MANAGEMENT OF ARCTIC MARINE OIL AND GAS ASSOCIATED NOISE

MAY 2025

ARCTIC COUNCIL

PAME

Protection of the Arctic Marine Environment

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Introduction

The Arctic Council's Protection of the Arctic Marine Environment (PAME) Working Group approved a 2021–2023 project on the *Management of Arctic Marine Oil and Gas Associated Noise*. Led by the United States, United Kingdom, and WWF, this project seeks to:

1) Identify current practices for noise reduction or elimination related to offshore or nearshore oil and gas operations in the Arctic, and
2) Consider if specific guidance related to noise from Arctic oil and gas operations is needed.

The *Management of Arctic Marine Oil and Gas Associated Noise* project provides an opportunity for participating Arctic states to share information about measures to mitigate the impact of noise on marine life and related human activities. Mitigation measures were considered across all phases of marine oil and gas operations. While vessels directly involved in marine oil and gas activities for construction, crewing, or icebreaking were included, ships transporting crude oil or gas were not.

Although the project focuses on oil and gas operations within marine areas of the pan-Arctic region (see Figure 1), some mitigation measures identified in this report are used for areas south of the Arctic Circle, e.g., the Norwegian Sea (Norway), offshore Labrador or Newfoundland (Canada), Cook Inlet (United States), or in other types of industrial marine activities (e.g., submarine pile driving in Swedish waters of the Baltic Sea). These measures were included to meet the project intent to gather information about the range of available measures for further discussion or consideration.

Figure 1: Map of the Arctic

Project Approach

The following steps were completed for this project from 2021–2023:

1. a questionnaire was sent to Arctic States requesting information on relevant noise management measures,
2. supplementary research was conducted to identify relevant supporting literature and review the references provided in the questionnaire responses,
3. a draft discussion document was circulated to questionnaire respondents to elicit input,
4. follow-up calls were held with questionnaire respondents (regionally or individually),
5. additional written comments were submitted by participating States, and 6) a draft report was prepared based on input from the calls and written comments and circulated for further review.

The questionnaire on noise management measures was sent in December 2021 to participants in PAME's Resource Exploration and Development Expert Group (REDEG), which consists of representatives of the Arctic Council. Responses were received from Canada, Finland,[1] the Kingdom of Denmark (including the Faroe Islands and Greenland),[2] Iceland,[3] Norway, Sweden,[4] and the United States. Further input was provided by the Aleut International Association and Inuit Circumpolar Council, as well as the project co-lead WWF.

Relationship to Other PAME Projects

While the *Management of Arctic Marine Oil and Gas Associated Noise Project* is PAME's first project focused on noise associated with Arctic marine oil and gas operations, it complements previous PAME work on Arctic oil and gas impacts and mitigation efforts as well as projects addressing underwater noise associated with commercial shipping.[5]

PAME first developed its *Arctic Offshore Oil and Gas Guidelines* in 1997, with updates in 2002 and 2009. The *Guidelines* recommend practices for regulators of offshore oil and gas activities, including considerations related to potential impacts associated with noise from

[1] Finland responded that there is limited Finnish-flagged vessel activity in the Arctic and no oil and gas or mining.
[2] Questionnaire response related to Greenland only.
[3] No noise-specific mitigations were identified. Noise impacts were considered in a past assessment of previously considered marine oil and gas activity, but no specific mitigations were required, and that activity has ceased.
[4] Although Sweden does not have Arctic marine waters or any oil and gas activities, they provided information about practices to mitigate underwater noise from other types of marine industrial activities in areas south of the Arctic.
[5] See projects: https://pame.is/projects/resource-exploration-and-development

seismic activities, explosives, and other disturbances during the life of the facility and decommissioning. The most recent *Guidelines*, completed in 2009, incorporate additional strategic actions such as environmental impact assessments. This update also emphasizes noise as a priority monitoring component during all phases of oil and gas activities to assess and minimize or mitigate adverse effects. [6]

PAME has also explored underwater noise in the Arctic through two recent reports, the State of Knowledge Report on Underwater Noise (2019) and the Underwater Noise Pollution from Shipping in the Arctic Report (2021):

- The State of the Knowledge Report (2019) provides an "overview of the current scientific knowledge on underwater noise in the Arctic" to better understand ambient sound levels created by underwater anthropogenic activities and the impacts of these activities on marine life in Arctic regions.[7]
- The Underwater Noise Pollution from Shipping in the Arctic Report focused on the increasing noise impacts in the Arctic from vessel activity. The report analyzes underwater noise and source levels produced by ships operating in the Arctic between 2013 and 2019, noting the changes over time as well as potential effects on noise sensitive species.[8] Phase II is expected to develop decision-support tools through validating the noise propagation models developed previously, estimating the excess noise contributed by shipping activities, and applying this modeling to assess the effectiveness of potential operational or technological noise mitigation measures.[9]

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[6] PAME. (1997). "Arctic Environmental Protection Strategy: Arctic Offshore Oil and Gas Guidelines." *Arctic Council, Protection of the Arctic Marine Environment (PAME).* Online report. Accessed August 2022. https://pame.is/images/03_Projects/Offshore_Oil_and_Gas/Offshore_Oil_and_Gas/oilandgasguidelines.pdf.; PAME. (2002). "Arctic Offshore Oil and Gas Guidelines." *Arctic Council, Protection of the Arctic Marine Environment (PAME).* Online report. Accessed August 2022. https://www.pame.is/images/03_Projects/Offshore_Oil_and_Gas/Offshore_Oil_and_Gas/ArcticGuidelines.pdf; PAME. (2009). "Arctic Offshore Oil and Gas Guidelines." *Arctic Council, Protection of the Arctic Marine Environment (PAME).* Online report. Accessed August 2022. https://oaarchive.arctic-council.org/handle/11374/63.

[7] PAME. (2019). "Underwater Noise in the Arctic: A State of Knowledge Report." Ministerial meeting in Rovaniemi, Finland, May 6-7, 2019. *Protection of the Arctic Marine Environment (PAME) Secretariat, Akureyri.* Accessed August 2022. https://oaarchive.arctic-council.org/handle/11374/2394?show=full.

[8] PAME. (2021b). "Underwater Noise Pollution from Shipping in the Arctic." *Arctic Council, Protection of the Arctic Marine Environment (PAME).* Online report. Accessed August 2022. https://www.pame.is/document-library/pame-reports-new/pame-ministerial-deliverables/2021-12th-arctic-council-ministerial-meeting-reykjavik-iceland/787-underwater-noise-pollution-from-shipping-in-the-arctic/file.

[9] PAME. (2021a). "PAME Work Plan 2021-2023." *Arctic Council, Protection of the Marine Environment (PAME)*. May 2021. Online report.

Background

This section provides a brief background on the sources of noise from offshore oil and gas activities, potential impacts associated with underwater noise, and the status of oil and gas activities in the Arctic.

2.1 Sources of Noise from Offshore Arctic Oil and Gas Activities

Offshore oil and gas activities include many types of noise-generating operations, involving vessels (e.g., survey, supply, crew, ice breakers/management), dredging, rock dumping, coring, seismic surveys (airguns, high resolution and exploration), sonars (e.g., for pipeline route surveys), communication and positioning systems, piledriving, support ships and drilling, and decommissioning activities (e.g., explosives, manual deconstruction). Table 1 shows noise-generating activities organized according to four simplified phases of oil and gas projects, though some activities may be present during all phases.

Table 1: Examples of noise-generating activities associated with offshore oil and gas

<table>
<tr><th>Phase</th><th>Potential Noise-generating Activities for Each Phase</th><th>Potential Noise-generating Activities for All Phases</th></tr>
<tr><td>Exploration</td><td>-Seismic (airgun) exploration
-Other airborne or vessel-based geophysical surveys
-Sonars (e.g., surveying pipeline routes, bathymetric surveys)
-Coring and sampling of seafloor sediments and bedrock
-Drilling operations</td><td rowspan="2">-Crew and supply vessels (ships, helicopters)

-Icebreakers/ice management

-Accidents (e.g. loss of control of a well, blowout, ship collision, sinking of a ship or a platform)</td></tr>
<tr><td>Construction/ Development</td><td>-Various types of drilling operations (drilling, well cementing, testing, hydraulic fracturing, completion, other downhole operations)
-Equipment and platform installation and connection (wellhead, seafloor equipment, pipelines), pile-driving, explosives, machinery, and flow noise</td></tr>
</table>

Production	-Drilling -Production related activities (machinery) -Pipeline flow noise and operation -Routine maintenance of pipelines, wells, seafloor equipment and platforms	
Decommissioning *(Not yet undertaken in the Arctic)*	-Operations related to plugging and abandonment of well(s), restoration of site (removal of platform, explosives, towing or other method of infrastructure and platforms deconstruction or removal), removal of seafloor equipment and wellhead	

Underwater noise from the anthropogenic activities in Table 1 vary widely in how far the sound travels, its intensity, frequency, and potential impacts.[10,11] For example, seismic surveys used to probe beneath the surface of the earth pulse acoustic energy from an airgun or airgun array pulled behind a vessel (see Figure 2). Airguns emit high intensity, short-duration, impulsive sounds at regular intervals (with most acoustic energy between 10 and 300 Hz, but also contain acoustic energy at frequencies up to approximately 10 kHz). Whereas vessel engines and propellers emit low-frequency, continuous, and non-impulsive sounds. When engaged in ice-breaking operations, icebreaker vessels stand out for the elevated levels of noise emitted compared to other vessels.[12] These noise sources (seismic surveys, vessels, and other anthropogenic activities) differ in sound pressure, duration, frequency, and in the particle motion they produce.[13,14]

[10] Duarte, C. M., Chapuis, L., Collin, S. P., Costa, D. P., Devassy, R. P., Eguiluz, V. M., . . . Juanes, F. (2021). "The soundscape of the Anthropocene Ocean." *Science, 371*(6529). doi:10.1126/science.aba4658.

