Arctic Operations Handbook

Generic Framework for Environmental Assessments

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Contents

Summary

The Dutch offshore industry has the ambition to execute operations on a large scale in Arctic areas, for instance for installation and operation of oil- and gas production facilities and pipelines. Currently, there is no standard for safe operations by service companies in Arctic offshore areas. Therefore a Joint Industry Project (JIP) was started to carry out the necessary investigations to enable the formulation of guidelines for specific Dutch offshore contractors' skills, and to contribute to internationally accepted standards and guidelines for Arctic operations. One of the deliverables of the JIP is an environmental assessment pilot.

The aim of the pilot is:

1. The development of a generic framework for environmental assessments. This generic framework will be used to assess possible environmental impacts in which both the intensity of pressures and the vulnerability of ecosystem components is incorporated (Figure 1). In addition, interactions of ecosystem components will be considered in this framework.

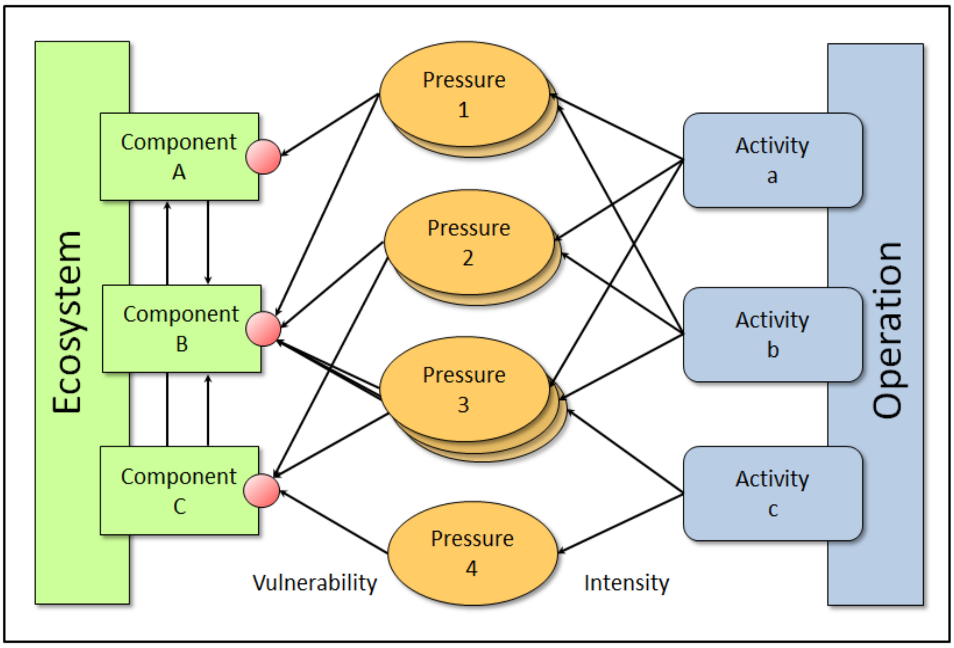

Figure 1 Cumulative effect assessment. The basic elements are Activities, Pressures and Ecosystem components. It is assumed that effects are a function of the intensity of pressures caused by activities and of the vulnerability of ecosystem components to those pressures. Adapted from Karman & Jongbloed (2008) [11], including interrelationships of the ecosystem components.

2. A case study in which the generic framework will be tested in order to evaluate its applicability and identify areas for further elaboration. Hereby the environmental impact of various trenching techniques will be determined in the Baffin Bay area.

This report describes the proposed generic framework for environmental assessments including a working procedure on how the framework should be used. The case study will be covered in another report.

During the development of a marine operation several project phases can be distinguished, each of them requiring a specific environmental assessment (Figure 2):

- During the **project preparation** it is important to gain insight in which ecosystem components are occurring in the area and if they might be influenced by the proposed activities. This is done in a **scoping assessment**, also known as a quick scan. During the scoping assessment it is qualitatively assessed which ecosystem-components are (potentially) affected by the proposed activities . Ecosystem components can be affected directly through the activity induced pressures, or affected indirectly through other ecosystem components.

- When **designing equipment** and/or during the operation preparation it is important to know the differences in ecological impact of the various scenarios, in order to be able to select the best option. This can be applied in a **prioritization assessment** in which a semi quantitative or quantitative assessment is performed to rank the expected effects, prioritize the areas for mitigation and identify potential mitigation measures. The prioritization phase provides information enabling decision making in an early stage of the project development and results in a scope definition for the next steps.

- **Baseline monitoring** is performed to access the actual population size/density of the ecosystem components prior to the execution of the proposed activities. The baseline monitoring is often done during the **operation preparation**.

- An **environmental impact assessment** (EIA) is required to obtain a **license to operate**. In an EIA the expected effects on (protected) ecosystem components are described, including potential mitigation measures. The EIA utilizes the information gathered during the previous steps.

- In general, a license to operate in a vulnerable ecosystem will only be issued with an obligation of **monitoring the effects** during and after the **execution of the operation**.

- Eventually, an **effect evaluation** is executed during the **project evaluation** where the results of the baseline and the effect monitoring are compared with the predictions in the EIA.

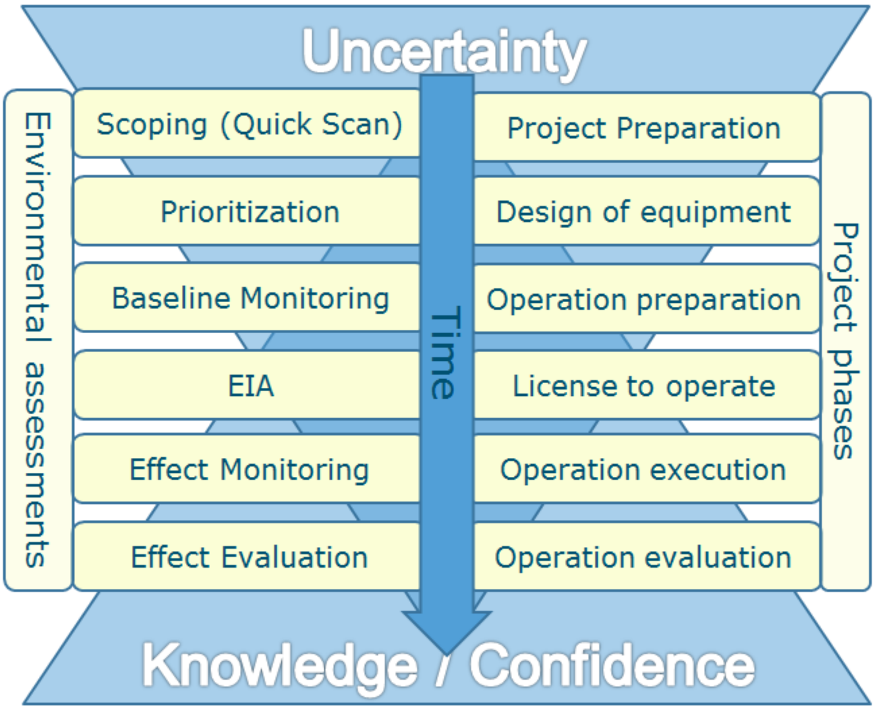

Figure 2: Environmental assessments per project phase.

This generic framework covers the environmental assessments during the first two project phases.

1. Scoping assessment

2. Prioritization assessment

For the current version of the generic framework the following gaps have been identified:

- Description of the phases: *baseline monitoring*, *EIA*, *effect monitoring* & *effect evaluation*
- Sensitivity & uncertainty analysis
- Species interactions in a semi quantitative assessment
- Natural variability of (marine) ecosystems
- Building with nature principles
- Description of the roles and responsibilities of the different maritime actors (oil companies, ship builders & contractors) during the execution of the maritime operation.

These gaps will be addressed in the further development of the Generic Framework (but not within the scope of this JIP).

Introduction

The Dutch offshore industry has the ambition to execute operations on a large scale in Arctic areas, for instance for installation and operation of oil- and gas production facilities and pipelines. The term Arctic refers to areas on the northern hemisphere where ice, permafrost and low temperatures may influence offshore operations and field development.

Currently, there is no standard for safe operations by service companies in Arctic offshore areas. To support this industry and to ensure development of steps towards minimum environmental impact, it is proposed to develop guidance/standards for such operations, focused on dredging, trenching, pipe lay, facilities installation and decommissioning activities.

For operations in the Arctic several types of equipment can be used, each with its specific advantages and disadvantages, operational as well as environmental. For instance, an important environmental consideration is the effect of dust plumes created during dredging. For a number of operations it has been stated that dust plumes need to be limited but this gives too little guidance for the actual choice for the operation. In addition, noise emissions by vessels, ice breaking or (trenching or pile driving) equipment have become an environmental concern in standard oil & gas operations, as well as exhaust gas emission of dredging operations. These and other pressures resulting from offshore operations are issues of concern, especially in the vulnerable Arctic marine and terrestrial ecosystems.

The Arctic Operations Handbook Joint Industry Project aims to carry out the necessary investigations to enable the formulation of guidelines for specific Dutch offshore contractors' skills, and to contribute to internationally accepted standards and guidelines for Arctic operations. An environmental assessment pilot forms one of the deliverables of the JIP.

The aim of the pilot is:

1. The development of a generic framework for environmental assessments. This framework will be used to assess possible environmental impacts in which both the intensity of pressures and the vulnerability of ecosystem components is used. In addition, interactions of ecosystem components will be considered in this framework. This framework currently covers only the first two project phases of a marine operation; the project preparation and the design of equipment.

2. A case study in which the generic framework will be tested in order to evaluate its applicability and identify areas for further elaboration. Hereby the environmental impact of various trenching techniques will be determined in the Baffin Bay area.

This report describes the proposed generic framework for environmental assessments, including a working procedure on how the framework should be used during the first two phases of the project (Project preparation & Design of equipment).

The proposed methodology of the assessment is described in Chapter 1 and the application of the method is described in Chapter 2. The case study will be covered in another report.

This work is executed by Heerema Marine Contractors, IMARES & TNO, in close coordination with INTEC-Sea and Jolmar/Canatec.

1 Generic framework - methodology

This generic framework comprises the methodology of an environmental assessment and the way it should be used by industry. The actual model is described in this chapter, whereas the application of the model is described in Chapter 2. Abbreviations and definitions are given at page 59-61.

1.1 Background

A Strategic environmental assessment (SEA) addresses the environmental implications of decisions made above project level, at the strategic tier of policies and plans (Figure 3). As a higher order environmental assessment process, SEA occurs when alternative futures and options for development and conservation are still open. In principle, the benefits of early environmental thinking should cascade downward resulting in more informed, efficient, and focused project-level assessments and decisions Noble & Harriman, 2013 [72]. SEA ensures the consideration of environmental issues at the outset of the decision-making process and can detect potential environmental impacts at an early stage, before the projects are designed.

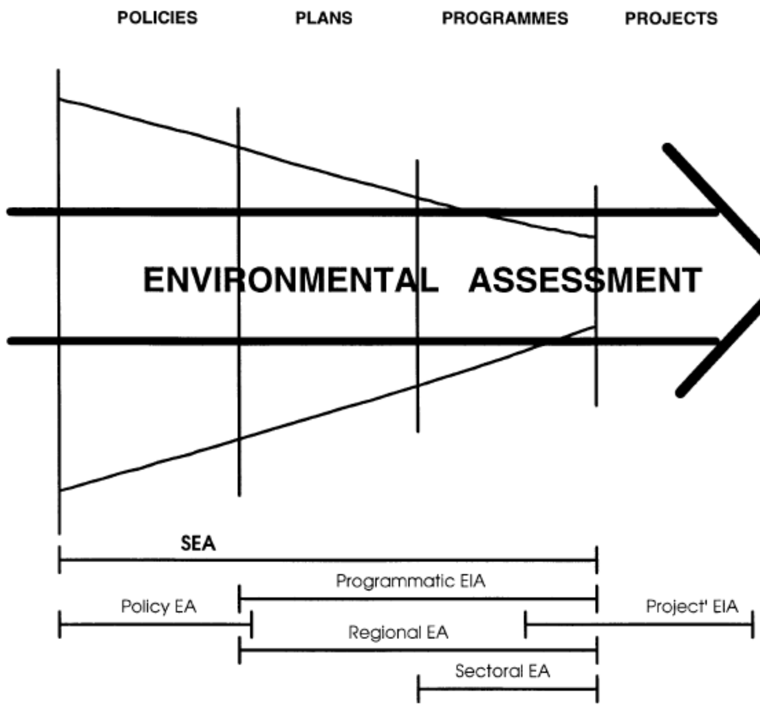

Figure 2: Focusing environmental assessment across sequential decision-making levels (Partidário & Clark, 2000 [73])

An Environmental impact assessment (EIA) is defined by the Arctic Environment Protection Strategy [2] as a process for identifying, predicting, evaluating, and mitigating the biophysical, social, and other relevant effects of proposed projects and physical activities prior to major decisions and commitments being made. The decision to apply an EIA and the requirements for that EIA depends on local jurisdictions. In the Arctic, EIA should be applied to activities associated with the exploitation of both renewable and non-renewable natural resources, public use, military activities and the development of infrastructure for different purposes that may cause significant environmental impacts [2].

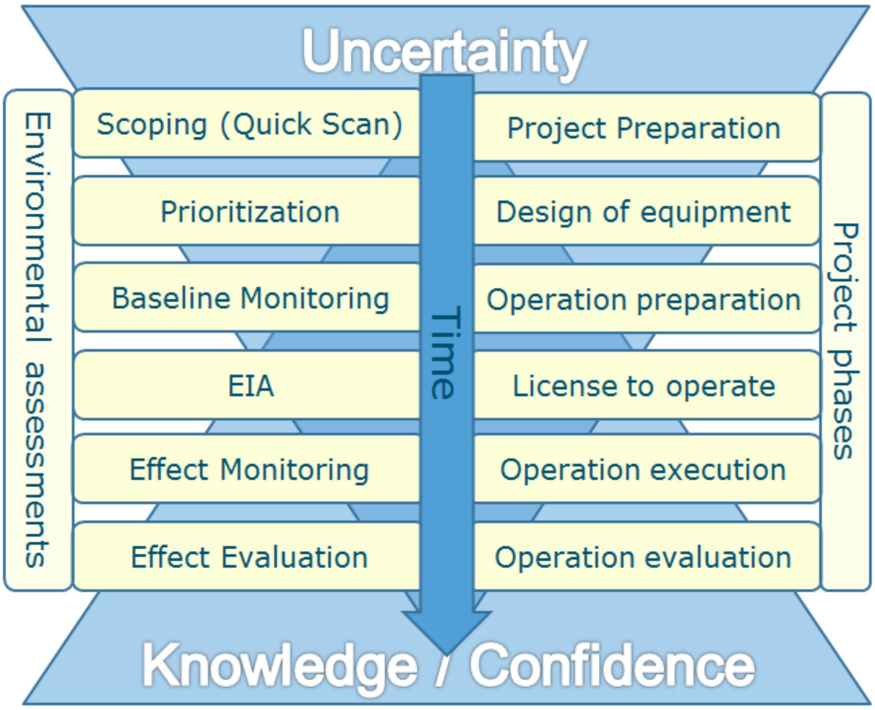

Figure 4: Environmental assessments per project phase.

Within this JIP, only the project EIA is considered. During the development of a marine operation several project phases can be distinguished, each of them requiring a specific environmental assessment (Figure 4):

- During the **project preparation** it is important to gain insight in which ecosystem components are occurring in the area and if they might be influenced by the proposed activities. This is done in a scoping assessment, also known as a quick scan.
- When **designing equipment** or during the operation preparation it is important to know the differences in ecological impact of the various scenarios, in order to be able to select the best option. This can be applied in a prioritization assessment.
- Baseline monitoring is performed to access the actual population size of the ecosystem components prior to the execution of the proposed activities. The baseline monitoring is often done during the **operation preparation**.
- An environmental impact assessment (EIA) is required to obtain a **license to operate**. In an EIA the expected effects on (protected) ecosystem components are described, including potential mitigation measures. The EIA utilizes the information gathered during the previous steps.
- Usually, a license to operate in a vulnerable ecosystem will only be issued with an obligation of monitoring the effects during and after the **execution of the operation**.
- Eventually, the results of the baseline and the effect monitoring can be assessed during the **project evaluation** and compared with the predictions in the EIA.

