper. 1997. A clupeid fish can detect ultrasound. **Nature** 389(6649):341.

Mann, D.A., Z. Lu, M.C. Hastings, and A.N. Popper. 1998. Detection of ultrasonic tones and simulated dolphin echolocation clicks by a teleost fish, the American shad (Alosa sapidissima). **J. Acoust. Soc. Am.** 104(1):562-568.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe. 2000a. Marine seismic surveys: analysis of airgun signals; and effects of air gun exposure on humpback whales, sea turtles, fishes and squid. Rep. from Centre for Marine Science and Technology, Curtin University, Perth, WA, for Australian Petroleum Production Association, Sydney, NSW.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe. 2000b. Marine seismic surveys – a study of environmental implications. **APPEA J.** 40:692-706.

McCauley, R.D., J. Fewtrell, and A.N. Popper. 2003. High intensity anthropogenic sound damages fish ears. **J. Acoust. Soc. Am.** 113(1):638-642.

Morris, C.J., D. Cote, B. Martin, and D. Kehler. 2018. Effects of 2D seismic on the snow crab fishery. **Fish. Res.** 197: 67-77.

Moulton, V.D. and M. Holst. 2010. Effects of seismic survey sound on cetaceans in the northwest Atlantic. Environmental Studies Research Funds Report No. 182. 28 p.

Moulton, V.D., B.D. Mactavish and R.A. Buchanan. 2005. Marine mammal and seabird monitoring of Chevron Canada Resources' 3-D seismic program on the Orphan Basin, 2004. LGL Rep. SA817. Rep. by LGL Limited, St. John's, NL, for Chevron Canada Resources, Calgary, AB, ExxonMobil Canada Ltd., St. John's, NL, and Imperial Oil Resources Ventures Ltd., Calgary, AB. 90 p. + appendices.

Moulton, V.D., B.D. Mactavish, R.E. Harris and R.A. Buchanan. 2006. Marine mammal and seabird monitoring of Chevron Canada Limited's 3-D seismic program on the Orphan Basin, 2005. LGL Rep. SA843. Rep. by LGL Limited, St. John's, NL, for Chevron Canada Limited, Calgary, AB, ExxonMobil Canada Ltd., St. John's, NL, and Imperial Oil Resources Ventures Ltd., Calgary, AB. 109 p. + appendices.

Moulton, V.D., P. Abgrall, M. Holst, and W.E. Cross. 2009. Efficacy of operational mitigation measures used to minimize impacts of seismic survey sound on marine mammals. LGL Rep. SA1019-1. Rep. from LGL Limited, St. John's, NL, King City, Ont., and Sidney, B.C., for Department of Fisheries and Oceans, Habitat Science Branch, Ottawa, Ont. 32 p. + appendix.

NMFS. 2016. Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-55. 178 p.

NMFS. 2018. 2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-59. 167 p.

Noble, B. 2015. Cumulative effects research: achievements, status, directions and challenges in the Canadian context. **Journal of Environmental Assessment Policy and Management** 17(1): 1-7.

Nowacek, D.P., C.W. Clark, P.Mann, P.J.O. Miller, H.C. Rosenbaum, J.S. Golden, M. Jasny, J. Kraska, and B.L. Southall. 2015. Marine seismic surveys and ocean noise: time for coordinated and prudent planning. Front. Ecol. Environ. 13(7):378-386.

Popper, A.N. and R.R. Fay. 1993. Sound detection and processing by fish: critical review and major research questions. **Brain Behav. Evol.** 41(1):14-38.

Popper, A.N. and R.R. Fay. 1999. The auditory periphery in fishes. p. 43-100 In: R.R. Fay and A.N. Popper (eds.), Comparative hearing: fish and amphibians. Springer-Verlag, New York, NY. 438 p.

Popper, A.N. and R.R. Fay. 2011. Rethinking sound detection by fishes. Hear. Res. 273(1-2):25-36.

Sand, O. 1981. The lateral line and sound reception. p. 459-478 In: W.N. Tavolga, A.N. Popper, and R.R. Fay (eds.), Hearing and sound communication in fishes. Springer-Verlag, New York, NY.

Wisniewska, D.M., L.A. Kyhn, J. Tougaard, M. Simon, Y.-T. Lin, A. Newhall, K. Beedholm, J. Lynch, and P.T. Madsen. 2014. Propagation of airgun pulses in Baffin Bay 2012. Aarhus University, DCE – Danish Centre for Environment and Energy. 150 p. Scientific Report from DCE – Danish Centre for Environment and Energy No. 109. Available at http://dce2.au.dk/pub/SR109.pdf