

Offshore Seismic Surveys in Greenland – Guidelines to Best Environmental Practices (BEP), Environmental Impact Assessments (EIA) and Environmental Mitigation Assessments (EMA) ²

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Summary

An Environmental Impact Assessment (EIA) of the seismic activities shall be prepared under one or more of the following conditions:

- The evaluation of the draft scope gives reason to concern for significant environmental impacts.
- The surveys lines are planned to overlap 'closed areas'.
- The survey is planned within the winter time (December to mid-June).
- The survey is planned to take place in waters north of 77 ° N in West Greenland and north of 74° N in East Greenland.

In cases where it is evaluated that the environmental impacts of a seismic survey will be minor an Environmental Mitigation Assessment (EMA) shall be prepared.

Stipulations

Kommentar [1]:

The impact of the seismic survey may extend past the lines into closed areas. "The survey impacts extend into 'closed areas'."

A draft scope of the project shall be received by the Mineral Resource Authority (MRA) 1st December the year before the planned activities.

A draft EIA/EMA shall be received by MRA 1st March the year the activities are to take place.

The EIA/EMA shall include a model of the expected noise propagation. If several surveys are planned to take place in the same general area a joint model including the noise propagation from all planned seismic surveys shall be included.

The model must be verified by noise measurements at selected and representative locations during the seismic survey, and the results shall be submitted to EAMRA within two months after completion of the survey.

The EIA/EMA shall include an environmental management plan.

Passive Acoustic Monitoring (PAM) shall be applied when visibility is reduced, that is at night, in poor visibility or during periods when sea state is above 3.

The PAM-system (sensitivity, species covered) and its deployment shall be described in the EIA/EMA.

Four Marine Mammals and Seabird Observers (MMSOs) shall be placed on the source vessel and two of these shall be certified PAM-operators. The MMSOs shall follow procedures outlined in the *Manual for Seabird and Marine Mammal Survey on Seismic Vessels in Greenland* (Link).

The collected data on marine mammals and seabirds as well as the MMSO-report must be submitted to EAMRA within two months after the completion of the survey.

Mitigation measures to be followed during survey

The lowest practicable power levels to achieve the geophysical objectives of the survey must be chosen. 4

Methods to reduce and/or baffle unnecessary high frequency noise produced by the airguns and to increase the directionality of the airguns must be evaluated.

Occurrence of marine mammal species that are likely to be present in the survey area must be evaluated, especially if they are particularly sensitive due to breeding, calving, pupping, migration etc.

Airguns should not be used outside the seismic lines, except in the cases mentioned below (mitigation gun, during ramp-up prior to arrival and between short transit lines) and for strictly necessary testing purposes.

In order to maximize detection of marine mammals in the exclusion zone, seismic lines shall as far as possible be initiated when visibility is good.

A *pre-shooting search* for marine mammals shall be conducted over a period of 30 minutes (60 minutes in waters > 200 m depth) before commencement of any use of the airguns, except during breaks shorter than 10 minutes between firing of the airguns.

A *ramp-up* procedure (20 minutes long) shall be applied every time the airguns are used, except during breaks less than 10 minutes between firing of the airguns. Ramp-up is not required when a single 'mini-airgun' (volume less than 10 cubic inches) is to be used.

An *exclusion zone* of 500 m around the airgun array shall be applied. If marine mammals are observed within 500 m during full power of the airgun array or during ramp-up, the output shall be reduced to the mitigation gun until the mammal has left the zone. If marine mammals (except polar bears on the ice) are detected within this zone during the pre-shooting search, the onset of ramp-up of the airguns array shall be delayed with 20 min. after the animal is outside the zone.

A *mitigation gun* shall be running if the array is shut down for any reason during the shooting of a seismic line.

During *unintentional shut-downs* the following shall be observed:

Kommentar [2]:

The propagation model should incorporate marine properties such as depth, salinity, turbidity, temperature, and the marine geology (ocean floor properties).

Kommentar [3]:

Ask for a preliminary report of the results prior to the start of the seismic survey to ensure the accuracy of the modelling. This was possible for seismic operations in the Canadian Beaufort.

Kommentar [4]:

PAM can be used minimally, but research has stated that it is not necessarily effective when seismic is operating as some marine mammals go silent or their communications are masked by the seismic sound. In addition, if a marine mammal is heard, estimating the distance to determine if a shutdown is required is difficult.

Kommentar [5]:

Suggests "Occurrence of and impacts to"

Kommentar [6]:

To define this further, if there is an exclusion zone, then state 'when the exclusion zone is visible as determined by the MMSOs.'

Kommentar [7]:

Setting the exclusion zone as a distance instead of a sound level negates the idea that sound is what the marine mammals need 'excluding' from. Sound travels differently based on depth, bottom type, etc. as defined above. I recommend a decibel level to avoid temporary threshold shift (TTS, temporary hearing damage). Usually this is set at 180dB for odontocetes and mysticetes. This may have changed in the recent literature, but as far as I know this is a conservative estimate of what can cause TTS in these animals. The estimates for pinnipeds in 176dB, for polar bears 190dB. The exclusion zones in the Canadian Beaufort Sea ranged from 500 m to 2.5 km for 180dB. This was the reason for the modelling.

If the break is shorter than 5 minutes the array can be re-initiated at full power without further actions.

If the shut-down is between 5 and 10 minutes, a visual scan shall be performed. If no marine mammals are detected within the 500 m exclusion zone the array can be restarted at full output. If marine mammals are present in the exclusion zone the operator must wait until 20 minutes after the animal has left the zone before commencing with ramp-up.

If the shut-down exceeds 10 minutes, a pre-shooting search and a ramp-up procedure shall be conducted before full power is initiated. If MMSO observations are made continuously before and during the entire break and verify that no marine mammals are present, the pre-shooting search can be omitted.

During *line change* the following shall be observed: 5

If the line change time is expected to be *less than 1 hour*, airgun firing must be reduced to the mitigation gun and the MMSOs shall remain on watch. If no marine mammals are present within the 500 m exclusion zone, the airguns can be restarted at full power at the start of the new seismic *line*. Otherwise wait until 20 minutes after the marine mammal has left the exclusion zone and subsequently ramp-up.

If the line change time is expected to *exceed one hour*, airgun firing shall be terminated at the end of the line and a full pre-shooting search and 20 minute ramp-up undertaken before the next line

After completion of the seismic survey, deliverables related to environment include:

- MMSO report.
- Systematic data collected by MMSOs.
- Report on noise measurements

These shall be submitted to EAMRA and its scientific advisors within two months after the completion of the seismic survey. 6

1 Introduction

Commercial seismic surveys waters are subject to environmental regulation (The Greenland Mineral Resources Act) and general requirements and documentation are described in *BMP Guidelines for application, execution and reporting of offshore hydrocarbon exploration activities (excluding drilling) in Greenland* (Link). A central issue in this context is that the operator must prepare an Environmental Impact Assessment (EIA) of the activity if there is a risk of significant impacts on the environment. If this risk is evaluated as minor the operator is required to submit an Environmental Mitigation Assessment (EMA).