Currently, this generic framework covers the environmental assessments during the first two project phases:

1. Scoping assessment
2. Prioritization assessment

1.2 General outline model

This section provides a short overview of the basic approach to assess effects on the ecosystem that arise from human activities. The assessment needs to identify the possible effects of planned activities. In that sense, it is a predictive method, making use of a conceptual and/or computerised model. Assumptions and outcomes of the model could be tested in a field-monitoring programme that enables validation of the model.

The basic elements of the model are Activities, Pressures and Ecosystem components and is applied as a combination of the Cumulative Effect Assessment (CEA) and the Ecosystem Effect Chain (EEC).

The CEA assesses the actual impacts of various pressures on selected ecosystem components, which can be species and habitats, but could also include specific ecosystem services, processes or functions. The basic approach of the CEA is the assumption that effects are a function of the intensity of pressures caused by activities and of the vulnerability of ecosystem components to those pressures (Figure 5).

Most assessments only include pressures which have a negative effect on the ecosystem components, e.g. mortality or a lower reproduction rate. However, some pressures may also have a 'stimulative' effect. An increase in nutrients for example, resulting from the discharge of an effluent, may lead to a higher density of phytoplankton. In this study we will consider 'negative' as well as 'stimulative' effects of pressures.

The ecosystem effect chain (EEC) approach explicitly includes interactions between populations and ecosystem components, and may therefore also reveal indirect impacts of the (direct) effects of human activities. Examples of those ecosystem interrelationships are predator-prey interactions, cannibalism, competition, mutualism etc. (section 3.1.9). The EEC requires detailed ecological knowledge on the nature of the interactions, and how these are to be quantified. Since we will combine the CEA methodology with the EEC in this study, we will therefore consider not only the effect of pressures on the ecosystem components, but also the interrelationships of the ecosystem components (Figure 5).

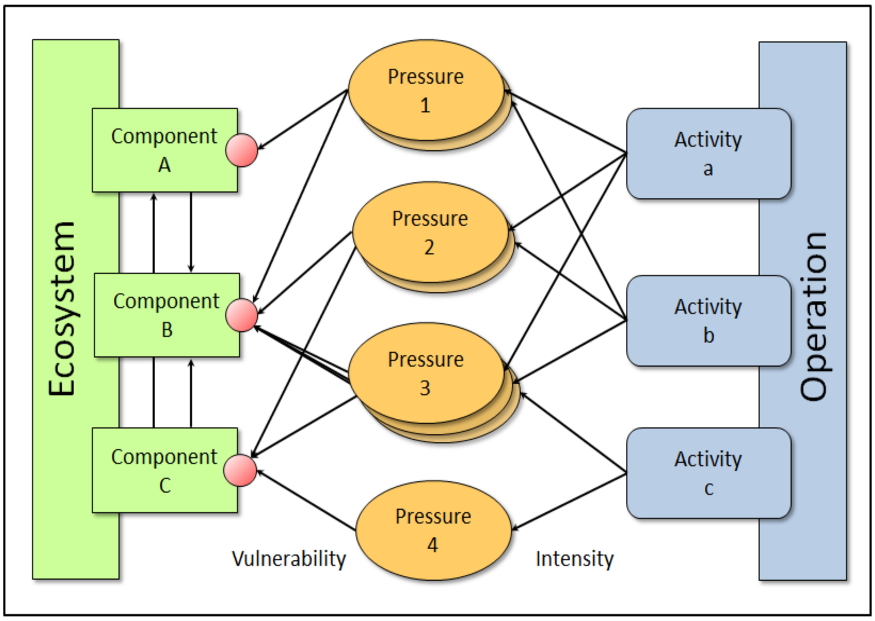

Figure 5: Cumulative effect assessment, adapted from Karman & Jongbloed, 2008 [11], including interrelationships of the ecosystem components

Although basic elements of CEA, i.e. activities – pressures – ecosystem components can be identified and related to each other, it does not show elements of space and time, which are the dimensions in which effects can cumulate (MacDonald, 2000 [12]).

1.3 Temporal aspects

Activities, pressures and ecosystem components often have temporal properties, and may therefore have an influence on the duration of the effects, and as a consequence also on the size of the effects on the ecosystem. Activities are usually time-bound, i.e. they take place in a specific period of the year, or last for a certain period of time. Also the intensities of pressures show fluctuations and the natural population size of ecosystem components may vary considerably over time (population dynamics).

As a first step, a potential impact assessment can be done in which the element of time can be disregarded by assuming all elements are present at the same time. This can be considered as a worst case, conservative approach. Depending on the available information and the goal of the assessment, temporal distribution can be implemented, e.g. by including seasonal differences in both the elements and their linkages. This allows for an assessment of the actual temporal confined impact.

To include temporal differentiation, a suitable time-scale has to be selected, e.g. based on ecological conditions and relevant for the activities to consider. For year-round activities, differentiation based on seasons may be relevant, while activities with short duration may only focus on the relevant ecological aspects during the activity, e.g. breeding season for birds, or growing season for phytoplankton. In high latitude areas, the growing season is very short in comparison to the temperate region. So, the highest biological activity, like primary production of algae and plants, takes place in a short summer season. The release of nutrients that enhance the growth of algae and plants, or the decrease of the transparency in the water column that reduces the growth potential of algae, will have their highest impact during the growing season. It may therefore be relevant to consider different seasons in the assessment. Another example is the presence of marine mammals. Whales usually have migration routes and are therefore only present during a specific time of the year. So, impacts may only arise when an activity takes place at the same time that marine mammals are in the area.

The factor time adds more complexity to the model when population dynamics are considered in the assessment. Time is an important property when considering the response of ecosystem components to disturbances (pressures). Response times may be seconds but can also be years. In addition, a disturbance could lead to a dynamic response of the ecosystem. In dynamic systems the fluctuations may extinguish, stay the same or even increase in time.

Temporal aspects are not only relevant within the timeframe of the proposed activities. Also future and past events are important, especially for the Arctic environment where human activities are historically scarce but now faces major developments.

1.4 Spatial aspects

In addition to temporal aspects, the activities, pressures and ecosystem components are furthermore limited to their spatial characteristics, i.e. they are bound to a limited area of the total environment. The intensity of pressures, like the concentration of a toxic compound, or the level of noise, is in general high near the actual activity and decreases with the distance. Spatial patterns are often also present in the density of ecosystem components, e.g. the distribution of a species is not homogeneous, but usually patchy.

A simple approach to include spatial dimension in a CEA is described by Halpern et al., 2008 [13, 14]. They mapped the intensity of pressures in geographic cells and included whether or not a specific ecosystem was present (0 or 1). Stelzenmüller et al., 2010 [15] follows a similar approach. Instead of using this binary ‘yes’ or ‘no’ approach, a more quantitative approach is also possible. The assessment could also include the probability of pressures and ecosystem components being present, as implemented by Zacharias & Gregr, 2005 [16].

The spatial delimitation of the study area is often difficult to establish. Whereas activities may take place on well-defined locations, their impact can stretch to a wider area as a result of the distribution of pressures and the spreading of the affected ecological components. For instance, particles may be distributed far off the actual location of the activity and accumulated toxic substances in organisms may have their (postponed) effect during reproduction, that may take place distant from the activity. However, usually the spatial dimension to assess the (combined) pressure of human activities, can be included by the use of GIS maps that show the location of activities and their pressures, and the (spatial) distribution of ecosystem components. These GIS maps can be produced for different seasons in case temporal aspects are relevant to incorporate in the assessment as well.

1.5 Level of detail

The previously presented methodology (CEA plus EEC) can be applied at three levels of detail:

1. Qualitative
   A qualitative assessment provides the answer whether an activity has a (potential) effect on an ecosystem component. The result of a qualitative assessment is an ecosystem components impact matrix (Table 1). Note that ecosystem components can be species and habitats, but could also include specific ecosystem services, processes or functions.

   The qualitative assessment is performed during the scoping phase often based on expert judgement, and applied as a first screening of relevant effects to consider in subsequent research.

   Table 1: Example of a qualitative effect matrix. In this matrix the effect on each ecosystem component (species or habitat) is indicated for each activity. A decrease of the ecosystem component is indicated in red, an increase is indicated in green. Effects are indicated by Yes (certainly an effect), ? (possibly an effect) or No (certainly no effect).

Qualitative Effect Matrix		Ecosystem Components						
		Phytoplankton	Zooplankton	Bowhead Whale	Arctic Cod	Walrus	Polar Bear	Sea Ice
Activities	Trenching	Yes	Yes	Yes	Yes	Yes	?	No
	Pipe Lay	No	No	?	No	No	No	No
	Backfill Material	Yes	Yes	Yes	Yes	?	?	No
	Seismic Research	No	No	Yes	Yes	Yes	?	No
	Presence Platform	No	No	Yes	Yes	?	?	No

2. Semi quantitative
   A semi quantitative assessment differs from the qualitative assessment by the categorical effect scores, indicating a relative magnitude of the impact (Table 2). A semi quantitative assessment is usually the most efficient approach to compare the environmental impact of different scenarios and therefore is often applied in the prioritization assessment.

Table 2: Example of a semi quantitative effect matrix. A decrease of an ecosystem component (species or habitat) is indicated in red, an increase is indicated in green. In this example a five point scale (--, -, -/+, +, ++) is used, indicating the relative magnitude of the impact. A possible effect is indicated by ? and no effect is indicated by 0.

Semi-quantitative effect matrix		Ecosystem Components						
		Phytoplankton	Zooplankton	Bowhead Whale	Arctic Cod	Walrus	Polar Bear	Sea Ice
Activities	Trenching	-	- / +	+	-	+	?	0
	Pipe Lay	0	0	?	0	0	0	0
	Backfill Material	-	-	-	-	?	?	0
	Seismic Research	0	0	+ +	+	- / +	- -	0
	Presence Platform	0	0	- -	+	?	?	0

3. <u>Quantitative</u>
A quantitative assessment determines the actual effect on the ecosystem components. The effect scores refer to the actual number/density of a certain species or the amount of habitat in the study area (Table 3). A quantitative assessment can be used during the prioritization assessment if a higher level of detail is required.

Table 3: Example of a quantitative effect matrix. A decrease in number/density of an ecosystem component is indicated in red, an increase is indicated in green. No effect is indicated by 0.

Quantitative Effect Matrix		Ecosystem Components						
		Phytoplankton	Zooplankton	Bowhead Whale	Arctic Cod	Walrus	Polar Bear	Sea Ice
Activities	Trenching	- 5%	- 5%	-1	- 1%	- 10%	- 2	0
	Pipe Lay	0	0	-0,1	0	0	0	0
	Backfill Material	- 2%	- 1%	-0,2	- 0,5%	-1%	- 1	0
	Seismic Research	0	0	-4	- 4%	-3%	-0,1	0
	Presence Platform	0	0	-0,1	+5%	+ 3%	+ 1	0

1.6 Sensitivity & uncertainty analysis

The aim of an uncertainty analysis is to identify and where possible to quantify the uncertainty in the assessment. A sensitivity analysis evaluates the effects of uncertainty in the input parameters and the computational algorithm on the output of the assessment.

A sensitivity and uncertainty analysis can be used to provide insight in the working of the methodology and test the robustness of the assessment with regard to its assumptions and formulated dose-response relationships.

It is outside the scope of this study to include a sensitivity and uncertainty analysis. However, it is relevant for each step in the assessment to clearly document the assumptions, the origin and the quality of the information used, and which knowledge or information is lacking that could improve the assessment.

There is usually a perception that uncertainties only arise in quantitative information, but uncertainties are of many kinds, including from political sources, to model output information. Unfortunately, there is no agreed terminology to refer to certain types of uncertainty, and in fact many typologies exist. In relation to model-based decision support three dimensions of uncertainty have been distinguished by Walker, 2003 [17]:

- Location of uncertainty
- Level of uncertainty
- Nature of uncertainty

The **location** of uncertainty refers to where the uncertainty manifests within the model complex. This type of uncertainty relates to uncertainties on the context, the model, and the inputs.
The context is an identification of the boundaries of the system to be modelled; how much of 'the real world' is included in the model? Within the scoping phase of the assessment, these boundaries need to be described. This could be e.g. the geographic boundaries, the part of the ecosystem that will be considered, the level of complexity of the ecosystem that will be considered etc..
Another uncertainty that is part of the 'location', is uncertainty of the conceptual model. For example, the dose-effect relationships are based on certain assumptions with regard to the shape, direction and nature of the response of the ecosystem component. This includes a.o. the translation from effects on behaviour to effects on the population level. In addition, the technical set-up of the model in a computer implementation may create uncertainties.
A third type of location refers to the data (inputs) that are associated to the reference system. Not only the activities that are considered have an impact on the outcome of the assessment, but also external (natural) forces do, like climate change. So, part of the inputs can be controlled by the way an activity is performed, but part of it cannot be controlled.

The **level** of uncertainty refers to the spectrum of knowledge. Optimally, the model is based fully on knowledge and information, but sometimes we have to admit that we hardly know anything about even crucial relationships. The level of uncertainty includes the statistical uncertainty, the type of uncertainty that is most commonly referred to in natural sciences. What is the deviation from the true value? This type of uncertainty is often quantifiable, and can be part of a sensitivity analysis.

Another type of uncertainty related to the level is scenario uncertainty. In this case, the mechanisms that leads to the outcomes are not well understood, and this makes it hard to formulate how 'true' the (model) outcome of the assessment is. Within the assessment, assumptions made on the dose-response relationships can be considered as an example. By changing assumptions of the model, a sensitivity analysis can be conducted to gain more insight in the quantitative consequences of this type of uncertainty.

A third type of uncertainty related to the level is what is called recognised ignorance, i.e. the fundamental uncertainty about the mechanisms and functional relationships being studied. In this case, we have little or no knowledge about the functional relationships and statistical properties and the scientific basis for developing scenarios.

The **nature** of uncertainty indicates whether the uncertainty is due to the imperfection of our knowledge or to the inherent variability of the phenomena being described.
If the uncertainty is knowledge related, the uncertainty can be reduced by more research and empirical effort. In case of variability uncertainty, more knowledge will not help to reduce the uncertainty. This type of uncertainty could be e.g. processes that relate to political willingness and external 'random' forces.

2 Generic framework - application

A stepwise approach (Therivel & Ross, 2007 [18], van der Walt, 2005 [19] is proposed for the elaboration of an environmental assessment in the Arctic, analogous to the development project of a marine operation (Figure 4):

1. Scoping phase: a qualitative assessment identifying which ecosystem-components are (potentially) affected by the proposed activities. Ecosystem components can be affected directly through the activity induced pressures, or indirectly through other affected ecosystem components. The qualitative assessment results in a scope definition for the next step.
2. Prioritization phase: a semi quantitative or quantitative assessment in order to rank the expected effects, prioritize the areas for mitigation and identify potential mitigation measures. The prioritization phase provides information enabling decision making in an early stage of the project development and results in a scope definition for the baseline monitoring and the EIA.
3. Baseline monitoring: one or more surveys to determine the baseline situation, such as population size of ecosystem components and other relevant indicators, prior to the execution of the proposed activities.
4. EIA phase: prediction of the (main) effects of the proposed activities as quantitative as possible.
5. Effect monitoring: surveys of the actual situation, such as population size of ecosystem components and other relevant indicators, during and after the implementation of the activities, based on a monitoring plan.
6. Effect Evaluation: a comparison between the results of the effect monitoring and the predictions of the EIA.

2.1 Phase 1: scoping

A qualitative assessment is used to determine the scope required for an assessment. During this phase it is qualitatively assessed whether ecosystem-components are (potentially) affected by the activity induced pressures and/or by interactions with other ecosystem components. The qualitative assessment results in a scope definition for the subsequent phases.

Figure 6 shows the steps which are carried out during this phase. Each step is described in the next sections.

