EMODnet Sea-basin checkpoints

Lot n° 1 - The Arctic

Start date of the project: 15/06/2015 - (36 months)

Final Report

Reporting Period: June 2015 – June 2018

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Disclaimer

Contents

1. Executive summary

In the final report for Sea Basin Checkpoint Arctic lot 1. The challenges performed and activities done by the consortium are presented. Over the last three years Arcadis, Wageningen Marine Research, MARIS and SINTEF worked together on analysing currently available data on the Arctic through analysing 10 challenges. In the course of this project reviews of available literature and data adequacy reports were written. Overall it was found that on a large number of topics not enough data was available to answer all aspects of the challenges. The challenges provided a clear overview on which data is available and where data is either missing or unavailable. The available data that was found is now more easily available through the Content Management System set up by the consortium. Through analysing the different challenges several things became clear about the Arctic.

- A large number of factors and even entire areas in the Arctic are unexplored.
- Some of the missing data do exist but it requires extensive processing or the data are not publicly available.
- A number of challenges were too specific or inappropriate for the Arctic.

Both the consortium and the expert panel who analysed the final results made recommendations on the continuation of the SBC. Both advised keep the data and metadata found throughout this project available to the public.

2. Introduction

This is the final report for the Sea Basin Checkpoint Arctic (lot 1). This project, with a running time of three years, started in June 2015. The SBC checkpoints were executed by a consortium consisting of Arcadis, Wageningen Marine Research (WMR), SINTEF and MARIS. The project was then executed with a core team, challenge leaders and judged by expert panels. The people involved in this are listed below:

Core team;

- Belinda Kater	Arcadis
- Martine van den Heuvel-Greve	WMR
- Peter Thijsse	Maris

Challenge leaders

- Jan-Tjalling van der Wal	WMR	Wind farm sitting
- Oscar Bos	WMR	Marine Protected Areas
- CJ Beegle-Strauss	SINTEF	Oil leak platform
- Eline van Onselen	Arcadis	Climate Change
- Bart Grasmeijer, Nathanael Geleynse	Arcadis	Coasts
- Harriet van Overzee	WMR	Fisheries management, Fisheries impact
- Arjan Tuijnder	Arcadis	Rivers
- Le Griffith, Nathanael Geleynse	Arcadis	Bathymetry
- Ainhoa Bianco	WMR	Alien species

Experts

- Anne Christine Brussendorff	ICES
- Colin Grant	IOPG, Metocean Consulting
- Hans Dahlin	Retired, EuroGOOS
- Aart Kroon	University of Copenhagen
- Srdan Dobricic	JRC
- Anna Stammler-Gossman	Arctic Centre, University of Lapland
- Maarten van Loonen	University of Groningen
- Ben van de Wetering	Retired, European Commission

The Arctic SBC project includes several challenges addressing data availability and adequacy for a specific additional purpose, e.g. wind farm siting or assessing riverine input. 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 was 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;
- Contributing to the identification of priorities both in terms of creation of new data and in 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";
- Assessing how well all available marine data meets the needs of users.

The project covered the Arctic Ocean as defined in the CIA factbook and therefore including 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. As can be seen in Figure 1, the European part of the Arctic area is relatively limited, making this Checkpoint a unique one among the other Sea Basin Checkpoints.

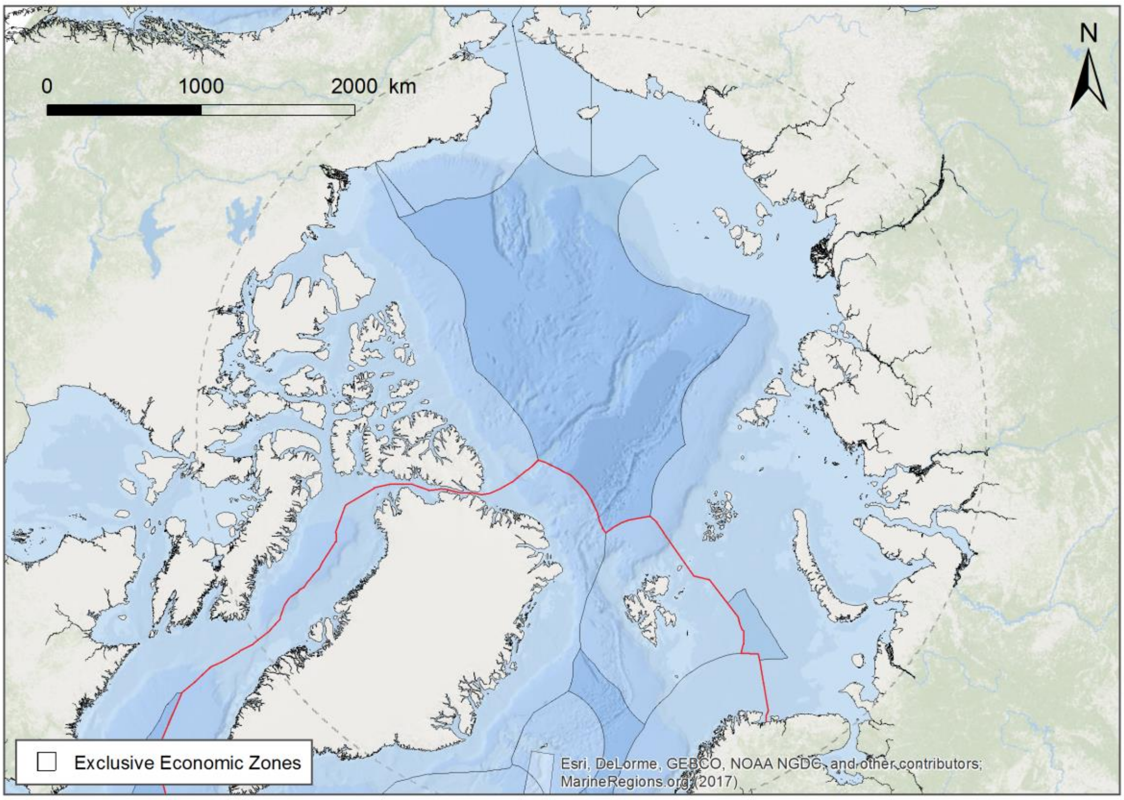

Figure 1: Arctic Area. The red line indicates the extent of the European Exclusive Economic zones.

3. Summary of the work done

Throughout the project the challenges were executed and the results of these and the other segments presented on the website. The challenges (work package 2-12) are summarised in chapter 4, in this chapter the other work packages (wp) are presented, with the exception of work package 17, project management which is represented in the project team meetings described in chapter 6.

3.1 Literature review (wp 1)

As part of the Arctic SBC project, a literature search was performed with the objective to identify data sets reported in documents and to evaluate whether the data sets are adequate for the purpose(s) of those documents. The literature review describes a framework for such an evaluation, but the actual evaluation is not yet performed. Here the focus lies on a systematic approach for searching literature, in order to obtain an initial body of literature and datasets for the project objectives.

3.2 The portal and dashboard (wp13)

The portal and dashboard of the Sea Basin Checkpoint Arctic can be found on www.emodnet-arctic.eu. The objective of the portal is to present the results of the project, including the results of the challenges. The results are meant as publication to the EU, but also to other users to re-use the outcome of the project.

The main content of the portal are the descriptions and results of the challenges (also indicating data gaps), and a dashboard that delivers insight in assessment of the quality and availability of available datasets. The overall dashboard publishes the results of the assessment reports used in the project. The quality score and adequacy of all datasets can be viewed in a user-friendly manner.