The present document describes the practices that must be followed during seismic surveys in Greenland waters in order to reduce impacts on marine mammals, and it also gives guidance to the preparation of EIA and EMA of seismic activities.

The Environment Agency for Mineral Resources Activities (EAMRA) decides, based on a *preliminary scope* (draft scope) of the seismic activities, whether an EIA or an EMA must be prepared. The expected content of a draft scope of the project is described in *Guidelines for submission of scope of project for offshore hydrocarbon exploration activities*. See Figure 1 for a timeline of the draft scope/EIA/EMA process.

Compared to previous guidelines to seismic surveys in Greenland waters some changes have been introduced. These apply to:

- A change from the previous protection/safety zone around the airgun array to an exclusion zone of 500 m similar to *Canadian* and US-regulation.
- The marine mammal protection areas and areas of concern.

Kommentar [8]:

However MMSOs should remain on watch.

Kommentar [9]:

A ramp up should always be performed. Is there a scientific reason for the one hour? If not, I recommend a ramp up.

Kommentar [10]:

Canadian protection varies regionally, and the Arctic regions especially do not rely on the minimum 500 m recommendation. It is from a 2004 Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment. It is the minimum requirement, and much work has been done on impacts and mitigation of seismic since then. Alaska does not use a 500 m exclusion zone but relies on a zone set through decibel levels to avoid TTS. A 500 m exclusion zone is thus not Best Environmental Practice.

- The number of MMSOs required on board the seismic vessel.
- A new table 5 in Appendix 1.
- The descriptive chapters have been removed, and interested readers are referred to the Strategic Environmental Impact Assessment reports (see below).

The major environmental concerns due to seismic surveys in Greenland waters relates to marine mammals (especially whales) and fish (including the fisheries), cf. the Strategic Environmental Impact Assessment reports (SEIA) covering most of the Greenland waters ([Link to the SEIAs](#)). Therefore marine mammals and fisheries will be in focus here. More detailed accounts of marine mammals and fish in Greenland waters can be found in these SEIAs.

Marine seismic surveys have so far only been conducted in the summer and fall (mid-June through November) when ice conditions are most favourable. Seismic surveys to be carried out outside these seasons or in the ice covered waters off North Greenland (to the north of 77° in the west and to the north of 74° N in the east) will always require an EIA. 7

List of abbreviations and acronyms

CTD = Conductivity, Temperature, Depth (oceanographic data)
 DCE = Danish Centre of Environment and Energy, Aarhus University
 EAMRA = Environment Agency for the Mineral Resources Activities, Greenland
 EEZ = Exclusive Economic Zone
 EMP = Environmental Management Plan
 GINR = Greenland Institute of Natural Resources
 IMO = International Maritime Organization ([Link](#))
 ISO = International Organization for Standardization
 IUCN = International Union for Conservation of Nature ([Link](#))
 JIP = International Association of Oil and Gas Producers Joint Industry Project
 JNCC = Joint Nature Conservation Committee, UK
 MARPOL = International Convention for the Prevention of Pollution from Ships ([Link](#))
 MMSO = Marine Mammal and Seabird Observer
 MRA = Mineral Resource Authority
 NORSOK = Norwegian standards for petroleum industry
 PAM = Passive Acoustic Monitoring
 SEIA = Strategic Environmental Impact Assessment
 VSP = Vertical Seismic Profiling 8

2 General considerations

Seismic surveys shall in Greenland be carried out in accordance with good international practice and in a safe and environmentally acceptable manner, which among others include that:

- Best Available Technology (BAT) and Best Environmental Practice (BEP) must be applied and used in order to minimize environmental impacts. For definition of these terms, please refer to OSPARs webpage ([Link 5 and below](#)¹).

¹ As defined in Appendix 1 of the OSPAR Convention BAT “means the latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste”. BEP is defined as “the application of the most appropriate combination of environmental control measures and strategies”.

It follows that BAT and BEP for a particular source will change with time in the light of technological advances, economic and social factors, as well as changes in scientific knowledge and understanding.

- All international rules, guideline and conventions are met: e.g. MARPOL Convention (Annexes IV and V), IMO (Ballast Water), OSPAR Convention, NORSOK, ISO 14001 etc.
- All national rules and guidelines in Greenland are met, including the regulation behind “Important areas for wildlife” (Link).
- Vessels engaged and machinery used in the exploration activities shall only use diesel and gasoil and with a sulphur content less than 1.5 % (weight). This is planned to be reduced due to MARPOL regulation to 0.5 % by Jan. 1, 2020.
- All non-degradable materials and structures deployed on the seabed shall be removed upon termination of the operation, unless EAMRA approves otherwise.
- EAMRA and its scientific advisors will during the consultation phase point out if relevant information is missing, if specific issues need elaboration and environmental standards/threshold values to be applied.

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3 Environmental Impact Assessment – EIA

An Environmental Impact Assessment (EIA) shall be prepared if one or more of the following conditions apply to the proposed activity:

- The evaluation of the scope gives reason to concern for significant environmental impacts.
- The surveys lines are planned to overlap ‘closed areas’.
- The survey is planned to take place in the winter time (December to mid-June).
- The survey is planned to take place in the waters north of 77 ° N in West Greenland and north of 74° N in East Greenland.

The EIA shall:

- Identify, predict and communicate potential environmental impacts of a proposed seismic project in all its phases.
- Cover the entire area that may be affected by the project, and especially by the noise propagation.
- Describe and assess the likelihood of environmental impacts and the effects of the environmental impacts.
- Present measures to address and mitigate the identified impacts.
- Include all aspects in relation to environment, nature, wildlife and human activities (fishery and hunting).
- Be updated if project, area, activities etc. are changed.
- Include a predictive model of the expected noise propagation from the seismic sound source (see below).
- Describe the chosen PAM system and document its validity to identify received sounds to species.
- Be delivered in Greenlandic, Danish and English.

The EIA must include:

- An extended non-technical summary including maps and figures. This part must be easy to read and understand for the public and decision makers as a stand-alone document.