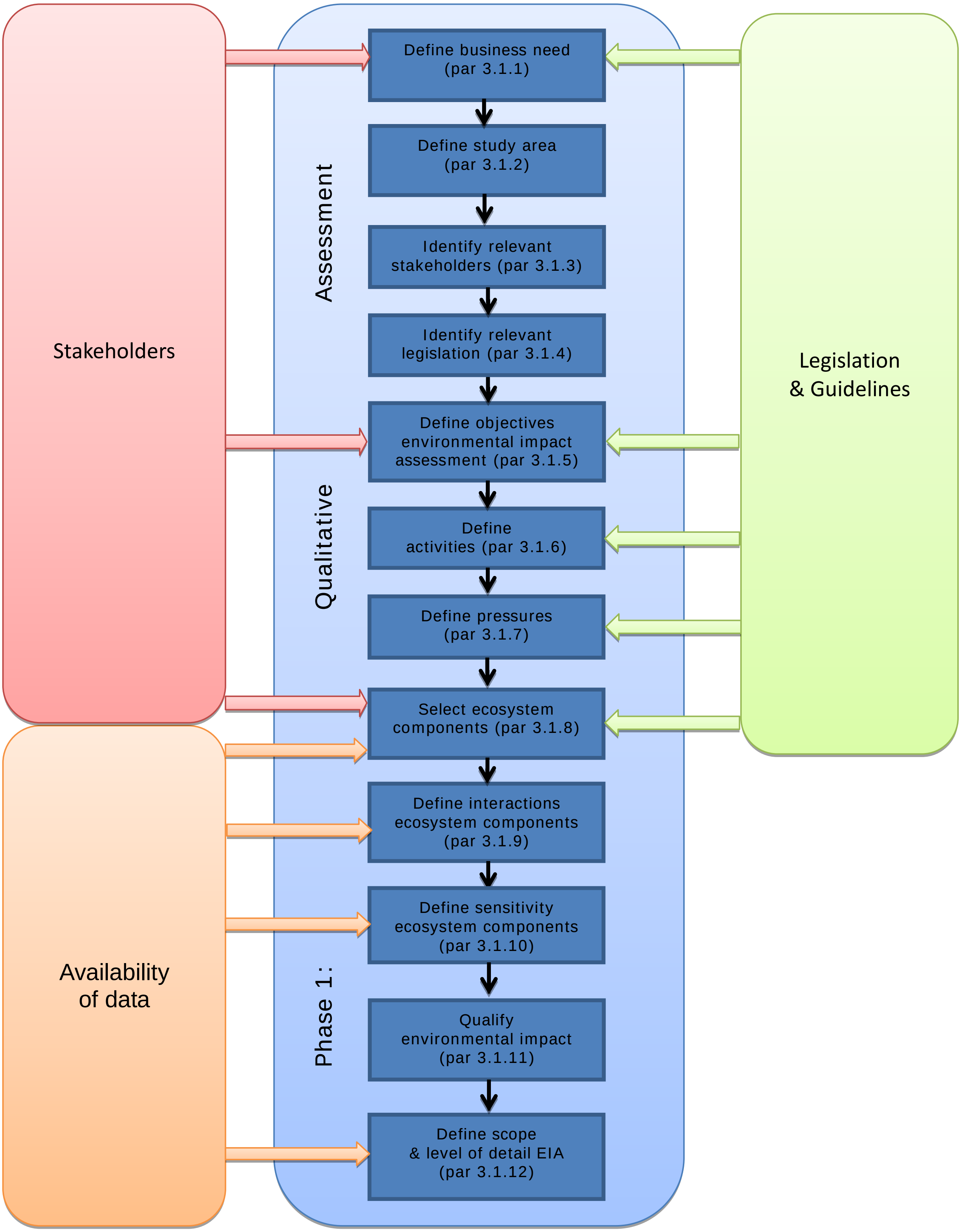

Figure 6: Phase 1; the 12 necessary steps that should be taken during a qualitative assessment. Note the steps which may be influenced by stakeholders, legislation and/or the availability of data.

2.1.1 Define business need/issue

A wide variety of business needs can trigger an environmental assessment. Typical examples are:

- *New business and spatial developments*; oil & gas drilling, trenching & pipe-lay operations, mining, new shipping routes, offshore wind farms etc.
- *Environmental policy*; wish for reduction of ecological footprint by choosing the least polluting alternative during the selection of operational activities or the development of new equipment.
- *Environmental regulations*; reassessment of existing activities to make sure they still comply with current or future legislation.
- *Stakeholders requirements*; public debate leading to new socially accepted environmental impact standards.

It is important to make a detailed description of the business need in order to align the objectives of the assessment. It needs to be perfectly clear ***what*** must be achieved to fulfil the business need.

2.1.2 Define study area

The study area is the location where the operational activities are executed. The definition of the study area contains two steps: describing the geographical and physical parameters. Information on the geographical and physical parameters can be obtained from the contractor, who usually has conducted a site survey at sea that contains an investigation of sediment conditions, bathymetry and corals (Hasle, 2009 [20]). The information should include:

Geographical information

- Country
- Area/location
- Coordinates
- Daylight length in relation to season

Physical information

Depending on the location on land or at sea the following information is needed to describe the study area:

Terrestrial study area

- Meteorology
- Topography: height, presence of water etc.
- Soil type, presence and depth of permafrost
- Vegetation: description of the vegetation types in the area
- Snow cover: seasonal pattern

Marine study area

- Meteorology
- Oceanography: water depth, currents, tides, seabed, sediment type and topography
- Sea ice and icebergs: seasonal pattern of ice coverage as well as presence of open water

2.1.3 Identify stakeholders

The Arctic is culturally and socio-economically a non-uniform and complex area. Stakeholders can be important during the assessment process in order to manage potential conflicts and create possible synergies. In addition, stakeholder involvement is essential and often mandatory. Conflicts and synergies often can arise where species, habitats or resources in the designated area of an activity are of relevance to more than one stakeholder, which is the case in almost all projects.

There are multiple possibilities to communicate, with various forms of interaction. In some cases the preferred method is communication from individual to individual; in other cases it is individual-group or group-group interaction. Sometimes face-to-face meetings are necessary to prevent individuals or groups from influencing each other during the process. Depending on the objectives a variety of consultation techniques are available. Examples are telephone interviews, face-to-face interviews, group interviews, workshops, internet surveys etc.

Clearly such moments of interaction should be well prepared. What is the agenda? What are the items to deal with? At least the objectives of the assessment and the selection of ecosystem components should be listed. For more guidance on stakeholder interaction processes please check Guidemaps (2004) [21], Taschner & Fiedler (2009) [22] and Lange & Wiersema (in prep) [79].

2.1.3.1 What is a stakeholder?

A stakeholder is an individual or group with a specific interest (stake) in species, habitats or resources in the designated area of an activity. Four categories of stakeholders can be identified: governments, industries, civil society and research organisations (Taschner & Fiedler, 2009 [22]. A primary stakeholder is directly influenced (positively or negatively) by an activity. A key stakeholder is an individual or group with a strong power position and major influence (Taschner & Fiedler, 2009 [22]). Stakeholders act on various levels, sometimes also on several levels at the same time. Generally there are four levels in which stakeholders are active: international, national, regional and local.

Stakeholders can act solely or as a group. When acting as a group of stakeholders, formal or informal coalitions are established to achieve more by working together. Mostly these coalitions occur within a specific category, e.g. associations of oil companies or civil society coalitions. Some stakeholders deliberately choose not to act within coalitions because they prefer to not compromise their aims and results. Hybrids also occur, such as public-private coalitions between governments and industries. A rather new trend is the coalition between industries and civil society, sometimes combined with governments and research organisations. The Arctic Council is an example of such a coalition.

2.1.3.2 Identifying relevant stakeholders

Stakeholders can have an interest in an activity from different perspectives. To identify which stakeholders are relevant for possible involvement, it is necessary to use some simple selection criteria. In other words, what could be the stakeholders' argument to be involved? To identify relevant stakeholders, three questions can be used as a guidance (Guidemaps, 2004 [21]):

a. Which stakeholders are using resources in the area or vicinity of the activity and may be influenced by environmental effects?
b. Which stakeholders have a moral, religious or political interest in the activity and its environmental effects?
c. Which stakeholders are legally required to be involved in the process?

The individuals and groups that are selected by answering these questions can be used to determine if their involvement is required for the process.

Table 4: Overview of categories of stakeholders, including examples for these categories

Government	Industries	Civil society	Research
United Nations (UNCLOS)	Pipe lay, trenching	NGOs (Greenpeace, WWF)	Universities (University of Arctic)
European Union (27 members)	Dredging	Indigenous peoples (Inuit, Sami, Nenets)	Research institutes (Finnish Arctic Centre)
Administrations (5 states)	Oil & gas	Local communities (Barrow, Alaska)	Scientific foundations (Norwegian Polar Instute)
Ministries (Dutch I&M, Dutch BuZa)	Shipping & transport	Protest groups	
States & provinces (Alaska)	Hydro/tidal/wave/wind		
Municipalities (Murmansk)	Fisheries & aquaculture		
	Tourism		

In the Arctic, indigenous peoples such as the Inuit of North America and Greenland play a crucial role in new developments. The Arctic area is huge and contains an enormous diversity of peoples, cultures, practices and conditions (Figure 7). Indigenous peoples of the Arctic share many similarities, e.g. they (Helander-Renvall, 2005 [74]):

- are indigenous to their lands;
- have been subjected to overall colonial activities by the surrounding states, and national and multinational companies;
- possess knowledge that is now regarded as useful regarding the management of lands, waters, and natural resources (traditional knowledge), receiving attention from scientists, politicians, and administrators of sustainability and biodiversity;
- are dependent on their traditional environmental knowledge to properly manage the resource base of their regions;
- view themselves as having a historical existence and identity that is separate and independent of the states now enveloping them.

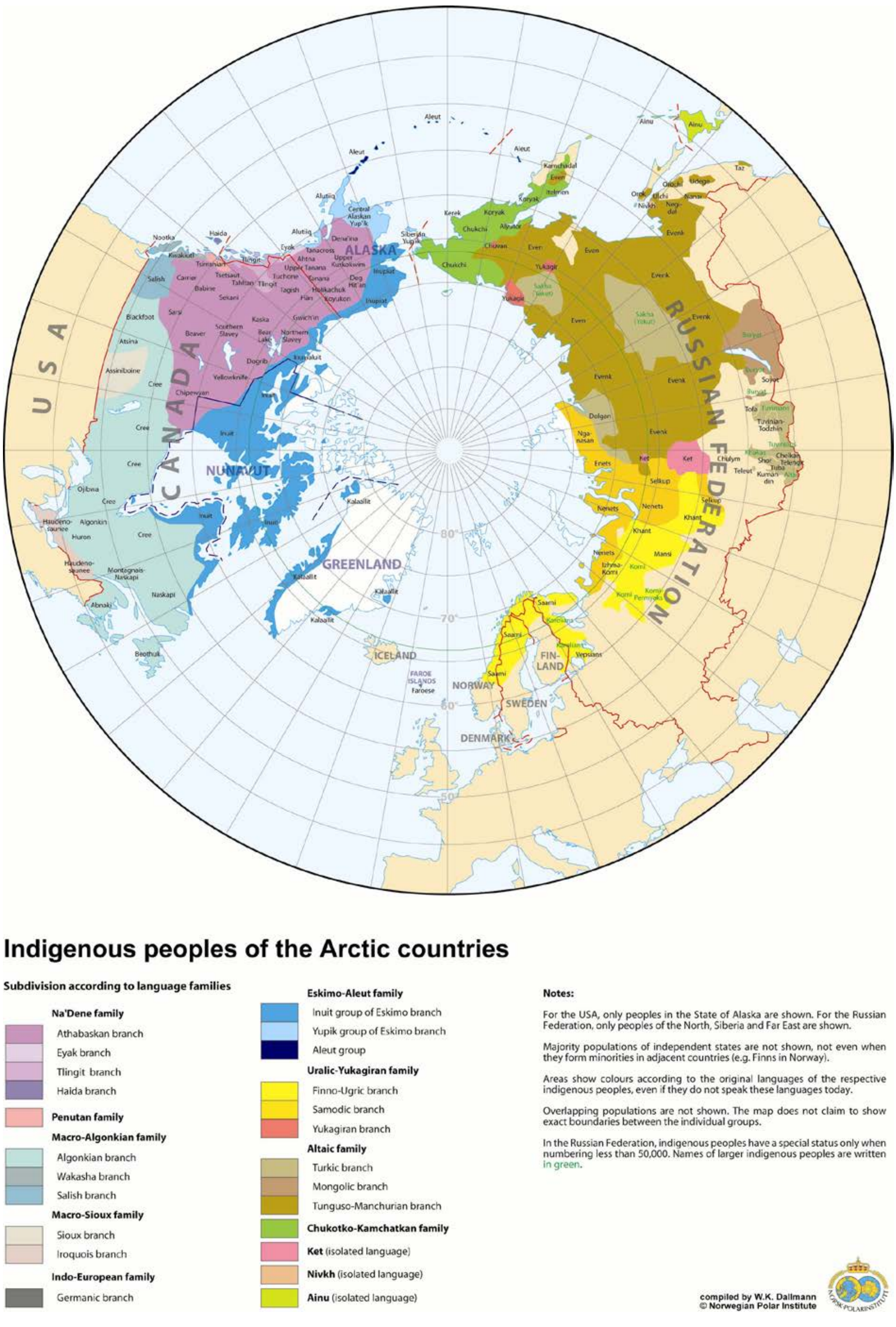

Figure 7 Indigenous peoples of the Arctic countries (http://ansipra.npolar.no/image/Arctic04E.jpg).

2.1.3.3 *Involving relevant stakeholders*

After identifying the relevant stakeholders, it is important to make clear who is going to be involved and why. Involving stakeholders into the process of the environmental assessment can be done for various reasons (Arctic Environment Protection Strategy, 1997 [2]):

- To provide a means for those who may be affected by the project by giving them the possibility to give input into the planning, assessment and monitoring of the project
- To inform people about the characteristics, location, and design of the proposed activity. People need information about a project to lessen anxiety and to plan accordingly.
- To determine the scope of the assessment. People who will be affected by an activity have a stake in identifying the important issues or concerns and alternatives to be analysed, and in setting the temporal boundaries of the environmental assessment.
- To acquire information. The individuals and communities affected are a primary source of information for the assessment. Local stakeholders can provide valuable knowledge on the existence of local species, habitats and resources.
- To establish mutually agreed rules and procedures for conducting public meetings and consultations to create ownership and legitimacy for decisions made during a environmental assessment project. Another reason is to build relations with individuals and groups and to provide the possibility to express their ideas and issues within the process of environmental assessment.

When getting into contact with stakeholders it is important to communicate what is expected and what their role and responsibility is during the process. It is also important to communicate what will be done with the input of stakeholders. In addition, stakeholders should know when they will be involved; in the initial stages, during and/or after the process?

As indigenous people play a crucial role in new developments, it is important to sufficiently involve them in these new developments. Full participation and responsibility in the decision-making process regarding the management of resources must be promoted (Helander-Renvall, 2005 [74]).

2.1.4 Identify relevant legislation & guidelines

This section firstly provides an overview of international requirements with respect to environmental assessments. It covers international decrees, conventions and agreements that provide basic guidelines on how to carry out an environmental assessment. Most of these regimes are not legally binding and do not involve sanctions when not complying to the rules. International regimes are implemented at a national level. Therefore the second section focuses on national legislation. In contrast with international rules, national legislation can be enforced by legal bodies such as the state, involving legally binding rules and possibly also sanctions if a project or an activity is not in compliance. It should be noted that this section does not aim to provide a complete legal framework to which Arctic operations should comply but only serves as an indication for legal requirements. Therefore, in this first phase of the assessment, it should be checked which legislation is in force within the study area. All requirements following the legislation should be addressed in the assessment.

2.1.4.1 International requirements

There is no legally binding guideline on how to perform an environmental assessment for the Arctic Region. However, several conventions apply to (a part of) the Arctic countries (see Table 5), requiring environmental assessments for specific (trans-boundary) activities planned to take place in the Exclusive Economic Zones.

On a global level, the United Nations Convention for the Law of the Sea (UNCLOS) is relevant. UNCLOS states[1] are required to conduct an assessment of the effects of activities taking place in their maritime jurisdiction on the marine environment located in the other states' jurisdiction as well as on areas beyond national jurisdiction (Molenaar & Koivurova, 2009 [24]), i.e. the high seas. OSPAR, ESPOO and London Convention (and protocols) are next in row using recommendations and agreements, but lacking the possibility of sanctioning; the UNCLOS acts as a backstop, having little enforcing power. OSPAR covers part of the Arctic region (Figure 8). The applicability of the Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention) and its SEA Protocol for the Arctic marine area is also limited. Some Arctic states are not parties to the Espoo Convention, the SEA Protocol has not yet entered into force, and some Arctic states have not even signed the SEA Protocol (Molenaar & Koivurova, 2009 [24]).

