RAPPORT FRA HAVFORSKNINGEN

Nr. 1-2018

ISSN 1893-4536 (online)

Detecting changes in the Arctic Ecosystem

– Long-Term Benthos Monitoring network for detecting changes in the Arctic benthic ecosystem (LTM-Benthos) 2017-2020

Jørgensen LL, Blicher M, Bluhm B, Christiansen JS, Fredriksen R, Hammeken N, Logerwell L, Ólafsdóttir SH, Roy V, Strelkova N, Sørensen J, Thangstad TH

HAVFORSKNINGSINSTITUTTET

www.hi.no

Project Report

Report:
RAPPORT FRA HAVFORSKNINGEN

No. – Year:
1-2018

Date:
09.01.2018

Title (Norwegian and English):
Registrering av endringer i det Arktiske økosystem: Det Pan-Arktiske nettverket for lang-tids overvåkning av benthos.

Detecting changes in the Arctic Ecosystem

Authors:
Jørgensen LL, Blicher M, Bluhm B, Christiansen JS, Fredriksen R, Hammeken N, Logerwell L, Ólafsdóttir SH, Roy V, Strelkova N, Sørensen J, Thangstad TH

Distribution: Open

Project no.:
15183

Assignor(s):
Danish Environmental Protection Agency at the Ministry of Environment and Food of Denmark (2017), and Nordisk Ministerråd, AG Fisk (2018-2020)

Assignor's reference:
(159)-2017-Arctic biodiversity

Program:
Barentshavet

Research group:
Økosystemprosesser

Number of pages in total:
31

Lis Lindal Jørgensen (Institute of Marine Research)

Project Leader

Martin Blicher (Greenland Institute of Nature Resources)

Project Leader

Content

1 Introduction

The LTM-Benthos workshop is financed by the Danish Environmental Protection Agency at the Ministry of Environment and Food of Denmark, as part of the project *Initiating North-Atlantic Benthos Monitoring* (INAMon) (**2017**), and by Nordisk Arbeidsgruppe for Fiskeriforskning ”AG-Fisk” through the Fisheries Cooperation of the Nordic Council of Ministers (**2018-2020**)

Main conclusions from the workshop in Copenhagen 2017:

Main purpose of this group is data exploration. For example, megafaunal community characterization, modeling of variables that influence these communities (environment, stressors, etc.)

Scaling of data matters: Depending on the objectives, required resolution of the data and analyses will vary, e.g. for managing trawl closures, fine-scale analyses are required; for understanding ecosystem change, broad-scale analyses are required.

Next steps include understanding potential outcomes and the limitations of the data analyses: identifying what management questions we can answer with existing baseline data, and what agencies/groups etc. would be users of our results.

Propose analyses and management uses of continued future monitoring, to emphasize value of long-term monitoring

How shall this report be referred:

Jørgensen LL, Blicher M, Bluhm B, Christiansen JS, Fredriksen R, Hammeken N, Logerwell L, Ólafsdóttir SH, Roy V, Strelkova N, Sørensen J, Thangstad TH (2017) Detecting changes in the Arctic Ecosystem. RAPPORT FRA HAVFORSKNINGEN nr. 1-2018, ISSN 1893-4536 (online)

2 Background

All Nordic countries are striving to ensure sustainable exploitation of their fishery resources. Traditionally this goal has been achieved by single stock management of target species.

However, in recent years there has been an increasing focus on the potential impact of commercial fisheries on the marine ecosystem, including non-target species and habitats.

Against this backdrop, the Marine Stewardship Council (MSC) has launched the MSC eco-label which is the consumers' guarantee that a fish or seafood product meets certain fisheries standards. For bottom fisheries, which are very common in Nordic countries, documentation and mitigation of the potential impact on seafloor habitat and its associated biological communities is essential for achieving MSC certification (www.MSC.org). For most Nordic nations, the data for Principle 1 (sustainable fish stocks: Fishing must be at a level that ensures it can continue indefinitely and the fish population can remain productive and healthy) for MSC is rather easily obtained, as they are executing very efficient stock assessments for most commercial stocks. The main challenge is with Principle 2 (Minimising environmental impacts: Fishing activity must be managed carefully so that other species and habitats within the ecosystem remain healthy). This is where lack of relevant data, or, perhaps lack of data presented in such way that is usable for the evaluation process, is preventing certification.

Besides regularly assessing stocks of target species themselves, there are both commercial and scientific interests in a more holistic approach to managing the ocean.

This project will explore how national **long-term monitoring** (LTM) programs, where benthic fauna is recorded as a part of the scientific fish assessment surveys, can provide relevant data for evaluating the state of the benthos and potential vulnerability toward fishery.

LTM programs have been initiated in the Nordic and other Arctic countries: 1) a joint annual Norwegian-Russian Ecosystem survey in the Barents Sea (2007-ongoing), 2) the *Initiating North Atlantic Benthos Monitoring* (INAMon) program in Greenland waters (2014-ongoing), which was granted support from the Nordic Council through the presidency project "Kortlægning af havbundens biodiversitet og sårbarhed i Arktis og Nordatlanten" (2015-ongoing), 3) a national program in Iceland waters (2015-ongoing), 4) a Multispecies Stock Assessment Surveys in Eastern Canadian Arctic waters (2004-ongoing, DFO Central and Arctic region), and 5) a NOAA ground fish assessment program (1982 and ongoing) (see figures below). There are also plans for a national program in the waters of the Faroe Islands (to be started in 2019). Nations also aim to collaborate on data integration and analysis methods from Arctic areas without extensive fisheries, such as Alaska and East Greenland where trawled benthos monitoring is conducted as part of scientific and/or oil- and gas-driven surveys.

Therefore, the national LTM programs and projects are largely comparable, as they have adopted the same approach by using national, already existing scientific commercial stock assessment surveys with benthic experts on-board to identify the bycatch caught together with the target species. This combined approach has shown to be a **cost- and time efficient way** to provide added information and value to national fish and seafood assessment programs (Jørgensen et al. 2015a).

Besides being relevant in relation to exploitation of fish and other seafood, this international collaboration on long-term benthos monitoring will:

- produce valuable information in relation to other environmental issues, such as off-shore oil exploration/exploitation, climate change impacts, invasive species etc.

- establish a research network that ensures a unique geographical coverage.
- ensure a standardized approach that allows extensive descriptions of megabenthic communities taken by fish trawls.
- facilitate spatially integrated understanding of the faunal composition and the vulnerability of benthic habitat and fauna to bottom trawling (Jørgensen et al. 2015b), climate change and other possible stressors.
- ensure coherent use of taxonomical level

Some species are already recognized as vulnerable to physical disturbance such as bottom trawling, while the effect of other environmental stressors on the remaining parts of the benthic community is *poorly* described (e.g. acidification).

This necessitates that benthos experts and data-holders from each nation meet at workshops for discussion, data-work and production of integrated maps and figures. During these workshops, data will be processed in accordance to pre-defined scientific questions, such as “identification and distribution of benthos easily taken by bottom trawl, expected to be impacted by climate warming, etc.”, and the results shall be plotted on common maps.

The overall goal of the LTM-Benthos network is to:

1. Identify the main **faunal community compositions**, based primarily on a series of annual by-catch data from national fisheries trawl surveys.
2. Identify communities or species **vulnerable** to: i) trawling, ii) climate change, and other identified stressors.
3. Explore ways to homogenize and combine national results to present Pan-Arctic maps showing seabed hotspots and vulnerable areas in the Nordic countries, Russia, Canada, and the USA.
4. Identify how we **communicate the results effectively to stakeholders, such as the Marine Stewardship Council (MSC), the Arctic Council, ICES, and national management authorities**.

3 Updated milestones

- 2017: Data preparation/standardization (CPH, Nov)
- 2018: 1) Species standardization and national taxonomic exchange (Seattle, Washington January), 2) Community data and analysis (Iceland, Reykjavik, November: responsible **Steinunn Hilma Ólafsdóttir and Lis Lindal Jørgensen**).
- 2019: Production of standardized maps to be communicated to stakeholders.
- 2020: Publish in ICES JOURNAL OF MARINE SCIENCE. Communication and outreach with invited stakeholders (need to be decided).