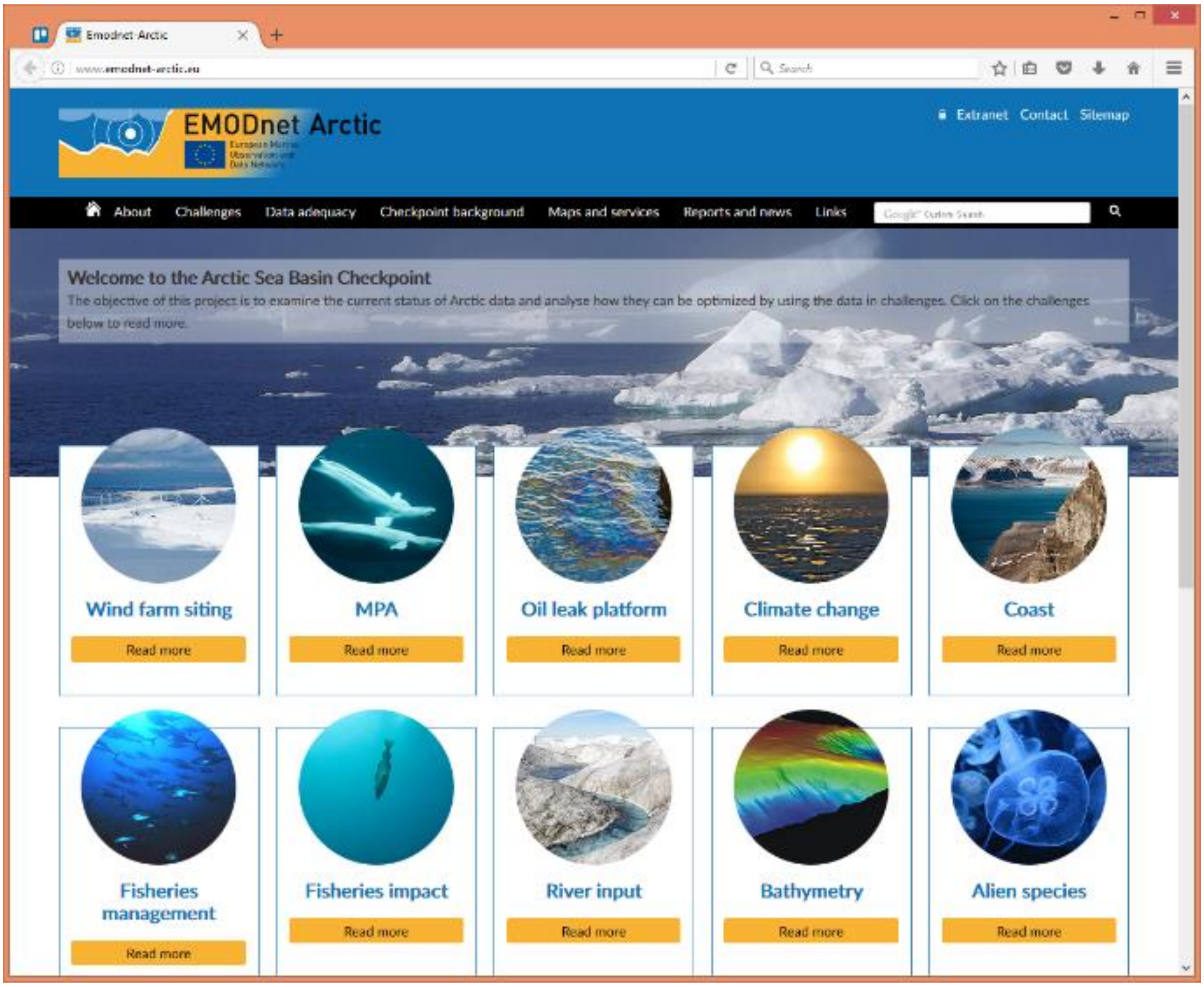

Figure 2: Homepage www.emodnet-arctic.eu

The website of the EMODNet Arctic checkpoint supports the challenges in publishing their outcome, as well as the workpackage handling the literature report and the Data Assessment Report (DAR).

3.2.1 Challenges

A template to describe the content and output of the challenges has been developed in close communication with the challenge leaders. For each challenge the portal provides:

- Description of the challenge
- Assessment round 1
- Assessment round 2
- Lessons learnt
- References
- Viewer with output geographic datasets
- Related datasets (see below)
- Related adequacy reports (see below)

Many of challenges have geographic datasets (maps, locations with time series) available as output. A map application consisting of a Geoserver backend and a CMS module has been developed to make these datasets available to users. The data is made available as WMS for re use in other portals, and datatables are made available for download as much as possible.

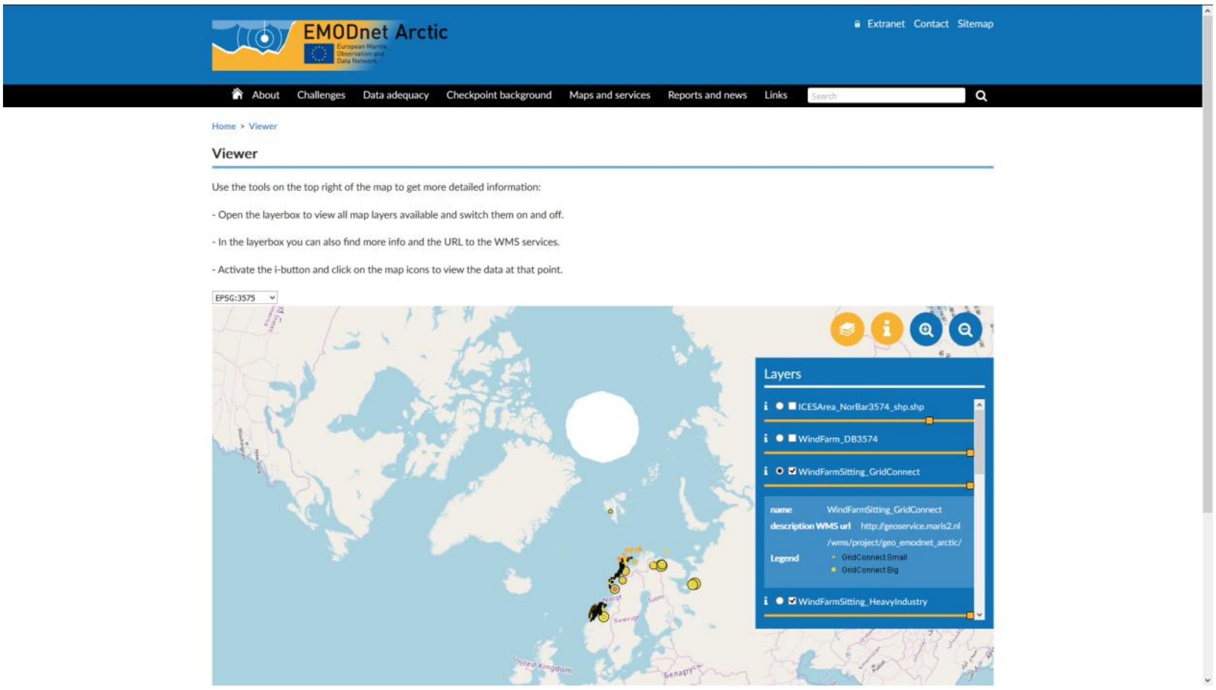

Figure 3: Mapviewer with the geographic datasets of Wind farm siting - link to WMS service provided

3.2.2 Literature report and Data Assessment Report

For the datasets and adequacy reports special CMS modules have been developed in which the WP leader and all challenge leaders have entered all reports used in the projects, as well as all datasets assessed during the answer to the challenge. The WP leaders of the literature report and DAR have provided the template for the CMS via which all challenge leaders have reported their literature research and assessments in a structured way.

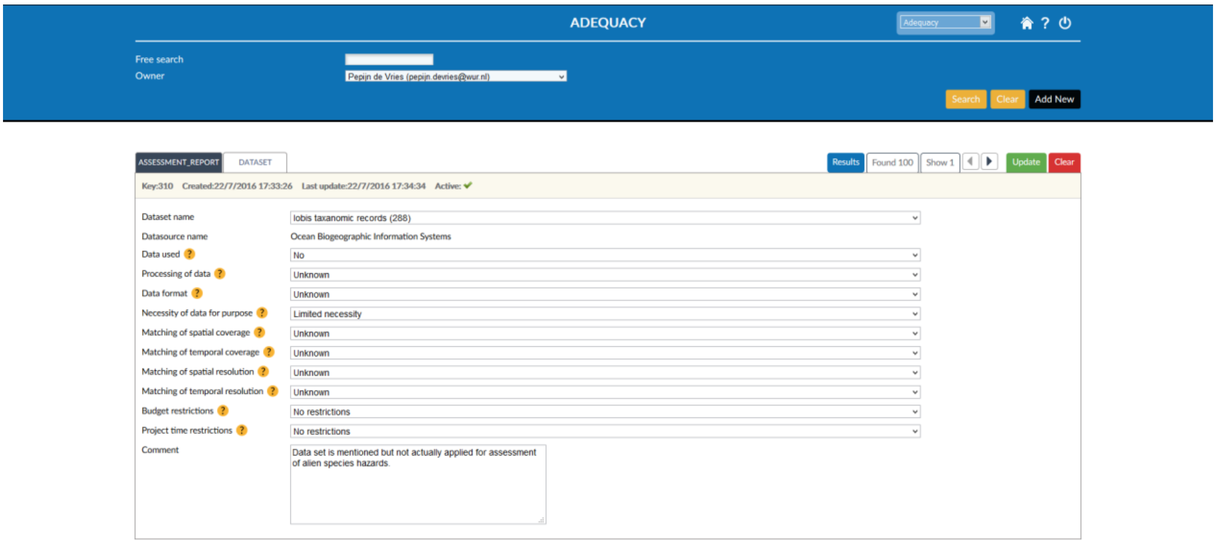

Figure 4: CMS entry page for Adequacy of a dataset

Because the collected data was structured it could be converted into very useful graphical diagrams, tables, etc. in order to report to the commission and EMODNet lots.