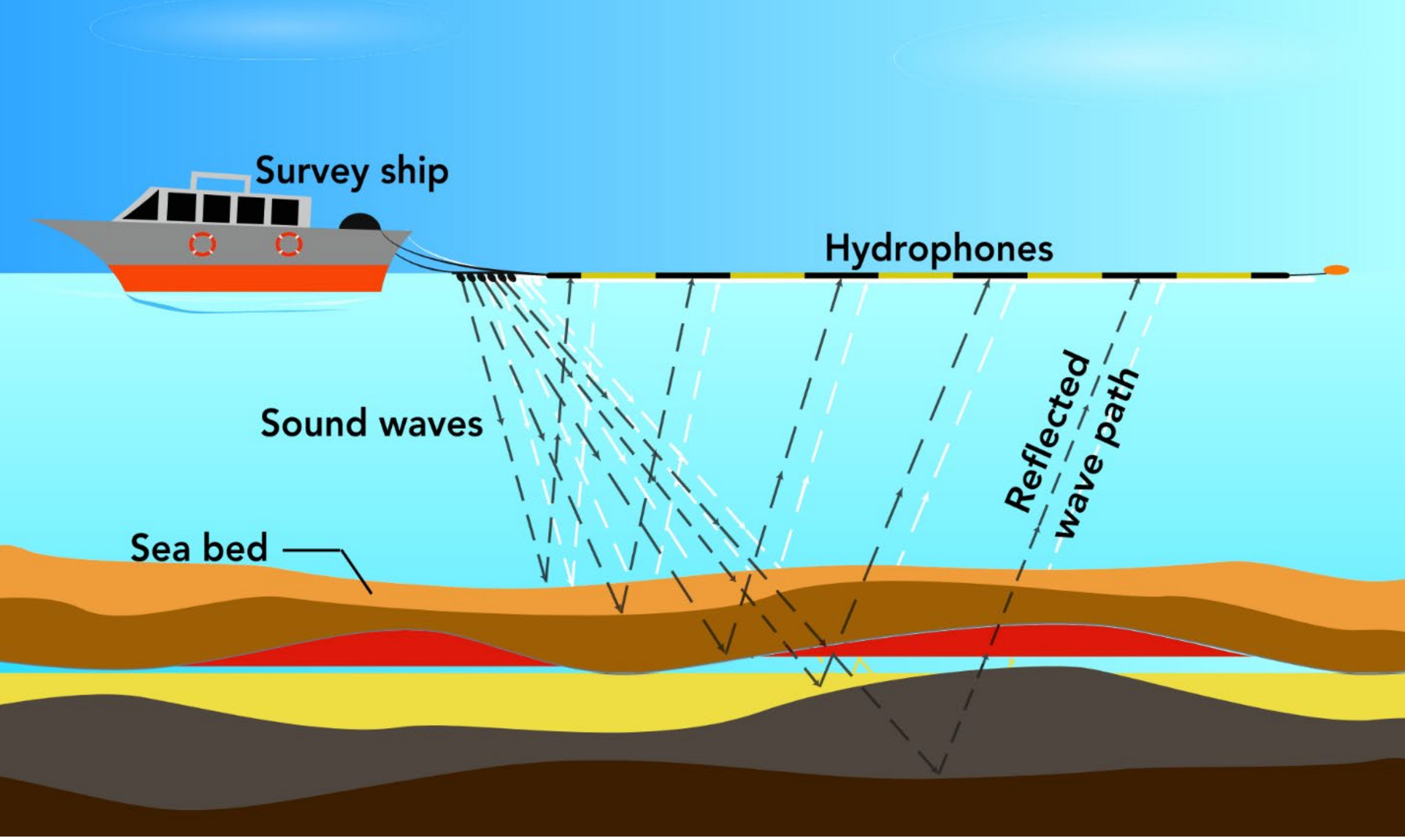
[11] Jiminez-Arranz, G., Banda, N., Cook, S., & Wyatt, R. (2020). "Review on existing data on underwater sounds produced by the oil and gas industry." *Joint Industry Programme on E&P Sound and Marine Life*.

[12] Roth, E. H., Schmidt, V., Hildebrand, J. A., & Wiggins, S. M. (2013). "Underwater radiated noise levels of a research icebreaker in the central Arctic Ocean." *The Journal of the Acoustical Society of America,* 133(4), 1971–1980. https://doi.org/10.1121/1.4790356.

[13]Manik, T., Kessinger, W. (2003). "Exploration Geophysics." *Encyclopedia of Physical Science and Technology*, 709–26. https://doi.org/10.1016/b0-12-227410-5/00238-6.

[14] Carroll, A.G., Przeslawski, R., Duncan, A., Gunning, M., Bruce, B. (2017). "A critical review of the potential impacts of marine seismic surveys on fish & invertebrates." *Marine Pollution Bulletin*. 114(1):9-24. ISSN 0025-326X. https://doi.org/10.1016/j.marpolbul.2016.11.038.

Figure 2: Typical seismic survey vessel and lateral view of an airgun array design.



2.2 Noise Impacts

PAME's 2019 *State of Knowledge* report has previously identified multiple studies which examined the behavioral impacts of anthropogenic underwater noise on Arctic fish and marine mammals. Noise from marine oil and gas activities can disturb and potentially harm marine biota[15] and interrupt the communication, navigation, and foraging activities of

[15] Popper, A. N., Hawkins, A. D., & Thomsen, F. (2020). "Taking the animals' perspective regarding anthropogenic underwater sound." *Trends in Ecology and Evolution, 35*(9), 787-794. doi:10.1016/j.tree.2020.05.002.

marine species.[16,17,18] Anthropogenic noise may also affect the development, anatomy, behavior, and physiological responses of marine species. Noise induced stress can lead to auditory masking, cochlear damage, individual and social behavioral changes, metabolism changes, and altered embryonic development.[19] Notably, acoustic impacts differ depending on source type, acoustic transmission, received level, and distance from the source.

The Canadian Science Advisory Secretariat reviewed the negative impacts of noise produced during offshore exploration activities on marine wildlife. Its 2020 Science Advisory Report raises various points of concern with respect to noise impacts of seismic sound practices and geotechnical surveying activities. Potential risks identified include physiological stress responses, behavioral disruptions, and acoustic masking.[20]

Other potential noise impact concerns include the adverse effects on critically important habitat for marine mammals and the cumulative effects of both acute and chronic anthropogenic sounds on marine environments and species, which can lead to temporary and occasional long-term habitat loss and changes in habitat use for acoustically sensitive species.[21] A controlled study of narwhal's reactions to sustained disturbance demonstrated that narwhals in Greenland are highly sensitive to variable background noise in their environment (even beyond 40 km from the sound source), including airgun pulses and vessel noise at very low exposure levels, which can "likely lead to reduced foraging success, and will, if combined with sustained disturbance over longer periods, have energetic costs at the population level." The United States notes that noise from machinery and vehicles

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[16] Guan, S., & Brookens, T. (2023). "An overview of research efforts to understand the effects of underwater sound on cetaceans." *Water Biology and Security*. doi:10.1016/j.watbs.2023.100141.

[17] Erbe, C., Marley, S.A., Schoeman, R. P., Smith, J.N., Trigg, L. E., Embling. C. B., (2019). "The Effects of Ship Noise on Marine Mammals—A Review." *Frontiers in Marine Science. Sec. Marine Conservation and Sustainability.* https://doi.org/10.3389/fmars.2019.00606.

[18] National Research Council (US) Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals. (2003). "Ocean Noise and Marine Mammals." *National Academies Press (US)*. Online Report. https://pubmed.ncbi.nlm.nih.gov/25057640/.

[19] Weilgart, L. (2018). "The Impact of Ocean Noise Pollution on Fish and Invertebrates." *Report by OceanCare*. Retrieved from: https://www.oceancare.org/wp-content/uploads/2017/10/OceanNoise_FishInvertebrates_May2018.pdf.; Peng, Chao, Xinguo Zhao, and Guangxu Liu. (2015). "Noise in the Sea and Its Impacts on Marine Organisms." *International Journal of Environmental Research and Public Health* 12, no. 10:12304–23. https://doi.org/10.3390/ijerph121012304.

[20] Canadian Science Advisory Secretariat. (2020). "Science Advisory Report: Review of the Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment." Accessed 2022. https://publications.gc.ca/collections/collection_2020/mpo-dfo/fs70-6/Fs70-6-2020-005-eng.pdf.

[21] Todd, V. L., Todd, I. B., Gardiner, J. C., Morrin, E. C., MacPherson, N. A., DiMarzio, N. A., & Thomsen, F. (2015). "A review of impacts of marine dredging activities on marine mammals." *ICES Journal of Marine Science*, 72(2), 328-340. https://doi.org/10.1093/icesjms/fsu187.

“could also cause pinniped behavioral modification and temporary displacement.”[22] Acoustic disturbances may impact marine mammals at the individual and population level, which impacts the local peoples’ reliance on marine mammals as a cultural resource and their food security.[23]

Norway’s ‘Integrated Ocean Management Plan’ summarizes another perspective on the state of knowledge regarding noise impacts in the marine environment: “Ambient noise levels are rising, primarily a result of the growing volume of shipping. Noise can disturb acoustic communication between marine mammals and make it more difficult for them to find and catch food and to navigate. Intense sound pulses produced by seismic activity, military sonar, detonations, and pile-driving can result in behavioral changes, auditory injury, and temporary threshold shifts in fish and marine mammals. Although much more has been learned over the past 10 – 15 years, little specific information is available about how noise pollution over time, often combined with other pressures, may affect populations of vulnerable species.”[24]

Seismic surveys have received particular attention. The measurement of sound signals from seismic surveys have indicated that, “noise from the same seismic source operated in different environments may have completely different sound transmission characteristics.”[25] For example, according to one study, a seismic source operating just seawards of a steep continental slope was not detected at receivers less than 150 km distance inshore of the survey, but it was detected at receivers more than 2000 km away in

[22] NOAA. (2020). “Takes of Marine Mammals Incidental to Specified Activities; Taking Marine Mammals Incidental to Ice Roads and Ice Trails Construction and Maintenance Activities on Alaska's North Slope.” Docket No. 200106-0003Federal *Register (85 FR 2988).*
[23] Williams, T. M., Blackwell, S. B., Tervo, O. M., Garde, E., Sinding, M. S., Richter, B., Heide-Jørgensen, M. P. (2022). “Physiological responses of narwhals to anthropogenic noise: A case study with seismic airguns and vessel traffic in the Arctic.” *Funtional Ecology*. https://doi.org/10.1111/1365-2435.14119; Blackwell, S. B., Tervo, O. M, Conrad, A., Samson, A.L. Garde, E., Hansen, R.G., Heide-Jørgensen, M.P. (2020). “Narwhals react to ship noise and airgun pulses embedded in background noise.” *Biol. Lett*. 17(11). Retrieved from: https://royalsocietypublishing.org/doi/10.1098/rsbl.2021.
[24] Norwegian Ministry of Climate and Environment. (2020). “Norway’s Integrated Ocean Management Plans: Barents Sea-Lofoten area; the Norwegian Sea; and the North Sea and Skagerrak.” Meld. St. 20 (2019-2020). Report to the Storting (white paper). Retrieved from: https://www.regjeringen.no/contentassets/5570db2543234b8a9834606c33caa900/en-gb/pdfs/stm201920200020000engpdfs.pdf.
[25] Chandra, S.K., McCauley, R.D., Duncan, A., Erbe, C., Gavrilov, A., Lucke, K., Parnum, L. (2016). “Underwater Sound and Vibration from Offshore Petroleum Activities and their Potential Effects on Marine Fauna: An Australian Perspective.” Project CMST 1218 Report 2015-13. https://appea.com.au/wp-content/uploads/2017/08/CMST-Underwater-Sound-and-Vibration-from-Offshore-Activities.pdf.

deep ocean waters towards Antarctica.[26] Another survey off the Alaskan North Slope detected signals from seismic airguns between 400 km and 1300 km from the source.[27] A review of the impacts of seismic surveys on fish, invertebrates, marine turtles and mammals concluded that seismic sounds in the marine environment are "neither completely without consequence nor certain to result in serious and irreversible harm to the environment,"[28] varying by condition of the environment and the exposed organisms. This variability requires more nuanced, evidence-based, and context-specific means of predicting response probability.

Impacts to marine mammals and other species in the marine ecosystem also impact the abundance and accessibility of critical food sources for people who rely on them. As one example, the Alaska Eskimo Whaling Commission explains its subsistence-hunting members' concerns about the disturbances caused by marine oil and gas on bowhead whale hunting as ranging from pollution (including noise) degrading the bowhead whales' health and habitat to threatening hunter safety or reducing access if the whales move farther offshore or otherwise change their migratory routes.[29]

Generally, PAME recognizes "there are several knowledge gaps related to noise impacts on Arctic marine mammals."[30] Without a complete state of knowledge on all noise-generating oil and gas activities, cumulative impacts of these underwater noises are largely unknown.

