Collecting literature for identifying data sets and data sources

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IMARES Report C072/16

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Literature Review, Arctic Sea Basin Checkpoint

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Summary

Observations in the marine area are generally made with a specific purpose in mind. Costs can be reduced and marine knowledge improved when data are reused for multiple purposes. The EU is now actively moving towards this new paradigm. The Arctic Sea Basin Checkpoint (SBC) project addresses the availability of data sets, i.e. data provided in a coherent set from a specific source, describing a specific parameter (for instance temperature, salinity, bird behaviour, etc.), and will evaluate the quality and adequacy for multiple purposes in the Arctic.

The Arctic Ocean falls within the Arctic region, that can either be defined as the area above the Arctic Circle at approximately 66° 34' N or as the region with an average temperature of less than 10 °C (50 °F) in July. It consists of shelve seas and a deep Arctic Ocean Basin with mountain ridges and an average depth of 1,000 m, with a maximum depth of 5,450 m. There is inflow of Atlantic and Pacific Water and the Arctic deep water. The Arctic Ocean receives a large amount of fresh water from rivers compared to other oceans. Most of the Arctic Ocean has a top layer with a relative low salinity and low temperature. The Arctic Ocean is covered with an approximately 1-4 m thick sea ice layer with 1 m thick ice being relative freshly formed and 4 m thick ice being multi-annual. The Arctic region experiences long and cold winters (temperatures range from -34 °C to 0 °C in January) and short and cool summers (temperatures range from -10 to +10 °C in July). Over the past 50 years the mean surface air temperature has increased globally but most pronounced in the Arctic (more than 2° C). Due to climate warming the sea ice content is decreasing.

The Arctic houses a wide variety of species that are adapted to extreme conditions and are unique for this region. Species are often highly dependent on each other for food and some of the species, such as ice algae and bearded seals, are dependent on the presence of floating ice.
About 4 million people live in the Arctic region of which 10% are indigenous to the region. The Arctic Sea Basin covers a number of seas under national jurisdictions (USA, Canada, Greenland/Denmark, Norway and Russia) as well as areas beyond national jurisdiction (high seas). Retreating sea ice in the Arctic opens up possibilities for increased human exploitation of the Arctic region. Especially the following human activities may increase in the future: Shipping; Fisheries; Oil & Gas exploitation and mineral extraction; and Tourism.

A lot of monitoring programs and databases are developed and coordinated within the separate Arctic states. Additionally larger international monitoring programs and databases are: EMODnet portal; Arctic Council working groups; Copernicus; International Council for the Exploration of the Sea – ICES; The Sustaining Arctic Observing Networks; The Arctic Portal; ArcticData; ACADIS; The Arctic Science Portal; and European Ocean Biogeographic Information System.

As part of the Arctic SBC project, a literature search was performed with the objective to identify data sets used in those documents and to evaluate whether the data sets are adequate for the purpose(s) of those documents. The report at hand describes a framework for such an evaluation. However, the actual evaluation is not yet performed. Here we focussed on a systematic approach for searching literature, in order to obtain an initial body of literature for the objectives described above.

Four different sources were used to obtain relevant literature:

- the specific websites listed in the project proposal were searched for relevant documents;
- peer reviewed literature was obtained from two search engines Scopus and Web of Science;
- additional (“grey”) literature was obtained from the Google search engine;
- the examples of literature listed in the project proposal, being: Lichota and Wilson (2010); Tedsen et al. (2014).

Searches in search engines were performed with predefined keywords. Different searches were specified for different themes, where each theme was represented by a work package in the Arctic SBC project. Search results were screened for relevance based on several criteria:

- related to the Arctic;
- relevant for the selected themes;
- a technical report or peer reviewed publication that describes the assessment of the state, exploitation or change of the marine environment or parts thereof.

On the specific websites, 1075 documents were found, of which 78 were considered relevant for our objectives. The searches on Scopus and Web of Science resulted in tens of thousands of hits. These were narrowed down to the 1,480 most relevant hits based on the applied keywords. After screening 511 documents were considered relevant. Of those 511 documents, 432 were available (from the WUR library) and included in the literature overview. Advanced searches in Google do not list the amount of hits, but were estimated to be around hundreds of thousands. For the search of each theme, the first 10 pages of hits were screened for relevance. In total 136 relevant documents were found with Google.

After merging the references from each of the four sources (and removing duplicates) 625 relevant documents were collected. 22 of those 625 were discovered on multiple sources. This indicates that these sources were complementary to each other. The documents were also linked to specific purposes / themes.

The 625 documents will be used in the future steps of the projects. They will be used to identify data sets and to evaluate the adequacy of those data sets for the purpose of the assessment reports. This evaluation will be presented in a separate report.

References in literature to goals not achieved because of inadequacy of data (e.g., unable to estimate coastal erosion accurately) have been listed for each assessment purpose. The main data limitations could be attributed to a lack of measurements. This was the case for the purpose of: Assessment of environmental impact and ecological status; Marine spatial planning; Assessment of (potential) MPAs; Assessment of navigational risks; and Assessment of risks posed by invasive species. For some other purposes inadequate data could also be attributed to other causes: Oil spill response (time to obtain data); Assessment of climate change and Assessment of coastal evolvement (lack of accuracy /precision); Fisheries management and impact and Assessment of riverine input (Reluctance of data-owners to release data).

Acronyms and definitions

The present report requires a good understanding of specific definitions and acronyms. A list of those is therefore provided in this chapter.

Additional purpose	The purpose for which a data set is used in an assessment report (see also 'original purpose').
Adequacy	The adequacy (or a set of indicators reflecting adequacy) of a data set used for a specific purpose (of an assessment report).
Assessment report	A technical report or peer reviewed publication that describes the assessment of the state, exploitation or change of the marine environment or parts thereof.
CMS	Content Management System. An online system which is part of the Arctic Sea Basin portal, in which data sources, data sets, assessment reports and parameters can be registered, including relations between these aspects.
DAR	Data Adequacy Report. In this report the adequacy of data sets is described.
Data set	Data provided in a coherent set from a specific source, describing a specific parameter (for instance temperature, salinity, bird behaviour, etc.)
Data source	The source (e.g. data portal) from which a data set is made available. This can for instance be an organisation or an initiative.
Mendeley	Software used to manage references in the literature review (https://www.mendeley.com/).
MPA	Marine Protected Area.
Original purpose	The purpose for which a data set was originally produced (see also 'additional purpose').
Parameter	A specific aspect describing the state or change of the marine environment (for instance temperature, salinity, bird behaviour, etc.). The common P02 vocabulary developed for SeaDataNet[1] is used and extended where necessary.
P02	A controlled vocabulary from SeaDataNet used to describe parameters.
Quality	The intrinsic quality (or indicators reflecting the quality) of a data set.
SBC	Sea Basin Checkpoint.
WP	Work Package.

[1] http://seadatanet.maris2.nl/v_bodc_vocab_v2/search.asp?lib=P02

1 Introduction

1.1 Background

Observations in the marine area are generally made with a specific purpose in mind. For example, bathymetry is surveyed to ensure safe navigation, fish are sampled to estimate the size of the stock and pollution concentration is measured to meet regulations on bathing water or agriculture production. Costs can be reduced and marine knowledge improved when data are reused for multiple purposes, other than for they were generated. The EU is now actively moving towards this new paradigm. But it is commonly known that, once the direct link between the collection of data and its application is broken, it becomes hard to determine what the priorities are for monitoring and who should monitor what. Furthermore, in order to avoid gaps and duplications, it is essential that each coastal state knows what its neighbours are doing.

The Marine Knowledge 2020 concept of sea-basin checkpoints was introduced within the "Marine Knowledge 2020" Communication and refined in the Roadmap, where each sea-basin is studied in separate projects. The literature review presented in the report at hand is part of such a Sea-Basin Checkpoint (SBC), namely: the Arctic SBC. The geographical scope of this SBC is the Arctic Ocean as defined in the CIA fact book (https://www.cia.gov/library/publications/the-world-factbook/) and refers to the body of water between Europe, Asia, and North America, mostly north of the Arctic Circle (see Annex 1). It thus includes Baffin Bay, Barents Sea, Beaufort Sea, Chukchi Sea, East Siberian Sea, Greenland Sea, Hudson Bay, Hudson Strait, Kara Sea, Laptev Sea, Northwest Passage, and other tributary water bodies.

Though the European Union has no direct coastline with the Arctic Ocean, the European Union is inextricably linked to the Arctic by a unique combination of history, geography, economy and scientific achievements (EC, 2016). Beyond areas of national jurisdiction, the Arctic Ocean contains parts pertaining to the high seas and the seabed managed by the International Seabed Authority. The sustainable management of the Arctic high seas are a global responsibility, hence also for the European Union. Furthermore, three Arctic States are also EU Member States: Denmark; Sweden; and Finland. The European Union furthermore maintains close relations with Iceland and Norway as members of the European Economic Area, while countries such as Canada and the United States are strategic partners of the EU (EC, 2016).

1.2 Arctic SBC

The literature review presented in the report at hand is part of the Arctic SBC. In addition to the literature review, the Arctic SBC is comprised of Work Packages (WPs) in the form of challenges (e.g., wind farm siting or assessing riverine input). Each challenge is designed such that it addresses data availability and adequacy for a specific additional purpose. The overarching objectives of this project is to examine the current data collection, observation, surveying, sampling and data assembly programmes in a sea basin, analyse how they can be optimised and deliver the findings to stakeholders through an internet portal. This is done by:

- a clearer view of synergies between different monitoring, observation and data collection programmes;
- an identification of how well the present data collection, monitoring and surveying programmes meet the needs of users;
- an identification of gaps;
- a view of where new technologies will allow faster, quicker and more accurate observation;

- an understanding of required temporal or spatial resolution of data products such as bathymetry or marine sediments;
- contribute to the identification of priorities both in terms of creation of new data and making existing data more available and usable. It will also help the Commission to determine priorities in the context of the "Marine Knowledge 2020" initiative. It follows a request for such a process in the public consultation on "Marine Knowledge 2020";
- assess how well all available marine data meets the needs of users.

1.3 EMODnet

Long term sustainable economic growth is the highest priority in the EU at the moment. One of the key drivers of sustainable growth is the concept of 'smart growth'. Smart growth means developing an economy based on knowledge and innovation. The marine and maritime sector or 'blue economy' was identified in a public consultation as having great potential and making a major contribution towards meeting Europe 2020 objectives. Again, emphasis was put on the importance of innovation. Innovation stems from having a strong, freely accessible knowledge base. Both the private and public sector need to contribute to and use the system. Knowledge management becomes therefore more important than ever.

In order to achieve the goals of the blue economy the EU has taken initiatives to improve the collection and accessibility of marine data. Already in 2007 the EU developed the principal of a European Marine Observation and Data Network (EMODnet) which would centralise European marine data according to one standard. The rationale behind a centralised network of data is to:

- Help the private sector compete in a global market, improve public decision making and improve scientific research by reducing the operating costs and delays experienced by these users, and
- Increase competition and innovation amongst users and re-users of marine data by providing wider access to quality-checked, rapidly available coherent marine data.

EMODnet is organised by 'lots' currently comprising:

- EMODnet-Biology
- EMODnet-Chemistry
- EMODnet-Physics
- EMODnet-Geology
- EMODnet-Bathymetry (previously Hydrography and Sea Bed Mapping)
- EMODnet-Physical habitats (previously Habitats)
- EMODnet-Human activity

1.3.1 EMODnet Checkpoints

EMODnet has initiated the Sea Basin Checkpoints to determine gaps in data and observation systems and priorities for an observation system that supports the delivery of sustainable growth and innovation. The overarching aim is to support the deployment of a marine observation infrastructure that offers the most effective support to the blue economy. The cost-effectiveness, reliability and utility of the existing monitoring infrastructure are to be assessed by developing products based on these data and to determe whether the products are meeting the needs of industry and public authorities. There are Sea Basin Checkpoint projects for the following basins: Atlantic Ocean, Arctic Ocean, Baltic Sea, North Sea, Mediterranean Sea and Black Sea.

1.3.2 The Arctic Checkpoints

Wind farm siting

The objective of this challenge is to find economically viable areas for offshore wind energy (OWE) development with little impact on both the ecosystem and other human activities, in the Norwegian Sea and Barents Sea. A collection of geographical datasets will be used in a GIS, for a multi-criteria analysis, to locate areas that meet technological requirements (a.o. water depth, wind and sea conditions), are economically viable (close to a market) and where possible outside areas that are important for the ecosystem and human activities. The result is a map highlighting the most suitable areas for OWE development, split by technology options (e.g. fixed or floating turbines). Elsewhere the number of conflicts will be shown, and if possible allowing access to information on what these conflicts are. The method and choices will be documented in a report.

Marine protected areas

In this challenge the network of Arctic MPAs is analysed, classifying them and describing their coherence and vulnerability to climate change. Data on MPAs from existing sources are gathered in a georeferenced database, classifying them according to the IUCN classification and analyse their coherence using OSPAR criteria. How species and habitats are affected by climate will be assessed. The result of this challenge is a report, maps and data layers showing an understanding of whether the available data is sufficient to predict the ecological coherence of a network of MPAs and how representative they might be of the Arctic. It also comprises an understanding of possible effects of climate change on the network of MPAs in the Arctic.

Oil platform leak

The objective of this challenge is to test the preparedness of operational tools for forecasting the effects of an oil spill. The challenge has the form of an unexpected oil spill in the Arctic region. The challenge inputs are organized through the series of Key Questions the responder will need to ask regarding the incident for the initial information required for forecasting the effects and information required to prepare products for response personnel:

1. What was spilled? – The nature of the product, particularly persistence and toxicity. Light condensates or light, highly refined products have initial high toxicity, but are not very persistent in the environment. Heavy fuel oils are very persistent, but not very toxic, usually causing harm via oiling fur or feathers or smothering. Crude oils have different combinations of both these characteristics.
2. Where will it go? – The trajectory of the spill is key information for providing basis for executing the response efficiently and estimating environmental risk.
3. Who will it hit? – Natural resources in the area vary in sensitivity to oil contact. Responders need to know the timing and variety of organisms in the path of the oil spill and their varying sensitivity to oil contact in order to best organize the response to minimize harm. Safety of human responders from inhalations, oil contact and other risks is also critically important.
4. How could the oil spill affect society? – Oil spills can lead to loss in revenues from tourism and lack of public trust.

Climate change

Climate change evaluates publicly available data on past climate change in the Arctic Ocean, for which nine parameters have been selected, focusing on temperature, ice and phytoplankton.
First all available data will be collected. Since all data will probably be provided in several different formats, the data will be processed to a uniform data format. Once everything is available, the data will be analysed, evaluated and data from different data sources will be compared. If needed, data will be combined into time series or geographical areas. For each parameters trend analyses over a period of 20, 50 and 100 years are performed. If data are missing, or data from different sources are inconsistent, it may be impossible to derive those parameters for the whole period, for the entire area or with a desired accuracy utilizing trends or numerical models.

Coasts

The Coast Challenge aims to produce spatial data layers and time plots for the parameters sea level rise and sediment balance per stretch of coast for the Arctic study area.

Sea level rise is influenced by changes in atmospheric pressure, melting of sea ice and polar ice caps and water temperature. A dramatic sea level rise acceleration in the Arctic Ocean was reported in the 1980s. The changes in the patterns of wind-driven and thermohaline circulation may account for the major increase of sea level in the Arctic Ocean and their accumulative action can explain more than 80% of the sea level variability during 1950-1990. In light of global change, this sea level rise could be a manifest of warming in the Artic coupled with a decrease of sea ice extent, warming of the Atlantic waters, changes in the Arctic Ocean circulation, and an increase in coastal erosion and thawing of permafrost. This also affects the sediment balance, which is defined as the amount of each type of sediment present along the Arctic coast. Thousands of kilometers of Arctic sea coast retreat 2-6 m/year under that action of shore erosion. This means that tens of square kilometers of Arctic land are lost to the sea every year. This shore erosion is a source of sediment moving from the sea to the land. Therefore, it plays a substantial part in formation of the Arctic sea sediment balance. Sediment discharge from rivers is a second important input into the sediment balance.
In this challenge we will assess whether the availability, consistency and resolution of existing data in these aspects is sufficient and if this is the case to calculate the average annual sea level rise and sediment balance per stretch of coast.

Fisheries management

Future changes in the Arctic place increasing importance on fisheries governance. This challenge aims to compile vital fisheries data to support region wide management. Through strong links with countries and Regional fisheries management organisations (RFMOs) collecting data in the Arctic sea basin, relevant databases will be identified, and where possible made available via the EMODnet portals. The available data will be scrutinised with a focus on gaps in available data and future data requirements for the region. The outcome will be tables for the Arctic region, by species with the highest spatiotemporal resolution possible, of mass/number of landings of fish and mass/number of discards and bycatch (incl. elasmobranchs, mammals, reptiles and seabirds). An analysis will be made of the available data quality and notable knowledge gaps.

Fisheries impact

The challenge on Fisheries Impact will examine the data relevant for assessing the impact of the most common fisheries in terms of its availability, accessibility and quality. There is increasingly more sophisticated information capable of providing more accurate indicators for seafloor disturbance but which also comes with increasing data requirements. This information includes capacity, logbook and VMS-based data on fishing activity as well as habitat maps. In this challenge all this information is considered. Using this information we will provide spatially and temporally resolved estimates of fishing impact.

River input

The objective of this challenge is to create time series of River related parameters: Water and Sediment Discharge, Temperature, Total Nitrogen, Phosphates and Salmon and Eel migration. Furthermore sources of information and knowledge gaps will be identified. In the first phase a literature review is carried out. A database of metadata will be created for all variables and data sources. In the second phase, the review phase, this database will be used to obtain an overview of data overlap, deficiencies, and other properties. Once the database is complete it is used to generate the time series.

Bathymetry

The availability of reliable information on bathymetry is essential for the maintenance of navigational safety. This challenge will explore the availability of suitable information on bathymetry and the confidence in available data, particularly taking account of the requirements for safe navigation.

Alien species

The objective of this challenge is to provide an up-to-date overview of alien species (non-indigenous species) in the Arctic with all relevant available data in an easily accessible form. Economic activities will increase the risk of introducing invasive non-indigenous species into the Arctic Ocean. Based on the many available databases that exist on non-indigenous species, an overview will be made on the non-indigenous species in the Arctic Ocean. As a result of this challenge, tables and interactive maps

will be produced of non-indigenous species in the Arctic Ocean. Both the table and map should provide information on the alien species in the form of taxonomy, year of introduction, reason for introduction, geographical area, impact on ecosystem and industrial facilities, and impact on economy.

1.4 The Marine Strategy Framework Directive

The Marine Strategy Framework Directive (MSFD) is the first dedicated and comprehensive piece of EU legislation explicitly aimed at the protection of the marine environment and natural resources. It creates a framework for the sustainable use of European marine waters through a flexible approach that respects the principle of subsidiarity. It defines common objectives to be met but is not overly prescriptive giving Member States the requisite flexibility needed to implement the Directive within their geographically-specific context. The overarching aim of the MSFD is to achieve good environmental status (GES) of the marine environment by 2020 and to protect the resource base upon which marine-related economic and social activities depend. The MSFD was adopted on 17 June 2008 and came into force on 15 June 2008. The first applicable deadline was transposition of the Directive's provisions into national legislation, which was required by 15 July 2010.

In order to achieve GES by 2020 each Member State is required to develop a strategy for its marine waters (or Marine Strategy). To assist Member States in achieving GES and in implementing the provisions of the Directive, a set of eleven qualitative descriptors are put forward in Annex I which describe what the environment will look like when GES has been achieved (see Table 1). A more detailed set of criteria and indicators to aid Member States in determining what each descriptor means in practice and to assist in measuring progress was published by the European Commission in 2010. Member States were required to conduct an initial assessment of the current environmental status of their marine waters in accordance with Article 8 by 15 July 2012. Simultaneously they also had to determine what GES means for their marine regions and sub-regions (Article 9) and identify environmental targets and indicators to assist in achieving GES by 2020 (Article 10).

Table 1. *The Descriptors used to determine GES (Annex I. MSFD)*

Descriptor number	Description
1	Biodiversity is maintained
2	Non-indigenous species do not adversely alter the ecosystem
3	The population of commercial fish species is healthy
4	Elements of food webs ensure long-term abundance and reproduction
5	Eutrophication is minimised
6	The sea floor integrity ensures functioning of the ecosystem
7	Permanent alteration of hydrographical conditions does not adversely affect the ecosystem
8	Concentrations of contaminants give no effects
9	Contaminants in seafood are below safe levels
10	Marine litter does not cause harm
11	Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Table 2 gives the relationship between the challenges and the descriptors of the MSFD. If there is a strong link, e.g. biodiversity D1 is important for the MPA challenge, this is indicated with an X. If there is a connection, but weak (e.g. oil leaks can induce contaminants in sea food) this indicated by an (x). Europhication (D5) is not scored because this is not formulated as a challenge for the Arctic Checkpoint.

Table 2. *Relationship between the challenges and descriptors of the MSFD.*

Challenge	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11
Wind farm siting	X			(x)		X	(x)				X
MPA	X			X		X	X	X		X	X
Oil platform leak								X	(x)		
Climate change	(X)	(x)									
Coasts						x	(x)				
Fisheries management	(X)		X					(x)			
Fisheries impact	X		X	(x)							
River input	(X)										
Bathymetry						X					
Alien species	X	X		(x)							

X: strong link; (X): weak link

1.5 Objective

For the literature review presented here, the objective is to identify and retrieve literature, from which relevant data sets and their sources can be identified and assessed with respect to availability, quality and adequacy.

The following objectives are part of this report:

- to define terms relevant for the Arctic SBC literature review
- to set up a framework for the management and assessment of data sets, based on the relation between relevant literature, data sets used in literature and the sources (i.e., data portals) from which the data set can be obtained
- to set up a systematic literature search such that
    - the effort made becomes clear
    - an initial body of literature is generated
- to perform the literature search and therewith identify relevant literature
- to identify future steps in order to complete the literature review.

The following questions to address the overall objective of the literature review will be answered in a different report (the so-called Data Adequacy Report) on the analysis of literature and data sets:

- what existing overviews of data are available?
- are there statements in literature to goals not achieved because of inadequacy of data (e.g. unable to estimate coastal erosion accurately)?
- is inadequacy due to reluctance of data-owners to release data, time taken to obtain data, lack of measurements, lack of accuracy or lack of precision?
- are there any statements made as to fitness for purpose of data– e.g. for fish stock or environmental assessments, for spatial planning, for licensing, for coastal protection, for safe navigation.

2 The Arctic Sea Basin

Information between quotation marks is taken directly from the respective websites.

The Arctic Ocean, as defined in the CIA fact book, includes Baffin Bay, Barents Sea, Beaufort Sea, Chukchi Sea, East Siberian Sea, Greenland Sea, Hudson Bay, Hudson Strait, Kara Sea, Laptev Sea, Northwest Passage, and other tributary water bodies. This falls within the Arctic region, that can either be defined as the area above the Arctic Circle at approximately 66° 34' N (see dashed blue line in Figure 1) or as the region with an average temperature below 10 °C (50 °F) in July (see red isotherm in Figure 1). The Arctic region consists of an ocean surrounded by land. The following states surround the Arctic Sea Basin: United States, Canada, Iceland, Greenland (Denmark), Norway, Sweden, Finland and Russia.

Figure 1. *The Arctic region, defined as the area above the Arctic Circle (dashed blue line) or the area north of the red isotherm, with all territory to the north having an average temperature of less than 10 °C (50 °F) in July (https://en.wikipedia.org/wiki/Arctic_Ocean).*

2.1 Abiotic environment

2.1.1 Bathymetry

The Arctic Ocean consists of shelve seas and a deep Arctic Ocean Basin with mountain ridges and depth up to 5 km (Figure 2). The shelve seas are found on the Canadian and Russian sides of the Basin. The Lomonosov Ridge divides the Arctic Ocean Basin into two basins: the Eurasian Basin (4,000-4,500 m deep) and the Amerasian Basin (about 4,000 m deep). The average depth of the Arctic Ocean is 1,000 m, with a maxumum depth of 5,450 m.

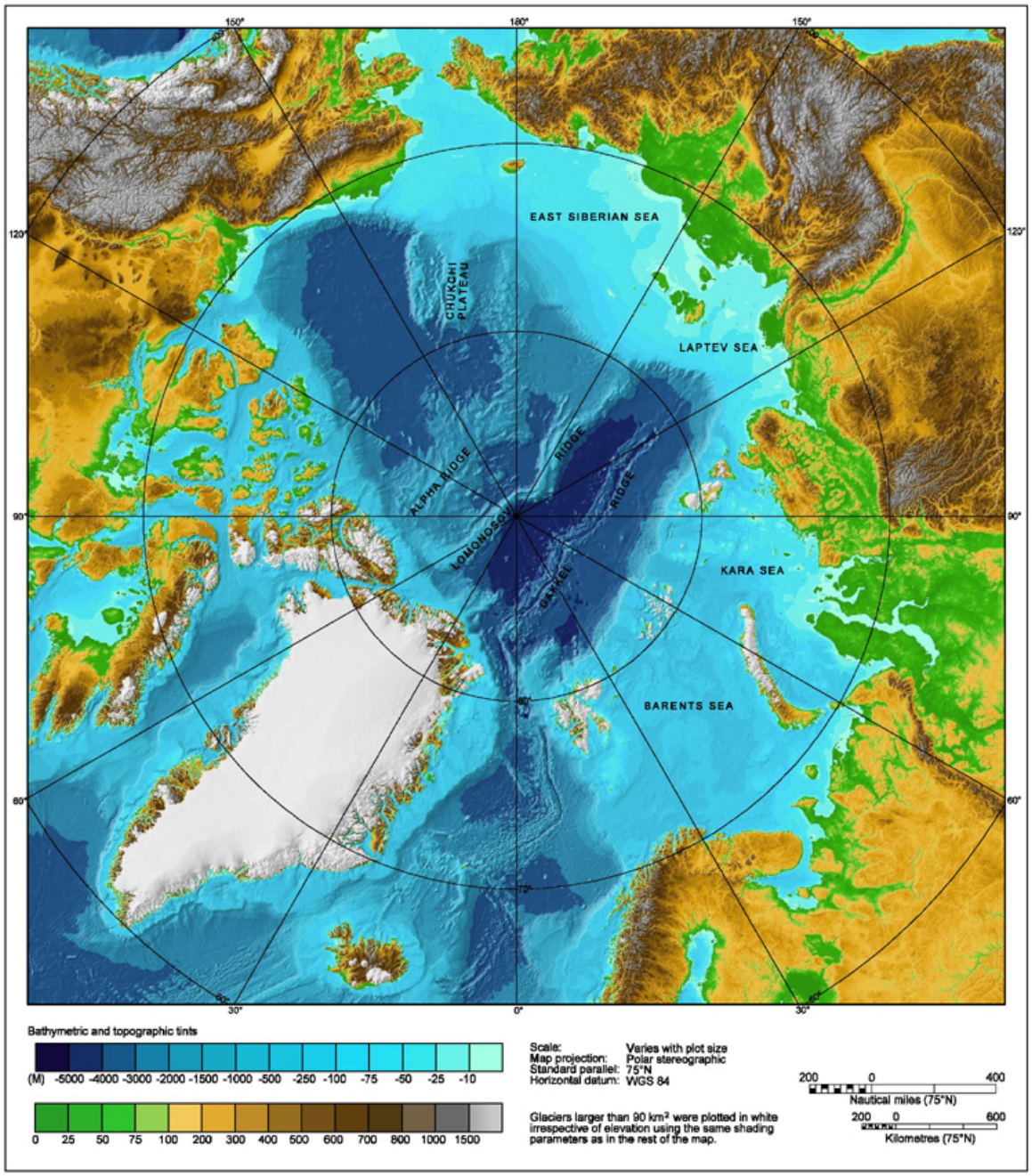


Figure 2. *Bathymetric map of the Arctic Ocean(http://www.ngdc.noaa.gov/mgg/image/IBCAO_betamap.jpg).*

The availability of reliable information on bathymetry is essential for the maintenance of navigational safety. Hydrographic survey and the publication of navigational charts is an important priority for national hydrographic agencies. This is supported by the work of local port and harbour authorities who are responsible for navigational safety within their port and harbour limits. Many coastal and

estuarine areas are very dynamic as a result of prevailing coastal processes and bathymetries may change rapidly as a result of changes in seabed morphology. In such areas, up-to-date hydrographic information is very important in ensuring that vessels can access and leave ports and harbours safely. A good knowledge of navigable depths in ports and harbours is also important commercially as accessibility is a key competitive advantage, particularly as the draughts of vessels continue to increase.

2.1.2 Currents

The Arctic Ocean connects to both the North Pacific through the Bering Strait, and the North Atlantic through the Greenland and Barents Seas. Pacific water enters the Arctic Ocean via de Bering Strait, whereas Atlantic water reaches the Arctic Ocean mainly via the Fram Strait, between Greenland and Svalbard, and via the Barents Sea (Figure 3). The dominant currents in the Arctic Ocean are the Beaufort Gyre, with a wind-driven clockwise circulation, and the transpolar drift, transporting sea ice from the East Siberian Sea and Laptev Sea towards the Fram Strait.

Figure 3. *Predominant surface ocean currents in the Arctic (AMAP, 1998).*

The Arctic Ocean composes of different water masses: the inflow of Atlantic and Pacific Water (and consequent halocline layers) and the Arctic deep water (Figure 4). The Arctic deep water is very dense and is composed of cold Arctic shelf water that sinks to the bottom and Greenland Sea Deep Water. Most of the Arctic Ocean has a top layer with a relative low salinity and low temperature (Polar Mixed Layer). This layer is fed by fresh water from rivers in Russia and Canada. On the European side of the Arctic Ocean, more saline surface waters enter from the Greenland and Barents Seas. The Pacific derived waters are fresher, and therefore lighter, than the North Atlantic waters, so the water properties across the Arctic Ocean integrate these two extremes. The deep Arctic Ocean is filled from the Atlantic side and represents a more recent history of deep water formation.

Beneath the water surface is the "Great Conveyor" of global heat transport, first discussed by Broecker (1991). This process begins in European waters with deep water formation off the eastern coast of Greenland, where saline waters derived from the Gulf Stream cool and evaporate to create water dense enough to sink to the ocean bottom. Monitoring of Denmark Strait and Faroe-Shetland Channel indicates this process of deep water production is slowing (Dickson and Brown 1994, Dickson et al. 2002) and the surface waters are freshening (Reverdin 2014). Overturning in the North Atlantic is now known to be slowing with more of the northward Gulf Stream water recycling within the North

Atlantic subtropical gyre and less in the North Atlantic Deep Water (NADW) (Bryden et al. 2005), but deep understanding of the variability is lacking.

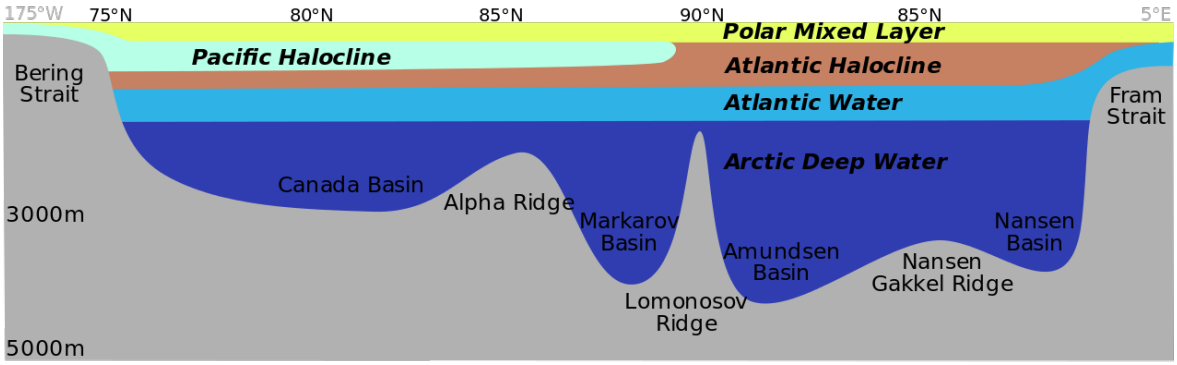


Figure 4. *Distribution of the major water mass in the Arctic Ocean. The section sketches the different water masses along a vertical section from Bering Strait over the geographic North Pole to Fram Strait. As the stratification is stable, deeper water masses are more dense than the layers above (https://en.wikipedia.org/wiki/Arctic_Ocean).*

2.1.3 Sea ice

The Arctic Ocean is covered with a 1-4 m thick sea ice layer with 1 m ice layer being relative freshly formed and 4 m thick ice layer being of multi-annual age. In winter the sea ice coverage grows, whereas in summer it shrinks again. Due to climate warming both sea ice extent (coverage) and volume are decreasing (Figure 5). Sea ice extent has been decreasing since the 1970s and appears to be accelerating, potentially related to changes in the melting season (Stroeve et al. 2007, Stroeve et al. 2014, Xia et al. 2014).

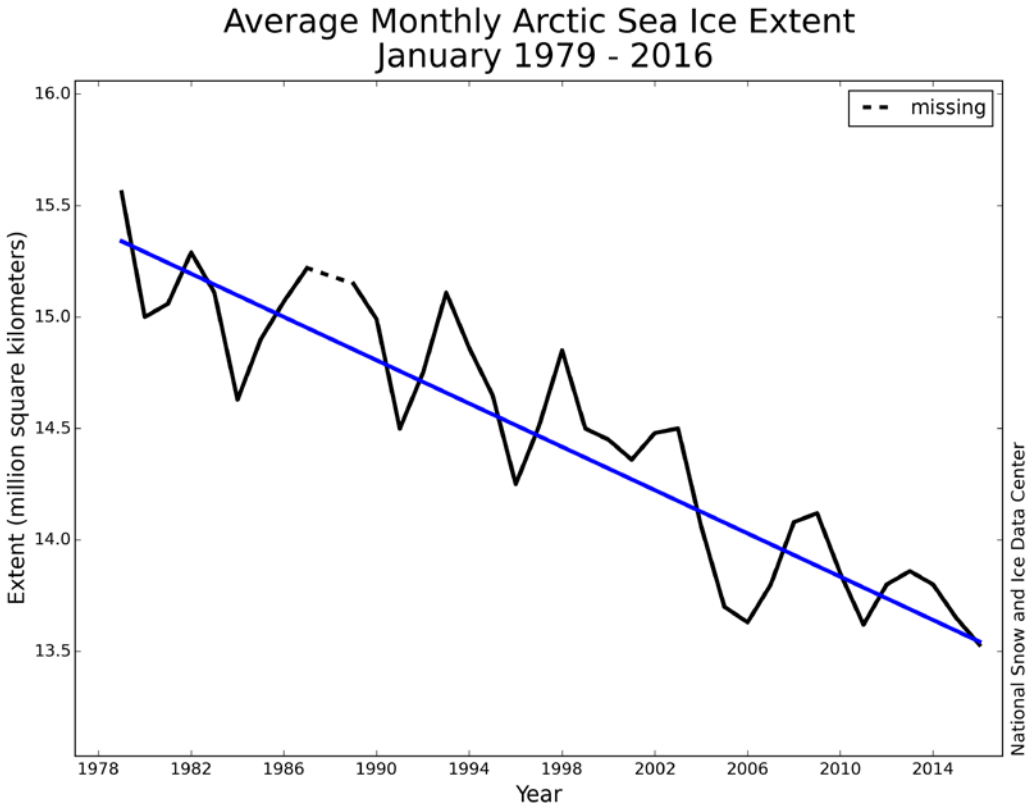


Figure 5. *Monthly January ice extent for 1979 to 2016 shows a decline of 3.2% per decade (National Snow and Ice Data Center).*

2.1.4 Climate

The Arctic region experiences long and cold winters and short and cool summers. This is due to the fact that within the Arctic Circle the sun disappears during the winter months and continuously shines during summer. The ocean water controls the temperature of the Arctic climate in coastal areas: in winter the ocean water (with a minimum temperature of -2 °C) prevents the air to cool down to extreme low values, whereas in summer the ocean cools the air preventing high temperatures. This moderating effect is stronger in summer than in winter as extended sea ice in winter can form an insulating layer preventing heat from the ocean from escaping to warm the air. Average January temperatures range from about -34 °C to 0 °C and average July temperatures range from about -10 to +10 °C. Predominant air masses are shown in Figure 6.

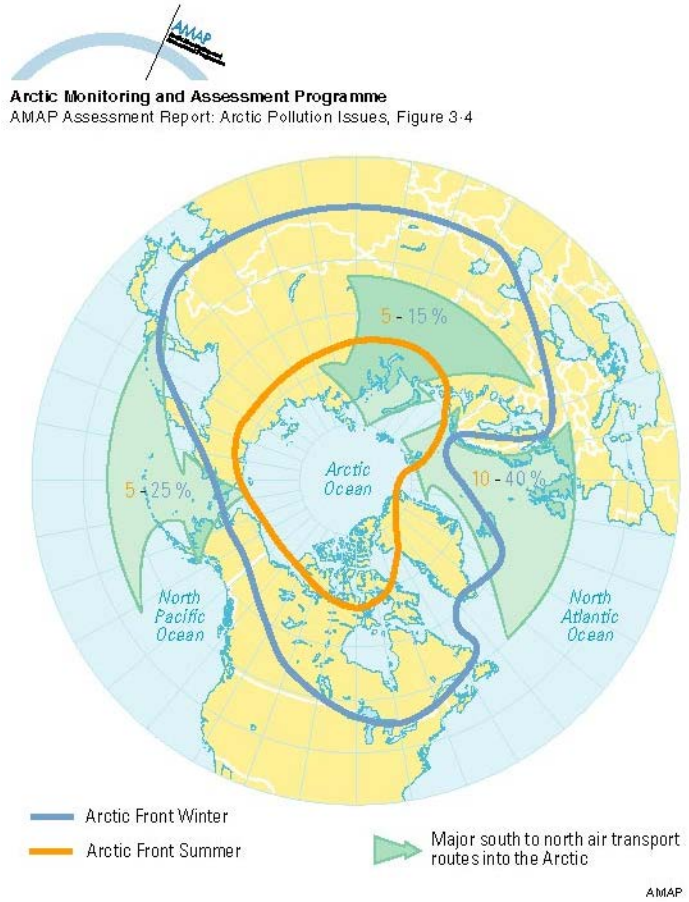


Figure 6. *The mean position of the Arctic air mass in winter (January) and summer (July), superimposed on the (summer value % (orange) - winter value % (blue)) frequency of major south-to-north transport routes into the Arctic (AMAP, 1998).*

Over the past 50 years the mean surface air temperature has increased globally. The increase is most pronounced in the Arctic and is more than 2° C (Figure 7).