On the level of the Arctic region, the Arctic Council was established in 1996 by the eight Arctic countries. In 1997, Council developed "guidelines with the aim at giving practical guidance for environmental assessments to all parties involved in development activities in the northern circumpolar areas, but especially to local authorities, developers and local people"[2]. This guideline addresses the special conditions in the Arctic, including climate, socio-cultural conditions and the functioning of the ecosystems. According to the Arctic Environment Protection Strategy, the precautionary principle should be included in Arctic EIA. The precautionary principle, used by the Rio Declaration on Environment and Development, is as follows: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" [2]. Another recommendation is to also consider the impacts of other projects and developments in the EIA.

On a European level, the EIA Directive applies. The EU Directive originates from 1985, and has been amended three times since (d.d. 2011). The Directive was brought in line with the Espoo Convention, Aarhus Convention and to include projects including CO2 handling [23]; "The EU EIA procedure can be summarized as follows: the developer may request the competent authority to say what should be covered by the EIA information to be provided by the developer (scoping stage); the developer must provide information on the environmental impact (EIA report – Annex IV); the environmental authorities and the public (and affected Member States) must be informed and consulted; the competent authority

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[1] The U.S.A. has not ratified UNCLOS

decides, taken into consideration the results of consultations. The public is informed of the decision afterwards and can challenge the decision before the courts". The Annex IV lists the information to be included in an EIA, in summary:

1. a description of the project,
2. an outline of the main alternatives,
3. a description of the aspects of the environment, more specifically: "A description of the aspects of the environment likely to be significantly affected by the proposed project, including, in particular, population, fauna, flora, soil, water, air, climatic factors, material assets, including the architectural and archaeological heritage, landscape and the interrelationship between the above factors." The Directive does not give guidance on how to assess the likely effects.
4. a description of the likely significant effects,
5. the description of the forecasting methods used to assess the effects on the environment,
6. a description of the envisaged 'mitigating' measures,
7. a non-technical summary of the information listed above,
8. an indication of any difficulties (technical deficiencies or lack of know-how) in compiling the required information.

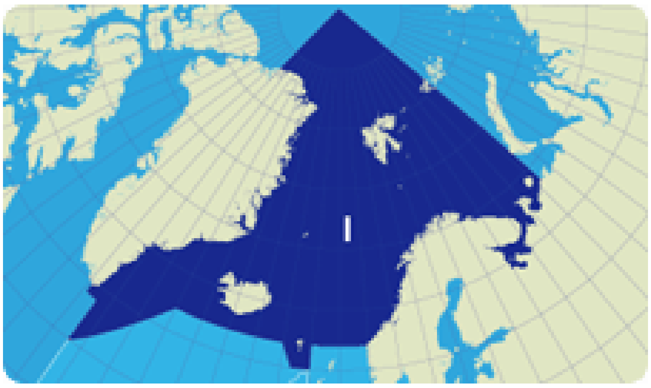

Figure 8 OSPAR Region I - Arctic Waters (http://www.ospar.org/)

The strength of regulation of activities in the marine environment is dependent on the enforcing power of those regulations dealing with the activity. An overview of the strength of regulation is presented in Appendix B. The majority of the relevant activities that may take place in the maritime area are covered by international regulation (Karman & Jongbloed, 2008 [11]). Only 4 of 30 activities are not covered by any of these international regulations (desalination plants, extensive mariculture, atmospheric deposition and land based inputs). Although it is difficult to identify measures to reduce diffuse inputs (i.e. atmospheric deposition and land based inputs) from the perspective of the management of the sea; the presence of these inputs might affect the capability of the ecosystem to deal with additional inputs from activities in the maritime area (i.e., reducing the carrying capacity).

It must be noted that for regulation under some of the mentioned international regulatory instruments, screening mechanisms may apply so that in practice plans, programmes and projects can be authorised without undergoing an SEA/EIA. For CEA the inclusion of many smaller activities might be as relevant as the inclusion of one larger activity and thus these size limits should not be used to exclude activities from the assessment.

Table 5: Overview of countries participating in various international conventions

Arctic States	UNCLOS	OSPAR	Espoo Convention	SEA Protocol	Arctic Council	EIA Directive (EU)
Iceland	+	+	-		+	+
Russian Federation	+		-		+	
Unites States of America			-		+	
Canada	+		+		+	
Norway	+	+	+	+	+	
Finland	+	+	+	+	+	+
Denmark (Greenland)	+	+	+	-	+	+
Sweden	+	+	+	+	+	+

- signed
+ participant

The way in which an EIA should be performed is thus the responsibility of national states. Therefore, the existing national requirements based on national legislation is described in the next section.

2.1.4.2 National requirements

Below a short overview is presented of relevant legislation on species, habitats and pollution in Norway, Canada, Greenland (Denmark), the United States of America and the Russian Federation. This overview aims to be a short guide to select relevant ecosystem components from legislation and to ensure compliance with national laws and regulations. It is not the intention to provide full lists of protected species and habitats. It is however the intention to indicate which legislation can be relevant when elaborating an environmental assessment in these countries. It is assumed that those countries who signed and ratified international conventions (see previous section) and treaties have implemented them on a national level. Therefore most descriptions apply to legally binding national acts. As a consequence, this section does not include international non-binding guidelines and decrees. The overview tries to be as complete as possible, however it might be that some acts have been missed due to lack of access to information or to language difficulties. Most legislation applies to offshore and near shore activities, while some legislation also applies to onshore activities. Access to the full texts of the acts and laws can be entered via the links in the list of references.

Norway

In Norway four regimes are relevant for environmental assessments. One of them is international, three of them are national regimes. The Bern Convention (Convention on the conservation of European wildlife and natural habitats), signed by Norway, aims to protect wild flora and fauna species, including their habitats. Endangered species are given extra attention. The Convention includes appendices in which species are specified [25]. The Nature Diversity Act of Norway protects biological, geological and landscape diversity and ecological processes through conservation and sustainable use [26]. The Norwegian Wildlife Act of 1981 protects all mammals, birds, reptiles and amphibians and their eggs, nests and lairs, unless otherwise specified [27]. The last act concerns the prevention of pollution. Act no. 6 of 1981 aims to protect the outdoor environment against pollution and to reduce existing pollution. In addition, the quantity of waste should be reduced including a better waste management. The scope of this act is rather broad; pollution is regarded as the introduction of solids, liquids or gases to air, water or ground. It also includes noise and vibrations, light, other radiations and temperature [28].

Canada

The environmental protection regimes of Canada can be divided into two categories; environmental enforcement and wildlife enforcement. The environmental enforcement category includes:

- The Environmental Enforcement Act (EEA) deals with the compliance, violations and sanctions of ten other sub-acts. Six of these acts are administered by Environment Canada and three of them by Parks Canada [29].
- The Canadian Environmental Protection Act prevents pollution and protects environment and human health. It prevents and manages risks posed by toxic and other harmful substances. The act covers, among others, marine pollution, disposal at sea, vehicle, engine and equipment emissions, fuels, hazardous wastes and environmental emergencies [30].
- The Pollution Prevention Provisions of the Fisheries Act deals with the deposit of deleterious substances such as oil into waters frequented by fish [31]. The federal Fisheries Act also protects fish and fish habitat by the fish habitat protection provisions.
- Habitat Management within Fisheries and Oceans Canada's (DFO) Central and Arctic Region are involved in the review of impacts to fish habitat which may result from works and undertakings in or near water. Additionally, DFO monitors for compliance and, if necessary, enforces the fish habitat protection provisions of the Fisheries Act.

The second category of wildlife enforcement covers the following acts:

- The Migratory Birds Convention Act from 1994 ensures the conservation of migratory bird populations by regulating potentially harmful human activities. All activities affecting migratory birds involve a permit, unless stated otherwise [32].
- The Canada Wildlife Act creates, manages and protects wildlife areas for research, conservation or interpretation of wildlife. Those habitats critical to migratory birds and other wildlife are preserved under the act, with special reference to those at risk. Activities that are potentially harmful to species and habitats are prohibited, unless a permit is issued [33].
- WAPPRIITA is an act on wild animal and plant protection. It also regulates, among others, the introduction of alien species into Canadian territories [34].
- The Species at Risk Act (SARA) aims to prevent wildlife species from disappearing and provide for the recovery of wildlife species that no longer exist. It also focuses on the endangered and threatened wildlife as the result of human activities, and the prevention of wildlife to become endangered and threatened [35].

Considering environmental assessment the Canadian government has put the Canadian Environmental Assessment Act, 2012 [78]. The CEAA and its regulations establish the legislative basis for the federal environmental assessment process. Regulations define a.o. the types of projects automatically subject to CEAA 2012 and the information to be provided in project descriptions.

Greenland (Denmark)

Since 2009 Greenland has self-government. This implies that Greenland has authority over resources in its subsoil. However, legislation on species, habitats and pollution are in fact a hybrid of Greenlandic and Danish acts. The Greenland Parliament Act on Mineral Resources aims to ensure appropriate exploitation and activities related to mineral resources and the use of subsoil. The act provides the rules for exploration and exploitation of mineral and hydrocarbon resources, including licensing procedures. It also contains rules for environmental protection, pollution and EIA's [36]. The Marine Environment Act from Denmark applies to Greenland since 2004. The act contributes to the safeguarding of nature and environment and the protection of flora and fauna. It also aims at preventing and reducing solid, liquid, gaseous or other pollution from ships, aircrafts, floating and fixed platforms, ports and harbours [37]. The Executive Order on Conservation of Birds deals primarily with hunting licenses. However, it also introduces Bird Protection Areas, specifying a period in the year in which certain areas may not be approached within a certain distance [38]. Greenland also has a nature preservation act. It aims to protect biodiversity, including species, habitats and ecosystems. The act does not mention specific rules for specific flora and fauna; it only provides the authority to certain departments of the government of Greenland [39].

United States of America

The USA has some 11 acts on protecting marine environments, species and habitats. Six of these acts deal with pollution, five with species and habitats. The acts on pollution include:

- The Federal Water Pollution Control Act or the Clean Water Act regulates discharges of pollutants into the waters of the USA. It also regulates standards for surface waters [40].
- The Clean Air Act regulates air emissions from stationary and mobile sources. The law authorizes EPA to establish National Ambient Air Quality Standards [41].
- The Toxic Substances Control Act involves restrictions relating to chemical substances and/or mixtures [42].
- The Oil and Gas Extraction Act focuses on synthetic-based drilling fluids. It provides limitations guidelines and standards for the discharge of synthetic-based drilling fluids [43].
- The Marine Protection, Research and Sanctuaries Act is also known as the Ocean Dumping Act. It prohibits the dumping of materials into the ocean that would degrade human health or the marine environment. Dredging is of specific importance in this act, since most dumped materials relate to this activity. Permits for dredging must be applied for under this act [44].
- The Resource Conservation and Recovery Act controls hazardous waste. It includes generation, transportation, treatment, storage, and disposal of hazardous waste [45].

The acts on species and habitats are the following:

- The National Environmental Policy Act establishes national environmental policy and goals for the protection, maintenance, and enhancement of the environment and provides a process for implementing these goals within the federal agencies. Under the act, the Council on Environmental Quality has been established EPA [46].
- The Endangered Species Act is a program for the conservation of threatened and endangered plants and animals and the habitats in which they are found. The Fish and Wildlife Service maintains a worldwide list of endangered species, including birds, fish, reptiles, mammals and crustaceans [47].
- The Marine Mammal Protection Act protects all marine mammals in US coastal and territorial waters. The act prohibits “the take” of marine mammals. Exceptions can be made, e.g. for indigenous peoples [48].
- The Migratory Bird Treaty Act implements various treaties and conventions between the U.S. and other nations for the protection of migratory birds. Taking, killing or processing migratory birds is prohibited [49].
- The Fish and Wildlife Coordination Act protects fish and wildlife that might be impacted as a result of federal projects that modify natural streams or bodies of water. The Fish and Wildlife Service evaluates these impacts [50].

Russian Federation

The Federal Law on Environmental Protection was approved in 2001. It defines the legal framework for environmental protection, biological biodiversity and natural resources in balance with socio-economic developments. It applies to the continental shelf and the exclusive economic zone of the Russian Federation. Article 34 mentions that construction, commissioning, operation of installations and facilities that directly or indirectly negatively impact the surrounding environment shall be performed within the environmental protection requirements. In addition, measures should be taken to protect and restore the environment, natural resources shall be used and recovered in a sound and consistent way in order to ensure environmental safety [51]. The Federal Law on Atmospheric Air Protection specifies the legal framework for atmospheric air protection, the application of the constitutional rights of citizens for a favourable environment and the provision of reliable information about its condition [52]. The Water Code of the Russian Federation includes the provisions for the use and protection of water bodies. It permits, among others, construction and operation of industrial facilities in water protection zones, on the condition that any negative impacts on the respective water bodies is ruled out [53]. The Federal Law on Industrial and Domestic Waste provides the legal basis for waste management to prevent adverse impacts on human health and the natural environment [54].

2.1.5 Define objectives

A next step in the process is to determine the ***objective*** of the environmental assessment. In general three types of objectives can be distinguished:

1. Determine the environmental impact of an activity/development.
2. Compare the relative environmental impacts of the different activities.
3. Determine the effect of mitigation/compensation measures.

Another aspect to consider is whether accidents/calamities/emergencies should be included in the assessment. This could be addressed by either:

- risk assessment with the objective to assess the risk (combination of the probability of an event and the severity of the environmental consequences of the event) and/or
- emergency response (action taken by personnel on or off the installation to control or mitigate a hazardous environmental event or initiate and execute abandonment [3])

This generic framework does not include emergencies. Guidance on how to address emergencies by risk assessment and emergency response is available in several ISO standards [1, 2, 6, 10].

The objective of the assessment is not only determined by the business need. It is usually also influenced by the availability of data, legislation & policy and requirements of stakeholders. An overview of relevant legislation is provided in 2.1.4. Note that this overview is not intended to provide a complete legal framework. Legal requirements applicable to the development should always be checked and be included in the objectives of the environmental assessment.

2.1.6 Define activities

In our framework we define activities as: "any action that is not a physical work, including the construction of an object/physical work, that may lead to an environmental effect" (adapted from Hegmann et al, 1999 [75]).

<u>General list of activities</u>

In this report we provide a set of activities that are potentially relevant for the assessment, to serve as a basis for identification of activities for a specific plan, program, or project. To derive a set of activities that are potentially relevant for the assessment, an inventory of activities was drawn up from each pressure that is specified in the section "Definition of pressures" (section 2.1.7). A complete overview of activities causing these pressures can be found in Appendix A of this report. These activities are presented on a sector level. For example, the activity "offshore oil and gas" comprises the whole sector offshore oil and gas consisting of many different exploration and development activities, such as drilling, transportation, production, etc. A more detailed list of activities can be found in the guidance document of Koss et al. (2011) [7], including the appended excel file [55].

Some activities cause only one or few pressures (e.g., fisheries), while other activities cause multiple pressures (e.g., offshore oil and gas). It should be noted that the number of pressures caused by an activity is not an indication of the severity nor of the extent of the overall impact caused by the activity.

Identification of activities

1. First step is to identify whether the project is covered by or subjected to international regulations, (see also section 2.1.4) to ensure that all legal and policy requirements (and recommendations) regarding environmental assessment are met.
2. Beside the activities planned or proposed by the contractor, activities already taking place or planned by third parties could also be included in the assessment. To which extent these should be addressed depends on the objectives of the assessment,
3. Next step is to determine the level of detail required for the assessment:
    a. Sector level. Activities are clustered in sectors, i.e. fisheries, shipping, offshore oil and gas. This level is appropriate for broad scale assessments where multiple sectors are involved. For some sectors (e.g. wind farms) distinction is made between the construction phase and operational phase.
    b. Activity level. This level is more detailed than the sector level and identifies the different activities within a sector. This level is appropriate for assessments of e.g. proposed activities, where activities can be defined in great detail (duration, intensity, equipment, location).
4. For identification of activities on a sector level the lists as provided in Appendix A, Appendix B and by Koss et al. (2011) [7, 55] can be used as a basis. All sectors/activities that are considered relevant for the assessment, i.e. the sector/activity is active in the area of concern (see section 2.1.2) should be identified as activity and included in the assessment.
5. For identification of activities on a more detailed level, distinction should be made between different types and/or different phases of activities exerting different pressures. For example, within the sector "fisheries", distinction can be made between "benthic trawling" and "pelagic trawling". These types of fisheries exert different pressures where "benthic trawling" affects the seafloor trough abrasion and "pelagic trawling" does not. Also distinction can be made between different phases, e.g. the active fishing and sailing from the harbour to the fishing grounds and vice versa. Each different type and/or phase of activities that can be distinguished on the basis of the related pressures (2.1.7) should be identified as activity and included in the assessment.

