Responding to global warming: new fisheries management measures in the Arctic.

Jørgensen LL[1], Bakke G[3] , Hoel AH[2,1]

1 Institute of Marine Research, N-9294 Tromsø, Norway

2 UiT - The Arctic University of Norway, N-9037 Tromsø, Norway

3 Directorate of Fisheries, Norway

Corresponding author: Lis L. Jørgensen; Tel: +47 97185556, lis.lindal.joergensen@imr.no

Running head: Fisheries management in the Arctic

Keywords: climate warming, sea ice reduction, fisheries regulations, bottom trawling, vulnerable species, Arctic, area-based management measures

Type of Paper: Research Article

Abstract

The northernmost commercial fisheries in the world take place in the northern Barents Sea up to around 80° N. This is an area where global warming is particularly intense and where large, previously ice-covered areas are now more accessible to fishing vessels. This raised questions whether existing conservation and management measures are adequate. In this paper, we discuss the process of developing new measures, including four large preliminary

closed areas covering 442022 km^2 and an additional ten closed areas covering more than 3260 km^2 that protects sites with biodiversity, specific to the region.

The new measures, now enacted by the Government as an amendment to the old regulation related to the management of impacts from bottom fisheries on ecosystems, is based on knowledge derived from more than 10 years of scientific surveys of the seabed ecology. A key finding here is that cost-efficient, large-scale mapping and monitoring of seabed ecosystems is important for the development of area-based regulations of fishing activities. In the process of developing the regulation the Directorate of Fisheries made its own analysis of the data from the scientific surveys by a novel approach using commercially available software. The amended regulation entered into force on 1st July 2019. Such area-based measures also contribute to the achievement of Aichi target 11 and UN Sustainable Development Goal 14.5 on protecting maritime areas.

1. Introduction

The 1,4 million km^2 Barents Sea is situated on the margin to the Arctic Ocean, to the north of Norway and northwest Russia at 70-83°N. It has the world´s northernmost large-scale commercial fisheries (annual landed value 15-20 billion Norwegian kroner). It is also one of the seas most affected by global warming. Over the last 4 decades, late summer temperatures increased by almost 1.5°C (Lind and Ingvaldsen 2012), the ice cover has decreased by 10% while the Atlantic Water inflow has increased (Årthun et al. 2012). The northern Barents Sea is experiencing the strongest declines in winter sea ice concentration and the most rapid surface warming in the entire Arctic, undergoing a transition from a cold

and stratified Arctic to a warm and mixed Atlantic climate regime (Lind et al. 2018). This is likely to have repercussions for the biology in this area (Frainer et al. 2017, Aune et al. 2018), including fish stocks expanding northwards (Fossheim et al. 2015) and a benthos system increasingly dominated by boreal species (Jørgensen et al. 2019).

Global warming has implications for fisheries management because target species may shift geographically (Cheung et al. 2009). Fishing activity in new fishing areas in the northern parts of the Barents Sea around Svalbard may occur (Misund et al. 2016) due to reductions in sea ice and the poleward shift of commercially important fish species such as cod (*Gadus morhua*) (Kjesbu et al. 2014) and haddock (*Melanogrammus aeglefinus*) (Landa et al. 2014). Bottom-contact fishing gears, in particular trawl, are considered the most widespread anthropogenic source of direct disturbance to the seabed and its associated biota. Areas that are not previously fished can be more strongly affected by fishing than areas that are already fished (Sciberras et al. 2018). But bottom trawling is also an important fishing method and significant to global seafood supply. Effects of persistent bottom fishing disturbance include reduced community production, changes in trophic structure and function due to decreases in faunal biomass, numbers and diversity, changes to the body size-and age-structure of benthic populations, and a shift towards communities dominated by fauna with faster life histories (van Denderen et al. 2015; Hiddink et al. 2006). Since biota and habitats differ in their degree of exposure and sensitivity to bottom trawling, knowledge of their distribution and sensitivity is required to assess impacts from fishing and to develop options or identify priorities for conservation and management.