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[26] Chandra, S.K., McCauley, R.D., Duncan, A., Erbe, C., Gavrilov, A., Lucke, K., Parnum, L. (2016). "Underwater Sound and Vibration from Offshore Petroleum Activities and their Potential Effects on Marine Fauna: An Australian Perspective." Project CMST 1218 Report 2015-13. https://appea.com.au/wp-content/uploads/2017/08/CMST-Underwater-Sound-and-Vibration-from-Offshore-Activities.pdf.

[27] Thode, A., Kim, K. H., Greene, C. R., Roth, E. (2010). "Long range transmission loss of broadband seismic pulses in the Arctic under ice-free conditions." *The Journal of the Acoustical Society of America*, 128 (4): EL181–EL187. https://doi.org/10.1121/1.3479686

[28] Fisheries and Oceans Canada. (2004). "Review of Scientific Information on Impacts of Seismic Sound on Fish, Invertebrates, Marine Turtles, and Marine Mammals: Habitat Status Report 2004/002." Online report. Accessed October 2022. https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/283727.pdf.

[29] AEWC. (2021). "Mitigation: Oil & Gas." *Alaska Eskimo Whaling Commission.* Website. Accessed October 2022. https://www.aewc-alaska.org/mitigation.

[30] PAME. (2019). "Underwater Noise in the Arctic: A State of Knowledge Report." Rovaniemi, Finland. May 2019. Protection of the Arctic Marine Environment (PAME) Secretariat, Akureyri (2019). Accessed August 2022. https://oaarchive.arctic-council.org/handle/11374/2394?show=full.

2.3 Marine Oil and Gas Activities in the Arctic

Norway and the United States are the only questionnaire respondents where Arctic marine oil and gas operations have advanced passed the exploration phase, although oil and gas extraction also takes place in waters of the Russian Federation. While exploration activity has occurred in all Participating States, there is no current or planned marine oil and gas activity in the Arctic waters of Canada, Iceland, Greenland/The Kingdom of Denmark, or the Faroe Islands/The Kingdom of Denmark. Table 2 summarizes activity north of the Arctic Circle to give an indication of the level of current or recent activity across the phases. (As discussed, mitigation measures applied in Arctic adjacent waters are included in Section 4).

Table 2: Marine oil and gas activities by phase conded north of the Arctic Circle in participating Arctic states; activity is not necessarily ongoing (information from respondents)

State	Exploration	Construction/ Development	Production	De-commissioning
Canada	Yes	--	--	--
Faroe Islands/ The Kingdom of Demark	Yes	--	--	--
Greenland/ The Kingdom of Denmark	Yes	--	--	--
Iceland	Yes	--	--	--
Norway	Yes	Yes	Yes	--
The United States	Yes	Yes	Yes	--

Regulatory Context

While the United Nations Convention on the Law of the Sea (UNCLOS) includes general provisions on the protection and preservation of the marine environment, resource development requirements specific to minimizing noise impacts from offshore oil and gas in the Arctic are left to the coastal State's national-level regulations. Table 3 provides an overview of national laws, policies, and guidance governing the mandated noise mitigation measures from marine oil and gas activities, only for the Arctic States that participated in the questionnaire for this project, which are described in further detail below. In several cases, the laws establish authorities or processes that would be used in the Arctic *if* activities were undertaken there or have been used in the past.

Table 3: National laws, policy, and guidance governing noise mitigation in Arctic marine oil and gas operations from participating Arctic States, based on questionnaire responses

Arctic State	Law, Policy, or Guidance	Relevance to Noise Mitigation
Canada	Impact Assessment Act	Establishes the environmental assessment process including consideration of noise.
	Canada-Newfoundland and Labrador Atlantic Accord Implementation Act	Under the Act, the Canada-Newfoundland and Labrador Offshore Petroleum Board (CNLOPB)[31] is responsible for conducting Strategic Environmental Assessments[32] and Project-Specific Environmental Assessments[33] in the Canada-Newfoundland and Labrador offshore area. Depending on the nature and scope of the project and environmental assessment, the CNLOPB may consult with government departments and agencies, such as Fisheries and Oceans Canada, to evaluate potential noise impacts.

[31] The Canada-Newfoundland and Labrador Offshore Petroleum Board is expected to be renamed the Canada-Newfoundland and Labrador Offshore Energy Regulator as a result of the coming into force of Bill C-49 on January 31, 2025: C-49 (44-1) - LEGISinfo - Parliament of Canada.
[32] Canada-Newfoundland and Labrador Offshore Petroleum Board. (n.d.). Strategic Environmental Assessments. Accessed January 2025. https://www.cnlopb.ca/sea/.
[33] Canada-Newfoundland and Labrador Offshore Petroleum Board. (n.d.). Project-Based Environmental Assessments. Accessed January 2025. https://www.cnlopb.ca/assessments/.

Arctic State	Law, Policy, or Guidance	Relevance to Noise Mitigation
	Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act	Under the Act, the Canada-Nova Scotia Offshore Energy Regulator (CNSOER)[34] is responsible for conducting Strategic Environmental Assessments and Project-Specific Environmental Assessments for activities proposed in the Canada-Nova Scotia offshore area.[35] Depending on the nature and scope of the project and environmental assessment, the CNSOER may consult with government departments and agencies, such as Fisheries and Oceans Canada, to evaluate potential noise impacts.
	Canada Oil and Gas Operations Act	Under the Act, the Canada Energy Regulator (CER) has regulatory responsibilities in other offshore areas (outside of the CNLOPB and CNSOER areas). In most cases, if not all, the assessment of the effects of a project on the environment or on socio-economic conditions would fall under the *Impact Assessment Act*. Projects needing an impact assessment under the Act are listed in the *Physical Activities Regulations*.[36]
	Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment	Describes mitigation measures for seismic operations that are incorporated into impact assessments (update is in process at the time

[34] Effective January 31, 2025, the Canada-Nova Scotia Offshore Petroleum Board was renamed to the Canada-Nova Scotia Offshore Energy Regulator.
[35] Canada-Nova Scotia Offshore Energy Regulator (n.d.). "Environmental Assessments." Accessed February 2025. https://cnsoer.ca/about-cnsoer/what-we-do/environmental-protection/environmental-assessments.
[36] Canada Energy Regulator. (2022). Environmental Assessments in North and Offshore Areas. https://www.cer-rec.gc.ca/en/about/north-offshore/environmental-assessments.html.

Arctic State	Law, Policy, or Guidance	Relevance to Noise Mitigation
		of this report, based on a 2020 scientific review).[37]
	Fisheries Act	May impose requirements to mitigate noise impacts on certain species.
	Marine Mammal Regulations	
	Oceans Act	
	Canada National Marine Conservation Areas Act	
	Species at Risk Act	
	Canada's Ocean Noise Strategy[38]	Provides a coordinated approach across the Government of Canada to minimize impacts from ocean noise on marine life.[39]
Iceland	Act on Prospecting, Exploration, and Production of Hydrocarbons (Act 13/2001)	Requires consideration of environmental impacts, such as underwater noise, during licensing.
The Kingdom of Denmark	Offshore Seismic Surveys in Greenland: Guidelines to Best Environmental Practices, Environmental Impact Assessments, and Environmental Mitigations	Describes measures such as modeling noise propagation associated with seismic activity, as well as methods to reduce – or monitor for – impacts to marine species.

[37] Fisheries and Oceans Canada. (2020). "Science Advisory Report: Review of the Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment." *Canadian Science Advisory Secretariat, National Capital Region*. https://publications.gc.ca/collections/collection_2020/mpo-dfo/fs70-6/Fs70-6-2020-005-eng.pdf.

[38] Canada's Ocean Noise Strategy is currently a draft document. A consultation ran from August 23, 2024 to October 22, 2024.

[39] Fisheries and Oceans Canada (2024). Canada's Ocean Noise Strategy (*draft*). https://www.dfo-mpo.gc.ca/oceans/publications/noise-bruit/strategy-strategie/index-eng.html.

Arctic State	Law, Policy, or Guidance	Relevance to Noise Mitigation
	Manual for Seabird and Marine Mammal Survey on Seismic Vessels in Greenland	Describes survey methods for use onboard during seismic activity.
Norway	The Petroleum Act	Sets requirements for ramp-up procedures during seismic shooting.
	The Pollution Control Act	Establishes authority to regulate pollution, including noise and vibrations.
	The Biodiversity Act	Considers impact of noise from pile-driving on fish spawning areas in project approvals.
	Integrated Ocean Management Plans	Discusses seismic exploration and other noise-making activities in general.
	Svalbard Environmental Protection Act	The purpose of this Act is to preserve a virtually untouched environment in Svalbard.
Sweden	The Continental Shelf Act	Establishes permitting for offshore activities such as piling and seismic surveys.
	The Swedish Environmental Code	Describes certain requirements in case of potential effects to protected areas.
	The EU Marine Strategy Framework Directive	Sets the acceptable levels for underwater noise in a given region.
United States	Outer Continental Shelf Lands Act (OCLSA)	Directs the Bureau of Ocean Energy Management to study and consider coastal, marine, and human environmental impacts when making decisions to manage the development of energy, mineral, and geological resources on the U.S. Outer Continental Shelf.

Arctic State	Law, Policy, or Guidance	Relevance to Noise Mitigation
	Marine Mammal Protection Act (MMPA)	Requires permitting of certain activities that may harass or harm marine mammals, whether intentionally or unintentionally.
	National Environmental Policy Act (NEPA)	Requires consideration of environmental impacts in federal permitting actions, including considerations under MMPA.
	Endangered Species Act (ESA)	May impose requirements to mitigate noise impacts on certain species.
	Magnuson-Stevens Fishery Conservation and Management Act	Considers elements of essential fish habitat and potential impacts to fishes.
	The National Oceanic and Atmospheric Administration's Ocean Noise Strategy	Guides the agency, often in collaboration with others, towards more effective and comprehensive understanding and management of ocean noise impacts on marine life.[40]

Sub-national jurisdictions may also have their own requirements, though an exhaustive list is not attempted here. For example, the North Slope Borough (NSB) in Alaska has regulations within its planning code stating that development may not "significantly impact surrounding properties with excessive noise." The Borough's land includes the largest on-shore oil and gas development in Alaska, and its jurisdiction includes submerged lands and waters.[41] In addition, a Borough resolution states that, while the final determination regarding offshore oil and gas development rests with the federal government, "the federal agencies and the developers must work in good faith with subsistence hunters to mitigate any impacts to subsistence resources and to the hunters' access to those resources that result from exploration and development of oil and gas."[42]

[40]National Oceanic and Atmospheric Administration. (2016). Ocean Noise Strategy Roadmap. https://oceannoise.noaa.gov/sites/default/files/2021-02/ONS_Roadmap_Final_Complete.pdf.

[41] North Slope Borough. (2023). "Our government." Retrieved from: https://www.north-slope.org/your-government/.

[42] North Slope Borough. (2008). "Resolution Serial No. 19-2008." Retrieved from: https://www.north-slope.org/wp-content/uploads/2022/04/NSB-Resolution-19-2008-Offshore-oil-and-gas.pdf.

Mitigation and Monitoring Measures

This section describes noise mitigation and monitoring measures for marine oil and gas operations in the Arctic. The discussion of mitigation measures focuses on the measures themselves, rather than describing each country's regulatory approach, agencies, and processes. The following types of mitigation measures were identified:

- Consideration of noise in project approval or planning
- Communication and engagement with Indigenous communities or other local communities
- Seasonal and/or geographic restrictions on activity
- Monitoring noise associated with oil and gas activity
- Monitoring for species presence during oil and gas activity (or prior to permitting)
- Other procedures for seismic exploration (e.g., exclusion zones, ramp-up periods)

Questionnaire responses indicate that similar mitigation strategies are shared among Arctic States with some variations. Unless otherwise referenced, information in this section is based on the questionnaire responses sent to REDEG as part of this project or comments provided in review.