Kommentar [11]:

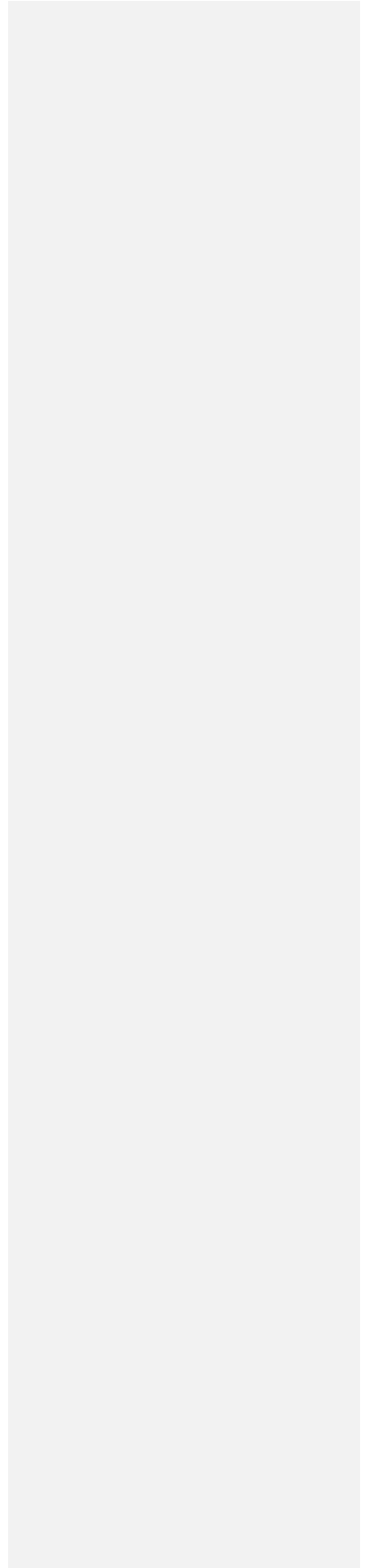
Suggests addition of “or other effective detection measures such as aerial drone overflights, additional vessels, or additional MMSOs.”

- An introduction describing the seismic project, its background and objectives.
- A thorough and focused description of the state of the environment before the start of activities.
- A description of the seismic project, with all phases from start to end.
- A description of considered alternatives and why they were rejected.
- An assessment of environmental impacts of the seismic survey, with an evaluation of alternative options compared to the preferred project option.
- An *environmental management plan* (EMP) describing management, control, mitigation of the identified impacts from other activities than seismic sound

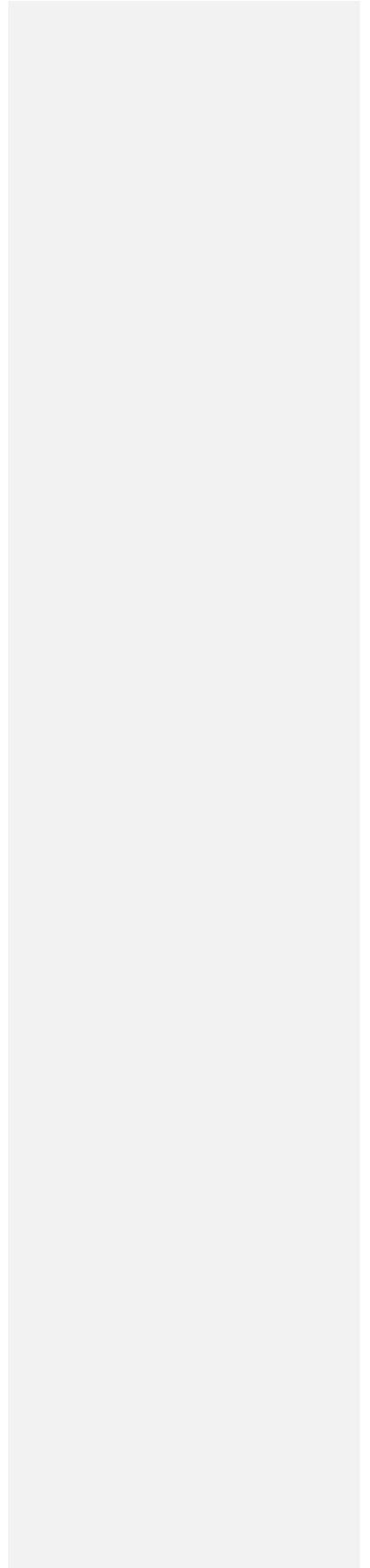
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propagation and emergency plans for un-planned events (fire, transport accidents and releases to the environment).

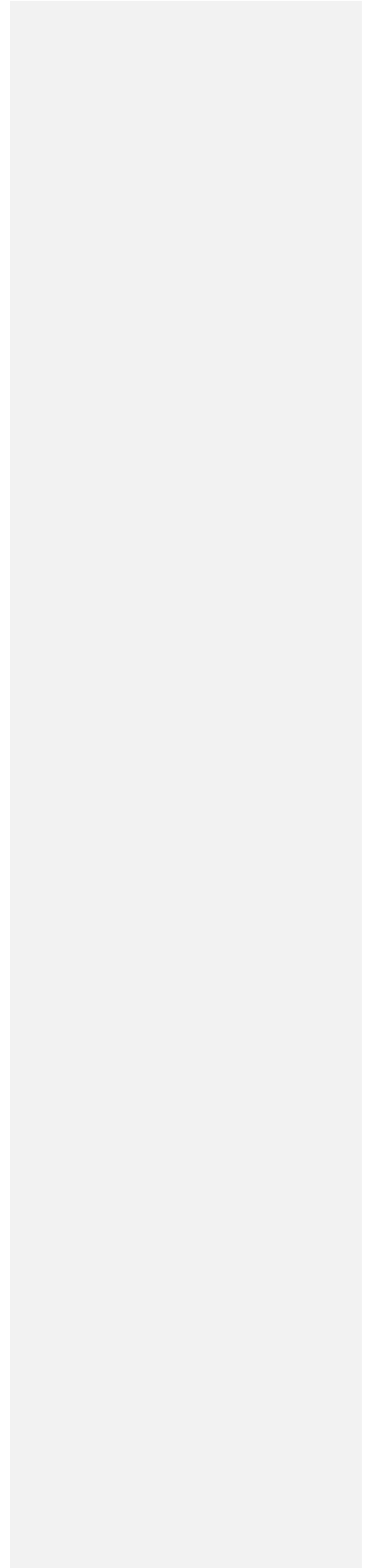
A waste management plan.



□ Conclusions.



References used in the EIA process and Glossary of terms and abbreviations.



□ Five information tables that must be completed and included in the EIA are found in Appendix 1. These tables cover the plan for the survey, the physical aspects of the airgun array, the methodology and the PAM monitoring.