Description of an activity

Information required for each activity is:

- *Operational description*; which activity is carried out (drilling, pipe lay, trenching) and in which order in relation to the other activities.
- *Technical description*; which materials and equipment are used during each activity.
- *Spatial boundaries*; the physical area in which the activity is carried out, see section 2.3.
- *Temporal boundaries*; which time of the year will the activity be carried out and for how long? Ecosystem components often show seasonal patterns. An area may have different functions during the year. It can for example be a breeding ground for birds in June and July, a stopover site for juvenile birds in August, whereas no birds are present in other months. It is therefore important to know the date limits of each activity, see also section 2.2.

2.1.7 Define pressures

Pressures can be defined as "the mechanism through which an activity has an effect on any part of the ecosystem" (Koss et al, 2011 [7]). Pressures can be physical (e.g. abrasion), chemical (e.g. introduction of synthetic components) or biological (e.g. introduction of microbial pathogens) and the same pressure can be caused by a number of different activities. For example, both aggregate extraction and navigational dredging cause abrasion, a physical damage pressure that can affect a number of different ecosystem components (Koss et al, 2011 [7]).
Note that effects and impacts are generally considered interchangeable terms (Spaling, 1994 [56]) and among various documents, sometimes even within, the terms are used alternately (Karman & Jongbloed, 2008 [11]). Here, 'impact' is used to represent the exposure of the ecosystem to certain pressures. 'Effect' is used to refer to specific changes in the ecosystem as a result of the impact. For example, fish

are exposed to chemical substances (impact), leading to reduced egg production (effect). In some fora, pressure is also used interchangeably with the terms human activity and/ or impact (Robinson & Knigths, 2011 [57]). However, distinction between the terms is important, as impacts are the consequence of pressures, and different pressures can result in the same impact. For example, the physical pressure 'abrasion' can result in impacts that include mortality to benthic invertebrates and change in habitat properties (such as particle size distribution, stability etc.), as can the 'smothering' pressure (Robinson & Knigths, 2011 [57]).

For pressures official lists are available, such as Annex II from the European Marine Strategy Framework Directive (MSFD) [58]. The 18 pressures listed in the MSFD (Directive 2008/56/EC) has been expanded to 25 pressures in the guidance of Koss et al. (2011) [7, 55]. The additional seven pressures (numbers 19 to 25) were considered as current or emergent threats to ecosystem components. A pressure list is included in Appendix C.

The pressures can be selected from the existing lists (see Appendix C) as mentioned above and adapted to regional specifications. All pressures that are considered relevant for the assessment, i.e. can be related to the identified sector/activities (see 3.1.6), should be identified as pressure and included in the assessment.

The result of this step is an exposure Matrix in which the pressures are mapped against the activities (Table 6).

Table 6: Exposure matrix; a pressure increase is indicated in red, a pressure decrease is indicated in green. Note that these are not actual data and only serve as an example.

Activities	**Pressures**			
	1	2	3	4
a	Yes	Yes	Yes	No
b	Yes	Yes	Yes	No
c	No	Yes	Yes	Yes
d	No	Yes	Yes	Yes

2.1.8 Identify relevant ecosystem components

Ecosystem Components are defined as habitats, species or species groups that are part of the ecosystem, and have a role as indicators in monitoring, assessing, and understanding ecosystem status, impacts of human activities and effectiveness of management measures in achieving objectives. Given these roles, the suites of indicators intended to fulfil them must be chosen with care. In both Canada and the European Union the approach of Valued Ecosystem Components (VECs) is used in environmental assessments. A VEC can be defined as any part of the environment that is considered important by the stakeholders involved in the assessment. Hence, a designated set of VECs will partly reflect the perspective of the various stakeholders involved in the selection process, and does not necessarily reflect the best ecological set of indicators.

Selection of ecosystem components is a re-iterative process with regard to relationships between components, that define the components role in the system. The step of describing the interactions between ecosystem components is elaborated in section 2.1.9. The selection of ecosystem components contains several steps:

1. Identifying the ecosystem components (potentially) present in the area.
   This first step is answering the question which species (potentially) occur in the study area. In the marine habitats representatives of the different trophic levels can belong to plankton (organisms that float or drift in water), nekton (organisms that can swim freely) or benthos (organisms that live on, in or near the seabed). They can also be categorized in different biotic communities, such as sea grass, coral reefs or sea ice. Theoretically, for both marine and terrestrial habitats different trophic levels ranging from primary producers to apex predators, should be assessed. This step results in a general (virtual) long list of species and/or species groups present in the area.

2. Identifying the ecosystem components that have to be assessed.
   The second step narrows the long list down by a number of considerations:

   A. Anthropogenic considerations
      - Nature Legislation
      - Stakeholders

   B. Ecological considerations
      - Role in the ecosystem
      - Sensitivity to pressures

   Ad A) Anthropogenic considerations focus on the legally protected species and on species considered relevant by stakeholders (see 3.1.3), for instance representing an economic value. All ecosystem components with a protected status and all ecosystem components which are of importance (for whatever reason) for the relevant stakeholders should be included in the assessment.

   Ad B) In general, the ecological status of species is ample known, but ideally the selection of ecosystem components should be based on the following **ecological** criteria:
   - Abundance
     Abundance consists of numbers and distribution of species. For some species this basic information is not readily available, but recent developments made it feasible to predict species' distribution. For example, Huetmann et al. (2011) [59] predicted the distribution of 27 seabird species north of the Arctic Circle during the ice-free summer period.
   - Seasonality in occurrence
     In the Arctic many species show a strong seasonal pattern in occurrence; often related to food availability depending on for instance snow or ice cover. Only species that use the area in the same period as the assessed activities will take place are selected.
   - Function of an area for the ecosystem component
     For example for seabirds an area can function as a feeding area in the breeding season and as a moulting area after the breeding season. Both the sensitivity and the vulnerability of an ecosystem component can vary according to the different functions:
     - food species
     - predators
     - stock structure

   Key species are of particular importance in the ecosystem, for instance the fish species Capelin *Mallotus villosus* as major prey of several marine species of higher trophic levels (Hjermann, 2010 [60]). In tundra ecosystems lemmings and voles are key components as major prey species for different predators, that in turn shape the numbers of other prey species. Apart from prey species apex predators can be a key species, e.g. polar bear *Ursus maritimus* as predator of seals, shaping the numbers of their prey species. These examples highlight the existence of interactions and relationships between ecosystem components; this topic will be discussed in more detail in the next section (3.1.9).

   Furthermore, the selection of the Ecosystem Components should be based on expected pressures, and thus select components that are potentially sensitive to these pressures. For instance fish larvae or marine mammals that are sensitive to underwater sound of certain frequencies. Application of this criterion will rely heavily on expert judgment since there is often a lack of empirical data on species' reactions to pressures. To minimize the risk of skewed subjective judgments a standardized method, such as the Delphi method, can be used. This method is a structured process for collecting knowledge from a group of experts by means of a series of questionnaires interspersed with controlled opinion feedback (Adler & Ziglio, 1996 [61]).

3. Identifying suitable indicators that describe the objectives (see section 3.1.5).
   Apart from their role in the ecosystem the selection of components needs to be re-iterative with regard to the defined objectives. There are no general guidelines for selection of a minimum number of essential indicators. On a population level these objectives relate to population condition, population size and species distribution. For population condition a suitable indicator consists of demographic characteristics like reproduction and mortality rate. For population size a suitable indicator is population abundance and/or biomass. On the larger scale of species distribution, distributional range and distributional pattern are suitable indicators.

The selection process is schematically presented in Table 7.

Table 7: Selection criteria for ecosystem components. An ecosystem component is included in the assessment if one or more selection criteria are relevant. Note that these are not actual data and only serve as an example.

Ecosystem component	**Selection criterion**				
	Legislation	Stakeholders	Ecology	Pressure	Overall
a	Yes	Yes	Yes	Yes	Yes
b	Yes	No	Yes	No	Yes
c	Yes	No	No	No	Yes
d	Yes	No	Yes	Yes	Yes
e	No	Yes	Yes	Yes	Yes
f	No	No	Yes	Yes	Yes
g	No	No	Yes	No	Yes
h	No	No	Yes	Yes	Yes
i	No	No	Yes	Yes	Yes
j	No	No	No	Yes	Yes
k	No	Yes	No	No	Yes
l	No	No	No	No	No

2.1.9 Define interactions of ecosystem components

To select and use ecosystem components as indicator for assessment of the impact of anthropogenic activities on ecosystem components and ultimately on an ecosystem, knowledge on interactions between ecosystem components is necessary. Ecosystem components are not isolated entities that coincidentally share an area, but they constitute an ecosystem by their role and place in a variety of interlinked food-chains forming a food-web (Figure 9). A food-chain starts with primary producers (e.g. algae and plants) that produce their own biomass by photosynthesis using solar energy and nutrients. Consumers are organisms that cannot synthesise their own food, and have to feed on other organisms. Apart from the first trophic level all other parts of the food chain are consumers. A simple food-chain consists of primary producers and consumers that can be categorized according to ascending trophic levels:

1. Primary producers: plants and algae making their own food.
2. Primary consumers: herbivores consuming plants or algae.
3. Secondary consumers: carnivores consuming herbivores.
4. Tertiary consumers: carnivores consuming other carnivores.
5. Apex or top predators: carnivores consuming other consumers and have virtually no predators.

With ascending trophic levels energy or biomass is lost. The efficiency with which energy or biomass is transferred from one trophic level to the next is about 10%. Therefore the number of trophic levels in a food chain is limited, and the numbers of apex predators are usually much lower than that of plants. Most ecosystem components are part of several food-chains, since they consume different food items. Thus forming a food-web with multiple relationships between the individual components. Detrivores consume decomposing organic matter and thus recycle nutrients that form the basis for primary production, but they are normally not included in food-chains.

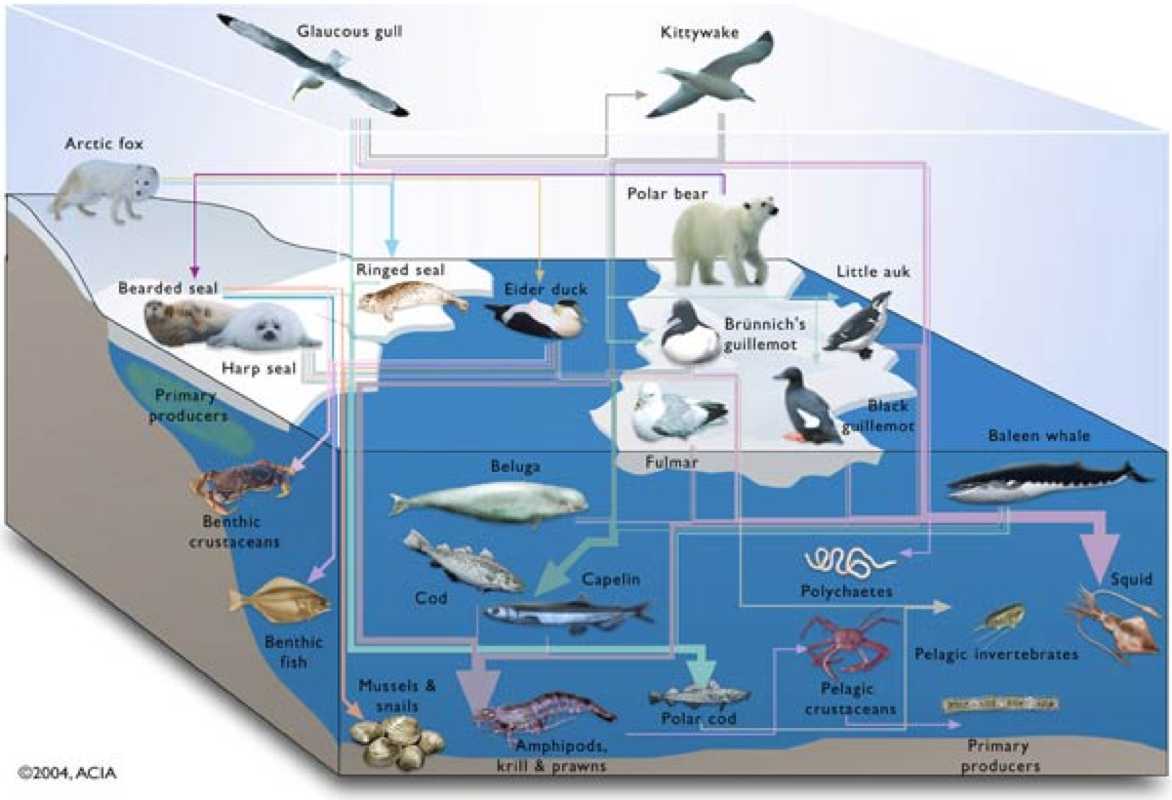

Figure 9 Arctic marine food web (Hassol et al, 2004 [76]).

Interactions are the effects organisms have on each other. Interactions can be interspecific or intraspecific. The effects of the interactions can be direct or indirect (e.g. cyclic abundance of prey species like lemmings that affect the number of predators who switch to alternative prey after lemming peak years). Effects can occur immediately or with a time lag. Theoretically, the variety of interactions can be categorised in a few main categories (Begon, 1996 [62]) summarized in Table 8.

Table 8: Main interactions between ecosystem components, - indicates a decrease, + an increase and 0 no effect.

Effect on X	Effect on Y	Type of interaction	Description
-	-	Competition	mutually detrimental interaction between individuals, populations or species
0	0	Neutralism	describes the relationship between two species which interact but do not affect each other. Since true neutralism is rare or nonexistent, its usage is often extended to situations where interactions are merely insignificant or negligible.
0	-	Amensalism	is a relationship in which a product of one organism has a negative effect on another organism in which one organism is harmed, while the other is neither affected nor benefited.
+	-	Antagonism (including predation and parasitism)	one species benefits at the expense of another
+	0	Commensalism	benefits one organism and the other organism is neither benefited nor harmed.
+	+ or 0	Ecological facilitation	describes species interactions that benefit at least one of the participants and cause no harm to either. Facilitations can be categorized as mutualisms, in which both species benefit, or commensalisms, in which one species benefits and the other is unaffected.
+	+	Mutualism	an interaction between two or more species, where species derive a mutual benefit, for example an increased carrying capacity.

The whole suite of interactions shape the structure and dynamics of ecosystems. An understanding of these relationships is essential to get a grip on the functioning of a species, and therefore on its suitability as an indicator for pressures. Of these interactions predation and competition are the most 'tangible' and therefore the best studied. In comparison to ecosystems in lower latitudes in general Arctic food-chains are relatively simple with only a few components. It does not mean, however, that the ecosystems are simple.

Because ecosystem components may have a profound effect on other ecosystem components, these interactions cannot be ignored in an environmental assessment. Due to the scale and complexity of ecosystems, and the difficulties in studying these relationships, the definition of interactions usually rely heavily on expert judgment.

In the qualitative assessment interactions between ecosystem components are identified (Table 9). Interactions may result in a decrease of an ecosystem component (e.g. predation, parasitism, competition etc.), but may also lead to an increase (e.g. a species who creates habitat for other species etc.).

Table 9: Interaction matrix; a decrease is indicated in red, an increase is indicated in green. In this example an increase in Ecosystem Component B results in an increase of Ecosystem Component D and an increase in D causes a decrease in B (predator-prey interaction). Ecosystem Component C reduces Ecosystem Component B (e.g. C feeds on the habitat of B). Note that an Ecosystem Component can also interact with itself, for example when age classes of the same species compete for the same resources or cannibalism. Note that these are not actual data and only serve as an example.

Ecosystem components	**Ecosystem components**			
	A	B	C	D
A	No	No	No	No
B	No	No	No	Yes
C	No	Yes	No	No
D	No	Yes	No	No

2.1.10 Define vulnerability ecosystem components to pressures

For a qualitative assessment of the linkage between activities-pressures and the linkage between pressures-ecosystem components, relevant combinations are identified; which ecosystems are potentially affected by the identified pressures? The linkage between pressures and ecosystem components results in a matrix as presented in the table below. The matrix is usually based on expert judgement in which characteristics of the ecosystem components are taken into account in assessing their vulnerability . For example, a reduction in turbidity may impact species that depend on the visibility to detect their prey, or reduce the availability of light for alga growth. In this type of assessment, the possible seriousness of the effect is not evaluated.