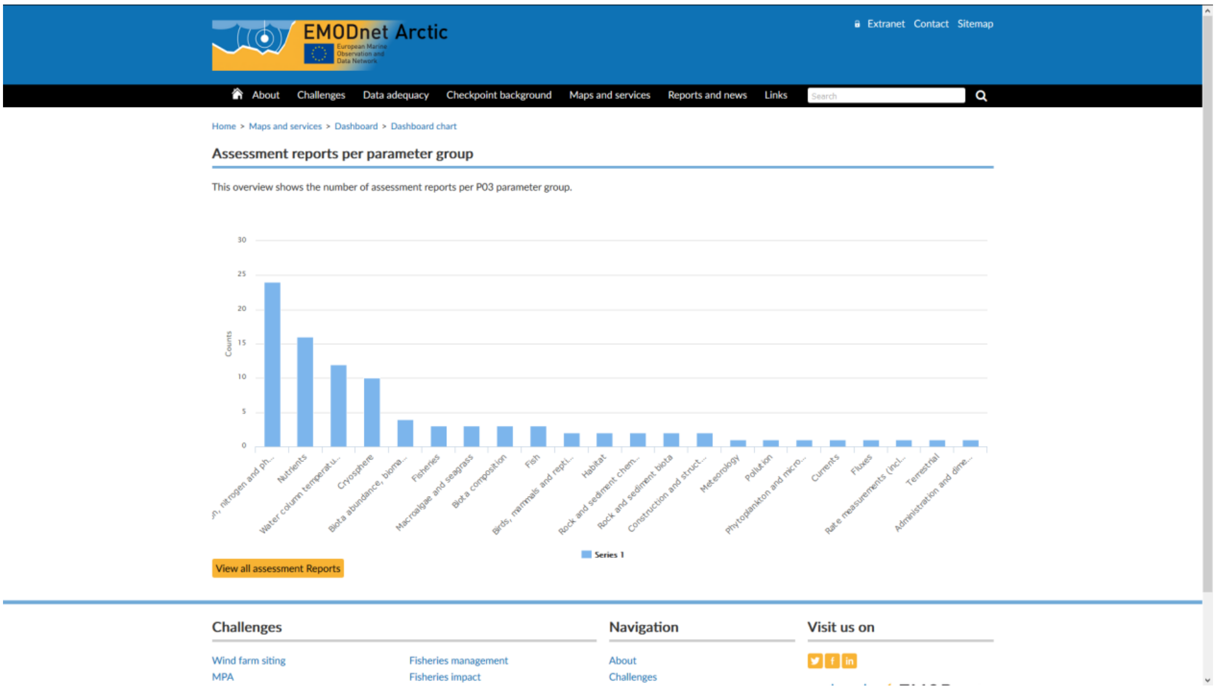

Figure 5: diagram of available reports per parameter

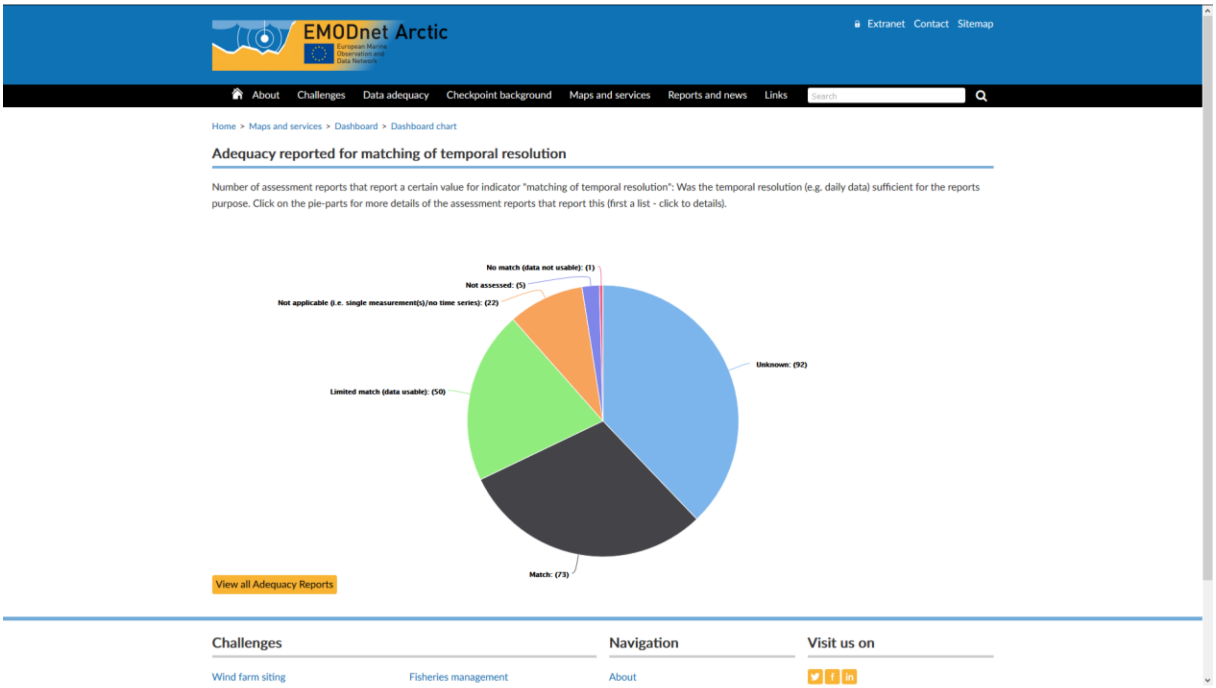

Figure 6: Adequacy summary of datasets assessed with respect to matching temporal resolution

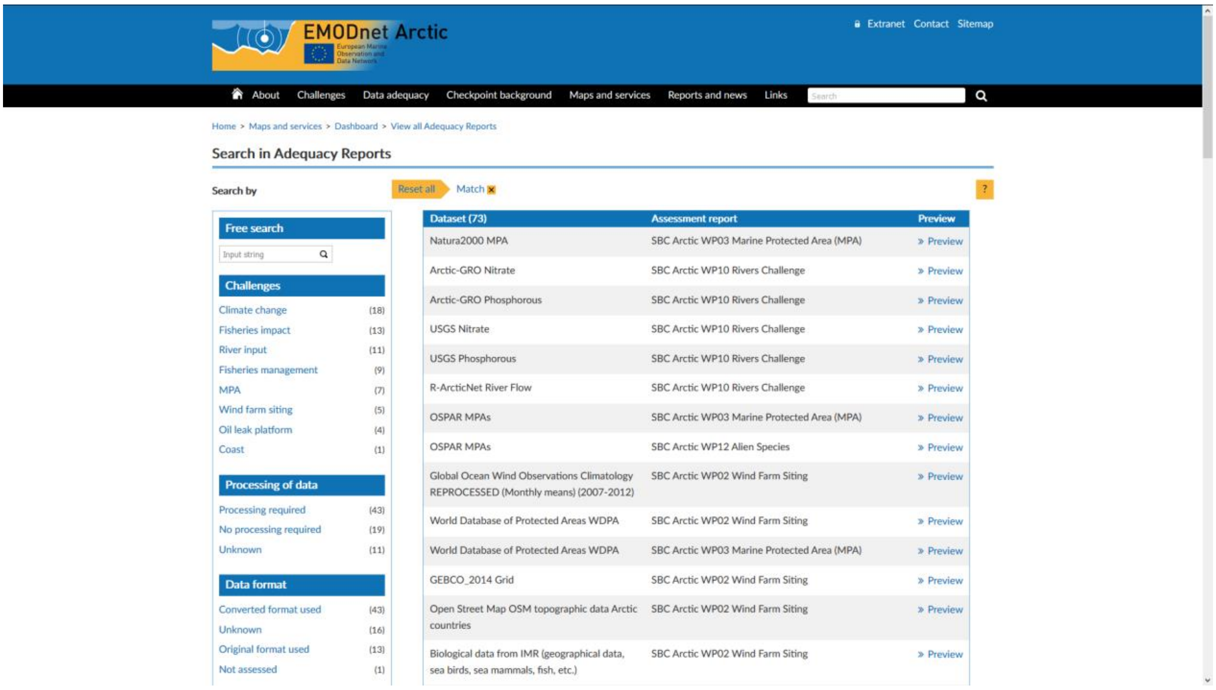

Figure 7: When clicked in the diagram of matching temporal resolution the user gets the list of datasets that match

3.3 Panel Reports (wp 14)

Two meetings with expert panels were held. The input from the first meeting was incorporated in the next phase of the project. The input of the second meeting was used as input for the final report.

3.4 Data Adequacy Reports (DARs) (wp15)

The Data Adequacy Reports (DARs) provide a view of the monitoring effort in the Arctic sea basin, with the aim to show how well the available marine data meets the needs of users (according to the questions asked by the EC through the challenges). The monitoring effort is elaborated from three different viewpoints:

1. the needs of users (e.g. fisheries managers, coastal protection authorities, ports);
2. per parameter (e.g. temperature, bathymetry, sea level rise);
3. the purposes for which data is used (e.g. marine spatial planning, assessment of (potential) MPAs, assessment of navigational risks).

As part of the Arctic SBC project, a structure for collecting information on data adequacy was developed: the Content Management System (CMS) (Figure 8). The structure of the CMS allows for an easy and clear presentation and analysis of the quality and adequacy of the assessed data sets, from many different angles and perspectives, of which the main results are presented in this DAR. The literature review and the challenges as registered in the CMS were used as input.

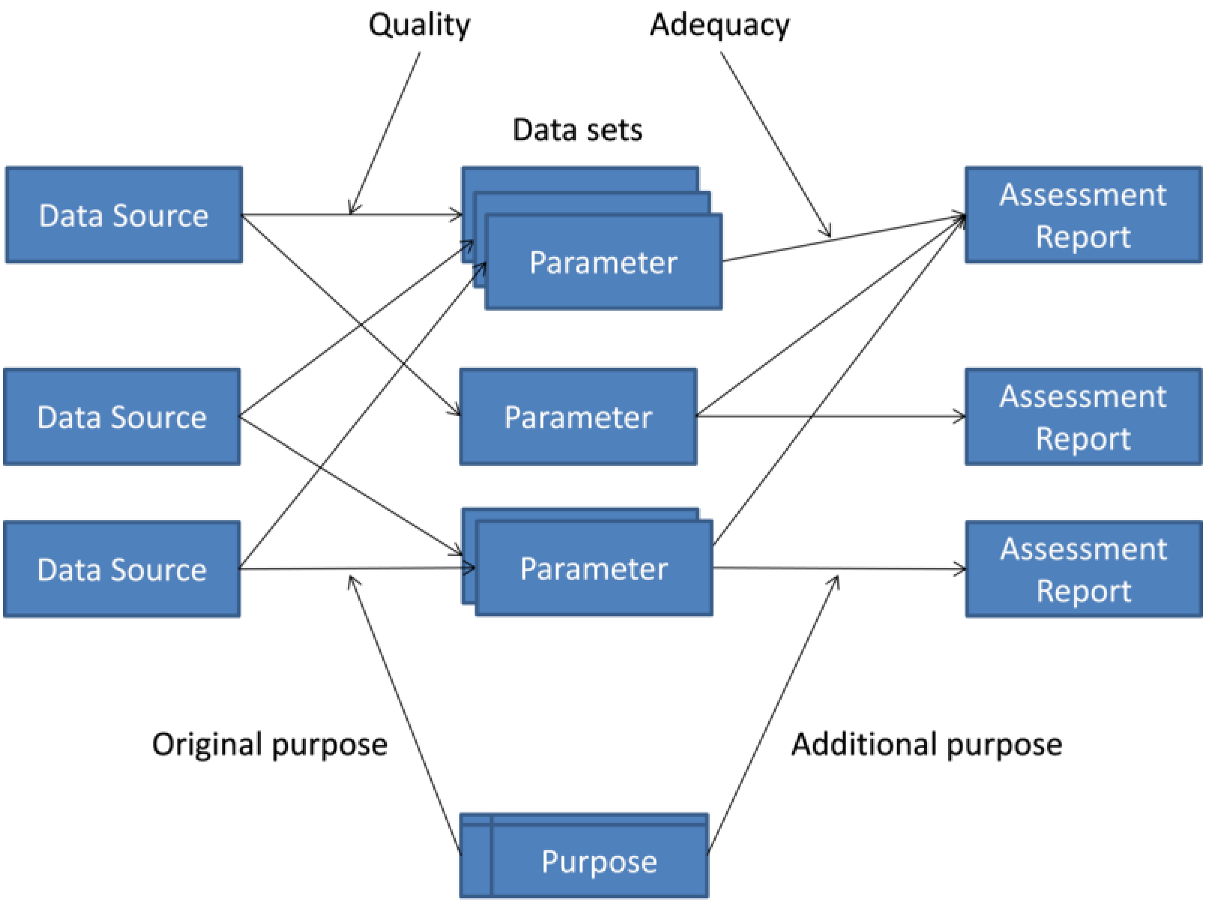

Figure 8 Schematic representation of the Content Management System.