4 Participants on the workshop and ocean areas covered

First and last name		Coming from	Representing national data from:
Lis Lindal Jørgensen	lis.lindal.joergensen@imr.no	Norway	Barents Sea (with Natalia)
Martin Blicher	mabl@natur.gl	Greenland	Greenland Seas
Nanette Hammeken	Nanette@natur.gl	Greenland	Greenland Seas
Steinunn Hilma Ólafsdóttir	steinunn.hilma.olafsdottir@hafogvatn.is	Iceland	Iceland Seas
Jan Sørensen	jans@savn.fo	Faroes	Faroe Seas
Virginie Roy	Virginie.Roy@dfo-mpo.gc.ca)	Canada	Eastern Canadian Arctic (Baffin Bay, Davis Strait, Hudson Strait
Bodil Bluhm	bodil.bluhm@uit.no	Norway	NE Greenland and Chukchi Sea
Jørgen Schou Christiansen	jorgen.s.christiansen@uit.no	Norway	NE Greenland
Rosalyn Fredriksen (student)	rfr012@post.uit.no	Norway	NE Greenland
Libby Logerwell	libby.logerwell@noaa.gov	USA	Bering Sea, Chukchi Sea and Beaufort Sea
Natalia Strelkova	n_anisim@pinro.ru	Russia	Barents Sea (with Lis)
Trude Thangstad	trude.thangstad@imr.no	Norway	GIS
Tom Christensen	toch@bios.au.dk	Denmark	CBMP_marine (Arctic Council)
Simon Jennings	simon.jennings@ices.dk	Denmark	ICES
Gunnstein Bakke	Gunnstein.Bakke@fiskeridir.no	Norway	Directorate of fisheries
Susse Wegeberg	sw@bios.au.dk	Denmark	Danish Center for Energy and Environment

5 Data Policy

The LTM-Benthos project will consist of a series of annual workshops where national representatives will work on their own data to produce a common Pan-Arctic master station database.

To maintain a predictable and secure data policy, the group agreed that no national raw data (i.e. species level) will leave the data owners. Geo-referenced processed station-data will be compiled in a common “Master Station-data” file for production of Pan-Arctic maps/figures/tables made by TT/LLJ.

Because of national limitations on data sharing, only LLJ will have the “Master Station-data” file.

Until agreed differently, LLJ will *not* distribute the Master file, and will only use this file in production of common Pan-arctic maps/figures/tables agreed to by the group.

6 Agenda

Tuesday 14.11

What are the project and why are we here. Data-policy (LLJ/MB)
All: short presentation on national program (**max 3 slides**)
The Barents Sea temperature sensitive and bottom trawl vulnerable mega-faunal communities (LLJ)
How to extract PanArctic results using National "traits" (LLJ)
All: Work with own national data.

Wednesday 15.11

All: Work with national data -> First metadata given to GIS-responsible (TT) to create PanArctic map on:

- Station temperature
- Station depth
- Station species richness
- Station biomass
- Station count
- Mean station temperature sensitivity and variance
- Mean station trawl vulnerability

15-17 Summing up, writing main conclusions including: way forward, possible data/map work, what to do next year, next network meeting, inclusion of fish data, more..?

Thursday 16-11: Stakeholder day

09:00-09:15 Welcome and explanation of the project by Lis L. Jørgensen and Martin Blicher
09:15-09:45 Presentation of benthic monitoring plans by each country (max 3 slides per nation)
09:45-10 The Barents Sea multiple impact study on benthos (LLJ/NA)
10-10:20 What did we achieve on this workshop (Pan-Arctic Maps) (all)

10:20-10:40 "Arctic council – Conservation of Arctic Flora and Fauna: Mandate, monitoring, assessments and communication" (Tom Christensen)
10:40-11 ICES – Assessing sensitivity of seabed habitats and species (Simon Jennings)
11-11:20 – Norwegian Fishery authorities – how to move from monitoring to management measures (Gunnstein Bakke)

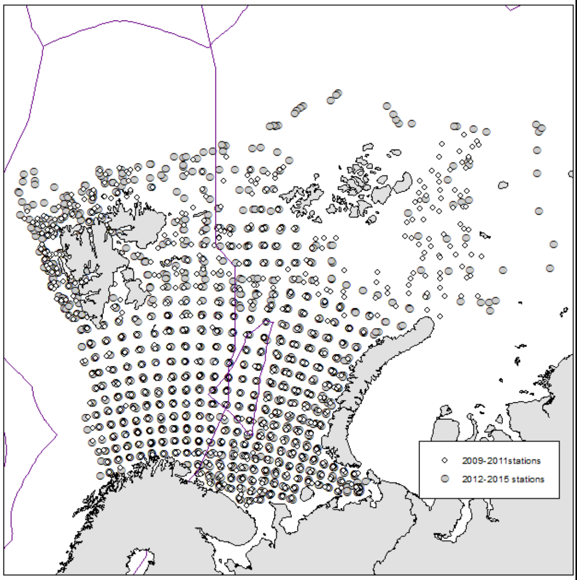
11:20-12 – Questions and discussion
13-14 – Discussion: what is a vulnerable species, how to proceed MSC, where to bring future monitoring and benthic science. How do the LTM-benthos work in the 3 years to come.
14-16 – Summing up, and conclusion

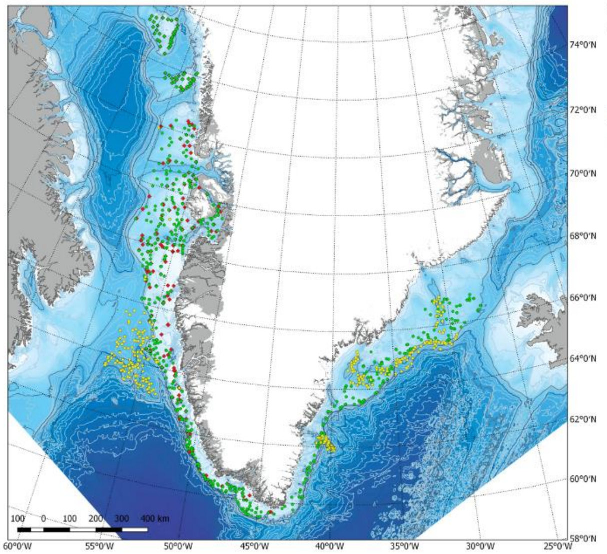
Friday 17.11

Drafting report from workshop and travel back home.

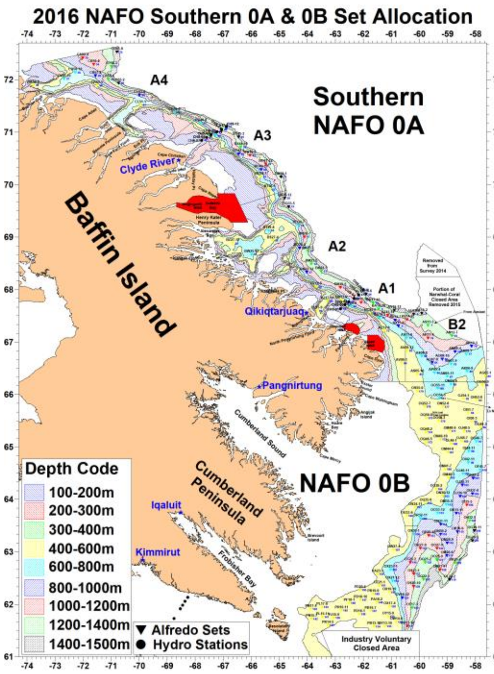
7 National programs

The workshop, consisting of Norwegian, Russian, Greenlandic, Icelandic, Faroese, Canadian, and American scientists, compiled a “master station-data” file for fish-trawled benthic fauna (i.e. megafauna) from more than 10,000 stations (figure 1, table 1 and appendix 1).