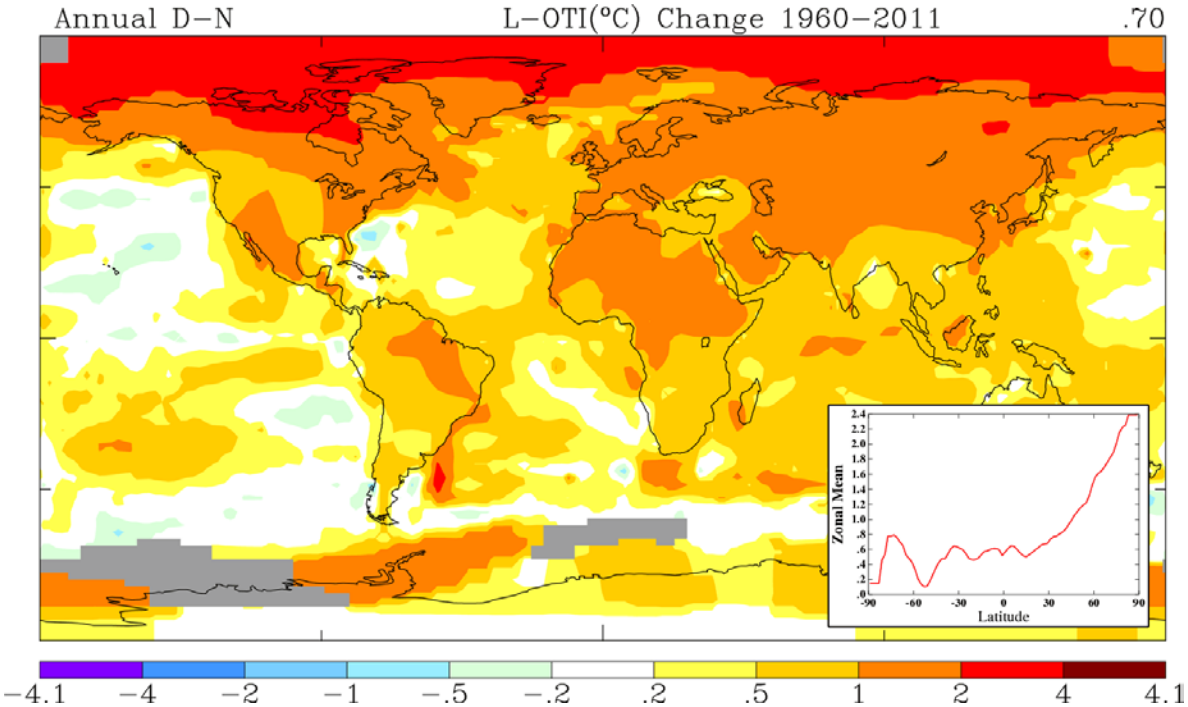


Figure 7. *Trends in mean surface air temperature over the period 1960 to 2011. The Arctic shows a red colour, indicating that the trend over this 50 year period is for an increase in air temperature of more than 2° C across much of the Arctic, which is larger than for other parts of the globe. The inset shows linear trends over the period by latitude (Credit: NASA GISS).*

2.1.5 Geology

The Arctic Ocean can be divided into two primary basins, the Eurasian Basin and the Amerasian Basin. The surface sediments of the Eurasian Basin are mainly silty clay or clayey silt, like the sediments in the western Arctic Ocean (Vorren & Thiede, 1994). Sea ice probably is the main primary source of the modern and Holocene sediments. Organic carbon content varies between 0.5 and 2% and is mainly of terrigenous origin. Higher amounts of marine organic matter are only preserved in the area north of Svalbard, indicating at least occasional ice-free conditions and increased surface-water production due to the influence of the West-Spitsbergen Current (Vorren & Thiede, 1994).
Figure 8 shows the bedrock geology of the Arctic.

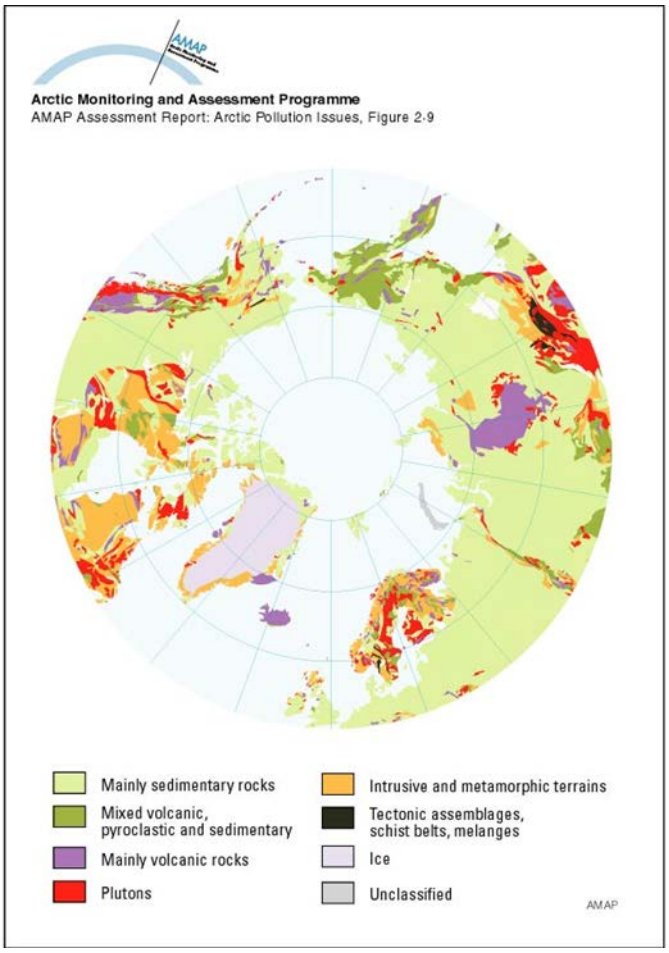


Figure 8. *Bedrock geology of the Arctic (AMAP, 2007).*

2.1.6 Rivers and coast

The Arctic Ocean receives a large amount of fresh water from rivers compared to other oceans. The major river basins in the Arctic Ocean are the Ob, Yenisey and Lena in Russia, and the Yukon and Mackenzie in the USA (Figure 9).

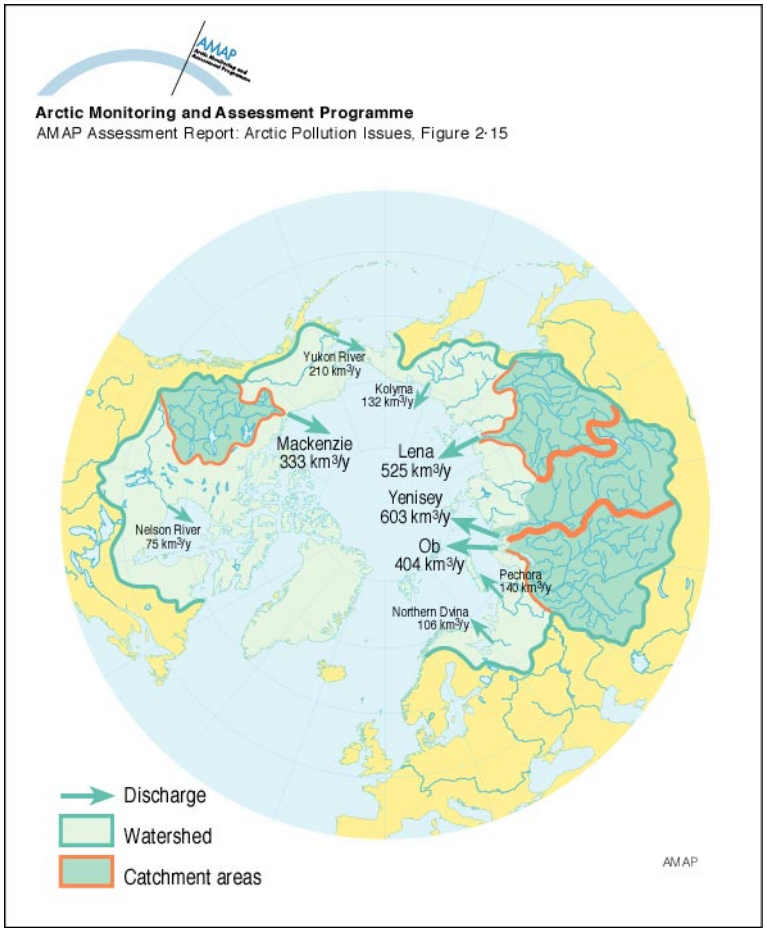


Figure 9. *Arctic Ocean watershed and catchment areas of some rivers and annual run-off (km^3/y) of major rivers to the Arctic Ocean (AMAP, 1998).*

Rivers form an important link of interaction between the land and the oceans. They naturally discharge water, loaded with sediment and nutrients into the seas and are home to both migratory and non-migratory fish species that depend on the river during all or part of their life cycle. Knowledge of the rivers' behaviour is crucial to the understanding of many parameters of the oceans ecosystem and physical system. Eutrophication for example, is caused by elevated amounts of phosphorus and nitrogen. A surplus of nutrients may cause undesirable algae blooms, that deplete the available oxygen, possibly increases temperature, and can deteriorate the ecosystem resulting in lower fish productivity. The source of these nutrients is often related to human activities, like agriculture or untreated sewage. The river provides the most important link between these land based activities and the effects that occur in the seas. Apart from nutrients, rivers supply sediment to seas and oceans, and although this sediment input may be important to counteract coastal erosion, it may also cause unwanted sedimentation of harbours and channels. Sediment loading can also negatively affect fish production especially if sediment loading occurs over spawning beds. Migratory species such as European eel and salmon thus can be subjected to nutrient inputs (eutrophication), and sediment loading which may impact their behaviour, spawning, habitat and growth. This is especially true in northern climates where even single variables such as temperature can significantly influence fish productivity and year-class strength in a river on an annual basis.

2.2 Biology

The Arctic houses a wide variety of species that are adapted to extreme conditions and are unique for this region. The region is characterised by high seasonality with a long dark winter, an extended period of continuous daylight during summer and a brief spring and autumn season. This results in a short and strongly coupled grow season for species living in the Arctic. Species are often highly dependent on each other for food. Energy transfer of key species within a food web can be followed through the season. Some of the species are directly connected to and/or dependent on the presence of floating ice, such as ice algae and bearded seals (Figure 10 and Figure 11.).

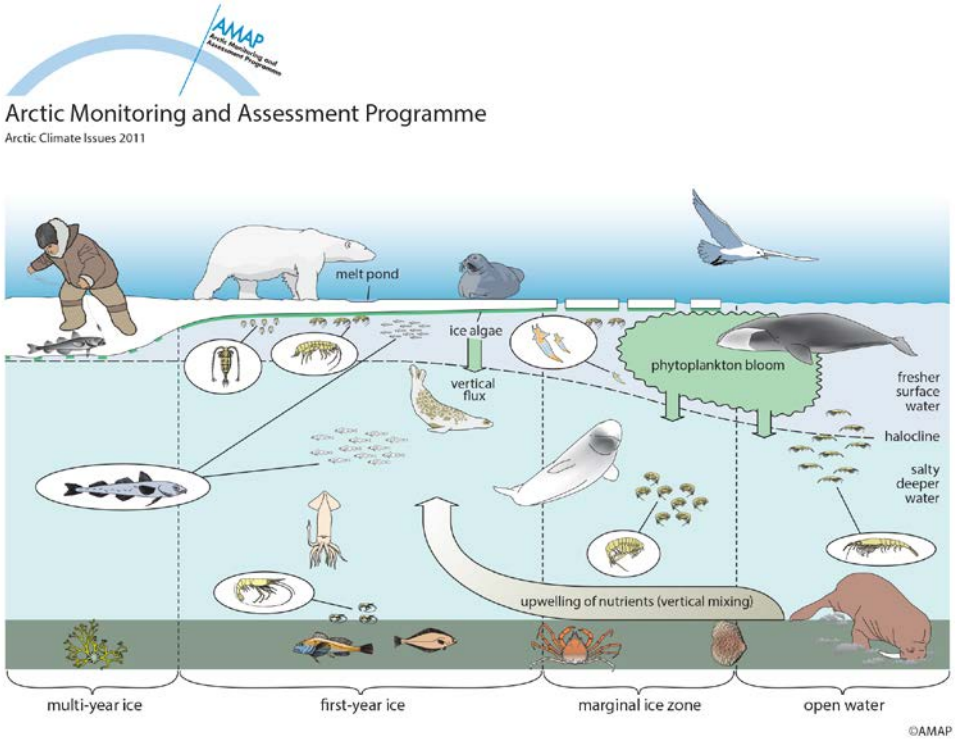


Figure 10. *A schematic overview of marine food webs in the Arctic (AMAP, 2012).*

Figure 11. *A bearded seal on floating ice in Kongsfjorden, Svalbard (© Martine van den Heuvel-Greve).*

The text below is taken directly from the Arctic Ocean Biodiversity website (www. arcodiv.org) and describes the main groups of species of the Arctic foodweb.

Algae

http://www.arcodiv.org/watercolumn_overview.html:

“The growth season of phytoplankton is severely constrained in Arctic Seas by snow and ice cover, low light angles and a relatively short season. The classic view is that phytoplankton production begins in April and ends in early September with a growth curve characterized by a single peak in primary production in late June to early July. Enhanced biological activity in the pelagic zone occurs on the Arctic shelf areas, where the seasonal retreat of the sea ice allows for the formation of ice-edge algal blooms. The melting of sea ice stimulates algal growth as more light enters the sea and the reduction of surface increases vertical stability. Phytoplankton blooms in spring are mainly dominated by diatoms and *Phaeocystis pouchetii*. The tremendous gradients in the large Arctic estuarine systems cause defined phytoplankton species assemblages, dominated by freshwater, brackish water or fully marine species.”

Invertebrates

http://www.arcodiv.org/watercolumn_overview.html:

“In the Arctic Ocean, zooplankton, such as copepods, form an important part of the marine community (Table 3). A number of species of krill also occur in the Arctic, and these provide a plentiful and important food source for fish, seabirds and whales.”

“Waters of the continental shelves have been studied in variable taxonomic detail in the Barents Sea, Kara Sea, Laptev Sea and Chukchi/Beaufort Seas, while the East Siberian Sea, whereas Canadian Archipelago through northern Greenland have been particularly understudied. Due to their high abundance and ease of capture, the taxonomic composition and life history of the larger more common copepods in the Arctic Ocean is relatively well understood. The same cannot be said for the smallest copepod species that are variably missed by collection techniques, all deep-water species, or the more fragile gelatinous forms.”

“Historically, effort has concentrated on copepods of the genus Calanus because they appear to dominate zooplankton biomass. As in most oceans, smaller copepod species are actually numerically dominant, yet relatively few studies have used sufficiently fine meshes to fully assess their contribution. Although copepods typically predominate in the basins, there is a broad assemblage of other planktonic groups in the Arctic that are only occasionally reported in full detail. Larvaceans (=Appendicularians), for example, have been shown to be abundant in Arctic polynyas and common in the central Arctic. Similarly, important and common predatory groups, such as the chaetognaths, amphipods, ctenophores and cnidarians have received detailed report in only a few surveys. Arctic chaetognaths may represent considerable biomass, and are thought to be important in controlling Calanus populations. Hyperiid amphipods can also be common in Arctic waters, and a similar potential to graze a notable proportion of the Calanus population. The importance of ctenophores and cnidarians in surface and deep waters, and their grazing impacts, are also particularly under-appreciated. The basic biodiversity of all these gelatinous animals is grossly underestimated in polar waters.”

http://www.arcodiv.org/watercolumn.html:

“One factor that complicates diversity of the Arctic is the inflow of waters from the adjoining oceans that carry their fauna into the Arctic Ocean. For many imported species it is simply too cold for them to be able to grow and reproduce, but they can be present in high numbers compared to the truly Arctic species. Thus, the shallow Chukchi Sea north of Bering Strait is almost completely composed of North Pacific species, while the Norwegian and Barents Seas are often dominated by North Atlantic Ocean species. The truly Arctic species are most prevalent in the deep basins.”

Table 3. *Diversity of invertebrate species in the Arctic Ocean (http://www.arcodiv.org/watercolumn_overview.html).*

Phyla	Group	World diversity	Total Arctic	Central Arctic
Cnidarians	hydromedusae	650	~50	15
	siphonophores	190	8	7
	scyphozoans	150	7	3
Ctenophores		80	12	12
Nemertines		97	2	2
Annelids	polychaetes	120	6	4
Molluscs	heteropods	35	0	0
	pteropods	160	3	2
	cephalopods	370	8	6
Crustaceans	cladocerans	8	4	0
	ostracods	169	9?	8?
	copepods	2000	156	97
	mysids	700	33	13
	amphipods	400	10	8
	euphausiids	86	7	3
Chaetognaths		80	5	5
Tunicates	larvaceans	64	5	5
	pyrosomes	8	0	0
	dolioids	17	0	0
	salps	45	0	0

Fishes

http://www.arcodiv.org/Fish.html:

“Arctic marine waters (the Arctic Ocean and its seas as well as the North Pacific south to about Cape Navarin and the Yukon Delta (Bering Sea) and the North Atlantic to Nova Scotia and the northern Barents Sea) are home to about 240 species of marine and diadromous (mostly anadromous) fishes. The number of species may differ among authors due to shifting of the arctic faunal barrier over time, differences in taxonomic opinion, and discovery of new species.”

“Two major taxonomic groups account for more than half (55%) the species: the suborder Cottoidei of the order Scorpaeniformes, including sculpins, snailfishes, and alligatorfishes (30%); and the suborder Zoarcoidei of the order Perciformes, including primarily eelpouts and pricklebacks (25%). Arctic anadromous fishes are mostly in the salmonid family (Salmonidae) of the order Salmoniformes, including ciscoes and whitefishes, trouts and chars, and salmons. Salmonids inhabit inshore and nearshore waters except for a few species that range far offshore during their ocean years.”

“Most Arctic Ocean marine fishes are benthic or demersal, living on or closely associated with the bottom. Few are pelagic, freely moving about in the water column like the glacial lantern fish, *Benthosema glaciale*, which stays at mesopelagic depths down to 1,250 m during the day and rises to epipelagic depths near the surface at night; or both demersal and pelagic, like the ice-loving (cryopelagic) Arctic cod, *Boreogadus saida*, which hides in under-ice crevices to avoid predators.”

Marine mammals

http://www.arcodiv.org/MarineMammals.html:

“Twelve species of Arctic marine mammals are either restricted to or dependant on the Arctic: polar bear, walrus, four species of whales (bowhead whale, grey whale, narwhal, beluga) and six species of ice-associated seals (bearded seal, ribbon seal, ringed seal, spotted seal, harp seal, hooded seal). Several additional species (e.g. sperm whales, blue whales, fin whales, humpback whales, killer whales, harbour porpoise) are spotted occasionally or even regularly within marginal waters of the Arctic. All are predators that capture their prey on or in the oceans. All are relatively long lived, and virtually all are critical food resources to the indigenous peoples of the Arctic.”

Marine birds

http://www.arcodiv.org/SeaBirds.html:

“There are 64 species of 'seabirds' that breed in the Arctic. About 50 million seabirds nest on Alaska's coast each summer, nesting in more than 1600 seabird colonies around the coast. Marine birds have special adaptations that allow them to live at sea and get all their food there. They come to land to raise their young each summer. Many nest on protected cliffs or islands, often in dense groups called colonies.”

2.3 Human activity

About 4 million people live in the Arctic region. 10% of these are indigenous to the region, representing over 40 different ethnic groups. During the middle of the last century population growth increased rapidly due to immigration because of the discovery of natural resources. Most of the people are gathered in relative large settlements, whereas indigenous communities are more widely scattered. More recent population growth in the Arctic has ceased and even decreased in some areas, such as Russia.

The Arctic Sea Basin covers a number of seas under national jurisdiction (USA, Canada, Greenland/Denmark, Norway and Russia) as well as areas beyond national jurisdiction (high seas).

There is an extensive international legal framework that applies to the Arctic, amongst others (EC, 2016):

- The **UN Convention on the Law of the Sea (UNCLOS)**, which asserts jurisdictional rights of nations in the various maritime zones. The EU is a signatory of UNCLOS;
- The **International Maritime Organisation (IMO)**, a specialised agency of the United Nations with responsibility for the safety and security of shipping and the prevention of maritime pollution by ships. All EU Member States are IMO Members. The European Commission has an observer status;
- The **Arctic Council** is an international, intergovernmental forum that is directly concerned with the Arctic's sustainable development and environmental protection. Founded in 1996, it does not address boundary or resource disputes or any other issue related to security matters. The EU is an ad hoc observer to Arctic Council proceedings, 3 Member States are members of the Arctic Council (the Kingdom of Denmark, Finland and Sweden), while seven Member States are permanent observers (France, Germany, Italy, the Netherlands, Poland, Spain and the United Kingdom);
- The **Barents Euro Arctic Council (BEAC)** is the forum for intergovernmental and interregional cooperation in the Barents Region. The European Commission is a full member;
- The **Northern Dimension** is a joint policy between the EU, Russia, Norway and Iceland. It was initiated in 1999 and aims at providing a framework to promote dialogue and concrete cooperation in issues such as economy, culture, environment and transport.
- The **OSPAR Convention** aims to protect the marine environment and ecosystems from emerging threats linked to pollution, maritime activities, together with climate change and increased human presence.

Retreating sea-ice in the Arctic opens up possibilities for increased human exploitation of the Arctic region. Especially the following human activities may increase in the future (Figure 12):

- Shipping
- Fisheries
- Oil & Gas exploitation and mineral extraction
- Tourism

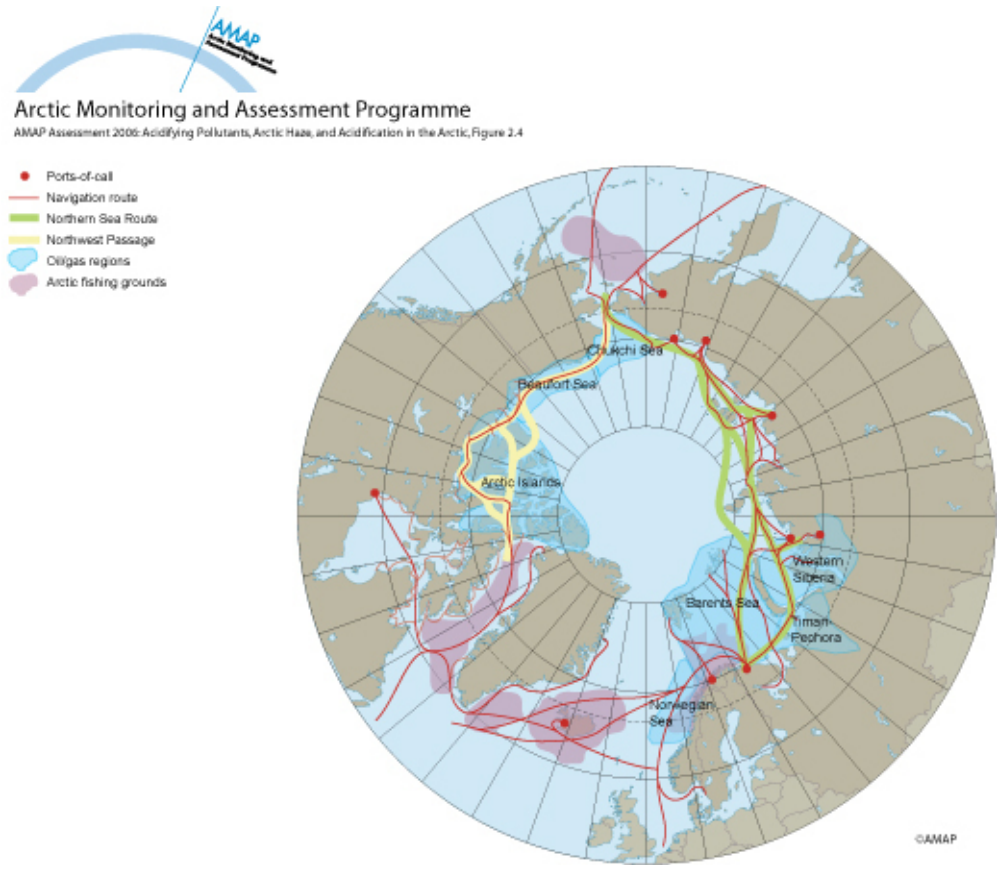


Figure 12. *Shipping routes, oil and gas regions, and fishing grounds in the Arctic (AMAP: http://www.amap.no/documents/doc/shipping-routes-oil-and-gas-regions-and-fishing-grounds-in-the-arctic/149)*

Shipping

http://www.gc.noaa.gov/gcil_arctic_shipping.html:

"The volume of ship traffic in the Arctic Ocean will increase over the coming century. Potential impacts from shipping include: the release of oil through accidental or illegal discharge, ship strikes on marine mammals, the introduction of alien species, disruption of migratory patterns of marine mammals, increased anthropogenic noise and increased atmospheric emissions (e.g. of black carbon – BC). The Arctic Council recently released the Arctic Marine Shipping Assessment which examines many of these issues and suggests possible measures that may be used to address them. The International Maritime Organization (IMO) is the primary international body that regulates international shipping. The Arctic Council, primarily through the Protection of the Arctic Marine Environment (PAME) working group, has become more active in attempting to anticipate and monitor the impacts of shipping on the Arctic marine environment."

Shipping is one of the main vectors for invasive species to the Arctic. Presently, the polar regions (Arctic and the Southern Ocean) is the least by non-indigenous species invaded realms of the world (Molnar et al. 2008). The relative absence of transport vectors and the low temperatures are important factors for the relative limited introduction of non-indigenous species to the Arctic ecosystem. However, due to the melting of the Arctic sea ice the north Pacific is connected to the north Atlantic ocean, resulting in new economic opportunities (shipping routes, sea mining). With these intensified economic activities, the risk of introducing exotic species in the Arctic sea increases. The rapid changes in the Arctic marine ecosystems related to climate change makes the system more vulnerable to invasive alien species (Norden 2014). Aquatic alien species can be found all over the globe and can cause serious problems such as harming native species, harming ecosystems and harming animal health, as well as posing a threat to public health, safety and economy (Crowl et al. 2008; Pimentel et al. 2005; Schiphouwer et al. 2012; Vander Zanden et al. 1999; Wilcove et al.

1998). In the Arctic ocean various alien species have been reported, such as the king crab and the snow crab, various species of microalgae, macro algae, molluscs and fish. As alien species can pose a serious threat to the marine ecosystem in many different ways, they have been included specifically in the European Marine Strategy Framework Directive (Descriptor 2: "Non-Indigenous Species introduced by human activities are at levels that do not adversely alter the ecosystem") and are a focal point for management by many different organisations and governments (Ojaveer et al. 2013).

Oil & gas

In 2008 the United States Geological Survey estimated that the Arctic regions contains 13 per cent of the world's remaining oil and 30 per cent of its gas. More than 70% of the mean undiscovered oil resources is expected to be present in five provinces: Arctic Alaska, Amerasia Basin, East Greenland Rift Basins, East Barents Basins, and West Greenland–East Canada. It is further estimated that approximately 84% of the undiscovered oil and gas occurs offshore.

Oil is already extracted in the Arctic region, most of them from onshore locations or in shallow sea areas (Figure 13).

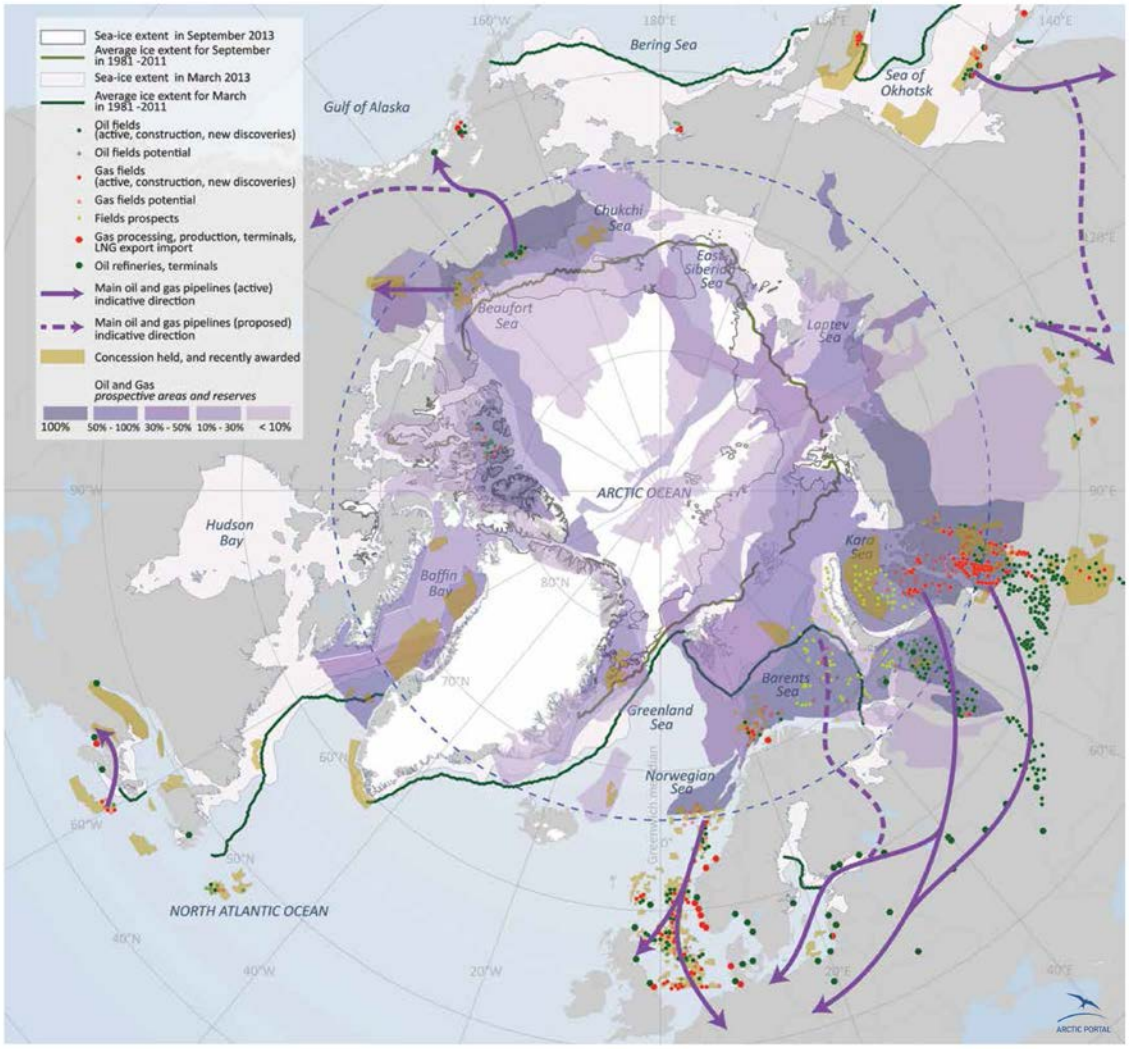


Figure 6.1: Main Oil and Gas Areas, Mining Sites and Sea-Ice Extent in the Arctic
Source: Arctic Portal, based on Nordregio; Johanna Roto and José Sterling, 2011, www.nordregio.se/Maps--Graphs/05-Environment-and-energy

Figure 13. *Main oil and gas areas and mining sites in the Arctic (http://www.arcticinfo.eu/images/Sada/Maps/map8.jpg)*

Fisheries

Fisheries are a key industry across the Arctic (Figure 14). Compared to regions such as the North Sea and Celtic Sea, they are based on relatively few fish species located in rich marine ecosystems in the low and sub-Arctic. The fisheries managementin the Arctic sea basin is only partly covered by regional

fisheries management organisations (RFMOs), but Arctic countries have well-established resource management regimes, including collection and analysis of data required for fisheries management.

Fishing impact is interpreted as any disturbance of the seafloor of fishing vessels operating mobile bottom gear. There are several ways to estimate the level of seafloor disturbance depending on the information available. With increasing dependency on more sophisticated information and methods the relevance and accuracy of the indicator(s) increases. The simplest and probably least accurate description is based on the capacity and effort of the vessels operating in the Arctic region combined with some categorization of the métiers in terms of their impact on the seafloor thereby allowing a transformation of the fishing effort into a capacity- or effort-based measure weighted by seafloor impact. The assumption here is that there is a relationship between the capacity (number of vessels) or effort (usually kWdays) and fishing impact. The rationale is that vessels that use heavier gear (e.g. beam trawl) or larger gears (e.g. multiple combined pair trawls) will need more engine power to haul their nets through the water and over the sea floor, thus causing an increased impact on the seafloor. This method can work across very different metiers and fisheries types as long as they are mobile (towed) gears. Gill nets, fykes, potting and creeling cannot be measured in the same way but have only minimal impact on the seabed so are not considered here as contributing to any fishing impact on the seafloor. While this is often applied as a best proxy for fishing impact in data-limited situations it is known for its potential for bias and lack of accuracy. Moreover, the spatial resolution of this type of information is usually low (i.e. regional or at best ICES rectangles as is required for logbook data).

More sophisticated but also more accurate indicators for seafloor disturbance are proposed by the Data Collection Framework (DCF) but these require high resolution data such as coming from Vessel Monitoring System (VMS) which, although collected by each member state as part of their DCF obligation are not readily available due to privacy issues. Data from fishing fleets in Europe has traditionally been collected by the state where the fish is landed and depending on the state various data collection programmes have been in place for many years. Over the last 20 years the EC has been working to bring these data collection programmes into a standardised format. This process cumulated in the establishment of the Data Collection Framework (DCF) in 2009. The DCF was developed to standardise fisheries data across the EU and ensure that member states operate fisheries data collection programmes that will meet the objectives of the common fisheries policy (CFP). Member states are now required to compile a wide range of biological and ecological data including the relevant data for this challenge, i.e. biological data for landings by area and species and stock related data from sampling programmes. Each of the nations involved in fishing in the North Sea are either bound by the EC fishing regulations or have agreements to follow similar reporting processes. Vessels over 15 meters must carry VMS and produce logbook data on all fishing activities. Vessels under 12 meters (10 meters in UK) are considered inshore vessels and do not need to report landings. However there catches are instead recorded by the registered fish traders who purchase at first sale. In most countries vessels over 15m operating in the North Sea are also required to carry VMS equipment that records their locations periodically. This data is held by the flag state of the vessel and is often subject to data protection regulations. VMS data, however, has complications in that VMS data from specific vessels come under the data protection act and need the permission of the vessel owner for their use. This means that even if VMS data exists it may not be available for general use.

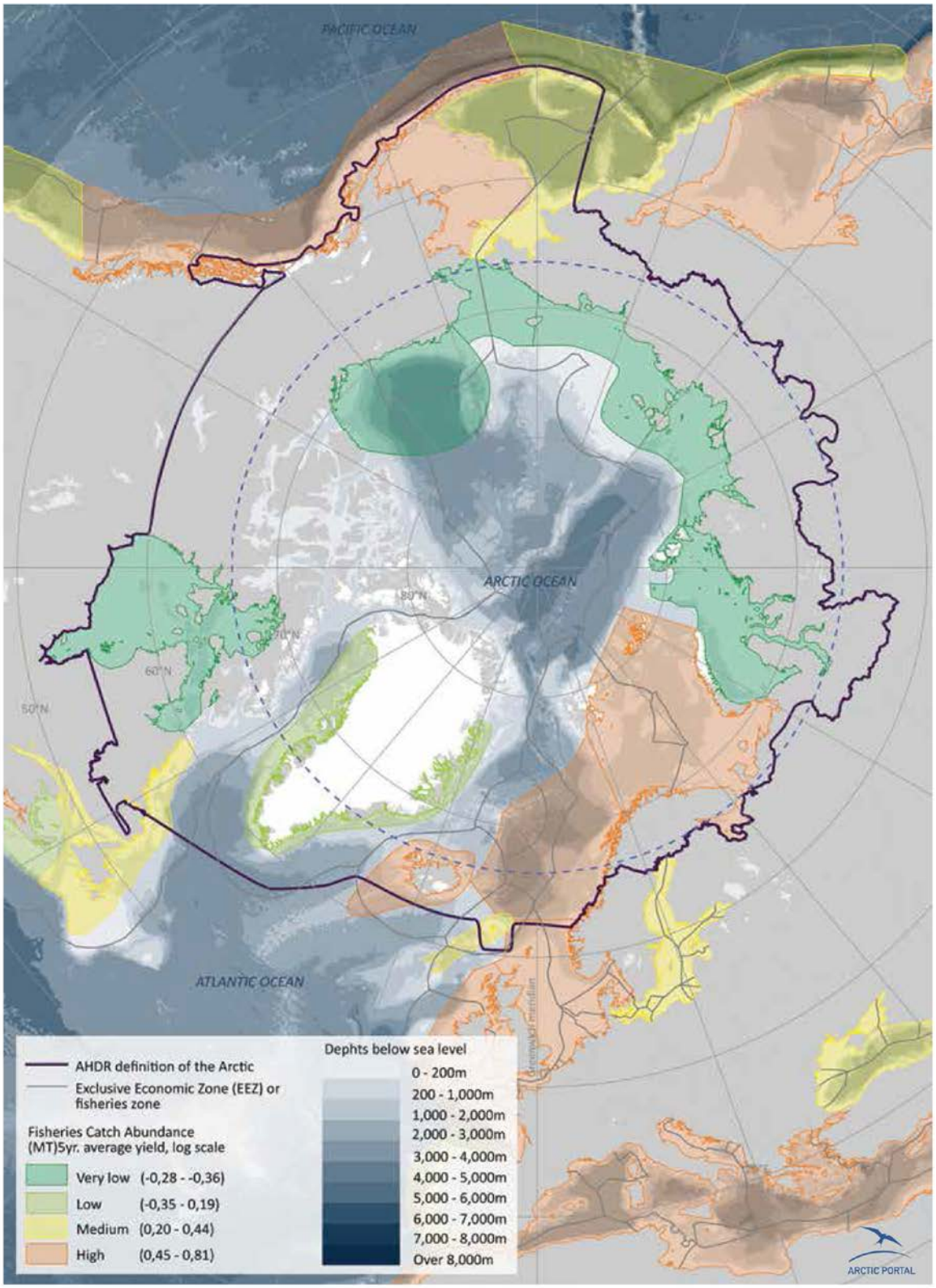


Figure 5.2: *Large Marine Ecosystems – Catch Abundance*
Source: Arctic Portal 2014.

Figure 14. *Catch abundance (http://www.arcticinfo.eu/images/Sada/Maps/map5.jpg).*

Tourism

Arctic tourism is a popular and rapidly-growing industry that is expanding in terms of tourists, tour operators, diverse recreational pursuits, geographic scope, and seasons of use. Advanced ship technologies together with improved marine charts and navigational aids have allowed cruise ship

travel to increase (Figure 15). The growing tourism industry presents both opportunities and challenges: opportunities to increase awareness of Arctic environmental issues and support for conservation, while providing a sustainable income source for northern communities; and environmental and cultural problems if tourism does not take these issues into account. To address these issues, the World Wide Fund For Nature (WWF) Arctic Programme began to develop principles and codes of conduct for Arctic tourism, and a mechanism for implementing them (http://awsassets.panda.org/downloads/wwf_tourism_conservation.pdf).