This section is intended to be broadly inclusive of the types of measures that have been identified by participating Arctic States as being relevant to the Arctic. The measures described include identified noise mitigation measures which may not be currently in use if the relevant oil and gas operations are not underway in the Arctic, but also draw on examples from sub-Arctic areas or commercial or industrial activities other than oil and gas operations. Finally, this section is based on questionnaire responses and comments provided during the draft review and project discussions, and the key documents listed in Annex 1 (noise-specific guideline documents developed by Canada and Greenland/Kingdom of Denmark).

Considering Noise Impacts in Project Approval or Planning

Most of the mitigation measures described in this section stem from impacts considered – and often commitments made – during a required environmental assessment and permitting process. While not a mitigation measure itself, environmental assessments[43] document the anticipated environmental impacts of a project before it is approved and

[43] Also called "environmental impact assessments" or "environmental impact statements"

implemented. While all the participating countries have requirements to conduct assessments including noise impacts, the specific approaches vary. For example, while most countries review individual project proposals, Norway sets requirements for the types of activities allowed (or prohibited) and any associated restrictions based on ecosystem-based impact assessments and management plans for Norway's three marine areas (North Sea, Norwegian Sea, and Barents Sea). Other countries, like the U.S. and Canada, conduct both broad-scale and project-specific environmental assessments for petroleum activities.

Generally, the relevant assessment elements include: determining the scope and nature of noise propagation through the area and what the impacts may be (done through various modeling approaches); inviting input on noise as well as other potential impacts from the public, communities, experts, or other agencies; and establishing or describing mitigations.

Noise modeling

Noise modeling of proposed seismic activities in a particular area may be conducted by the regulating agency or the company proposing a noise-generating project. Noise from sources other than seismic surveys are generally considered qualitatively. Approaches to considering potential noise impacts vary and may be evaluated qualitatively or quantified using noise modeling to determine an acoustic footprint and identify potential impacts (either by considering known animal habitats or modeling animal movements).

In the United States, noise modeling generally consists of two, or sometimes three, steps. First, the sound field of a sound-generating activity is modeled based on characteristics of the source and the physical environment, which is known as acoustic modeling. Second, by overlaying the marine mammal density information for a certain species or population in the geographical area of the activity, the number of animals exposed to sound level above a given acoustic threshold is then predicted. This is called exposure modeling. Some models further incorporate animal movement to make more realistic predictions of exposure numbers. Animal movement models may incorporate behavioral parameters including swim speeds, dive depths, course changes, or reactions to certain sound types, among other factors. Exposure modeling may be conducted for a range of scenarios including different seasons, energy (e.g., pile-driving hammers), mitigation strategies (e.g., 6 dB versus 10 dB of noise attenuation), and levels of effort (e.g., number of piles per day).

The Kingdom of Denmark's best practices guide for seismic surveys in Greenland explains that the noise modeling required of operating companies, "should be based on actual bathymetry, knowledge of sediment properties (to the degree available) and realistic assumptions regarding vertical sound speed profiles and ice cover." The government will put companies in contact with each other to develop a joint model if more than one seismic survey is planned for the same general area. The guidelines add, “For assessment of cumulative effects the total sound exposure level (across all airgun pulses, all concurrent surveys and activities in the area) per 24 hours shall be presented. Modelling should include all biologically relevant parts of the frequency spectrum, which for seismic surveys means frequencies up to at least 48 kHz at ranges out to 20 km, and frequencies up to at least 20 kHz at ranges beyond 20 km."[44]

Input to the process

In addition to issues raised by the lead agency conducting the review process, noise impacts or mitigations may often be raised by other agencies (such as those with responsibility for fisheries or marine mammals) or through consultative processes with affected communities or sub-national governments. These processes typically are not specific to noise-related issues and may be handled differently in different places.

Establishing noise mitigations

Environmental assessments or subsequent project approvals or licenses/leases may also include commitments to implement specific mitigation measures such as those discussed in the rest of Section 4. For example, in Canada the Statement of Canadian Practice specifies that operators may be required to implement regionally appropriate mitigations based on the review of potential project impacts. The mitigation measures identified through the environmental assessment process may vary across projects, species, seasons, or locations.

Communications and Engagement with Indigenous and Other Local Communities

Communications and planning with Indigenous Peoples and other local communities regarding oil and gas operations can mitigate impacts to culturally important resources and subsistence activities, such as hunting and fishing. This can be done in the planning stages and/or with real-time notifications, agreements, and communications.

Example mitigations include:

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[44] Boertmann, D., Boye, T., Wegeberg, S., & Mosbech, A., (2015). "Offshore Seismic Surveys in Greenland: Guidelines to Best Environmental Practices, Environmental Impact Assessments and Environmental Mitigation Assessments." 47 p. https://www.govmin.gl/images/stories/petroleum/environmental_reports/Guidelines_UK_2_Dec.pdf.

- Operators are required to conduct an 8-week public consultation process with hunters and fishers as part of their Environmental Mitigation Assessment prior to conducting seismic surveys. (Greenland)

- Operators must bring a fishery liaison officer on board during seismic surveys. (Greenland and Norway)

- Operators are required to develop plans with local communities to avoid or eliminate impacts. In Alaska, the agreements between industry and subsistence users are used to "develop and implement measures to eliminate the threat of adverse effects to bowhead whales, bowhead whale habitat, and subsistence uses from offshore oil and gas exploration activities." The agreements include areas and times that must be avoided to prevent disturbing marine mammals before a hunt and require use of village-based communication centers to relay information between hunters and industry regarding movements of animals and industry activities.[45] (United States)

- Operators are expected to engage with relevant fisheries groups and Indigenous communities during the environmental assessment process for seismic and exploration drilling projects. Fisheries liaison officers are required on board during seismic operations and are sometimes required during exploration drilling activities. (Canada)

Dog-sledding in Greenland

[45] For more information, see the Alaska Eskimo Whaling Commission website at: https://www.aewc-alaska.org/mitigation.

Seasonal and Geographic Restrictions

While oil and gas activities may be prohibited completely in some areas, "seasonal and geographic restrictions" refer to limitations or prohibitions on noise-generating activities in a particular area and/or during a particular time of year. Seasonal and geographic restrictions may encompass all marine oil and gas activity, or relate only to a specific activity, such as seismic exploration. These restrictions are intended to reduce impacts of anthropogenic noise on certain species during particularly sensitive times such as fish spawning or marine mammal calving. In some Arctic States, activities are restricted based on dates on the calendar, while in other cases limitations may be project-dependent (like in Canada where restrictions and mitigations are identified during the EA process) or based on species observations in the vicinity or during hunting activities. Examples include:

- No exploration drilling in oil-bearing formations in specified areas during ***fish spawning*** season (1 Feb–1 Jun) and no seismic surveys during fish spawning migration/spawning season (1 Jan–1 May) in the Norwegian Sea. (Norway)
- Seismic activity must avoid known areas used by marine mammals and marine fish at critical times (e.g., spawning, breeding, feeding, nursing, and migration), which are determined on a project basis. For example, although related to freshwater activity, restricted activity timing windows were established in Nunavut and the Northwest Territories for ***fish spawning and incubation*** periods when spawning fish, eggs, and fry are vulnerable to disturbance or sediment. Restricted activity periods are determined on a case-by-case basis according to the species of fish in the water body, determined by whether those fish spawn in the spring, summer, fall or winter, and where the water body is located. (Canada)[46]
- Begin ice road construction as soon as conditions allow to reduce impacts to ***ringed seals*** and remain at least 150 m from any known seal structure after 1 March. Operators must conduct a follow-up assessment in May to determine the fate of seal structures that are identified during operating activity. (United States)
- Operators must observe a one-mile operational exclusion zone around all known ***polar bear dens*** during the denning season (November–April, or until the female

[46] Department of Fisheries and Oceans Canada. (n.d.). "Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat." *Government of Canada*. Online report. Accessed March 2023. https://www.dfo-mpo.gc.ca/pnw-ppe/timing-periodes/nu-eng.html.; Department of Fisheries and Oceans Canada. (n.d.). "Northwest Territories Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat." *Government of Canada.* Online report. Accessed March 2023. https://www.dfo-mpo.gc.ca/pnw-ppe/timing-periodes/nwt-eng.html.

and cubs leave the areas). Should previously unknown occupied dens be discovered within 1 mile of activities, work in the immediate area must cease. (United States)

- No seismic activity during known seasons and areas where ***beluga, narwhal, bowhead whale, and walrus*** are present. (Greenland)

- All non-essential boat and barge traffic should be scheduled to avoid periods when ***bowhead whales*** are migrating through the area to where they may be affected by sound from the project. (United States)

- Vessels will avoid transit within ***North Pacific right whale critical habitat***, or exercise caution and reduce speed to 10 knots while within North Pacific right whale critical habitat if unavoidable. (The United States)

- Helicopters may not hover or circle within 0.5 miles of walrus on ice, and aircraft may not fly below 1,500 feet near ***walrus or polar bears***. (United States)

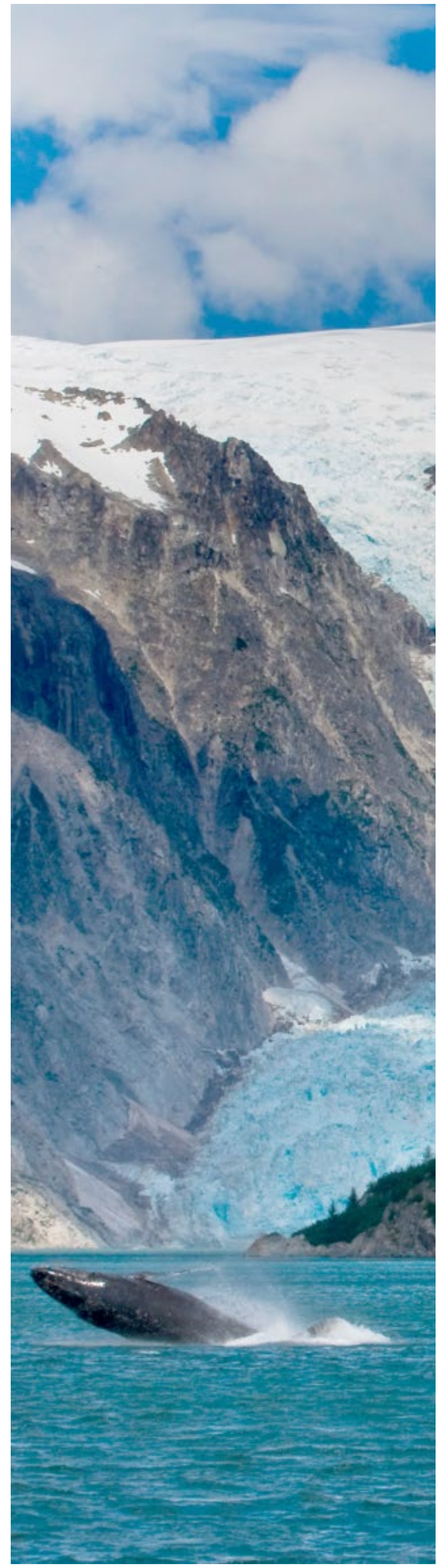
- Vessels are not allowed through the Beaufort and Chukchi Seas before 1 July *both* to allow marine mammals to disperse from winter ice leads and avoid disturbance of hunting activity (the exact date is flexible). (United States)

- Activities may be limited when marine mammals are mating and birthing in the summer. This is determined on a case-by-case basis through the permitting process. (Sweden)

Example restrictions focused on ***hunting and fishing*** include:

- Restrict noise-generating activities during subsistence whaling seasons; restrictions end when quotas are met or at set seasonal date, whichever arrives first. (The United States)

- Vessels conducting seismic surveys shall maintain a prudent distance to vessels engaged in fishery activities, as well as fixed and floating fishing gear. Particular caution shall be exercised when large groups of fishing vessels are observed. (Norway)



Monitoring Noise Associated with Oil and Gas Activity

Acoustic monitoring may be used to measure the actual noise generated by marine oil and gas activities. This is typically done to validate the modeling or assumptions about noise impacts that were developed during the environmental assessment process.