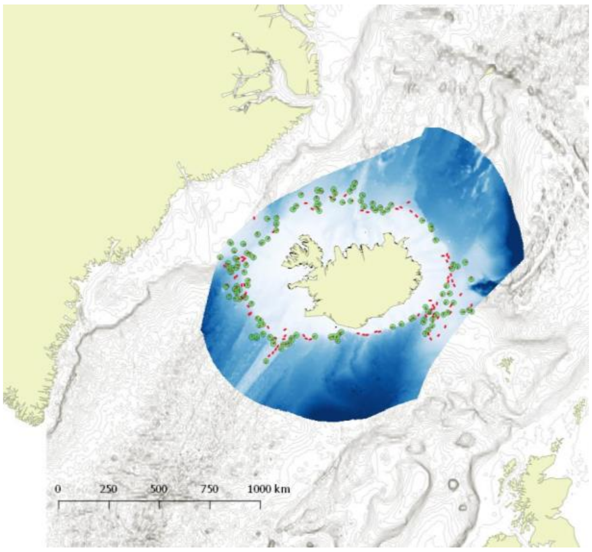




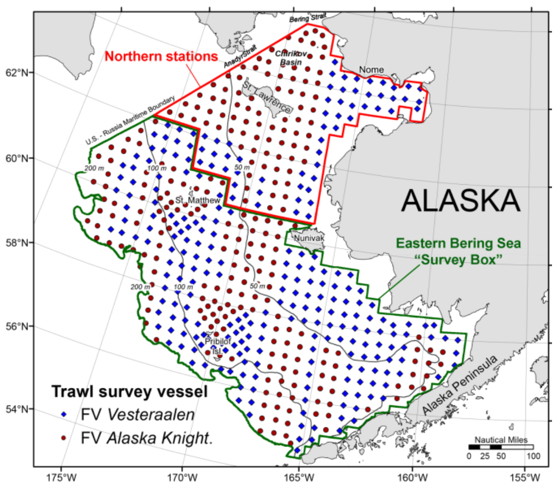
Region: Barents Sea. **Data sampling:** 2009-2015. **Gear type:** Campelen Trawl. **Stations covered:** 2280 **Responsible:** Lis Lindal Jørgensen (IMR) and Natalia Anisimova (PINRO)	**Region:** Greenland south. **Data sampling:** 2015-16 **Gear types:** Cosmos, Alfredo, Beam. **Stations covered:** c. 1100 **Responsible:** Martin Blicher and Nanette Hammeken (GINR)



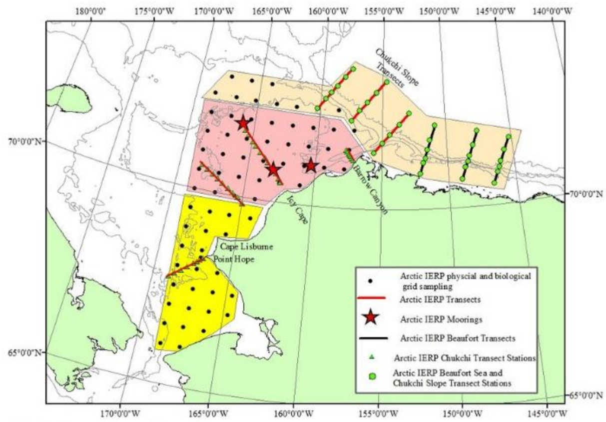
Region: Eastern Canadian Arctic.
Data sampling: Year 2016 shown (but data cover 2004-2016, see Appendix 1)
Gear type: Alfredo trawl shown
Number of stations: 4,375 (2004-2016, see Appendix 1)
Responsible: Virginie Roy and Kevin Hedges (DFO)



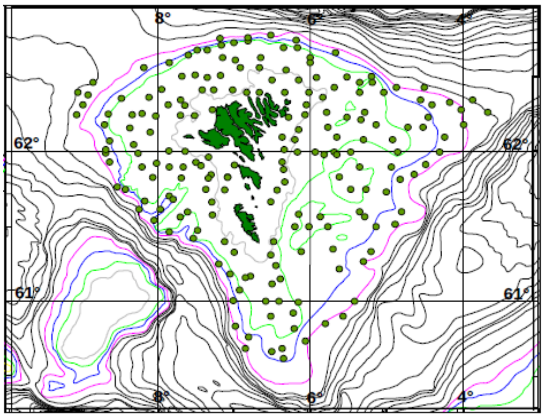
Region: Iceland.
Data sampling: 2015-2016
Gear type: Golden top.
Stations covered: 151
Responsible: Steinunn Hilma Ólafsdóttir (MFRI) and Guðmundur Guðmundsson (IINH)

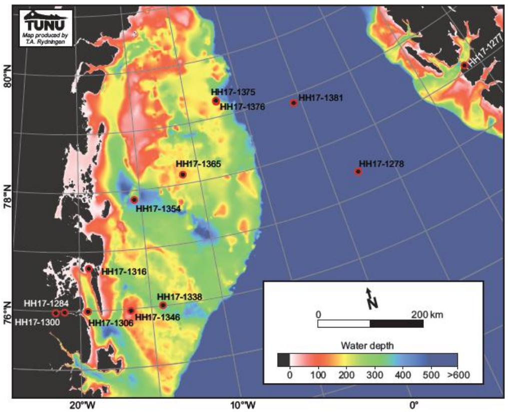


Region: Bering Sea SE:
Data sampling: Year 1982-present.
Gear type: 83-112 Eastern Otter Trawl.
Stations covered: 376.
Region: Bering Sea N:
Data sampling: 2010, 2017.
Gear type: 83-112 Eastern Otter Trawl.
Stations covered: 144
Responsible: Libby Logerwell (NOAA)



Region: Alaska Seas
Data sampling: Year 2017, 2019
Gear type: 3-m Plumb Staff Beam Trawl.
Stations covered: 73.
Responsible: Libby Logerwell (NOAA)





Region: The Faroe Islands: No benthos megafauna data from fish-trawl.
Responsible: Jan Sørensen.

Region: Northeast Greenland.
Gear type: Campelen trawl and Agassiz trawl
Data sampling: 2015 and 2017
Stations covered: 32
Responsible: Jørgen S. Christiansen/Bodil Bluhm and master student Rosalyn Fredriksen (UiT)

Table 1. Summary of the trawl gear type used on national fisheries assessment surveys (Appendix table 2).

	Gear type and target species						
Nation/Area	**Agassiz**	**Alfredo**	**Beam trawl**	**Campelen**	**Cosmos**	**Otter trawl**	**Golden Top**
Canada		Greenland Halibut		Northern and Striped shrimps	Northern and Striped shrimps		
Greenland (GINR)		X	x		x		
NE Greenland (TUNU)	x			x			
Iceland							x
Norway/Russia				Deep sea shrimp			
US			x			x	

A vast amount of data is available for monitoring purposes already, as DFO (Fisheries and Oceans Canada), NOAA (USA) and IMR (Norway)/PINRO (Russia) have been recording benthos bycatch on national fisheries surveys for several years, while Greenland and Iceland have just started, and the Faroe Islands are in the process of starting up (Appendix 1). However, gear type, protocols and taxonomic expertise vary between countries. Therefore, during this workshop, we explored ways of treating data that could facilitate a Pan-Arctic comparison without or with minimized bias by sampling gear type and taxonomic expertise.

8 Standardization of data

The network agreed to produce Pan-Arctic maps based on “species/taxon number”, “abundance of individuals” and “biomass” per trawl haul, based on national data from the specified trawl types. “Abundance” and “biomass” were cube-root transformed, and “species number”, “abundance” and “biomass” per trawl haul for each trawl type were standardized by extracting a normalized value from the distribution of species data (x) characterized by the mean study-area species number ($\bar{x}$) and the study-area standard deviation (Stdev): ($Std = \frac{(\mathrm{x}-\bar{x})}{\mathrm{Stdev}}$)

Then the national standardized station-data was plotted on a gridded Pan-Arctic map. Standardized data from multiple survey years was averaged within each grid cell. The maps show mean and standard deviation of several years standardized values per grid cell (size 0.5° long x 1° lat) (Figures 1-4).