In general we have found that the available datasets that have been evaluated in the present study show a limited match with the quality requirements for the purpose for which it is used (the challenges). For the spatial and temporal aspects, in most cases there was an association between the quality (i.e., resolution and coverage) and data requirements (match of quality for a specific purpose). As (for at least most challenges in the present project) the focus is on the entire Arctic region, a partial mismatch can be expected for many European data sources (such as EMODnet) which only focus on the European part of the Arctic. Only a small fraction of datasets were classified as unsuitable for specific purposes.

Within the scope of this study we identified some data sources and data sets that are particularly 'popular' for Arctic based studies, which indicates that those datasets are reused many times. The original purpose for which data was generated is often not reported or not known. In case the purpose is known, data sources and data sets are often (re)used for the same purpose. For some original purposes, the datasets are reused for multiple additional purposes and some additional purposes use data generated with multiple original purposes.

This first DAR was reviewed by the Commission and the Panel and their input was addressed in the

3.5 Stakeholder workshop (wp 16)

On Tuesday 13 June 2017, members of the Svalbard Integrated Arctic Earth Observing System (SIOS) and the SBC Arctic project team met to get acquainted and identify potential joined topics.

On Wednesday 14 June, 2017 an international workshop 'Arctic sea basin data – the Svalbard case' took place at Huset, Longyearbyen, Svalbard. This additional workshop was funded by the Svalbard Strategic Fund. The purpose of the workshop was to present the SBC Arctic project and obtain input into the project from local experts of the Svalbard science community.

1. The goal of the workshop was to:
2. Present the initial results of the SBC Arctic project on Arctic sea basin data
3. Evaluate current Arctic marine monitoring programmes and datasets
4. Connect existing activities in Arctic marine data utilisation
5. Identify joined knowledge gaps in marine data in the entire Arctic area and specifically the Svalbard area (relevant for Ny-Ålesund flagship programmes)

3.6 Report on the future of the Sea Basin Checkpoint:

This interim report considers what our team thinks are critical steps for the future and possible follow-ups for this project and for specific actions and research. It provides overviews of all the challenges and identifies possible future actions. It also gives an insight into possibilities for the future regarding the Sea Basin Checkpoints and Emodnet.

4. Main results for the respective challenges - data adequacy assessments

4.1 Wind farm siting

Challenge summary

The objective of the Wind Farm Siting Challenge was to find economically viable areas for Offshore Wind Development (OWE) development with little impact on both the ecosystem and other human activities, in the Norwegian Sea and Barents Sea. For the Arctic Ocean Checkpoint project we translated this into the identification of areas that best fit these goals.

Fixed wind turbines. Of the 13 blocks spread out along the Norwegian coast in a technical OWE assessment none remained after taking into account other sea uses. Most were excluded due to their locations being in major shipping routes or marine protected areas.

Floating wind turbines. Of the 290 blocks in a technically suitable area, 124 blocks remained after taking into account other sea uses. Six of these blocks are in the Russian part of the Barents Sea (ICES area Ib), on the Murman Rise. The remaining blocks are in Norwegian waters (ICES area IIa2), mostly around the Lofoten and Tromsø. West of Trondheim the combination of other sea uses resulted in only a few remaining OWE blocks. These can be seen in Figure 9.

This challenge derived its datasets predominantly from sources outside EMODnet. This is mostly due to the fact that the study area is located outside the focal area of EMODnet, and is therefore not covered. This situation may change in the future as the Arctic has been recognised as an area where more attention from the European Union is warranted, and therefore also from EMODnet. The main dataset for this challenge, the wind resource, was available from Copernicus and thus from an EU-related source. Two ecosystem-related data layers that were planned for this challenge could not be included. No datasets were found that could be used as a reliable basis for 1) bird migration routes, and 2) sea mammal migration routes. This is identified as a data gap. This is a more general data gap, not specific to the Arctic, as such maps/datasets are also not available for e.g. the North Sea.

Lessons learned

With the available data an adequate assessment can be made for the potential development of offshore wind parks in the Norwegian Sea and Barents Sea.

Offshore development of wind energy in this region will have to rely on floating turbine technology. This technology may need several more years to mature sufficiently before successful deployment in Arctic and sub-Arctic waters. For an in-depth assessment of the economics of an offshore wind farm, specific information is needed regarding the technology used to locate moring sites and assessing geophysical conditions on and in the seabed.

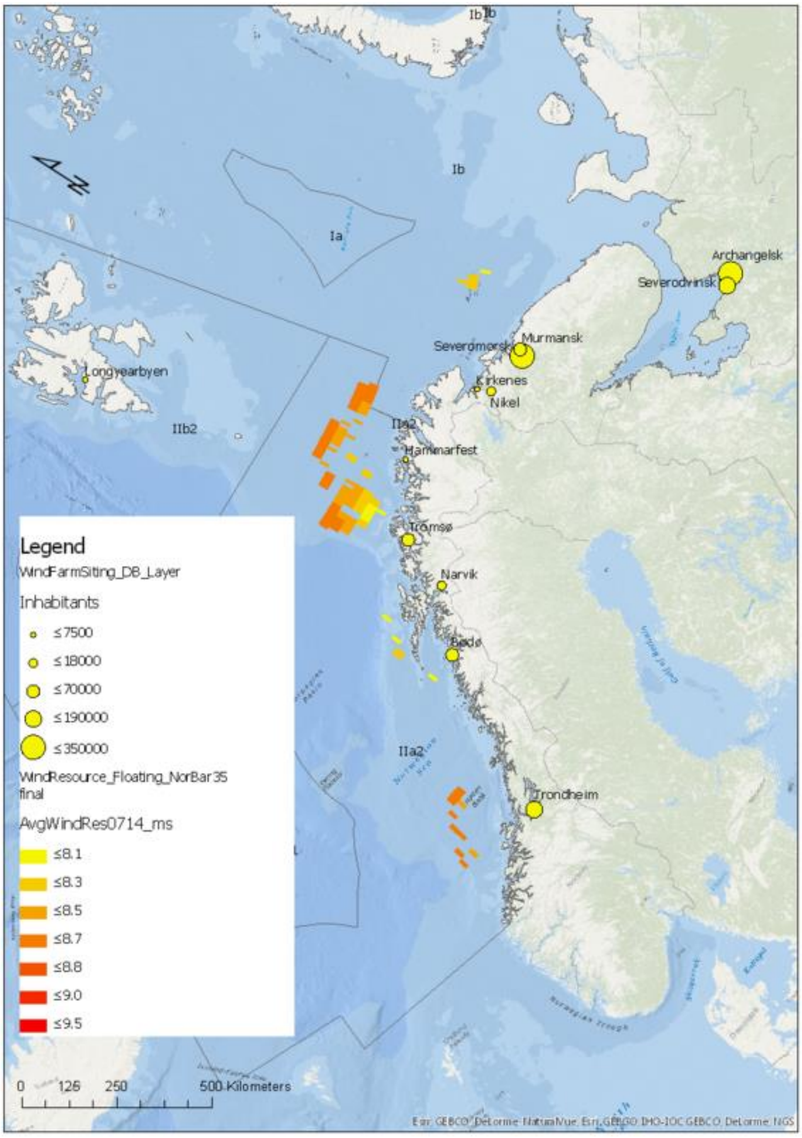

Figure 9 Map showing the area with potential for developing (floating) offshore wind energy parks in the Norwegian Sea and Barents Sea, based on the first round of assessments within 'SeaBasin Checkpoints – lot Arctic'. Also shown are human settlements that may play a role in this development.

Expert panel judgement on fit for purpose of available data

Yes in the Norwegian area.

4.2 Marine protected areas (MPAs)

Challenge summary

In this challenge the network of Arctic MPAs was analysed. Data on MPAs were obtained from various sources, the most comprehensive being the World Database on Marine Protected Areas. In total, 492 MPAs were included. EU Natura 2000 areas are not present in this part of the world. From the OSPAR database with 333 records, only eight MPAs were inside the Arctic region and these were included. Vulnerable Marine Ecosystems (VMEs) were not present in this region either. 11 Norwegian MPAs and five proposed Norwegian MPAs were included. For Iceland a protected area on land was associated with the sea, as was confirmed by national sources, and therefore included. The geographical information for these were derived from MPAtlas. For the USA, 38 additional MPAs as published by NOAA were included, including several fishery closures. A check on the Canadian data sources from DFO did not reveal any new MPAs compared to the Word database. The same was true for the MPAs of Greenland and Russia. The network of EBSAs was included as well. All identified MPAs for the Arctic region can be seen in Figure 10.

MPA information does not include specifics on species and/or habitats that justify designation as an MPA and does not present species that are specifically protected by the MPA. A selection of species was therefore made to further study the coherence of MPA networks. While the available data was sufficient to complete the coherence analysis, the process was complicated by the fact that the species data had to be obtained from different sources. This meant that the methodology had to be altered to achieve comparable results.