The UN Food and Agriculture Organization FAO is the UN body responsible for developing the global norms for the management of fisheries. To protect vulnerable marine ecosystems,

the FAO has developed several international instruments, including international guidelines for the management of deep sea fisheries.[1] Here, the concept of "Vulnerable Marine Ecosystems" (VMEs) is critical, addressing attributes of marine ecosystems that are critical to their structure and function.

In what follows, we describe the i) scientific monitoring of the Barents Sea ecosystems established by the Institute of Marine Research, ii) its analyses of the seabed ecosystems based on this monitoring, and iii) the resulting information to the Directorate of Fisheries for management purposes. Finally, we iv) discuss the ensuing advice to the Government and the regulation adopted 29th March 2019. The regulation entered into force 1st July 2019.

In doing so, this article addresses the broader topic of how fisheries management can contribute to biodiversity conservation, in addition to ensuring that fisheries are sustainable. The Convention on Biological Diversity calls on states to mainstream biodiversity in their sectoral management of activities affecting biodiversity, cfr. its Decision XIII – 3 on actions to achieve the Aichi biodiversity targets including with respect to mainstreaming and the integration of biodiversity within and across sectors.[2] This article demonstrates how "other effective area-based measures" can contribute to the achievement of Aichi target 11 and SDG 14.5 by the mainstreaming of biodiversity in fisheries management in Norway´s northernmost fisheries regions.

[1] http://www.fao.org/fishery/topic/166308/en
[2] https://www.cbd.int/decisions/cop/?m=cop-13).

2. Norway´s fisheries management

The Barents Sea and its continental shelf is divided between Norway and Russia by a 2010 boundary. Transboundary fish stocks in the Barents Sea are managed by a Joint Norway-Russia Fisheries Commission established in 1975. The decisions of the Joint Fisheries Commission are based on scientific advice from the International Council for the Exploration of the Sea (ICES). In ICES, Norwegian and Russian scientists cooperate with scientists from a number of other countries on data analysis and stock assessment, based on annual surveys to collect data to this end (Kovalev and Bogstad 2011). The final management advice is issued by the ICES Advisory Committee where members from every ICES member country serve.

The decisions of the commission are implemented by domestic measures by Norway and Russia in their the respective waters, complemented by additional measures that follow from national policies. The 2008 Living Marine Resources Act in Norway, the objective of which is to ensure a sustainable management of the living marine resources, explicitly states the need for management to lend weight to an "ecosystem-based approach that takes into consideration habitats and biological diversity" (para 7(b)).[3] The measures discussed here follows from national policy in Norway.

Area-based management measures have been a staple of fisheries management in Norway for several decades (Gullestad et al. 2017), and the 2008 Living Marine Resources Act explicitly mandates the establishment of such measures in fisheries management. Over the last decades there has been an increasing interest in such measures also in international

[3] https://lovdata.no/dokument/NL/lov/2008-06-06-37

fisheries management (FAO 2006), and in 2010 the cooperation under the Convention on Biological Diversity adopted the Aichi Targets which committed nations to protect 10% of their ocean and coastal areas,[4] an objective also stated in the Sustainable Development Goals adopted by the UN General Assembly in 2015.[5] The term used for sectoral area-based management measures in CBD is "other effective conservation measures, ("OECMs") which are not fully fledged MPAs, but still offers protection of biodiversity in general in a defined geographical area. The new measures discussed here targets fishing with gear that is likely to touch the bottom during fishing such as bottom trawl, gillnets, longline and pots. Other human activities in the area that may come in physical contact with the bottom is not covered. However, currently no such activities take place except for research activities and other significant activities impacting the seabed are not likely to emerge in the near- to medium term future.[6] The area covered by the measures addressed here is part of a larger ocean area covered by the Norwegian Management Plan for the Barents Sea. This plan is updated regularly by the Storting, the Norwegian Parliament.[7] It is a mechanism to monitor all activities across all sectors, the state of the environment and to assess any threats to vulnerable and threatened species and habitats, and to make cross-sectoral overarching decisions related to the need for new management measures. This mechanism ensures that any new activities that may come in physical contact with the seabed will be assessed and that necessary measures will be decided on. The measures discussed here may therefore be regarded as OECMs as defined by CBD.