9 Preliminary Pan-Arctic maps

9.1 Metadata

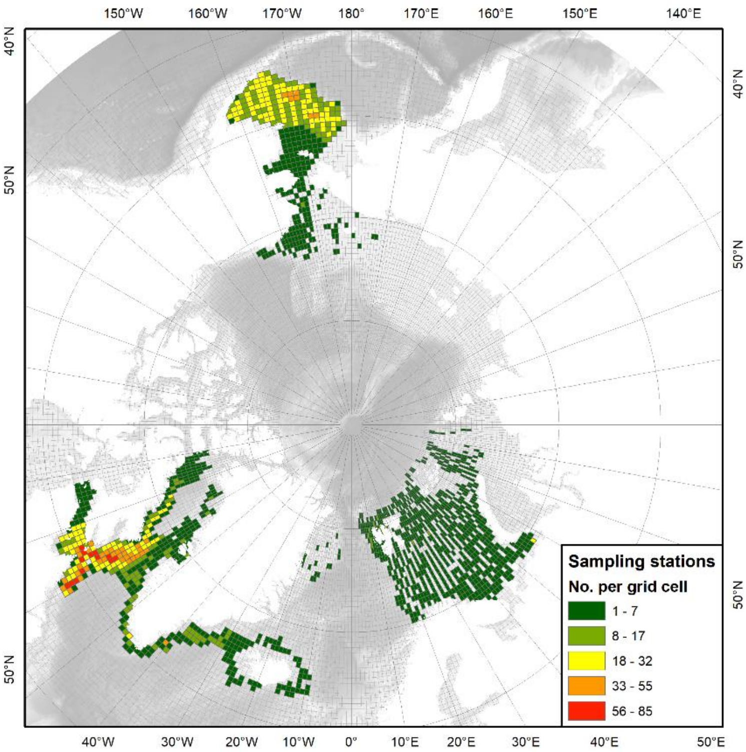


Figure 1. *Counts per grid are the number of* ***station samples*** *summed over all survey years.*

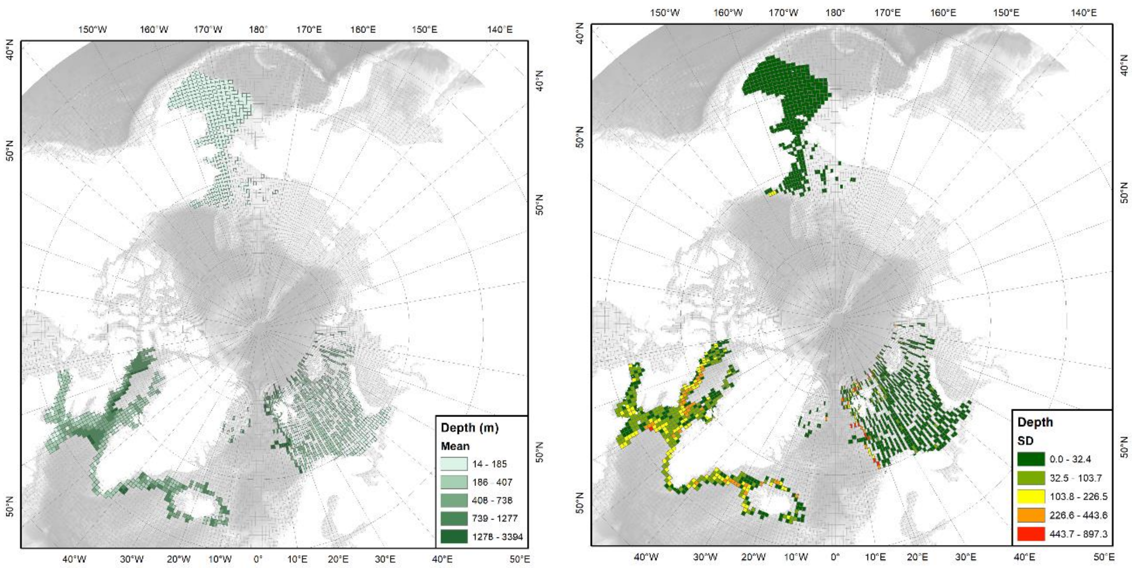


Figure 2. *Mean (left) and standard deviation (right) of bottom depth at the sampling stations represented in each grid cell (meters).*

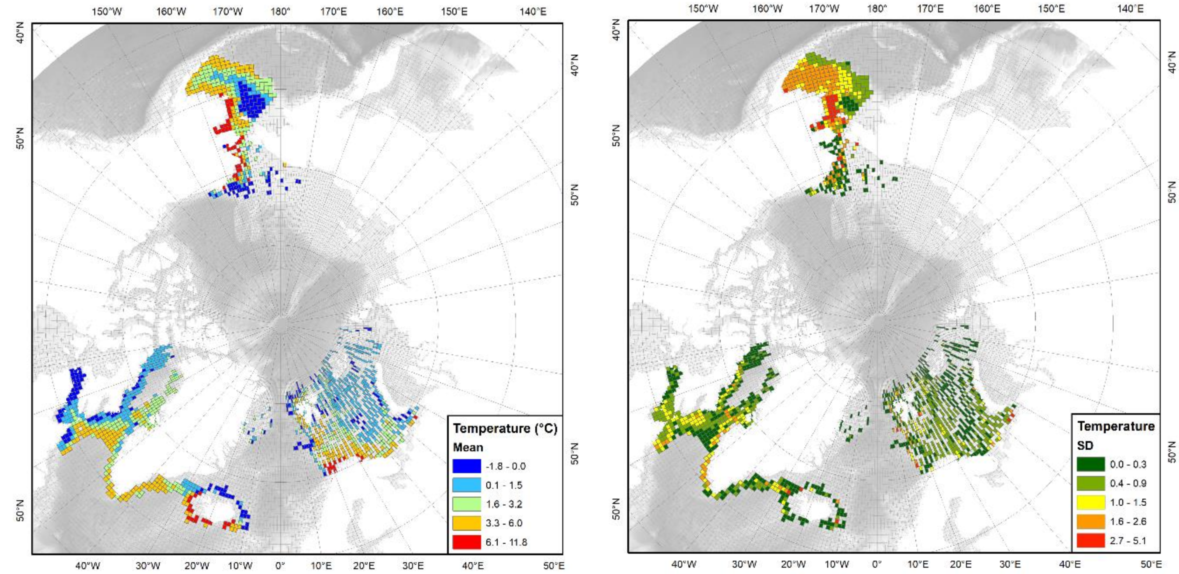


Figure 3. *Mean (left) and standard deviation (right) of bottom temperature at the sampling stations represented in each grid cell (°C).*

9.2 Faunistic data

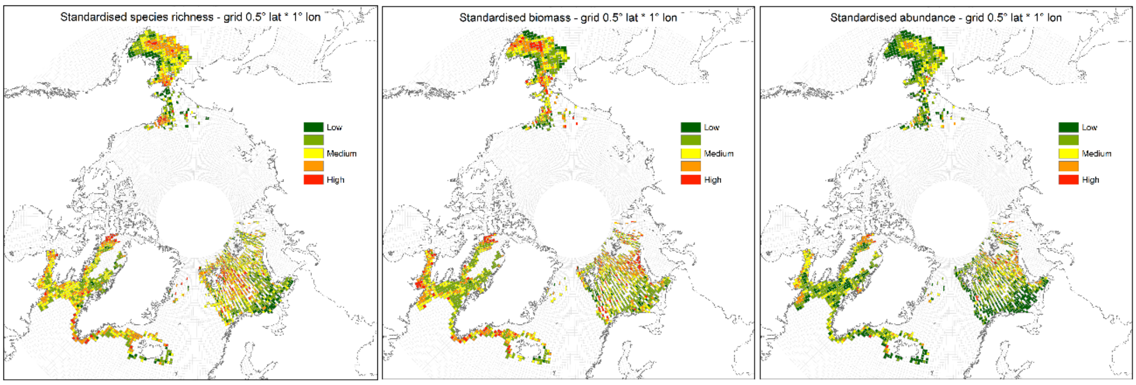


Figure 4a. *Mean species richness, biomass and abundance per grid cell of standardized megafauna data.*

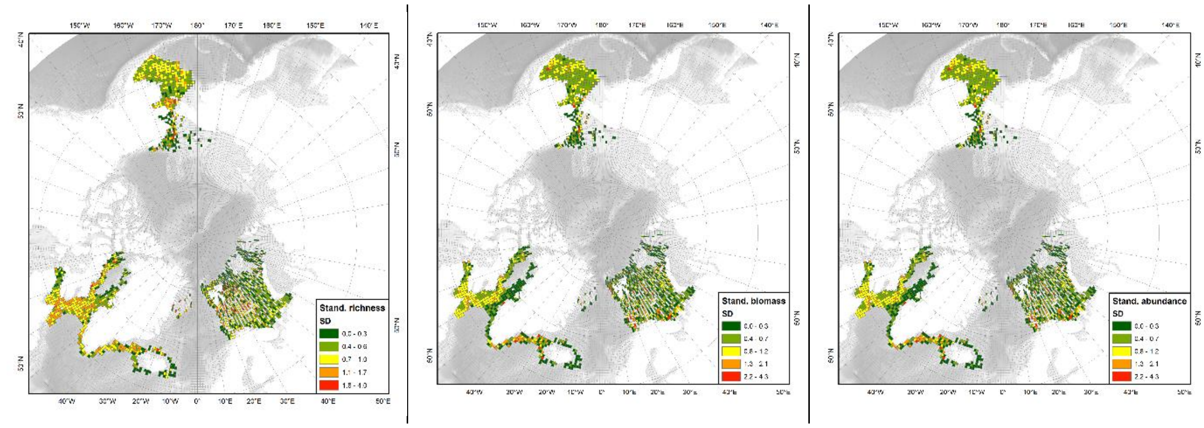


Figure 4b. *Standard deviation of species richness, biomass and abundance per grid cell of standardized megafauna data.*

The results from the final maps will allow us to expand and further develop on one of the project goals (vulnerable need to be defined on next ws):

- 3) Explore ways to standardize and combine national results to present a **Pan-Arctic map showing seabed hotspots and vulnerable areas** in the Nordic countries, Russia, USA and Canada.