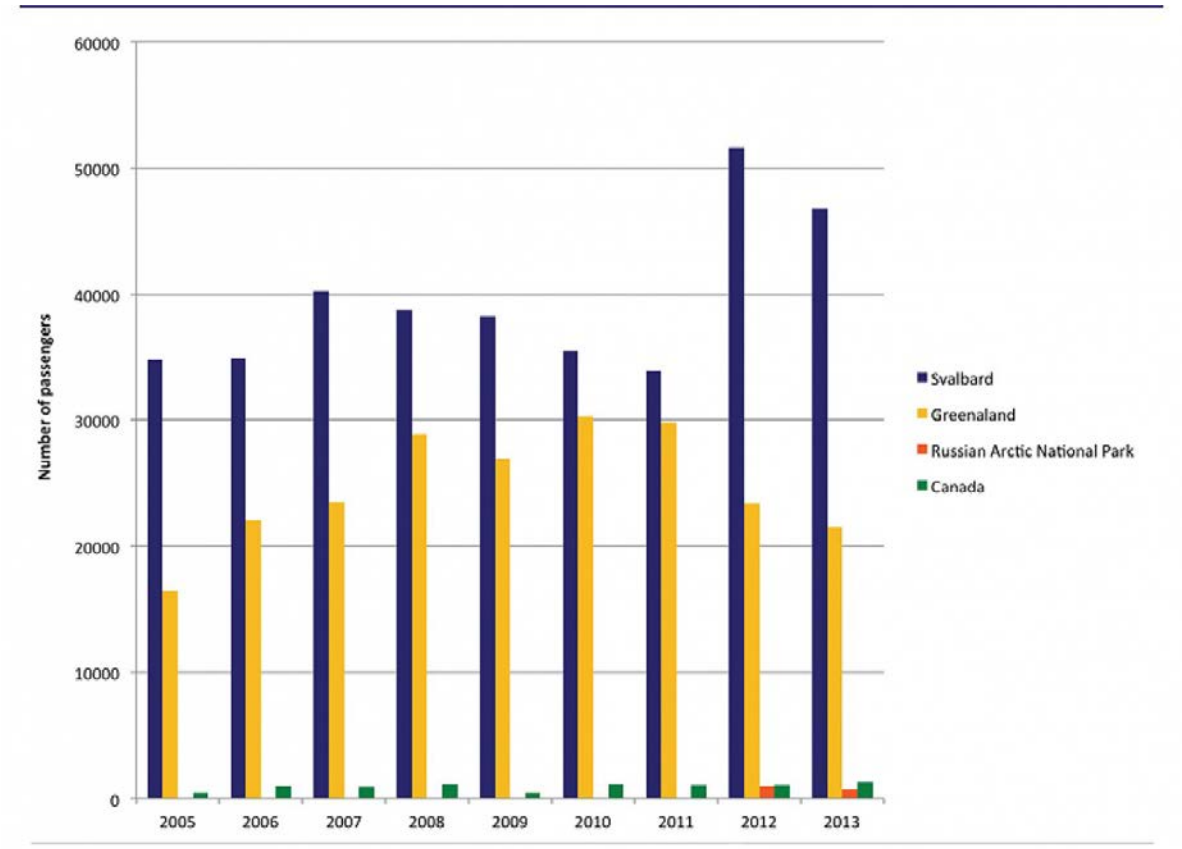


Figure 15. *Cruise tourism in Arctic areas by numbers of passengers (http://www.arcticinfo.eu/images/Sada/Graphs/graph2.jpg).*

Marine Protected Areas (MPAs)

Within the Arctic, different types of national MPAs have been established under national legislations, for which a good overview is available in the World Database of Protected Areas (WDPA) by the UN/IUCN. Also high seas MPAs known as Vulnerable Marine Ecosystems (VMEs) have been established by Regional Fisheries Management Organisations (RFMOs). In addition, a number of Ecologically and Biological Significant Areas (EBSAs) have been defined: focus areas that may qualify as MPAs in the future, but are not MPAs now. In the challenge the focus is only on the established MPAs.

3 Major Arctic Sea Monitoring programs and databases

A lot of monitoring programs and databases are developed and coordinated within the separate Arctic states. Additionally larger international monitoring programs and databases exist. This chapter gives a summarised overview of the most important datasources available on the internet. The information is mostly copied from the webpages about this datasources, therefore in the title of each paragraph the URL will be given as the source of information. A more complete, but less detailed, list of (Arctic) data sources is given in Annex 6.

3.1 EMODnet portal (www.emodnet.eu)

The European Marine Observation and Data Network (EMODnet) is a consortium of organisations within Europe that assembles marine data, data products and metadata from diverse sources in a uniform way (see also paragraph 1.3). EMODnet data can be used for those areas showing overlap between the datasets and the Arctic ocean.

3.2 Arctic Council working groups (www.arctic-council.org)

The Arctic Council is the leading intergovernmental forum promoting cooperation, coordination and interaction among the Arctic states, Arctic Indigenous communities and other Arctic inhabitants on common Arctic issues, in particular on issues of sustainable development and environmental protection in the Arctic. This article contains a backgrounder on the Arctic Council and its work.

The work of the Council is primarily carried out in six Working Groups.

- The Arctic Contaminants Action Program (ACAP) acts as a strengthening and supporting mechanism to encourage national actions to reduce emissions and other releases of pollutants.
- The Arctic Monitoring and Assessment Programme (AMAP) monitors the Arctic environment, ecosystems and human populations, and provides scientific advice to support governments as they tackle pollution and adverse effects of climate change.
- The Conservation of Arctic Flora and Fauna Working Group (CAFF) addresses the conservation of Arctic biodiversity, working to ensure the sustainability of the Arctic's living resources.
- The Emergency Prevention, Preparedness and Response Working Group (EPPR) works to protect the Arctic environment from the threat or impact of an accidental release of pollutants or radionuclides.
- The Protection of the Arctic Marine Environment (PAME) Working Group is the focal point of the Arctic Council's activities related to the protection and sustainable use of the Arctic marine environment.
- The Sustainable Development Working Group (SDWG) works to advance sustainable development in the Arctic and to improve the conditions of Arctic communities as a whole.

Most relevant of these working groups for SBC Arctic are AMAP, CAFF, PAME and SDWG.

3.2.1 Arctic Monitoring and Assessment Programme – AMAP (www.amap.no)

AMAP is one of six Working Groups of the Arctic Council. The Arctic Monitoring and Assessment Programme (AMAP) is a programme designed to deliver sound science-based information for use in policy- and decision-making. Its assessment activities are internationally coordinated, subject to

rigorous peer-review and make use of the most up-to-date results from both monitoring and research. The AMAP programme is implemented in the circum-Arctic region.

3.2.2 Conservation of Arctic Flora and Fauna – CAFF (http://www.caff.is/)

CAFF is the biodiversity working group of the Arctic Council and consists of National Representatives assigned by each of the eight Arctic Council Member States, representatives of Indigenous Peoples' organizations that are Permanent Participants to the Council, and Arctic Council observer countries and organizations. The CAFF Working Group operates by the Arctic Council Rules of Procedures.

CAFF serves as a vehicle to cooperate on species and habitat management and utilization, to share information on management techniques and regulatory regimes, and to facilitate more knowledgeable decision-making. It provides a mechanism to develop common responses on issues of importance for the Arctic ecosystem such as development and economic pressures, conservation opportunities and political commitments.

The Circumpolar Biodiversity Monitoring Program (CBMP) is an international network of scientists, government agencies, indigenous organizations and conservation groups working together to harmonize and integrate efforts to monitor the Arctic's living resources.

The CBMP focuses its efforts on five key program areas:

- Data management (the Arctic Biodiversity Data Service)
- Capacity building
- Reporting
- Coordination and integration of Arctic monitoring
- Communication, education and outreach

CBMP experts are developing four coordinated and integrated Arctic Biodiversity Monitoring Plans to help guide circumpolar monitoring efforts. Results will be channeled into effective conservation, mitigation and adaptation policies supporting the Arctic. These plans represent the Arctic's major ecosystems:

- Marine
- Freshwater
- Terrestrial
- Coastal

3.2.3 Protection of the Arctic Marine Environment – PAME (http://www.pame.is/)

PAME is the focal point of the Arctic Council's activities related to the protection and sustainable use of the Arctic marine environment and provides a unique forum for collaboration on a wide range of activities in this regard. PAME's mandate is to address policy and non-emergency pollution prevention and control measures related to the protection of the Arctic marine environment from both land and sea-based activities. These measures include coordinated strategic plans as well as developing programs, assessments and guidelines, within the following main themes:

- Arctic Shipping
- Marine Protected Areas
- Arctic Offshore Oil and Gas
- Ecosystem Approach to Management
- Arctic Marine Strategic Plan 2015-2025

PAME carries out activities as set out in bi-annual work plans approved by the Arctic Council on the recommendation of the Senior Arctic Officials. These activities led by PAME include circumpolar and regional action programmes and guidelines complementing existing legal arrangements aimed at protection of the Arctic marine environment from both land and sea-based activities.

3.2.4 Sustainable Development Working Group – SDWG (www.sdwg.org/)

The goal of the Sustainable Development program of the Arctic Council is to propose and adopt steps to be taken by the Arctic States to advance sustainable development in the Arctic. This includes pursuing opportunities to protect and enhance the environment and the economies, culture and health of indigenous peoples and Arctic communities. The guiding tenet running throughout the work of the SDWG is to pursue initiatives that provide practical knowledge and contribute to building the capacity of indigenous peoples and Arctic communities to respond to the challenges and benefits from the opportunities in the Arctic region.

The SDWG carries out projects and activities, as approved by Senior Arctic Officials (SAOs), in the following thematic areas:

- Arctic human health: To broaden the scope and strengthen the integration of human health activities within the Council by developing concrete initiatives to improve the health and well-being of Indigenous Peoples and other Arctic residents.
- Arctic socio-economic issues: To advance on a better understanding of the human influences on the Arctic environment and the socio-economic conditions of Indigenous Peoples and Arctic communities
- Adaptation to climate change: To strengthen the work of the Council by reducing vulnerability and implementing adaptation initiatives related to climate change in the Arctic, including practical community-based actions.
- Energy & Arctic communities: To consider future projects and activities in relation to the Arctic region as energy consumer, and the importance of environmentally friendly economic activity in the energy sector to ongoing social and economic development in the Arctic region.
- Management of natural resources: To consider that Indigenous Peoples and Arctic communities rely on the sustainable use of natural resources for their health and economic well-being; increases in shipping, petroleum activities, fishing, mining as well as external influences such as climate change and variability, require that the management of resources is based on a holistic perspective.
- Arctic cultures & languages: To support Arctic cultures; to reduce the loss of Arctic Indigenous languages and to follow-up on the Arctic Indigenous Languages Symposium.
- Strategic planning: To develop a more integrated and inclusive approach to managing and planning SDWG priority-based activities undertaken in collaboration with other Arctic Council Working Groups, Permanent Participants, Arctic community stakeholders and external partners.

3.3 Copernicus (www.copernicus.eu)

Copernicus is a European system for monitoring the Earth. Copernicus consists of a complex set of systems which collect data from multiple sources: earth observation satellites and in situ sensors such as ground stations, airborne and sea-borne sensors. It processes these data and provides users with reliable and up-to-date information through a set of services related to environmental and security issues.

The services address six thematic areas: land, marine, atmosphere, climate change, emergency management and security. They support a wide range of applications, including environment protection, management of urban areas, regional and local planning, agriculture, forestry, fisheries, health, transport, climate change, sustainable development, civil protection and tourism.

3.4 International Council for the Exploration of the Sea – ICES (www.ices.dk)

The International Council for the Exploration of the Sea (ICES) is a global organization that develops science and advice to support the sustainable use of the oceans. ICES is a network of more than 4000 scientists from over 350 marine institutes in 20 member countries and beyond. 1600 scientists participate in our activities annually. Through strategic partnerships the work also extends into the Arctic, the Mediterranean Sea, the Black Sea, and the North Pacific Ocean. ICES is committed to building a foundation of science around one key challenge: integrated ecosystem understanding of marine ecosystems. ICES advances this through the coordination of oceanic and coastal monitoring and research, and advises international commissions and governments on marine policy and management issues. Their goal is to provide the best available science for decision-makers to make informed choices on the sustainable use of the marine environment and ecosystems.

ICES has a well-established Data Centre, which manages a number of large dataset collections related to the marine environment. The majority of data – covering the Northeast Atlantic, Baltic Sea, Greenland Sea, and Norwegian Sea – originate from national institutes that are part of the ICES network. The ICES Data Centre provides marine data services to ICES member countries, expert groups, world data centres, regional seas conventions (HELCOM and OSPAR), the European Environment Agency (EEA), Eurostat, and various other European projects and biodiversity portals.

Dataset collections are organized around specific thematic data portals as well as an overarching data warehouse. The current dataset portals provided by ICES are:

- Biological community;
- Contaminants and biological effects;
- Eggs and larvae;
- Fish predation (stomach contents);
- Fish trawl survey;
- Historical plankton;
- Ocean physics and chemistry.

3.4.1 Fish stock assessments

DATRAS (www.ices.dk/marine-data/data-portals/Pages/DATRAS.aspx)
DATRAS (the Database of Trawl Surveys) is an online database of trawl surveys that allows users to upload survey data and anyone to access the data products. DATRAS has been developed to collate and document the survey data, assure data quality, standardise data formats and calculations, and ease data handling and availability. With the possibility for instant remote access, the data from DATRAS are used for stock assessments and fish community studies by the ICES community and public users.

DATRAS stores data collected during various fish trawl surveys coordinated by ICES expert groups. The survey data are covering the Baltic Sea, Skagerrak, Kattegat, North Sea, English Channel, Celtic Sea, Irish Sea, Bay of Biscay and the eastern Atlantic from the Shetlands to Gibraltar. At present, there are more than 45 years of continuous time series data in DATRAS, and survey data are continuously updated by national institutions.

DATRAS has an integrated quality check utility. All data, before entering the database, have to pass an extensive quality check. Data products (such as CPUE per area or indices) and raw data, can be freely downloaded according to the ICES Data policy.

Stock assessment (www.ices.dk/marine-data/tools/Pages/stock-assessment-graphs.aspx)
The ICES ecosystem advice is based on assessment results that are presented in stock assessment standard graphs and data tables. Data and plots are available in ICES Stock assessment Database.

The ICES Stock Assessment Database data are available for the analytically assessed ICES stocks from 2014 onwards. Plots and data from previous assessments will be made available when the data and settings have been quality controlled.

Catch statistics (http://www.ices.dk/marine-data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx)
Annual nominal catches of more than 200 species of fish and shellfish in the Northeast Atlantic region are officially submitted by 20 ICES member countries. ICES has been gathering and publishing fisheries statistics since 1904. The current data is collected and coordinated in collaboration with Statistical Office of the European Communities (EUROSTAT). The data sources are the national statistical offices, in some countries the collection and compilation of fisheries statistics are handled by specialized organizations.

The Northeast Atlantic historical catch statistics for 1903-49 are available in .xlsx and .csv formats. The other dataset with historical data for 1950-2010 is formatted in .xls and .csv formats. Newer data for 2006-2014 are arranged into a separate dataset, updated annually. The available data formats are .xlsx and .csv.

The geographical breakdown is according to the ICES system of subareas, divisions and subdivisions. The area-coding for the older data is converted to the one used today, where the principle of only subdividing areas but not creating cross-cutting new areas was followed.

Data presented in the datasets are not corrected for non-reported landings where such may have occurred.

3.4.2 Action area - Arctic research (http://www.ices.dk/explore-us/Action%20Areas/Pages/Arctic.aspx)

The Arctic marine environment will undergo major changes in the coming decades due to on-going climate change and increases in human activities. This makes Arctic research a priority area for ICES from the perspective of better understanding ecological processes and human impacts in this ecosystem.

A number of ICES groups focus on subarctic fish stocks in the Barents Sea, around Iceland and East Greenland, and some widely distributed and straddling stocks.

ICES also conducts and develops Integrated Ecosystem Assessments for the Barents Sea as part of the Ecosystem Approach to Fisheries Management.

The annual ICES Report on Ocean Climate (IROC)and the biannually published ICES Zooplankton Report cover subarctic waters.

Several other subjects are addressed - ranging from hydrography and warming of the Arctic Ocean to evaluating the environmental risks of shipping, oil and gas exploitation, and the spread of non-native species.

3.4.3 ICES Project - EMODnet Biology (http://www.ices.dk/explore-us/projects/Pages/EMODNET-Biology.aspx)

The EMODnet biological data portal provides access to different thematic databases and to several long-term national marine biological monitoring datasets from all European regional seas.

The project identifies and focuses on biological data types, species, species attributes, sampling methods and biological indicators to support the variety of legislations, and will create biological data products to support environmental legislations including the Marine Strategy Framework Directive (MSFD).

ICES role is to give access to fish data from the International bottom trawl survey database DATRAS, and biological community data from regional monitoring programmes.

3.4.4 ICES Project - EMODnet Chemistry 2 (http://www.ices.dk/explore-us/projects/Pages/EMODnet-Chemistry2.aspx)

EMODNET Chemistry 2 aims to continue the development of the infrastructure for the collection, management, quality control and visualization of chemical data in the marine environment. This in support of European policies (MSFD) to drive a sustainable development.

The specific objectives of EMODNET Chemistry 2 are to:

- Assemble existing data from public and private organisations relating to the state of sea basins; processing them into interoperable formats which includes agreed standards, common baselines or reference conditions; assessments of their accuracy and precision and creating data products as defined in this tender;
- Develop, test, operate and maintain a portal allowing public access and viewing of data, metadata and data products as below
- Monitor and report on the effectiveness of the system in meeting the needs of users in terms of ease and speed of use, quality of information and fitness for purpose of the data and products delivered;
- Analyse what further steps need to be taken to improve the accuracy, precision, coverage and ease of use of the data
- Keep the portal operational and be prepared to transfer to the Commission or to a party designated by the Commission.

ICES is work package leader on user interaction, including technical guidance and linkages to the Marine Strategic Framework Directive (MSFD).

3.5 The Sustaining Arctic Observing Networks (www.arcticobserving.org)

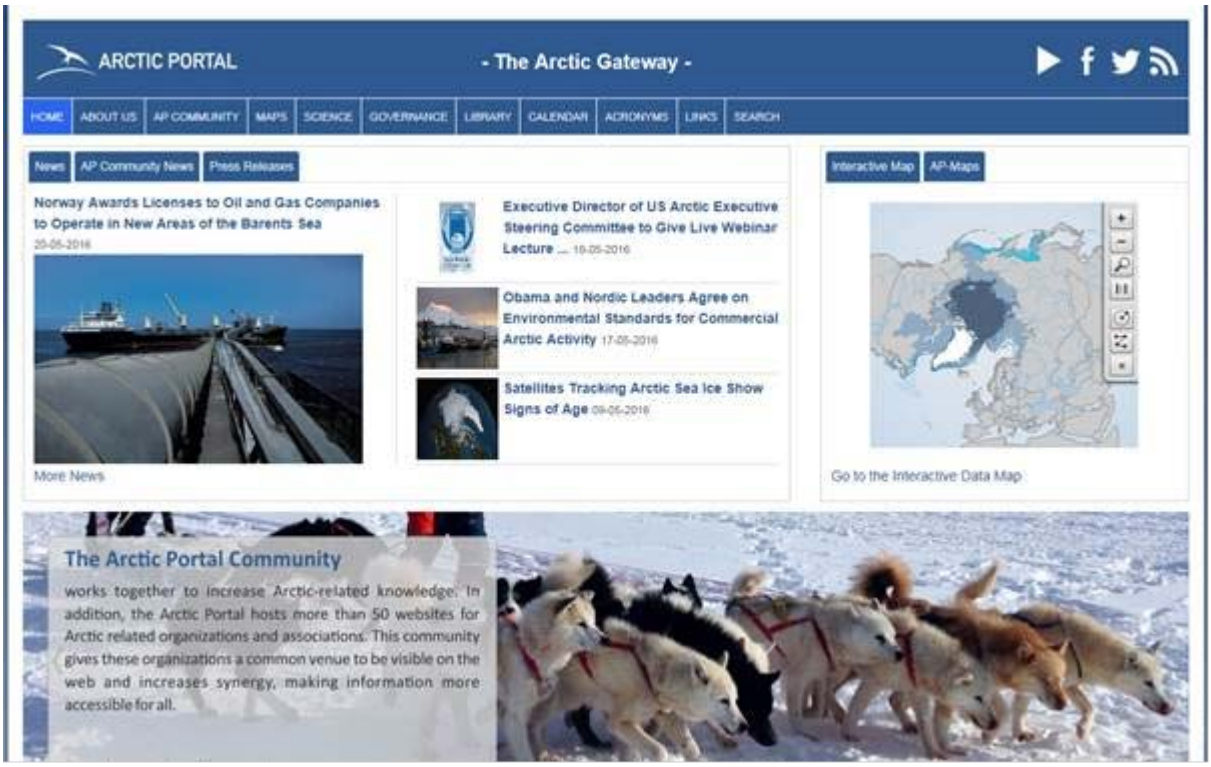
SAON facilitates partnerships and synergies among existing observing and data networks. The SAON process was initiated by the Arctic Council (AC) in 2007. Its goal is also to promote sharing and synthesis of data and information.

3.6 The Arctic Portal (www.arcticportal.org)

The Arctic Portal is a comprehensive gateway to Arctic information and data on the internet, increasing information sharing and co-operation among Arctic stakeholders and granting exposure to Arctic related information and data.

The Arctic Portal is operated in consultation and co-operation with members of the Arctic Council and its Working Groups, Permanent Participants, Observers and other Stakeholders.
The Arctic Portal is a network of information and data sharing and serves as host to many web sites in a circumpolar context, supporting co-operation and outreach in science, education, and policy making.
The Arctic Portal is managed as non-profitable organization, located in Akureyri, Iceland, under an international board of directors.

The Arctic Portal provides web presence to over 50 scientific institutions, associations and projects of international importance and participates in Arctic research projects such as European Commission funded EU Arctic Information Centre Initiative, Arctic Council SDWG endorsed Arctic Maritime and Aviation Transportation Infrastructure Initiative, the Arctic Council SAON project, the EU 7th framework program funded Permafrost project and many others.



3.7 ArcticData (portal.inter-map.com)

Arcticdata is a web portal housed under the Arctic Portal, where spatial datasets with attached attribute data from CAFF and PAME are being made available to the public and research community to access and use as needed. Interesting aspects of the database are:

Arctic fauna:

- Polar bears population
- Wild reindeer and caribou

Arctic shipping routes:

- Shipping routes
- Ports of entry
- Arctic sea ports

Sea ice:

- Historical low sea ice extent
- Annual maximum ice extent
- Annual minimum ice extent

Fishing:

- Arctic peoples and communities
- Reindeer husbandry organisations

Intermezzo: example polar bears from Arctic Data
Polar bears are distributed throughout the ice-covered waters of the circumpolar Arctic. This top-level predator is of interest because it is an iconic species of the Arctic and one that is particularly vulnerable to changes in sea ice. They are fundamentally dependent upon sea ice as a platform for hunting seals, travelling, finding mates, and breeding. As a species highly specialized for and dependent on the sea ice habitat, polar bears are particularly sensitive and vulnerable to changes in their environment. Over the past several decades there have been a number of studies that have documented significant reductions in sea-ice cover in parts of the Arctic, and changes in the dates of break-up and freeze-up of the sea ice that are a consequence of climate warming. If climate warming in the Arctic continues, diminished ice cover and extended ice-free seasons will have profound negative effects on the ability of polar bear subpopulations to sustain themselves, particularly those at the southern parts of their range.

3.8 ACADIS (https://www.eol.ucar.edu/field_projects/acadis)

ACADIS is a collaborative project between the University Corporation for Atmospheric Research (UCAR), the National Center for Atmospheric Research (NCAR), and the National Snow and Ice Data Center (NSIDC). ACADIS developed the Arctic Data Explorer - offering accessible, multifaceted and efficient navigation of interdisciplinary Arctic data. NSIDC manages and distributes scientific data on snow, ice, glaciers, frozen ground, and climate interactions.
As of late March 2016, all ACADIS data and publications are available via the NSF Arctic Data Center. The ACADIS Gateway is no longer available. All future data and publication submissions should be made directly to the NSF Arctic Data Center. Further information can be found in the NSF Arctic Data Center Q & A document (see https://www.eol.ucar.edu/field_projects/acadis).

3.9 The Arctic Science Portal (www.arctic.gov/portal/index.html)

This portal can be thought of as a library of links (URLs) to websites where Arctic data are made publicly available. Main focus is on the US Arctic.

3.10 European Ocean Biogeographic Information System (www.eurobis.org)

The European Ocean Biogeographic Information System – EurOBIS – is an online marine biogeographic database compiling data on all living marine creatures. The principle aims of EurOBIS are to centralize the largely scattered biogeographic data on marine species collected by European institutions and to make these data freely available and easily accessible. All data go through a number of quality control procedures before they are made available online, assuring a minimum level of quality necessary to put the data to good use. The available data are either collected within European marine waters or by European researchers and institutes outside Europe. The database focuses on taxonomy and distribution records in space and time; all data can be searched and visualised through a set of online mapping tools.
EurOBIS covers an area of about 22 million km² and includes all the continental shelf seas of Europe, including the Mediterranean shelf and the Baltic Sea. The geographic boundaries are set to 90N – 70E – 26N – 45W, but exclude the Red Sea, the Persian Gulf and the Kara Sea. These areas are covered by other regional OBIS nodes.

3.11 The Arctic Regional Ocean Observing System (http://www.arctic-roos.org)

The Arctic Regional Ocean Observing System (Arctic ROOS) is the Arctic node under EuroGOOS - the European Global Ocean Observing System. It has been established by a group of 14 member institutions from nine European countries working actively with ocean observation and modelling systems for the Arctic Ocean and adjacent seas. Arctic ROOS promotes, develops and maintains operational monitoring and forecasting of ocean circulation, water masses, ocean surface conditions, sea ice and biological/chemical constituents.

4 Structured literature search

4.1 A framework for data management and assessment

4.1.1 Introduction

Before starting with the identification of relevant literature, a framework is required in which project data can be assessed. This framework will help to understand in which context literature will be collected. Given the overarching objectives of identifying and assessing data sets, the framework should encompass the relation between relevant literature, data sets used in literature and the sources (i.e. data portals) from which the data set can be obtained.

Note that a list of definitions used in the framework and throughout this report is included at the beginning of this report.

4.1.2 The framework

The framework used for the management and assessment of data sets is presented in Figure 16. It shows the relation between data source, data sets and assessment reports. All elements of the framework and terms used are described below in the following sections. Note that the setup of this framework is presented here, but the application and results will be presented in future reports. Thus the identification of data sets used in the assessment reports and the evaluation of the adequacy and quality of that set for the overall result of the Arctic SBC will be presented in a separate report. The report at hand will focus on the right-hand part of the scheme presented in Figure 16, namely the collection of the main body of literature (assessment reports).

The scheme presented in Figure 16 is implemented in an online 'Content Management System' (CMS), which is part of the Arctic Sea Basin portal (the CMS is only accessible with a password). The CMS contains modules in which data sources, data sets, assessment reports and parameters can be registered by project members. Relations between these aspects can also be specified by the project team.

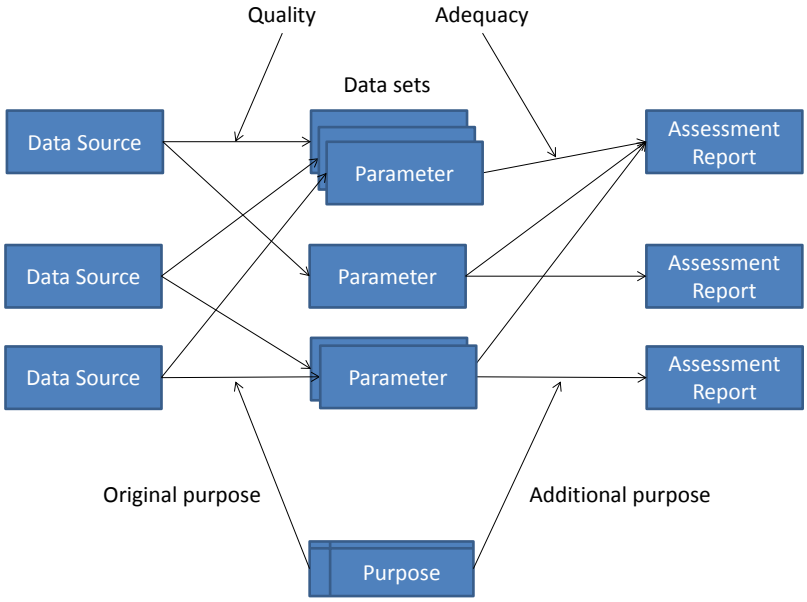


Figure 16. *Conceptual framework, showing the relations between data sources, data sets and assessment reports.*

4.1.3 Data sources

In the literature review, a preliminary list of (potentially) relevant data sources is identified. This list is based on data sources that are already identified in the Mediterranean Sea and North Sea SBC projects (only those that are also relevant for the Arctic SBC), supplemented with relevant data sources that the WP leaders already know. At this stage, the list is not yet linked to specific data sets but it is imported into the CMS such that it can be linked at a later moment.

4.1.4 Data sets / parameters

A data set is a coherent set of data for a specific parameter (e.g., temperature, or bird abundance), from a specific data source (i.e., data portal). Parameters are based on the P02 level vocabulary of SeaDataNet[2]. The advantage of using existing definitions for parameters is that it can be linked to information from other initiatives using the same definitions. An assessment report can make use of more than one data set. Multiple data sets can exist for a single parameter (i.e., originating from different sources). These relationships are visualised in Figure 16.
Although data sets are not yet identified at this stage, the framework to evaluate them is developed in the literature review.

4.1.5 Assessment reports

The literature that is collected will be referred to, in this report, as "assessment reports". Assessment reports are in the present context defined as "*technical reports or peer reviewed publications that describe the assessment of the state, exploitation or change of the marine environment or parts thereof.*" Assessments as described in such reports are generally based on data which can originate from a data set.

4.1.6 Purposes

For each data set it will be recorded what the 'original purpose' was (i.e., the purpose for which the data set was generated) if known and with which purpose it was used in an assessment report ('additional purpose'). This way, the original purpose can be compared with additional purposes eventually. Hence, a list of purposes should be defined. Work packages (WPs), which are part of the project, are used as a basis for the definition of these purposes.

As described in the introduction of this report, the Arctic SBC project is comprised of WPs in the form of challenges (e.g., wind farm siting or assessing riverine input). Each challenge is designed such that it addresses data availability and adequacy for a specific additional purpose. However, in the original project call, these challenges are not directly linked to specific purposes. In fact, some challenges don't even serve a direct practical purpose (other than addressing data availability and quality), for instance the 'bathymetry' challenge. Therefore, a list of purposes is defined and linked to the challenges/WPs as defined in the project (Table 4). The list was established by defining a closely matching purpose for each challenge. For reasons of completeness, purposes were added to the list: 'Assessment of environmental impact' and 'Assessment of ecological status'. These were considered relevant purposes by the Arctic SBC literature review team but not covered by a specific challenge/WP. The list of purposes as presented in Table 4 is expected to cover the main purposes for which data could be generated and used within the scope of the Arctic Ocean.

[2] http://seadatanet.maris2.nl/v_bodc_vocab_v2/search.asp?lib=P02

Table 4. *A list of purposes and most closely matching work packages in the project.*

Purpose	Most closely matching Work Package
Assessment of environmental impact[#]	NA - Impact assessment
Assessment of ecological status[#]	NA – Ecological assessment
Marine spatial planning	WP02 Wind farm siting
Assessment of (potential) MPAs	WP03 MPA
Oil spill response	WP04 Oil leak platform
Assessment of climate change	WP05 Climate Change
Assessment of coastal evolvement	WP06 Coast
Fisheries management	WP07 Fisheries management
Stock assessment	WP07 Fisheries management + WP08 Fisheries impact
Assessment of riverine input	WP10 River input
Assessment of navigational risks	WP11 Bathymetry
Assessment of risks posed by invasive species	WP12 Alien species

There is no specific WP/challenge within the project focusing on this particular purpose. It will only be addressed in the literature review and data adequacy report of the project. Note that the purpose "Assessment of environmental impact" was included before the search and thus literature was searched for this particular purpose. However, the purpose "Assessment of ecological status" was included after the search to address literature that was focussed on the assessment of the ecological status of habitats and/or species, which could not be linked to any of the other predefined purposes.

Each WP will eventually also produce an assessment report that will be included in the final analysis of literature and data sets. This will not be part of the report at hand as the WPs are still ongoing.

4.1.7 Data set quality

The quality of a data set is considered to be an intrinsic property of the set (i.e., it does not depend on its use). The quality of a data set will be evaluated by using a set of indicators. These indicators are selected based on work done in the Mediterranean Sea and North Sea SBC projects (see also section 4.4). Balancing between detail and practicability, the indicators are basically a set of closed questions, which can be scored with the CMS. The set of quality indicators are listed in Annex 2. Note that the quality is not assessed as part of the literature review presented in the report at hand. It is included to give a complete outline of the methodology that will be applied.

4.1.8 Data set adequacy

The adequacy of a data set is not considered to be an intrinsic property of the set, as it depends on the specific purpose for which it was used. In this project, the adequacy of a data set will therefore be evaluated for each separate assessment report in which it was used. The adequacy of a data set will therefore be a summary of the collection of assessment reports in which it was used. Like quality, the adequacy will be evaluated by a set of indicators (in the form of closed questions). These indicators can also be scored with the CMS. The set of adequacy indicators are listed in Annex 3. Note that the adequacy is not assessed as part of the literature review presented in the report at hand. It is included to give a complete outline of the methodology that will be applied.

4.2 Searching for literature

4.2.1 Definition of literature for the literature review

The literature that is collected is referred to as "assessment reports". For the literature review it is necessary to have clear understanding of what will be considered to be an assessment report. In the context of the Arctic SBC , an assessment report is defined as specified before:

A technical report or peer reviewed publication that describes the assessment of the state, exploitation or change of the marine environment or parts thereof.

Following this definition, an assessment report does not include information presented as:

- Websites
- Flyers
- Posters
- Progress reports
- Meeting reports/minutes

4.2.2 Literature sources

Literature will be obtained from the following sources:

- Search engines as listed in project proposal:
    - For peer-reviewed literature:
        - Scopus
        - Web of Science
    - For technical reports:
        - Google
- Websites provided in the original call text and proposal of the project (see Table 5 in the next section).
- Examples of assessment report listed in the project proposal, being:
    - Lichota and Wilson (2010)
    - Tedsen *et al.* (2014)

Search results from each of these sources are screened for relevance and are eventually merged to form a single literature body the will be used in the follow up of this study. Figure 17 outlines this process. Note that the searching and screening step is combined for the specific websites and Google, as search results cannot be readily exported for those searches. As most peer-reviewed literature does currently not have open access, a check for availability is also necessary. The searches in the search engines and on the websites are described in more detail below.

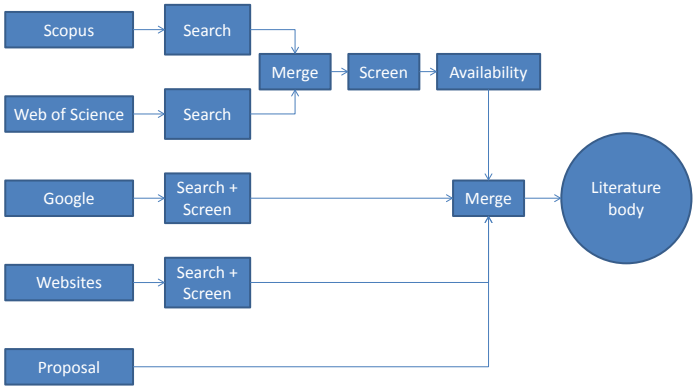


Figure 17. *Flow diagram illustrating the process of obtaining a literature body from the different sources.*

4.2.3 Search protocol

4.2.3.1 Search engines

For searching the engines, a set of keywords are formulated for each purpose in consultation with the WP leaders. In addition for each search engine a specific search is specified for each purpose. Annex 4 lists the specific searches that are carried out as such.

Some searches will result in an excessive number of hits. When a search results in more than 100 hits, the search results are sorted by relevance and only the first 100 hits will be screened for inclusion in the literature review. Specifically for Google, which will not list the number of hits of an advanced search, only the first 10 pages of search results will be evaluated for relevance.

4.2.3.2 Websites

The websites provided in the original call text and proposal of the project were searched for relevant assessment reports. More information on how each website was searched is described in Table 5.

Table 5. *A list of organisations (from the project proposal) whose websites were searched for relevant assessment reports. For more details on screening for relevance, see section 4.3.*

Organisation	How assessment reports were searched
The Arctic Monitoring and Assessment Programme (AMAP)	AMAP is a working group of the Arctic Council. The Assessment Reports provided by AMAP are divided into 5 categories. The documents of 2 categories (scientific reports and non-AMAP reports) were screened for relevance (see section 4.3). The other categories (summary reports, popular, policy makers summary) were excluded as they are based on the scientific reports and are thus not expected to provide additional information.
The Sustaining Arctic Observing Networks (SAON) (www.arcticobserving.org)	The website provides an overview of publications which were all screened for relevance (see section 4.3).
The Arctic Portal (www.arcticportal.org)	A library is available containing a collection of Arctic relevant scientific and educational material. Considering the scope of the library, there is no need to search for topics. A search restricting literature to the types "Article", "Book Section", "Monograph", "Book", "Thesis" (therewith excluding types such as websites, video's, presentations) was performed. Search results were screened for relevance (see section 4.3).
ArcticData (www.arcticdata.is)	The ArcticData website is a means to gather and share data. It does not contain a library and does not contain assessment reports
ACADIS (nsidc.org/acadis)	The ACADIS website contains a library with scientific publications, which is not searched because these are already covered by the search in Scopus and Web of Science. However, it also contains special reports and annual reports, from 1985 – 2013. These reports were screened for relevance (see section 4.3).
Conservation of Arctic Flora and Fauna (CAFF)	CAFF is the biodiversity working group of the Arctic Council and provides assessment documents (http://www.caff.is/assessment-series), which were screened for relevance (see section 4.3).
Arctic Report Card	Arctic Report Card: Update for 2012 (http://www.arctic.noaa.gov/reportcard). The Arctic Report Card is updated annually by assessing a wide range of environmental observations throughout the Arctic. Only the most recent version was screened for relevance (see section 4.3).
Arctic Wells	Arctic Wells > Documents (http://arctic-wells.com/document). A collection of reports, assessments, and articles addressing Arctic oil and gas issues, from drilling and exploration to challenges and status reports. All documents were screened for relevance (see section 4.3).
Arctic Yearbook	Arctic Yearbook (http://www.arcticyearbook.com). The Arctic Yearbook is an international and interdisciplinary peer-reviewed publication that is published online with the aim of being the preeminent repository of critical analysis on the Arctic region, with a mandate to inform observers about the state of Arctic geopolitics and security. Four yearbooks are available, which were screened for relevance (see section 4.3).
GRID-Arendal	GRID-Arendal (http://www.grida.no/publications) provides a library of reports, publications, and resources that address multiple environmental and social concerns. All documents were screened for relevance (see section 4.3).