The EIA shall document that the seismic survey is carried out in accordance with good international practices and in a safe and environmentally acceptable manner including e.g.:

- The Best Available Technology (BAT), Best Environmental Practice (BEP) and Best Practicable Control Technology (BPT) will be applied at all times.
- Discharges/emissions from fuel combustion, incineration plants, etc. shall meet all international rules, guidelines and conventions (IMO Ballast Water Convention, IMO MARPOL, OSPAR etc.).
- The environmental management and control shall comply with the requirements set out in ISO 14001.

In general, an EIA of seismic activities shall focus on the potential environmental conflicts (areas, species), on the potential impacts and on the suggested mitigation measures.

The assessment of impacts shall include cumulative impacts, including other seismic surveys in the same general area (simultaneously, previously (including previous years) and if possible also in the future) and also other disturbing activities such as fishery.

General and irrelevant background information such as descriptions of terrestrial mammals and birds should not be included. References to a relevant Strategic Environmental Impact Assessments **will** under normal circumstances be sufficient (Link to the SEIAs).

The EIA must provide direct mitigation solutions to reduce the effects of the seismic survey and these should be in terms of reduced acoustic output, increased directionality of airguns, reduced high frequency output, **careful** planning to avoid overlap with sensitive species in the area, careful consideration of other planned activities in the same area (drilling, other seismic activities, shipping, fisheries etc.).

The EIA must describe the chosen PAM system and document its validity to identify received sounds to species (ex. how species will be recognised). The EIA must describe how often and how the PAM system will be used. The EIA must also document the acoustic properties of the system, for example the sensitivity of the system, its operational dynamic range in relation to self-noise, background noise of the sea and airgun noise.

A significant part of the EIA will be a *predictive model of the expected noise propagation* from the seismic activities. The model must be state of the art and build on updated valid environmental data collected in the focal area. The model must include a relevant number of sample positions at relevant distances from the seismic survey. The model must include 11

frequencies up to at least 48 kHz at ranges up to 20 km and frequencies up to 20 kHz beyond 20 km. The requirements of the noise model are described in Section 5 below.

The operator must comply with the best practice mitigation guidelines described in Section 6 that generally follows the Joint Nature Conservation Committee, **UK** (JNCC 2010) guidelines (Link).

There are, however, a few rules for Greenland that are beyond the JNCC 2010 guidelines, why reference to the latter (or other marine mammal mitigation guidelines) are not sufficient when planning seismic surveys in Greenland waters.

The EIA will be made public and subject to a consulting period of 8 weeks. It will subsequently be evaluated by EAMRA and its scientific advisors for subsequent consideration by the Greenland Government.

The EIA timeline (Figure 1):

- A *draft scope* of work must be submitted by December 1st the year before the planned survey.

Kommentar [12]:

Does this mean a company can reference a SEIA as their entire EIA or that they may use it to reference certain sections?

Kommentar [13]:

Suggests to add "temporal and spatial" between "careful" and "planning".

Kommentar [14]:

Further above it is stated that there is a switch to Canada/US standards? Please clarify.

- Within December 15th EAMRA together with EAMRA's scientific advisors evaluate whether an EIA is required or not and the company receives notification hereof and comments to the *draft scope*.
- If an EIA is required the *final draft scope* will be subject to a public pre-consultation for 35 days according to the Mineral Resources Act.
- After the public pre-consultation has ended the company prepares a *white paper* including all the comments from the public pre-consultation and the company's response to these. This may lead to changes and/or amendments to the *final scope*.
- The *draft EIA* must be submitted to EAMRA before 1st March.
- The *draft EIA* will be evaluated by EAMRA to ensure that all the requirements are fulfilled before it is released for public consultation.
- The *draft EIA* will be made public and subject to a public consultation period of 8 weeks including public consultation meetings.
- After the end of the public consultation period the company prepares a *white paper* which includes and addresses all the comments from the public consultation meetings and the written comments. This may lead to changes and/or amendments to the *draft EIA*.
- The *white paper* and the (amended) *draft EIA* will subsequently be evaluated by EAMRA and EAMRA's scientific advisors, and subsequently the *final EIA* will be handed to the Greenland Government for their approval.

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Figure 1. Timeline for the EIA/EMA process when applying for offshore seismic surveys in Greenland. Rectangles indicate documents and rounded rectangles processes. 13

4 Environmental Mitigation Assessment – EMA

If the expected environmental impacts of a planned seismic survey are assessed (based on the draft scope) to be limited, an *Environmental Mitigation Assessment* (EMA) shall be prepared.

An EMA can be perceived as a reduced Environmental Impact Assessment, and shall only focus on the mitigation measures proposed for the current activity.

The EMA shall:

- Present the technical data of the seismic equipment, e.g. volume and source level of the airgun array.
- Present the measures to mitigate impacts on marine mammals.
- Be updated if project, area, activities etc. is changed.
- Include a predictive model of the expected noise propagation from the seismic sound source (see below).
- Describe the chosen PAM system and document its validity to identify received sounds to species.
- Be delivered in Greenlandic, Danish and English.

The EMA must include:

- An extended non-technical summary including maps and figures. The document must be easy to read and understand for the public and decision makers as a stand-alone document.
- An introduction describing the seismic project, its background and objectives.
- A description of the seismic project, with all phases from start to end.
- An assessment of environmental impacts of the seismic survey, with an evaluation of alternative options compared to the preferred project option.
- A description of the measures adopted to mitigate environmental impacts from the sound propagation.

- An *environmental management plan* (EMP) describing management, control, mitigation of the identified impacts from other activities than the seismic sound propagation, emergency plans for unplanned events (fire, transport accidents and releases to the environment), and training programs for employees related to environmental matters etc.
- A *waste management plan*.
- Conclusions.
- References used in the EMA process and glossary of terms and abbreviations.
- Five information tables that must be completed and included in the EMA are found in Appendix 1. These tables cover the plan for the survey, the physical aspects of the airgun array, the methodology and the PAM monitoring.

The EMA shall document that the seismic survey is carried out in accordance with good international practices and in a safe and environmentally acceptable manner including e.g.: 14

- The Best Available Technology (BAT), Best Environmental Practice (BEP) and Best Practicable Control Technology (BPT) will be applied at all times.
- Discharges/emissions from fuel combustion, incineration plants, etc. shall meet all international rules, guidelines and conventions (IMO Ballast Water Convention, IMO MARPOL, OSPAR etc.).
- The environmental management and control shall comply with the requirements set out in ISO 14001.

In general, the EMA shall clearly describe and evaluate the expected effects of the seismic survey and the actions planned to reduce these effects.