10 Seabed hotspots and vulnerable areas

10.1 Seabed morphology (fig 2)

10.1.1 Eastern Canadian Arctic (Baffin Bay, Davis Strait, Hudson Strait)

Baffin Bay lies between Canada and Greenland and is characterized by a deep basin level in the central western portion (nearly 2,500 m). This basin is flanked on the east by a continuous series of banks shallower than 400 m which extend about 400 km westward from the western Greenland coast. The basin's western slope is more abrupt and abuts a relatively narrow shelf shallower than 200 m along the Baffin Island coast. Baffin Bay is bounded on the south by the sill of Davis Strait (300 km wide and 1,000 m deep) which separates it from the Labrador Sea. Hudson Strait is a narrow (100 km) and long (400 km) channel with a mean depth of 300 m, connecting the Hudson Bay to the Labrador Sea.

References

Hamilton, J.M., and Y. Wu. 2013. Synopsis and trends in the physical environment of Baffin Bay and Davis Strait. Can. Tech. Rep. Hydrogr. Ocean Sci. 282: VI + 39 p.

Muench, R. D. 1970. The physical oceanography of the northern Baffin Bay region. PhD thesis, University of Washington.

Straneo, F., and F. Saucier. 2008. The outflow from Hudson Strait and its contribution to the Labrador Current. Deep Sea Research Part I: Oceanographic Research Papers 55: 926-946.

10.1.2 Northeast Greenland

The seabed morphology of the Northeast Greenland fjords and shelf area is strongly heterogeneous and comprises several basins, banks and troughs, which may be considered submerged extensions of the fjords. The geomorphological features date back to the last glacial maximum (Laberg et al., 2017) and, in addition to the ongoing ice scouring, create a diverse and dynamic habitat for benthic organisms. The Northeast Greenland shelf is at its broadest between longitudes 20- 5ºW and latitudes 74- 81ºN, where it extends more than 300 km from the coastline (Arndt et al., 2015). The region is covered by fast ice in the fjords and sea ice on the shelf for most of the year (Christiansen 2012), but has in the recent years been more accessible for scientific surveys and commercial exploitation due to loss of sea ice (Stroeve et al., 2012; Christiansen 2017).

References

Arndt, J. E., Jokat, W., Dorschel, B., Myklebust, R., Dowdeswell, J. A., & Evans, J. (2015). A new bathymetry of the Northeast Greenland continental shelf: Constraints on glacial and other processes. *Geochemistry, Geophysics, Geosystems, 16*(10), 3733-3753.

Christiansen, J.S. (2012). The TUNU-Programme: Euro-Arctic marine fishes — diversity and adaptation. In: di Prisco G, Verde C (eds) Adaptation and evolution in marine environments, vol. 1, From pole to pole. Springer, Berlin Heidelberg, pp 35–50. doi:10.1007/978-3-642-27352-0_3

Christiansen. J.S. (2017). No future for Euro-Arctic ocean fishes? *Marine Ecology Progress Series* 575: 217–227

Laberg, J. S., Forwick, M., & Husum, K. (2017). New geophysical evidence for a revised maximum position of part of the NE sector of the Greenland ice sheet during the last glacial maximum. *Arktos, 3*(1),

Stroeve, J. C., Serreze, M. C., Holland, M. M., Kay, J. E., Malanik, J., & Barrett, A. P. (2012). The Arctic's rapidly shrinking sea ice cover: a research synthesis. *Climatic Change*, *110*(3), 1005-1027.

10.1.3 West-Greenland

The coastline in Greenland is traversed by numerous fjords, many of them acting as direct links between the inland ice sheet and the ocean. Moreover, many islands are scattered directly off the coast resulting in a variety of shallow benthic habitats. The continental shelf often extends >100 km offshore; most narrow in the southern part where mixed and hard substrates are frequent, and broadening in the northern parts with more soft sediments. A mix of shallow banks (<50 m) and deep troughs (>300 m) results in a highly complex bathymetry and surface geology in the shelf area. Iceberg scouring marks are found down to several hundred meters depth. The continental slope continues down to >2000 meters depths. Even at these depths the seabed in South Greenland still consists of mixed substrates due to strong currents. Other deep areas without such strong water movement consist of homogenous soft substrate.

10.1.4 Iceland

Iceland is a volcanic island situated on the intersection between the Mid-Atlantic and the Greenland-Iceland-Scotland (GISR) ridges. The GISR connects the continental shelves of eastern Greenland and Iceland, and of Iceland and the Faroes plateau.

The shelf around Iceland is relatively flat. It extends 15-150 km offshore; most narrow in the southern part and is most broad in the western part. The shelf break is also most steep in the southern continental shelf and more inclining in the west and north. The shelf is intersected by several glacially eroded troughs dominated by sedimentation of fine materials. In contrast, the Mid-Atlantic ridge, divided into the Reykjanes ridge in the southwest and on the Kolbeinsey Ridge on the north, is characterized by volcanic activity, faults, craters and pillow lavas, with geothermal vents in some locations. Recent efforts in high-resolution bathymetry mapping by MFRI shows in detail how iceberg plough marks, moraines and pockmarks appear on the shelf, and slides and slide scars, gullies and submarine channels on the shelf slope.

10.1.5 Faroe Islands

The Faroe Islands (Faroes) is an archipelago on the Greenland-Iceland-Scotland (GISR) ridges consisting of 18 islands about halfway between Norway and Iceland. The Faroese plateau is heavily eroded by glacial ice and by post-glacial wave action, wind and run-off (Waagstein and Rasmussen, 1975; Rasmussen and Noe-Nygaard, 1990) and has a triangular form which gradually falls off and reaches 400 m depth about 100 km from the coast. It is still to be recognized along the 1,000 m depth contour, although drawn somewhat towards the northeast, and broken in some places, viz. around 500 m depth to the west where the upper slope is continuous with the Faroe-Iceland ridge, and between 800 and 900 m where the mid-slope contours connect to the Faroe Bank southwest of the Faroes. Very steep slopes are found in the north towards the Norwegian Basin with depths of more than 3,000 m, in the east in parts of the Faroe-Shetland Channel down to about 1,500 m, and in the southwest in the Faroe Bank Channel down to 800 m (Simonsen et al 2002, The IOS bathymetric chart; Westerberg, 90/91, bathymetric chart redrawn for BIOFAR).

The seabed is mostly a mixed gravelly bottom sometimes with rocky outcrops, and better sorted bottoms with decreasing grain size at larger depths. A substantial component on all bottoms is debris deposited during the last ice age. On the plateau shell fragments of many sizes are abundant, sometimes giving the bottom the character of shell-gravel or shell-sand. Soft bottoms are found in the fjords and in a few depressions on the outer shelf (Waagstein and Rasmussen 1975, Tendal et al. 2004).

References
Rasmussen, J. and Noe-Nygaard, A. 1990. *The origin of the Faroe Islands in text, pictures and maps*. Geological Survey of Denmark. Special issue.
Simonsen, K. et al. 2002. New Bathymetry for the. Faroe Shelf. Faculty of Science and Technology University of the Faroe Islands. NVDRit 2002:7, 9 pp.
Tendal, O. S. et al. 2004. The BIOFAR 1 programme: background, accomplishment, and some outcome from inter-Nordic benthos investigations around the Faroe Islands (NE Atlantic). Biofar Porceedings 2004: 9-20.
Waagstein, R. and Rasmussen, J. 1975. Glacial erratics from the sea floor southeast of the Faroe Islands and the limit of glaciation. *Fróðskaparrit* 23: 101-119.
Westerberg, H. 1990/91? *Benthic temperatures in the Faroe area*. Department of Oceanography, University of Gothenburg. Report no 51.19 pp

10.1.6 The Barents Sea

The Barents Sea is a continental shelf sea with an average depth of 230 m and with several bank areas (50–200 m), and basins and trenches occur down to a maximum depth of about 500 m. The bottom sediments change with water depth and relief (slope) of the seabed, with finer mud predominating in deeper areas that experience slow bottom-water movement, and sandy to stony substrates common on shallower banks with stronger currents.