Organisation	How assessment reports were searched
NOAA Fisheries	NOAA Fisheries (Alaska Fisheries Science Center) Publications database (http://access.afsc.noaa.gov/pubs/search.php) was searched using the keyword “Arctic” in Title, restricted to the following document types: AFSC Technical Memorandum, Book, Book Review, Document Chapter, F/NWC Technical Memorandum, Other Documents, Other Technical Memorandum, Processed Report. These search results were screened for relevance (see section 4.3).
Polar Research Board of the National Academies	Polar Research Board of the National Academies (http://dels.nas.edu/prb). Resources include studies in progress, presentations, press releases, and expert and workshop reports. Only the expert reports were subjected to the selection criteria (see section 4.3).
Protection of the Arctic Marine Environment (PAME)	PAME is a working group of the Arctic Council. The PAME Document Library (http://www.pame.is/document-library-single-art) offers minister, meeting and other reports, framework and document plans, and the Regional Programme of Action, as well as other resources. The PAME reports, AMSA documents and EA reports were screened for relevance (see section 4.3). Meeting and progress reports were disregarded.
Shell	Shell Corporation > Studies and Reports (http://www.shell.us/aboutshell/projects-locations/alaska/studies-reports-plans.html). No valid link, therefore no further search is conducted.
Arctic Coasts	State of the Arctic Coast 2010: Scientific Review and Outlook (http://www.arcticcoasts.org). A joint assessment of the state of the Arctic coast that draws on initial findings regarding climate change and human dimensions for the Arctic as a whole. One document that was subjected to the selection criteria (see section 4.3).
USGS Alaska Science Center	USGS Alaska Science Center > Recent Publications on Sea Ice (http://alaska.usgs.gov/science/biology/remote_sensing/sea_ice.html). A collection of publications pertaining to sea ice, including thickness changes, ice extent, and annual trends. No valid link, therefore no further search is conducted.
EMODnet (European Marine Observation and Data Network)	Contains no library or other references to assessment reports.
Copernicus projects	The Copernicus library (http://www.copernicus.eu/library/) contains amongst others study reports and technical documents. All documents were screened for relevance (see section 4.3).
ICES	Searched the ICES library (http://www.ices.dk/publications/library/Pages/default.aspx) by restricting to the Arctic Ocean ecoregion. Search results were screened for relevance (see section 4.3).
Marine conventions: The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR)	Searched the OSPAR library (http://www.ospar.org/about/publications) for keyword “Arctic”. Search results were screened for relevance (see section 4.3).
Regional hydrographic commissions: Arctic Regional Hydrographic Commission (ARHC)	There are 14 Regional Hydrographic Commissions (RHCs) of which one is relevant to the scope of this study: the ARHC. All documents found on the ARHC site (https://www.iho.int/srv1/index.php?option=com_content&view=article&id=435&Itemid=690&lang=en) were screened for relevance (see section 4.3).

Organisation	How assessment reports were searched
Marine Strategy Framework Directive (MSFD) process	Available on the MSFD website (http://www.msfd.eu/) is a link to the Knowledge-based Sustainable Management for Europe's Seas (KnowSeas) website (http://www.knowseas.com/). There a list of publications is available, divided into papers published in scientific journals and project publications. The peer-reviewed papers are already covered in the main literature search, thus only project documents were screened for relevance (see section 4.3).

4.3 Screening search results for relevance

The search actions as described above may still result in references that are irrelevant for the project. Therefore, the search results need to be screened for relevance. There is a slight difference in the screening procedure applied to the search results from Google, when compared with the results from the Scopus and Web of Science search engines. This is because the results from the latter can easily be imported into a reference manager, whereas the Google results cannot.

The screening criteria that are applied are:

- The document must have relevance to the Arctic (marine) environment
- The document must match with our definition of 'assessment reports'.
- The content must be relevant for (the purposes as defined in) this project. This will be based on expert judgment of the WP leaders (see Annex 5 for an overview of specific criteria used for each WP).
- Must be publically available or directly from the library used for this project: Wageningen UR Library[3] (library.wur.nl).

For the Artic SBC we assume that a publicly available document is not only easy to assess, but it should also be possible to read it. Therefore we use only English keywords, assuming English to be the overall language. We do not exclude documents in other languages with English summaries, as they appear in our search.

4.3.1 Screening listed website results

Relevant websites are searched by the review team as described in Table 5. Each search result is screened for relevance according to the main screening criteria listed above, excluding the criteria for relevance of content. This means that all fully available technical reports or peer reviewed publications in English, that describe the assessment of the state, exploitation or change of the Arctic marine environment or parts thereof, are considered relevant.

4.3.2 Screening Scopus and Web of Science results

Each WP leader is provided with the search results for the searches that are most relevant for their WP (see Annex 4) which can be imported directly into the reference manager Mendeley. Each WP leader is asked to screen the references following the criteria above. This means that specific criteria have to be specified for each purpose. A list of criteria used by each of the WP leaders is listed in Annex 5. WP leaders are also asked to keep track of the number of references that are excluded (preferably documenting the reason why) and the number of references that are included.

[3] Wageningen UR Library is a centralised shared service centre and is part of Wageningen UR Facility Services. Available at the library are: 42,612 journals; 15,802 electronic journals; 530 databases and 554,690 books/monographs. IMARES employees have full access to this library

Screening is performed based on the document's title, abstract and keywords only. As a final step the references are screened for availability (i.e., whether it can be retrieved directly from the WUR library). Only available documents can be included in the overall body of literature.

4.3.3 Screening Google results

Each WP leader is sent a link for the specified Google search (see Annex 4). The WP leaders are asked to screen the search results following the same criteria as described above. However, references cannot be imported automatically into a reference manager. Therefore, WP leaders were asked to manually enter the reference in Mendeley, but only when the reference is considered to be relevant. Only the first 10 pages of each search were screened.

4.3.4 Aggregation of screening results

Results of the screening procedure are sent back to the review team by the WP leaders. The review team will merge and analyse the results from the screening procedure. This means removing duplicate results and determining the resulting number of references for each purpose. The references to assessment reports are finally imported in the CMS of the project.

4.4 Links with other SBCs

4.4.1 Use of earlier SBC projects

Two SBC projects already started before the Arctic SBC kicked off: namely the Mediterranean Sea[4] and the North Sea[5] SBC. At the kick-off the data adequacy report (DAR) from the Mediterranean Sea SBC was already available (Manzella *et al.*, 2015). From the North Sea SBC informal material was available involving data screening by the North Sea Checkpoint, including valuation criteria. Material from both SBCs was used for the development of the framework (see section 4.1) in which the data will be assessed in the Arctic SBC. Data sources identified in both earlier SBC projects are also screened for relevance for inclusion in the Arctic SBC project.

4.4.2 Deviation from earlier SBC projects

Earlier SBC projects did not distinguish between 'data sets' and 'assessment reports' as defined in the Arctic SBC. This distinction was created in the current project to improve the differentiation between the quality of the data and the adequacy of the data (as the latter depends on the purpose for which it is used).

Previous SBC projects used combined indicators for both quality and adequacy, whereas in the Arctic SBC they are addressed separately. Indicators as used in the previous SBC projects also showed a different strategy. The North Sea SBC uses a limited set of mostly binary (yes/no) indicators, whereas the Mediterranean Sea SBC uses a large set of indicators with a more detailed scoring system. In the present Arctic SBC project a balance between the two approaches is used distinguishing more between quality and adequacy.

A list of indicators that will be included can be found in Annexes 2 and 3.

[4] http://www.emodnet.eu/med-sea-checkpoints
[5] http://www.emodnet.eu/northsea

4.5 A list of data sources

Annex 6 lists the data sources as they are currently identified. In the remainder of the project, the list may be expanded with sources identified in each of the WPs or assessment reports.

4.6 Searching for assessment reports

4.6.1 Searching listed websites

Relevant websites were searched by the review team as described in section 4.2. An overview of the searches is presented in Annex 7. A total of 1,075 documents were screened for relevance (see section 4.3.1).

4.6.2 Searching peer-reviewed literature

In total, 22 searches were performed to identify potentially relevant references from peer-reviewed literature: a search in both of the selected search engines (Scopus and Web of Science) for each of the 11 specified purposes.

As these searches can result in duplicate results (due to overlap of the search engines and the individual searches), duplicates are first removed. In total 1,480 hits are retrieved from these 22 searches. Figure 18 illustrates the overlap in search results between the different searches. It also shows how many references were collected for each WP, which were used as input for the procedure in which they are screened for relevance. The figure also shows that the search results from Scopus and Web of Science are often complementary to each other.

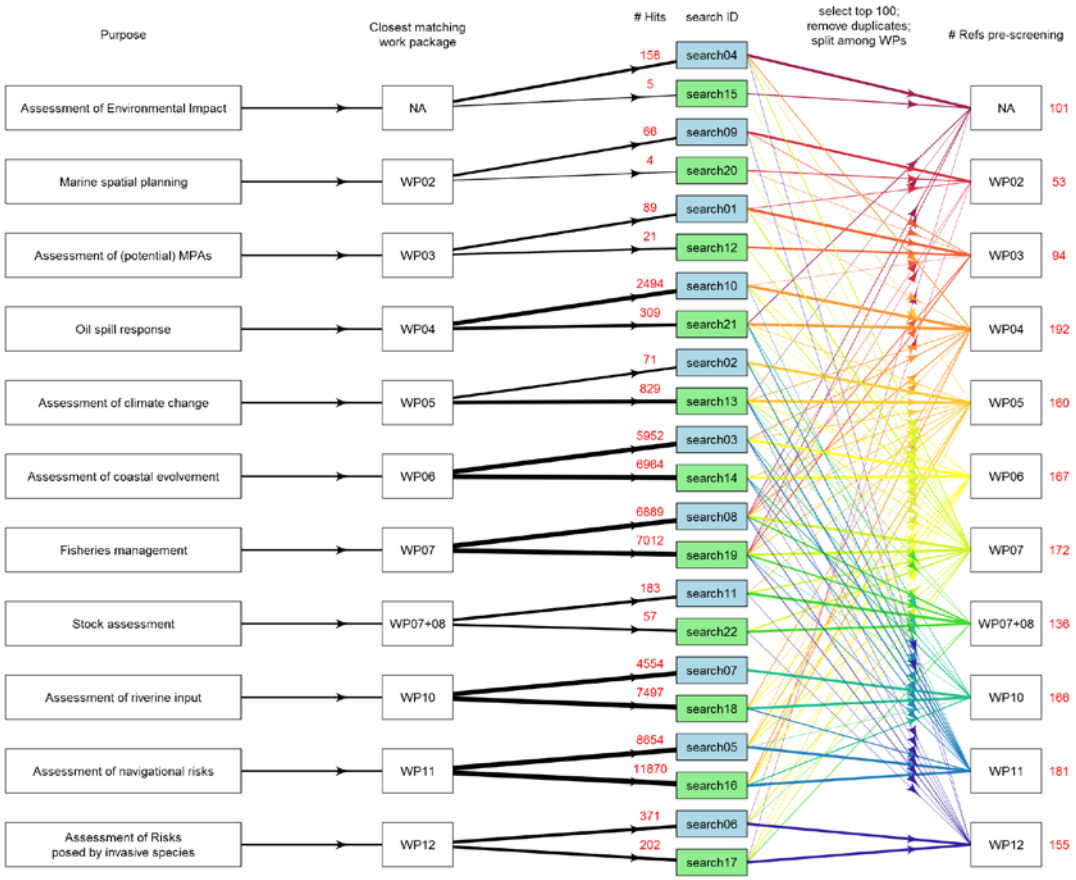


Figure 18. *Diagram of the search results of peer-reviewed literature, showing the number of references used as input for the process of screening for relevance. Boxes on the left hand side are the predefined purposes, which are linked to their closest matching work package. These are linked to the specific searches (as listed in Annex 4) and the number of hits generated by those searches (light blue boxes are searches in Scopus, light green boxes in Web of Science). Only the first 100 most relevant hits are selected for each search. Duplicates removed and the references split among the WPs. There is some overlap of references between the WPs. Thickness of the arrows indicate the number of references.*

4.6.3 Searching Google

The searching and screening is combined for the Google search engine. This is done because search results cannot be readily exported from Google. It is therefore most effective to only document the relevant hits for these searches. The results for this screening process are described in section 4.7.3.

4.7 Screening search results for relevance

4.7.1 Screening listed website results

A total of 1,075 documents were screened for relevance. This resulted in 78 Assessment Reports. More details are provided in Annex 7. These were linked to the predefined purposes as listed in Table 4. Figure 19 and Figure 20 show the number of documents found for each purpose and per originating website respectively. These illustrations also show the overlap of documents between purposes and websites.

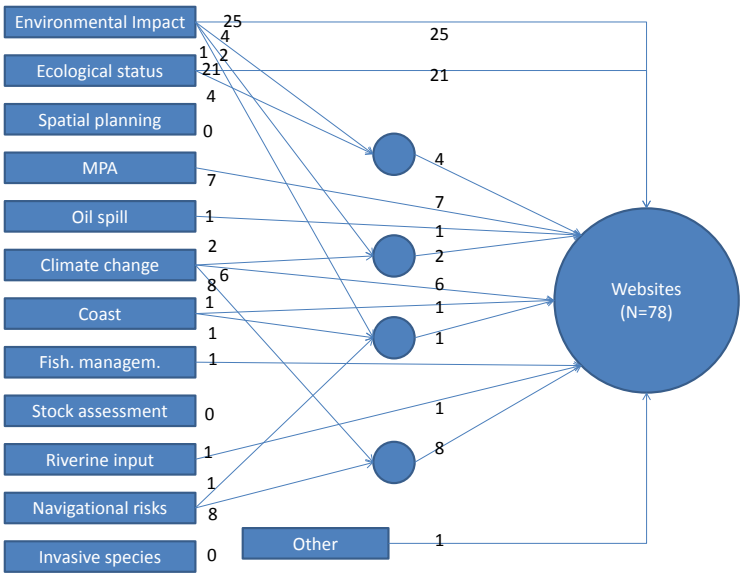


Figure 19. *Number of relevant documents found on the listed websites, specified per purpose. Small discs represent the merging of duplicates. The large disc represents the total body of literature obtained from the specific websites.*

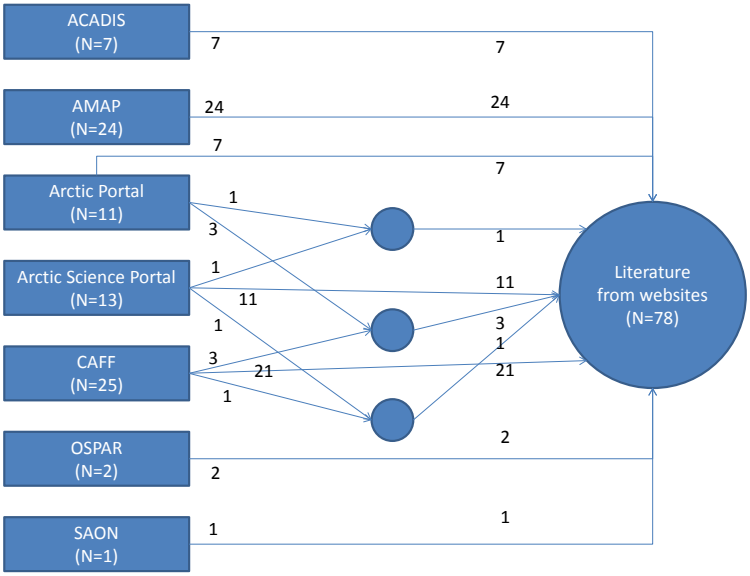


Figure 20. *Number of relevant documents found, specified per specific website (see Annex 7 for details). Small discs represent the merging of duplicates. The large disc represents the total body of literature obtained from the specific websites.*

4.7.2 Screening Scopus and Web of Science results

For this screening process, the search results as presented in section 4.6.2 are used as input. Table 6 shows the number of relevant studies filtered from the Scopus and Web of Science search results. Note that the totals per purpose in this table correspond with the red numbers on the right-hand side of Figure 18.

Table 6. *A summary of the screening results of the peer-reviewed literature obtained with searches in Scopus and Web of Science. Detailed results are presented in Annex 5.*

Purpose	Closest matching WP	Total included	Total excluded	Total screened
Assessment of Environmental Impact Assessment	NA	58	43	101
Marine Spatial Planning	WP02	17	36	53
Assessment of (potential) MPAs	WP03	15	79	94
Oil Spill response	WP04	57	135	192
Assessment of Climate Change	WP05	83	77	160
Assessment of coastal evolvement	WP06	94	73	167
Fisheries management	WP07	24	148	172
Stock assessment	WP07+08	32	104	136
Assessment of riverine input	WP10	50	116	166
Assessment of navigational risks	WP11	76	105	181
Assessment of risks posed by invasive species	WP12	37	118	155
Total[#]		511		1,480

Note that duplicates are removed from these totals. The totals are therefore not equal to the sum of the rows above.

Table 6 shows that in total 511 documents are considered to be relevant based on the screening of their title, abstract and keywords. However, of those 511 documents, 432 (85%) are available from the WUR library. In Figure 21 the numbers of documents are linked back to the purpose to which the searches were originally linked. The figure also shows some overlap between the purposes. This overlap is largest for the purposes ‘fisheries management’ and ‘stock assessment’. Note that no documents were found for the purpose ‘ecological assessment’. This is because this purpose was defined at a later stage and no specific searches were performed for this purpose.

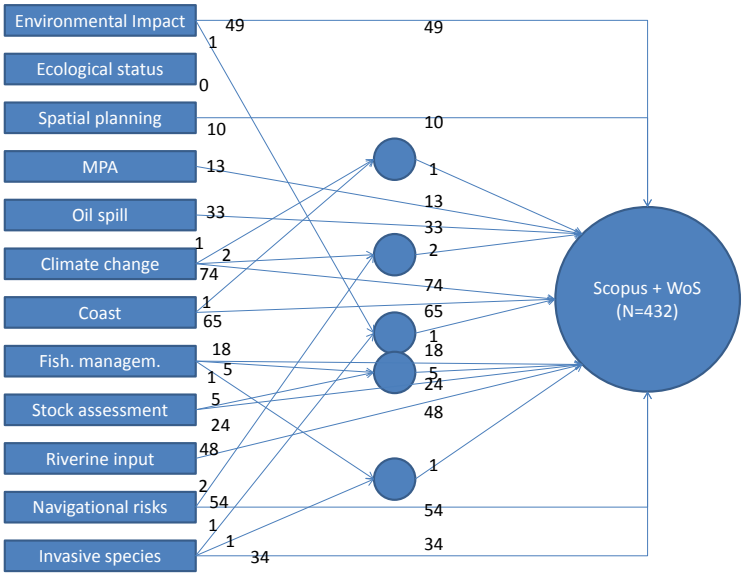


Figure 21. *Number of relevant documents found with Scopus and Web of Science, specified per purpose. Small discs represent the merging of duplicates. The large disc represents the total body of literature obtained from Scopus and Web of Science.*

4.7.3 Screening Google results

Google searching and screening results are visualised in Figure 22. In this diagram, the relevant documents are also linked to the purpose of the original searches. There is only small overlap of documents that were found linked to multiple purposes. Note that no documents were found for the purpose 'ecological assessment'. This is because this purpose was defined at a later stage and no specific searches were performed for this purpose.

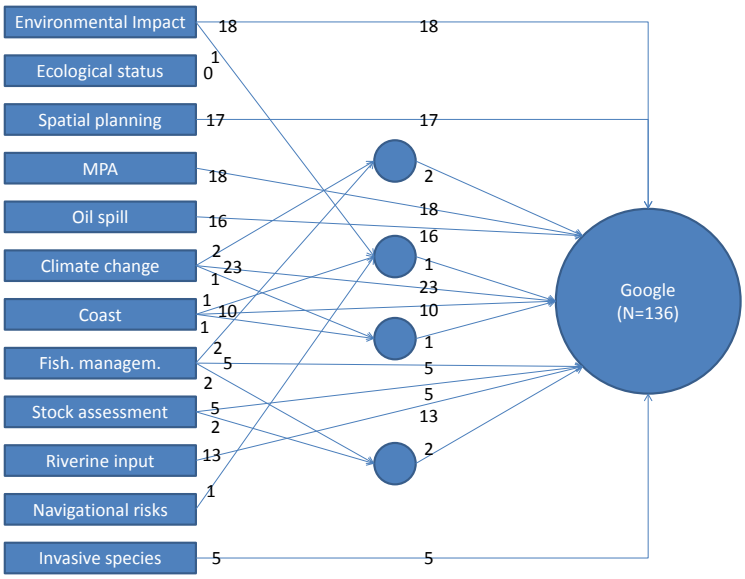


Figure 22. *Number of relevant documents found with Google, specified per purpose. Small discs represent the merging of duplicates. The large disc represents the total body of literature obtained from Google.*

4.8 Aggregation of results

The results for each of the searching and screening steps are now merged and duplicates are removed. Figure 23 shows that most relevant assessment reports are obtained with the searches in the search engines Scopus and Web of Science (mostly containing peer-reviewed literature), followed by Google. There is only a moderate overlap between the documents obtained from the different sources, indicating that the search actions performed have been complementary.

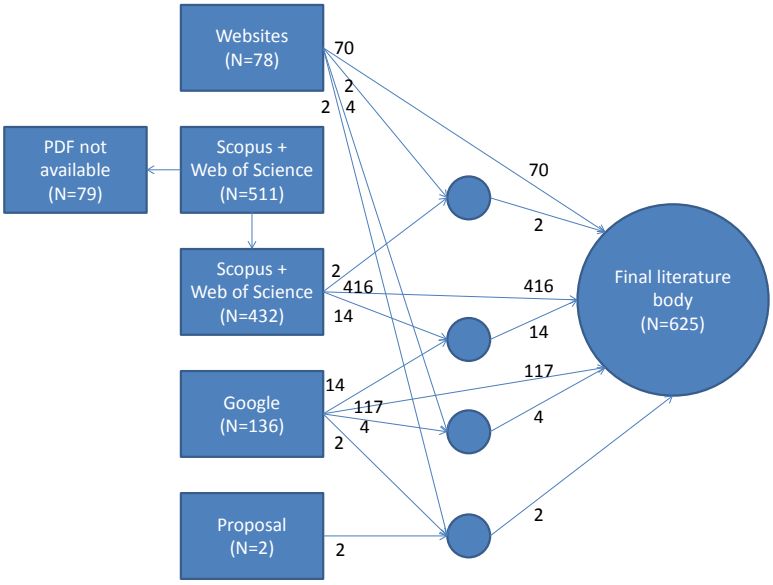


Figure 23. *Number of relevant documents, specified per source. Small discs represent the merging of duplicates. The large disc represents the total body of literature obtained from Google.*

Figure 24 shows the same results, but then specified per purpose. The number of documents obtained per purpose is highly variable. There are also some documents that serve multiple purposes.

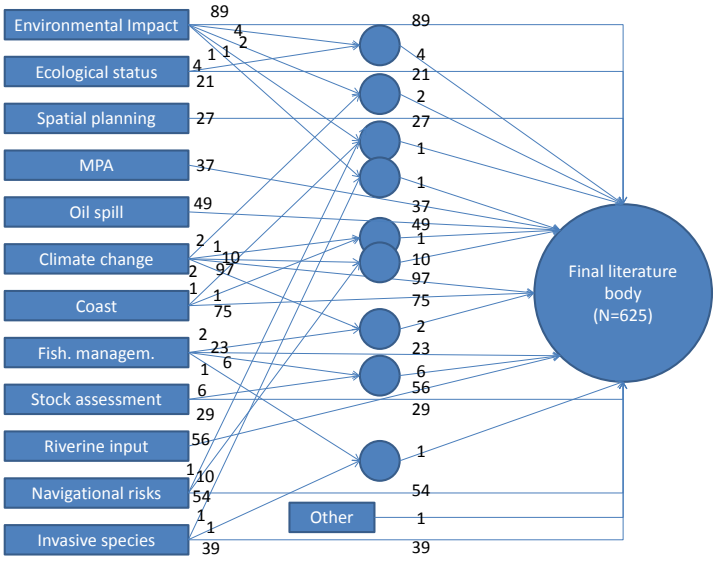


Figure 24. *Number of relevant documents obtained from all sources, specified per purpose. Small discs represent the merging of duplicates. The large disc represents the total body of literature to be used in future steps.*

The 625 documents will be used in the future steps of the projects. They will be used to identify data sets and to evaluate the adequacy of those data sets for the purpose of the assessment reports.

5 Overview of datasets, datasources and parameters

This section holds the list of data sets, their associated P02 parameter and the source from which it originates, as they are currently listed in the content management system (CMS) of the project (Table 7). Note that this list only shows the current state and will be updated in the future.

Table 7. *List of data sets, their associated P02 parameter and the source from which it originates.*

Parameter (P02)	Data set	Data Source
(ADUN) Administrative units	EBSA Arctic	Convention on Biological Diversity CBD
(ADUN) Administrative units	Marine Protected Areas - management plan active (marin_vp_oppstart)	Miljødirektoratet.NO
(ADUN) Administrative units	Marine Protected Areas - management plan inactive (marin_vp_ikke_oppstart	Miljødirektoratet.NO
(ADUN) Administrative units	Marine Protected Areas - proposed (foreslatt_vern_utm33)	Miljødirektoratet.NO
(ADUN) Administrative units	MPAtlas - Russia	MPAtlas: Russia
(ADUN) Administrative units	Open Street Map OSM topographic data Arctic countries	Open Street Map
(ADUN) Administrative units	AMAP Boundary	The Arctic Biodiversity Data Service (ABDS) Data Portal
(ADUN) Administrative units	MPA inventory 2014	USA NOAA National Marine Protected Areas Center
(ADUN) Administrative units	World Database of Protected Areas WDPA	World database on protected areas
(ALAT) Horizontal spatial co-ordinates	DataBasin Alaska Arctic Vegetation	DataBasin.org
(ALAT) Horizontal spatial co-ordinates	DataBasin Arctic Field Research Projects	DataBasin.org
(ALAT) Horizontal spatial co-ordinates	DataBasin Circumpolar Arctic Bioclimate Subzones	DataBasin.org
(ALAT) Horizontal spatial co-ordinates	DataBasin Circumpolar Arctic Lake Cover (% water coverage)	DataBasin.org
(ALAT) Horizontal spatial co-ordinates	DataBasin Circumpolar Arctic Landscape	DataBasin.org
(ALAT) Horizontal spatial co-ordinates	DataBasin Circumpolar Arctic Region Floristic Provinces	DataBasin.org
(ALAT) Horizontal spatial co-ordinates	DataBasin Circumpolar Arctic Substrate Chemistry	DataBasin.org
(ALAT) Horizontal spatial co-ordinates	DataBasin Circumpolar Arctic Vegetation	DataBasin.org
(ALAT) Horizontal spatial co-ordinates	Natura2000 MPA	Natura2000
(ALAT) Horizontal spatial co-ordinates	OSPAR MPAs	OSPAR map of MPAs
(ALAT) Horizontal spatial co-ordinates	Ramsar sites	Ramsar

Parameter (P02)	Data set	Data Source
(ALAT) Horizontal spatial co-ordinates	IUCN Red List of Threatened Species Extent	The IUCN Red List of Threatened Species
(ALAT) Horizontal spatial co-ordinates	UNESCO world heritage list MPA	Unesco
(ALAT) Horizontal spatial co-ordinates	WDPA MPA	World database on protected areas
(APDA) Horizontal platform movement	MarineTraffic ship positions, velocity and heading	Marine traffic
(ASLV) Sea level	INSITU_ARC_NRT_OBSERVATIONS_013_031_sea_surface_height_above_sea_level	Copernicus Marine Environment Monitoring Service
(ASLV) Sea level	SEALEVEL_ARC_SLA_L3_NRT_OBSERVATIONS_008_025	Copernicus Marine Environment Monitoring Service
(ASLV) Sea level	SEALEVEL_GLO_MDT_L4_REF_OBSERVATIONS_008_013	Copernicus Marine Environment Monitoring Service
(ASLV) Sea level	SEALEVEL_GLO_MSS_L4_REF_OBSERVATIONS_008_015	Copernicus Marine Environment Monitoring Service
(ASLV) Sea level	SEALEVEL_GLO_REF20YTO7Y_L4_OBSERVATIONS_008_034	Copernicus Marine Environment Monitoring Service
(ASLV) Sea level	SEALEVEL_GLO_SLA_L3_NRT_OBSERVATIONS_008_017	Copernicus Marine Environment Monitoring Service
(ASLV) Sea level	SEALEVEL_GLO_SLA_L3_REP_OBSERVATIONS_008_018	Copernicus Marine Environment Monitoring Service
(ASLV) Sea level	SEALEVEL_GLO_SLA_MAP_L4_NRT_OBSERVATIONS_008_026	Copernicus Marine Environment Monitoring Service
(ASLV) Sea level	SEALEVEL_GLO_SLA_MAP_L4_REP_OBSERVATIONS_008_027	Copernicus Marine Environment Monitoring Service
(ASLV) Sea level	Permanent Service for Mean Sea Level (PSMSL)	Global Sea Level Observing System (GLOSS)
(ASLV) Sea level	Permenant Service for Mean Sea Level	Permanent service for mean sea level
(ASLV) Sea level	UH Sea Level Center (UHSLC) Tide Gauge Data "Quality" Daily Data	University of hawaii sea level center
(ASLV) Sea level	UH Sea Level Center (UHSLC) Tide Gauge Data "Quality" Hourly	University of hawaii sea level center
(ATEM) Atmospheric emissions	AMAP gridded_Hg_emissions_2010v1	The Arctic Monitoring and Assessment Programme (AMAP)
(ATEM) Atmospheric emissions	AMAP gridded_Hg_emissions_2010v1_sector_subsets_2jan2014	The Arctic Monitoring and Assessment Programme (AMAP)
(BDRV) Biodiversity indices	Top 10 species (biodiversity)	Mareano
(CDTA) Air temperature	natice 15-Day WISIF Graphs (temperature)	U.S. National Ice Center / Naval Ice Center
(CNTX) Phytoplankton generic biomass in water bodies	ARCTIC_REANALYSIS_BIO_002_005_mole_concentration_of_phytoplankton_expressed_as_nitrogen_in_sea_water	Copernicus Marine Environment Monitoring Service
(COGE) Coastal geomorphology	Geomorphology: coastal cliff recession	GeoBasis - ZERO
(COGE) Coastal geomorphology	Geomorphology: topographic beach profile	GeoBasis - ZERO
(COGE) Coastal geomorphology	Bank Height of 48 Sampling Locations Along the Beaufort Sea Coast, Alaska	Soil carbon and material fluxes across the eroding Alaska Beaufort
(COGE) Coastal geomorphology	Coastal Type of of 48 Sampling Locations Along the Beaufort Sea Coast, Alaska	Soil carbon and material fluxes across the eroding Alaska Beaufort

Parameter (P02)	Data set	Data Source
(COGE) Coastal geomorphology	Erosion Rate of 48 Sampling Locations Along the Beaufort Sea Coast, Alaskaa	Soil carbon and material fluxes across the eroding Alaska Beaufort
(COGE) Coastal geomorphology	ASTER GLOBAL DEM	USGS Earth Explorer
(COGE) Coastal geomorphology	Global 30 Arc-Second Elevation (GTOPO30)	USGS Earth Explorer
(COGE) Coastal geomorphology	Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010)	USGS Earth Explorer
(COGE) Coastal geomorphology	Interferometric Synthetic Aperture Radar (IFSAR) Alaska	USGS Earth Explorer
(COGE) Coastal geomorphology	Light Detection and Ranging (LIDAR)	USGS Earth Explorer
(COGE) Coastal geomorphology	Map showing Beaufort Sea coastal erosion and accretion between Flaxman Island and the Canadian border, northeastern Alaska thirty-year coastline comparison, sediment volumes released, and physiographi	USGS Store
(CORG) Particulate total and organic carbon concentrations in the water column	Arctic-GRO Particulate carbon	Arctic Great Rivers Observatory (Arctic-GRO)
(CPWC) Chlorophyll pigment concentrations in water bodies	ARCTIC_REANALYSIS_BIO_002_005_mass_concentration_of_chlorophyll_in_sea_water	Copernicus Marine Environment Monitoring Service
(CPWC) Chlorophyll pigment concentrations in water bodies	INSITU_ARC_NRT_OBSERVATIONS_013_031_mass_concentration_of_chlorophyll_a_in_sea_water	Copernicus Marine Environment Monitoring Service
(CPWC) Chlorophyll pigment concentrations in water bodies	OCEANCOLOUR_ARC_CHL_L3_NRT_OBSERVATIONS_009_047	Copernicus Marine Environment Monitoring Service
(CPWC) Chlorophyll pigment concentrations in water bodies	OCEANCOLOUR_ARC_CHL_L3_REP_OBSERVATIONS_009_069	Copernicus Marine Environment Monitoring Service
(CPWC) Chlorophyll pigment concentrations in water bodies	OCEANCOLOUR_ARC_OPTICS_L3_NRT_OBSERVATIONS_009_046	Copernicus Marine Environment Monitoring Service
(CPWC) Chlorophyll pigment concentrations in water bodies	Chlorophyll Concentration (MODIS-A)	EMIS/GMIS
(CRYS) Snow and ice mass, thickness and extent	Regional Ice Charts	Arctic Regional Ocean Oberving System (ROOS)
(CRYS) Snow and ice mass, thickness and extent	SEASONAL ICE EXTENT IN Mill SQ.Km	Arctic Regional Ocean Oberving System (ROOS)
(CRYS) Snow and ice mass, thickness and extent	ARCTIC_ANALYSIS_FORECAST_PHYS_002_001_a_sea_ice_thickness	Copernicus Marine Environment Monitoring Service
(CRYS) Snow and ice mass, thickness and extent	ARCTIC_REANALYSIS_PHYS_002_003_sea_ice_thickness	Copernicus Marine Environment Monitoring Service
(CRYS) Snow and ice mass, thickness and extent	SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_002	Copernicus Marine Environment Monitoring Service
(CRYS) Snow and ice mass, thickness and	SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_002	Copernicus Marine Environment Monitoring Service

Parameter (P02)	Data set	Data Source
extent		
(CRYS) Snow and ice mass, thickness and extent	SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_003	Copernicus Marine Environment Monitoring Service
(CRYS) Snow and ice mass, thickness and extent	DataBasin Circum-Arctic Map of Permafrost and Ground Ice Conditions	DataBasin.org
(CRYS) Snow and ice mass, thickness and extent	natice 15-Day WISIF Graphs	U.S. National Ice Center / Naval Ice Center
(CRYS) Snow and ice mass, thickness and extent	natice Daily Ice Edge GRIB Files	U.S. National Ice Center / Naval Ice Center
(CRYS) Snow and ice mass, thickness and extent	natice MIZ (PNG) Files	U.S. National Ice Center / Naval Ice Center
(CRYS) Snow and ice mass, thickness and extent	DAILY ICE MAP FROM SSMI, NERSC	Arctic Regional Ocean Oberving System (ROOS)
(DOCC) Dissolved organic carbon concentration in the water column	Arctic-GRO DOC	Arctic Great Rivers Observatory (Arctic-GRO)
(DOCC) Dissolved organic carbon concentration in the water column	USGS DOC	United States Geological Survey (USGS) Water-Quality Data for the Nation
(DOXY) Dissolved oxygen parameters in the water column	ARCTIC_REANALYSIS_BIO_002_005_mass_concentration_of_oxygen_in_sea_water	Copernicus Marine Environment Monitoring Service
(DOXY) Dissolved oxygen parameters in the water column	INSITU_ARC_NRT_OBSERVATIONS_013_031_moles_of_oxygen_per_unit_mass_in_sea_water	Copernicus Marine Environment Monitoring Service
(EWSB) Wind strength and direction	Global Ocean Wind Observations Climatology REPROCESSED (Monthly means) (2007-2012)	Copernicus Marine Environment Monitoring Service
(EWSB) Wind strength and direction	WIND_GLO_WIND_L3_NRT_OBSERVATIONS_012_002	Copernicus Marine Environment Monitoring Service
(EWSB) Wind strength and direction	WIND_GLO_WIND_L4_NRT_OBSERVATIONS_012_004_wind	Copernicus Marine Environment Monitoring Service
(EWSB) Wind strength and direction	WIND_GLO_WIND_L4_REP_OBSERVATIONS_012_003_wind	Copernicus Marine Environment Monitoring Service
(EWSB) Wind strength and direction	GMN Wind	Global Marine Networks
(EWSB) Wind strength and direction	Cross-Calibrated Multi-Platform Ocean Surface Wind Vector L3.0 First-Look Analyses	Physical Oceanography Distributed Active Archive Center (PODAAC)
(FCST) Fish and shellfish catch statistics	Harvest information for community	Alaska Department of Fish and Game
(FCST) Fish and shellfish catch statistics	Statistics commercial fisheries	DFO Fisheries and Oceans Canada Marine Protected Areas
(FCST) Fish and shellfish catch statistics	Fisheries catches	Dg environment joint research centre eurostat european environment agency
(FCST) Fish and shellfish catch statistics	Commercial fish landings with Good Environmental Status information	Eea

Parameter (P02)	Data set	Data Source
(FCST) Fish and shellfish catch statistics	Fish catches	Emodnet Human activities
(FCST) Fish and shellfish catch statistics	Global capture production	Food and agriculture organization of the united nations fisheries and aquaculture department
(FCST) Fish and shellfish catch statistics	Catch and effort	Iccat
(FCST) Fish and shellfish catch statistics	Catch statistics	ICES data portal
(FCST) Fish and shellfish catch statistics	Catch and landings reports	National oceanic and atmospheric administration (noaa)
(FCST) Fish and shellfish catch statistics	Fisheries catches	Sea Around Us
(FCST) Fish and shellfish catch statistics	Fisheries landings and discards	STECF data dissemination
(FEFF) Fishing effort	Ship traffic lines fishing vessels	Arctic Geographical Information System (ArkGIS)
(FEFF) Fishing effort	Bottom Trawling and Dredging by Marine Ecoregion	DataBasin.org
(FEFF) Fishing effort	Fisheries effort	Dg environment joint research centre eurostat european environment agency
(FEFF) Fishing effort	Regional fishing effort and capacity	Eea
(FEFF) Fishing effort	Fisheries effort	STECF data dissemination
(GP080) Fishing by-catch	ICES workinggroup report Bycatch of Protected Species	ICES library, Data Outputs
(GP087) Fishery characterisation	Fishing fleet	European Atlas of the Seas
(HBCH) Habitat characterisation	Essential Fish Habitats	Arctic Integration Portal
(HBCH) Habitat characterisation	Marine Landscapes	Norges geologiske undersøkelse NGU
(HBCH) Habitat characterisation	Seabed habitats	Emodnet seabed habitats
(HBCH) Habitat characterisation	Habitats and biotopes	MESMA Geoportal
(HBEX) Habitat extent	Salt Marsh Abundance by Marine Ecoregion	DataBasin.org
(HBEX) Habitat extent	Subsea permafrost and sea ice extent in the northern hemisphere	DataBasin.org
(HBEX) Habitat extent	Tree line in the northern hemisphere	DataBasin.org
(HBEX) Habitat extent	Seabed habitats	Emodnet seabed habitats
(HBEX) Habitat extent	Vulnerable biotopes	Mareano
(HBEX) Habitat extent	Habitats and biotopes	MESMA Geoportal
(HEAV) Wave height estimates	GMN Wave	Global Marine Networks
(HEAV) Wave height estimates	Jason-1 Altimeter Geophysical Data	Physical Oceanography Distributed Active Archive Center (PODAAC)
(ICEM) Ice motion and related parameters	ARCTIC_ANALYSIS_FORECAST_PHYS_002_001_a_sea_ice_velocity	Copernicus Marine Environment Monitoring Service
(ICEM) Ice motion and related parameters	ARCTIC_REANALYSIS_PHYS_002_003_sea_ice_velocity	Copernicus Marine Environment Monitoring Service
(ICEM) Ice motion and related parameters	SEAICE_ARC_SEAICE_L3_REP_OBSERVATIONS_011_010	Copernicus Marine Environment Monitoring Service
(ICEM) Ice motion and	Sea Ice Concentration SIC_CRDP (SSMI, Arctic & Antarctic)	Integrated Climate Data Center -