The EMA must provide direct mitigation solutions to reduce the effects of the seismic survey and these should be in terms of reduced acoustic output, increased directionality of airguns, reduced high frequency output, careful planning to avoid overlap with sensitive species in the area, careful consideration of other planned activities in the same area (drilling, other seismic activities, shipping, fisheries etc.).

Appendix 1 contains five information tables that must be completed and included in the EMA.

The EMA must describe the chosen PAM system and document its validity to identify received sounds to species (e.g. how species will be recognised?). The EMA must describe how often and how the PAM system will be used. The EMA must also document the acoustic properties of the system, for example the sensitivity of the system, its operational dynamic range in relation to self-noise, background noise of the sea and airgun noise.

A significant part of the EMA is a predictive model of the expected noise pollution from the seismic activities. The model must be state of the art and build on updated valid environmental data collected in the focal area. The model must include a relevant number of sample positions at relevant distances from the seismic survey. The model must include frequencies up to at least 48 kHz at ranges up to 20 km and frequencies up to 20 kHz beyond 20 km. The requirements of the noise model are described in Section 5 below.

The operator must comply with the best practice mitigation guidelines described in Section 6 that generally follows the JNCC 2010 guidelines (Link).

There are, however, a few rules for Greenland that are beyond the JNCC 2010 guidelines, why reference to the latter (or other marine mammal mitigation guidelines) are not sufficient when planning seismic surveys in Greenland waters.

EMA timeline (Figure 1):

- A *draft scope* of the planned seismic activities must be submitted by December 1st the year before the planned survey.
- Within December 15 EAMRA together with EAMRA's scientific advisors evaluate whether an *EIA* or an *EMA* is required, and the company receives notification hereof.
- If an *EMA* is required, the *draft EMA* shall be submitted to EAMRA before 1st March.

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- The *draft EMA* will be evaluated by EAMRA together with EAMRA's scientific advisors to ensure that all requirements are fulfilled before it is released for public consultation.
- The *draft EMA* will be made public and subject to a public consultation period for 8 weeks. After the end of the public consultation period the company prepares a so called white paper which includes and addresses all the comments from the public consultation. This may lead to changes and/or amendments to the *draft EMA*. The white paper and the (amended) *draft EMA* will subsequently be evaluated and finally approved by EAMRA.

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5 Modelling impact areas of the noise

Seismic data acquisition has increased in recent years in Greenland waters and may increase further. This means that marine mammal populations may be exposed to seismic surveys several times over the course of the ice-free season, which potentially may result in cumulative effects.

In order to take account of the area actually encompassed by a seismic survey as well as potential other surveys in the same general area, *a model of the expected noise propagation must be included in the submitted EIA/EMA*. The model 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 more detailed and current the environmental data are, the better the results of the model. Modelling should not be restricted to the surface layer but extend to at least 1000 m depth or to the seabed. Horizontally, the model should extend to cover all areas exposed to levels likely to affect marine mammals. If more than one survey is planned for the general area of the model, a joint model including all planned seismic surveys shall be included. This can replace models prepared individually by each company. Information about other potential surveys must be sought well in advance from the EAMRA/MRA. If other industrial noise sources occur in the area, these shall also be included in the model.

5.1 Estimated noise levels to be presented in the model

The seismic noise propagation model shall result in project sound levels at different ranges and depths from the airgun array (depths relevant for the species in the area). Noise levels to be presented in the model are peak-to-peak sound pressure levels referenced to 1 µPa (peak-peak), rms sound pressure levels referenced to 1 µPa (rms measured over 90% of pulse duration, as defined by Malme *et al.* 1986; Blackwell *et al.* 2004; Madsen 2005) and in sound exposure levels referenced to 1 µPa²·s. per pulse. For assessment of cumulative effects the total sound exposure level (across all airgun pulses and 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.

5.2 Documenting modelled noise propagation loss

Actual sound exposure within the modelled area must be documented at selected and representative locations during conduction of the seismic survey. Monitoring can be conducted over the total or a

Kommentar [15]:

It would be helpful to state what these are for each marine mammal species and what threshold will be used (such as Temporary Threshold Shift). Brandon Southall has done a lot of work on this.

substantial part of the survey period, by means of deployed autonomous data-loggers, or measurements can be obtained from a measuring vessel during a representative part of the survey. The planned recording scheme is to be approved by the EAMRA before the seismic survey is approved. 17

Recordings must be made at several depths at each position, preferably down to the maximum depth utilised by species in the area, but at least to a depth below the sound speed minimum, as determined from the vertical sound speed profile. At least three recording ranges must be sampled and at least out to a distance of 50 km range from the survey area. Sound speed profiles must be obtained at each recording position, either directly or from synchronous measurements of depth, salinity and temperature (CTD-measurements). The analysed recordings must be delivered in a report to EMARA following the performed survey. The measured received levels must be reported corresponding to the values of the propagation model in peak-to-peak values, rms and energy flux density (as specified in Appendix 1 Table 3). 18

6 Seismic surveys, best environmental practice

The primary aim of these best practice guidelines is to prevent physical injuries on marine mammals during seismic surveys. Behavioural impacts are not, or only to a limited extent, expected to be mitigated. Pre-shoot search and ramp-up procedures are the key components of the mitigation, although there is limited experimental evidence on the efficacy of these procedures.

6.1 The planning phase

The optimal mitigation is obtained by careful and thoughtful planning of the survey. When planning a seismic survey:

- Choose the lowest practicable power levels to achieve the geophysical objectives of the survey. The necessity of the chosen power level must be documented in the EIA/EMA.
- Seek methods to reduce and/or baffle unnecessary high frequency noise produced by the airguns and to increase the directionality of the airguns. This must be described and the effects documented in the EIA/EMA.
- Determine which marine mammal species are likely to be present in the survey area and assess if there are any seasonal or habitat considerations that need to be taken into account, for example periods of migration, breeding, calving or pupping. Consideration of this information must be reflected in the EIA/EMA, and must be concise and based on conclusions. The EIA/EMA must clearly specify if data deficiency hinders evaluation of possible effects on species in the area.
- Obtain knowledge from the EAMRA/MRA about other planned seismic surveys in nearby licensing areas in Greenland and Canada
- The pre-shooting and the ramp-up procedures shall be included in the general workplans.

6.2 Surveys

6.2.1 Exclusion zone (500 metres)

An *exclusion zone* of 500 m from the centre of the array shall be maintained when operating the airguns.