10.1.7 Bering, Chukchi and Beaufort Seas

The seasonally ice-covered Bering and Chukchi Sea shelves are among the largest continental shelves in the world, average water depth is 50 m. In contrast, the Beaufort Sea has a relatively narrow shelf, quickly dropping to depths greater than 1000 m less than 80 km from shore. The Chukchi Sea shelf is marked by several shoals and canyons: Herald Canyon and Herald Shoal in the Western-Central Chukchi Sea; and Hanna Shoal and Barrow Canyon in the Eastern Chukchi. The Bering Sea has some of the largest submarine canyons in the world, namely the Bering, Pribilof, Zhemchug, Pervenets and Navarin canyons, which are on the eastern Bering Sea continental shelf break.

10.2 Main Pan-Arctic ocean water masses (fig 3)

10.2.1 Eastern Canadian Arctic (Baffin Bay, Davis Strait, Hudson Strait)

Baffin Bay is a semi-enclosed basin bordered by the Eastern Canadian Arctic and West Greenland. Arctic Ocean water enters Baffin Bay mainly through three passages at Nares Strait, Jones Sound, and Lancaster Sound. These cold, fresh northern inflows travel southward on the western portion of Baffin Bay as the Baffin Island Current, eventually exiting via Davis Strait. A branch of the Baffin Island Current flows into the northern Hudson Strait, where it affects the southern Baffin Island Shelf. A seaward branch of the Baffin Island Current mixes with water flowing out of Hudson Strait and reaches the Labrador Shelf, forming the Labrador Current. Warm, saline water from the North Atlantic, mostly made of waters originating from the Irminger and East Greenland Currents, flows north through Davis Strait then along the eastern side of Baffin Bay as the West Greenland Current.

References

Hamilton, J.M., and Y. Wu. 2013. Synopsis and trends in the physical environment of Baffin Bay and Davis Strait. Can. Tech. Rep. Hydrogr. Ocean Sci. 282: VI + 39 p.

Stewart, P. L., P. Pocklington, and R. A. Cunjak. 1985. Distribution, Abundance and Diversity of Benthic Macroinvertebrates on the Canadian continental shelf and Slope of Southern Davis Strait and Ungava Bay. Arctic 38: 281-291.

Zweng, M. M., and A. Münchow. 2006. Warming and freshening of Baffin Bay, 1916–2003. Journal of Geophysical Research: Oceans 111: C07016.

10.2.2 Northeast Greenland

The Northeast Greenland shelf biota is primarily subjected to the outflow of subzero waters from the Arctic Ocean proper via the Fram Strait on the west, i.e. the East Greenland Current (EGC) (Michel et al., 2015). However, Atlantic water masses stemming from the West Spitzbergen Current (WSC, core temperature >2°C) east in the Fram Strait may also penetrate into the shelf area via the Return Atlantic Current (RAC) (Hopkins, 1991; Christiansen et al., 2016; Håvik et al., 2017).

References

Christiansen, J.S., Bonsdorff, E., Byrkjedal, I., Fevolden, S.E. and others (2016). Novel biodiversity baselines outpace models of fish distribution in Arctic waters. Sci Nat 103: 8

Hopkins, T.S. (1991). The GIN Sea – A synthesis of its physical oceanography and literature review 1972 – 1985. *Earth – Science Reviews, 30,* p. 175 – 318.

Håvik, L., Pickart, R. S., Våge, K., Torres, D., Thurnherr, A. M., Beszczynska-Möller, A., … & von Appen, W. J. (2017). Evolution of the East Greenland Current from Fram Strait to Denmark Strait: synoptic measurements from summer 2012. *Journal of Geophysical Research: Oceans, 122*(3), 1974-1994.

Michel, C., Hamilton, J., Hansen, E., Barber, E., Reigstad, M., Iacozza, Seuthe, L., Niemi, A. (2015). Arctic Ocean outflow shelves in the changing Arctic: A review and perspectives. *Progress in Oceanography.* 139, p. 66 – 88.

10.2.3 West-Greenland

The relatively warm, saline Atlantic water that enters the North Atlantic, Barents Sea and Arctic Ocean interacts with the atmosphere to form various masses of waters in the area around Greenland. Three main hydrographic regions are the Greenland Sea, the Irminger Sea and West Greenland. Shelf waters in the Greenland Sea are dominated by Polar water, forming the East Greenland current. Further off-shore is a mix of Atlantic water and Arctic intermediate water. Bottom water on the slope and basin are formed by the cooling and subsequent formation of sea ice during winter. The East Greenland current continues southward to the Irminger Sea where it is mixed with the Irminger water, which is a mix of Atlantic water and water masses that are derived locally by winter cooling and sinking. During its movement from East to West Greenland the characteristics of the Irminger water continue to change due to mixing with other water masses forming the West Greenland current, which is gradually cooled during the northward flow. Sub-Atlantic water is the major component of the warm saline water found along the fishing banks of West Greenland deeper than c. 200 m depth.

10.2.4 Iceland

Oceanography and near-bottom temperatures of the southern and western shelf and basins are markedly different. They are influenced by warm and saline waters of the North Atlantic Current (NAC) in the south, and the Arctic and Polar waters in the north The warm Irminger Current (IC), which is a branch of the North Atlantic Current (NAC), flows northward off the south and western coasts of Iceland, and meets the cold East Greenland Current (EGC) that flows from the north along the east coast of Greenland and the Denmark Strait. A mixture of the IC and EGC heads along the north east coasts forming the East Iceland Current (EIC). Near bottom temperatures on the deep basins are strongly influenced by the presence of the Greenland-Iceland-Scotland (GISR) ridge, which constitutes a barrier that separates the cold water of the Arctic and Nordic seas, from the relatively warmer waters of the North Atlantic. Average minimum near-bottom temperatures in the basin south of Iceland are around 4°C, and in the deep north and east are below 1.5°C.

10.2.5 Faroe Islands

The Faroe shelf and upper slope is influenced mainly by south coming warm Atlantic water to a depth of about 500 m. On the northern and eastern side of the Faroes there is an admixture of more cool East Icelandic water roughly around 400-600 m depth. On the shallower part of the plateau the Atlantic water is modified because of retention by a residual current. At depths from roughly 600 m downwards the area is dominated by cold water from the Norwegian Sea flowing southwards through the Faroe-Shetland Channel, turning west south of the Faroes and running northwest through the Faroe Bank Channel and then spreading out westwards south of the Faroe-Iceland Ridge. On the shelf bottom temperatures are fluctuating around 8° C and then gradually decrease to < 0° C at about 600 m depth (Westerberg 1990, Hansen 2000, Tendal et al. 2004).

References

Hansen, B. 2000. Havið. Føroya skúlabókagrunnur. 232 pp.

Tendal, O. S. et al. 2004. The BIOFAR 1 programme: background, accomplishment, and some outcome from inter-Nordic benthos investigations around the Faroe Islands (NE Atlantic). Biofar Porceedings 2004: 9-20.

Westerberg, H. 1990/91? *Benthic temperatures in the Faroe area*. Department of Oceanography, University of Gothenburg. Report no 51.19 pp

10.2.6 The Barents Sea

In the Barents Sea, the warm Atlantic and coastal waters flow into the southwestern part and keep the southern Barents Sea relatively warm and ice free. Colder Arctic Water dominates in the northern Barents Sea and these areas are seasonally ice covered. The border area between the Atlantic and Arctic water masses forms the oceanographic Polar Front, however, branches of Atlantic water flow northwards below the Arctic water. Atlantic water also enters the northern Barents Sea from the north in deeper areas between Svalbard and Franz Josef Land.

10.2.7 Bering, Chukchi and Beaufort Seas

During summer, the Southeastern Bering Sea shelf waters are differentiated into 3 domains (inner, middle and outer) separated by oceanographic fronts associated with the 50, 100 and 200 m isobaths, respectively (Hunt et al. 200). In many respects, the Northern Bering Sea is more closely connected in hydrographic characteristics to the Chukchi Sea to its north than to the southern Bering Sea. An

Arctic–subarctic temperature front separates the northern and southern sectors of the Bering Sea (Grebmeier et al. 2006).