Parameter (P02)	Data set	Data Source
related parameters		ICDC - Hamburg University
(ICEM) Ice motion and related parameters	Sea Ice Thickness SIT_CRDP (Arctic)	Integrated Climate Data Center - ICDC - Hamburg University
(ICEM) Ice motion and related parameters	Arctic Ice Charts	Nansen Environmental and Remote Sensing Center (NERSC)
(IPHY) Snow and ice physical properties and characteristics	ACADIS Physical/chemical and biological measurements of properties of sea ice and under-ice water collected near Barrow	ACADIS
(IPHY) Snow and ice physical properties and characteristics	SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_008_sea_ice_surface_temperature	Copernicus Marine Environment Monitoring Service
(IRBO) Stable isotope enrichment in biota	ACADIS Arctic cod fatty acid concentration and stable carbon isotope data from Arctic Alaska	ACADIS
(LIBI) Biota lipid concentrations	ACADIS Arctic cod fatty acid concentration and stable carbon isotope data from Arctic Alaska	ACADIS
(LIBI) Biota lipid concentrations	ACADIS Ice seal fatty acid concentrations and stable carbon isotopes of individual fatty acids from the Bering Sea and Arctic Alaska	ACADIS
(MBAN) Bathymetry and Elevation	GEBCO_2014 Grid	Gebco
(MBAN) Bathymetry and Elevation	One Stop Datashop (OSDS) Continental Shelf Programme	GRID Arendal
(MBAN) Bathymetry and Elevation	NOAA Bathymetric Data Viewer	NOAA Bathymetric Dataset
(MBAN) Bathymetry and Elevation	IBCAO	NOAA Data Catalog
(MBAN) Bathymetry and Elevation	IBCAO Gridded Bathymetric Data	NOAA Data Catalog
(MBAN) Bathymetry and Elevation	ICBAO Contour Data Files	NOAA Data Catalog
(MBAN) Bathymetry and Elevation	International Bathymetric Chart of the Arctic Ocean, Version 2.23	NOAA Data Catalog Version 2.23
(MBAN) Bathymetry and Elevation	batharcst	USGS Arctic Bathymetry
(MBAN) Bathymetry and Elevation	anadbath	USGS Bathymetric Maps
(MBAN) Bathymetry and Elevation	berchuk	USGS Bathymetric Maps
(MBAN) Bathymetry and Elevation	chukbath	USGS Bathymetric Maps
(MBAN) Bathymetry and Elevation	nosbath	USGS Bathymetric Maps
(MBAN) Bathymetry and Elevation	Beaufort Sea coastal erosion, sediment flux, shoreline evolution, and the erosional shelf profile	USGS: Map showing Beaufort Sea coastal erosion, sediment flux, shoreline evolution, and the erosional shelf profile
(NOYS) Acoustic noise in the water column	ACADIS Passive acoustic data from Davis Strait - C1	ACADIS
(NOYS) Acoustic noise in the water column	ACADIS Passive acoustic data from Davis Strait - C6	ACADIS
(NTOT) Particulate total and organic nitrogen concentrations in the water column	Arctic-GRO Particulate nitrogen	Arctic Great Rivers Observatory (Arctic-GRO)
(NTRA) Nitrate	Arctic-GRO Nitrate	Arctic Great Rivers Observatory

Parameter (P02)	Data set	Data Source
concentration parameters in the water column		(Arctic-GRO)
(NTRA) Nitrate concentration parameters in the water column	ARCTIC_REANALYSIS_BIO_002_005_mole_concentration_of_nitrate_in_sea_water	Copernicus Marine Environment Monitoring Service
(NTRA) Nitrate concentration parameters in the water column	GSN Nitrate	Unified Federal Service for Observation and Control of Environmental Pollution (OGSNK) and GSN
(NTRA) Nitrate concentration parameters in the water column	GEMSTAT nitrate	United nations environment programme global environment monitoring system (unepgems)
(NTRA) Nitrate concentration parameters in the water column	USGS Nitrate	United States Geological Survey (USGS) Water-Quality Data for the Nation
(PHOS) Phosphate concentration parameters in the water column	ARCTIC_REANALYSIS_BIO_002_005_mole_concentration_of_phosphate_in_sea_water	Copernicus Marine Environment Monitoring Service
(PHOS) Phosphate concentration parameters in the water column	Arctic Great Rivers Observatory Project River Biogeochemistry Dataset	Pan-Arctic River Transport of Nutrients, Organic Matter, and Suspended Sediments
(PPAB) Light absorption in the water column	OCEANCOLOUR_ARC_OPTICS_L3_REP_OBSERVATIONS_009_068	Copernicus Marine Environment Monitoring Service
(PPRD) Primary production in the water column	Primary Production (SEAWIFS)	EMIS/GMIS
(PSAL) Salinity of the water column	ARCTIC_ANALYSIS_FORECAST_PHYS_002_001_a_sea_water_salinity	Copernicus Marine Environment Monitoring Service
(PSAL) Salinity of the water column	ARCTIC_REANALYSIS_PHYS_002_003_sea_water_salinity	Copernicus Marine Environment Monitoring Service
(PSAL) Salinity of the water column	INSITU_ARC_NRT_OBSERVATIONS_013_031_sea_water_salinity	Copernicus Marine Environment Monitoring Service
(PSAL) Salinity of the water column	INSITU_ARC_TS_REP_OBSERVATIONS_013_037_sea_water_salinity	Copernicus Marine Environment Monitoring Service
(PSST) Skin temperature of the water column	SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_008_sea_surface_temperature	Copernicus Marine Environment Monitoring Service
(PSST) Skin temperature of the water column	SST_ARC_SST_L4_NRT_OBSERVATIONS_010_008_b	Copernicus Marine Environment Monitoring Service
(RFVL) Horizontal velocity of the water column (currents)	INSITU_ARC_NRT_OBSERVATIONS_013_031_sea_water_velocity	Copernicus Marine Environment Monitoring Service
(RVDS) River flow and discharge	ArcticRIMS Water Discharge River	ArcticRIMS
(RVDS) River flow and discharge	ART-Russia River temperature paper page	ART-Russia River temperature paper page
(RVDS) River flow and discharge	R-ArcticNet River Flow	R-ArcticNet
(RVDS) River flow and discharge	USGS Water Discharge River	United States Geological Survey (USGS) Surface-Water Data for the Nation

Parameter (P02)	Data set	Data Source
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	AquaNIS introduction of non-indigenous species per region	AquaNIS
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	BIOTIC - Biological Traits Information Catalogue. Marine Life Information Network.	Biotic
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	DAISIES invasive species presence in European regions	DAISIE Delivering Alien Invasive Species Inventories for Europe
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	DataBasin Arctic char (Salvelinus alpinus) distribution and status by HUC8	DataBasin.org
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	DataBasin Arctic cisco (Coregonus autumnalis) distribution and status by HUC8	DataBasin.org
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	DataBasin Arctic grayling (Thymallus arcticus) distribution and status by HUC8	DataBasin.org
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	DataBasin Arctic lamprey (Lampetra camtschatica) distribution and status by HUC8	DataBasin.org
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	EASIN Geodatabase	EASIN European Alien Species Information Network
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	EASIN-Lit	EASIN European Alien Species Information Network
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	GISIN List	GISIN Global Invasive Species Information Network
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	ARMS: Arctic Register of Marine Species	MarBEF
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	NOBANIS invasive alien species	NOBANIS The European Network on Invasive Alien Species
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	Aquatic Invasions	REABIC Regional Euro-Asian Biological Invasions Centre
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	BioInvasions Records	REABIC Regional Euro-Asian Biological Invasions Centre

Parameter (P02)	Data set	Data Source
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	Management of Biological Invasions	REABIC Regional Euro-Asian Biological Invasions Centre
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	The AquaInvader Database	REABIC Regional Euro-Asian Biological Invasions Centre
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	SeaLifeBase	SeaLifeBase
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	USGS Ocean Biogeographic Information System USA (OBIS-USA)	The Arctic Science Portal
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	IUCN Red List of Threatened Species Status	The IUCN Red List of Threatened Species
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	WoRMS taxonomical data	WoRMS World Register of Marine Species
(SBC_ARCTIC01) Species taxonomy, status and/or meta-information	CABI	ISC The CABI Invasive Species Compendium
(SIXX) Concentration of silicon species in the water column	Arctic-GRO Silicon	Arctic Great Rivers Observatory (Arctic-GRO)
(SIXX) Concentration of silicon species in the water column	GEMSTAT silicon	United nations environment programme global environment monitoring system (unepgems)
(SIXX) Concentration of silicon species in the water column	USGS silicon	United States Geological Survey (USGS) Water-Quality Data for the Nation
(TDNT) Dissolved total and organic nitrogen concentrations in the water column	Arctic-GRO Total nitrogen	Arctic Great Rivers Observatory (Arctic-GRO)
(TDPX) Dissolved total or organic phosphorus concentration in the water column	Arctic-GRO Phosphorous	Arctic Great Rivers Observatory (Arctic-GRO)
(TDPX) Dissolved total or organic phosphorus concentration in the water column	GSN Phosphorous	Unified Federal Service for Observation and Control of Environmental Pollution (OGSNK) and GSN
(TDPX) Dissolved total or organic phosphorus concentration in the water column	GEMSTAT phosphorous	United nations environment programme global environment monitoring system (unepgems)
(TDPX) Dissolved total or organic phosphorus concentration in the	USGS Phosphorous	United States Geological Survey (USGS) Water-Quality Data for the Nation

Parameter (P02)	Data set	Data Source
water column		
(TEMP) Temperature of the water column	ARCTIC_ANALYSIS_FORECAST_PHYS_002_001_a_sea_water_potential_temperature	Copernicus Marine Environment Monitoring Service
(TEMP) Temperature of the water column	ARCTIC_REANALYSIS_PHYS_002_003_sea_water_potential_temperature	Copernicus Marine Environment Monitoring Service
(TEMP) Temperature of the water column	INSITU_ARC_NRT_OBSERVATIONS_013_031_sea_water_temperature	Copernicus Marine Environment Monitoring Service
(TEMP) Temperature of the water column	INSITU_ARC_TS_REP_OBSERVATIONS_013_037_sea_water_temperature	Copernicus Marine Environment Monitoring Service
(TEMP) Temperature of the water column	Sea Surface Temperature (MODIS-T)	EMIS/GMIS
(TEMP) Temperature of the water column	Arctic Regional Climatology: temperature statistical mean 1° grid	Oceanographic data center
(TEMP) Temperature of the water column	USGS Water Temperature River	United States Geological Survey (USGS) Surface-Water Data for the Nation
(TRAN) Transport activity	ABDS	The Arctic Science Portal
(TSED) Concentration of suspended particulate material in the water column	Suspended Sediment Flux Kolyma	A circumpolar perspective on fluvial sediment flux to the Arctic Ocean
(TSED) Concentration of suspended particulate material in the water column	Suspended Sediment Flux Lena	A circumpolar perspective on fluvial sediment flux to the Arctic Ocean
(TSED) Concentration of suspended particulate material in the water column	Suspended Sediment Flux Mackenzie	A circumpolar perspective on fluvial sediment flux to the Arctic Ocean
(TSED) Concentration of suspended particulate material in the water column	Suspended Sediment Flux Ob	A circumpolar perspective on fluvial sediment flux to the Arctic Ocean
(TSED) Concentration of suspended particulate material in the water column	Suspended Sediment Flux Pechora	A circumpolar perspective on fluvial sediment flux to the Arctic Ocean
(TSED) Concentration of suspended particulate material in the water column	Suspended Sediment Flux Severnaya Dvina	A circumpolar perspective on fluvial sediment flux to the Arctic Ocean
(TSED) Concentration of suspended particulate material in the water column	Suspended Sediment Flux Yenisey	A circumpolar perspective on fluvial sediment flux to the Arctic Ocean
(TSED) Concentration of suspended particulate material in the water column	Suspended Sediment Flux Yukon	A circumpolar perspective on fluvial sediment flux to the Arctic Ocean
(WSTR) Wind stress and shear	WIND_GLO_WIND_L4_NRT_OBSERVATIONS_012_004_wind_stress	Copernicus Marine Environment Monitoring Service
(WSTR) Wind stress and shear	WIND_GLO_WIND_L4_REP_OBSERVATIONS_012_003_wind_stress	Copernicus Marine Environment Monitoring Service
(ZATX) Zooplankton	ACADIS	ACADIS

Parameter (P02)	Data set	Data Source
taxonomy-related abundance per unit volume of the water column	Canada_Basin_Zooplankton_2003_2006_Rutzen_Hopcroft	
(ZATX) Zooplankton taxonomy-related abundance per unit volume of the water column	ACADIS Chukchi_Zooplankton_1976_Pavshtiks	ACADIS
(ZATX) Zooplankton taxonomy-related abundance per unit volume of the water column	ACADIS Frobisher_Bay_Zooplankton_1967-1971_Grainger	ACADIS
(ZATX) Zooplankton taxonomy-related abundance per unit volume of the water column	ACADIS Zooplankton Composition and Abundance in the Laptev Sea and adjacent Nansen Basin, summer, 1993 (Polarstern ARK-IX/4)	ACADIS
(ZZZZ) Unspecified	Biological data from IMR (geographical data, sea birds, sea mammals, fish, etc.)	Havforskningsinstituttet IMR Institute of Marine Research
(ZZZZ) Unspecified	Alaska Environmental Sensitivity Index (ESI) maps	National oceanic and atmospheric administration (noaa)
(ZZZZ) Unspecified	IUCN Red List of Threatened Species (species range, geographical data)	The IUCN Red List of Threatened Species
(ZZZZ) Unspecified	canadian Sea Ice information	Canadian Ice Service
(ZZZZ) Unspecified	Map protected areas Greenland	Naalakkersuisut

In addition, the data sets (and their associated P02 parameter) currently considered or used for each challenge are listed in Table 8 per WP. The availability and appropriateness of datasets for the individual challenges will be addressed in the DAR.

Table 8. *List of datasets currently considered or used for each challenge (i.e. Work Package (WP)), including their associated P02 parameter and source.*

Data Source	Data set	Parameter (P02)
WP02 Wind Farm Siting		
World database on protected areas	World Database of Protected Areas WDPA	(ADUN) Administrative units
Open Street Map	Open Street Map OSM topographic data Arctic countries	(ADUN) Administrative units
MPAtlas: Russia	MPAtlas - Russia	(ADUN) Administrative units
World database on protected areas	WDPA MPA	(ALAT) Horizontal spatial co-ordinates
Ramsar	Ramsar sites	(ALAT) Horizontal spatial co-ordinates
Copernicus Marine Environment Monitoring Service	Global Ocean Wind Observations Climatology REPROCESSED (Monthly means) (2007-2012)	(EWSB) Wind strength and direction
Copernicus Marine Environment Monitoring Service	WIND_GLO_WIND_L4_NRT_OBSERVATIONS_012_004_wind	(EWSB) Wind strength and direction
Copernicus Marine	WIND_GLO_WIND_L4_NRT_OBSERVATIONS_012_004_wind_stress	(WSTR) Wind stress and

Data Source	Data set	Parameter (P02)
Environment Monitoring Service		shear
Copernicus Marine Environment Monitoring Service	WIND_GLO_WIND_L3_NRT_OBSERVATIONS_012_002	(EWSB) Wind strength and direction
Copernicus Marine Environment Monitoring Service	WIND_GLO_WIND_L4_REP_OBSERVATIONS_012_003_wind	(EWSB) Wind strength and direction
Copernicus Marine Environment Monitoring Service	WIND_GLO_WIND_L4_REP_OBSERVATIONS_012_003_wind_stress	(WSTR) Wind stress and shear
Marine traffic	MarineTraffic ship positions, velocity and heading	(APDA) Horizontal platform movement
Gebco	GEBCO_2014 Grid	(MBAN) Bathymetry and Elevation
Norges geologiske undersøkelse NGU	Marine Landscapes	(HBCH) Habitat characterisation
Havforskningsinstituttet IMR Institute of Marine Research	Biological data from IMR (geographical data, sea birds, sea mammals, fish, etc.)	(ZZZZ) Unspecified
Miljødirektoratet.NO	Marine Protected Areas - management plan active (marin_vp_oppstart)	(ADUN) Administrative units
Miljødirektoratet.NO	Marine Protected Areas - management plan inactive (marin_vp_ikke_oppstart	(ADUN) Administrative units
Miljødirektoratet.NO	Marine Protected Areas - proposed (foreslatt_vern_utm33)	(ADUN) Administrative units
WP03 Marine Protected Area (MPA)		
Natura2000	Natura2000 MPA	(ALAT) Horizontal spatial co-ordinates
OSPAR map of MPAs	OSPAR MPAs	(ALAT) Horizontal spatial co-ordinates
The IUCN Red List of Threatened Species	IUCN Red List of Threatened Species Status	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
The IUCN Red List of Threatened Species	IUCN Red List of Threatened Species (species range, geographical data)	(ZZZZ) Unspecified
Unesco	UNESCO world heritage list MPA	(ALAT) Horizontal spatial co-ordinates
World database on protected areas	World Database of Protected Areas WDPA	(ADUN) Administrative units
WoRMS World Register of Marine Species	WoRMS taxonomical data	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
USA NOAA National Marine Protected Areas Center	MPA inventory 2014	(ADUN) Administrative units
MPAtlas: Russia	MPAtlas - Russia	(ADUN) Administrative units
Havforskningsinstituttet IMR Institute of Marine Research	Biological data from IMR (geographical data, sea birds, sea mammals, fish, etc.)	(ZZZZ) Unspecified
Convention on Biological Diversity CBD	EBSA Arctic	(ADUN) Administrative units
Miljødirektoratet.NO	Marine Protected Areas - management plan active (marin_vp_oppstart)	(ADUN) Administrative units
Miljødirektoratet.NO	Marine Protected Areas - management plan inactive (marin_vp_ikke_oppstart	(ADUN) Administrative units
Miljødirektoratet.NO	Marine Protected Areas - proposed (foreslatt_vern_utm33)	(ADUN) Administrative

Data Source	Data set	Parameter (P02) units
WP04 oil spill		
NERSC neXtSIM coupled ice ocean model	Ice coverage (x,y,t)	(CRYS) Snow and ice mass, thickness and extent
NERSC TOPAZ coupled ice ocean model	Ice thickness (x,y,t)	(CRYS) Snow and ice mass, thickness and extent
NERSC neXtSIM coupled ice ocean model	Ice coverage (x,y,t)	(CRYS) Snow and ice mass, thickness and extent
NERSC TOPAZ coupled ice ocean model	Ice thickness (x,y,t)	(CRYS) Snow and ice mass, thickness and extent
Norwegian Meteorological Institute (Met.no) Wind / Weather	Wind (x,y,z=surface,t)	(EWSB) Wind strength and direction
Norwegian Meteorological Institute (Met.no) Wind / Weather	Significant wave height (x,y,t)	(WVST) Wave height and period statistics
Norwegian Meteorological Institute (Met.no) Wind / Weather	Cloud cover (x,y,t)	(CHEX) Cloud cover height and extent
Norwegian Meteorological Institute (Met.no) Wind / Weather	Air temperature (x,y,t)	(CDTA) Air temperature
Norwegian Meteorological Institute (Met.no) Wind / Weather	Precipitation (x,y,t)	(CPRP) Precipitation and evaporation
	Plankton species (x,y,z,t)	(PYTT) Plankton abundance per unit volume of the water column
World Wildlife Federation - ArkGIS	Fish species (x,y,z,t)	(FATX) Fish abundance in water bodies
World Wildlife Federation - ArkGIS	Bird species – seabirds (x,y,z,t)	(BRDA) Bird counts
World Wildlife Federation - ArkGIS	Mammal species – marine mammals (x,y,z,t)	(CETA) Cetacean abundance
World Wildlife Federation - ArkGIS	Human Use	(ALAT) Horizontal spatial co-ordinates
World Wildlife Federation - ArkGIS	Shipping Routes	(ALAT) Horizontal spatial co-ordinates
Nansen Environmental and Remote Sensing Center (NERSC)	NERSC TOPAZ coupled ice ocean model output	(ICEM) Ice motion and related parameters
Norwegian Meteorological Institute (Met.no) Wind / Weather	Sea Ice Concentration	(CRYS) Snow and ice mass, thickness and extent
Norwegian Meteorological Institute (Met.no) Wind / Weather	Sea Ice Extent	(CRYS) Snow and ice mass, thickness and extent
SINTEF Oil Weathering Model		

Data Source	Data set	Parameter (P02)
Arctic ERMA (Emergency Response Management Application		
Arctic Collaboration Environment (ACE)		
Norwegian Metoerological Institute (Met.no) forecast data		
NERSC neXtSIM coupled ice ocean model		
NERSC TOPAZ coupled ice ocean model		
		(RFVL) Horizontal velocity of the water column
	Horizontal Currents, U(x,y,z,t)	(currents)
		(TEMP) Temperature of the water column
	Ocean Water temperature T(x,y,z,t)	
		(PSAL) Salinity of the water column
	Ocean Salinity S(x,y,z,t)	
Nansen Environmental and Remote Sensing Center (NERSC)	NERSC TOPAZ coupled ice ocean model output	(ICEM) Ice motion and related parameters
WP05 Climate change		
MarBEF	ARMS: Arctic Register of Marine Species	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
Norges geologiske undersøkelse NGU	Marine Landscapes	(HBCH) Habitat characterisation
Havforskningsinstituttet IMR Institute of Marine Research	Biological data from IMR (geographical data, sea birds, sea mammals, fish, etc.)	(ZZZZ) Unspecified
Arctic Integration Portal	Essential Fish Habitats	(HBCH) Habitat characterisation
Alaska Department of Fish and Game	Harvest information for community	(FCST) Fish and shellfish catch statistics
EMIS/GMIS	Chlorophyll Concentration (MODIS-A)	(CPWC) Chlorophyll pigment concentrations in water bodies
EMIS/GMIS	Primary Production (SEAWIFS)	(PPRD) Primary production in the water column
EMIS/GMIS	Sea Surface Temperature (MODIS-T)	(TEMP) Temperature of the water column
Integrated Climate Data Center - ICDC - Hamburg University	Sea Ice Concentration SIC_CRDP (SSMI, Arctic & Antarctic)	(ICEM) Ice motion and related parameters
Integrated Climate Data Center - ICDC - Hamburg University	Sea Ice Thickness SIT_CRDP (Arctic)	(ICEM) Ice motion and related parameters
Global Sea Level Observing System (GLOSS)	Permanent Service for Mean Sea Level (PSMSL)	(ASLV) Sea level
The Arctic Monitoring and Assessment Programme (AMAP)	Arctic Climate Issues 2011: Changes in Arctic Snow, Water, Ice and Permafrost	
SeaLifeBase	SeaLifeBase	(SBC_ARCTIC01) Species taxonomy, status and/or

Data Source	Data set	Parameter (P02)
		meta-information
Biotic	BIOTIC - Biological Traits Information Catalogue. Marine Life Information Network.	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
WoRMS World Register of Marine Species	WoRMS taxonomical data	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
MESMA Geoportal	Habitats and biotopes	
Oceanographic data center	Arctic Regional Climatology: temperature statistical mean 1° grid	(TEMP) Temperature of the water column
Permanent service for mean sea level	Permenant Service for Mean Sea Level	(ASLV) Sea level
The IUCN Red List of Threatened Species	IUCN Red List of Threatened Species (species range, geographical data)	(ZZZZ) Unspecified
The IUCN Red List of Threatened Species	IUCN Red List of Threatened Species Status	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
The IUCN Red List of Threatened Species	IUCN Red List of Threatened Species Extent	(ALAT) Horizontal spatial co-ordinates
U.S. National Ice Center / Naval Ice Center	natice Daily Ice Edge GRIB Files	(CRYS) Snow and ice mass, thickness and extent
U.S. National Ice Center / Naval Ice Center	natice 15-Day WISIF Graphs	(CRYS) Snow and ice mass, thickness and extent
U.S. National Ice Center / Naval Ice Center	natice 15-Day WISIF Graphs (temperature)	(CDTA) Air temperature
Arctic Regional Ocean Oberving System (ROOS)	DAILY ICE MAP FROM SSMI, NERSC	
Arctic Regional Ocean Oberving System (ROOS)	SEASONAL ICE EXTENT IN Mill SQ.Km	(CRYS) Snow and ice mass, thickness and extent
Arctic Regional Ocean Oberving System (ROOS)	Regional Ice Charts	(CRYS) Snow and ice mass, thickness and extent
Canadian Ice Service	canadian Sea Ice information	
DataBasin.org	Subsea permafrost and sea ice extent in the northern hemisphere	(HBEX) Habitat extent
DataBasin.org	DataBasin Arctic Field Research Projects	(ALAT) Horizontal spatial co-ordinates
DataBasin.org	DataBasin Circumpolar Arctic Vegetation	(ALAT) Horizontal spatial co-ordinates
DataBasin.org	DataBasin Circum-Arctic Map of Permafrost and Ground Ice Conditions	(CRYS) Snow and ice mass, thickness and extent
DataBasin.org	DataBasin Alaska Arctic Vegetation	(ALAT) Horizontal spatial co-ordinates
Food and agriculture organization of the united nations fisheries and aquaculture department	Global capture production	(FCST) Fish and shellfish catch statistics
Emodnet seabed habitats	Seabed habitats	
Mareano	Vulnerable biotopes	
Mareano	Top 10 species (biodiversity)	(BDRV) Biodiversity indices

Data Source	Data set	Parameter (P02)
Copernicus Marine Environment Monitoring Service	ARCTIC_ANALYSIS_FORECAST_PHYS_002_001_a_sea_water_salinity	(PSAL) Salinity of the water column
Copernicus Marine Environment Monitoring Service	ARCTIC_ANALYSIS_FORECAST_PHYS_002_001_a_sea_ice_velocity	(ICEM) Ice motion and related parameters
Copernicus Marine Environment Monitoring Service	ARCTIC_ANALYSIS_FORECAST_PHYS_002_001_a_sea_ice_thickness	(CRYS) Snow and ice mass, thickness and extent
Copernicus Marine Environment Monitoring Service	ARCTIC_ANALYSIS_FORECAST_PHYS_002_001_a_sea_water_potential_temperature	(TEMP) Temperature of the water column
Copernicus Marine Environment Monitoring Service	ARCTIC_REANALYSIS_PHYS_002_003_sea_water_salinity	(PSAL) Salinity of the water column
Copernicus Marine Environment Monitoring Service	ARCTIC_REANALYSIS_PHYS_002_003_sea_ice_velocity	(ICEM) Ice motion and related parameters
Copernicus Marine Environment Monitoring Service	ARCTIC_REANALYSIS_PHYS_002_003_sea_ice_thickness	(CRYS) Snow and ice mass, thickness and extent
Copernicus Marine Environment Monitoring Service	ARCTIC_REANALYSIS_PHYS_002_003_sea_water_potential_temperature	(TEMP) Temperature of the water column
Copernicus Marine Environment Monitoring Service	ARCTIC_REANALYSIS_BIO_002_005_mass_concentration_of_chlorophyll_in_sea_water	(CPWC) Chlorophyll pigment concentrations in water bodies
Copernicus Marine Environment Monitoring Service	SEALEVEL_GLO_SLA_L3_NRT_OBSERVATIONS_008_017	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_GLO_SLA_L3_REP_OBSERVATIONS_008_018	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_ARC_SLA_L3_NRT_OBSERVATIONS_008_025	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_GLO_SLA_MAP_L4_NRT_OBSERVATIONS_008_026	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_GLO_REF20YTO7Y_L4_OBSERVATIONS_008_034	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_GLO_SLA_MAP_L4_REP_OBSERVATIONS_008_027	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_GLO_MDT_L4_REF_OBSERVATIONS_008_013	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_GLO_MSS_L4_REF_OBSERVATIONS_008_015	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	OCEANCOLOUR_ARC_CHL_L3_NRT_OBSERVATIONS_009_047	(CPWC) Chlorophyll pigment concentrations in water bodies
Copernicus Marine	OCEANCOLOUR_ARC_CHL_L3_REP_OBSERVATIONS_009_069	(CPWC) Chlorophyll

Data Source	Data set	Parameter (P02)
Environment Monitoring Service		pigment concentrations in water bodies
Copernicus Marine Environment Monitoring Service	OCEANCOLOUR_ARC_OPTICS_L3_NRT_OBSERVATIONS_009_046	(CPWC) Chlorophyll pigment concentrations in water bodies
Copernicus Marine Environment Monitoring Service	OCEANCOLOUR_ARC_OPTICS_L3_REP_OBSERVATIONS_009_068	(PPAB) Light absorption in the water column
Copernicus Marine Environment Monitoring Service	SST_ARC_SST_L4_NRT_OBSERVATIONS_010_008_b	(PSST) Skin temperature of the water column
Copernicus Marine Environment Monitoring Service	SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_008_sea_surface_temperature	(PSST) Skin temperature of the water column
Copernicus Marine Environment Monitoring Service	SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_008_sea_ice_surface_temperature	(IPHY) Snow and ice physical properties and characteristics
Copernicus Marine Environment Monitoring Service	SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_003	(CRYS) Snow and ice mass, thickness and extent
Copernicus Marine Environment Monitoring Service	SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_002	(CRYS) Snow and ice mass, thickness and extent
Copernicus Marine Environment Monitoring Service	SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_002	(CRYS) Snow and ice mass, thickness and extent
Copernicus Marine Environment Monitoring Service	SEAICE_ARC_SEAICE_L3_REP_OBSERVATIONS_011_010	(ICEM) Ice motion and related parameters
Copernicus Marine Environment Monitoring Service	INSITU_ARC_NRT_OBSERVATIONS_013_031_mass_concentration_of_chlorophyll_a_in_sea_water	(CPWC) Chlorophyll pigment concentrations in water bodies
Copernicus Marine Environment Monitoring Service	INSITU_ARC_NRT_OBSERVATIONS_013_031_sea_water_salinity	(PSAL) Salinity of the water column
Copernicus Marine Environment Monitoring Service	INSITU_ARC_NRT_OBSERVATIONS_013_031_sea_water_temperature	(TEMP) Temperature of the water column
Copernicus Marine Environment Monitoring Service	INSITU_ARC_NRT_OBSERVATIONS_013_031_sea_surface_height_above_sea_level	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	INSITU_ARC_TS_REP_OBSERVATIONS_013_037_sea_water_temperature	(TEMP) Temperature of the water column
Copernicus Marine Environment Monitoring Service	INSITU_ARC_TS_REP_OBSERVATIONS_013_037_sea_water_salinity	(PSAL) Salinity of the water column
Nansen Environmental and Remote Sensing Center (NERSC)	Arctic Ice Charts	(ICEM) Ice motion and related parameters
WP06 Coasts		
Global Sea Level Observing System (GLOSS)	Permanent Service for Mean Sea Level (PSMSL)	(ASLV) Sea level
USGS Store	Map showing Beaufort Sea coastal erosion and accretion between Flaxman Island and the Canadian border, northeastern Alaska	(COGE) Coastal geomorphology

Data Source	Data set	Parameter (P02)
	thirty-year coastline comparison, sediment volumes released, and physiographi	
USGS Earth Explorer	Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010)	(COGE) Coastal geomorphology
USGS Earth Explorer	Global 30 Arc-Second Elevation (GTOPO30)	(COGE) Coastal geomorphology
USGS Earth Explorer	Interferometric Synthetic Aperture Radar (IFSAR) Alaska	(COGE) Coastal geomorphology
USGS Earth Explorer	Light Detection and Ranging (LIDAR)	(COGE) Coastal geomorphology
GeoBasis - ZERO	Geomorphology: coastal cliff recession	(COGE) Coastal geomorphology
GeoBasis - ZERO	Geomorphology: topographic beach profile	(COGE) Coastal geomorphology
NOAA Data Catalog Version 2.23	International Bathymetric Chart of the Arctic Ocean, Version 2.23	(MBAN) Bathymetry and Elevation
Soil carbon and material fluxes across the eroding Alaska Beaufort	Erosion Rate of 48 Sampling Locations Along the Beaufort Sea Coast, Alaskaa	(COGE) Coastal geomorphology
Soil carbon and material fluxes across the eroding Alaska Beaufort	Coastal Type of of 48 Sampling Locations Along the Beaufort Sea Coast, Alaska	(COGE) Coastal geomorphology
Soil carbon and material fluxes across the eroding Alaska Beaufort	Bank Height of 48 Sampling Locations Along the Beaufort Sea Coast, Alaska	(COGE) Coastal geomorphology
Permanent service for mean sea level	Permenant Service for Mean Sea Level	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_GLO_SLA_L3_NRT_OBSERVATIONS_008_017	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_GLO_SLA_L3_REP_OBSERVATIONS_008_018	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_ARC_SLA_L3_NRT_OBSERVATIONS_008_025	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_GLO_SLA_MAP_L4_NRT_OBSERVATIONS_008_026	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_GLO_REF20YTO7Y_L4_OBSERVATIONS_008_034	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_GLO_SLA_MAP_L4_REP_OBSERVATIONS_008_027	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_GLO_MDT_L4_REF_OBSERVATIONS_008_013	(ASLV) Sea level
Copernicus Marine Environment Monitoring Service	SEALEVEL_GLO_MSS_L4_REF_OBSERVATIONS_008_015	(ASLV) Sea level
Gebco	GEBCO_2014 Grid	(MBAN) Bathymetry and Elevation
WP07 Fisheries management		
DFO Fisheries and Oceans	Statistics commercial fisheries	(FCST) Fish and shellfish

Data Source	Data set	Parameter (P02)
Canada Marine Protected Areas		catch statistics
DataBasin.org	Bottom Trawling and Dredging by Marine Ecoregion	(FEFF) Fishing effort
Dg environment joint research centre eurostat european environment agency	Fisheries catches	(FCST) Fish and shellfish catch statistics
Food and agriculture organization of the united nations fisheries and aquaculture department	Global capture production	(FCST) Fish and shellfish catch statistics
Emodnet Human activities	Fish catches	(FCST) Fish and shellfish catch statistics
Iccat	Catch and effort	(FCST) Fish and shellfish catch statistics
ICES data portal	Catch statistics	(FCST) Fish and shellfish catch statistics
ICES library, Data Outputs	ICES workinggroup report Bycatch of Protected Species	(GP080) Fishing by-catch
Alaska Department of Fish and Game	Harvest information for community	(FCST) Fish and shellfish catch statistics
STECF data dissemination	Fisheries landings and discards	(FCST) Fish and shellfish catch statistics
Sea Around Us	Fisheries catches	(FCST) Fish and shellfish catch statistics
WP08 Fisheries Impact		
Iccat	Catch and effort	(FCST) Fish and shellfish catch statistics
Mareano	Vulnerable biotopes	
Dg environment joint research centre eurostat european environment agency	Fisheries effort	(FEFF) Fishing effort
Eea	Regional fishing effort and capacity	(FEFF) Fishing effort
Emodnet seabed habitats	Seabed habitats	
European Atlas of the Seas	Fishing fleet	
Arctic Geographical Information System (ArkGIS)	Ship traffic lines fishing vessels	(FEFF) Fishing effort
Marine traffic	MarineTraffic ship positions, velocity and heading	(APDA) Horizontal platform movement
MESMA Geoportal	Habitats and biotopes	
USA NOAA National Marine Protected Areas Center	MPA inventory 2014	(ADUN) Administrative units
DFO Fisheries and Oceans Canada Marine Protected Areas	Statistics commercial fisheries	(FCST) Fish and shellfish catch statistics
OSPAR map of MPAs	OSPAR MPAs	(ALAT) Horizontal spatial co-ordinates
World database on protected areas	WDPA MPA	(ALAT) Horizontal spatial co-ordinates
World database on protected areas	World Database of Protected Areas WDPA	(ADUN) Administrative units
The Arctic Biodiversity Data Service (ABDS) Data Portal	AMAP Boundary	(ADUN) Administrative units
Naalakkersuisut	Map protected areas Greenland	
STECF data dissemination	Fisheries effort	(FEFF) Fishing effort
Arctic Integration Portal	Essential Fish Habitats	(HBCH) Habitat

Data Source	Data set	Parameter (P02) characterisation
MPAtlas: Russia	MPAtlas - Russia	(ADUN) Administrative units
Miljødirektoratet.NO	Marine Protected Areas - proposed (foreslatt_vern_utm33)	(ADUN) Administrative units
WP10 Rivers Challenge		
Arctic Great Rivers Observatory (Arctic-GRO)	Arctic-GRO Nitrate	(NTRA) Nitrate concentration parameters in the water column
Arctic Great Rivers Observatory (Arctic-GRO)	Arctic-GRO Phosphorous	(TDPX) Dissolved total or organic phosphorus concentration in the water column
Arctic Great Rivers Observatory (Arctic-GRO)	Arctic-GRO Total nitrogen	(TDNT) Dissolved total and organic nitrogen concentrations in the water column
Arctic Great Rivers Observatory (Arctic-GRO)	Arctic-GRO Particulate nitrogen	(NTOT) Particulate total and organic nitrogen concentrations in the water column
R-ArcticNet	R-ArcticNet River Flow	(RVDS) River flow and discharge
United States Geological Survey (USGS) Water-Quality Data for the Nation	USGS Nitrate	(NTRA) Nitrate concentration parameters in the water column
United States Geological Survey (USGS) Water-Quality Data for the Nation	USGS Phosphorous	(TDPX) Dissolved total or organic phosphorus concentration in the water column
United States Geological Survey (USGS) Surface-Water Data for the Nation	USGS Water Discharge River	(RVDS) River flow and discharge
United States Geological Survey (USGS) Surface-Water Data for the Nation	USGS Water Temperature River	(TEMP) Temperature of the water column
ArcticRIMS	ArcticRIMS Water Discharge River	(RVDS) River flow and discharge
Pan-Arctic River Transport of Nutrients, Organic Matter, and Suspended Sediments	Arctic Great Rivers Observatory Project River Biogeochemistry Dataset	(PHOS) Phosphate concentration parameters in the water column
ART-Russia River temperature paper page	ART-Russia River temperature paper page	(RVDS) River flow and discharge
A circumpolar perspective on fluvial sediment flux to the Arctic Ocean	Suspended Sediment Flux Yenisey	(TSED) Concentration of suspended particulate material in the water column
A circumpolar perspective on fluvial sediment flux to the Arctic Ocean	Suspended Sediment Flux Lena	(TSED) Concentration of suspended particulate material in the water column
A circumpolar perspective on fluvial sediment flux to the Arctic Ocean	Suspended Sediment Flux Ob	(TSED) Concentration of suspended particulate material in the water column

Data Source	Data set	Parameter (P02)
A circumpolar perspective on fluvial sediment flux to the Arctic Ocean	Suspended Sediment Flux Pechora	(TSED) Concentration of suspended particulate material in the water column
A circumpolar perspective on fluvial sediment flux to the Arctic Ocean	Suspended Sediment Flux Kolyma	(TSED) Concentration of suspended particulate material in the water column
A circumpolar perspective on fluvial sediment flux to the Arctic Ocean	Suspended Sediment Flux Severnaya Dvina	(TSED) Concentration of suspended particulate material in the water column
A circumpolar perspective on fluvial sediment flux to the Arctic Ocean	Suspended Sediment Flux Mackenzie	(TSED) Concentration of suspended particulate material in the water column
A circumpolar perspective on fluvial sediment flux to the Arctic Ocean	Suspended Sediment Flux Yukon	(TSED) Concentration of suspended particulate material in the water column
WP11 Bathymetry		
NOAA Bathymetric Dataset	NOAA Bathymetric Data Viewer	(MBAN) Bathymetry and Elevation
NOAA Data Catalog	ICBAO Contour Data Files	(MBAN) Bathymetry and Elevation
NOAA Data Catalog	IBCAO Gridded Bathymetric Data	(MBAN) Bathymetry and Elevation
NOAA Data Catalog	IBCAO	(MBAN) Bathymetry and Elevation
GRID Arendal	One Stop Datashop (OSDS) Continental Shelf Programme	(MBAN) Bathymetry and Elevation
USGS Bathymetric Maps	berchuk	(MBAN) Bathymetry and Elevation
USGS Bathymetric Maps	chukbath	(MBAN) Bathymetry and Elevation
USGS Bathymetric Maps	nosbath	(MBAN) Bathymetry and Elevation
USGS Bathymetric Maps	anadbath	(MBAN) Bathymetry and Elevation
USGS Arctic Bathymetry	batharcst	(MBAN) Bathymetry and Elevation
NOAA Data Catalog Version 2.23	International Bathymetric Chart of the Arctic Ocean, Version 2.23	(MBAN) Bathymetry and Elevation
WP12 Alien Species		
MarBEF	ARMS: Arctic Register of Marine Species	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
The Arctic Science Portal	USGS Ocean Biogeographic Information System USA (OBIS-USA)	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
The Arctic Science Portal	ABDS	(TRAN) Transport activity
DAISIE Delivering Alien Invasive Species Inventories for Europe	DAISIES invasive species presence in European regions	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
EASIN European Alien Species	EASIN-Lit	(SBC_ARCTIC01) Species

Data Source	Data set	Parameter (P02)
Information Network		taxonomy, status and/or meta-information
EASIN European Alien Species Information Network	EASIN Geodatabase	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
GISIN Global Invasive Species Information Network	GISIN List	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
REABIC Regional Euro-Asian Biological Invasions Centre	The AquaInvader Database	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
REABIC Regional Euro-Asian Biological Invasions Centre	BioInvasions Records	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
REABIC Regional Euro-Asian Biological Invasions Centre	Aquatic Invasions	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
REABIC Regional Euro-Asian Biological Invasions Centre	Management of Biological Invasions	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
NOBANIS The European Network on Invasive Alien Species	NOBANIS invasive alien species	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
ISC The CABI Invasive Species Compendium	CABI	
SeaLifeBase	SeaLifeBase	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
AquaNIS	AquaNIS introduction of non-indigenous species per region	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
Biotic	BIOTIC - Biological Traits Information Catalogue. Marine Life Information Network.	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information
WoRMS World Register of Marine Species	WoRMS taxonomical data	(SBC_ARCTIC01) Species taxonomy, status and/or meta-information

6 Specific literature review on inadequate data

6.1 References in literature to inadequate data

References in literature to goals not achieved because of inadequacy of data (eg. unable to estimate coastal erosion accurately) are listed for each assessment purpose (Table 9). For each limitation that has been identified, reasons for inadequacy are provided, if known. Additional information is provided in Annex 8, including any statements made to the fitness for purpose of data. The information on inadequate data, as listed in Table 9 and described in Annex 8 above, are also presented per parameter (Table 10).