The coherence analysis resulted in identification of sea ice as threatened habitat. Sea ice is an essential habitat for a variety of Arctic species and is currently only to a very small extent included within MPA boundaries.

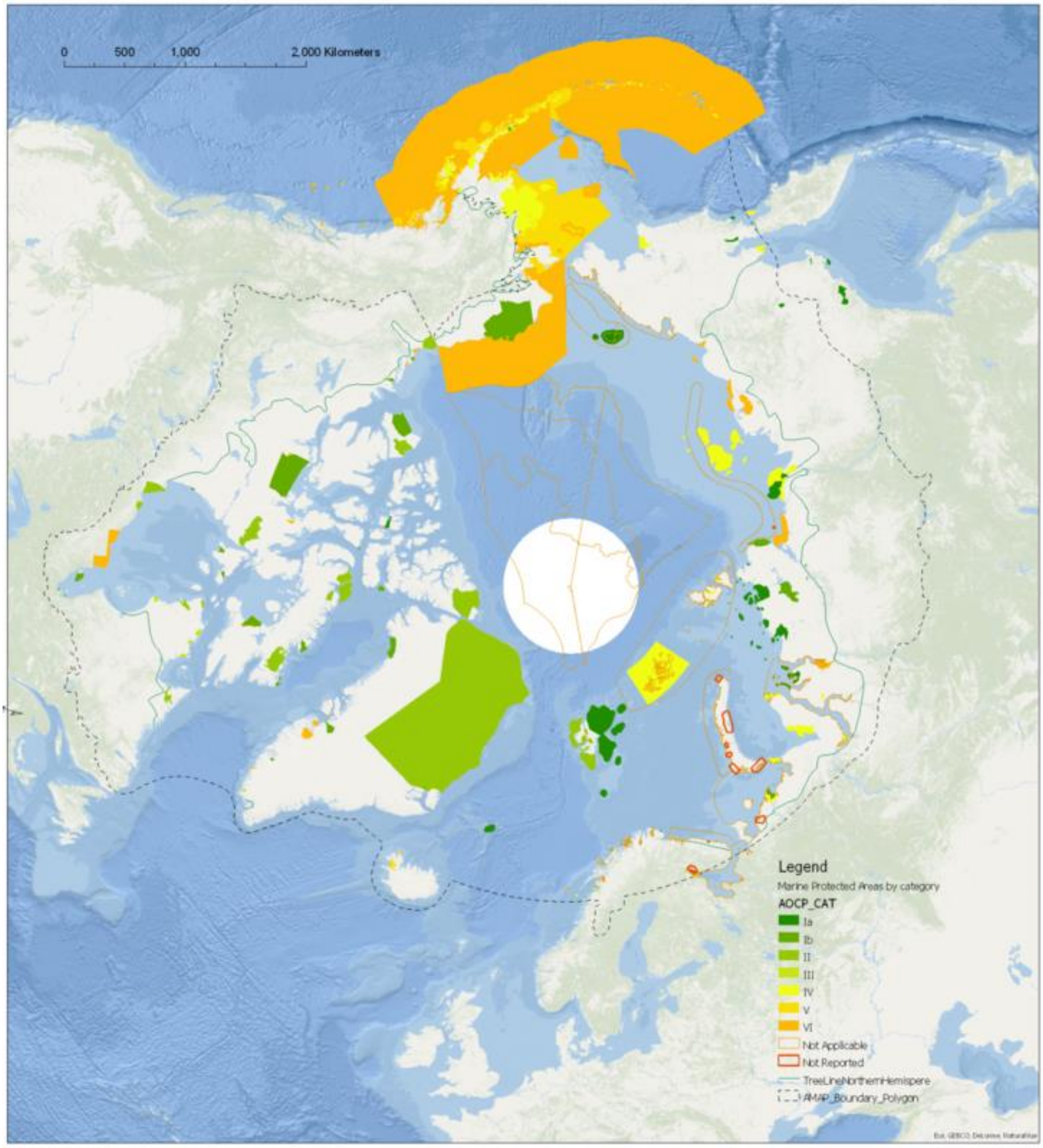

Figure 10 MPAs in the Arctic classified according to the IUCN categories (final results, July 2016). The IUCN categories are: Ia - Strict Nature Reserve, Ib -Wilderness area, II - National Park, III - Natural Monument or feature, IV - Habitat/species management, *V* - Protected landscape/seascape, VI - Protected area with sustainable use of natural resources (for details, see the IUCN classification). Not Applicable: the IUCN Management Categories are not applicable to a specific designation type. This currently applies to World Heritage Sites and UNESCO MAB Reserves. Not Applicable also applies to a site that does not fit the standard definition of a protected area (PA_DEF field = 0). Not Reported: for protected areas where an IUCN category is unknown and/or the data provider has not provided any related information.

Lessons learned

- The World Database on Protected Areas contained 90% of the MPAs, but is not complete.
- The current MPA database as developed for the Arctic SBC project is relatively complete.
- Geographical Information Systems (GIS) maps need to be projected to a polar projection, because otherwise select-by-location operations give unexpected results. For example, when searching for an area 50 km away from a certain point, a non-polar projection gives incorrect results.

Expert panel judgement on fit for purpose of available data

Yes, for presence, No for additional information e.g. protected values.

4.3 Oil platform leak

Challenge summary and lessons learned

The unannounced exercise was an oil spill scenario that included ice covered waters. The results show advancement in both Arctic data access and post Deepwater Horizon oil spill preparedness and response since 2010. SINTEF and OSRL provided timely and detailed information on trajectory, Resources At Risk and details about the area. However, there was also some information missing that would have allowed us to make a complete ecological impact prediction. For instance, little information is available on the distribution of sensitive species in the region.

A recommendation is to get a better understanding on the distribution of sensitive marine species to better assess and mitigate impacts of oil spills in the Arctic area. Sensitive areas for marine birds and mammals need to be further identified and updated in the Arctic for management purposes. An example is the sensitivity mapping that was conducted in south Svalbard (Weslawski et al. 1997)[1]. The most sensitive species and their distribution need to be mapped in online Environmental Sensitivity Index (ESI) maps, and need to include seasonality. Additionally, knowledge on the behaviour of oil in colder climates needs to be expanded. There are extensive general studies in the public domain – general because oil chemistry is proprietary. SINTEF has an Oil Weathering Model and detailed database by subscription. Focus on prevention is very important in the Arctic.

Expert panel judgement on fit for purpose of available data

Yes, for the current challenge set up

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[1] Weslawski, J. M., Wiktor, J., Zajaczkowski, M., Futsaeter, G., & Moe, K. A. (1997). Vulnerability assessment of Svalbard intertidal zone for oil spills. Estuarine, Coastal and Shelf Science, 44, 33-41.

4.4 Climate Change

Challenge summary and lessons learned

The Climate Change Challenge evaluated publicly available data on climate change and its effects in the Arctic Sea Basin. Nine sub-challenges were set for which parameters have been selected, focusing on (among others) temperature, ice and phytoplankton.

Temperature (grid). There is enough data available to complete this sub-challenge. A lot of data is available. The real challenge is to find the appropriate dataset required to answer specific questions. In the case of 10 and 50 year time spans, data needs to be available both temporally and spatially, which is not always the case. During the past 10 and 50 years, monitoring strategies have changed and priorities have shifted back and forth, creating gaps in knowledge and data. These gaps cannot be filled as we cannot go back in time to add monitoring points or change the monitoring strategy. However, we can learn from the gathered data (and the missing data) in setting up new monitoring strategies. Sea temperature is directly related to climate change and keeping track of sea water temperature, especially in the Arctic area, can therefore be very useful for monitoring and evaluating the effects of climate change.

Temperature (time-series). This sub-challenge was divided into two scenarios:

1. Time series of average annual temperature at sea surface for the entire study area;
2. Time series of average annual temperature at sea bottom for the entire study area.

For the first scenario relevant information and data were available. Although a time series, with adjustable time periods, could not be found. Still, the data to construct such time series is present and downloadable free of charge. For the second scenario there is less information available. Freely available information was limited to one research study over the course of one year (2012) on different locations and comparative data from set time periods. A time series for sea bottom temperature between 2007 until 2014 was found in a research paper. This paper was not available free of charge and there was no option online for retrieving the dataset.

A limitation for both scenarios is that when averaging the temperatures from the entire Arctic into one mean temperature important local differences get overlooked.

Internal energy (time-series). For this challenge no conclusion on the availability of data could be drawn. The question asked in this challenge needs to be reviewed and made explicit. Is the data necessity focused on the internal energy of the sea, including mechanical energy, external energy and thermal energy and potential energy? Or is there a need for data on subsets of internal energy like thermal energy or wave energy?

Ice cover (grid). There was not enough data available to complete this sub-challenge. In all the data sets, the decline in the extent of solid ice is evident, though more so in the Atlantic sector than in the Bering Sea sector. However, as the sea ice thickness parameter differs from sea ice extent, other research techniques are necessary and these produce different data. Lessons learned during this sub-challenge:

- Data on sea-ice thickness (especially in kg m2 /year) is not readily available as it is a hard to measure.
- More data on ice thickness is becoming available relatively recently with new measuring techniques and the use of models.

Ice cover (map). Enough data was available to complete this sub-challenge. A clear decrease in sea-ice extent can be seen.

- Measuring techniques have changed significantly over the past 100 years so data is not always comparable

Ice cover (time-series). No data is available on sea ice mass. However, time-series can be made for sea ice extent and sea ice thickness. Most of the identified datasets start in the 1960s, when sonar became available, or in 1978 when satellites became available. It is therefore not possible to create a time-series spanning 100 years.

A lot of data concerning sea ice extent is freely available and being regularly updated. Furthermore, scientists are increasingly sharing data publicly. Getting a total overview of data available on sea ice extent throughout the Arctic requires combining datasets. Only then will true gaps in knowledge become obvious.

Sea ice thickness is a different matter. Although data is available, none of it is directly usable. All data needs to be combined, converted or processed before time-series can be made. However, many papers have created time-series using the available data, suggesting that differently organised data sets exist.