The likelihood of exposure to the pressures could be taken into account in case the spatial and temporal distribution of both the pressure and the ecosystem component is known. It should be clearly documented whether the matrix is based on a potential interaction, or is based on actual information of the spatial and temporal distribution of both pressures and ecosystem components.

Table 10: Vulnerability matrix; a decrease of an ecosystem component due to the exposure of a pressure is indicated in red, an increase is indicated in green.? indicates a possible effect. Note that these are not actual data and only serve as an example.

Pressures	**Ecosystem components**			
	A	B	C	D
1	Yes	No	Yes	?
2	No	No	No	Yes
3	Yes	No	No	No
4	No	No	No	Yes

2.1.11 Qualify Environmental impact

When the results of the exposure matrix (Table 6) are combined with the vulnerability matrix (Table 10) the initial impact matrix can be derived (Table 11).

Table 11: Initial impact matrix; an increase of a pressure is indicated in red, a decrease in green. A decrease of an ecosystem component is indicated in red, an increase in green.? indicates a possible effect. Note that these are not actual data and only serve as an example.

			Ecosystem components			
Activities	**Pressure**	**Exposure**	A	B	C	D
a	1	Yes	No	No	No	No
	2	Yes	No	No	No	Yes
	3	Yes	Yes	No	No	No
	4	No	No	No	No	No
b	1	Yes	Yes	No	Yes	?
	2	Yes	No	No	No	Yes
	3	Yes	Yes	No	No	No
	4	No	No	No	No	No
c	1	No	No	No	No	No
	2	Yes	No	No	No	Yes
	3	Yes	Yes	No	No	No
	4	Yes	No	No	No	Yes
d	1	No	No	No	No	No
	2	Yes	No	No	No	Yes
	3	Yes	Yes	No	No	No
	4	Yes	No	No	No	Yes
Cumulated effect induced by pressures			Yes	No	Yes	?

Then, the results of the initial impact matrix (Table 11) are combined with the interaction matrix (Table 9) and summarized in the final impact matrix (Table 12). This is an iterative process and can be a complicated step. In this case the cumulated effect induced by pressures is negative on ecosystem component A (Table 11). Ecosystem component A does not affect other ecosystem components and vice versa (Table 9). The overall effect on ecosystem component A therefore doesn't change. The cumulated effect induced by pressures increases ecosystem component C which causes a decrease in ecosystem Component B. The decrease of ecosystem component B doesn't have any effect of ecosystem component D (an increase would have had an effect; Table 9). The effect on ecosystem component D by the cumulated effect induced by pressures is not clear. If ecosystem component D would increase, an additional decrease of ecosystem component B is possible.

Table 12: Final (qualitative) impact matrix; an increase of a pressure is indicated in red, a decrease in green. A decrease of an ecosystem component is indicated in red, an increase in green.? indicates a possible effect. Note that these are not actual data and only serve as an example.

			Ecosystem components			
Activities	**Pressure**	**Exposure**	A	B	C	D
a	1	Yes	No	No	No	No
	2	Yes	No	No	No	Yes
	3	Yes	Yes	No	No	No
	4	No	No	No	No	No
b	1	Yes	Yes	Yes	Yes	?
	2	Yes	No	No	No	Yes
	3	Yes	Yes	No	No	No
	4	No	No	No	No	No
c	1	No	No	No	No	No
	2	Yes	No	No	No	Yes
	3	Yes	Yes	No	No	No
	4	Yes	No	?	No	Yes
d	1	No	No	No	No	No
	2	Yes	No	No	No	Yes
	3	Yes	Yes	No	No	No
	4	Yes	No	?	No	Yes
Cumulated effect induced by pressures & ecosystem interactions			Yes	Yes	Yes	?

The final impact matrix can be simplified to a qualitative effect matrix (Table 13). In this case all activities have a negative effect on Ecosystem Component A. Ecosystem Component B is not affected by activity a, is negatively affected by activity b and possibly negatively affected by activity c & d. Ecosystem Component C is (eventually) not negatively affected by any activity. Ecosystem Component D is negatively affected by activity a, the cumulative effect of the other activities is not known.

Table 13: Qualitative Effect Matrix; a decrease of an ecosystem component is indicated in red, an increase in green. ? indicates a possible effect. Note that these are not actual data and only serve as an example.

	Ecosystem Component			
Activities	A	B	C	D
a	Yes	No	No	Yes
b	Yes	Yes	Yes	?
c	Yes	?	No	?
d	Yes	?	No	?

2.1.12 Define scope & level of detail

The scope definition for further research is based on the matrices achieved during the previous steps. In principle, all ecosystem components that are in no way affected by pressures or the other ecosystem components are not included in the scope. This also applies to activities and pressures that have no impact on ecosystem components.

After defining the elements included in the assessment, the desired level of detail of the assessment needs to be established for the prioritization phase. If the objective of the assessment is to compare the (relative) environmental impacts of various activities, a semi quantitative assessment is probably the most efficient approach. A quantitative approach can also be used for the prioritization phase. Hereby, the *actual* environmental impact will be assessed (cf what is the change in population numbers or densities). A quantitative assessment requires detailed information in space and time concerning:

1. the intensity of pressures caused by the activities
2. dose-response relationships describing the effects on ecosystem components caused by pressures.
3. dose-response relationships describing the effects on ecosystem components caused by interactions with other ecosystem components.

2.2 Prioritization phase: semi quantitative assessment

The result of the semi quantitative assessment is also an effect matrix (cf Table 13). However, it differs from the qualitative assessment by the categorical effect scores, indicating the magnitude of the impact.

The semi quantitative assessment is used to compare the ***relative*** impact of the various (sub) activities. It is often used to identify and prioritize potential areas for mitigation.

So far, it has not been elaborated how species interactions can be incorporated in a semi quantitative assessment. Therefore, species interactions will be left out of this analysis and will not be included in the categorical effect scores of the semi quantitative assessment.

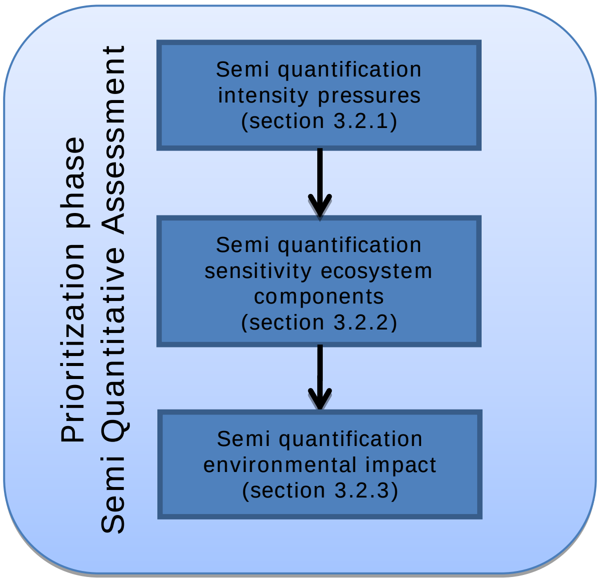

Figure 10: Prioritization phase using a semi quantitative assessment. Note that the environmental impact is determined by the intensity of the pressures in combination with the vulnerability of the ecosystem components. Species interactions are (yet) not included.

2.2.1 Semi quantification intensity pressures

The intensity of pressures is based on the relation between activity and pressure. For example, the activity 'benthic trawling', expressed in presence of vessels (hours actively fishing) results in the pressure 'abrasion', expressed as the frequency in which a predefined area is abraded in a predefined period.

Eventually the collected information of the activities is used to categorize the intensity of the pressures. Usually, this is done by expert judgement according to a classification scheme. An example of such a classification scheme, including criteria, is presented in Table 14.

A different classification scheme has been developed by Robinson et al. 2011 [57] for weighting linkages and assessing high threat combinations between sector/pressures and ecosystem components. The guidance document for this approach is available at www.liv.ac/odemm/outputs/guidancedocuments. A similar approach is used for the development of a Vulnerability Matrix (Tillin, 2010 [63]), available at http://randd.defra.gov.uk/Document.aspx?Document=MB0102_9721_TRP.pdf

Table 14: Classification for the assessment of the intensity of pressures based on three criteria: size of disturbed area; duration of disturbance and frequency of disturbance (Tamis et al, 2011 [64]).

Intensity pressure	Score	Exposed area in relation to total area (%)	Duration of exposure	Frequency of exposure
Marginal	1	< 0.01%	Several minutes	Rare (once a year or less)
Low	2	0.01-0.1%	Hours, up to 1 day	Occasional (multiple times a year)
Medium	4	0.1-1%	Days/weeks	Common (weekly or daily)
High	8	> 1%	Month(s)	(Nearly) continuous (multiple times per day or continuous disturbance)

In the semi quantitative exposure matrix (Table 15) the intensity of each pressure per activity is categorized by a classification scheme.

Table 15: Semi quantitative exposure matrix with categorical effect scores based on the classification scheme in table 14. A pressure increase is indicated in red, a decrease is indicated in green. Note that these are not actual data and only serve as an example.

Activities	**Pressures**			
	1	2	3	4
a	4	1	4	
b	2	2	2	
c		1	8	2
d		2	1	1

2.2.2 Semi quantification vulnerability ecosystem components

This vulnerability should be specific for the type and level of effect that is considered of interest for the assessment (e.g. mortality, reduced reproduction or feeding efficiency). Sparse data sets and system complexity have compelled conservation scientists to estimate data through expert judgment and other scoring procedures (Wolman, 2006 [65]). Semi quantitative methods thus mostly rely on expert judgement to classify the vulnerability of ecosystem components to specific pressures.

To combine the effects on individual species, similar endpoints should be used. In case the assessment is not based on one uniform endpoint, e.g. mortality, an additional step should be included in the assessment to derive one single endpoint. Jak et al. (2000) and Karman et al. (2009) [66, 67] describe a method to integrate the effects of potential exposures. They combined mortality with reproduction to derive a single population measure.

In a semi quantitative assessment the linkage between pressure and ecosystem components is weighted by expert judgement according to a classification scheme. An example of such a classification scheme, including criteria, is presented in Table 16. It should be noted that this classification scheme was developed for assessment of potential impact on Natura 2000 targets. The criteria “effect indication” and “ecological conditions” were included because they were relevant for this purpose. The classification scheme (i.e. criteria) used for a semi quantitative assessment should be appropriate for the aim and scope of the study. As already mentioned in the semi quantitative assessment of the intensity of pressures (section 3.2.1), different classification schemes have been developed (Robinson & Knights, 2011 [57]), which could be used as guidance for a semi quantitative assessment. Also Arctic specific conditions should be considered in the development of a classification scheme, e.g. slow growth rates and recovery. A suitable scheme for the Arctic will be developed within the case study (Faidutti et al, in prep).

Table 16: Classification for the assessment of vulnerability based on three criteria: effect indication, recovery and ecological conditions (Tamis et al 2011 [64]).

Category	Score	Effect indication	Recovery	Ecological conditions (as defined in policy)
Marginal	1	Not sensitive	Instant	No effect
Low	2	Low	Days	Effect on ecological condition
Medium	4	Medium	Months	Effect on ecological condition and/or the pressure is to be avoided
High	8	High	More than one year	Effect on ecological condition in combination with a target to improve the conservation status

In the semi quantitative vulnerability matrix (Table 17) the vulnerability of each ecosystem component per pressure is categorized by a classification scheme.

Table 17: Semi quantitative vulnerability matrix based on the classification scheme in table 16. A decrease of an ecosystem component as a result of an increase in pressure is indicated in red, an increase of an ecosystem component as a result of an increase in pressure is indicated in green. Note that these are not actual data and only serve as an example.

Pressures	**Ecosystem components**			
	A	B	C	D
1	4	0	1	2
2	0	0	0	2
3	8	0	0	0
4	0	0	0	4

2.2.3 Semi quantification environmental impact

The ecological impact can be assessed on a semi quantitative level by multiplying the intensity score (Table 16) with the vulnerability score (Table 17). By adding up all pressure scores per activity this results in a cumulative impact score per activity. By adding up all pressure scores per ecosystem component this results in a cumulative impact score per ecosystem component. This approach is demonstrated for offshore oil and gas activities in Natura 2000 areas (Tamis et all [64]).

Table 18: Semi quantitative impact matrix based on the semi quantitative exposure matrix (Table 16) and the semi quantitative vulnerability matrix (Table 17). An increase of a pressure is indicated in red, a decrease in green. A decrease of an ecosystem component is indicated in red, an increase in green. Note that these are not actual data and only serve as an example.

			Ecosystem components			
Activities	**Pressure**	**Exposure**	A	B	C	D
a	1	4	0		0	0
	2	1				2
	3	4	32			
	4					
b	1	2	8		2	4
	2	2				4
	3	2	16			
	4					
c	1					
	2	1				2
	3	8	64			
	4	2				8
d	1					
	2	2				4
	3	1	8			
	4	1				4
Cumulated effect induced by pressures			128		2	4

The semi quantitative impact matrix can be simplified to a semi quantitative effect matrix (Table 19). In this example all activities have a negative effect on ecosystem component A. Ecosystem component B is not affected by any activity. Ecosystem component C increases due to activity b. Ecosystem component D is negative affected by activity a, but is increased by activity c, resulting in an overall increase.

Table 19: Semi quantitative effect matrix. This table summarizes the semi quantitative impact matrix (Table 18). A decrease of an ecosystem component is indicated in red, an increase in green. Note that these are not actual data and only serve as an example.

	Ecosystem component			
Activities	A	B	C	D
a	32			2
b	24		2	0
c	64			6
d	8			0
total	128		2	4

2.3 Prioritization phase: quantitative assessment

The result of the quantitative assessment is also an effect matrix (cf Table 13 and Table 19). It differs from the qualitative and the semi quantitative assessment by the numerical quantified effect scores, indicating the expected decrease/increase of the population size/density of the ecosystem components. The quantitative assessment is used when the ***actual*** effect on the ecosystem components needs to be established.

As a first step, the preliminary impact is determined by the intensity of the pressures in combination with the vulnerability of the ecosystem components. The expected fluctuations in the population size/density of the ecosystem components induced by the pressures is then used to assess additional changes through interactions with other ecosystem components. Finally, the recovery potential is assessed to quantify the final environmental impact.

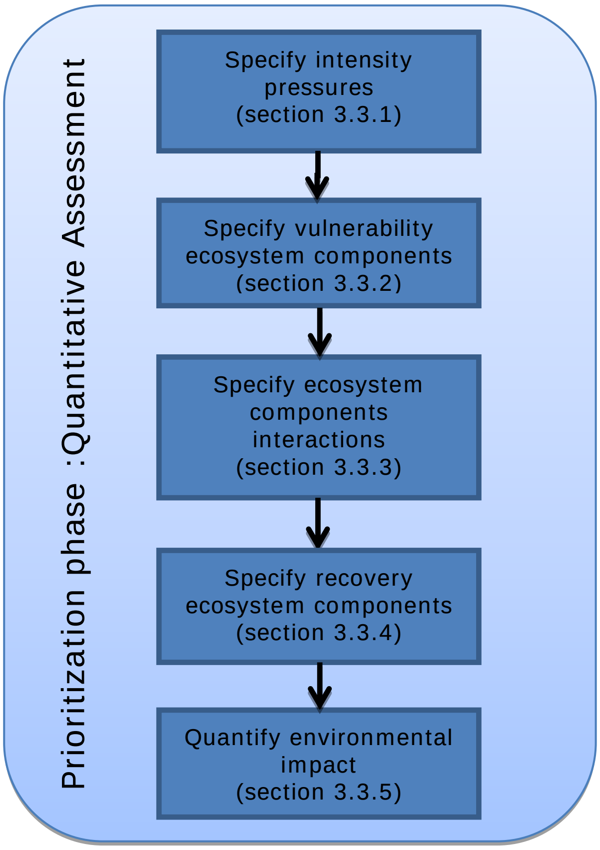

Figure 11: Prioritisation phase, using a the quantitative assessment. Note that the environmental impact is preliminary assessed by the intensity of the pressures in combination with the sensitivity of the ecosystem components. The expected decrease/increase of the ecosystem components induced by the pressures is then used to determine additional changes by interactions of the ecosystem components. Finally, the recovery potential is assessed to quantify the final environmental impact.