Table 9. *Overview of references to inadequate data per purpose, indicating reasons for inadequacy.*

Purpose	Reluctance to release data	Time to obtain data	Lack of measure-ments	Lack of accuracy / precision	References
Assessment of environmental impact			x		AMAP (1998); CAFF (2010); OSPAR (2009)
Assessment of ecological status			x		CAFF (2010); Vassily et al. (2011); Böhm et al. (2012)
Marine spatial planning (WP02)			x		Vassily et al. (2011); Hoel (2010)
Assessment of (potential) MPAs (WP03)			x		CAFF (2010); Boertmann et al. (2010)
Oil spill response (WP04)		x	x		Wynja et al. (2015); US-MMS (2009)
Assessment of climate change (WP05)			x	x	Houghton et al. (1995); Oliver-Smith (2009)
Assessment of coastal evolvement (WP06)			x	x	Lantuit et al. (2012); Proshutinsky *et al*. (2004)
Fisheries management and impact assessment, including stock assessment (WP07 & WP08)	x		x		Gerritsen et al. (2013); Jennings and Lee (2012); Lambert et al. (2012); Lee et al. (2010); Piet and Hintzen (2012); EEA (2015)
Assessment of riverine input (WP10)	x		x		ArcticRIMS Project
Assessment of navigational risks (WP11)			x		Arctic Council (2009, 2015)
Assessment of risks posed by invasive species (WP12)			x		Chan et al. (2015) Goldsmit et al (2014)

Table 10. *Overview of references to inadequate data per parameter.*

Description
Activities: Information on a spatial scale of activities present in OSPAR Region I (Arctic waters) is sparse (OSPAR, 2009).
Baseline coastal information (e.g. shoreline form, substrate, and vegetation type): There is a large information gap regarding Arctic shorelines (Wynja et al., 2015).
Bathymetry: Adequate data was available to quantify the length and variability of the Northern Sea Route (NSR) navigation season (Stephenson et al., 2014). Data availability and quality was sufficient for development of a digital seafloor geomorphic features map, although new, higher resolution, bathymetric data would improve the map (Harris et al., 2014).
Biodiversity: The Arctic Climate Impact Assessment clearly demonstrated a general lack of information on quantified effects of climate change on biodiversity (CAFF, 2010). The information on marine and coastal biological diversity of the Russian Arctic is sufficient for a preliminary outline of future marine spatial planning (Vassily et al., 2011). In Norway, a set of indicators are monitored over time, deriving adequate data to assess whether planned objectives are achieved (Hoel, 2010). Chan *et al*. (2015) could not determine the invasion status of Canadian Arctic species with confidence due to insufficient baseline biodiversity information for Canada's Arctic coastal systems. Data is lacking, particularly with respect to benthic invertebrate biodiversity (Archambault et al. 2010; Piepenburg et al. 2011)
Chlorophyl-a: Lack of satellite based Chl-a data due to clouds or ice (Jeffries *et al*., 2015).
Coastal erosion: Datasets are restricted spatially and most of the database segments were characterized using discrete measurements of erosion along the coastline that were then extrapolated to the rest of the segment (Lantuit et al., 2012). In remote areas, north of 80°N, records were often unavailable and the erosion data was generated from maps of sea ice cover.
Ecosystem services: Better (detailed and accurate) data on the nature, extent and value of Arctic ecosystem services (e.g. subsistence, cultural uses, shoreline protection) are needed (UNEP, 2014).
Fisheries data (e.g. harvests, effort): In Russia, data is not available, confidential or fabricated (University of Alaska Fairbanks, 1996).
Fishing gear type: The VMS data itself contain no information on the gear type used (Gerritsen et al., 2013). Data has to be gathered from other sources. Full information on the gears used by non-UK vessels could not be accessed (Lambert et al., 2012).
Hydrographic data: The quality of the data varies widely from modern, high resolution hydrographic surveys to no sounding information in some areas (Arctic Council, 2009).
Ice data: The needs of mariners for ice information are currently met by a number of organizations, including national ice services that produce information for the Arctic that is generally freely available as a public service funded by tax-payers; academic institutions that provide ice information as part of an ongoing research program or to support field research campaigns; and commercial ice information services that provide services that are specific to individual clients with particular needs. As more ships venture into the Arctic and the demand for ice information and related services increases, there will be increasing pressure on the resources of ice information providers (Arctic Council, 2009). NOAA (2014) reports the following: "Accurate weekly sea ice information is important for many stakeholders to operate in the marine environment, including the U.S. Coast Guard, Arctic coastal communities and Alaska Native populations, the oil and gas and fishing industries, first responders to emergencies, and scientific researchers. Current sea ice forecasts are based primarily on satellite data, simple sea ice drift calculations, and Arctic weather models. Generating timely forecasts depends on the ability to collect basic observations and rapidly process the information. To improve weekly sea ice forecasts, NOAA is developing and refining higher spatial resolution regional sea ice models for Alaska waters that can assimilate both weather and sea ice observations." A compilation of National Ice Center (NIC) sea ice data sets is provided by Fetterer (2006), offering a valuable record of ice conditions that supplements records from other sources. Adequate data was available to quantify the length and variability of the Northern Sea Route (NSR) navigation season (Stephenson et al., 2014). Fetterer (2006) provides a selection of documentation related to National Ice Center (NIC) sea ice charts in digital format. The NIC sea ice chart series begins in 1972, and offers a valuable record of ice conditions that supplements records from other sources, such as passive microwave satellite data. Researchers using the NIC data sets distributed by NSIDC will benefit from understanding how charts are created, what data sources are used, how charts have been digitized in the past, and how chart information has changed over the years (Fetterer, 2006).
Non-indigenous Species (NIS): Inadequate data on NIS in the Arctic Ocean (Goldsmit et al., 2014; Chan *et al*., 2015). The Arctic Ocean is the least sampled of the world´s oceans (Arctic Council 2009).
Pollution levels: inadequate data coverage/significant data gaps, in particular for Alaska and parts of Russia (AMAP, 1998).
Population status: Studies of the status of char populations in Arctic regions are generally lacking. Insufficient or no data to provide an assessment of Polar bear subpopulation status, especially for the Russian subpopulations (CAFF, 2010).
Population trend data: Population trend data from the Arctic Species Trend Index (ASTI) data set are not evenly

distributed throughout the Arctic region, with gaps in spatial coverage in Russia, Greenland (particularly northern parts) and islands off the northern coast of Canada (Böhm *et al.,* 2012).

Precipitation: The accuracy of precipitation minus evaporation (P-E) reanalysis data over the open ocean, and the river discharge data, is not sufficient to allow robust conclusions to be drawn. The P-E estimates over the Arctic Ocean are less accurate than the other investigated factors (wind, water density, river runoff, etc.) (Proshutinsky et al., 2004).

Reproductive phenology of birds and mammals: The reproductive phenology of birds and mammals appears to be less responsive to changes in the physical environment but a conclusive comparison among taxa is hampered by the scarcity of data (CAFF, 2010).

River discharge: Real-time river discharge data has been underutilized within the ocean-atmosphere modeling community with typical 3-5 year delays in data posting and a deterioration in gauge networks even in previously well-monitored parts of the globe has been identified by the Arctic-RIMS project (http://rims.unh.edu/background.shtml).

Sea level: Sea level observations at some stations have had different locations in summer and winter, some of which were interrupted during replacement. Therefore much of the sea level data collected before 1949–1950 cannot be used because of the absence of a reliable geodetic survey. The existing sea level data sets in the Arctic are relatively short for the analysis of global sea level rise. The Arctic Ocean sea level time series have well pronounced decadal variability which corresponds to the variability of the North Atlantic Oscillation index. Because of the strength of this variability and the relatively short sea level time series, our assessments of sea level trends remain somewhat uncertain (Proshutinsky et al., 2004).

Sensitive areas: A full overview of biologically sensitive areas in the Arctic marine ecosystem, including on the high seas areas beyond national jurisdictions, is lacking (CAFF, 2010).

Snow depth: Our knowledge of snow depth on top of Arctic sea ice is limited (Zygmuntowska et al., 2014).

Species distribution: A lack of data has been identified for the establishment of protected areas for the Northern right whale, the Narwal in East Greenland, and for some other marine mammals (Boertmann et al., 2010). The lack of information about distribution of sponges makes it very difficult to evaluate trends (CAFF, 2010).

Stock assessments: The current availability of stock assessments is not sufficient (EEA, 2015).

Vessel position: Generally, only vessels >15 m are monitored in Europe, and they typically transmit position records at intervals of 2 h. Reported limitations of Vessel Monitoring Systems (VMS) records are: incomplete coverage of vessel activities, long durations between position records, and a lack of information on whether a vessel is actually fishing when the position is reported (Gerritsen *et al*., 2013; Lambert *et al*., 2012). Restrictions on data access and the absence of standardized methods of analysis hamper data exchange and their use in assessment and planning (Lambert *et al*., 2012). For example, Piet and Hintzen (2012) limited their study to their Dutch EEZ only instead of all European waters because there are still confidentiality issues that prevent access to the international VMS data. Only a small proportion of fishing vessels are equipped with Automatic Identification System (AIS) and spatial coverage of the data is incomplete because data are only recorded if a vessel is within VHF range of a base station (Gerritsen et al., 2013). VMS greatly increase the availability of data on the distribution of fishing activity, providing vessel-specific high-resolution data from all fishing grounds used by larger vessels (Jennings and Lee, 2012).

Wave data: Buoys that measure the wave heights and directions are essential for model validation but none of these exist in the Arctic for operational reporting. Because of the necessity to deal with winter ice, a new generation of buoys will have to be developed (Arctic Council, 2009).

Weather data: The coverage of INMARSAT Global Maritime Distress Safety System transmissions, marine safety information in the form of gale and storm warnings is in place but not fully covers the high seas regions of the Arctic (Arctic Council, 2009). The Arctic Council (2009) reports: “Although weather forecasts for the Arctic are based on the same tools using the same techniques as in other areas of the world, the scarcity of observations in the Arctic makes the monitoring of the weather more difficult than in areas with more observations. Meteorological observations in the Arctic rely on drifting buoys placed on top of the sea ice. A new generation of buoys that will withstand multiple freeze-thaw cycles is currently under development and is urgently needed to provide surface observations in the Arctic Ocean. The ability to measure the conditions of the atmosphere and ocean from satellites is, however, developing rapidly and, with adequate surface validation, the quality of weather forecasts will approach the quality used in other areas.” NOAA (2014) reports the following: “Weather analysis and prediction capabilities are currently poorer in the Arctic than in other parts of the United States. Major challenges for long-term modeling being addressed by NOAA include the lack of good physical data regarding winds and clouds. Although accurate forecasts and models depend upon the availability of observations, existing observations in the Arctic are very limited in both geographic scope and frequency. The ability of NOAA and its partners to deploy a variety of sensing devices to collect observations, from buoys and other in situ technologies to airborne and satellite sensors, is key to improving weather and sea ice forecasts. Real-time satellite data are critical for accurate forecasting and warning of events, such as rapid sea ice formation and frequent storms that pose major hazards to life, property, and economic activities in the Arctic.”

In addition to these references to inadequate data, we searched for available documents providing a review of Arctic data. Here, we summarise findings from: the National Academy of Sciences (2001 & 2006); Lichota & Wilson (2010); and NOAA (2014).

The strategy for providing geophysical data sets to the polar science community was reviewed (National Academy of Sciences, 2001). Ten high-priority measurements have been identified that were lacking or deficient in ways that present significant obstacles to progress on fundamental science issues:

- polar precipitation,
- surface albedo,
- freshwater discharge from terrestrial regions,
- all-sky surface temperature,
- surface turbulent fluxes,
- permafrost,
- ocean surface salinity,
- ice sheet mass flux,
- land surface characteristics, and
- sea ice thickness.

However, these data gaps were identified 15 years ago, and thus do not reflect the current status. More recently, the National Academy of Sciences published a report outlining the potential scope, composition, and implementation strategy for an Arctic Observing Network (AON) (National Academy of Sciences, 2006). The Committee on Designing an Arctic Observing Network Polar Research Board identified critical gaps in spatial and temporal coverage, thematic and disciplinary coverage, and data access and management (National Academy of Sciences, 2006). It is reported that most general ocean and atmospheric circulation models are not as effective as they could be in representing northern regions, because: the models do not have sufficient observational data to adequately reproduce the state of the Arctic Ocean, sea ice, and atmosphere; and the models do not adequately incorporate critical system-level feedbacks or reflect the chaotic physics of arctic climate (National Academy of Sciences, 2006). Thus considering data adequacy, there is a need for observational data for model calibration and validation and assimilation of observational data by reanalysis. The National Academy of Sciences (2006) has summarised variables that have been identified by the Committee on Designing an Arctic Observing Network Polar Research Board as an initial set of essential measurements for the AON. These are referred to as either key variables[6] or key indicator variable[7]. The table is divided into three clusters—physical, biogeochemical, and human dimensions and also highlights critical gaps in observations varying from spatial or temporal details to thematic considerations. The latter are more common among the biogeochemical and human-dimension variables (National Academy of Sciences, 2006).

[6] A key variable is a variable that is fundamental and related to questions that are important throughout the Arctic, is essential to an overall understanding of the arctic system, and is also relevant at the local scale. A key variable is a necessary component of integrated monitoring because changes in associated variables cannot be understood without knowledge of changes in the key variable. The key variable is a disaggregated driver of lowerlevel changes. An example is temperature (National Academy of Sciences, 2006).

[7] A key indicator variable is a response variable or index that can be conveniently measured to denote changes in one or more key variables. Examples are phenology (the timing of events) and indices of human activity. For example, the proportion of whales harvested in open water by an arctic community during autumn rather than spring can be an indicator of climate-driven changes in sea ice cover. Key indicator variables may manifest themselves differently at different locations (National Academy of Sciences, 2006).

Table 11. *The Arctic Observing Network's 31 Key Variables and Key Indicator Variables (National Academy of Sciences, 2006).*

Variable[a]	Examples of Why the Variable Is Important	Critical and Major Gaps in Observations (spatial, temporal, or thematic)
PHYSICAL VARIABLES		
Albedo (K)	• Influences global change (through changes in cloud, land, and ocean cover—including ice and snow cover)	• Time sequences of fields of albedo, particularly in vegetated areas where there is masking, and also over ice
Elevation/bathymetry (including shoreline) (K)	• A fundamental measure of shape of Earth's surface • Influences ocean and atmosphere circulation (including microclimate) • Reveals coastal erosion • Controls how materials are transported • Important for glacier motion • Potential hazards for transportation	• Whole Arctic Ocean (patchy coverage) • Coverage at high resolution (elevation in coastal regions)
Ice characteristics (including thickness, extent, and concentration) (K)	• Influences arctic energy balance • Reservoir of stored fresh water • Affects coastal erosion • Influences marine and lacustrine transportation • Affects biological habitat • Affects hunting success	• Sea ice thickness everywhere • Sea ice concentration in summer • Sea ice extent in coastal areas • Glacier thickness • Permafrost thickness and ground ice concentration
Precipitation (K)	• Controls biological community distribution • Influences human water supply and causes droughts and flooding	• Arctic Ocean • Topographically complex areas • River systems smaller than the Arctic's 10 largest systems • Southeast Alaska to Prince William Sound
Pressure (K)	• Driver of winds and ocean circulation, glacier motion (i.e., basal pressure)	• Marginal seas • Central Arctic Ocean (below surface)
Radiation (K) (spectral composition and fluxes from thermosphere to shallow ocean)	• Ultimate driver of weather and climate, biological activity, human health (e.g., UV damage)	• Spectrally resolved radiation • Surface across entire arctic
Salinity (K)	• Affects ocean density distribution and circulation • Affects biological community distribution and populations	• Arctic Ocean
Snow depth/ water equivalent (K)	• Affects arctic energy balance • Insulates underlying soils/sea ice • Affects biological activity (e.g., caribou distributions, ringed seal reproduction) • Affects winter transportation for humans	• Perennial sea ice • Entire Arctic Ocean • Distribution on land
Soil moisture (K)	• Affects runoff, vegetation, biological productivity, terrestrial transportation	• Everywhere in subsurface areas
Temperature (K)	• Direct measure of global warming • Moderates all chemical and biochemical reactions • Controls biological community boundaries • Causes changes in permafrost that affect infrastructure	• Entire Arctic Ocean plus subarctic seas • Atmosphere (especially above the first few meters) • Terrestrial subsurface (particularly in the Central Siberia, Russian North East, and areas in Canada and China) • Lack of year-round temperature in ocean
Velocity (K)	• Feature of weather (storms, winds), ocean circulation, glacier motion, river runoff	• Arctic Ocean and marginal seas; height-resolved circulation above troposphere and over oceans

Table 6. *Continued.*

Variable[a]	Examples of Why the Variable Is Important	Critical and Major Gaps in Observations (spatial, temporal, or thematic)
Water vapor concentration (including cloud properties) (K)	• Influences radiation budget (both up- and down-welling) through attenuation of UV-B • Cloud and precipitation formation if aerosols are present • Strongest radiatively active gas (i.e., more than carbon dioxide) • Accelerates stratospheric ozone depletion if ice crystal deposition occurs	• Greenland • Arctic Ocean • Subarctic seas
Freshwater flux (I)	• Influences ocean salinity and circulation • Has impacts on fisheries, landscape change and human habitation and travel, wetland distribution	• Declining number of gauging stations plus not always at river mouth • Glacier runoff • Small rivers • Contributions to Bering Strait
Lake level (I)	• Affects human and other biological habitation and activity, water resources and fisheries, land use, lacustrine transportation • A key land-water boundary and indicator of water balance	• Entire arctic
Sea level (I)	• Influences coastal dynamics, human and other biological habitation and activity, oil and gas exploration, marine transportation • A key land-water boundary and indicator of water balance	• Alaskan and Canadian coastline • Russian Arctic: many sites are not operational • Greenland—more than half of the Danish gauges in Greenland have been abandoned
Aerosol concentration (K) (physical or biogeochemical variable)	• Influences air quality and human health, atmospheric energy balance, global climate, cloud formation	• Aerosol chemistry • Limited beyond ARM sites (over time or space)
Land cover (I) (Physical or biogeochemical variable)	• Influences habitat fragmentation, water balance, coastal erosion, transportation, animal migration, biological community boundary change, land use and management	• High resolution surface characteristics
BIOGEOCHEMICAL VARIABLES		
Atmospheric chemistry and the contribution of trace gases (ozone, nitrous oxide, methane) (K)	• Influences human health (ozone) • Most are radiatively active gasses • Relevant to carbon sequestration • Reveals nitrous oxide releases • Reveals effects of land use/cover change	• Quantitative understanding of sources, sinks, and chemical processes in lower atmosphere
Biodiversity (including species distributions) (I)	• Reveals natural and anthropogenic impacts on species richness and ecosystems, invasive species impacts, endangered species impacts • Indicator of ecosystem structure	• Basic species list for the Arctic • Genetic libraries • Basic nomenclature
Biomass (K)	• Relevant to food supply; ecosystem health, structure, and function; carbon sequestration and allocation; ocean color (i.e., by influencing albedo and thus transmission of light); • Affects albedo by masking of snow	• Frequency and methods for assessing biomass on land, ocean, sea ice
Carbon concentration (K)	• Impact on global warming (radiatively active gas—carbon dioxide, methane) • Influences biological productivity, carbon sequestration, food web dynamics, ecosystem structure	• Terrestrial (including surface) observations and in biosphere (particularly in Russia and Canada) • Winter coverage
Nutrient concentration (K)	• Affects primary production, ecosystem structure and function, food webs/trophic interactions, energy fluxes • Fundamental element of life	• Localized measurements (soils, vegetation, water) • Understanding of function in biocomplex systems

Table 6. *Continued.*

Variable[a]	Examples of Why the Variable Is Important	Critical and Major Gaps in Observations (spatial, temporal, or thematic)
Contaminant concentration (I)	• Affects human and animal health, water quality, atmospheric composition • Indicator of anthropogenic activity and impacts	• U.S. arctic • Critical chemical species • Gaps in human levels
Dissolved oxygen concentration (I)	• Indicator of biological production and exchange with the atmosphere	• Frequency of temporal coverage and density of spatial coverage
Phenology, organismal behavior, and performance (I)	• Reveals changes in bud break, growing season, migratory timing, food availability for migrant birds, reproductive success, albedo, and carbon sequestration • Indicator of timing and success of biological events	• Allometric data • Biomass • Reproductive success • Hibernation ecology
Tracer chemistry (natural tracers rather than localized tracer additions) (biogeochemical or physical variable) (I)	• Indicator of biogeochemical and physical processes, changes in pathways, climate-water interactions • Reveals fundamental properties of aquatic systems	• Spatial and temporal patchiness throughout the arctic system • Frequently, lack of multitracer approaches
HUMAN-DIMENSION VARIABLES		
Human demographics (population size and structure (K), births, deaths, migration (I))	• Impacted by and impacting climate change, resources, globalization, infrastructure, governance, resource availability and utilization, land use, capacity of ecosystems to support subsistence economy, patterns and variability in social change, population sizes/habitat fragmentation	• Disaggregated data by gender, indigenous/ nonindigenous • Regional gaps
Health (e.g., birth weight, breast milk quality, cause of death, cultural health) (I)	• Help reveal quality of life, standard of living, human potential • Indicator of human condition	• Mental health and diet • Access to health care • Quality of health care • Regional gaps
Cultural diversity (I)	• Help reveal quality of life, standard of living, human potential • Indicator of human condition	• Cultural diversity (indigenous participation in government and research, languages in use, religious membership)
Education (e.g., graduates, enrollment) (I)	• Human potential • Indicator of human condition	• Access to education • Understanding needs for education
Economic indicators (e.g., employment, subsistence, government structure) (I)	• Help reveal quality of life, human-environment relations, social change • Show effects of globalization and devolution of control to local people • Indicator of human activity	• Assessment of new institutions in the Arctic • Tracking employment opportunities • Disaggregation of economic indicators (e.g., gender differences)

NOTE: Column 1 lists the variable plus whether it is a key variable (K) or a key indicator variable (I). Column 2 gives examples of why the variable is important. Column 3 gives examples of major and critical gaps in observations. Variables are arranged alphabetically followed by assignment to one of three clusters—physical, biogeochemical, or human. There are intimate relationships among variables in the three clusters, so these assignments are not necessarily perfect or unchangeable. Furthermore, a continued discussion of the human variables in particular will require input from fields not included in this Committee, and more work will be needed to incorporate this dimension into the AON. The list is, as stated earlier, intended as a starting point for discussion.

[a]K = key variable, I = key indicator variable.

The Sustaining Arctic Observing Networks (SAON) states that the concepts of free, open, and timely (i.e. shortest possible time for) access to high-quality data should be supported and promoted, at the same time recognizing legitimate restrictions and practicalities (Lichota & Wilson, 2010). Furthermore, the following was concluded on data management (Lichota & Wilson, 2010): “SAON should acknowledge the need for sustained long-term data archives; promote efforts to ensure that data are archived in these repositories. If such archives do not exist, SAON should promote efforts to establish (and fund over the longer-term) such archives. Every SAON network must have one or more long-term sustained data archive. The SAON data management strategy should acknowledge that different data types (TEK, research data, operational monitoring data, etc.) require different solutions (there is no one-size-fits-all data solution). SAON needs to recognize that affiliated networks/program have their own established data policies that apply to providers of data and users of data. SAON should endeavor to ensure that, as they are developed over time, the data policies operated by SAON partner programs/networks aspire to and are compatible with the general SAON data management principles

as stated above. Funding for data management should be an integral part of funding for all data collection activities. Funding needs to be allocated to both project/program (i.e. data collection)-related expenses and long-term data archiving expenses. If necessary (to ensure open and timely access to data) funding agencies should consider using holdback of funding until data have been appropriately archived and are accessible. SAON should support standardization of metadata and could attempt to define its own (high-level) metadata profile based on existing activities (e.g. extension of IPY activities in this respect). SAON should encourage publication (of data) in open access journals. SAON could consider a data dissemination protocol based around the (Arctic) member states and national SAON implementation approaches. SAON needs to conduct additional work to gain perspectives relating to data management associated with social-economic sciences as these groups were under-represented at the data management workshop."

NOAA (2014) reports the following: "Despite the ongoing efforts of agencies and private industry, information gaps remain in Arctic observing. The Alaska Ocean Observing System (AOOS) attempts to fill this gap by providing easy access to a network of critical ocean and coastal observations, data, and information products. AOOS' primary activities include hosting centralized data with webbased tools and products, working with marine users to fill gaps in ocean monitoring, and fostering collaborations to meet multiple stakeholder needs. There are four focus areas for AOOS: safe marine operations, coastal hazard mitigation, tracking ecosystem and climate trends, and monitoring water quality."… "The present rate of sea ice loss, with its regional and global impact, creates an urgency to improve sea ice predictions at all time scales, from the short term (i.e., daily to weekly) to seasonal and decadal time scales." …"Increasing air and ocean temperatures, thawing permafrost, loss of sea ice, and ecosystem shifts are evidence of widespread and dramatic change. Critical environmental, economic, and national security issues are emerging, many of which are having significant impacts on human lives, livelihoods, and coastal communities. Meeting the information needs for Alaska, with its vast size, remote population, and cultural diversity, presents NOAA with unique challenges. "

6.2 References in literature to fitness for purpose

As described in Annex 8 regarding references found in literature to inadequate data per purpose, there were no specific statements found in literature to fitness for purpose of data. Nevertheless, several studies generally addressed the following issues:

- Marine spatial planning
    - Although recommendations are made for more data/research on several areas, it is stated by the editors of the atlas of marine and coastal biological diversity of the Russian Arctic that the information makes it possible to give a preliminary outline of the future marine spatial planning (Vassily *et al*., 2011).
    - In Norway, a set of indicators are monitored over time to assess the extent to which the objectives of the integrated ocean management plan, as a strategy to meet rapid climate change, are achieved (Hoel, 2010).
    - Baseline coastal information created as part of the eSPACE project provides a rich dataset for use in coastal management and planning (Wynja *et al*., 2015).
- Oil spill response
    - Baseline coastal information created as part of the eSPACE project is invaluable for emergency preparedness in the case of an oil spill (Wynja *et al*., 2015).
- Fisheries management and fisheries impact assessment:
    - Stock assessments provide the best source of information on the status of commercial species, and allow for a more complete and coherent assessment at the European and regional level (EEA, 2015).
    - Vessel monitoring systems (VMS) greatly increase the availability of data on the distribution of fishing activity, providing vessel-specific high-resolution data from all fishing grounds used by larger vessels (Jennings and Lee, 2012). In Europe, vessel monitoring systems (VMSs) were introduced for fishery control and enforcement purposes, but are increasingly used to support the assessment of fishing activity and marine spatial planning. The capacity to assess ecosystem impacts will be influenced

by the availability of detailed information on the location and intensity of bottom fishing activities (Lambert et al., 2012).

- Riverine input
    - The Arctic-RIMS project (http://rims.unh.edu/background.shtml) notes that the timely identification and interpretation of changing Arctic hydrology is becoming increasingly difficult. It is also mentioned that, despite these problems, the Arctic appears to be an ideal setting to develop an integrated water cycle monitoring capacity since most of the river discharge into the Arctic Ocean is delivered through but a small number of large rivers.
- Invasive species
    - Robust information on the early stages of most introductions, whether successful or not, may provide essential information on the vectors transporting the species as well as the invasion process in itself. However, data is lacking thus there is a need for sampling and monitoring high-risk locations such as ports (Goldsmit *et al*., 2014).

The Arctic GOOS (the Arctic node under EuroGOOS - the European Global Ocean Observing System), will build on a number of existing data archiving and distribution systems in the Arctic Ocean and surrounding seas to provide environmental information to a wide range of users. One of the issues necessary to meet the requirements of all its users is to implement advanced data quality control and validation systems. These systems should ensure that the large volumes of data required and collected are fit for purpose (Sandven et al., 2005).

7 Discussion and future steps

7.1 Data set evaluation

The work described in the report at hand mainly focussed on the structured approach for identifying data sources and assessment reports. From both, data sets will be identified which will be evaluated for quality and adequacy (Figure 25). While identifying data sets from both the sources and assessment reports, new data sources and assessment reports can also be identified. Also from the work done in other WPs new assessment reports, data sets and/or data sets can be identified. This will be an iterative process, where the collected information will be stored in the CMS.

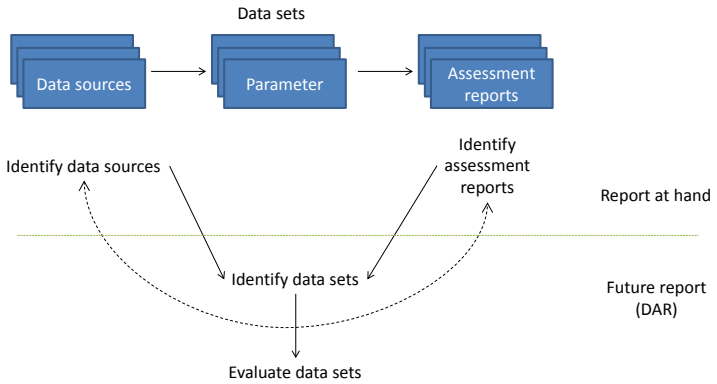


Figure 25. *Schematic overview of the work presented in the report at hand and the future work that will be presented in the Data Adequacy Report (DAR).*

Data sets will be evaluated for quality and adequacy by scoring the indicators as listed in Annexes 2 and 3, while they are collected or afterwards. Results will be aggregated and presented in a Data Adequacy Report (DAR) and will also be disseminated from the project website (http://emodnet-arctic.eu).

7.2 Linking the data quality and adequacy to users

The results of the literature review will eventually provide information on the data quality and adequacy per purpose (Table 4 and Figure 16). These results will be used in the Data Adequacy Report (DAR), which will in part focus on the needs of users. Therefore the purposes need to be linked to the need of the users. First, a list of users needs to be defined (fisheries managers, coastal protection, national authorities responsible for the Marine Strategy Framework Directive, ports, shipping, offshore energy exploration, pipeline laying etc.). Then these users will be linked to the purposes in a contingency table (Table 12). Based on this table information the data adequacy will be aggregated to the level of users.

Table 12. *Example of a contingency table linking users to specific purposes.*

Users	Purpose 1	Purpose 2	Purpose 3	Purpose n
User 1		X		
User 2	X	X	X	
User 3			X	
User n	X			X

Note that results on users will not be presented in the report at hand, but will be part of the DAR.

8 Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 187378-2015-AQ-NLD-RvA). This certificate is valid until 15 September 2018. 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. The scope can be found at the website of the Council for Accreditation (www.rva.nl).

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Justification

Report C072/16
Project Number: 4313100028

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of IMARES.

Approved:	Dr. Ruud H. Jongbloed Senior Research Scientist	Dr. R.G. Jak Senior Research Scientist
Signature:		
Date:	14-07-2016	

Approved:	Dr. ir. Tammo P. Bult Business Unit Manager
Signature:	
Date:	14-07-2016

Annex 1 The Arctic region

The definition of the Arctic region as used in our project, mostly north of the Arctic circle (dotted line). Source: https://www.cia.gov/library/publications/the-world-factbook/

Annex 2 Data set quality indicators

Table 2.1

Data set quality indicators, their scoring options and explanation

Indicator	Possible responses	Explanation
Spatial coverage	Global Arctic Arctic Partial Unknown Not assessed	This indicates which spatial region the data set covers
Temporal coverage	Decades Years Month or less Unknown Not assessed Not applicable	This indicates which time period the data set covers
Accessibility	Direct Download (no account) Download (account needed) Data at request Online viewing only Unknown Not assessed	This indicates the ease of access of the data set
Costs	Free of charge Payed account Payed download Unknown Not assessed	This indicates the costs associated with the data set
Service level	Service quality statement available Service quality statement not available Unknown Not assessed	This indicates whether the data source provides a service quality statement
Responsiveness	Same day More than a day Unknown Not assessed	This indicates the speed with which the information is disseminated
Processing level	Raw data Processed data Unknown Not assessed	This indicates the level of processing of the data as provided from the source
Spatial resolution	>=10 km (>= 5°) >=1 <10 km (>=0.5° < 5°) <1 km (<0.5°) Unknown Not assessed Not applicable (e.g. site, river)	This indicates the spatial resolution of the data set

Indicator	Possible responses	Explanation
Temporal resolution	>= Year >= Month < Year >= Day <Month <Day Unknown Not Assessed Not applicable (no time series)	This indicates the temporal resolution (time interval) of the data in the set
Temporal window	Forecast Hindcast (Near) real-time Historical Unknown Not assessed Not applicable	This indicates what the 'temporal window' of the data set is
Vertical resolution	0 >0 Unknown Not assessed	This indicates whether the data set has a vertical spatial resolution (height) or not
Is the original purpose for which the data was collected known? (If yes, select purpose from available list)	Yes No Not assessed	This indicates whether the original purpose (the purpose for which the data is generated) is known

Some notable indicators that we are aware of (i.e., identified in the earlier SBC projects) but will not be evaluated in the Arctic SBC are:

- Accuracy. Although the accuracy of positional and temporal information is highly relevant, it is generally captured by the precision (i.e., the resolution) in which the data is provided. In the present study only the resolution (precision) is scored.
- Completeness. It will be virtually impossible to evaluate the completeness of all data sets in the identified data sources. This should be addressed case specific in the other WPs (when incompleteness is encountered).
- Lineage. This indicator describes the life-cycle of a dataset, from where and how it was collected up to how it is disseminated. Although some specific aspects will be addressed (e.g., level of processing) in the current study, the complete lineage cannot be scored with a proper single closed question.
- Visibility. This indicator should give information on the visibility of the data set. It is difficult to determine an objective indicator for visibility. Although the Mediterranean Sea SBC project has come up with such an objective indicator it is very laborious and gives only limited information and is therefore not included in the Arctic SBC
- User-friendliness. While accessing several data sets it became apparent that the user-friendliness, with which data is offered by data sources, is highly variable. Unfortunately, user-friendliness is also hard to score subjectively. An option would be to set up a rating system, where multiple users could rate the user-friendliness. To get a balanced idea of the user-friendliness this would require the rating of a large number of users which is not feasible in the context of the current project.

Annex 3 Data set adequacy indicators

Adequacy indicators apply to the adequacy of a data set for the use with a specific purpose in a specific assessment report. Some of the indicators are similar to the quality indicators. However, when assessing the adequacy it is determined whether the provided quality is sufficient for the purpose of the assessment report.

Table 3.1
Data set adequacy indicators, their scoring options and explanation

Indicator	Possible responses	Explanation
Data used	Yes No Unknown Not assessed	This indicates whether a data set was only considered to be used in an assessment report, or was actually used.
Processing of data	No processing required Processing required Unknown Not assessed	This indicates if the data set required any processing for its use in the assessment report.
Data format	Original format used Converted format used Unknown Not assessed	This indicates whether a data set was used directly in the file/data format as provided by the source, or reformatting was required.
Necessity of data for purpose	Absolute necessity Limited necessity Unknown Not assessed	This indicates the level of necessity of the data set for the purpose in the assessment report in which it was used.
Matching of spatial coverage	Match Limited match (data usable) No match (data not usable) Unknown Not assessed	This indicates whether the spatial coverage of the data set as required for the purpose of the assessment report matches with that of the data set as provided.
Matching of temporal coverage	Match Limited match (data usable) No match (data not usable) Unknown Not assessed	This indicates whether the temporal coverage of the data set as required (required time period) for the purpose of the assessment report matches with that of the data set as provided (available time period).
Matching of spatial resolution	Match Limited match (data usable) No match (data not usable) Unknown Not assessed Not applicable (e.g. site, river)	This indicates whether the spatial resolution of the data set as required for the purpose of the assessment report matches with that of the data set as provided.
Matching of temporal resolution	Match Limited match (data usable) No match (data not usable) Unknown Not assessed Not applicable (i.e. no time series)	This indicates whether the temporal resolution of the data set as required for the purpose of the assessment report matches with that of the data set as provided.

Indicator	Possible responses	Explanation
Budget restrictions	No restrictions Some restrictions (data usable) Restrictions (data not usable) Unknown Not assessed	This indicates whether the project of the assessment report in which the data set was considered or used had budget restrictions that could affect the usability of the data set.
Project time restrictions	No restrictions Some restrictions (data usable) Restrictions (data not usable) Unknown Not assessed	This indicates whether the project of the assessment report in which the data set was considered or used had time (or planning) restrictions that could affect the usability of the data set (e.g., data could not be obtained in time).