If marine mammals (except polar bears on the ice) are detected within this zone *during the pre-shooting search*, the ramp-up of the seismic sources shall be delayed until their passage, or the transit of the vessel results in the marine mammals being more than 500 metres away from the source. In both cases, there should be a 20 minute delay from the time of the last sighting within 500 metres of the source to the commencement of the ramp-up, in order to determine whether the animals have left the area. If PAM is used it is the responsibility of the PAM operator to assess any acoustic detections and determine if there are likely to be marine 19

Kommentar [16]:

Suggestion to include nearshore hydrophones that monitor sound levels near marine hunting areas or communities, when relevant.

Kommentar [17]:

This is good to mention, as it is difficult to monitor - some impacts have been found to occur more than 20 km away. However behavioural impacts should be assessed within the EIA. Species such as narwhal are sensitive to sound and seismic behavioural impacts may be significant depending on the time and location. Behavioural impacts can be mitigated through spatial and temporal planning.

Kommentar [18]:

As stated above, if the decibel level that causes harm (typically understood as Temporary Threshold Shift) is the basis for the exclusion zone, then the exclusion zone needs to be based on decibel levels, not meters.

mammals in the water within 500 metres of the source. If the PAM operator considers marine mammals are present within that range, then the start of the operation should be delayed as outlined above.

If marine mammals are detected within the zone (even when they are on ice) whilst the airguns are *firing at full power or during ramp-up*, firing must be reduced to only the smallest airgun in the array (*mitigation gun*), which should prevent further approach of animals to the array. Full power may be regained as soon as the animals are outside the 500 m exclusion zone.

If marine mammals are likely to be in the area, seismic activities may as far as possible only be commenced during the hours of daylight when visual mitigation using Marine Mammal and Seabird Observers (MMSOs) is possible.

Passive Acoustic Monitoring (PAM) is required if the operator still plans to commence seismic activities during the hours of darkness, low visibility, or during periods when the sea state is not conducive to visual mitigation (e.g. sea state above 3).

6.2.2 Pre-shooting search

A pre-shooting search must normally be conducted over a period of 30 minutes before commencement of any use of the airguns. The MMSO shall make a visual assessment to determine if any marine mammals are within 500 meters of the centre of the airgun array.

However, in deep waters (>200 m) the pre-shooting search must be extended to 60 minutes as deep diving species (e.g. sperm whale and beaked whales) are known to dive for longer than 30 minutes. A deep water pre-shooting search for the next start up can be commenced while a line is still being shot, provided that the airguns are turned off when the first line is ended.

If PAM is used in conjunction with visual monitoring, the PAM operator should ensure the system is deployed and being monitored for vocalisations during each designated pre-shooting period.

6.2.3 The ramp-up

The ramp-up (soft start) is the time from when the air guns are turned on till full operational power is obtained. Power must be built up slowly and gradually from a low energy start-up (e.g. starting with the smallest airgun in the array and gradually adding in others) over 20 minutes to give adequate time for marine mammals to leave the area. An increase of approximately 6 dB/minute is recommended. Ramp-up shall be applied every time firing of the airguns is initiated, the only exceptions being for certain types of airgun testing, and the use of a 'mini-airgun' (single gun volume less than 10 cubic inches). 20

Figure 2. Action diagram during pre-shooting search and ramp-up. See full explanation in Section 6.2.

To minimise additional noise in the marine environment, a ramp-up (from commencement of ramp-up to commencement of the line) should not be significantly longer than 20 minutes (for example, ramp-ups longer than 40 minutes are considered to be excessive). Once the ramp-up has been performed and the airguns are at full power the survey line must start immediately.

Where possible, ramp-ups should be planned so that they commence within daylight hours. 21

Figure 3. Action diagram during breaks. See full explanation in Section 6.2.

6.2.4 Unplanned breaks in shooting

If, for any reason, firing of the airguns has stopped and not restarted for at least 10 minutes, then a 20 minute ramp-up must be carried out. If no MMSO was on watch before the break a pre-shooting search has to be carried out as well. After any unplanned break in firing for between 5 and 10 minutes the MMSO shall make a visual assessment for marine mammals (not a pre-shooting search, given that an MMSO was on duty immediately prior to the stop) within 500 metres of the centre of the airgun array. If a marine mammal is detected while the airguns are not firing the MMSO shall advise to delay commencement, as per the pre-shooting search, delay and ramp-up instructions

Kommentar [19]:

In the Canadian Beaufort it was found that bowhead whales were less likely to move away from sound when they were in their feeding areas, resulting in mitigation that stated that the seismic program could only shoot when the entire exclusion zone was visible. For species that may behave similarly in their critical habitat, special mitigations may be required.

Kommentar [20]:

This is inconsistent with the statement above that discusses the "one-hour" allowance for a seismic operation to fire the full array from just the single airgun.

Kommentar [21]:

... Or times when the exclusion zone is visible.

above. If no marine mammals are present then they can advise to commence firing the airguns. If the break is of less than 5 minutes, the airguns can start firing at full power immediately. If possible the mitigation gun (see Section 6.2.2) should remain firing when otherwise the entire array is shut down. See Figure 3.

6.2.5 Site survey and Vertical Seismic Profiling (VSP)

These kind of seismic surveys shall apply both pre-shooting search and ramp-up procedure.

Use only of a 'mini-airgun' (single airgun with a volume of less than 10 cubic inches) do not require ramp-up, however, a pre-shooting search shall still be conducted before its use. 22

6.2.6 Airgun testing

Airgun tests may be required before a survey commences, or to test damaged or misfiring guns following repair or to trial new arrays. The following guidance is provided to clarify when a ramp-up is required:

- If the intention is to test all airguns at full power, a 20 minute ramp-up is required.
- If the intention is to test a single airgun at low power, a ramp-up is not required.
- If the intention is to test a single airgun, or a number of guns on high power, the airgun or airguns should be fired at lower power first, and the power then increased to the level of the required test; this should be carried out over a time period proportional to the number of guns being tested and ideally not exceed 20 minutes in duration.

MMSOs must maintain a watch as outlined in the pre-shooting search guidance (Section 6.2.3) before any instances of gun testing.

6.3 Line change

Depending upon the type of seismic survey being undertaken, the time for a line change can vary. Specific line changes procedures are not necessary for all types of seismic surveys, for example, in certain regional surveys where there is a significant distance between the lines, and for VSP operations.

If the line change time is expected to *exceed one hour*, airgun firing shall be terminated at the end of the line and a full pre-shooting search and 20 minute ramp-up undertaken before the next line (see Figure 4).

If line change is expected to be *shorter than one hour*, the array should be operated at a lower output or with the mitigation gun (see Section 6.2.2) and the MMSOs shall remain on watch. With small airguns (site surveys) the Shot Point Interval (SPI) may be increased to max. 5 minutes during the turn. If no marine mammals are present within the 500 m exclusion zone, the airguns can be restarted at full power at the start of the new seismic line. Otherwise wait until 20 minutes after the marine mammal has left the exclusion zone and subsequently ramp-up (Figure 4). 23

Figure 4. Action diagram during line changes. See Section 6.3.