[4] https://www.cbd.int/sp/targets/
[5] SDG 14.5: https://www.un.org/sustainabledevelopment/oceans/
[6] Petroleum-related activities are limited to the southern Barents Sea.
[7] The latest update was in spring 2020.

In response to such developments and to previously adopted encouragements by the UN General Assembly for fisheries management to contribute to the conservation of biodiversity,[8] Norway in 2011 adopted a regulation protecting all marine ecosystems below 1000 meters from impacts by bottom fishing gear by prohibiting fishing unless certain conditions were met.[9] Bottom fishing gear includes all types of gear that under normal fishing operations are likely to have impacts on the sea bed. This, in combination with other area-based measures related to fisheries management brought the seabed areas under protection from bottom fishing gear to over 50% of the total Norwegian seabed area (FKD 2013).

3. The Arctic Barents Sea ecosystem and the fisheries

The northern Barents Sea have an Arctic climate and an ice-associated ecosystem. The southern Barents Sea has an Atlantic climate. This is mainly due to colder, fresher Arctic Waters dominating in the north throughout the year while warm saline Atlantic Water enters from the southwest (Lind et al. 2018). Atlantic Water flows northward along the west coast of the Svalbard archipelago and meets the cold Artic Water north and east of Svalbard. Benthic species in the southern Barents Sea follow this warm western current and are found far north and east of Svalbard. Species that are usually recorded deep on the continental slope or in Arctic areas are found in relatively shallow areas in the Yermak

[8] For examplethe two resolutions addressing impacts of bottom fishing in the fisheries resolutions in 2009 and 2011. See A/Res/70/75 where this is followed up upon. https://documents-dds-ny.un.org/doc/UNDOC/GEN/N15/414/49/PDF/N1541449.pdf?OpenElement

[9] Forskrift 1. juli 2011 nr. 755 om regulering av fiske for å beskytte sårbare marine økosystemer. https://lovdata.no/dokument/SF/forskrift/2011-07-01-755

Plateau northwest of Svalbard and in the northern Barents Sea (Jørgensen et al. 2015, 2019).

Targeted species in the commercial fisheries in the Barents Sea include cod, haddock, capelin, beaked redfish, Greenland halibut, as well as shrimp and snow crab. The fisheries in the Northern Barents Sea - more than 1.000 km from the mainland - is mostly by bottom trawl, mainly by vessels from Norway and Russia but also from Iceland, Greenland, the Faroe Islands and the EU. The fisheries are regulated by quotas and restrictions on gear (mesh size, requirements to trawl design, use of grids, etc), as well as minimum sizes of fish and area closures, including real time closures (Gullestad et al. 2015). There are also strict reporting requirements and a Coast Guard presence with at sea inspections, an important element of the enforcement of regulations.

The scientific basis for the scientific advice provided by ICES is developed by the Institute of Marine Research (IMR) and Knipovich Polar Research Institute of Marine Fisheries and Oceanography, Russia (PINRO). A significant step in their cooperation was the initiation of ecosystem surveys in 2004 (Michaelsen et al. 2013), where several vessels conduct a synoptic survey campaign in late summer and early fall covering both the Norwegian and the Russian parts of the Barents Sea. The ecosystem campaigns have vastly expanded the amount and types of data that are collected on an annual basis from this ecosystem.

4. Developing new measures in a warming sea

4.1 The request from the ministry

The northward expansion of commercial fish-stocks combined with reduction of sea ice expose areas around Svalbard to more fishing. The *Ministry of Trade, Industry and Fisheries* therefore asked the Directorate of Fisheries to examine the vulnerability of these areas to fishing and to recommend regulatory action,[10] in cooperation with the IMR.

4.2 The process of developing a new regulation

4.2.1 Long term monitoring data.

Responding to the request from the Ministry of Trade, Industry and Fisheries (figure 1), the Directorate of Fisheries initially asked the IMR whether different benthos species could be used as a proxy for identifying areas with vulnerable marine ecosystems. The IMR initiated a project (Jørgensen 2017), based on already existing long-term monitoring data of benthos in the Barents Sea, including the waters around Svalbard. These data were obtained from the annual joint IMR and PINRO Barents Sea Ecosystem Survey (Michalsen et al. 2013) and the SI_Arctic project[11]. The success of this long-term monitoring of benthos was due to adding taxonomic expertise to the already existing annual ecosystem surveys and other surveys for assessing commercial fish and shrimp stocks. The entire catch of the scientific bottom-trawls was now examined, yielding both fish and benthos data from a regular station grid annually.