Annex 4 Literature search definitions

For each purpose the search will structured as follows (if the search engine allows nested searches): TITLE-ABS-KEY("arctic" AND ("shore" OR "coast" OR "marine" OR "sea*" OR "ocean*") AND ("keyword2" OR "keyword2" OR etc.)). Keywords were defined in consultation with WP leaders.

The listed terms were searched for specifically in the title and abstract and keywords if possible. Search results are sorted by relevance. If a search results in more than 100 hits, only the first 100 hits (or first 10 pages in Google) will be screened for relevance (and thus inclusion) in the context of this project.

Each search action was labelled with a unique search identifier, such that search results can be traced back to this id. Five searches were modified after an initial test search, namely the searches with the following identifiers: 02, 13, 24, 28 and 29 (see table below). These searches were modified because the initial search resulted in little relevant literature. The structure of these searches may therefore deviate from the other searches. The table below list the final searches as they were eventually used in the systematic search.

Table 4.1

Systematic searches performed for each specific purpose (and the closest matching WP) to identify assessment reports. Number of hits shows the total number of hits before selecting the 100 most relevant hits. Google advanced searches do not list number of hits and are thus not available. Google searches were carried out by the WP leaders between February 19 and March 7, 2016. Search identifiers (ids) were assigned to each of the searches.

Purpose	Closest matching WP	Search engine	Search	Number of hits	Date of search	search id
Assessment of Environmental Impact	NA (literature review team)	Scopus	TITLE-ABS-KEY("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Environmental Impact Assessment" OR "Environmental Effect Assessment"))	158	22.01.2016	search04
Marine spatial planning	WP02 Windfarm siting	Scopus	TITLE-ABS-KEY("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Marine spatial planning" OR "Wind farm"))	66	22.01.2016	search09
Assessment of (potential) MPAs	WP03 MPA	Scopus	TITLE-ABS-KEY("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("MPA" OR "Marine Protected Area"))	89	22.01.2016	search01
Oil spill response	WP04 oil platform leak	Scopus	TITLE-ABS-KEY("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Oil spill" OR "Oil spill response" OR "platform"))	2494	22.01.2016	search10
Assessment of climate change	WP05 climate change	Scopus	TITLE-ABS-KEY("arctic" AND "Climate Change" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Ice cover" OR "ice coverage" OR "seawater temperature" OR "Internal sea energy" OR "ice mass" OR "greenland" OR "ice loss" "migrations" OR "animal behaviour" OR "traditional way of life" OR "reindeer husbandry" OR "whaling" OR "fishing" OR "phytoplankton abundance"))	71	22.01.2016	search02
Assessment of coastal evolvement	WP06 Coasts	Scopus	TITLE-ABS-KEY("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Coast" OR "Coastline" OR "erosion" OR "sediment balance" OR "sea level"))	5952	22.01.2016	search03
Fisheries management	WP07 fisheries management	Scopus	TITLE-ABS-KEY("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Fisheries" OR "Fisheries management" OR "landings" OR "discards" OR "bycatch" OR "capacity" OR "effort" OR "impact" OR "policy"))	6889	22.01.2016	search08
Stock assessment	WP07/08 fisheries management/ impact	Scopus	TITLE-ABS-KEY("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Fish stock" OR "stock assessment"))	183	22.01.2016	search11

Purpose	Closest matching WP	Search engine	Search	Number of hits	Date of search	search id
Assessment of riverine input	WP10 river input	Scopus	TITLE-ABS-KEY("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Nutrient" OR "river" OR "riverine" OR "nitrate" OR "phosphate" OR "discharge" OR "eutrophication" OR "silicate"))	4554	22.01.2016	search07
Assessment of navigational risks	WP11 bathymetry	Scopus	TITLE-ABS-KEY("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Navigational risks" OR "Navigation" OR "Shipping" OR "bathymetry" OR "sea ice"))	8654	22.01.2016	search05
Assessment of Risks posed by invasive species	WP12 alien species	Scopus	TITLE-ABS-KEY("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Invasive species" OR "Exotic species" OR "Alien species" OR "non-indigenous species" OR "introduction"))	371	22.01.2016	search06
Assessment of Environmental Impact	NA (literature review team)	Web of Science	TS=("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Environmental Impact Assessment" OR "Environmental Effect Assessment"))	5	22.01.2016	search15
Marine spatial planning	WP02 Windfarm siting	Web of Science	TS=("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Marine spatial planning" OR "Wind farm"))	4	25.01.2016	search20
Assessment of (potential) MPAs	WP03 MPA	Web of Science	TS=("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("MPA" OR "Marine Protected Area"))	21	22.01.2016	search12
Oil spill response	WP04 oil platform leak	Web of Science	TS=("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Oil spill" OR "Oil spill response" OR "platform"))	309	25.01.2016	search21
Assessment of climate change	WP05 climate change	Web of Science	TS=("arctic" AND "Climate Change" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Ice cover" OR "ice coverage" OR "seawater temperature" OR "Internal sea energy" OR "ice mass" OR "greenland" OR "ice loss" "migrations" OR "animal behaviour" OR "traditional way of life" OR "reindeer husbandry" OR "whaling" OR "fishing" OR "phytoplankton abundance"))	829	22.01.2016	search13

Purpose	Closest matching WP	Search engine	Search	Number of hits	Date of search	search id
Assessment of coastal evolvement	WP06 Coasts	Web of Science	TS=("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Coast" OR "Coastline" OR "erosion" OR "sediment balance" OR "sea level"))	6964	22.01.2016	search14
Fisheries management	WP07 fisheries management	Web of Science	TS=("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Fisheries" OR "Fisheries management" OR "landings" OR "discards" OR "bycatch" OR "capacity" OR "effort" OR "impact" OR "policy"))	7012	25.01.2016	search19
Stock assessment	WP07/08 fisheries management/ impact	Web of Science	TS=("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Fish stock" OR "stock assessment"))	57	25.01.2016	search22
Assessment of riverine input	WP10 river input	Web of Science	TS=("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Nutrient" OR "river" OR "riverine" OR "nitrate" OR "phosphate" OR "discharge" OR "eutrophication" OR "silicate"))	7497	25.01.2016	search18
Assessment of navigational risks	WP11 bathymetry	Web of Science	TS=("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Navigational risks" OR "Navigation" OR "Shipping" OR "bathymetry" OR "sea ice"))	11870	22.01.2016	search16
Assessment of Risks posed by invasive species	WP12 alien species	Web of Science	TS=("arctic" AND ("shore" OR "coast" OR "marine" OR "Sea*" OR "Ocean*") AND ("Invasive species" OR "Exotic species" OR "Alien species" OR "non-indigenous species" OR "introduction"))	202	22.01.2016	search17
Assessment of Environmental Impact	NA (literature review team)	Google	https://www.google.nl/search?as_q=%22arctic%22&as_epq=&as_oq=%22Environmental+Impact+Assessment%22+%22Environmental+Effect+Assessment%22+%22shore%22++%22coast%22+%22marine%22+%22Sea*%22+%22Ocean*%22&as_eq=&as_nlo=&as_nhi=&lr=lang_en&cr=&as_qdr=all&as_sitesearch=&as_occt=any&safe=images&as_filetype=pdf&as_rights=			search26

Purpose	Closest matching WP	Search engine	Search	Number of hits	Date of search	search id
Marine spatial planning	WP02 Windfarm siting	Google	https://www.google.nl/search?as_q=%22arctic%22+%22Marine+spatial+planning%22&as_epq=&as_oq=%22Wind+farm%22+%22shore%22+%22coast%22+%22marine%22+%22Sea*%22+%22Ocean*%22&as_eq=&as_nlo=&as_nhi=&lr=lang_en&cr=&as_qdr=all&as_sitesearch=&as_occt=any&safe=images&as_filetype=pdf&as_rights=			search31
Assessment of (potential) MPAs	WP03 MPA	Google	https://www.google.nl/search?as_q=%22arctic%22+%22MPA%22+%22Marine+Protected+Area%22&as_epq=&as_oq=%22shore%22++%22coast%22+%22marine%22+%22Sea*%22+%22Ocean*%22&as_eq=&as_nlo=&as_nhi=&lr=lang_en&cr=&as_qdr=all&as_sitesearch=&as_occt=any&safe=images&as_filetype=pdf&as_rights=			search23
Oil spill response	WP04 oil platform leak	Google	https://www.google.nl/search?as_q=%22arctic%22+%22Oil+spill%22&as_epq=&as_oq=%22Oil+spill+response%22+%22platform%22+%22shore%22+%22coast%22+%22marine%22+%22Sea*%22+%22Ocean*%22&as_eq=&as_nlo=&as_nhi=&lr=lang_en&cr=&as_qdr=all&as_sitesearch=&as_occt=any&safe=images&as_filetype=pdf&as_rights=			search32
Assessment of climate change	WP05 climate change	Google	https://www.google.nl/#q=%22arctic%22+%22climate+change%22+%22Ice+cover%22+OR+%22ice+coverage%22+OR+%22seawater+temperature%22+OR+%22Internal+sea+energy%22+OR+%22ice+mass%22+OR+%22greenland%22+OR+%22ice+loss%22+OR+%22migrations%22+OR+%22animal+behaviour%22+OR+%22traditional+way+of+life%22+OR+%22reindeer+husbandry%22+OR+%22whaling%22+OR+%22fishing%22+OR+%22phytoplankton+abundance%22+OR+%22marine%22+filetype:pdf			search24
Assessment of coastal evolvement	WP06 Coasts	Google	https://www.google.nl/search?as_q=%22arctic%22&as_epq=&as_oq=%22Coast%22+%22Coastline%22+%22erosion%22+%22sediment+balance%22+%22sea+level%22+%22shore%22++%22coast%22+%22marine%22+%22Sea*%22+%22Ocean*%22&as_eq=&as_nlo=&as_nhi=&lr=lang_en&cr=&as_qdr=all&as_sitesearch=&as_occt=any&safe=images&as_filetype=pdf&as_rights=			search25
Fisheries management	WP07 fisheries management	Google	https://www.google.nl/search?as_q=%22arctic%22+%22Fisheries%22&as_epq=&as_oq=%22Fisheries+management%22+%22landings%22+%22discards%22+%22bycatch%22+%22capacity%22+%22effort%22+%22impact%22+%22policy%22+%22shore%22+%22coast%22+%22marine%22+%22Sea*%22+%22Ocean*%22&as_eq=&as_nlo=&as_nhi=&lr=lang_en&cr=&as_qdr=all&as_sitesearch=&as_occt=any&safe=images&as_filetype=pdf&as_rights=			search30

Purpose	Closest matching WP	Search engine	Search	Number of hits	Date of search	search id
Stock assessment	WP07/08 fisheries management/ impact	Google	https://www.google.nl/search?as_q=%22arctic%22+%22Fish+stock%22&as_epq=&as_oq=%22stock+assessment%22+%22Oil+spill+response%22+%22platform%22+%22shore%22+%22coast%22+%22marine%22+%22Sea*%22+%22Ocean*%22&as_eq=&as_nlo=&as_nhi=&lr=lang_en&cr=&as_qdr=all&as_sitesearch=&as_occt=any&safe=images&as_filetype=pdf&as_rights=			search33
Assessment of riverine input	WP10 river input	Google	https://www.google.nl/search?as_q=%22arctic%22&as_epq=&as_oq=%22Nutrient%22+%22river%22+%22riverine%22+%22nitrate%22+%22phosphate%22+%22discharge%22+%22eutrophication%22+%22silicate%22&as_eq=&as_nlo=&as_nhi=&lr=lang_en&cr=&as_qdr=all&as_sitesearch=&as_occt=any&safe=images&as_filetype=pdf&as_rights=			search29
Assessment of navigational risks	WP11 bathymetry	Google	https://www.google.nl/search?as_q=%22arctic%22&as_epq=&as_oq=%22Navigational+risks%22+%22Navigation%22+%22Shipping%22+%22bathymetry%22+%22sea+ice%22+%22shore%22++%22coast%22+%22marine%22+%22Sea*%22+%22Ocean*%22&as_eq=&as_nlo=&as_nhi=&lr=lang_en&cr=&as_qdr=all&as_sitesearch=&as_occt=any&safe=images&as_filetype=pdf&as_rights=			search27
Assessment of Risks posed by invasive species	WP12 alien species	Google	https://www.google.nl/search?q=arctic+invasive+species+filetype%3Apdf&oq=arctic+invasive+species+filetype%3Apdf&aqs=chrome..69i57j69i64.683j0j4&sourceid=chrome&ie=UTF-8			search28

Annex 5 Specific screening criteria for each WP

For each work package specific inclusion/exclusion criteria may have been applied. The table below lists all the specific criteria (and the number of resulting documents) as used for each work package. Work package 03 (Marine Protected Areas) applied additional criteria that are not all listed in the table below. For this WP, documents were excluded when:

- The keyword “MPA” mismatches the intended meaning of “Marine Protected Area”: Mega Pascal; millipascal; Multi Profit Analysis; Moderate Resolution Imaging Spectroradiometer (MODIS) potential open water algorithm; modal push-over analysis
- The document focuses on the ‘sub-arctic’ or ‘Antarctic’
- The study was too global/generic (e.g. on MPAs in general) or not focused on the Arctic (e.g. on MPAs in other parts of the world);
- Only focussed on terrestrial, freshwater and/or atmospheric compartments (i.e., do not include the marine environment);
- Off subject (e.g. focussing on tourism)

Table 5.1

Inclusion and exclusion criteria as applied for each work package and the resulting number of documents

Purpose	Closest matching WP	Detailed screening criteria	Number of references	Status	Number of references	Total
Assessment of Environmental Impact Assessment	NA	Included	58	Included	58	101
		Off topic	40	Excluded	43	
		Not an assessment report	2			
		Unavailable from WUR library	1			
Assessment of Marine Spatial Planning	WP02	Included	17	Included	17	53
		Engineering study	7	Excluded	36	
		Maintenance	5			
		Micro-siting	2			
		Outside search area	3			
		OWT design	13			
		Safety	3			
		Unavailable from WUR library	3			
Assessment of Marine Protected Areas	WP03	MPA information	5	Included	15	94
		Species information	9			
		MSP and governance aspects	1			
		Off topic	6	Excluded	79	
		Too general	12			
		Mismatch keyword	61			
Oil spill response	WP04	Included	57	Included	57	192
		Off topic	119	Excluded	135	
		Outside spatial range	16			
Assessment of Climate Change	WP05	Animal behaviour/traditional way of life	39	Included	83[#]	160
		Phytoplankton	5			

Purpose	Closest matching WP	Detailed screening criteria	Number of references	Status	Number of references	Total
		Salinity	1			
		Sea ice	33			
		Temperature	10			
		Off topic	53	Excluded	77	
		Outside time scope	14			
		Outside spatial range	3			
		Too much focussed on governance	4			
		On models	3			
Assessment of coastal evolvement	WP06	Included	73	Included	73	167
		Excluded	94	Excluded	94	
Fisheries management	WP07	Effort	2	Included	24[#]	172
		Background info subarctic	1			
		Background on habitat	1			
		Background on bycatch	3			
		Background info	22			
		Background info effort	5			
		Governance	29	Excluded	148[#]	
		Not Arctic	12			
		Not relevant	84			
		Abiotic effects	22			
		Background info	3			
Stock assessment	WP07+08	Background info effort	2	Included	32	136
		Background info stocks	24			
		Background on habitat	3			
		Background on management	1			
		Background info subarctic	2			
		Governance	13	Excluded	104	
		Not Arctic	16			
		Not relevant	56			
		Abiotic effects	19			
Assessment of riverine input	WP10	Included	50	Included	50	166
		Excluded	116	Excluded	116	
Assessment of navigational risks	WP11	Included	76	Included	76	181
		Not an assessment report	8	Excluded	105	
		Not an assessment report / Off topic	2			
		Off topic	91			
		Not Arctic	4			
Assessment of risks posed by invasive species	WP12	Included	37	Included	37	155
		Not an assessment report	4	Excluded	118	
		Not Arctic	24			

Purpose	Closest matching WP	Detailed screening criteria	Number of references	Status	Number of references	Total
		Off topic	89			
		Unavailable from WUR library	1			

Because of an overlap between the detailed screening criteria the references are not exclusively linked to one criteria. The number of references included or excluded is thus not equal to the sum of the numbers of references listed per criteria.

Annex 6 Preliminary list data sources

Table 6.1
A preliminary list of data sources as currently identified

Data source name	URL	Comment
Aarhus university department of bioscience marine ecology roskilde	https://www.bodc.ac.uk/data/information_and_inventories/edmed/org/729/	Denmark
ACADIS	http://nsidc.org/acadis	ACADIS is a collaborative project between the University Corporation for Atmospheric Research (UCAR), the National Center for Atmospheric Research (NCAR), and the National Snow and Ice Data Center (NSIDC). ACADIS developed the Arctic Data Explorer - offering accessible, multi-faceted and efficient navigation of interdisciplinary Arctic data.
AquaNIS	http://www.corpi.ku.lt/databases/index.php/aquanis/	
Arctic Geographical Information System (ArkGIS)	http://arkgis.org/	
Arctic Great Rivers Observatory (Arctic-GRO)	http://arcticgreatrivers.org/data.html	
Arctic Regional Ocean Oberving System (ROOS)	http://www.arctic-roos.org/	
ArcticData	http://www.arcticdata.is	A web portal housed under the Arctic Portal, where spatial datasets with attached attribute data from CAFF and PAME are being made available to the public and research community to access and use as needed.
Argos cls	http://www.argos-system.org/?nocache=0.3616816425917363	Worldwide tracking and environmental monitoring by satellite
Biotic	http://www.marlin.ac.uk/biotic	
British oceanographic data centre (bodc)	http://www.bodc.ac.uk/	
Canadian Ice Service	http://www.ec.gc.ca/glaces-ice/?lang=En	
Center of the Ice Hydrological and Meteorological Information of the AARI	http://www.aari.nw.ru/index_en.html	
Centre d'etudes techniques maritimes et fluviales (cetmef)	https://www.bodc.ac.uk/data/information_and_inventories/edmed/org/555/	French portal
Cnes	https://cnes.fr/en/web/CNES-en/3773-about-cnes.php	CNES is the French government agency responsible for shaping and implementing France's space policy in Europe.

Data source name	URL	Comment
Collecte localisation satellite	http://www.cls.fr/web/en/115-ground-segments-and-operations.php	French portal but probably also Arctic data?
Complex systems research center (csrc) university of new hampshire	http://www.csrc.sr.unh.edu/dataprod.shtml	The Complex Systems Research Center (CSRC) at the University of New Hampshire investigates “the effects of human disturbance on the Earth’s biogeochemical processes
Copernicus Marine Environment Monitoring Service	http://marine.copernicus.eu/	
DAISIE Delivering Alien Invasive Species Inventories for Europe	http://www.europe-aliens.org/	
Danish Geodata Agency (Geodatastyrelsen)	http://gst.dk/	
Danish Meteorological Institute	http://www.dmi.dk/en/vejr/	
Data support section of the computational and information systems laboratory at the national center for atmospheric research	http://rda.ucar.edu/	CISL’s mission is to support and advance the geosciences with world-class computing, data management and research in mathematics and computational science
DataBasin.org	http://databasin.org/	Searchable data-portal by CBI (global, free)
Dg environment joint research centre eurostat european environment agency	http://ec.europa.eu/eurostat/web/environmental-data-centre-on-natural-resources	Eurostat’s Environmental Data Centre on Natural Resources (EDCNR) is an online repository for a broad range of data on Natural Resources in Europe.
Eea	http://www.eea.europa.eu/data-and-maps	European environment agency
EASIN European Alien Species Information Network	http://easin.jrc.ec.europa.eu/	
Emodnet bathymetry	http://www.emodnet.eu/bathymetry	
Emodnet chemistry	http://www.emodnet.eu/chemistry	
Emodnet Coastal mapping	http://www.emodnet.eu/coastal-mapping	
Emodnet geology	http://www.emodnet.eu/geology	
Emodnet Human activities	http://www.emodnet.eu/human-activities	
Emodnet physics	http://www.emodnet.eu/physics	
Emodnet seabed habitats	http://www.emodnet.eu/seabed-habitats	
European Atlas of the Seas	http://ec.europa.eu/maritimeaffairs/atlas/maritime_atlas/	
European centre for medium-range weather forecasts	http://www.ecmwf.int/	global weather forecasts

Data source name	URL	Comment
European global ocean observing system (eurogoos)	http://eurogoos.eu/	
European space agency	http://www.esa.int/ESA	
European space agency – Climate Change Initiative	http://esa-cci.nersc.no/?q=products	
Food and agriculture organization of the united nations fisheries and aquaculture department	http://www.fao.org/fishery/geoinfo/en	
Gebco	http://www.gebco.net/	bathymetry of the world's oceans
General NOAA Operational Modeling Environment	http://response.restoration.noaa.gov/gnome	
GISIN Global Invasive Species Information Network	http://www.gisin.org/	
Global Marine Networks	http://www.globalmarinenet.com/free-grib-file-downloads/	Wind and wave forecasts
Iccat	https://www.iccat.int/en/introduction.htm	Atlantic tuna
ICES data portal	http://ecosystemdata.ices.dk/	
ICES library, Data Outputs	http://ices.dk/publications/library/Pages/default.aspx	Searchable data-portal from ICES
Ifremer	http://wwz.ifremer.fr/institut_eng	French institute
Ifremer ERSAT	http://cersat.ifremer.fr/oceanography-from-space/our-domains-of-research/sea-ice	
Ifremer idmsismer	https://www.bodc.ac.uk/data/information_and_inventories/edmed/org/486/	
Insu	http://www.insu.cnrs.fr/	French institute. INSU coordinates strategic planning for European astronomy (ASTRONET) and collaborates in the development of European observation networks (RESIFEPOS, ERA-MIN, ICOS, IAGOS, EMSO, etc).
Insu (i national sciences de l'univers) serv d'obs en milieu littoral – somlit	http://www.insu.cnrs.fr/node/1247	part of INSU
Isac – institute of atmospheric sciences and climate	http://www.isac.cnr.it/	
ISC The CABI Invasive Species Compendium	http://www.cabi.org/isc/	
Jrc – institute for environment and sustainability (ies)	https://ec.europa.eu/jrc/en/institutes/ies	
Marbef – marine biodiversity and ecosystem functioning	http://www.marbef.org/	
Mareano	http://www.mareano.no/kart/mareano.html	

Data source name	URL	Comment
Marine renewable integrated application platform	http://www.marina-platform.info/	
Marine traffic	http://www.marinetraffic.com/en/	
Mercator ocean	http://www.mercator-ocean.fr/	
MESMA Geoportal	http://mesma.ucc.ie/geoportal/	
Met office	http://www.metoffice.gov.uk/	
Meteo france	http://www.meteofrance.com/	
Nansen Environmental and Remote Sensing Center (NERSC)	http://thredds.nersc.no/	
National and Kapodistrian university of Athens department of physics atmospheric modeling and weather forecasting group	http://forecast.uoa.gr/about.php	
National oceanic and atmospheric administration (noaa)	http://www.noaa.gov/	
Natura2000	http://natura2000.eea.europa.eu/	
Natural England Database	http://www.naturalengland.org.uk /ourwork/conservation/biodiversity /threats/nonnativeaudit.aspx	
Netherlands institute of ecology centre for estuarine and marine ecology (nioo-ceme)	http://data.nioo.knaw.nl/imis.php?module=dataset&dasid=665	
NOBANIS The European Network on Invasive Alien Species	https://www.nobanis.org/	
Norwegian Petroleum Directorate	http://www.npd.no	
Oceanographic data center	https://www.nodc.noaa.gov/OC5/ regional_climate/	
OSPAR map of MPAs	http://carto.mpa.ospar.org/1/ospar.map	
PANGAEA	http://www.pangaea.de	
Permanent service for mean sea level	http://www.psmsl.org/data/obtaining/map.html	
Polar Data Catalogue Metadata and Data Entry	https://www.polardata.ca	
Ramsar	http://www.ramsar.org/ sites-countries/the-ramsar-sites	
R-ArcticNet	http://www.r-arcticnet.sr.unh.edu/ v4.0/index.html	
SAHFOS	http://www.sahfos.ac.uk/	

Data source name	URL	Comment
Seadatanet – pan-european infrastructure for marine data 2	http://seadatanet.maris2.nl/v_cdi_v3/search.asp	
Seadatanet – pan-european infrastructure for marine data management	http://www.seadatanet.org/	
SeaLifeBase	http://www.sealifebase.org/	
Service contract concerning coastal erosion evaluation of the needs for action	http://www.eurosion.org/database/index.html	Link to GIS database doesn't seem to work
SWARP portal	http://swarp.oceandatalab.com/	
Systeme d'observation du niveau des eaux littorales	http://www.sonel.org/?lang=en	
The Arctic Biodiversity Data Service (ABDS) Data Portal	http://geo.abds.is/geonetwork/srv/eng/catalog.search#/home	
The Arctic Monitoring and Assessment Programme (AMAP)	http://www.amap.no/	AMAP is one of six Working Groups of the Arctic Council.
The Arctic Portal	http://www.arcticportal.org	The Arctic Portal is a comprehensive gateway to Arctic information and data on the internet, increasing information sharing and co-operation among Arctic stakeholders and granting exposure to Arctic related information and data.
The Arctic Science Portal	http://www.arctic.gov/portal/index.html	This portal can be thought of as a library of links (URLs) to websites where Arctic data are made publicly available. Main focus is on the US Arctic.
The IUCN Red List of Threatened Species	http://www.iucnredlist.org/	
The Sustaining Arctic Observing Networks (SAON)	http://www.arcticobserving.org	The SAON process was initiated by the Arctic Council (AC) in 2007. Its goal is to enhance Arctic-wide observing activities by facilitating partnerships and synergies among existing observing and data networks ("building blocks"), and promoting sharing and synthesis of data and information.
U.S. National Ice Center / Naval Ice Center	http://www.natice.noaa.gov/Main_Products.htm	
Unesco	http://whc.unesco.org/en/list/	
Unified Federal Service for Observation and Control of Environmental Pollution (OGSNK) and GSN		Data source predates the internet era. The data cannot be found online. It is referenced in several assessment reports.
United nations environment programme global environment monitoring system (unepgems)	http://www.gemstat.org/	

Data source name	URL	Comment
United States Geological Survey (USGS) Water-Quality Data for the Nation	http://waterdata.usgs.gov/nwis/qw	
University of hawaii sea level center	http://ilikai.soest.hawaii.edu/uhslc/data.html	
University of new hampshire	http://www.unh.edu/	
WCO	http://www.westernchannelobservatory.org.uk/	
World database on protected areas	http://www.protectedplanet.net/	
World Ocean Database	http://www.nodc.noaa.gov/OC5/WOD/pr_wod.html	
WoRMS	http://www.marinespecies.org/	
Wwf	http://www.worldwildlife.org/pages/conservation-science-data-and-tools	

Annex 7 Website search results

Table 7.1

Search results per website, indicating the number of search results (documents that were subjected to the selection criteria) and the number of selected documents (i.e. documents that meet the selection criteria as described in section 2.6.3)

Source	# Documents Search results	Selected	Selection criteria remarks
The Arctic Monitoring and Assessment Programme (AMAP) (http://www.amap.no/)	40	24	The Assessment Reports provided by AMAP are divided into 5 categories, of which 2 (scientific reports and non-AMAP reports) were searched for relevant input. The other types (summary reports, popular, policy makers summary) are based on the scientific reports and are thus not expected to provide additional information.
The Sustaining Arctic Observing Networks (SAON) (www.arcticobserving.org)	~60	1	Documents available are mostly focussed on data management and financing. Also national and organisational reports are provided. These documents do not meet the general selection criteria. Some documents were considered relevant but were published in scientific journals and thus already covered by the peer-reviewed search in Scopus and Web of Science. Therefore no documents were selected.
The Arctic Portal (www.arcticportal.org)	23	11	A library is available containing a collection of Arctic relevant scientific and educational material. Considering the scope of the library, there is no need to search for topics. A search restricting literature to the types "Article", "Book Section", "Monograph", "Book", "Thesis" (therewith excluding types such as websites, video's, presentations) resulted in 341 hits. These were narrowed down by a search using the keyword "assessment" in the title, resulting in 23 hits, of which 8 were relevant.
ArcticData (www.arcticdata.is)	0	0	The ArcticData website is a means to gather and share data. It does not contain a library and does not contain assessment reports.
ACADIS (nsidc.org/acadis)	15	7	The ACADIS website contains a library with scientific publications, which is not searched because these are already covered by the search in Scopus and Web of Science. However, it also contains special reports (#14) and annual reports (#26), from 1985 – 2013. From the annual reports, only the most recent was selected. Some of the special reports were only available as a webpage format, these were excluded.
The Arctic Science Portal (www.arctic.gov/portal/index.html)			The Arctic Science Portal website is a library of links (URLs) to websites where Arctic data are made publicly available. We accessed the listed sites as presented below:
	116	25	CAFF is the biodiversity working group of the Arctic Council. It contains 116 assessment documents (http://www.caff.is/assessment-series), of which 25 met the selection criteria.

Source	# Documents Search results	Selected	Selection criteria remarks
	1	1	Arctic Report Card: Update for 2012 (http://www.arctic.noaa.gov/reportcard). The Arctic Report Card is updated annually by assessing a wide range of environmental observations throughout the Arctic.
	18	2	Arctic Wells > Documents (http://arctic-wells.com/document). A collection of reports, assessments, and articles addressing Arctic oil and gas issues, from drilling and exploration to challenges and status reports.
	4	0	Arctic Yearbook (http://www.arcticyearbook.com). The Arctic Yearbook is an international and interdisciplinary peer-reviewed publication that is published online with the aim of being the preeminent repository of critical analysis on the Arctic region, with a mandate to inform observers about the state of Arctic geopolitics and security. Four yearbooks are available, but the documents do not include environmental assessments.
	143	4	GRID-Arendal > Publications (http://www.grida.no/publications). A library of reports, publications, and resources that address multiple environmental and social concerns. Series of publications include Environmental Outlook, Vital Graphics, and Rapid Response Assessments.
	36	1	NOAA Fisheries Publications database containing 7005 records. Searched for keyword “Arctic” in Title, restricted to the following document types: AFSC Technical Memorandum, Book, Book Review, Document Chapter, F/NWC Technical Memorandum, Other Documents, Other Technical Memorandum, Processed Report. This resulted in 36 hits. Some were not fully available (only reference), others were outside (geographical) scope. Only 1 was considered relevant.
	30	3	Polar Research Board of the National Academies (http://dels.nas.edu/prb). Resources include studies in progress, presentations, press releases, and expert and workshop reports. Only the expert reports were subjected to the selection criteria.
	154	1	Protection of the Arctic Marine Environment Library (http://www.pame.is/document-library-single-art). The PAME Document Library offers minister, meeting and other reports, framework and document plans, and the Regional Programme of Action, as well as other resources. Provides 106 PAME reports, 32 AMSA documents, 16 EA reports). Disregarding meeting and progress reports.
	0	0	Shell Corporation > Studies and Reports (http://www.shell.us/aboutshell/projects-locations/alaska/studies-reports-plans.html). No valid link, therefore no further search is conducted.

Source	# Documents		Selection criteria remarks
	Search results	Selected	
	1	1	State of the Arctic Coast 2010: Scientific Review and Outlook (http://www.arcticcoasts.org). A joint assessment of the state of the Arctic coast that draws on initial findings regarding climate change and human dimensions for the Arctic as a whole.
	0	0	USGS Alaska Science Center > Recent Publications on Sea Ice (http://alaska.usgs.gov/science/biology/remote_sensing/sea_ice.html). No valid link, therefore no further search is conducted.
EMODnet (European Marine Observation and Data Network)	0	0	Dataportal, no library or other reference to assessment reports
Copernicus projects	53	0	The Copernicus library (http://www.copernicus.eu/library/) contains a.o. policy documents (#34), study reports (#14) and technical documents (#5). However, there are no documents that match the definition of assessment report.
ICES	9	0	Searched the ICES library restricted to Arctic Ocean ecoregion resulted in nine hits of which none were considered relevant.
Marine conventions: The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR)	2	2	Searched the OSPAR library containing 567 records for keyword “Arctic” resulted in two hits.
Regional hydrographic commissions: Arctic Regional Hydrographic Commission (ARHC)	9	0	There are 14 Regional Hydrographic Commissions (RHCs) of which one is relevant to the scope of this study: the ARHC. The ARHC only provides Term of Reference documents and meeting reports, thus there are no documents provided that match our definition of assessment report.
Marine Strategy Framework Directive (MSFD) process	18	0	Available on the MSFD website (http://www.msfd.eu/) is a link to the Knowledge-based Sustainable Management for Europe's Seas (KnowSeas) website (http://www.knowseas.com/). There a list of publications is available, divided into papers published in scientific journals and project publications (#18). The peer-reviewed papers are already covered in the main literature search, thus only project documents were searched. There were no Arctic assessment reports found.
Total	1075	83[#]	

This number includes duplicates. Excluding duplicates, the total is 77

Annex 8 List of relevant literature

Table 8.1 lists all 625 available and relevant documents as obtained by the systematic searches.

Table 8.1

The final list of 625 relevant documents which were obtained by the systematic search. The column 'Search' indicates from which search the document was obtained: A = from the project proposal; B = from the websites listed in the project proposal; C = from the searches in Scopus and Web of Science; and D = from the searches in Google. The column 'Closest matching WP' shows the work package and its associated 'purpose' linked to the document (see Table 4 in the main text) (note that EI = Environmental impact and EA = Ecological assessment, for which no work packages are specified in the project). The column 'Website' indicates from which of the websites listed in the proposal a document originates.

Authors	Publication year	Title	URL	Closest matching WP	Website	Search
Barrett, Andrew P.	2003	National Operational Hydrologic Remote Sensing Center Snow Data Assimilation System (SNODAS) Products at NSIDC	http://nsidc.org/pubs/documents/special/nsidc_special_report_11.pdf	WP05, WP11	ACADIS	B
Barry, R G.	2013	Data on the Geographical Distribution of Sea Ice	http://nsidc.org/pubs/special/15/nsidc-special-report-15.pdf	WP05, WP11	ACADIS	B
Fricker, Helen Amanda	2013	SIO 115 Ice in the Climate System	http://nsidc.org/pubs/special/16/NSIDC-special-report-16.pdf	WP05, WP11	ACADIS	B
Maslanik, J, T Agnew, M Drinkwater, W Emery, C Fowler, R Kwok, and A Liu	1998	Passive Microwave Data	http://nsidc.org/pubs/documents/special/nsidc_special_report_8.pdf	WP05, WP11	ACADIS	B
National Snow and Ice Data Center	2014	2013-2014 Annual Report National Snow and Ice Data Center	http://nsidc.org/pubs/annual/NSIDC_Annual_Report_2013-2014_web.pdf	WP05, WP11	ACADIS	B
Serreze, M.C.; Maslanik, J.A.; Key, J.	1997	Atmospheric and Sea Ice Characteristics of the Arctic Ocean and the Sheba Field Region in the Beaufort Sea	http://nsidc.org/pubs/documents/special/nsidc_special_report_4.pdf	WP05, WP11	ACADIS	B
Stroeve, J, and J Smith	2002	Comparison of Near Real-Time DMSP SSM / I Daily Polar Gridded Products and SSM / I Polar Gridded Products	http://nsidc.org/pubs/documents/special/nsidc_special_report_10.pdf	WP05, WP11	ACADIS	B

Authors	Publication year	Title	URL	Closest matching WP	Website	Search
ACIA, and International Arctic	2005	Arctic Climate Impact Assessment	http://www.amap.no/documents/doc/arctic-arctic-climate-impact-assessment/796	WP05	AMAP	B
AMAP	1998	AMAP Assessment Report. Arctic Pollution Issues	http://www.amap.no/documents/doc/amap-assessment-report-arctic-pollution-issues/68	EI	AMAP	B
AMAP	2002	AMAP Assessment 2002: Radioactivity in the Arctic Mb	http://www.amap.no/documents/doc/amap-assessment-2002-radioactivity-in-the-arctic/93	EI	AMAP	B
AMAP	2003	AMAP Assessment 2002: The Influence of Global Change on Contaminant Pathways To, Within, and from the Arctic. Arctic Monitoring and Assessment Programme (AMAP)	http://www.amap.no/documents/doc/amap-assessment-2002-the-influence-of-global-change-on-contaminant-pathways-to-within-and-from-the-arctic/94	WP05, EI	AMAP	B
AMAP	2006	AMAP Assessment 2006 : Acidifying Pollutants , Arctic Haze , and Acidification in the Arctic Mb	http://www.amap.no/documents/doc/amap-assessment-2006-acidifying-pollutants-arctic-haze-and-acidification-in-the-arctic/91	EI	AMAP	B
AMAP	2007	ASSESSMENT 2007: OIL AND GAS ACTIVITIES IN THE ARCTIC - EFFECTS AND POTENTIAL EFFECTS. VOLUME 1	http://www.amap.no/documents/doc/assessment-2007-oil-and-gas-activities-in-the-arctic-effects-and-potential-effects.-volume-1/776	EI	AMAP	B

Authors	Publication year	Title	URL	Closest matching WP	Website	Search
AMAP	2007	ASSESSMENT 2007: OIL AND GAS ACTIVITIES IN THE ARCTIC - EFFECTS AND POTENTIAL EFFECTS. VOLUME 2	http://www.amap.no/documents/doc/assessment-2007-oil-and-gas-activities-in-the-arctic-effects-and-potential-effects.-volume-2/100	EI	AMAP	B
AMAP	2009	AMAP Assessment 2009: Radioactivity in the Arctic	http://library.arcticportal.org/1215/1/Amap_Radioactivity 2009.pdf	EI	AMAP	B
AMAP	2011	Arctic Monitoring and Assessment Program 2011: Mercury in the Arctic	http://www.amap.no/documents/doc/amap-assessment-2011-mercury-in-the-arctic/90	EI	AMAP	B
AMAP	2013	AMAP Assessment 2013: Arctic Ocean Acidification	http://www.amap.no/documents/doc/amap-assessment-2013-arctic-ocean-acidification/881	EI	AMAP	B
AMAP	2015	AMAP Assessment 2015 : Methane as an Arctic Climate Forcer	http://www.amap.no/documents/doc/amap-assessment-2015-methane-as-an-arctic-climate-forcer/1285	WP05	AMAP	B
AMAP	2015	AMAP Assessment 2015: Black Carbon and Ozone as Arctic Climate Forcers	http://www.amap.no/documents/doc/amap-assessment-2015-black-carbon-and-ozone-as-arctic-climate-forcers/1299	WP05	AMAP	B
Bidleman, Terry F., Paul A. Helm, Birgit M. Braune, and Geir Wing Gabrielsen	2010	Polychlorinated Naphthalenes in Polar Environments - A Review	http://www.amap.no/documents/download/35	EI	AMAP	B
Butt, Craig M., Urs Berger, Rossana Bossi, and Gregg T. Tomy	2010	Levels and Trends of Poly- and Perfluorinated Compounds in the Arctic Environment	http://www.amap.no/documents/download/41	EI	AMAP	B

Authors	Publication year	Title	URL	Closest matching WP	Website	Search
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Forbes, D. L.	2011	State of the Arctic Coast 2010. Scientific Review and Outlook	http://ipa.arcticportal.org/files/sac/state of the arctic rept.pdf	WP06	Arctic Science Portal	D, B
Nuka Research and Planning Group LLC	2010	Oil Spill Prevention and Response in the U.S. Arctic Ocean: Unexamined Risks, Unacceptable Consequences	http://www.pewtrusts.org/~/media/legacy/oceans_north_legacy/page_attachments/oil-spill-prevention.pdf	WP02, WP04	Arctic Science Portal	D, B
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Annex 9 References in literature to inadequate data

References in literature to goals not achieved because of inadequacy of data (eg unable to estimate coastal erosion accurately) are listed for each assessment purpose. For each limitation that has been identified, reasons for inadequacy are provided, if known. In addition, any statements found in literature regarding the fitness for purpose of data is described.