Ice lost from Greenland. This challenge was to present a time series showing the mass of ice lost from Greenland. This data is readily available with easy and free access. The data shows that the mass balance of the Greenland ice sheet is a complex system which has strong regional differences. Lessons learned are:

- The GRACE satellite dataset is the only dataset which is translated into a timeseries.
- When searching for Greenland ice mass change, most information found is based on the GRACE satellite data.
- Because the only time series is derived from the GRACE dataset, the time period only ranges back to 2002.
- Other depictions of ice mass variation are either comparative or cumulative.

Traditional way of life. Climate change impacts the traditional way of life, affecting for instance animal behaviour such as migration routes. People that still actively pursue their traditional way of life in the Arctic try to be adaptive to changing conditions. For example, Inuit in the Canadian Arctic are flexible, showing responses to varying climatic conditions. A similar optimism can be found for sustaining subsistence systems, pointing at the long history of subsistence systems and its apparent resilience (Kofinas et al., 2010)[2]. However, changing climatic conditions may prove to be too problematic for certain types of traditional hunting as simple things like access to the food source may cause a significant reduction in the availability of subsistence resources in the future (Brinkman et al. 2016)[3].

Lessons learned:

- There are many types of traditional life, with communities varying in traditions, size, etc., and information is not always available;
- Information on animal migration and the influence of climate change on migration behaviour is available for some species, such as caribou and bowhead whales;
- Information is usually available in text-form as scientific published peer-reviewed papers, not as data sets with actual numbers;
- Behavioural changes and effects of climate change will not always be directly related, as complex interactions and relations can alter parts of the system or combinations of different systems;
- Climate change is not the only thing affecting the traditional way of life: globalization, westernization and modernization are some of the other factors influencing the traditional way of life.

Phytoplankton. It is not possible to select the most common phytoplankton species in Arctic Sea Basin, as the area is simply too large and diverse. Even on a smaller scale common species differ from year to year and season to season. No direct conclusion can therefore be drawn from the assembled data.

Lessons learned:

- Data on phytoplankton is available, but limited in detail, time and space;
- More data is available on species groups than on an individual species level;
- More data is available on Chlorophyll concentrations;
- Phytoplankton are strongly linked to climate change;
- Most studies focus on either zooplankton or primary production in a broad sense, generally focusing on chlorophyll concentrations rather than on individual species.

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[2] Kofinas, G. P., Chapin, F. S., BurnSilver, S., Schmidt, J. I., Fresco, N. L., Kielland, K., ... & Rupp, T. S. (2010). Resilience of Athabascan subsistence systems to interior Alaska's changing climate This article is one of a selection of papers from The Dynamics of Change in Alaska's Boreal Forests: Resilience and Vulnerability in Response to Climate Warming. Canadian Journal of Forest Research, 40(7), 1347-1359.

[3] Brinkman, T. J., Hansen, W. D., Chapin, F. S., Kofinas, G., BurnSilver, S., & Rupp, T. S. (2016). Arctic communities perceive climate impacts on access as a critical challenge to availability of subsistence resources. Climatic Change, 139(3-4), 413-427.

- Available data are sporadic both on a temporal and spatial level, and are presented in different formats requiring different levels of processing.
- Gaps were observed in both time and space of monitored areas with regards to individual phytoplankton species. Data found were not always up-to-date.
- There are not many permanent monitoring stations for phytoplankton. A lot of data were derived from research expeditions or cruises. Differences in time and space complicated a comparison between datasets.
- Chlorofyl may be a good proxy for phytoplankton and may be monitored via satellites.

Expert panel judgement on fit for purpose of available data

Yes, for recent data, No for historical data and marine exploitation by local people.

4.5 Coasts

Challenge summary and lessons learned

The Coast Challenge aimed to produce spatial data layers and time plots for parameters, namely sea level rise and sediment balance per stretch of coast for the Arctic study area. However, arctic coastal dynamics database information is poor for the Arctic area. The following lessons were learned:

- In general, coastal research in the Arctic is (1) poorly coordinated until recently (or still is), (2) local and (3) not directly presented in databases.
- Permafrost data are missing or coming from different sources or disciplines. Some are collected from an engineering task and have to be formatted before use.
- There are different types of coastal drivers which influence coastal erosion and/or growth. An integral view of which driver is dominant in what region is not available. We recommend using existing data and new monitoring data, linking satellite images to in situ research to create a database.
- Databases use varying units and measuring points, creating a chaotic image of available data. We recommend standardising coastal units in volumetric changes where possible, again combining satellite images and in situ research to create a uniform whole.
- Annual sediment balance data is not available for the entire Arctic region. Local data, both in space in time, is sparsely available. We recommend an integrated monitoring program, covering the entire Arctic region.

Expert panel judgement on fit for purpose of available data:

Yes, for recent data, No for historical data.

4.6 Fisheries management

Challenge summary

Data on Arctic fisheries are increasingly important for fisheries governance and management in the region. However, a significant portion of international waters in the Arctic Ocean is currently not covered by any specific fisheries regulatory framework. The compilation of catch data and identifying gaps are vital requirements to support wide management of the region, and could assist management by giving:

- Indications of declining historic fisheries
- Indications of new, growing fisheries
- Measures of track records of fishing by different countries across the region as a whole.

This challenge focused on compiling vital fisheries data, i.e. removals by the fisheries. The objective of this challenge was to collect and process fisheries landings data, including discards and bycatch information. The available data has been scrutinised to identify current gaps while also considering future use of the data.

Fisheries landings. The term 'landings' is used for the portion of catch that is brought on shore, while the term 'catch' refers to the total of fish captured, whether landed or not (i.e. discards). Because landings exclude discards, the weight of landings is less that the weight of the catch. For the data presented for this objective it is not always clear whether the data related to commercial fisheries catch or fisheries landings. Datasets provided by the Food and Agriculture Organization (FAO) of the United Nations, the Northwest Atlantic Fisheries Organization (NAFO), and the International Council for the Exploration of the Sea (ICES) were used to compile fisheries landings (or catch) data for the Arctic area.

Discards and bycatch Within this study the term 'discarding' refers to that portion of unwanted catch (i.e. fish), which is returned to the sea for whatever reason. Discards may be dead or alive. The term 'bycatch' in this study refers to incidental catches of mammals, reptiles and seabirds. The amount of discards and bycatch depends on the fishing technique that is used. Generally, targeted single species fisheries generate few discards, but can cause incidental bycatch of megafauna, while mixed fisheries (i.e. fisheries that target several species) may generate higher amounts of discards. Monitoring programmes, such as observer or self-sampling programmes, are used to estimate the magnitude of discards and/or bycatch in different types of fisheries. Such collected data is not readily available. They can be presented in scientific journals or even in grey literature. Estimates of discarding and bycatch are therefore less readily available than landings or catch data.

Overall it is concluded that currently the available information on discards and bycatch for the Arctic area is scarce. Only fragmented discards and bycatch information was found. Within this challenge it is therefore not possible to create a comprehensive overview of discards and bycatch for the Arctic area.

Lessons learned

- As the Arctic area only covers parts of the FAO major fishing areas, the FAO catch database is not sufficient in generating an overview of all landings/catches for the Arctic area. Data were also extracted from the ICES and NAFO databases.
- It is not possible to generate an overall comprehensive overview of discards and bycatch in the Arctic area; only fragmented data has been found.
- Benthic invertebrate fisheries, such as shrimp and crab fisheries, form an important type of fisheries in the Arctic that needs to be taken into account in terms of catches, discards, bycatch, and fisheries impacts.

Expert panel judgement on fit for purpose of available data

No

4.7 Fisheries impact

Challenge summary

This challenge focused on collecting information on the impact of fisheries in the Arctic. Fisheries impact is interpreted as any disturbance of the seafloor by fishing vessels operating mobile bottom gear. There are several ways to estimate the level of seafloor disturbance depending on the information available.

For this challenge it was assumed that a relationship exists between the capacity (number of vessels) or effort (usually kWdays) and fishing impact. The degree of impact depends on the fishing technique that is used. Vessels using heavier (e.g. beam trawls) or larger gears (e.g. multiple combined pair trawls) 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 métiers (i.e. a fishing activity which is characterised by one catching gear group and a group of target species, operating in a given area during a given season) and fisheries types as long as they are mobile (towed) gears. Gill nets, fykes and creeling cannot be measured in the same way, but these fishing types have only minimal impact on the seabed and were therefore excluded from this analysis.

This challenge focused on compiling information on the actual impact of fisheries in the Arctic. The objective of this challenge was to collect and process fishing capacity and effort data. Furthermore, as the degree of impact also depends on type of habitat that is disturbed, this challenge also looked into compiling habitat information for the Arctic area.

Fishing capacity and fishing effort. Fishing capacity is considered to be a fairly crude proxy of fisheries impact (Piet et al., 2006)[4] as there is no straightforward relationship between fishing capacity and the pressure exerted on the ecosystem. Only if the vessels engage in fishing do they contribute to pressure. Within this challenge the number of vessels per fishing métier has been used as indicator for fishing capacity.

Fishing effort is a better proxy for fishing impact and more often applied in data-limited situations. However, again the link between fishing effort and fisheries impact is certainly not directly correlated as the impact of one unit of fishing effort on the ecosystem may differ between métiers and/or the sensitivity of the area exposed to that specific fishing method. More sophisticated but also more accurate indicators for seafloor disturbance require high resolution data such as data that comes from Vessel Monitoring System (VMS). This data is held by the flag state of the vessel and is often subject to data protection regulations. As VMS data from specific vessels come under the data protection act it is not readily available for general use.

At present the available information that has been found on fishing impact for the Arctic area is scarce; only fragmented data has been found. Within this challenge we therefore did not succeed in generating an overall overview of fishing impact.