Benthic megafauna catches from the scientific bottom trawl (Campelen 1800 shrimp trawl, towing distance: 0.75 nautical miles [~1.4 km] per station) was processed by identifying to the lowest possible taxon, and counting and weighing per taxa (Jørgensen et al. 2015). This

[10] Letter from the Ministry of Trade, Industry and Fisheries of 8 June 2016 to the Directorate of Fisheries.
[11] The Norwegian Research Council (project 228896) cruise program (2014-2017).

process has been carried out in August-September each year from 2009 and onwards. More than 4,000 stations have been sampled resulting in >70 tons of megabenthic biomass, >15 mill individuals and >1000 taxa entities with 650 identified to species level. Given the amount of data available and the spatial distribution of the stations it was concluded that previous peer reviewed results (see below) and specific selected species could be used as a proxies for vulnerable marine ecosystems (see below).

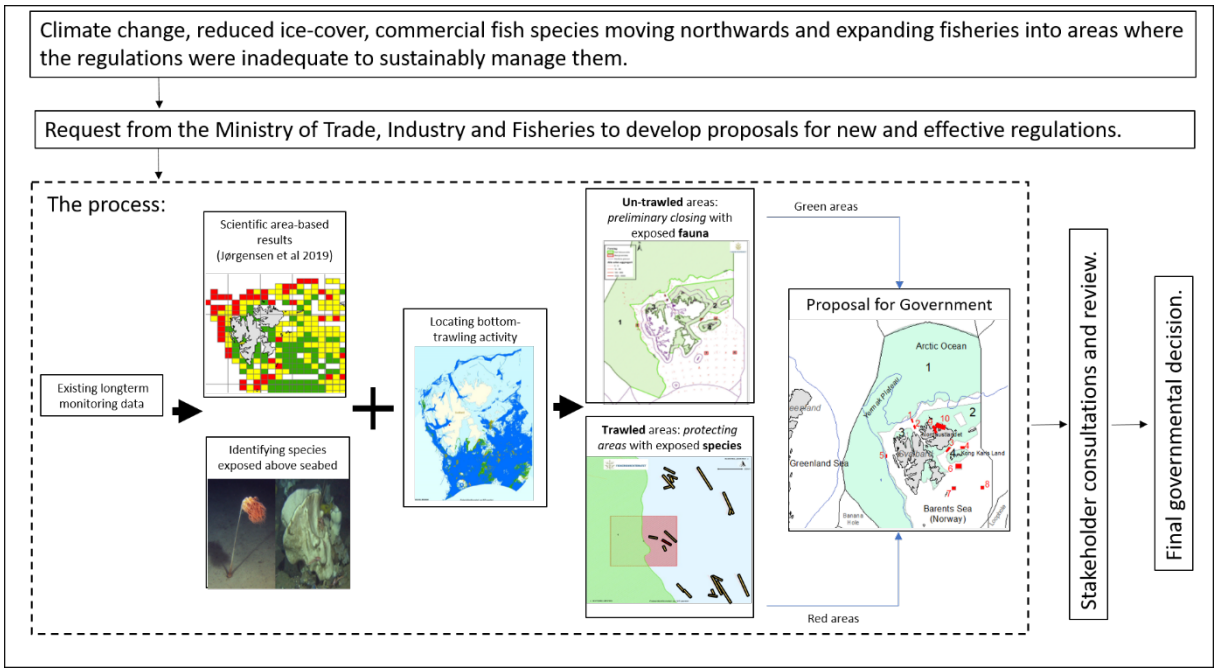

Figure 1. The rationale and the request from the government (upper left); the process in the Institute of Marine Research and the Directorate of Fisheries (the box); the evaluation and review of the product leading to the final governmental decision (lower right).