Examples of acoustic monitoring of noise associated with oil and gas activity include:

- During seismic activity, companies are required to record, analyze, and report actual sound exposure at representative locations. Recordings must be taken at certain depths down to the maximum depths used by species in the area, sample at least three recording ranges, and extend least 50 km from the survey area. (The government does not enforce these requirements, but industry is expected to ensure adherence to permit requirements).[47] (Greenland)
- Acoustic monitoring is required before and during all types of exploration and delineation drilling (including vertical seismic profile activities) along with a plan outlining the operators' methods and technologies to be used during activity to verify impacts described in the environmental assessment process. (Canada)
- Operator must measure underwater sounds produced by project-related activities. (United States)
- Operators must conduct acoustic monitoring to document sound levels, characteristics, and transmissions of airborne sounds with expected source levels of greater than or equal to 90 dB in air. (United States)
- Noise related to seismic activity must be reported to the relevant agency. (Norway)

[47] Boertmann, D., Boye, T., Wegeberg, S., & Mosbech, A., (2015). "Offshore Seismic Surveys in Greenland: Guidelines to Best Environmental Practices, Environmental Impact Assessments and Environmental Mitigation Assessments." 47 p. https://www.govmin.gl/images/stories/petroleum/environmental_reports/Guidelines_UK_2_Dec.pdf.

Monitoring for Species Presence During Oil and Gas Activity

Species present before, during, or after oil and gas activities are monitored to collect information about species presence in and around oil and gas operating sites, and potentially affected areas. Species monitoring serves two main functions:

(1) Inform planning for, or assessment of, noise or other impact mitigation measures, and

(2) Identify species present in the area to make real-time adjustments to oil and gas activity underway. [48]

Species monitoring may include methods such as passive acoustic monitoring or other types of sensors, remote sensing, biologging, optical cameras, aerial surveys, biotelemetry and wildlife tracking, and observations.[49] Different approaches may be used in different places. While national-level requirements or guidelines generally do not specify a particular approach, the technologies or procedures may be specified on a project-by-project basis.

Examples of monitoring required ***specifically for seismic exploration activities*** include:

- *Data collection:* Onboard Marine Mammal and Seabird Observers (MMSO) use a standardized method for data collection and sharing when monitoring species from vessels conducting seismic surveys. Data is reported to agencies and academic advisors hired by the government to help build understanding of species abundance and distribution. Monitors also search the area prior to airgun use and during ramp up.[50] (Greenland)

- *Monitoring safety zones:* Marine Mammal Observers monitor a safety zone of at least 500 m around the airgun array for a seismic survey, including a continuous

[48] Marine Mammal Commission. (n.d.). "Oil and Gas Developments in Marine Mammals." Accessed August 2022. https://www.mmc.gov/priority-topics/offshore-energy-development-and-marine-mammals/offshore-oil-and-gas-development-and-marine-mammals/.

[49] Lahoz-Monfort, J. J, Magrath, M. J. (2021). "A Comprehensive Overview of Technologies for Species and Habitat Monitoring and Conservation." *BioScience,* 71(10): 1038–1062. Accessed August 2022. https://doi.org/10.1093/biosci/biab073.

[50] Johansen, K. L., Boertmann, D., Mosbech, A., Hansen, T. B.. (2015). "Manual for seabird and marine mammal survey on seismic vessels in Greenland." 4th revised edition, April 2015. Aarhus University, 74 pp. *Scientific Report from DCE – Danish Centre for Environment and Energy No. 152.* Retrieved from: http://dce2.au.dk/pub/SR152.pdf.

observation for 30 minutes before starting to ensure that there are no cetaceans or other protected species or species of concern present. (Canada, United States[51]) In general, the safety zone size is determined based on the noise level of the source and the species likely present. (United States)

- *Detection methods:* Passive acoustic monitoring (PAM) or other cetacean detection methods are required during seismic surveys. Best practices dictate that this will be conducted from the vessels conducting seismic surveys to supplement observations from the MMSOs (Greenland, United States).

- *Shutdowns based on monitoring:* Operators must take precaution and shut down sound sources if any cetaceans are identified within a safety zone (either acoustically or visually) until it can be determined that the cetacean(s) is outside the safety zone, or until non-identified cetacean vocalizations have not been detected for a period of at least 30 minutes[52] (Canada) and within an established given distance (United States).

Example of monitoring required ***specifically for vessels*** *(*other than those involved in seismic activity):

- Operational and support vessels are to be staffed with dedicated Protected Species Observers to alert crew of the presence of marine mammals and to initiate adaptive mitigation responses, particularly in North Pacific right whale critical habitat. (United States)

There is recognition of the tradeoffs of different types of monitoring, e.g., observers or PAM. Typically, in Sweden, observers are not used alone since it is recognized that visual observations are difficult and require extensive training. Guidelines for seismic activity in both Canada and Greenland acknowledge the tradeoffs of PAM – on the one hand, it is a technology with no associated negative environmental impact, and it can be used in low visibility conditions; however, it can only detect individuals that are vocalizing at the time. In Greenland, seismic activity should "as far as possible only be initiated when visibility is

[51] This prescribed safety zone distance for airguns (500 m) is specific to the U.S. Gulf of America where low frequency hearing specialists are limited.

[52] Fisheries and Oceans Canada. (2020). Science Advisory Report: Review of the Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment. Canadian Science Advisory Secretariat, National Capital Region. https://www.dfo-mpo.gc.ca/oceans/publications/seismic-sismique/index-eng.html.

good."[53] However, PAM must be used when visibility is "poor," at night, or at or above a Sea State 3 (waves 60 cm/2 ft).[54] In Canada, PAM or another cetacean detection technology must be used to monitor the safety zones prior to ramp-up in cases of low visibility, and may also be required if vocalizing cetaceans are expected to be present based on the environmental assessment or identified critical habitat.[55]

Guidelines for best practices for offshore seismic surveys in Greenland also note the potential future use of PAMGuard for real-time monitoring of marine mammal presence during seismic activity. PAMGuard is an open-source software,[56] and is already standard practice for multiple sectors to detect vocalizing marine mammals in real time.

Other Seismic Activity Procedures

This sub-section summarizes the procedures in place to mitigate seismic activity noise impacts in addition to those already discussed. Guidelines in several states focus specifically on seismic activity. Canada's *Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment* (2008)[57] and Kingdom of Denmark/Greenland's *Offshore Seismic Surveys in Greenland: Guidelines to Best Environmental Practices, Environmental Impact Assessments and Environmental Mitigation Assessments* (2015)[58] describe measures related to assessing potential impacts associated with seismic exploration activity and mitigating those impacts. Both documents also mention the

[53] Boertmann, D., Boye, T., Wegeberg, S., & Mosbech, A., (2015). "Offshore Seismic Surveys in Greenland: Guidelines to Best Environmental Practices, Environmental Impact Assessments and Environmental Mitigation Assessments." 47
p. https://www.govmin.gl/images/stories/petroleum/environmental_reports/Guidelines_UK_2_Dec.pdf.

[54] Ibid 53.

[55] Fisheries and Oceans Canada. (2008). "Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment." https://neb-one.gc.ca/en/about/north-offshore/statement-canadian-practice-with-respect-mitigation-seismic-sound-in-marine-environment.html.

[56] Boertmann, D., Boye, T., Wegeberg, S., & Mosbech, A., (2015). "Offshore Seismic Surveys in Greenland: Guidelines to Best Environmental Practices, Environmental Impact Assessments and Environmental Mitigation Assessments." 47
p. https://www.govmin.gl/images/stories/petroleum/environmental_reports/Guidelines_UK_2_Dec.pdf.

[57] The SOCP has undergone periodic review, as was intended at the time of its completion in 2008. In 2020, a scientific review resulted in agreement from participants that there "is sufficient new information to support an update to the measures in the SOCP." (Fisheries and Oceans Canada, 2020).

[58] Ibid. 56

importance of planning seismic surveys to avoid fish and marine mammals especially during sensitive seasons or life stages.[59]

The measures listed here are specific to the seismic survey itself. Seasonal and geographic restrictions and requirements for monitoring during seismic activity are discussed in the previous sections.

Mitigations specific to seismic procedures include:

- Pre-shooting clearance windows require that an area be clear of certain species prior to beginning airgun use, or if firing has stopped for any reason, such as to move to a new target location. This is a specified time, usually 30 or 60 minutes.[60] The method for determining species presence will vary, and may be based on PAM, visual observation, or a combination of approaches. (Canada, Greenland, Sweden, United States)

- Airgun firing must ramp-up gradually to encourage animals to avoid the area before the airgun array is firing at full power. (Canada, Greenland, Norway, Sweden, United States) This is usually done over 20 minutes (Canada, Greenland, United States) and it is noted that too long a ramp up (exceeding 40 minutes) can create excessive noise in an area. (Greenland)

- If marine species are identified in the exclusion zone while the airgun array is firing,[61] shooting must scale back to using just the smallest gun in the array to discourage them from approaching further. Return to full power happens only after they have left the area. (Greenland)

- If marine species are identified in the exclusion zone (within 1000m for marine mammals and 1500m for calving females) of the firing airgun array ,[62] shooting must stop until animals have left the area. (United States) Return to full power happens only after they have left the area.

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[59] The OSPAR Commission has also developed assessment and monitoring guidelines related to both impulsive and ambient underwater noise. OSPAR Commission. (2014). "Monitoring Guidance for Underwater Noise in European Seas." *OSPAR Agreement 2014-08.* Accessed October 2022. https://www.ospar.org/documents?v=33031.

[60] Greenland requires this to be a 60-minute period in waters deeper than 200 m since some deep-diving species will stay below the surface longer than 30 minutes. Boertmann et al. (2015).

[61] In both Canada and Greenland this is 500 m around the noise source.

[62] In both Canada and Greenland this is 500 m around the noise source.