(1) Assessment of environmental impact

References to inadequate data

Pollution levels are monitored in the Arctic (AMAP, 1998). Levels of PCB and DDT seem to be higher in both biotic and abiotic media around Svalbard, the southern Barents Sea, and eastern Greenland than in the Canadian High Arctic. Levels of HCH seem to be higher in the Canadian Arctic. Causes and mechanisms in focusing these and similar important contaminants are not fully understood. Other such regions may exist, but inadequate data coverage, in particular for Alaska and parts of Russia, may mean that all such areas have not yet been identified (AMAP, 1998).
There is a need to obtain a spatial distribution of the magnitude of contaminant levels on a circumpolar basis. Priority should be given to (AMAP, 1998):

- Significant data gaps, particularly from the United States and Russian sites.
- Metals (mercury and cadmium), and POPs in organisms for which there are concerns for biological effects.

The Arctic Climate Impact Assessment clearly demonstrated a general lack of information on quantified effects of climate change on biodiversity (CAFF, 2010).
Information on a spatial scale of activities present in OSPAR Region I (Arctic waters) is sparse (OSPAR, 2009). For example, only very small quantities of marine aggregates for land fill and construction have been extracted in Norway. However, the exact location of the dredging sites is not provided, so the activity cannot be assessed (OSPAR, 2009). Information on the E&P industry is also sparse. There are a number of oil and gas platforms located off Trondheim (Norway) and off the northern Norwegian coast. Seismic surveys have been documented off the Lofoten (northern Norway) and further South (Cefas data) but the data is not sufficient enough to provide an estimate of the activity level for seismic surveys in Region I (OSPAR, 2009). Offshore wind farm activity in Region I was zero as of February 2008 (three wind farms with 334 turbines applied for, relatively near shore). Mariculture production values are high compared to other regions and seal scarers are commonly used at least in fish farms in Norwegian water (www.lofitech.no). There was no information provided by the Contracting Parties on shipping or activities generating sonar for Region I (OSPAR, 2009).
Detailed information about the values of ecosystem services in the Arctic is often incomplete at best, and the traditional benefits of Arctic ecosystems (e.g. subsistence, cultural uses, shoreline protection) typically take place outside the case economy and may be looked entirely (UNEP, 2014). Better (detailed and accurate) data on the nature, extent and value of Arctic ecosystem services are needed. Acquiring such data is urgently needed, partly driven by the scale and speed of change (UNEP, 2014).

Reasons for inadequacy

The inadequacy of data, as identified above, can be attributed to a lack of measurements.

Fitness for purpose

There were no specific statements found in literature regarding the fitness for purpose of data.

(2) Assessment of ecological status

References to inadequate data

Jeffries *et al*., (2015) mention lack of satellite based Chl-a data due to clouds or ice. However, there was no remark that the lack of data was hampering the assessment.
A biodiversity assessment for the Arctic (CAFF, 2010) reported the following data limitations:

- For several subpopulations of polar bears, there is insufficient or no data to provide an assessment of status, especially for the Russian subpopulations[8].
- Studies of the status of char populations in Arctic regions are generally lacking.
- The reproductive phenology of birds and mammals appears to be less responsive to changes in the physical environment but a conclusive comparison among taxa is hampered by the scarcity of data.
- The lack of information about distribution of sponges makes it very difficult to evaluate trends.

Using the Arctic Species Trend Index (ASTI) data set, Böhm *et al.* (2012) evaluated the spatial distribution and quality of biodiversity monitoring across the Arctic for use in identifying critical gaps in monitoring coverage: "At present, the Arctic data set comprises population trend data from 366 unique locations across the Arctic. However, these are not evenly distributed throughout the region, with large clusters in northern Scandinavia and the Bering Sea region. Russia, on the other hand, is sparsely covered, making analysis of spatial patterns in the region difficult, if not impossible. However, the few Russian locations contain information on a large number of vertebrate populations and for long time periods (albeit with a small number of data points within each time series). This allows for the analysis of congruence in population trend patterns across species. Other obvious gaps in spatial coverage of the ASTI data set are found in Greenland, particularly northern parts, and islands off the northern coast of Canada. ASTI marine data are primarily concentrated in the Bering Sea but are currently sparse elsewhere. These gaps may indicate real gaps in monitoring effort or may simply indicate failure to obtain already existing data for certain areas, or a combination of the two. While all efforts have been made to collect all available data, this still has implications for interpreting data coverage, as lack of data does not necessarily imply lack of monitoring. Analysis of spatial data gaps can, and should, spark initiatives to address these deficiencies. However, it is also important to address other aspects of data quality, such as length and completeness of time series, when designing future monitoring programs or when considering changes to current monitoring. Many of the series in the present data set start in the 1970s and 1980s and cover at least 10 years, although some of the data from northern Canada are characterised by shorter time series with a smaller number of data points. In northern Scandinavia and the Bering Sea, the majority of time series are both long and complete, providing a sound basis for analysis of long-term trends".

Based on evaluation of the dataset describe above, the following was concluded (Böhm *et al.,* 2012): "The spatial analysis of time span (time series length) and annual records (time series fullness) showed that while some areas are well monitored (e.g. Northern Scandinavia, Bering Sea), data are sparse for other regions (e.g. Northern Russia). Examining population trend data by decade highlighted the reduction in data sets since 2000, either by dropping existing monitoring sites or by not initiating new monitoring programs. However, it is possible that some of these data are simply not available in the literature yet. Gaps can be filled both by initiating new monitoring and, in some cases, by obtaining already existing data."

An atlas for the marine and coastal biological diversity of the Russian Arctic was published (Vassily et al., 2011), considering the components of marine biotopic and biological diversity most essential in the era of changing climate and increasing anthropogenic pressures. Some recommendations are made for more data/research regarding specific areas (Vassily et al., 2011).

Reasons for inadequacy

The inadequacy of data, as identified above, can be attributed to a lack of measurements.

Fitness for purpose

There were no specific statements found in literature regarding the fitness for purpose of data.

(3) Marine spatial planning

References to inadequate data

[8] Note that in 2011 an Atlas for the marine and coastal biological diversity of the Russian Arctic was published (Vassily et al., 2011).

As mentioned previously an atlas of marine and coastal biological diversity of the Russian Arctic is available (Vassily *et al.*, 2011), where some recommendations are made for more data/research regarding specific areas.
On-going monitoring of the ecosystem and its components is central to the management plan (Hoel, 2010). In Norway, a number of indicators have been selected for the physical environment, as well as for various species of plankton, fish, marine mammals, seabirds, etc. The set of indicators are monitored over time to assess the extent to which the objectives of the plan are achieved (Von Quillfeldt, 2010, cited by Hoel, 2010). Every year a number of monitoring programs are executed to check on the status of the indicators. Thus for Norway, no data inadequacy was reported.
Hoel (2010) also addresses the costs of acquiring data for marine spatial planning: "In terms of science, ecosystem-based oceans management is very demanding, and in remote and ice-covered areas this becomes extremely costly. The costs of monitoring programs and assessment activities are substantial. This gives governments the central role in ecosystem-based oceans management. Only governments have the means to fund the substantial scientific programs required and the authority to devise and enforce regulation of human activity. This raises important questions about the organization of science relative to policy-making, and the need to ensure that the science is not influenced by non-scientific concerns."

Reasons for inadequacy
The inadequacy of data, as identified above, can be attributed to a lack of measurements.

Fitness for purpose
There were no specific statements found in literature regarding the fitness for purpose of data. However, there are studies indicating sufficient data for the purpose of marine spatial planning:

- Although recommendations are made for more data/research on several areas, it is stated by the editors of the atlas of marine and coastal biological diversity of the Russian Arctic that the information makes it possible to give a preliminary outline of the future marine spatial planning (Vassily *et al.*, 2011).
- In Norway, a set of indicators are monitored over time to assess the extent to which the objectives of the plan are achieved (Hoel, 2010).

(4) Assessment of (potential) MPAs

References to inadequate data
A full overview of biologically sensitive areas in the Arctic marine ecosystem, including on the high seas areas beyond national jurisdictions, is lacking (CAFF, 2010).
No protection zoned can be designated for the Northern right whale, occurring in summer only in offshore waters between Southeast Greenland and Iceland, due to lack of data (Boertmann *et al.*, 2010). Also for some other marine mammals this is not possible. In many protected areas for the Narwal protection areas in West Greenland are established. Areas in East Greenland are new and based on the available data, which in many areas is inadequate (Boertmann *et al.*, 2010).

Reasons for inadequacy
The inadequacy of data, as identified above, can be attributed to a lack of measurements.

Fitness for purpose
There were no specific statements found in literature regarding the fitness for purpose of data.

(5) Oil spill response

References to inadequate data
One of the most important initial steps in response to an oil spill at sea is the assessment of the extent of the oil slick and the quantity (i.e. thickness) distribution of oil within it (US-MMS, 2009). The US-MMS (2009) reports the following: "A critical gap in spill response is the lack of capability to accurately measure and map the thickness of oil on water and to rapidly send this information to response personnel in the command post. This includes the ability to determine the thickest portions of the oil slick and to operate effectively in bad weather or darkness. "

While significant efforts have been put toward documenting baseline coastal information across Canada's southern regions, there is a large information gap regarding Arctic shorelines (Wynja *et al*., 2015). Baseline coastal information, such as shoreline form, substrate, and vegetation type, is required for prioritizing operations, coordinating onsite spill response activities, and providing information for wildlife and ecosystem management. Wynja *et al*. (2015) state the following: “The Canadian Arctic shoreline spans more than 162,000 km (DFO, 2013) and makes up almost three-quarters (71%) of the total Canadian coastline. There are significant information gaps regarding basic information such as the shoreline types present in the Canadian Arctic compared with, for example, the St. Lawrence River and the British Columbia coast. Lantuit *et al*. (2011) attributed the lack of information in the Arctic to its remoteness and low population density along the coasts, which in turn has limited the economic significance of studies along northern coasts. Beyond this, because of the difficultly and cost associated with collecting marine data, there is comparatively less information available on marine environments compared with terrestrial ones (Canessa *et al*., 2007). In 2009, Environment Canada initiated a national project in the Canadian Arctic to improve emergency preparedness and response related to potential oil spills and their impact on coastal ecosystems. The Emergency Spatial Pre-SCAT for Arctic Coastal Ecosystems (eSPACE) project for use before application of the shoreline cleanup and assessment technique (SCAT) was initiated to provide baseline mapping to support a range of coastal planning activities, including oil spill response and cleanup efforts.”
In 2012, NOAA launched the Arctic Environmental Response Management Application (Arctic ERMA). ERMA is a web-based tool that assists both emergency responders and environmental resource managers in dealing with incidents that may harm the environment. This system integrates and synthesizes data into a single interactive map, providing quick geo-spatial visualizations and improving communication and coordination (NOAA, 2014).
Raye *et al*. (2014) present a summary of ice research programs currently performed in the United States, ranging from perpetual programs such as satellite based observations, characterization and statistical products from the NSIDC, and numerical modeling to one-off studies and expeditions. At this time, the U.S. Coast Guard has no data on appropriate search swipe widths to assist search and rescue (SAR) mission controllers in developing search plans for ice-covered waters. Should a maritime mishap occur in the icy Arctic waters, search and rescue controllers have only “liquid-water” search performance data available to guide search pattern assignments for response craft (Raye *et al*., 2014).

Reasons for inadequacy

The inadequacy of data, as identified above, can be attributed to:

- Time to obtain data:
  - the lack of capability to accurately measure and map the thickness of oil on water and to rapidly send this information to response personnel in the command post.
- Lack of measurements:
  - there are significant information gaps regarding basic information such as the shoreline types present in the Canadian Arctic ;
  - comparatively less information available on marine environments compared with terrestrial ones.

Fitness for purpose

There were no specific statements found in literature regarding the fitness for purpose of data. However, a recent study indicates that baseline coastal information created as part of the eSPACE project is invaluable for emergency preparedness in the case of an oil spill but also provides a rich dataset for use in coastal management and planning (Wynja *et al*., 2015).

(6) Assessment of climate change

References to inadequate data

Until the 1990s, our knowledge of Arctic sea ice thickness was determined by sparse field campaigns or submarine measurements giving only limited insight into the overall Arctic sea ice thickness. Over the last decade both laser and radar altimeters have been used to estimate sea ice thickness on a basin-wide scale (Zygmuntowska *et al*., 2014).
There are inadequate data to determine whether consistent global changes in climate variability or weather extremes have occurred over the 20th century (Houghton *et al*., 1995). Our ability to

determine the current state of the global hydrological cycle, let alone changes in it, is hampered by inadequate spatial coverage, inhomogeneities in climate records, poor data quality, and short record lengths. Nonetheless, some new aspects of changes and variations of the hydrological cycle have begun to emerge (Houghton *et al.*, 1995). Note that these statements were made 2 decades ago and progress has been made, such as by the EU FP7 project ACCES (Arctic Climate Change Economy and Society). Monitoring activities for long-range and longterm observations of the Arctic Ocean including in-situ and remote sensing observations of the Atmosphere, Sea-Ice and Ocean, are a major development for the ACCESS project (EC, 2014).
In a more recent study (Oliver-Smith, 2009) the following remark was made, although not specific to the Arctic: "Adequate projections of local impacts will still depend on the careful analysis of local vulnerabilities which continues to represent a significant challenge. The main obstacles to comprehensive vulnerability assessment at any scale are: 1) incomplete knowledge of the processes involved in sea level and their interactions; 2) inadequate data on existing conditions; 3) challenges in developing scenarios for climate change at local and regional levels; and 4) the dearth of appropriate analytical methods for some kinds of impacts".
Our knowledge of snow depth on top of Arctic sea ice is limited (Zygmuntowska *et al.*, 2014). Snow depth can be measured directly in the field, but these measurements are limited to field campaigns in a local area during a couple of weeks. The most comprehensive compilation of in situ data so far is based on manmade observations taken during Soviet drifting stations between 1954 and 1991 (Zygmuntowska *et al.*, 2014).

Reasons for inadequacy
The inadequacy of data, as identified above, can be attributed to:

- Lack of measurements
    - inadequate spatial coverage
    - short record lengths
    - inadequate data on existing conditions
- Lack of accuracy /precision
    - poor data quality
    - inhomogeneities in climate records

Fitness for purpose
There were no specific statements found in literature regarding the fitness for purpose of data.

(7) Assessment of coastal evolvement

References to inadequate data
The assessment of coastal evolvement involves the average annual sea level rise and sediment balance per stretch of coast. In the Arctic Ocean, changes in salinity are more important for sea level variability than changes in temperature, and the combination of freshening of the Arctic seas with warming and salinization of the Atlantic layer therefore leads to the rise of sea level along coastlines and the fall of sea level in the central parts of the Arctic Basin (Proshutinsky *et al.*, 2004).
A fundamental problem in determining the rate of sea level change in the Arctic has been the lack of accurate data from sites along the Arctic Ocean coastline, but with the release of the data for the Russian sector of the Arctic in 2003 this circumstance has improved dramatically (Proshutinsky *et al.*, 2004). Approximately 70 tide gauge stations in the Barents Sea and Siberian seas (Kara, Laptev, East Siberian, and Chukchi Seas) have recorded sea level changes from the 1950s through the 1990s (Proshutinsky *et al.*, 2004). These sea level data were collected by the Arctic and Antarctic Research Institute (AARI) and data sets were made available for analysis by the international community and the monthly mean relative sea level records for all gauges are now included in the Permanent Service for Mean Sea Level archive (http://www.pol.ac.uk/psmsl/pub/nucat.dat). Relative sea level monthly data from 71 tide gauges in the Barents, Kara, Laptev, East Siberian, and Chukchi Seas have been analysed in order to estimate the rate of sea level change and major factors responsible for this process in the Arctic Ocean (Proshutinsky *et al.*, 2004). Regarding data, Proshutinsky *et al.* (2004) state the following:

- The existing sea level data sets in the Arctic are relatively short for the analysis of global sea level rise. The Arctic Ocean sea level time series have well pronounced decadal variability which corresponds to the variability of the North Atlantic Oscillation index. Because of the

strength of this variability and the relatively short sea level time series, our assessments of sea level trends remain somewhat uncertain.

- The accuracy of precipitation minus evaporation (P-E) reanalysis data over the open ocean, and the river discharge data, is not sufficient to allow robust conclusions to be drawn. The P-E estimates over the Arctic Ocean are less accurate than the other investigated factors (wind, water density, river runoff, etc.).
- It is clear that there is disagreement among the different investigators as to the observed rates of sea level rise in the Arctic Ocean and as to the cause(s) of the phenomenon. The problem is that different scientists employ different data sets and focus upon different time periods for data averaging, statistical analysis and modelling.
- Sea level observations at some stations have had different locations in summer and winter, some of which were interrupted during replacement. Therefore much of the sea level data collected before 1949–1950 cannot be used because of the absence of a reliable geodetic survey.

Lantuit et al. (2012) report on erosion in the Arctic using yearly coastal erosion (and aggradation) rates based on the best datasets available, that is, the ones covering the longest time span (as coastline erosion is characterized by high interannual variability). Data was used from: Jorgenson and Brown (2005), Lantuit and Pollard (2008), Solomon (2005), Jones et al. (2008, 2009a, 2009b) and Lantuit et al. (2010b). The rates are expressed in meters per year, and refer to the distance between the shoreline location from one year to the next in a direction essentially perpendicular to the coast. The resulting database is published as a freely available dataset on the PANGAEA information System (https://www.pangaea.de/). Some data limitations were reported (Lantuit et al., 2012):

- The datasets are restricted spatially and most of the database segments were characterized using discrete measurements of erosion along the coastline that were then extrapolated to the rest of the segment.
- Records are generally from local scientific investigations, industry reports, ship-based observations, or local monitoring efforts. In remote areas, north of 80°N, such records were often unavailable and the erosion data was generated from maps of sea ice cover.
- The quality of quantitative parameters for geomorphology (backshore elevation and dry bulk density), cryolithology (ground ice content), and geochemistry (organic carbon content) was assessed. Because of the sparse nature of the data available, a quantitative assessment of the accuracy of the data records was deemed irrelevant.

Reasons for inadequacy

The inadequacy of data, as identified above, can be attributed to:

- Lack of measurements
  - relatively short sea level time series;
  - coastal erosion data is spatially restricted, based on single measurements extrapolated to the rest of the coastal segment;
  - lack of erosion data in remote areas.
- Lack of accuracy and/or precision
  - sea level observations at some stations have had different locations in summer and winter, some of which were interrupted during replacement;
  - insufficient accuracy of precipitation minus evaporation (P-E) reanalysis data over the open ocean, and river discharge data.

Fitness for purpose

There were no specific statements found in literature regarding the fitness for purpose of data.

(8) Fisheries management and -impact, including stock asessments

References to inadequate data

References due to inadequate data for impact assessment were found in literature (Gerritsen et al., 2013; Jennings and Lee, 2012; Lambert et al., 2012; Lee et al., 2010; Piet and Hintzen, 2012). The introduction of vessel monitoring systems (VMS) greatly increased the availability of data on the distribution of fishing activity, providing vessel-specific high-resolution data from all fishing grounds used by larger vessels (Jennings and Lee, 2012). Lambert et al. (2012) states: *"…the capacity to*

assess ecosystem impacts will be influenced by the availability of detailed information on the location and intensity of bottom fishing activities. In Europe, vessel monitoring systems (VMSs) were introduced for fishery control and enforcement purposes, but are increasingly used to support the assessment of fishing activity and marine spatial planning", thereby referring to: EC (1997); Dinmore *et al*. (2003); Murawski *et al*. (2005); and Mills *et al*. (2007). AIS data contain vessel position and speed, like VMS data, but are transmitted by VHF radio, rather than satellite. AIS data have a very high temporal resolution (the most common time interval between records is 10 s) as opposed to the 2h interval of VMS (Gerritsen *et al*., 2013). The following references to inadequate data were found in literature:

- Vessel Monitoring Systems (VMS)
    - Due to uncertainty in the vessel position during the 2-h interval between VMS records, the number of times a location is trawled cannot be accurately estimated (Gerritsen *et al*., 2013)
    - Gear type: the VMS data itself contain no information on the gear type used (Gerritsen *et al*., 2013). Data has to be gathered from other sources. Lambert *et al*., (2012) mentions that they could not access full information on the gears used by non-UK vessels which caused limitation of their maps (i.e. did not include foreign vessels)
    - Overestimation of the dispersion of fishing activity, and hence overestimation of the patchiness, is necessarily greater in less-actively fished areas because there is less probability that a fishing position will be recorded in any given grid cell, even if a fishing track crosses it (Jennings and Lee, 2012).
    - Given that the original purpose of introducing VMSs was for fishery control and enforcement purposes, the use of VMS data for research and impact assessment has some limitations: incomplete coverage of vessel activities, long durations between position records, and a lack of information on whether a vessel is actually fishing when the position is reported. At present, the last of these is inferred from a range of vessel speeds that relate to typical towing behaviour by different metiers. Generally, only vessels >15 m are monitored in Europe, and they typically transmit position records at intervals of 2 h. Researchers therefore have to make assumptions and interpretations when using VMS data as the main source of information on fishing activities (Lambert *et al*., 2012).
    - VMS provide limited information on activity close to the coast where most vessels >15 m long operate (Lambert *et al*., 2012).
    - Restrictions on data access and the absence of standardized methods of analysis hamper data exchange and their use in assessment and planning (Lambert *et al*., 2012).
    - Piet and Hintzen (2012) limited their study to their Dutch EEZ only instead of all European waters because there are still confidentiality issues that prevent access to the international VMS data.
- Automatic Identification System (AIS)
    - Only a small proportion of fishing vessels are equipped with AIS and spatial coverage of the data is incomplete because data are only recorded if a vessel is within VHF range of a base station (Gerritsen *et al*., 2013).

Fisheries management greatly relies on stock assessments. Stock assessments provide the best source of information on the status of commercial species, and allow for a more complete and coherent assessment at the European and regional level (EEA, 2015). However, according to literature, the current availability of stock assessments is not sufficient. For example, the EEA (2015) states the following: "*It should be noted that the assessed stocks, i.e. those stocks for which GES information can be calculated, correspond to 60% of the EU commercial catch. Thus, even our knowledge about commercial fish species as a subset of overall fish species remains partial*."

For the Bering Sea, there are many sources of fisheries data on harvests, effort, ex-vessel value, wholesale, employment and residence, market structure, investments, infrastructure and other factors in the U.S. Federal Government agencies, State of Alaska agencies, and in industry and private hands (University of Alaska Fairbanks, 1996). In Russia, extreme fisheries privatization has kept data confidential or fabricated. Information on local fisheries, which are in competition with commercial fishers, is not available (University of Alaska Fairbanks, 1996). It has been predicted in the nineties that data collection will become more difficult in the future since: there are over 100 companies

fishing in the Bering Sea using other's quota to increase their take; small companies don't tell what they take to increase their take; and any control is difficult (University of Alaska Fairbanks, 1996).

Reasons for inadequacy

The inadequacy of data, as identified above, can be attributed to:

- Reluctance of data-owners to release data
  - Confidentiality issues
  - Restrictions on data access
- Lack of measurements
  - Limited use and spatial coverage of AIS
  - VMS provide limited information on activity close to the coast
  - Limited time interval of VMS data
  - VMS data itself contain no information on the gear type used
  - Stock assessments only available for a small part of fish species

Fitness for purpose

There were no specific statements found in literature regarding the fitness for purpose of data. However, the following general statements were found in literature regarding data for fisheries management and fisheries impact assessment:

- Stock assessments provide the best source of information on the status of commercial species, and allow for a more complete and coherent assessment at the European and regional level (EEA, 2015).
- Vessel monitoring systems (VMS) greatly increase the availability of data on the distribution of fishing activity, providing vessel-specific high-resolution data from all fishing grounds used by larger vessels (Jennings and Lee, 2012).
- In Europe, vessel monitoring systems (VMSs) were introduced for fishery control and enforcement purposes, but are increasingly used to support the assessment of fishing activity and marine spatial planning. The capacity to assess ecosystem impacts will be influenced by the availability of detailed information on the location and intensity of bottom fishing activities (Lambert et al., 2012).

(9) Assessment of riverine input

References to inadequate data

The Arctic-RIMS project (http://rims.unh.edu/background.shtml) integrates several well-established data sets and tools to produce time-varying, region-wide aerological and land surface water budgets including river inputs to the Arctic Ocean and its 18 subsidiary seas. The project identifies the following data limitations:

- real-time river discharge data has been underutilized within the ocean-atmosphere modeling community with typical 3-5 year delays in data posting.
- deterioration in gauge networks even in previously well-monitored parts of the globe.

Furthermore, the following is described: "The situation is particularly troublesome across the Russian Arctic. In contrast, there are reliable sources of operational meteorological and oceanological data for the purposes of weather forecasting. The mismatch between river discharge and meteorological data availability interferes with the construction of validated pan-Arctic water budgets. The timely identification and interpretation of changing Arctic hydrology is becoming increasingly difficult. Despite these problems, the Arctic appears to be an ideal setting to develop an integrated water cycle monitoring capacity since most of the river discharge into the Arctic Ocean is delivered through but a small number of large rivers. Only 12 hydrological gauges are required to capture 91% of total monitored area and 85 % of discharge."

Reasons for inadequacy

The inadequacy of data, as identified above, can be attributed to:

- Reluctance of data-owners to release data
  - delays in data posting.
- Lack of measurements
  - deterioration in gauge networks.

Fitness for purpose

There were no specific statements found in literature regarding the fitness for purpose of data.

(10) Assessment of navigational risks

References to inadequate data

All shipping in the Northern Sea Route (NSR) is constrained to some degree today by sea ice and bathymetry (Stephenson *et al.*, 2014). The availability of reliable information on bathymetry is essential for the maintenance of navigational safety. Stephenson et al. (2014) reports: "A synthesis of INSROP data concluded that bathymetry and severe ice conditions together contribute to making the NSR east of the Kara Sea a 'complicated and even extreme system … one of the most difficult anywhere to conduct marine operations' (Brigham et al. 1999). Few studies (Khon et al. 2010; Stephenson et al. 2011,2013) have attempted to model the future navigation season of the NSR using GCM sea ice projections, and none have accounted for the additional constraint of bathymetry on marine accessibility." Stephenson *et al.* (2014) quantified the length and variability of the NSR navigation season as constrained by both sea ice and bathymetry over the next 15 years. The available data was not hampering the assessment, reported limitations were related to modelling (Stephenson *et al.*, 2014). Arctic Council (2009, 2015); Stephenson et al. (2014); Harris et al. (2014) Harris et al. (2014) present the first digital seafloor geomorphic features map (GSFM) of the global ocean, including the Arctic ocean (**Figure 26**). The GSFM is based on interpretation of the Shuttle Radar Topography Mapping (SRTM30_PLUS) 30-arc second database (Becker et al., 2009), supplemented with additional data sources around Australia (Whiteway, 2009) and on the European continental shelf (EMODNet, 2013). Data availability and quality was sufficient for the purpose of the study as there were no references found to inadequate data. However, data could be improved since Harris et al. (2014) conclude: "As new, higher resolution, bathymetric data become available and as our knowledge of the oceans improves, the GSFM will also change and improve."

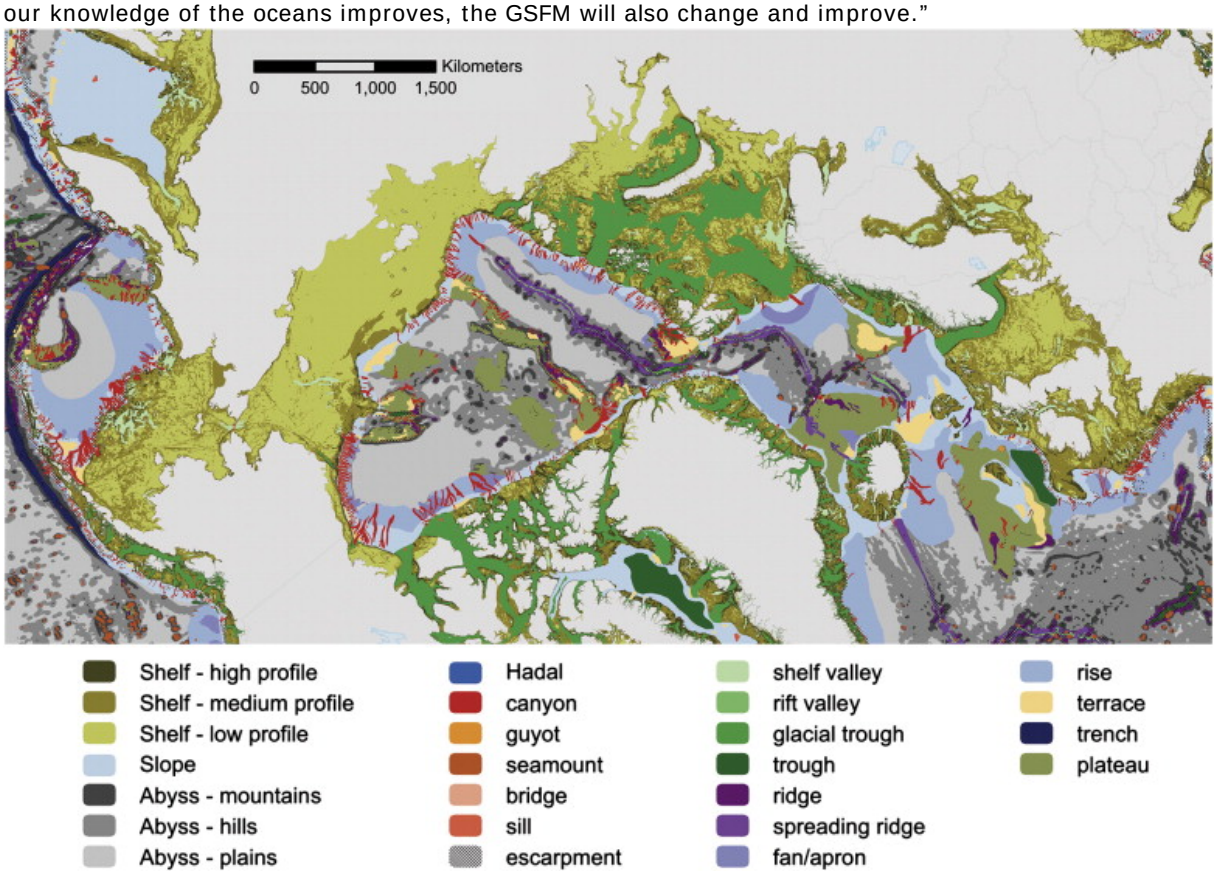

Figure 26 Geomorphic features map of the Arctic Ocean. Dotted white lines mark boundaries between major ocean regions. Basins are not shown (Harris *et al.*, 2014).

The Arctic Council documents and tracks progress in implementing the 17 recommendations in the 2009 Arctic Marine Shipping Assessment (AMSA) Report (Arctic Council, 2015). One of the recommendations is investing in hydrographic, meteorological and oceanographic data: "That the Arctic states should significantly improve, where appropriate, the level of and access to data and information in support of safe navigation and voyage planning in Arctic waters. This would entail increased efforts for: hydrographic surveys to bring Arctic navigation charts up to a level acceptable to

support current and future safe navigation; and systems to support real-time acquisition, analysis and transfer of meteorological, oceanographic, sea ice and iceberg information." The status of progress is (Arctic Council, 2015): "the Arctic Council's Working Group on the Protection of the Arctic Marine Environment (PAME) and the Arctic Regional Hydrographic Commission (ARHC) continued to focus on areas of common interest, in particular on surveying and charting in the Arctic Region. At PAME's invitation, the ARHC submitted information on Arctic hydrography and nautical charting, made a presentation on the subject at PAME's September 2014 meeting, and is working to collect and analyze Arctic information that relates to safe and efficient marine navigation. PAME is exploring how it might support the ARHC by facilitating the provision of hydrographic and bathymetric data."
The Arctic Marine Shipping Assessment 2009 Report (Arctic Council, 2009) states the following:

- Hydrographic data
  "While there are published charts whose physical limits cover both the Canadian Northwest Passage and the Russian Northern Sea Route, the quality of the underlying data varies widely from modern, high resolution hydrographic surveys to no sounding information in some areas. The quality and accuracy of navigational charts is entirely dependent on the hydrographic data used to compile them. Hydrographic surveys in the Arctic are logistically very complicated, expensive to undertake and highly dependent on weather and ice conditions. In addition, hydrographic offices normally prioritize their efforts based on a risk classification approach. Because the Arctic has traditionally seen smaller volumes of marine traffic, these risks have been perceived as low compared to other regions and progress in improving hydrographic coverage in the Arctic has been painstakingly slow. International Hydrographic Organization (IHO) provides the current state of hydrographic surveys for member countries throughout the world. In Greenland, the limit for navigable waters has been set to 75 degrees northern latitude due to the permanent ice cover and the sparse population of its east coast. Within Canada, a high proportion of Arctic waters are inadequately surveyed or covered by frontier surveys only. A similar situation exists in the Russian Federation where ice conditions have precluded the systematic survey of the central parts of the Laptev and East Siberian seas. Only passage sounding data is available for the deep water areas of the Sea of Okhotsk and the Bering Sea."
- Ice data
  "As more ships venture into the Arctic, the demand for ice information, as well as other ocean data, products and services, will continue to increase and the resources available to meet this increased demand will be stretched. The ice parameters needed in the future will not change significantly but will be required over larger geographic areas and longer periods of the year. Operators will still need to know where the ice is and isn't; where it's going to be, how closely packed it is and how thick and strong it is; generally, how difficult it will be to go around or, when necessary, go through. These parameters will be needed on a variety of space and time scales - from the hemispheric to the local, from months and weeks to daily or even hourly - to support tactical and strategic route planning for ships, scientific study and the development of policy and regulations to ensure safe marine practices. The needs of mariners for ice information are currently met by a number of organizations, including national ice services that produce information for the Arctic that is generally freely available as a public service funded by tax-payers; academic institutions that provide ice information as part of an ongoing research program or to support field research campaigns; and commercial ice information services that provide services that are specific to individual clients with particular needs. As more ships venture into the Arctic and the demand for ice information and related services increases, there will be increasing pressure on the resources of ice information providers."
- Weather data
  "Modern weather information, including information for shipping, is based on numerical models. Numerical weather prediction analyses and forecasts are available for the Arctic from all of the major meteorological centers that run global models. States having the need for more detailed information for the Arctic areas have implemented high resolution models covering the Arctic region according to their needs. Within the coverage of INMARSAT Global Maritime Distress Safety System transmissions, marine safety information in the form of gale and storm warnings is in place consistent with all other high sea areas in the world. However, no responsibility has yet been assigned for the high seas regions of the Arctic outside the coverage of INMARSAT, although an initiative is underway to do so by the World Meteorological Organization. Several states have offered to issue and/or prepare weather

information for the Arctic. Progress in this initiative is expected and routine weather bulletins for the high Arctic areas may be in place in a few years. Prediction of the development and paths of lows giving rise to high winds is of particular concern for Arctic shipping. " "Although weather forecasts for the Arctic are based on the same tools using the same techniques as in other areas of the world, the scarcity of observations in the Arctic makes the monitoring of the weather more difficult than in areas with more observations. Meteorological observations in the Arctic rely on drifting buoys placed on top of the sea ice. A new generation of buoys that will withstand multiple freeze-thaw cycles is currently under development and is urgently needed to provide surface observations in the Arctic Ocean. The ability to measure the conditions of the atmosphere and ocean from satellites is, however, developing rapidly and, with adequate surface validation, the quality of weather forecasts will approach the quality used in other areas."

- Wave data
  "Because of the ubiquitous presence of sea ice, waves have not been a major navigational hazard in the Arctic. However, with less sea ice to dampen the waves, this will no longer be the case in the future. Wave information is typically packaged along with marine weather information in sea ice-free areas. New operational modelling capability will be needed to deal with a partial ice cover and its effect on wave generation and transmission. Buoys that measure the wave heights and directions are essential for model validation but none of these exist in the Arctic for operational reporting. Because of the necessity to deal with winter ice, a new generation of buoys will have to be developed."

Reasons for inadequacy

The inadequacy of data, as identified above, can be attributed to a lack of measurements.

Fitness for purpose

There were no specific statements found in literature regarding the fitness for purpose of data.

(11) Assessment of risks posed by invasive species

References to inadequate data

Chan *et al*. (2015) mention in their study that there can be no conclusions drawn on the presence of NIS based on the available data: *"To date, there have been no ship-mediated NIS reported in the Canadian Arctic, including Churchill, but systematic surveys to detect NIS have been limited (Goldsmit et al. 2014). Thus, absence of evidence should not be mistaken for evidence of absence."* Chan *et al*. (2015) could not determine the invasion status of Canadian Arctic species with confidence due to insufficient baseline biodiversity information for Canada's Arctic coastal systems.
Goldsmit et al (2014) mentions the lack of information on NIS in the Arctic Ocean, also referring to other studies: *"To date, there have been no reported ship-mediated NIS in Arctic Canadian waters; however, the Arctic Ocean is the least sampled of the world´s oceans (Arctic Council 2009), and few systematic surveys have been conducted in this region of the country (particularly for benthic invertebrates) making it problematic in determining if newly reported species are native or introduced. In particular, the systematics and biogeography of benthic coastal invertebrates in the region are poorly known and mostly underestimated (Archambault et al. 2010)."* There is a lack of robust information on the early stages of most introductions, whether successful or not. Lack of baseline data or insufficient taxonomic information can result in unnoticed changes related to aquatic community composition and existing populations of native species (Goldsmit *et al*., 2014). Goldsmit *et al*. (2014) also state the following: *"It is extremely important to know what was previously present to be able to identify new arrivals. The Canadian Arctic coasts can be considered a poorly studied area particularly with respect to benthic invertebrate biodiversity (Archambault et al. 2010; Piepenburg et al. 2011) thus emphasizing the importance of sampling and monitoring high-risk locations such as ports."*

Reasons for inadequacy

The inadequacy of data, as identified above, can be attributed to lack of measurements.

Fitness for purpose

There were no specific statements found in literature regarding the fitness for purpose of data. However, the following general remark was made: “Robust information on the early stages of most introductions, whether successful or not, may provide essential information on the vectors transporting the species as well as the invasion process in itself. However, data is lacking thus there is a need for sampling and monitoring high-risk locations such as ports” (Goldsmit *et al.*, 2014).

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IMARES (Institute for Marine Resources and Ecosystem Studies) is the Netherlands research institute established to provide the scientific support that is essential for developing policies and innovation in respect of the marine environment, fishery activities, aquaculture and the maritime sector.

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'To explore the potential of marine nature to improve the quality of life'

The IMARES mission

- To conduct research with the aim of acquiring knowledge and offering advice on the sustainable management and use of marine and coastal areas.
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