4.2.2 Peer review science-based results

Multiple locations (see also grid-map in figure 1, based on trawled stations) shallower than 1000 m around Svalbard, including the Yermak plateau, have complex habitats with high species diversity (up to mean 65 species per grid cell), high biomass (up to mean 300 kg) and abundances (up to mean 50000 individuals) and are inhabited by upraised, large bodied

223 species, with no or low mobility, and therefore easily damaged by a bottom trawl (Jørgensen
224 et al. 2019). This "susceptibility of benthos species to be caught or damaged by the trawlgear"
225 is based on a given taxon's body size (Shin et al. 2005), morphology, and mobility (Jørgensen
226 et al. 2015, 2019). Immobile species with large and upright bodies or arms stretched out in the
227 water to increase prey search volume, are morphological features (body shapes) easily hit,
228 damaged and caught by or entangled in trawling gear, and have been reported at reduced
229 densities in trawled areas (Kaiser et al. 2000). The existing biodiversity regulation from 2011
230 – restricting bottom trawling deeper than 1000 m but not limiting it in shallower waters[12] -
231 was therefore not adequate to protect these benthic ecosystems in the Barents Sea. Here, the
232 presence of vulnerable marine ecosystems in a wider area was now documented. When seen
233 together with retreating ice-cover, the expansion of commercial fish species to the north and
234 increasing fishing activity it prompted the process to develop the management action
235 described here.
236

237 ### 4.2.3 Developing data for regulatory action
238

239 To obtain additional knowledge on presence of benthos, meetings were held with science,
240 management and the fishing industry represented by the vessel owners´ association to discuss
241 i) experiences with bycatch of benthic organisms such as sponges and corals (VME indicator
242 species) and ii) the need for new regulations. From this it was concluded that the Norwegian
243 fishing fleet try to avoid large benthos catches as it is detrimental to fishing. They do this by
244 using their historical knowledge of where the "good fishing areas" are. Also, it was clarified
245 that some vessels were planning to move north- and eastwards to potential new fishing areas
246 to follow the northwards expansion of the commercial fish species.

[12] There are however a number of other regulations in Norwegian fisheries limiting where trawl gear can be used, for example in the 12 nautical mile territorial waters.

A "move on rule" regulation was adopted in 2011 by the Government[1] for ijnstances where VMEs indicator species are taken in excess of threshold values. The regulation applied to all waters under Norwegian jurisdiction, including the Fisheries Protection Zone around Svalbard and the Fisheries Zone around Jan Mayen. But the regulation did not make a distinction between fished and previously non-fished areas. Previously unfished areas in the Barents Sea were therefore open to commercial fishing when the sea ice retreated. This is not in line with common international standards in fisheries management. Regional fisheries management organizations (RFMOs) such as the Northeast Atlantic Fisheries Commission have divided waters under their regulatory mandates into new and existing fishing areas respectively. Regular commercial fishing is not allowed in new fishing areas.

To be in line with common international standards in fisheries management, areas with *existing* fishing and *without* fishing in the last 10 years (trawled and untrawled areas in Figure 1) were identified for the northern Barents Sea. Focus were on untrawled areas with fauna susceptible to bottom trawling.

For this purpose, Vessel Monitoring Systems (VMS) data were used. Fishing vessels are required to transmit their position by satellite every hour, including information on ship call sign, date, time, GPS position, heading, and speed. Vessel speed was used as a proxy for trawling, and the VMS data was combined with fish catch data from the electronic logbook. This allowed for ascertaining whether fishing activity was bottom or pelagic.

All activities of the Norwegian fishing vessels and all foreign ones, except those flying the flag of Russia, are tracked. The VMS data cover all gear types, bottom trawl, gillnet, longline and pots. The new fishing areas were delineated using the geographical distribution of VMS

activity as a basis, and then combining it with depths, the territorial waters, base lines and the boundaries toward other jurisdictions.

The scientific identification of fauna susceptible to trawl gear (Jørgensen et al 2019) was used as the main argument for applying a precautionary approach to areas *without* previous fishing, particularly trawling. This resulted in the 10 closed areas in the northern Barents Sea. Another approach was used to identify vulnerable species *within* the trawled areas. For the purpose of protection of benthos within the trawled areas, the Directorate of Fisheries adapted the VME indicator species approach (e.g. sponges and sea pens) as defined by the FAO Deep-sea Fisheries Guidelines.