Habitat information. Habitat information has been obtained from various sources. Different working groups within the Arctic Council provide some kind of information on important areas within the Arctic area. For example, the biodiversity working group of the Arctic Council (CAFF) presents information on protected and important areas. There are also different European initiatives, e.g. EUNIS and MAREANO, that provide some kind of habitat information for specific Arctic parts of the Northeast Atlantic. Furthermore, Challenge 3 (Marine Protected Areas) may provide additional information on areas within the Arctic that deserve special conservation and/or are more vulnerable to fishing.

Problems and gaps

- Only fragmented data were found for fishing impact. Furthermore, coding of the presented unit of effort data is not always clear making it not possible to use the data.
- Due to privacy issues, high-spatial resolution data on fishing impact is not readily available for general use.
- Specific organisations that were addressed to identify accessible data did not reply.

Lessons learned

- Information on fishing impact is scarce and mostly on low-spatial level resolution; it was not possible to generate an overall overview of fishing impact in the Arctic area.
- Different sources provide information on important areas within the Arctic ocean. These areas are defined in different ways, each providing insight on areas that deserve special conservation.

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[4] Piet, G.J., F.J. Quirijns, L. Robinson & S.P.R. Greenstreet, 2006. Potential pressure indicators for fishing, and their data requirements. ICES Journal of Marine Science, 64: 110-121.

Expert panel judgement on fit for purpose of available data

No

4.8 River input

Challenge summary

The pan-Arctic watershed contains many rivers with several of Earth's largest rivers. These rivers exert a disproportionate influence on the Arctic ocean as they transport more than 10% of global river discharge into the Arctic Ocean, which contains only ~1% of global ocean volume. In order to understand the dynamics of the Arctic ocean it is crucial to be able to quantify the discharge and nutrient fluxes originating from the rivers from this pan-Arctic watershed into the Arctic ocean. There are six Arctic rivers in this pan-Arctic watershed that have basin area's exceeding 500 000km^2 (the Ob', Yenisey, Lena, Mackenzie, Yukon and Kolyma). Combined these "Big 6" cover 67% of the pan-Arctic watershed and 63% of the total discharge into the Arctic ocean. The next eight largest rivers and their watersheds together only cover an additional 11% of this area and 16% of the discharge, with 22% of the area and 21% of the discharge left for the remaining 'smaller rivers' of the Arctic.

Figure 11 Map of the pan-Arctic watershed, showing its major rivers with the six largest in dark grey and the next eight largest in light grey. The dark grey line indicates the boundary of the pan-Arctic watershed

The objective for the River Challenge of the Sea Basin Checkpoint Arctic project is to provide time series of the annual input into the Arctic Ocean of:

- Water volume (mass)

- Water temperature (average)
- Sediment
- Total nitrogen and Phosphates
- Salmon and Eel (inwards and outwards)

Lessons Learned
The data availability is very different for the requested parameters. Most data is available for the volume of water discharge. For some large Russian rivers time series are quite long, more than 70 years, up to more than 100 years. But many time series are relatively short, a few decades in many cases, and often incomplete. It is worrying that stations have been closed and data are delayed.

The data availability for the other parameters is much worse. Water quality monitoring is expensive, especially at remote sites. Therefore, measurements are erratic, time series are short and measurement protocols differ between sites.

Bring and Destouni (2009)[5] have also studied the status of the Arctic monitoring effort. They conclude that especially the water quality monitoring is fragmented, and this restricts environmental modelers, policy makers and the public in their ability to integrate accessible data and accurately assess bio- geochemical changes in the Arctic environment. They note that the recent PARTNERS project (now continued as the Arctic-GRO) improves the situation, but large areas remain unmonitored. Bring and Destouni (2009) show that there is a significant difference between the characteristics of the monitored and unmonitored areas which limits the possibilities to generalize hydrological and hydrochemical impact assessments based on monitoring data. Even if the quality monitoring were at a level comparable to the quantity monitoring, the short time series still poses a significant problem.

Expert panel judgement on fit for purpose of available data

No

4.9 Bathymetry

Challenge summary
The Bathymetry challenge had the objective to produce a digital map of water depth and uncertainty in water depth and to indicate priority areas for surveying for safer navigation taking

[5] Bring, A., & Destouni, G. (2009). Hydrological and hydrochemical observation status in the pan-Arctic drainage basin. Polar Research, 28(3), 327–338.

into account emerging needs. The challenge focused on the area between longitude 25°W eastwards to longitude 168°W.

Activities included the gathering and integration of available datasets and mapping coverages, including bathymetric and shipping data from international databases. Two primary comprehensive bathymetric databases were identified: the International Bathymetric Chart of the Arctic Ocean (IBCAO, v 3.0) and the United States Arctic Multibeam Compilation (USAMBC, v 1.0). Both databases are a compilation of datasets of various origin, date, resolution and quality. In particular, the IBCAO database is freely accessible and provides well-documented data, including large processed data sets that can be readily post-processed by users, for example, in GIS.

A detailed elaborate international database of shipping data throughout the Arctic was not found. However, the challenge identified general information on the main Arctic Sea routes from national and international sources. In addition, valuable information was found on the main Arctic Ports, forming the nodes of the sea routes. Harbours are important features within the other Challenges and often stimulate the acquisition of bathymetric data.

Lessons learned

- Data is sufficient for general research and interest, but insufficiently granular to be used for navigation.

Expert panel judgement on fit for purpose of available data

No

4.10 Alien species

Challenge summary

The objective of this challenge were to provide a table and digital map of alien species in the Arctic Sea Basin and to assess (potential) impacts of alien species on ecosystem and economy using indicators. Alien species are species living outside their native distributional ranges, having arrived as a result of human activities.

The challenge identified that there is no comprehensive and Arctic-specific database for alien species available. Therefore information on aliens in the Arctic Ocean was compiled from various database sources and scientific literature into a new overview focused specifically on Arctic alien species. 101 established and potential alien species in the Arctic were identified in the challenge (see Table 1. Overview of marine alien species in the Arctic: http://www.emodnet-arctic.eu/alien-species).

The available information on the identified alien species considered established in the Arctic region (from GBIF data) suggests that the majority was introduced via shipping (hull fouling or ballast water), and some via fisheries or aquaculture activities. While these activities may increase the speed of local dispersal and range extension, the temperature range of most of these species suggest that they may also be able to naturally disperse into the Arctic. As many of the established species are fouling species, habitats with hard substrates are likely to be more sensitive to potential colonisation, while sheltered bays and inlet areas may also be sensitive to colonisation by planktonic species. While many species may have negligible effects, those that are ecological engineers or cause cascading effects in the food web may disrupt the functioning of the ecological system. Species that interfere with fisheries or aquaculture may also have an economic impact in the area

Lessons learned

The challenge highlighted several lessons learned and knowledge gaps that consequently limited our ability to detect and predict the presence and (potential) impact of alien species in the Arctic. These consisted of:

- There is no existing clear and complete overview of alien species specifically in the Arctic Ocean. Databases that deal with alien species do not include the Arctic region, whereas databases that concern the Arctic region, do not, or only partly, cover the species identified to be alien.
- The availability of data on the presence of alien species in the Arctic and the distribution of these species in the Arctic is scarce.
- The border defining the Artic region is unclear, making the search for Arctic-specific information difficult.
- The status of a species as ‘alien’ or ‘native’ is not always clear due to the lack of regular monitoring in the Arctic area. Species may also be alien in one region of the Arctic, but native in another region in the Arctic. An example being *Oithona similis*, that is native for most of the Arctic, but identified as alien for the Canadian ports.
- The information available relied on sporadic scientific studies that were limited in time and space (giving no indication of change), and is therefore potentially incomplete and quickly out of date. Continued and systematic research is necessary to maintain an up-to-date and relevant list of Arctic alien species.
- Observations of Arctic alien species is often based on presence in ballast water (in Canada and Svalbard), not on actual settlement and establishment in the marine environment.
- Biological and environmental data is often lacking for the identified Arctic alien species.
- Reliable and unbiased reports on (potential) impacts of alien species in the Arctic are scarce.
- The effect of climate change on the ability for certain species to expand their range to include the Arctic is currently unclear.
- Some source websites were only available in Norwegian or French (although it is unclear if they provided the appropriate data). Where English versions were available, they were often less complete than the original version.
- Some source websites were not user-friendly. Data was often difficult to access and required various search methods for different websites.
- No databases were found in Russian or Chinese. Whether these do not exist (publicly) or were not found due to the language is unclear.

Expert panel judgement on fit for purpose of available data

No

5. Main gaps encountered for the respective challenges

In Table 1 the main gaps per challenge and proposed solutions are presented. In Chapter 7 overall recommendations are done.

Table 1 Main gaps and proposed solutions

Main gaps	Challenge	Measures taken/solutions proposed
Impact of floating turbines on seabed is unknown	Wind farms	Further research of impact on sea-bed of turbine moorings.
Not enough data available e.a. wind strength		Refinement of existing grids.
No data available on bird migration routes.		Datasets for maps of bird migration routes and sea mammal migration routes.
Sea ice is not sufficiently protected	Marine Protected Areas	Explore possibilities and use of MPAs in sea-ice habitats.
Lack of biodiversity and distribution data		Habitat mapping, including benthic systems.
Lack of biodiversity and distribution data		Create quantitative targets in MPAs
Lack of biodiversity and distribution data		Create overview of protected species in MPAs
Lack of biodiversity and distribution data	Oil platform leak	Research the sensitivity of relevant species, including seasonality.
Limited information on where oil spills could be most catastrophic and what to do if one occurs.		Monitor oil and gas development, develop risk analyses and mitigating measures.
Limited understanding of oil behaviour in colder climates		Oil slick behaviour in cold regions and sea-ice in models.
Lack of data	Climate change	Study CO2 and salinity in the Arctic Ocean.
Insufficient modelling relations between data		Link physical and biological parameters.
Insufficient availability of readily processable data		Create large databases with unified data suitable for modelling.
Insufficient modelling relations between data		Link phytoplankton data to alien species and shipping routes.
Insufficient availability of readily processable data		Connect all large existing data collection and distribution organisations such as NOAA, Met Office, JODC, etc.
Insufficient availability of readily processable data		Standardization of data
Lack of climate change awareness		Illustrate the positive feedback loop of climate change and use this for educational purposes.
Lack of data		Pan-Arctic approach on the study of phytoplankton.
Lack of data		Research of the melting permafrost and the subsequent effects.
Lack of data		Study trends in large mammals, ecosystem engineers, birds, etc.
Lack of data		Study the impact of climate change on indigenous Arctic cultures.
Lack of data	Coasts	Focus on multi-year research on a select amount of stations instead of looking at many stations inconsistently.