6.4 Passive Acoustic Monitoring (PAM)

Visual observation is an ineffective mitigation tool during periods of darkness, poor visibility or during periods when the sea state is not conducive to visual mitigation (e.g. sea state above 3), as it will not be possible to detect marine mammals in the vicinity of airgun sources. Under such conditions, PAM is considered to be the only currently available technique to detect marine mammals. However, the different systems have their limitations. Moreover, only vocalising individuals can be detected, while silent marine mammals will go undetected.

PAM systems consist of hydrophones that are deployed in the water column, and the detected sounds are processed using specialised software. Trained PAM operators are needed to set up and deploy the equipment, to interpret the detected sounds and to trouble-shoot occurring problems.

6.4.1 Use of PAM as a mitigation tool

Kommentar [22]:
I'm glad this is stated.

PAM can provide a useful supplement to visual observations undertaken by MMSOs. However, in many cases it is not as accurate as visual observations for determining range. If for example, the range accuracy of a system is estimated at +/- 300 metres, animals detected and calculated to be within 500 metres from the source could, in reality, be $500 + 300 = 800$ metres away, and their detection would still lead to a delay in the ramp-up. In the absence of PAM systems capable of range determination, range judgements of the trained PAM operator will constitute the basis for deciding whether an area is free from whales prior to the ramp-up. 24

In all cases where PAM is employed, a description of the system, its sensitivity, species covered and an explanation on how the applicant intends to deploy PAM to greatest effect shall be included in the EIA/EMA (see Appendix 1 Table 4 for details).

Software to process and analyse whales' sounds has been developed in recent years. An example is PAMGuard, an open-source software that has been developed as part of the International Association of Oil and Gas Producers Joint Industry Project (JIP). PAMGuard is still in a transition period between use as a research tool and as a widespread monitoring tool. Users are therefore encouraged actively to contribute to their development and refinement.

6.5 Marine Mammal and Seabird Observers

At least four trained Marine Mammal and Seabird Observers (MMSOs) including two certified PAM-operators shall be on board the seismic vessels operating in Greenland waters in order to observe continuously when operating the airguns.

They shall be especially trained in observation methodology and in mitigation of impacts on marine mammals and at least two shall be certified in operating the PAM-system, including trouble shooting the system. Besides marine mammal registration, the MMSOs shall also document skills in seabird identification and registration. A list of trained Greenlandic MMSOs can be found here: [Link](#).

The MMSOs shall be placed on the source vessel (where the airguns are being deployed from), unless alternative arrangements have been agreed with EAMRA. Communication channels between the MMSOs, the crew on the bridge and the airgun crew shall be in place before commencement of the pre-shooting search (this may require portable VHF radios). The MMSOs shall be made aware of the timing of the proposed operations, so that there is adequate time to conduct the pre-shooting search.

Two MMSOs shall be posted at the observation site when shooting. See also *the Manual for Seabird and Marine Mammal Survey on Seismic Vessels in Greenland* ([Link](#)).

The licensee shall bear all costs associated with the MMSOs participation in the operation, and the licensee shall agree with the MMSOs on working hours, wages, insurance and communication systems on board.

Observation shall be conducted from an observation box that shelters the MMSOs from the weather. See *Manual for Seabird and Marine Mammal Survey on Seismic Vessels in Greenland* ([Link](#)). It is the responsibility of the seismic contractor that an observation box is installed on the seismic vessel somewhere suitable for observation without compromising safety.

The MMSOs have three tasks.

#1 to monitor marine mammals before start-up and during seismic surveys in order to mitigate and observe safety distances to whales and seals.

#2 to collect data on abundance and distribution of seabirds and marine mammals through systematic surveys. 25

#3 to operate the PAM-system, thus requiring that at least two of the MMSO's shall be certified PAM-operators.

The tasks are specified in the *Manual for Seabird and Marine Mammal Survey on Seismic Vessels in Greenland* (Link).

The purpose of the second task is to improve the knowledge on temporal and spatial distribution of marine mammals and seabirds in the Greenland waters. The collected data will be included in the DCE/GINR-database of background information. This is available to the companies operating in Greenland waters when they prepare EIAs of their specific activities.

Data shall be collected according to DCE standards to fit into the databases; see the *Manual for Seabird and Marine Mammal Survey on Seismic Vessels in Greenland* (Link).

The collected data and the MMSO-report shall be submitted to EAMRA and the scientific advisors within two month after the completion of the survey.

The report (printed and file) and the data (electronic copy only) shall be submitted to each of EAMRA, DCE and GINR. The addresses are:

Environment Agency for the Mineral Resources Activities (EAMRA)

Imaneq 1A, 801 (Nuuk Center) P.O. Box 1614

3900 Nuuk, Greenland

DCE – Danish centre for energy and environment

Aarhus University

att. David Boertmann

Frederiksborgvej 399

P.O. Box 258

DK-4000 Roskilde, Denmark

PINNGORTITALERIFFIK

Greenland Institute of Natural Resources

att. Josephine Nymand

Kivioq 2

P.O. Box 570

3900 Nuuk, Greenland 26

7 Protection areas for marine mammals in relation to seismic surveys

This section designates two types of areas related to the occurrence of marine mammals: Areas of concern and closed areas.

Areas of concern are where specific sensitive species of seals, walrus and whales occur and where there is a risk of overlap with seismic surveys. If seismic surveys are planned to overlap with these areas in the season indicated on the map, specific regulation in order to protect these species from disturbance may be introduced.

In the *closed areas* seismic surveys as a rule are not possible. However, limited seismic surveys can be allowed after specific application, including a detailed shooting program and proposal of impact studies on the marine mammal in question. Limited seismic survey means that only one company operates, that only a few and short lines are placed inside the protected area and that they are widely spaced (> 10 km).

The areas of concern and the protection areas are shown on the overview maps on Figures 4-7. GIS-files (shp-format) can be downloaded from the MRA-website to see the exact borders of these areas (Link).

7.1 Sensitive species

The strategic environmental impacts assessments (SEIA) so far carried out in Greenland, designate the following marine mammals as particularly sensitive to seismic surveys (The SEIAs can be found here):

Kommentar [23]:

Suggestion to write "If seismic survey project areas..." instead. If "project area" is used, it allows for the impacts of seismic to be included in the range that may overlap into areas of concern or closed areas. As stated before, the impacts of the seismic survey may extend past the lines into "areas of concern" and "closed areas".