2.3.1 Specify intensity pressures

The collected information of the activities is used to quantify the (cumulated) intensity of the pressures. For a quantitative assessment the intensity of pressures to which an ecosystem component is exposed needs to be expressed at an absolute scale. The unit of measurement for each pressure should be identified as such that it can be related to the exposure-response relationships.

The intensity of pressures is often high near the actual activity and decreases with the distance. When pressures show significant spatial variation it might be necessary to use a grid in which the intensity of the pressures is mapped per geographic cell. In addition to spatial patterns, the intensity of pressures may also have temporal properties. This may require the recognition of time steps in the assessment.

In the quantitative exposure matrix (Table 20) the intensity of each pressure per activity is quantified.

Table 20: Quantitative exposure matrix; a pressure increase is indicated in red, a decrease is indicated in green. In this example we assume that the pressures do not have spatial and temporal properties. Note that these are not actual data and only serve as an example.

	Pressures			
Activities	1	2	3	4
a	1 ml/s	50 db	2 kW	0
b	5 ml/s	120 dB	5 kW	0
c	0	100 dB	1 kW	1%
d	0	80 dB	4 kW	5%

2.3.2 Specify vulnerability ecosystem components

In the quantitative assessment, the vulnerability of the ecosystem components is directly linked to the intensity of each relevant pressure by the use of exposure-response relationships (Jak et al 2000 [66], Karman et al 2009 [67]). The exposure-effect relationships describe the relation between the intensity of a potential exposure (e.g. the cadmium concentration in water) and the effect on the population (in case the ecosystem component concerns a species).

Several end-points are to be assessed in order to describe the effect at population level, such as age at first reproduction, reproduction rate and mortality.

As an example, in the CUMULEO-RAM model (de Vries et al, 2010 [68]) the effect on a population is expressed as a fraction between 0 and 1:

Fraction Effect = f (Exposure intensity)

Under the following preconditions:

- if the exposure intensity = 0, than effect = none = 0
- if the exposure intensity = maximum, than effect = maximum = 1

Many types of functions can describe the above relationships, i.e. logistic curve, linear relation, etc. An appropriate function type per pressure has to be selected (de Vries et al, 2010 [68]) which is applicable for all relevant ecosystem components. Therefore, for each pressure, only the values of the parameters differ per ecosystem component. The function has been quantified based on several calibration points, which have been derived from literature information on the sensitivity of the species for that pressure.

A few general parameters have been used as much as possible in the different functions:

m = median effect intensity, intensity of disturbance at which effect = 50%
d = threshold value, disturbance intensity at which effect will occur
c = intensity-effect coefficient, indicating the slope of the function

The variables are:

y = *the effect on survival and/or reproduction (fraction between 0 and 1)*
x = *the disturbance intensity of the potential exposure.*

In case the (temporal and/or spatial) distribution of pressure intensity and the distribution of the ecosystem component(s) are known (by prediction or based on field measurements), the level of effect can also be assessed on a temporal and spatial scales. That is, for a certain spatial grid and/or period of time, the effect can be quantified.

In the quantitative sensitivity matrix (Table 21) the sensitivity of each ecosystem component is quantified per pressure.

Table 21: Quantitative vulnerability matrix; a decrease in population size/density of an ecosystem component is indicated in red, an increase is indicated in green. In this example we assume that the pressures as well as the ecosystem components do not have spatial and temporal properties. Note that these are not actual data and only serve as an example.

Pressures	**Ecosystem components**			
	A	B	C	D
1	2%	0	1%	0.50%
2	0	0	0	0,01%/dB
3	1%/kW	0	0	0
4	0	0	0	1%/%

2.3.3 Specify interactions ecosystem components

Interactions between ecosystem components (Table 8) can be quantified by deterministic and stochastic models. Deterministic models are used when population sizes are large, rendering it possible to ignore fluctuations due to chance. When population sizes are small stochastic models are used. These models take demographic and environmental stochasticity, and the occurrence of (natural) catastrophes into account. Stochastic models in ecology are among the most mathematically complex models in science.

The classic deterministic model by Lotka-Volterra (1925 [69] & 1920 [70]) describes competition without specifying what species compete for. Therefore this model allows for a description of competition for resources or predator-prey relationships. This model led to a cascade of new models based on several assumptions, restrictions and mutual reactions. The performance of both deterministic and stochastic models depends heavily on the availability of quantitative information on the species' interactions. This information, however, is scarce.

In the quantitative interaction matrix (Table 22) the effect of each ecosystem component on each other ecosystem component is quantified.

Table 22: Quantitative interaction matrix; a decrease in population size/density of an ecosystem component is indicated in red, an increase is indicated in green. In this example we assume that the interactions are linear relationships and that spatial and temporal properties can be ignored. Note that these are not actual data and only serve as an example.

Ecosystem components	**Ecosystem components**			
	A	B	C	D
A	0	0	0	0
B	0	0,1%	0	0,5
C	0	2%	0	0
D	0	2%	0	0

2.3.4 Quantify recovery ecosystem components

The recovery of ecosystem components could be separately assessed in a quantitative assessment, expressed as the recovery time and/or the fraction of ('permanent') change after the activity has stopped.

The recovery can be predicted from the population dynamic characteristics of species, and the interactions with the (changed) environment and with other species. Populations may recover as a result of reproduction and/or recolonisation (migration). Depending on the species, it may take weeks or years until a population has returned to a 'normal' age distribution. Migration may be much faster, but depends also on the presence of the species in the surrounding area and their motile abilities.

The recovery rate is not only dependent on the characteristics of the species, but also on their environment. In case the substrate has changed, recovery may only be possible after the substrate has recovered as well. In some cases, the substrate will never recover and the habitat of a species partly be lost for ever. Also species interactions are very important in estimating recovery rates. Shifts in the community structure, induced by pressures from activities, may increase or decrease the rate of recovery. For example, in case a predator is more severely affected by an activity than its prey, prey species may recover more quickly. Another example is the dependence on so-called biobuilders, like mussels forming beds. Some species are strongly associated to these biological structures, and in case these are affected, the recovery of associated species will take longer than predicted from their intrinsic recovery potential. At first, the biological structure needs to recover, before its associated fauna will recover.

The assessment of the recovery rate often involves many uncertainties, and therefore the recovery is often empirically assessed after the activity has taken place. This thus requires a monitoring and evaluation process, including field studies that may take several years after the activity has stopped. For some specific cases, results from these kind of studies can be used to predict the recovery of similar type of activities and/or environments.

In the recovery matrix (Table 23) the recovery rate of each ecosystem component is specified after a certain time span. Note that the recovery rate after an initial decrease may differ from the recovery rate after an initial increase.

Table 23: Recovery matrix; in this example the recovery rate of each ecosystem component is specified after an initial decrease or increase. Note that these are not actual data and only serve as an example.

Ecosystem Components	Recovery after	
	Decrease	**Increase**
A	50%/year	0
B	0	0
C	100%/year	100%/year
D	25%/year	0

2.3.5 Quantification environmental impact

When the results of the quantitative exposure matrix (Table 20) are combined with the quantitative vulnerability matrix (Table 21) the initial impact matrix can be derived (Table 24).

Table 24: Initial quantitative impact matrix based on the quantitative exposure matrix (Table 20) and the quantitative sensitivity matrix (Table 21). An increase of a pressure is indicated in red, a decrease in green. A decrease of an ecosystem component is indicated in red, an increase in green. Note that these are not actual data and only serve as an example.

			Ecosystem components			
Activities	**Pressure**	**Exposure**	A	B	C	D
a	1	1%	0	0	0	0
	2	50dB	0	0	0	0.50%
	3	2kW	2%	0	0	0
	4	0	0	0	0	0
b	1	5%	10%	0	5%	2.50%
	2	120 dB	0	0	0	1.20%
	3	5 kW	5%	0	0	0
	4	0	0	0	0	0
c	1	0	0	0	0	0
	2	100 dB	0	0	0	1%
	3	1 kW	1%	0	0	0
	4	1%	0	0	0	1%
d	1	0	0	0	0	0
	2	80 dB	0	0	0	0.80%
	3	4 kW	4%	0	0	0
	4	5%	0	0	0	5%
Cumulated effect induced by pressures			22.0%	0.0%	5.0%	12.0%

The secondary quantitative impact matrix (Table 25) can be established with the initial impact scores (Table 24) and the ecosystem interaction matrix (Table 22). This can be an iterative process and can be a complicated step.

Table 25: Quantitative secondary impact matrix based on the quantitative initial impact matrix (Table 24) and the quantitative interaction matrix (Table 22). An increase of a pressure is indicated in red, a decrease in green. A decrease of an ecosystem component is indicated in red, an increase in green. Note that these are not actual data and only serve as an example.

			Ecosystem components			
Activities	**Pressure**	**Exposure**	A	B	C	D
a	1	1%	0	0	0	0
	2	50dB	0	0	0	0.50%
	3	2kW	2%	0	0	0
	4	0	0	0	0	0
b	1	5%	10%	15%	5%	2.50%
	2	120 dB	0	0	0	1.20%
	3	5 kW	5%	0	0	0
	4	0	0	0	0	0
c	1	0	0	0	0	0
	2	100 dB	0	0	0	1%
	3	1 kW	1%	0	0	0
	4	1%	0	1%	0	1%
d	1	0	0	0	0	0
	2	80 dB	0	0	0	0.80%
	3	4 kW	4%	0	0	0
	4	5%	0	5%	0	5%
Cumulated effect induced by pressures & ecosystem interactions			22.0%	21.0%	5.0%	5%

Eventually, the final impact matrix (Table 26) is derived by combining the secondary impact matrix (Table 25) with the recovery matrix (Table 23).

Table 26: Final quantitative impact matrix based on the quantitative secondary impact matrix (Table 25) and the recovery matrix (Table 23). An increase of a pressure is indicated in red, a decrease in green. A decrease of an ecosystem component is indicated in red, an increase in green. Note that these are not actual data and only serve as an example.

			Ecosystem components			
Activities	**Pressure**	**Exposure**	A	B	C	D
a	1	1%	0	0	0	0
	2	50dB	0	0	0	0.50%
	3	2kW	2%	0	0	0
	4	0	0	0	0	0
b	1	5%	10%	0	0	2.50%
	2	120 dB	0	0	0	1.20%
	3	5 kW	5%	0	0	0
	4	0	0	0	0	0
c	1	0	0	0	0	0
	2	100 dB	0	0	0	1%
	3	1 kW	1%	0	0	0
	4	1%	0	1%	0	1%
d	1	0	0	0	0	0
	2	80 dB	0	0	0	0.80%
	3	4 kW	4%	0	0	0
	4	5%	0	5%	0	5%
Cumulated effect induced by pressures, ecosystem interactions & recovery			22.0%	6%	0	5%

The final quantitative impact matrix (Table 26) can be simplified to a quantitative effect matrix (Table 27). In this case all activities have a negative effect on ecosystem component A, resulting in an overall decrease of approximately 22%. Ecosystem component B is not affected by activity a & b, and negatively affected by activity c & d, causing an approximate overall decline of 6%. Ecosystem component C is (eventually) not affected by any activity. Ecosystem component D is negatively affected by activity a and positively affected by the other activities, overall resulting in an increase of some 5%.

Table 27: secondary quantitative impact matrix. A decrease of an ecosystem component is indicated in red, an increase in green. Note that these are not actual data and only serve as an example.

Activities	**Ecosystem component**			
	A	B	C	D
a	2%	0	0	0.5%
b	15%	0	0	1.3%
c	1%	1%	0	0
d	4%	5%	0	4.2%
total	22.0%	6%	0	5%

3 Conclusions

This chapter gives a brief overview of the proposed generic framework to perform an environmental assessment in Arctic ecosystems. Furthermore, areas in the proposed approach are identified which haven't been elaborated extensively and may be improved in the future (GAP analysis).

3.1 Generic Framework

The actual model we propose is a combination of a CEA (cumulative effect assessment) and an EEC (ecosystem effect chain). The basic approach of the CEA is the assumption that effects are a function of the intensity of pressures caused by activities and of the sensitivity of ecosystem components to those pressures. The EEC approach includes interactions between populations and ecosystem components, and may therefore also reveal indirect impacts. Examples of those ecosystem interrelationships are predator-prey interactions, cannibalism, competition, mutualism etc.

Furthermore, most environmental assessments only include pressures in the analysis which have a negative effect on the ecosystem components, e.g. mortality or a lower reproduction rate. However, some pressures may also have a 'stimulative' effect. In this study we have considered 'negative' as well as 'stimulative' effects of pressures.

We propose a stepwise application of the model during the project development of a marine operation, each of them requiring a specific environmental assessment. The first phase is a qualitative assessment which is used to determine which ecosystem components are (potentially) affected by the activity induced pressures and/or by interactions with other ecosystem components. The qualitative assessment results in a scope definition for the next phases. The 12 steps which are required for the qualitative assessment are described in section 3.1. External influences as the requirements of stakeholders, legislation and the availability of data are important factors to take into account during this phase.

The next step is the prioritization phase in which the ecological impact of the various scenarios is compared to select the best option. This phase can be elaborated using a semi quantitative approach or a quantitative approach. For the semi quantitative assessment we defined three steps, described in section 3.2. A quantitative assessment is elaborated in 5 steps, described in section 3.3.

3.2 GAP analysis

During the development of the generic framework we identified areas which have not been elaborated extensively and may be improved in the future. An overview of the identified gaps is given below.

Baseline monitoring, EIA, Effect monitoring & Effect evaluation
The generic framework so far includes a description of the scoping and the prioritization phase. The other steps (Baseline Monitoring, EIA, Effect Monitoring & Effect Evaluation) are not elaborated yet.

Sensitivity & Uncertainty analysis
The aim of an uncertainty analysis is to identify and where possible to quantify the uncertainty in the assessment. A sensitivity analysis evaluates the effects of uncertainty in the input parameters and the computational algorithm on the output of the assessment. A sensitivity and uncertainty analysis can be used to test the robustness of the assessment. So far, we do not have a clear picture of how a sensitivity and uncertainty analysis should be performed in the proposed methodology.

Species interactions in a semi quantitative assessment

Apart from the effects of the activity induced pressures, species interactions may have a profound additional effect on the ecosystem components, possibly greatly influencing the results of the assessment. So far we haven't been able to include species interactions in the categorical effect scores of the semi quantitative assessment.

Natural variability of marine ecosystems

The natural variability of marine ecosystems can be very high. E.g. changes in climate, ocean currents and upwelling can influence species distribution and production at different temporal and spatial scales. The actual patterns observed in the marine realm are always a combination of natural and human-induced drivers of change. And if monitoring data are going to be used to determine the (long-term) effects of different human activities it is a prerequisite to also estimate the contribution of natural variability. So far, the natural drivers of change have not been addressed in this report and this needs more attention.

Building with nature principles

The concept building with nature (BwN) aims to create opportunities for nature and – if possible- making use of natural processes during the execution of a project. So far, these principles have not been included in this generic framework, but have shown to be promising in more temperate regions.

Actors of maritime operations

In the current version of the Generic Framework the roles of the different maritime actors (oil companies, ship builders and contractors) are not specifically described during the various project phases of a maritime operation. It is likely that the suitability of the Generic Framework will increase when the roles and responsibilities of the various maritime actors are described more specifically.

Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 57846-2009-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Abbreviations

CEA	Cumulative effect assessment
EEC	Ecosystem effect chain
EIA	Environmental impact assessment
VEC	Valued ecosystem components
SEA	Strategic environmental assessment

Definitions

Anthropogenic
Caused or influenced by humans.

Accident
A sudden, unplanned, unintentional and undesired event or series of events that causes physical harm to a person or damage to property, or which has negative effects on the environment [1].

Activity
Any action that is not a physical work, including the construction of an object/physical work, that may lead to an environmental effect (adapted from Hegmann, 1999 [77]).

Cumulative environmental effects
Additive (aggregate), synergistic, or antagonistic (neutralizing) environmental changes of multiple impacts from past, present, and future development activities that degrade valuable ecosystem components. The pathways can be difficult to determine because direct and indirect impacts can crowd or lag in time and space or become apparent only after specific triggers or thresholds are exceeded [2].

Ecosystem
A community of organisms who interact with each other, as well as with their environment.

Ecosystem component
A species, species group or habitat that is part of an ecosystem.

Effect
A change within an ecosystem component that is a result of a pressure or an interaction with another .

Emergency
An unplanned event which has caused injury, loss or damage or which is an actual or potential threat to human life or the environment and has made it necessary to deviate from the planned operation or suspend the use of standard operating procedures.