Insufficient availability of readily processable data		Use existing databases and fill with public standard format.
Insufficient availability of readily processable data		Standardization of coastal movements.
Insufficient modelling relations between data		Explore the link between sea-ice and coastal movement.
Lack of data		Explore the possibility of monitoring using remote sensing.
Lack of data	Fisheries management & impact	More information on Arctic fish habitats and benthic fisheries.
Insufficient availability of readily processable data		Catch and landing data standardization, including bycatch.
Insufficient availability of readily processable data		Focus on the release of international data sources and update international databases with national datasets
Lack of data		Research potential endemic Arctic fishing stocks.
Lack of data		Shrimp, shellfish and crab fisheries research.
Lack of data	River input	Multiyear monitoring at relevant locations.
Lack of data		Support Arctic-GRO initiative for taking water quality and quantity measurements.
Insufficient availability of readily processable data		Focus on standardization.
Insufficient availability of readily processable data		Focus on the release of international data sources
Insufficient modelling relations between data		Effects of changing rivers due to melting permafrost.
Lack of data		Constituents research.
Mismatch of challenge and region		Focus fish research on relevant local species.
Lack of data	Bathymetry	Measure the remaining 89% unmapped area of the Arctic with multibeam.
Lack of data		Focus on shipping routes and ports.
Lack of data		Seabed mapping, including seabed habitats.
Lack of data	Alien species	Conduct an organised monitoring programme on invasive species in a selection of main ports around the Arctic, using traditional and innovative tools (such as eDNA).
Lack of (readily available) data		Improve current databases by adding Arctic areas to alien species databases and adding alien species information to Arctic databases.
Insufficient availability of readily processable data		Improve communication and coordination with other national monitoring in Russia and Canada to further obtain comprehensive, standardised and reliable Arctic-specific information
Insufficient availability of readily processable data		Standardization of international methods.
Lack of data		Develop innovative measurement methods.
Lack of data		Studies on the impact of invasive species in the Arctic.
Insufficient modelling relations between data	Other	Research fishery functions and shipping (use of the ocean). Not only monitoring but analysis and availability
Lack of data		Harbour and port monitoring, biotic and abiotic factors.
Lack of data		Release of international data (Russian)

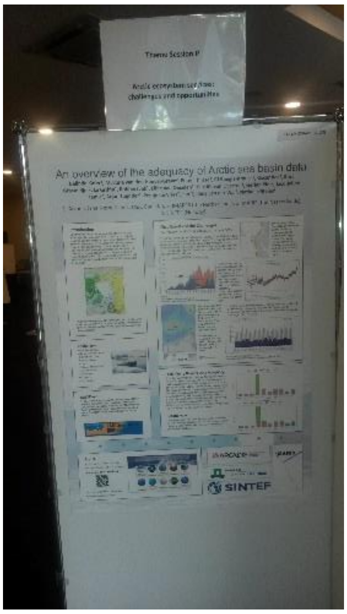
6. Outreach and communication activities

In Table 2 the different outreach activities organised by the project team. Only major project team meetings are displayed, besides these the core team had monthly skype meetings, several of which were joined by the challenge leaders, and there was extensive communication within all the challenges.

Table 2 Outreach and communication activities

Date	Media	Title	Short description and/or link to the activity
June 2015	Meeting	Kick-off meeting core team	Core team meeting discussing an action plan
September 2015	Meeting	Kick-off meeting core team and challenge leaders	Core team and challenge leaders met to discuss the action plan
March 2016	Meeting	Interim meeting core team and challenge leaders	Core team and challenge leaders met discussing progress and project planning
19-23 September 2016	Poster presentation	The 2016 ICES annual science conference	Results of the challenges were presented in poster format, there was a high interest in the overview of fisheries and Marine Protected area's in particular.
October 2016	Meeting	Interim meeting core team	Core team met discussing progress and project planning
3 November 2016	Poster presentation	NWO Dutch polar research symposium	Results of the challenges were presented in poster format, there was a high interest in the overview of fisheries and Marine Protected area's in particular.
30/31 January 2017	Meeting	Expert panel meeting 1	The experts discussed the progress and results of the project
13-14 June 2017	Meeting	Svalbard Stakeholders Workshop	Members of the Svalbard Integrated Arctic Earth Observation System (SIOS) and the SBC Arctic project team met to get acquainted and identify potential joined topics. On day two, an international workshop 'Arctic sea basin data – the Svalbard case' took place at Huset, Longyearbyen, Svalbard. This additional workshop was funded by the Svalbard Strategic Fund. The purpose of the workshop was to present the SBC Arctic project and obtain input into the project from local experts of the Svalbard science community. The goal of the workshop was to: 1. Present the initial results of the SBC Arctic project on Arctic sea basin data 2. Evaluate current Arctic marine monitoring programmes and datasets

			3. Connect existing activities in Arctic marine data utilisation 4. Identify joined knowledge gaps in marine data in the entire Arctic area and specifically the Svalbard area (relevant for Ny-Ålesund flagship programmes)
September 2017	Meeting	Final meeting core team and challenge leaders	Core team and challenge leaders met discussing activities done and view on the future
February 2018	Meeting	Final meeting core team	Core team discussing activities done and view on the future
May 2018	Meeting	Expert panel meeting 2	The experts discussed the results of the project and their view on the future
-	Website	Emodnet Data Portal	The portal and dashboard of the Sea Basin Checkpoint Arctic can be found on www.emodnet-arctic.eu. The objective of the portal was to present the results of the project, including the results of the challenges. Next to results of the challenges attention was paid to the data gaps. The overall dashboard publishes the results of the assessment reports used in the project. The quality score and adequacy of all datasets can be viewed. Furthermore, a background on the Sea Basin Checkpoints and a Report and News section provide general information on the project.



ICES Conference **NWO symposium**

Impressions of the Svalbard workshops

7. Recommendations for follow-up actions by the EU

Both the project team and an expert panel provided their view on the future of the Sea Basin Checkpoints. Suggestions were made per challenge, both for the use of challenges and the use of the data found. These can be found in the report on the Future of the Sea Basin Checkpoints and in the Expert Panel Meeting Report 2. In this chapter the overall view on the project is presented from both the project team and the expert panel.

The project team

Even though the goal of checkpoints are checks in time, a repetition of this process is recommended after three to five years' time after the closure of the current Checkpoints. All the basic systems are now in place (website and CMS) and experience has been gained on the useful methods (Data Management, Data Adequacy Assessments) to repeat the process in an efficient way. A repetition, however, will only be relevant if in the meantime data gaps have been addressed and/or different challenges are identified. Both the Web portal as main publishing tool and the Content Management System have proven easy to use, giving both structure to the output as well as the challenges, and can be used again when needed. For a new round of checkpoints, new or adapted challenges may be selected based on both the outcomes of the first challenges and new insights and needs.

We feel that the challenges have been able to identify relevant lessons learned and recommendations with regards to data availability and adequacy, as well as knowledge gaps. These may serve as valuable input for future projects, monitoring and funding activities as commissioned by the EC and member states. The Data Adequacy Assessment can be used to further enhance disclosure of data, possibilities to connect databases and sources and to stimulate cooperation between networks, countries and knowledge bases. The use and distribution of big open data are needed for an effective management of marine regions with a focus on visibility and transparency of data sets as well as on sharing and distributing. EMDnet has proven a valuable functional portal for data users and providers. This may be further enhanced, possibly in combination with EOOS. EMODnet thematic portals have proven useful functional portals for data users and providers, however because the Arctic regio have not been a focus area in the tenders the amount of available data was still minimal. This may be further enhanced by additional monitoring and data collection, as well as improved data sharing towards EMODNet, possibly in combination with EOOS.

To summarize, our final recommendation would be as follows:

1. Use the outcomes of the challenges as input for projects, monitoring and funding on the short term. Try to fill in the current urgent knowledge gaps and uncover and connect existing data.

2. Use the outcomes of the Data Adequacy Assessments to promote disclosure of data, to connect different data sources and databases, and to stimulate cooperation between networks, countries and knowledge bases.
3. Keep on using EMODnet as a functional portal for data users and providers, possibly in combination with EOOS. Keep on stimulating the use and distribution of big open data, focusing on visibility and transparency as well as on sharing and distributing.
4. Repeat the Checkpoints in three to five years after closing of the current Checkpoints. For the new round, use new or adapted challenges based on both the outcomes of the first challenges and the current scientific insights and needs. Shorten the length of the Checkpoints to get an even more specific outcome to that point in time and space.
5. Repeat this cycle.

The expert panel

The first and main recommendation of the panel is to ensure that the metadata on the datasets collected through this project remain available. The panel suggests that promoting the use of the metadata should be the main goal for the next five years. This can be done by connecting the metadata to the EMODnet network and by merging metadata sets into other sites. A review on the use of project (meta)data after five years should be used to decide on a possible repetition of the project.

Special consideration should be given to standardizations of parameters and a systematic approach to monitoring and assessment. The changing Arctic is a unique region governed by multiple countries. Setting up a monitoring standard acceptable to all parties will help ensure the usability and addition of data to the current set of databases and metadata. A start on this can be made by cooperation between several of the countries, proving the concept to convince others, or perhaps through an organisation such as the Arctic Council where all parties are organised.