- Operators should minimize excess noise by using the lowest practicable power levels, (Greenland, Canada, United States) and frequency (Sweden). (Specific values are not mandated, just the intent that the lowest possible power should be used)
- Ensure the most targeted directionality possible is used, to minimize the propagation of sound horizontally as much as possible. (Greenland)
- Seismic surveys in poor visibility should be avoided, but if visibility is poor (e.g., fog, darkness) then PAM is required to supplement visual observations. (Sweden, United States)

plans, (3) implement mitigation and monitoring of operations, and (4) evaluate and improve.[69] A variety of factors can determine the extent and level of effort needed to implement these practices, such as the availability of baseline data, survey type, physical features and human activity within the operational area, and potentially affected species.[70]

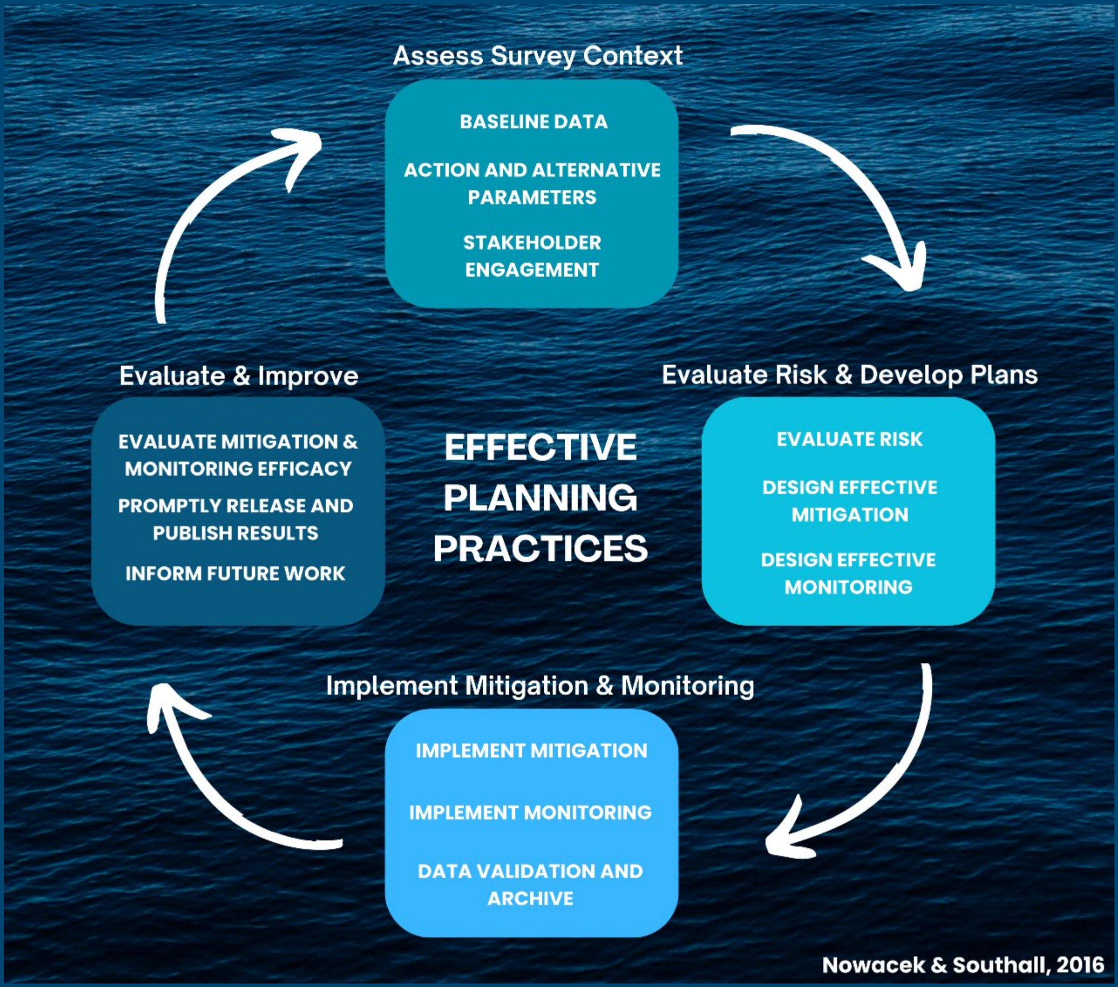

Figure 3: An adaptation of Figure 2 in Nowacek & Southall (2016), which outlines elements of the four effective planning practices for seismic and environmental imaging surveys.[71]

[69] Ibid 68.
[70] Ibid 68.
[71] Ibid 68.

Opportunities for Further Collaboration

This project demonstrated the willingness of several Arctic States, Permanent Participants, and Observers to share time and expertise regarding the mitigation of noise from Arctic marine oil and gas activities. Potential areas for further collaboration were discussed in small group calls or provided in draft comments. The following suggestions were recommended by the project participants but are not intended to be policy recommendations or reflective of consensus across the Arctic. Potential benefits and options are presented for further consideration, collaboration, and discussion.

Consider developing an addendum to PAME's oil and gas guidelines focused on noise. One of the two objectives for this project was to consider the need for Arctic guidelines related to mitigating noise impacts from Arctic marine oil and gas activities. Developing such a guideline would provide the opportunity for project participants to take a logical next step in the process started by this project, diving more fully into discussion of mitigation options, their effectiveness, and the details of implementation. It may also afford an opportunity to engage a wider participation from industry and affected communities.

Need for specific guidance related to noise from Arctic oil and gas operations:

- The geographic scale of the issue requires a coordinated approach: noise from oil and gas activities can travel up to thousands of kilometers underwater, so has potential effects far beyond local or national scales.

- Contributions from other noise-producing activities in the Arctic mean that underwater noise from multiple sources should be considered cumulatively to enable effective management. Activities include increasing shipping, infrastructure development and renewable energy development.

- As stated above, in some cases, a lack of knowledge precluded the setting of more specific regulations. Given the sensitivity of Arctic marine species to the effects of underwater noise, guidelines should be in place to recommend options in the absence of full knowledge, for example, adopting precautionary approaches.

- The Arctic Ocean's marine ecosystems are changing, resulting in shifts in noise-sensitive species in both space and time. Changes in ocean temperatures and sea ice thickness and extent also affect how noise propagates underwater. Coordinated guidance is needed to specify approaches that are appropriate and account for a rapidly changing system.

- Many populations of noise-sensitive species are migratory, moving across national borders multiple times within a single year. Coordination across Arctic states is needed to help understand cumulative exposure potential for migratory species and safeguard them from impacts.

Benefits of specific guidance

Developing such a reference could provide an opportunity to enhance current guidelines by:

- Standardizing the terminology used (e.g., by specifying use of terminology from the ISO 3740 standard for the determination of sound power levels or noise sources)[72] could assist with measurement, monitoring, reporting and mitigation of oil and gas related noise across Arctic jurisdictions and comparisons outside the Arctic region.

- Promoting the use of best available technologies, as applicable, in each jurisdiction across the region to enhance demand for quieter technologies, provide more consistent mitigation measures for migratory species, and create predictability and a level-playing field for regulated operators who often operate internationally.

- Potentially facilitating operator compliance and therefore effectiveness.

- Collating potentially effective measures for mitigating noise across the full project lifecycle: Most measures in place now focus on the exploration phase. Based on questionnaire responses, decommissioning of Arctic oil and gas operations has not yet occurred.

- Providing an assessment of the effectiveness of mitigation measures inventoried in this report and in use by the sector. While this is challenged by current gaps in the understanding of impacts and the many local factors that determine noise effects (discussed in Section 2), such an effort could start with a review of the best available scientific information and discussion on where precautionary approaches should be employed in the absence or only partial presence of scientific evidence.

- Systematizing additional resources by external bodies on monitoring and mitigating the impacts of noise, for example, by the UN Convention on Biological Diversity,[73]

[72] "ISO 3740:2019(En) Acoustics — Determination of Sound Power Levels of Noise Sources — Guidelines for the Use of Basic Standards." (2019). *International Organization for Standardization: Online Browsing Platform*. https://www.iso.org/obp/ui/#iso:std:iso:3740:ed-3:v1:en.

[73] CBD. (2020). "Notification: Peer review of CBD Technical Series: Anthropogenic Underwater Noise: Impacts on Marine and Coastal Biodiversity and Habitats, and Mitigation and Management Measures." Convention on Biological Diversity. https://www.cbd.int/kb/record/notification/3019?FreeText=Underwater%2520noise+%28.;

the European Commission Marine Strategy Framework Directive, [74] and the UN Convention on the Conservation of Migratory Species.[75]

Potential challenges of specific guidance

- Mitigation and management measures are often dependent on the risk level associated with a specific area, which will vary across the Arctic depending on species present, physical features, other human activities, local legislation or regulations, proximity of protected areas, and more.
- Consistent uptake and use of best available technologies or mititgation techniques may not be realistic across the region.
- The specific traditional and cultural importance or use of the land (e.g., fishing, hunting) by Indigenous communities may make umbrella guidance difficult to apply.

Share information regarding emerging technological approaches to reduce noise impacts, monitor underwater noise, or determine the presence of marine species.

While some mitigation measures discussed in Section 4 are prescriptive procedures during seismic surveys (e.g., ramp-up), the Arctic States do not currently have collective, regional requirements for the use of specific technologies in noise mitigations. Variable technology use, combined with the anticipated emergence of new and quieter technologies, may yield opportunities to share information and identify best available technologies as they emerge. Consistent use of best available technologies across the region could enhance demand for quieter technologies and create predictability and a level-playing field for regulated operators who often operate internationally.

Technologies to reduce impacts from seismic exploration are a particular focus due to the widespread recognition of the potential harm caused by using airguns. Two emerging

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CBD. (2020). Draft Publication: Anthropogenic Underwater Noise: Impacts on Marine and Coastal Biodiversity and Habitats, And Mitigation And Management Measures. Technical Series Publication. https://www.cbd.int/doc/notifications/2020/cbd-ts-underwater-noise-peer-review-en.pdf.

[74] European Union Directorate-General for Environment. (2022). Zero pollution and Biodiversity: First ever EU-wide limits for underwater noise. News Article. https://environment.ec.europa.eu/news/zero-pollution-and-biodiversity-first-ever-eu-wide-limits-underwater-noise-2022-11-29_en.

[75] CMS. (2020). “CMS Family Guidelines on Environmental Impact Assessments for Marine Noise-generating Activities.” Convention on the Conservation of Migratory Species of Wild Animals. Accessed March 2023. https://www.cms.int/en/guidelines/cms-family-guidelines-EIAs-marine-noise.; Prideaux G, 2017, ‘Technical Support Information to the CMS Family Guidelines on Environmental Impact Assessments for Marine Noise-generating Activities’, Convention on Migratory Species of Wild Animals, Bonn.

options were suggested by input offered through this project for future consideration: eSeismic (processing data from smaller airgun arrays with reduced sound pressure and exposure) and marine vibrators (Vibroseis) (using vibrations instead of airguns, which uses a lower source amplitude).[76] Information could be shared about both the benefits and other considerations of new technological approaches, with consideration of Arctic species and systems.

Likewise, coordinated passive acoustic monitoring and monitoring of anthropogenic underwater noise could improve understanding of noise baselines in the Arctic and the potential risk of introducing noise into that environment from marine oil and gas activities. This approach could inform management targets or mitigation requirements and support cumulative impact assessments and ecosystem-based management efforts.

Assessing and improving methods for determining presence of marine species in real-time is another future area of collaboration. Technologies (e.g., PAM, infra-red, observers) could be informed and improved through industry- and science-led assessments, not only specific to monitoring prior to industrial activities, but also engaging the broader scientific community. This engagement may become particularly relevant as populations of noise-sensitive species, such as sea ice-associated marine mammals, are shifting their distributions in time and space in response to climate change.

Consider how PAME's MEMA work is applicable to noise-generating activities and if additional work on engagement of Arctic Indigenous peoples before, during, and after noise-generating activities would be useful.