Emergency response (ER)
Action taken to control or mitigate a hazardous event .

Endangered species
Means a wildlife species that is facing imminent extirpation or extinction [4]. Where ‘extinction’ means the end of a species, i.e. the death of the last individual of the species and ‘extirpated’ means locally extinct.

Environment
Environment encompasses the natural (biological and physical) environment and the human (social, cultural and economic) environment. The conceptualization of the environment, from the point of view of each arctic country, can be found at the information site on the WWW or from the national EIA authorities [2].

Environmental impact assessment
A process for identifying, predicting, evaluating, and mitigating the biophysical, social, and other relevant effects of proposed projects and physical activities prior to major decisions and commitments being made [2].

Habitat
Means (a) in respect of aquatic species, spawning grounds and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or areas where aquatic species formerly occurred and have the potential to be reintroduced; and (b) in respect of other wildlife species, the area or type of site where an individual or wildlife species naturally occurs or depends on directly or indirectly in order to carry out its life processes or formerly occurred and has the potential to be reintroduced [4].

Impact (environmental impact)
An alteration to the natural environment arising from the activity in question [1].

Interaction
The effect of ecosystem components on each other.

Intensity
The magnitude and/or duration of a pressure.

Likelihood
Chance of the occurrence of an event.

Mitigation
Limitation of the undesirable effects of a particular event [3, 5]

Pollution
The introduction by man, directly or indirectly of substances or energy into the marine environment which results, or is likely to result in hazards to human health, harm to living resources and marine ecosystems, damage to amenities or interference with other legitimate uses of the sea [1].

Pressure
The mechanism through which an activity has an effect on any part of the ecosystem. Pressures can be physical (e.g. abrasion), chemical (e.g. introduction of synthetic components) or biological (e.g. introduction of microbial pathogens), Koss et al 2011 [7].

Recovery
Recovery is defined as ‘a return to a normal state of health, mind, or strength’ (http://oxforddictionaries.com/), but such a ‘normal state’ is often not known for marine populations and ecosystems [8]. For the purpose of an EIA, the normal state can be established by baseline monitoring.

Review
Activity undertaken to determine the suitability, adequacy and effectiveness of the subject matter to achieve established objectives [6].

Risk
Combination of the probability of an event (the chance that a specified hazardous event will occur) and the (severity of the) consequences of the event [3, 5, 10].

Risk assessment
The quantitative evaluation of the likelihood of undesired events and the likelihood of harm or damage being caused together with the value judgments made concerning the significance of the results (Lloyds Register Definition).

Seabed
Material below the elevation of the sea floor or ocean floor [9].

Seafloor
Interface between the sea and the seabed [9]. NOTE Refers to the upper surface of all unconsolidated material, also termed mudline.

Sensitivity
The degree of effect on an ecosystem component due to the exposure of a pressure.

Species at risk
Extirpated, endangered or threatened species or a species of special concern [4]. Where 'extinction' means the end of a species, i.e. the death of the last individual of the species; 'extirpated' means locally extinct; 'endangered' means facing imminent extirpation or extinction; and 'threatened' means likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.

Stakeholder
Person or organization that can affect, be affected by, or perceive themselves to be affected by a decision or activity [6]. NOTE A decision maker can be a stakeholder.

Strategic Environmental Assessment
A systematic process for evaluating the environmental consequences of a proposed policy, plan or program initiative in order to ensure they are fully included and appropriately addressed at the earliest appropriate stage of decision-making on par with economic and social considerations [1].

The precautionary principle
Used by the Rio Declaration on Environment and Development and defined as follows: Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation [2].

Traditional knowledge (TK)
Is the accumulated knowledge of natural ecosystems, based on the spiritual health, culture, and language of the people, and which is passed to successive generations through stories, song, dance, and myths to ensure the survival of the people and the integrity of the socio-cultural and socio-economic systems of the people [2].

Justification

Rapport C192/13
Project Number: 4305 106 906

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Drs. M.J. van den Heuvel-Greve
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Signature:

Date: 3 December 2013

Approved: Drs. F.C. Groenendijk
Head department Maritime

Signature:

Date: 3 December 2013

Appendix A

Matrix of relevant activities per disturbance

Source: Karman & Jongbloed, 2008 [11]

Smothering
- dredging
- offshore oil and gas
- dumping of sludge
- surface mining
- trenching

Sealing
- wind parks
- land reclamation
- offshore oil and gas
- artificial islands
- coastal reconstruction
- pipelines

Siltation
- dredging
- land-based input (rivers, runoff)
- dumping of sludge
- trenching

Abrasion
- shipping
- fisheries
- dredging
- trenching

Selective extraction
- dredging
- surface mining
- bioprospecting
- scientific research
- trenching

Non-selective extraction
- pipelines
- cables

Noise
- dredging
- offshore oil and gas
- surface mining
- shipping
- wind parks
- ports
- fisheries
- tourism
- land reclamation
- coastal reconstruction
- artificial island
- trenching
- pipe laying
- working vessels (e.g. tugs, supply vessels, pipe carriers)
- defense activities

Visual
- wind parks
- offshore oil and gas
- artificial islands
- shipping
- tourism
- defense activities
- trenching
- pipe laying
- working vessels (e.g. tugs, supply vessels, pipe carriers)

Migration barrier
- wind parks
- land reclamation
- artificial islands
- pipelines

Electromagnetic radiance
- cables

Water/tidal flow changes
- land reclamation
- artificial islands
- pipelines
- coastal reconstruction

Introduction of synthetic compounds
- land-based input (rivers, runoff)
- offshore oil and gas
- dumping of sludge
- shipping
- fisheries
- tourism
- intensive mariculture
- atmospheric deposition
- defense activities
- wastewater treatment plant

Introduction of non-synthetic compounds
- land-based input (rivers, runoff)
- offshore oil and gas
- dumping of sludge
- shipping
- fisheries
- tourism
- atmospheric deposition
- defense activities
- wastewater treatment plant

Introduction of radio nuclides
- land-based input (rivers, runoff)
- offshore oil and gas

Nutrient enrichment
- land-based input (rivers, runoff)
- atmospheric deposition
- wastewater treatment plant

Organic enrichment
- intensive mariculture
- extensive mariculture
- dumping of sludge

Changes in thermal regime
- cooling water
- offshore oil and gas
- wastewater treatment plant

Changes in turbidity
- dredging
- offshore oil and gas
- dumping of sludge
- land-based input (rivers, runoff)
- surface mining
- wastewater treatment plant
- trenching
- pipe laying

Changes in salinity
- land-based input (rivers, runoff)
- cooling water
- offshore oil and gas
- coastal reconstruction
- wastewater treatment plant

Changes in pH
- CO2 storage

Introduction of litter
- tourism
- shipping

Introduction of microbial pathogens
- tourism
- wastewater treatment plant
- intensive mariculture
- extensive mariculture

Introduction of non-native species
- shipping
- tourism
- intensive mariculture
- extensive mariculture

Selective extraction of species
- fisheries
- bioprospecting
- scientific research

Appendix B

Overview of activities in International Regulation

An overview of the strength of regulation is presented in Table 1. The text below is taken over from the report of Karman & Jongbloed [11] and describes the different regulations.

Table 1. Analysis of the strength of regulation (enforcing power) of the various maritime activities, decreasing from 1 to 5. 1: EU EIA/SEA; 2: OSPAR; 3: ESPOO; 4: LC; 5: UNCLOS [11].

Activity	Strength of regulation
archeology	1 (3, 5)
artificial islands	2 (5)
artificial reefs	2 (4)
atmospheric deposition	-
bioprospecting	5
cables	2 (5)
CO2 storage	2 (4, 5)
coastal reconstruction	1 (3,)
cooling water	1 (3)
defense activities	5
desalination	-
dredging (harbors, waterways)	1 (2, 3)
dumping of (dredged) sludge	1 (3, 4, 5)
dumping, other	4
mariculture, extensive	-
mariculture, intensive	1 (2, 3, 5)
fisheries	1 (3)
hydro energy	1 (3)
land reclamation	1 (3, 5)
land-based input (rivers, runoff)	-
marine biofuel production (eg., algae, weed)	5
offshore oil and gas	1 (2, 3, 5)
pipelines	1 (2, 3, 5)
ports	1 (3, 5)
scientific research	5
shipping	5
aggregate extraction	1 (2, 3, 5)
tourism	1 (2)
wastewater treatment plant	1 (2)
wind parks	1 (2, 3, 5)

Regulated Activities by UNCLOS

UNLCLOS specifies various activities in sections throughout the Convention text. Included activities are:

Pollution from vessels
Dumping
Laying cables or pipelines
Marine Scientific research
Constructing and operating artificial islands and installations
Military activities
Archaeology
Marine prospecting

Regulated activities by LC

Annex 1 of the Protocol provides an overview of waste or other material that may be considered for dumping. The following is included in this annex:

dredged material
sewage sludge
fish waste (or material resulting from fish processing)
vessels/platforms/man-made structures at sea
inert, inorganic geological material
organic material of natural origin
bulky items primarily comprising iron, steel, concrete and similar unharmful materials for which the concern is physical impact, if no other disposal options (e.g., for small islands)
carbon dioxide streams from carbon dioxide capture processes

Regulated activities For EIA and SEA by Espoo Convention and Kiev Protocol and EU EIA and SEA directives

The EU EIA and SEA Directives, the Espoo Convention and the Kiev Protocol all refer to projects, plans or programmes which might be subject to environmental impact assessment. The basis for these lists if formed by the EU EIA directive, which is referred to directly in the EU SEA directive. The Espoo Convention list of activities is equal to the KIEV protocol List of Activities (Annex 1), which are in turn closely related to the EIA Directive's list of projects (Annex 1). Both the EU-EIA Directive and the Espoo convention further provide a (more detailed) list of 'other' projects (Annex II of both documents). All elements of the list provided by the Espoo Convention are also included in the list of the EU-EIA Directive. The latter also includes works for transport of water resources, waste water treatment plants, installations for intensive rearing of poultry and construction of overhead power lines. No differences exist, however, in activities related to the maritime area. In general, the list of the EU-EIA Directive is more detailed and includes size related criteria.

Projects referred to in the Convention:

crude oil refineries	waste disposal installations for incineration etc.
thermal power stations and other combustion and nuclear (thermal load)	large dams and reservoirs
production or enrichment of nuclear fuels	groundwater abstraction
smelting of cast-iron and production non-ferrous metals	pulp and paper manufacturing
extraction of asbestos	major mining and processing f ores or coal
integrated chemical installations	offshore hydrocarbon production
construction of motorways, railways, etc	major hydrocarbon storage facilities
large diameter oil and gas pipelines	deforestation of large areas
trading ports, inland waterways and ports	*any not listed activity that causes concern for transboundary impacts*

Plans or programmes referred to in the protocol:

Agriculture	waste management
Forestry	telecommunications
Fisheries	tourism
energy, industry including mining	town and country planning or landuse
Transport	
regional development	

Other projects if EIA required nationally (relevant selection for the marine environment):

intensive fish farming	fish-meal and fish-oil factories
Industrial installations for the production of electricity, steam, hot water	pipelines for transport of gas or oil
Industrial installations for carrying electricity, steam, hot water	pipelines for transport of chemicals with diam > 800 mm, length > 40 km
surface storage of fossil fuels and natural gas	construction of harbours and port installations
underground storage of combustible gases	trading ports, piers for loading and unloading
installations for hydroelectric power production	canalization of flood-relief works
wind parks	construction of airports and airfields
installations related to nuclear fuel or waste	sludge deposition sites
underground mining	coastal work to combat erosion and maritime works capable of altering the coast through construction
extraction of minerals by marine or fluvial dredging	marina's
deep drillings	reclamation of land from the sea
Shipyards	

Activities not covered by international regulation

- *Extensive mariculture*
  Extensive mariculture involves little or no input from the producer and relies on the natural production of a water body. Environmental effects relate to the potential introduction of alien species, extraction of species and reduction of biodiversity. The impact is considered low to medium, at a local scale.
- *Desalination*
  Desalination of seawater to produce fresh water for drinking or irrigation, leads to an effluent of high salinity, containing various process chemicals, that is often discharged into the marine environment. Intake of water for desalination usually results in a loss of marine species due to impingement (i.e., collision with screens at the intake) or entrainment.

Furthermore, when assessing cumulative effects of activities at sea, diffuse inputs might need to be considered as well.

- Atmospheric deposition
- Land-based input (rivers, runoff)

Appendix C

Overview of pressures

Source: The ODEMM Linkage Framework Userguide (Koss et al 2011 [7])

Pressure Code	Pressure Name	Pressure Definition	Listed in the MSFD
1.	Smothering	By man-made structures or disposal of materials to the seafloor.	Yes
2.	Substrate loss	Sealing by permanent construction (e.g. Coastal defences, wind turbines) or change in substrate type due to loss of key characteristic features (physical and/ or biological). Natural substrate is lost and replaced by a different kind of substrate	Yes
3.	Changes in siltation	Change in the concentration and/or distribution of suspended sediments in the water column from runoff, dredging etc.	Yes
4.	Abrasion	Physical interaction of human activities with the seafloor and with seabed fauna/flora causing physical damage and/or mortality (e.g. from trawling or anchoring).	Yes
5.	Selective extraction of non-living resources	Sand & gravel (aggregates) extraction, or removal of surface substrates for exploration of subsoil	Yes
6.	Underwater noise	Underwater noise created from shipping acoustic surveys, etc.	Yes
7.	Marine litter	Marine litter originates from numerous sources and consists of different materials including: plastics, metal, glass, rubber, wood and cloth.	Yes
8.	Thermal regime change	Change in temperature (average, range and variability) due to climate change, or more locally due to outfalls/industry.	Yes
9.	Salinity regime change	Change in salinity (average, range and variability) due to climate change, or locally due to constructions affecting water flow.	Yes
10.	Introduction of synthetic compounds	Introduction of pesticides, antifoulants, and pharmaceuticals into marine waters.	Yes
11.	Introduction of non-synthetic compounds	Introduction of heavy metals and hydrocarbons into marine waters.	Yes
12.	Introduction of radionuclides	Introduction of radionuclides into marine waters.	Yes
13.	Introduction of other substances	Introduction of solids, liquids or gases not covered by 10-12 or 14-15	Yes
14.	Nitrogen and Phosphorus enrichment	Input of fertilisers, and other Nitrogen & Phosphorous rich substances.	Yes
15.	Input of organic matter	Organic enrichment e.g. from industrial and sewage effluent into rivers and coastal areas, from aquaculture or from fishing discards.	Yes
16.	Introduction of microbial pathogens	Introduction of microbial pathogens into marine waters.	Yes
17.	Introduction of non-indigenous species and translocations	Introduction of non-indigenous species and translocations by the activities of a particular sector (e.g. through shipping or aquaculture).	Yes

18.	Selective extraction of species	Extraction (and subsequent mortality) of any marine fauna (vertebrate or invertebrate) from their natural habitat, including incidental non-target catch(e.g. by commercial fishing, recreational angling and collecting/harvesting).	Yes
19.	Death or injury by collision	Death or injury of marine fauna due to impact with moving parts of a human activity, e.g. marine mammals with ships/ jet skis, seabirds with wind turbines etc.	No
20.	Barrier to species movement	Preventing the natural movement of motile marine fauna along a key route of travel (e.g. a migration route) due to barrages, causeways, wind turbines, and other man-made structures.	No
21.	Emergence regime change	Changes to natural sea level regime (average, range and variability), e.g. widespread sea level rise due to climate change or locally due to barrages or other structures.	No
22.	Water flow rate changes	Change in currents (speed, direction, and variability) due to climate change, or locally due to barrages or other manmade structures.	No
23.	pH changes	Change in pH (average, range or variability) due to climate change or localized effects, e.g. runoff from landbased industry.	No
24.	Electromagnetic changes	Change in the amount and/or distribution and/or periodicity of electromagnetic energy emitted in a marine area (e.g. from electrical sources such as underwater cables).	No
25.	Change in wave exposure	Change in the size, number, distribution and/or periodicity of waves along a coast due to climate change, or localized due to installation of coastal structures.	No
26*.	Visual disturbance	Change in normal behaviour of species (e.g. avoidance of an area by birds) due to presence of humans; boats; airplanes; constructions; and flairs.	No*

* This pressure is not included in the ODEMM linkage table user guide (Koss et al 2011 [7]) but has been selected from (Karman et al 2009 [67]).