- White whale or beluga (*Delphinapterus leucas*).
- Narwhal (*Monodon monoceros*).
- Bowhead whale (*Balaena mysticetus*).
- Walrus (*Odobenus rosmarus*).

Outside the areas covered by the strategic impact assessments a fifth very sensitive whale occurs:

- Northern right whale (*Eubalaena glacialis*).

Many other marine mammals (whales, seals and polar bear) occur in the seas surrounding Greenland. It is either not possible to designate protection areas for these or they are considered as less sensitive to seismic surveying. 27

The beluga whales arrive from Arctic Canada to Northwest Greenland in early October (Heide-Jørgensen et al. 2003) and may overlap the season for seismic surveys for a short period. Narwhals on the other hand occur in the seismic season in Northwest Greenland and East Greenland. They have specific summering areas where high numbers may occur. Several whales have been tracked by satellite telemetry both in Northwest Greenland and in East Greenland. The results of these trackings indicate also specific migration corridors and wintering areas. Outside the seismic season narwhals occur in the drift ice off East Greenland and in Baffin Bay and northern Davis Strait (Heide-Jørgensen & Laidre 2006, Heide-Jørgensen et al. 2013).

Bowhead whales in West Greenland occur only in the season with sea ice (December-June). In East Greenland another stock of bowhead whales occur – the Critically Endangered Spitsbergen Stock (cf. IUCN). Surveys and tracking studies in recent years indicate that the Northeast Water Polynya and the semi-permanent ice edge between the polynya and Île de France are important summer habitats for whales of this stock (Boertmann et al. 2009a, b, 2015, Boertmann & Nielsen 2010, Lydersen et al. 2012).

The Northern right whale is very rare (total population: a few hundred individuals) and the global red list status is ‘critically endangered’. A few individuals occur in summer in offshore waters between Southeast Greenland and Iceland (Mellinger et al. 2011), and no protection areas can be designated due to lack of data.

Walrus occurs in the seismic season in Northwest and Northeast Greenland. Walruses are dependent on localised, shallow (< 100 m) banks, where they feed on bivalves and where many individuals assemble. During winter (outside the seismic season), walruses assemble in the shallow parts of Store Hellefiskebanke off central West Greenland and in polynyas off northwest and northeast Greenland. Whales and seals are important for the Greenland subsistence hunt, and especially the summer hunt for narwhals in Melville Bay is at risk of being impacted by seismic surveys (Link to report on studies in 2012). The hunt for walrus, beluga and bowhead whale takes mainly place outside the season for seismic surveys.

More information on these species can be found in the strategic environmental impacts assessments of oil activities in the Greenland seas (Link).

7.2 Protection areas

7.2.1 Beluga (white) whale

There is only one area of concern for this whale (Figure 5), and the overlap period with seismic surveys is limited to October 1st to November 30th. 28

7.2.2 Narwhal

There are several closed areas in Northwest and East Greenland. They are all summer habitats, and the closed period is June 1st to September 30th (Figure 6).

Areas of concern include two periods October 1st to November 30th and June 1st to September 30th.

7.2.3 Bowhead whale

There are so far no closed areas related to bowhead whales, but there are extensive areas of concern and for two different periods: autumn (October 1st to November 30th) and summer (June 1st to September 30th) indicated (Figure 7). However, improved knowledge may give reason to designate closed areas in the future, especially in Northeast Greenland.

7.2.4 Walrus

There are extensive closed areas for walrus in Northeast Greenland, applying to the haul-out sites and the summer feeding grounds. Areas of concern are mainly located in Northeast Greenland (Figure 8), and the periods are October 1st to November 30th and June 1st to September 30th. 29

Figure 5. Area of concern for beluga/white whale in the period Oct. 1st to Nov. 30th. Does not apply to winter and spring. 30

Figure 6. Areas of concern and closed areas for narwhal. Autumn (Oct. 1st to Nov. 30th) and summer (Jun. 1st to Sep. 30th) indicated. Does not apply to winter and spring. 31

Figure 7. Areas of concern for bowhead whale. Autumn (Oct. 1st to Nov. 30th) and summer (Jun. 1st to Sep. 30th) indicated. Does not apply to winter and spring. 32

Figure 8. Areas of concern, protected areas and haul-out sites for walrus. Autumn (Oct. 1st to Nov. 30th) and summer (Jun. 1st to Sep. 30th) indicated. Does not apply to winter and spring. 33

8 Areas with commercial fishery

No regulation of seismic surveys is proposed in relation to fish and fishery, except for a general recommendation of contacting the fishing and hunting association and bringing a fishery liaison officer (FLO) on board when appropriate. However, maps of the most important fishery grounds are presented here to provide general information on potential areas of overlap with seismic surveys. The maps in Figures 8 and 9 show the areas where commercial fishery has taken place during the years 1999 to 2013 from boats larger than 30 foot. However, new fishing grounds may develop in the future and for instance pelagic fishery resources of particularly mackerel, but also herring, blue whiting and capelin are emerging in East Greenlandic waters.

Temporary effects on the fishery cannot be excluded if seismic surveys take place here in the fishing season, but so far, fishermen have not reported reduced catches in areas where also seismic surveys have been carried out.

Measures to protect spawning: Atlantic cod should be considered in the future, if the now depleted stock increases to the point where high concentrations again are found during the spawning season.

34

Figure 9. Map of trawling activity 1999 to 2013. Density of commercial trawl fishery recorded as tracks summed from 1999 to 2013. Benthic fishery displays the highest densities following particular subsea terrain characteristics such as depths limitations and bottom quality and as such is more intensive. Pelagic fisheries on mackerel in East Greenlandic waters and previously on pelagic redfish in the Southern Greenlandic waters cover larger areas extensively and consequently of less density. Source data from Greenland Fisheries Licence Control Authority, processed and analysed by Greenland Institute of Natural Resources. 35

Figure 10. Map of fishery with passive gears activity 1999-2013. Summed density of commercial fishery recorded as point positions summed from 1999 to 2013. The map primarily covers fishery by passive gears as long-lines, gillnets and traps on species such as Greenland halibut, snow crab, and lump sucker

from smaller vessels, but also some older trawling positions only recorded as single position points. Source data from Greenland Fisheries Licence Control Authority processed and analysed by Greenland Institute of Natural Resources. 36

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10 Appendix 1

Table 1. General survey data information needed Reply

Type of survey: 2D, 3D, VSP, other
Target depth during data collection, km (below seabed)
Map of the area with all seismic lines shown

Start and end dates for the survey
Expected continuous duration, days
Duty cycle of operation (in hours/24 hours).
Number and names of vessels towing airgun arrays
Number and types of accompanying vessels
Will survey be carried out in ice?
Intended use of icebreakers?