Building on work that PAME has done in the *Meaningful Engagement of Indigenous Peoples and Local Communities in Marine Activities (MEMA)* project and existing practices implemented by Arctic states and Indigenous organization, additional guidance could be developed to focus on the methods for engagement of Indigenous peoples before, during, and after significant marine noise-generating activities.

This may include input or agreements before a project or activity, real-time communications during the noise-generating activity, the role of Indigenous observers, input from Indigenous Knowledge holders on marine species, including their important habitats and presence in project areas, and responses and impacts of noise to inform activities, sharing information on actual recorded noise levels or impacts back to the

[76] Matthews, Marie-Noël R., Darren S. Ireland, David G. Zeddies, Robert H. Brune, and Cynthia D. Pyć. (2020). "A Modeling Comparison of the Potential Effects on Marine Mammals from Sounds Produced by Marine Vibroseis and Air Gun Seismic Sources." *Journal of Marine Science and Engineering* 9, no. 1:12. https://doi.org/10.3390/jmse9010012.

communities, or other methods as developed with input from Indigenous organizations and regulators.

There may be technological approaches useful to this purpose as well, such as the use of "geofences" that allow coastal residents to designate areas they use or care about. This method is being demonstrated in the Bering Sea for shipping through a program that allows, for example, subsistence hunters to create a geofence around an important area and receive a notification when a vessel transmitting an Automated Identification System signal enters that area.[77] This provides a mechanism to alert people who may be impacted by activity in a particular area and could be used to communicate plans for noise-generating activities determined to reach those areas.

Coordinate with PAME group working on underwater noise from Arctic shipping to identify potential synergies.

This project's scope specifically excluded most vessels, except those directly involved in marine oil and gas operations such as ice breakers or crew boats, to avoid any overlap with PAME's other projects related to underwater noise associated with increased Arctic shipping. However, potential synergies for future activities should be explored to maximize the efficiency and benefits of both efforts where possible. While these two sources of noise in the Arctic may have different impacts and be regulated differently, there could be complementary future activities, for example, exploring cumulative impacts, developing complementary decision-support tools, filling knowledge gaps and ensuring meaningful engagement of communities.

[77] Northern Latitudes Partnerships. (2020). "Deploying Geofence Technology in Western Alaska to Protect Marine Mammal Haulouts." Accessed January 2023. https://www.northernlatitudes.org/geofencing-what-it-is-and-how-it-works/.

References

AEWC. (2021). "Mitigation: Oil & Gas." *Alaska Eskimo Whaling Commission.* Accessed March 2023. https://www.aewc-alaska.org/mitigation.

Blackwell, S. B., Tervo, O. M, Conrad, A., Samson, A.L. Garde, E., Hansen, R.G., Heide-Jørgensen, M.P. (2020). "Narwhals react to ship noise and airgun pulses embedded in background noise." Biol. Lett. 17(11). Retrieved from: https://royalsocietypublishing.org/doi/10.1098/rsbl.2021.

Boertmann, D., Boye, T., Wegeberg, S., & Mosbech, A., (2015). "Offshore Seismic Surveys in Greenland: Guidelines to Best Environmental Practices, Environmental Impact Assessments and Environmental Mitigation Assessments." 47 p. https://www.govmin.gl/images/stories/petroleum/environmental_reports/Guidelines_UK_2_Dec.pdf

Canada Energy Regulator. (2022) "Environmental Assessments in North and Offshore Areas." https://www.cer-rec.gc.ca/en/about/north-offshore/environmental-assessments.html.

Canada Energy Regulator. (2022). "Fact Sheet: NEB's Role in Arctic Offshore Seismic Exploration." Accessed January 2023. https://www.cer-rec.gc.ca/en/about/north-offshore/archive/publications/fact-sheet-nebs-role-in-arctic-offshore-seismic-exploration.html.

Canada-Newfoundland and Labrador Offshore Petroleum Board (n.d.). "Strategic Environmental Assessments." Accessed January 2025. https://www.cnlopb.ca/sea/.

Canada-Newfoundland and Labrador Offshore Petroleum Board (n.d.). "Project-Based Environmental Assessments." Accessed January 2025. https://www.cnlopb.ca/assessments/

Canada-Nova Scotia Offshore Energy Regulator (n.d.). "Environmental Assessments." Accessed February 2025. https://cnsoer.ca/about-cnsoer/what-we-do/environmental-protection/environmental-assessments.

Canadian Science Advisory Secretariat. (2020). "Science Advisory Report: Review of the Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment." Accessed 2022. https://www.dfo-mpo.gc.ca/oceans/publications/seismic-sismique/index-eng.html.

Carroll, A.G., Przeslawski, R., Duncan, A., Gunning, M., Bruce, B. (2017). "A critical review of the potential impacts of marine seismic surveys on fish & invertebrates." *Marine Pollution Bulletin*, 114(1):9-24. ISSN 0025-326X. https://doi.org/10.1016/j.marpolbul.2016.11.038.

CBD. (2020). "Notification: Peer review of CBD Technical Series: Anthropogenic Underwater Noise: Impacts on Marine and Coastal Biodiversity and Habitats, and Mitigation and Management Measures." Convention on Biological Diversity. https://www.cbd.int/kb/record/notification/3019?FreeText=Underwater%2520noise+%28.

CBD. (2020). “Anthropogenic Underwater Noise: Impacts on Marine and Coastal Biodiversity and Habitats, and Mitigation and Management Measures.” Draft Technical Series Publication. https://www.cbd.int/doc/notifications/2020/cbd-ts-underwater-noise-peer-review-en.pdf.

Cision US Inc. (n.d). “Global Oil & Gas Seismic Technology Industry Report 2021: Future of Seismic Technologies in the O&G Industry.” Online report. Accessed 2022. https://www.prnewswire.com/news-releases/global-oil--gas-seismic-technology-industry-report-2021-moving-seismic-data-to-cloud-and-high-performance-computing-drive-tectonic-shift-in-geoscience-workflows-301465136.html.

Chandra, S.K., McCauley, R.D., Duncan, A., Erbe, C., Gavrilov, A., Lucke, K., Parnum, L. (2016). “Underwater Sound and Vibration from Offshore Petroleum Activities and their Potential Effects on Marine Fauna: An Australian Perspective.” *Project CMST 1218 Report 2015-13*. https://appea.com.au/wp-content/uploads/2017/08/CMST-Underwater-Sound-and-Vibration-from-Offshore-Activities.pdf.

Christiansen, F. G. (2021). “Greenland petroleum exploration history: Rise and fall, learnings, and future perspectives.” *Resources Policy*, 74, 102425, ISSN 0301-4207. https://doi.org/10.1016/j.resourpol.2021.102425.

CMS. (2020). “CMS Family Guidelines on Environmental Impact Assessments for Marine Noise-generating Activities.” *Convention on the Conservation of Migratory Species of Wild Animals.* Accessed March 2023. https://www.cms.int/en/guidelines/cms-family-guidelines-EIAs-marine-noise.

Department of Justice Canada. (2009 – revised 07,2022).“Canada Oil and Gas Operations Act (R.S.C., 1985, c. O-7).” Online Document. Accessed March 2023. https://laws-lois.justice.gc.ca/eng/acts/o-7/.

Erbe, C., Marley, S.A., Schoeman, R. P., Smith, J.N., Trigg, L. E., Embling. C. B. (2019). “The Effects of Ship Noise on Marine Mammals—A Review.” *Frontiers in Marine Science*. https://doi.org/10.3389/fmars.2019.00606.

European Union Directorate-General for Environment. (2022). “Zero pollution and Biodiversity: First ever EU-wide limits for underwater noise.” News Article. https://environment.ec.europa.eu/news/zero-pollution-and-biodiversity-first-ever-eu-wide-limits-underwater-noise-2022-11-29_en.

Fewtrell, J.L., McCauley, R.D. (2012). “Impact of air gun noise on the behaviour of marine fish and squid.” *Marine Pollution Bulletin*, 64(5):984–993. https://doi.org/10.1016/j.marpolbul.2012.02.009.

Fisheries and Oceans Canada. (2008). “Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment”. https://neb-one.gc.ca/en/about/north-offshore/statement-canadian-practice-with-respect-mitigation-seismic-sound-in-marine-environment.html.

Fisheries and Oceans Canada. (2020). “Science Advisory Report: Review of the Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment.”

Canadian Science Advisory Secretariat, National Capital Region. https://publications.gc.ca/collections/collection_2020/mpo-dfo/fs70-6/Fs70-6-2020-005-eng.pdf.

Florian, A., Simard, Y., Roy, N., Gervaise, C., Bandet, M. (2017). "Effects of Shipping on Marine Acoustic Habitats in Canadian Arctic Estimated via Probabilistic Modeling and Mapping." *Marine Pollution Bulletin* 125, no. 1-2: 115–31. https://doi.org/10.1016/j.marpolbul.2017.08.002.

Government of Nunavut. (2017). "Type of Seismic Surveys Infographic." *National Energy Board, Canada.* Online document. https://www.regjeringen.no/en/dokumenter/nature-diversity-act/id570549/.

Guan, S., Brookens, T. (2023). "An overview of research efforts to understand the effects of underwater sound on cetaceans." *Water Biology and Security*. doi:10.1016/j.watbs.2023.100141.

International Maritime Organization. (2018). "Further information related to impacts of underwater noise on marine life." Submitted by the International Whaling Commission to the Marine Environment Protection Committee (MEPC 7/INF.9). Accessed December 2024.

International Maritime Organization. (2023). "Revised guidelines for the reduction of underwater radiated noise from shipping to address adverse impacts on marine life."Marine Environment Protection Committee (MEPC.1/Circ.906). Accessed December 2024.

International Whaling Commission. (2018). "Resolution on Anthropogenic Underwater Noise." *Resolution 2018-4*. Accessed December 2024. https://iwc.int/management-and-conservation/environment/anthropogenic-sound.

Interreg North Sea Region. (2021). "10 Years of North Sea Sound Monitoring." *JOMOPANS project*. Retrieved from: https://northsearegion.eu/media/17501/interreg_jomopans_10-years-of-north-sea-soundscape-monitoring_final.pdf.

ISO. (2019). "ISO 3740:2019(En) Acoustics — Determination of Sound Power Levels of Noise Sources — Guidelines for the Use of Basic Standards." *International Organization for Standardization: Online Browsing Platform*. https://www.iso.org/obp/ui/#iso:std:iso:3740:ed-3:v1:en.

JNCC. (2017). "JNCC guidelines for minimizing the risk of injury to marine mammals from geophysical surveys." *Joint Nature Conservation Committee.* Aberdeen, UK. Online report. Accessed March 2023. http://jncc.defra.gov.uk/.

Juretzek, C. Schmidt, B., Boethling, M. (2021). "Turning Scientific Knowledge into Regulation: Effective Measures for Noise Mitigation of Pile Driving." https://www.mdpi.com/2077-1312/9/8/819/pdf.

Johansen, K.L., Boertmann, D., Mosbech, A. & Hansen, T.B. (2015). "Manual for seabird and marine mammal survey on seismic vessels in Greenland." 4th revised edition, April 2015. *Aarhus University, DCE – Danish Centre for Environment and Energy*, 74 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 152 http://dce2.au.dk/pub/SR152.pdf

Lahoz-Monfort, J. J., Magrath, M. J. (2021). "A Comprehensive Overview of Technologies for Species and Habitat Monitoring and Conservation." *BioScience,* 71(10): 1038–1062. Accessed August 2022. https://doi.org/10.1093/biosci/biab073.