The key water mass types of the Northern Bering – Chukchi Sea region are defined primarily by seasonally varying salinity in the spring and summer, with more saline, nutrient-rich Anadyr Water (AW) transiting northward on the western side of the northern Bering and Chukchi Seas. Fresher, more nutrient-limited Alaska Coastal Water (ACW) flows northward on the eastern side of the northern Bering and Chukchi Seas. South of Bering Strait, in the open water season, a third water mass of intermediate salinity, Bering Shelf Water (BSW), lies between AW and ACW. As these waters flow north through Bering Strait, the AW and BSW mix to form a modified Bering Sea Water, called Bering Shelf-Anadyr Water (BSAW) (Grebmeier et al. 2006).

Alaskan Beaufort Sea water properties are known to be controlled by the annual freeze–thaw cycle and inflows from the oceanic and coastal boundaries (Weingartner et al. 2005). Cross-shelf differences in water column properties are probably quite large. In summer and fall, these gradients are established by river runoff, ice melt, and shelfbreak processes, while in winter, the shelfbreak processes and the landfast/pack ice boundary likely lead to spatial heterogeneity (Pickart 2004).

References

Grebmeier, J.M., Cooper, L.W., Feder, H.M., and Sirenko, B.I. 2006. Ecosystem dynamics of the Pacific-influenced Northern Bering and Chukchi Seas in the Amerasian Arctic. Prog. Oceanogr. **71**: 331–361. doi:10.1016/j.pocean.2006.10.001.

Hunt, G.L.J., Stabeno, P., Walters, G., Sinclair, E., Brodeur, R., Napp, J., and Bond, N.A. 2002. Climate change and control of the southeastern Bering Sea pelagic ecosystem. Deep. Res. II **49**: 5821–5853.

Pickart, R.S. 2004. Shelfbreak circulation in the Alaskan Beaufort Sea: mean structure and variability. J. Geophyisical Res. **109**: 1–14.

Weingartner, T., Okkonen, S.R., and Danielson, S.L. 2005. Circulation and Water Property Variations in the Near shore Alaskan Beaufort Sea, Final Report. *In* OCS Study MMS.

10.3 Main Pan-Arctic faunistic baseline patterns (fig 4):

Areas with high species richness, and/or abundance and/or biomass can be considered benthic “hotspots”. Such “hotspots” can include benthic species who might create complex biogenic structures attracting other species, in turn increasing the diversity.

Areas with both high species richness, abundance and biomass (benthic “hotspots”) are tentatively identified in the SE Bering Sea, Northern Bering Sea, Baffin Bay, northeastern Barents Sea and the area between Greenland and Iceland (Figures 4a and 4b). This need to be verified when figures are finish.

11 Further use of data

During the workshop, we discussed the possibilities and limitations of benthos trawl-data. We agreed that the approach is considered semi-quantitative (e.g. only indicating large or small catches rather than given an exact measure on what was present on the seabed) because fish-trawl equipped with rock hopper gear can jump on the seafloor, smaller animals are sieved out through the mesh, but also due to the difficulty in resolving certain taxonomic groups. We therefore focus on documenting large-scale patterns and long-term trends in key components of the benthic community identified annually through a standardized sampling method. The LTM-Benthos network will continue to explore the available data to further identify key parameters for such monitoring purposes.

Suggested further Pan-Arctic analyses

- Identify and map Vulnerable Marine Ecosystem (VME) megafauna indicators
- Identify and map invasive species
- Investigate and map structures of the megafauna community (abundance, functions, groups, morphology, etc.)
- Identify areas of interest (such as hotspots in species richness, functional and ecological significant areas/EBSA, VME indicators, and invasive species) that should be investigated further.
- Perform megafauna community analyses on species level and on “trait/functional” level.
- Obtain environmental parameters correlated with megafauna community characteristics (temperature, depth, salinity, productivity)
- Investigate change in community time series data due to temperature sensitivity, and other.

12 Stakeholder day

Below we summarize the main topics of the stakeholder presentations and discussions during the stakeholder session.

Caff

Arctic Council – Conservation of Arctic Flora and Fauna: Mandate, monitoring, assessments and communication" (Tom Christensen)

Recommendation: CBMP focuses on large-scale and long-term changes related to drivers/stressors (SAMBR report). LTM-Benthos should use future CBMP reports as a platform to promote use of data on a finer scale to meet management requests.

Norwegian Fishery authorities

– how to move from monitoring to management measures (Gunnstein Bakke)

https://kart.fiskeridir.no/fiskeinord: Example of how megafauna VME indicator species can be used by management and the importance of fine geographic scale. Need for close corporation with scientist and use of raw data.

ICES

– Assessing sensitivity of seabed habitats and species (Simon Jennings)

Recommendation: Introduced relevant ICES working groups: Working group on fisheries benthic impact and trade-offs (WGFBIT, new 3 year group starting in 2018); and working group on spatial vessel monitoring system (VMS) data (WGSFD) which has VMS tool packets, and is involved in the Trawling Best Practices project (available reports). Encouraged the LTM-Benthos group to look into the possibilities of VMS data available, relevant papers, and advisory sheets.

Feedback by Simon Jennings (contact for working groups in ICES):
Australian approaches for systematic risk assessment of impacts on many species:
Overview paper: http://www.sciencedirect.com/science/article/pii/S0165783611000324
Examples of their work and applications are in their management reports here:
http://www.afma.gov.au/sustainability-environment/ecological-risk-management-strategies/

In relation to obtaining code for VMS analysis and interacting with scientists who would be keen to work on such topics:
-Open source package for analyzing VMS and logbook data in common formats
http://nielshintzen.github.io/vmstools/
-Working Group developing methods of VMS analysis
http://www.ices.dk/community/groups/Pages/WGSFD.aspx
-Contact Chairs: niels.hintzen@wur.nl and christian.dorrien@thuenen.de
-The Working Group on Fisheries Benthic Impact and Trade-offs (WGFBIT) which will seek to further develop and apply methods for assessing fishing impacts on benthos (Chair: Tobias van Kooten, Ole Eigaard ore@aqua.dtu.dk and Gert van Hoeij, first meeting 12-16 Nov 2018 in Copenhagen.

Book with chapters covering evolution of VME and EBSA perspectives:
http://eu.wiley.com/WileyCDA/WileyTitle/productCd-1118392647.html

13 Main conclusions/questions from the stakeholder day

Our data sets can cover the need of different stakeholders:

- For detailed management purposes, data resolution is often high enough to:
    - Establish protection for vulnerable species
    - Define areas of interest, with suggestion of further targeted research effort
- For broad scale interpretation of benthic status in the Arctic region, the data has the broad coverage needed.
- For monitoring purposes i.e. to detect changes, the data can with time be used to:
    - detect changes in the functionality of communities,
    - follow changes in distribution of species
    - detect invasive species

Open questions include: How is the benthic communities expected to be distributed 25 years from now? What environmental drivers (temperature, depth, but also salinity, sediment, primary production) cause the present and predicted future community distribution? What are the present and predicted future human stressors on communities (such as trawling)?

LTM-Benthos data can be used to support the management of fisheries and also provide valuable information in relation to MSC ecolabeling. We will investigate how to deal with principle 2 (see above).