Lefevre, J.S. (2013). "A pioneering effort in the design of process and law supporting integrated Arctic Ocean management." *Environmental Law Reporter*, 43:10893-10908.

Manik, T., Kessinger, W. (2003). "Exploration Geophysics." *Encyclopedia of Physical Science and Technology* , 709–26. https://doi.org/10.1016/b0-12-227410-5/00238-6.

Marine Mammal Commission. (n.d.). "Oil and Gas Developments in Marine Mammals." Accessed August 2022. https://www.mmc.gov/priority-topics/offshore-energy-development-and-marine-mammals/offshore-oil-and-gas-development-and-marine-mammals/.

Masud, N., Hayes, L., Crivelli, D., Grigg, S., Cable, J. (2020). "Noise pollution: acute noise exposure increases susceptibility to disease and chronic exposure reduces host survival." *Royal Society Open Science.* doi:10.1098/rsos.200172.

Matthews, M. R., Ireland, D. S., Zeddies, D. G., Brune, R. H., Pyć, C.D. (2020). "A Modeling Comparison of the Potential Effects on Marine Mammals from Sounds Produced by Marine Vibroseis and Air Gun Seismic Sources." *Journal of Marine Science and Engineering* 9, no. 1:12. https://doi.org/10.3390/jmse9010012.

National Research Council (US) Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals. (2003). "Ocean Noise and Marine Mammals." *National Academies Press (US)*. https://pubmed.ncbi.nlm.nih.gov/25057640/.

NOAA. (2020). "Takes of Marine Mammals Incidental to Specified Activities; Taking Marine Mammals Incidental to Ice Roads and Ice Trails Construction and Maintenance Activities on Alaska's North Slope." Docket No. 200106-0003. *Federal Register* (85 FR 2988).

NOAA Fisheries. (1972) "Marine Mammal Protection Act (MMPA): Full text as Amended." https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-protection-act.

NOAA Fisheries. (1973). "Endangered Species Act. Endangered Species Conservation." https://www.fisheries.noaa.gov/national/endangered-species-conservation/endangered-species-act.

Norwegian Ministry of Climate and Environment. (2020). "Integrated Ocean Management Plans: Barents Sea–Lofoten area; the Norwegian Sea; and the North Sea and Skagerrak." *Meld. St. 20*. Report to the Storting (whitepaper). https://www.regjeringen.no/contentassets/5570db2543234b8a9834606c33caa900/en-gb/pdfs/stm201920200020000engpdfs.pdf.

Norwegian Petroleum Directorate. (n.d). "The Petroleum Act (Norway)." https://www.npd.no/en/regulations/regulations/petroleum-activities/.

North Slope Borough. (2008). “Resolution Serial No. 19-2008.” Retrieved from: https://www.north-slope.org/wp-content/uploads/2022/04/NSB-Resolution-19-2008-Offshore-oil-and-gas.pdf

North Slope Borough. (2023). “Our government.” Retrieved from: https://www.north-slope.org/your-government/

Northern Latitudes Partnerships. (2020). “Deploying Geofence Technology in Western Alaska to Protect Marine Mammal Haulouts.” Accessed January 2023. https://www.northernlatitudes.org/geofencing-what-it-is-and-how-it-works/.

Nowacek, D. P., Southall, B. L. (2016). “Effective planning strategies for managing environmental risk associated with geophysical and other imaging surveys.” Gland, Switzerland: IUCN. 42pp. http://dx.doi.org/10.2305/IUCN.CH.2016.07.en

Offshore Technology. (n.d). “How Ultrasonic Tech Could Open Up Arctic Exploration.” https://offshore.nridigital.com/offshore_technology_focus_oct19/how_ultrasonic_tech_could_open_up_arctic_exploration.

Orkustofnun. (2001). “Iceland Act on Prospecting, Exploration and Production of Hydrocarbons No. 13.” Retrieved from: https://nea.is/media/olia/Act-No-13-2001-14102014.pdf.

OSPAR Commission. (2020). “OSPAR inventory of measures to mitigate the emission and environmental impact of underwater noise.” Retrieved from: https://www.ospar.org/documents?v=37745.

OSPAR Commission. (2014). “Monitoring Guidance for Underwater Noise in European Seas.” *OSPAR Agreement 2014-08*. Retrieved from: https://www.ospar.org/documents?v=33031.

PAME. (1997). “Arctic Environmental Protection Strategy: Arctic Offshore Oil and Gas Guidelines.” *Arctic Council, Protection of the Arctic Marine Environment (PAME).* Online report. Accessed August 2022.https://pame.is/images/03_Projects/Offshore_Oil_and_Gas/Offshore_Oil_and_Gas/oilandgasguidelines.pdf.

PAME. (2002). “Arctic Offshore Oil and Gas Guidelines.” *Arctic Council, Protection of the Arctic Marine Environment (PAME).* Online report. Accessed August 2022. https://www.pame.is/images/03_Projects/Offshore_Oil_and_Gas/Offshore_Oil_and_Gas/ArcticGuidelines.pdf.

PAME. (2009). “Arctic Offshore Oil and Gas Guidelines.” *Arctic Council, Protection of the Arctic Marine Environment (PAME).* Online Report. Accessed August 2022. https://oaarchive.arctic-council.org/handle/11374/63.

PAME. (2019). “Underwater Noise in the Arctic: A State of Knowledge Report.” Rovaniemi, Finland. May 2019. *Protection of the Arctic Marine Environment (PAME) Secretariat, Akureyri (2019).* Accessed August 2022. https://oaarchive.arctic-council.org/handle/11374/2394?show=full.

PAME. (2021a). “PAME Work Plan 2021-2023.” Online report. *Arctic Council, Protection of the Marine Environment (PAME).* May 2021.

PAME. (2021b). “Underwater Noise Pollution from Shipping in the Arctic.” *Arctic Council, Protection of the Arctic Marine Environment (PAME).* https://www.pame.is/document-library/pame-reports-new/pame-ministerial-deliverables/2021-12th-arctic-council-ministerial-meeting-reykjavik-iceland/787-underwater-noise-pollution-from-shipping-in-the-arctic/file.

Paxton, A. B., Taylor, J. C., Nowacek, D. P., Dale, J., Cole, E., Voss, C. M., Peterson, C.H. (2017). “Seismic Survey Noise Disrupted Fish Use of a Temperate Reef.” *Marine Policy* 78: 68–73. https://doi.org/10.1016/j.marpol.2016.12.017.

Peng, C., Zhao, X., Liu, G. (2015). “Noise in the Sea and Its Impacts on Marine Organisms.” *International Journal of Environmental Research and Public Health* 12, no. 10: 12304–23. https://doi.org/10.3390/ijerph121012304.

Popper, A. N., Hawkins, A. D., Thomsen, F. (2020). “Taking the animals' perspective regarding anthropogenic underwater sound.” *Trends in Ecology and Evolution, 35*(9), 787-794. doi:10.1016/j.tree.2020.05.002.

Prideaux, G. (2017). “Technical Support Information to the CMS Family Guidelines on Environmental Impact Assessments for Marine Noise-generating Activities.” Convention on Migratory Species of Wild Animals, Bonn. https://www.cms.int/sites/default/files/basic_page_documents/CMS-Guidelines-EIA-Marine-Noise_TechnicalSupportInformation_FINAL20170918.pdf

Ronen, Shuki, Steve Chelminski, and George Steel. (2019). “The Tuned Pulse Source in layman’s terms*.” Sercel Company website*. https://www.sercel.com/products/Lists/ProductPublication/The_Tuned_Pulse_Source_in_layman’s_terms_Nov2019.pdf.

Roth, E. H., Schmidt, V., Hildebrand, J. A., Wiggins, S. M. (2013). “Underwater radiated noise levels of a research icebreaker in the central Arctic Ocean.” *The Journal of the Acoustical Society of America*, 133(4), 1971–1980. https://doi.org/10.1121/1.4790356.

SGU. (n.d). “The Continental Shelf Act.” *Geological Survey of Sweden*. https://www.sgu.se/en/physical-planning/sea-and-coast/the-swedish-continental-shelf-act/.

Slabbekoorn, H., Bouton, N., Opzeeland, I., Coers, A., Cate, C., Popper, A. N. (2010). “A Noisy Spring: The Impact of Globally Rising Underwater Sound Levels on Fish.” *Trends in Ecology & Evolution* 25, no. 7: 419–27. https://doi.org/10.1016/j.tree.2010.04.005.

The Pollution Control Act. Regjeringen. *Government of Norway*. (n.d.). “Pollution Control Act.” Accessed August 2022. https://www.regjeringen.no/en/dokumenter/pollution-control-act/id171893/.

Thode, A., Kim, K. H., Greene, C. R., Roth, E. (2010). “Long range transmission loss of broadband seismic pulses in the Arctic under ice-free conditions.” *The Journal of the Acoustical Society of America*, 128 (4): EL181–EL187. https://doi.org/10.1121/1.3479686

Todd, V. L., Todd, I. B., Gardiner, J. C., Morrin, E. C., MacPherson, N. A., DiMarzio, N. A., Thomsen, F. (2015). "A review of impacts of marine dredging activities on marine mammals." *ICES Journal of Marine Science*, 72(2), 328-340. https://doi.org/10.1093/icesjms/fsu187.

United Nations Convention on the Law of the Sea (UNCLOS). (Effective 1994). "Article 81. Drilling on the continental shelf. Article 82. Payments and contributions with respect to the exploitation of the continental shelf beyond 200 nautical miles." pg 52. https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf.

"United States National Environmental Policy Act." (n.d). Accessed October 2022. https://ceq.doe.gov

University of the Witwatersrand Johannesburg. (2021). "Geophysicists develop innovative seismic technologies." Accessed October 2022. https://www.wits.ac.za/news/latest-news/research-news/2021/2021-01/geophysicists-develop-innovative-seismic-technologies.html.

Weilgart, L. (2018). "The Impact of Ocean Noise Pollution on Fish and Invertebrates." *Report by OceanCare.* Retrieved from: https://www.oceancare.org/wp-content/uploads/2017/10/OceanNoise_FishInvertebrates_May2018.pdf.

Williams, T. M., Blackwell, S. B., Tervo, O. M., Garde, E., Sinding, M. S., Richter, B., Heide-Jørgensen, M. P. (2022). "Physiological responses of narwhals to anthropogenic noise: A case study with seismic airguns and vessel traffic in the Arctic." *Functional Ecology*, 36, 2251–2266. https://doi.org/10.1111/1365-2435.14119

Annex I – Arctic State Guidelines Received Specific to Noise from Marine Oil and Gas Operations

Boertmann, D., Boye, T., Wegeberg, S., & Mosbech, A., (2015). “Offshore Seismic Surveys in Greenland: Guidelines to Best Environmental Practices, Environmental Impact Assessments and Environmental Mitigation Assessments.” 47 p. https://www.govmin.gl/images/stories/petroleum/environmental_reports/Guidelines_UK_2_Dec.pdf

Fisheries and Oceans Canada. (2020). “Science Advisory Report: Review of the Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment.” *Canadian Science Advisory Secretariat, National Capital Region*. https://publications.gc.ca/collections/collection_2020/mpo-dfo/fs70-6/Fs70-6-2020-005-eng.pdf.

Fisheries and Oceans Canada. (2008). “Statement of Canadian Practice with respect to the Mitigation of Seismic Noise in the Marine Environment.” https://neb-one.gc.ca/en/about/north-offshore/statement-canadian-practice-with-respect-mitigation-seismic-sound-in-marine-environment.html.

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