14 HOMEWORK before next workshop November 2018

- **Protocol on species to exclude from species list, and what species to lump together at a certain taxonomic level (MB)**
- **Community analyses (homework based on common matrices — LLJ) on species and trait (Lis start to circulate) level.**
- **Species list and definitions from “VME indicator species” or “VME habitat” (SO)**
- **Info about and definitions within EBSA (Biologically and Ecologically Significant Areas) — (VR). Documents in a shared Google Drive folder.**
- **VMS data from ICES (see Simon Jennings box above) – can we use this? (NH)**
- **NEXT MEETING: Iceland, Reykjavik, November 2018 – send meeting Doodle to all (SO/LLJ).**

15 Appendix 1: Total number of trawl hauls (stations) per year and gear type from data sources used during the workshop

Count of Stations	Gear type						
Nation/Area	**Agassiz**	**Alfredo**	**Beam trawl**	**Campelen**	**Cosmos**	**Otter trawl**	**Golden Top**
Canada							
2004		13					
2005				91			
2006		61		222	72		
2007				233	88		
2008		86		225	74		
2009				248	128		
2010		118		249	20		
2011		80		249	70		
2012		163		244	13		
2013		80		241	66		
2014		131		275			
2015		145		265			
2016		157		268			
Greenland (GINR)							
2015		149			318		
2016		171			352		
Iceland							
2015							47
2016							104
NE Greenland (TUNU)							
2015				9			
2017	7			9			
Norway/Russia							
2009				342			
2010				318			
2011				391			
2012				245			
2013				486			
2014				165			
2015				334			
USA							
2004			14				
2007			7				
2008			21			22	
2009			15			376	
2010						518	
2011						376	
2012			15			447	
2013						376	
2014						376	
2015			67			376	
2016						376	
2017						144	

16 Appendix 2: The trawl gear type used on national fisheries assessment surveys.

Source: Blicher ME, Hammeken Arboe N, Jørgensen LL, Burmeister A, Gudmundson G, Olafsdottir SH, Sørensen J, Kenchington E and Archambault P (2015) Development of minimum standards for long-term monitoring of marine bottom-living fauna communities in the Arctic-Atlantic: Pilot study in Greenland. Technical Report nr. 94, Greenland Institute of Natural Resources, Greenland. ISBN 87-91214-71-8, ISSN 1397-3657. 39 pp. http://www.natur.gl/publikationer-og-formidling/rapporter-tekniske/

Country	**Greenland**			
Area	West Greenland		East Greenland	
Survey	Shrimp Fish Survey	Greenland Halibut Survey	Shrimp Fish Survey	Greenland Halibut Survey
Ship(s) — research vessels only	RV Pâmiut	RV Pâmiut	RV Pâmiut	RV Pâmiut
Cost per day (ship and all staff)	100000 DKK	100,000 DKK	100,000 DKK	100,000 DKK
Additional scientific staff 1 person per day	2000 DKK	2000 DKK	2000 DKK	2000 DKK
Berths (Number)	24	24	24	
Crew	11 to 13	13	13	
Scientific Staff	5	7	7	
Berths left	6 — 8	4	4	
Duration of survey (days)	47	15	37	
Number of stations (trawl hauls)	225	60	95	70
Trawl type	Cosmos 2000	Alfredo III	Cosmos 2000	Alfredo III
Mesh size codend (mm)	20	30	20	30
Daily sampling period (trawling)	08.00 — 20.00 UTC	24 hour	08.00 — 20.00 UTC	24 hour
Tow duration (minutes) or distance (NM)	15 min	30 min	15 min	30 min
Towing speed (knots)	2.0 — 2.5	3	2.0 — 2.5	3
Area covered (NAFO / ICES)	1B-1F, part of 1A and part of 0A	1C and 1D	14B	14B
Longitude (South to North)	59°30' N to 72°30' N	62°30' N to 66°15' N	59°30' N to 67°00' N	61°45' N to 67°00' N
Depth interval (meter)	50 — 600	400 — 1500	50 — 600	400 — 1500
Area surveyed (km2)	186,220	52,306	118,107	37,397
Benthos sampling; equipment available/part of standard survey (+=yes, — = no)				
Groundfish trawl	+/-	+/-	+/-	+/-
Beam trawl/dredge/sledge	+/-	+/-	+/-	+/-
Grab/corer	+/-	+/-	+/-	+/-
Camera	+/-	+/-	+/-	+/-

Video	-/-	-/-	-/-	-/-
Acoustic	-/-	-/-	-/-	-/-
Environmental sampling; equipment available/part of standard survey (+=yes, — = no)				
CTD	+/+	+/+	+/+	+/+
Trawl temp logger	+/+	+/+	+/+	+/+
Water sampler	+/-	+/-	+/-	+/-

Country Area	**Faroe Islands**		**Iceland**	
Survey	Feb-March	August	Feb-March	October
Ship(s) — research vessels only	Magnus Heinason	Magnus Heinason	Árni Friðriksson (ÁF) + 3 other ships	Árni Friðriksson (ÁF) in deep + 1 other ship in shallow waters
Cost per day (ship and all staff)	80,000 DKK	80,000 DKK	140,000 DKK (ÁF, only ship)	140,000 DKK (ÁF, only ship)
Additional scientific staff 1 person per day	—	—	5000 DKK	5000 DKK
Berths (Number)	18	18	33	33
Crew	9	13	18	18
Scientific Staff	4	5	7 (without benthos)	7 (without benthos)
Berths left	5	0	11	11
Duration of survey (days)	28	28	26	24
Number of stations (trawl hauls)	129	229	Total 562; around 130 for ÁF	Total 380; 162 in shallow; 220 in deep (ÁF)
Trawl type	112 feet Box	112 feet Box	Mars trawl	"Golden Top"nr. 77 in shallow /"Golden top" nr. 78 in deep
Mesh size codend (mm)	40	40	40	40
Daily sampling period (trawling)	12 hour	24 hour	24 hour	24 hour
Tow duration (minutes) or distance (NM)	60 min	60 min	4nm	3nm
Towing speed (knots)	3-3.5	3-3.5	3.8	3.8
Area covered (NAFO / ICES)	Vb1b, Vb2	Vb1b, Vb2	Va1, Va2	Va1, Va2
Longitude (South to North)	60°30' N to 62°30' N	60°30' N to 62°30' N	63 to 67°N/10 to 27°W	62 to 67°N/10 to 0°W
Depth interval (meter)	65-700	65-700	20-500	20-400/ 150-1500

Area surveyed (km2)	47,000	47,000	250,000	150,000
Benthos sampling; equipment available/part of standard survey (+=yes, — = no)				
Groundfish trawl	+/+	+/+	+/+	+/+
Beam trawl/dredge/sledge	-/-	-/-	+/-	+/-
Grab/corer	-/-	-/-	+/-	+/-
Camera	-/-	-/-	+/-	+/-
Video	-/-	-/-	+/-	+/-
Acoustic	+/-	+/-	+/+	+/+
Environmental sampling; equipment available/part of standard survey (+=yes, — = no)				
CTD	+/-	+/-	+/-	+/-
Trawl temp logger	+/+	+/+	+/+	+/+
Water sampler	-/-	-/-	+/-	+/-

Country Area	**Norway/Russia** Barents Sea	**Canada** Davis Strait/Baffin Bay
Survey	August-September	Greenland Halibut survey
Ship(s) — research vessels only	Helmer Hanssen, GO Sars (GOS), Vilnyus, Johan Hjort (JH)	RV Pâmiut
Cost per day (ship and all staff)	200,000NKR	100,000 DKK
Additional scientific staff 1 person per day	2,800 NKR + 12 working Hours	16,000 DKK
Berths (Number)	GOS: 45, JH: 39	24
Crew	GOS: 15, JH: 14	13
Scientific Staff	Depends on project	7
Berths left	Depends on project	4
Duration of survey (days)	from 10 — 30 days per ship	32
Number of stations (trawl hauls)	400	184
Trawl type	Campelen 1800	Alfredo III
Mesh size codend (mm)	16-22	30
Daily sampling period (trawling)	24 hour	24 hour
Tow duration (minutes) or distance (NM)	15 min	30 min
Towing speed (knots)	3	3
Area covered (NAFO / ICES)	IIb2, IIb1, IIa1, IIa2, Ib, Ia	southern 0A, 0B
Longitude (South to North)	65 — 85°N	61°N to 72.7°N
Depth interval (meter)	<500	400-1500
Area surveyed (km2)	1,500,000	115,722
Benthos sampling; equipment available/part of standard survey (+=yes, — = no)		
Groundfish trawl	+/+	+/+
Beam trawl/dredge/sledge	-/-	+/-
Grab/corer	+/-	+/-
Camera	-/-	+/-
Video	-/-	-/-
Acoustic	+/+	-/-
Environmental sampling; equipment available/part of standard survey (+=yes, — = no)		
CTD	+/+	+/+
Trawl temp logger	+/+	+/+
Water sampler	+/+	+/+

Retur: Havforskningsinstituttet, Postboks 1870 Nordnes, NO-5817 Bergen

HAVFORSKNINGSINSTITUTTET
Institute of Marine Research

Nordnesgaten 50 – Postboks 1870 Nordnes
NO-5817 Bergen
Tlf.: +47 55 23 85 00 – Faks: +47 55 23 85 31
E-post: post@imr.no

www.hi.no

HAVFORSKNINGSINSTITUTTET