The characteristics of the species susceptible to be caught or damaged by a trawl are shared also by the species regularly used as a proxy for the presence of vulnerable marine ecosystems such as hard and soft corals, sponges and seapens.[13] There is thus no deviation from the basic approach used internationally in Norway except for the introduction of one additional species, sea lilies. The main new element here is the type of data used to map their presence, the presentation of the data, station by station and the approach taken when the data is presented as a rationale for the proposed regulation to the government.

The quantity (biomass per species group, per trawl haul calculated as catch per 15 minute trawling to make it possible to compare densities across all stations) and distribution data (positions for shooting and hauling of each scientific trawl haul) of the VMEs within sponges (e.g. *Geodia* sp), sea pens (e.g. *Umbellula encrinus*), cauliflower corals (Nephtheidae), and the sea lilies (e.g. *Heliometra glacialis*) were taken from the existing scientific long term

[13] See FAO and various international organizations regulating fisheries, such as the Northeast Atlantic Fisheries Commission, NEAFC.

294 monitoring series and geo-referred as quantitative “trawl-lines” by the use of ArcGis. FAO
295 includes stalked sea lilies as a VME indicator species. The sea-lilies around Svalbard was
296 unstalked, but they were still included as a VME indicator species in this study.
297
298 The Directorate of Fisheries plotted the VME indicator species data from ~4000 trawl hauls
299 on a map by ArcGIS (ArcMap 10.6.1). To compare the biomass of VMEs across all stations,
300 the quantitative data for each species (e.g. *Umbellula encrinus*) or group (e.g. sponges), were
301 sorted into four quantitative categories by the logarithmic function built into ArcMap (e.g. 0-
302 9 kg, 10-99 kg, 100-999 kg, 1000-9999 kg). The ArcGis program was set to define the
303 thresholds for each species or group automatically. The result was lines on the map between
304 the position were the trawl reached the bottom and the position where it was lifted. These
305 lines were graded in four colors. The darker the color the higher the biomass of the species or
306 group selected.
307
308 The map is available online https://kart.fiskeridir.no/fiskeinord and interactive, and the viewer
309 can alternate between maps showing the distribution of single species or groups as well as
310 showing all species and groups together. The latter function made it possible to identify
311 whether any areas had higher densities of vulnerable species combined with high biomass.
312 Areas with vulnerable species and groups were mainly in areas already designated as new
313 fishing areas, but vulnerable species were also recorded in already trawled areas and therefore
314 in the need of protection.
315
316 The delineation decisions, the process of drafting the final regulatory proposal for the
317 Government, and the final execution of the regulation, were done by the Directorate of
318 Fisheries. This novel way of using and visualizing scientific data was designed to fit the

management purpose at hand. This included making information easily accessible at a relevant geographical scale. For the purpose of drawing up boundaries for closed areas, the Directorate of Fisheries used raw data at the most detailed level (hence per trawl haul). Raw data per trawl-haul were used because data aggregated into e.g. grids prevent detailed drawing of lines and may fail to follow boundaries already set by regulations. The usual way of presenting information in grids was not useful for the purpose here, in particular since grids are to coarse for drawing up boundaries for closed areas. Neither to they follow the boundaries between jurisdictional areas, such as the territorial waters. Since such boundaries are fixed by regulations they often make sense for other management purposes as well and did so here.

Presence of *Geodia* sponges (up to 730 kg/nm west of Svalbard) and the sea pen *Umbellula encrinus* (up to 0.013 kg/nm east of Svalbard) were the justification for the protected red areas 3 and 5 respectively (figure 2). Sponges (up to 87 kg/nm) and cauliflower corals (0.7 kg/nm) were suggested as justification for the protected area north of the Hinlopen Strait (the protected red areas 1 and 2 in figure 2), while a combination of high biomass of sponges (26 – 40 kg/nm), cauliflower corals (up to 1.3 kg/nm), and sea lilies (5-13 kg/nm) suggested the 3 protected areas (the red areas 4, 7, 8 in figure 2) north of Kong Karls Land and southeast of Svalbard. Additional data of sea pens (*Funiculina quadrangularis*) from the Norwegian seabed mapping programme (MAREANO[14]) brought red area 6, south of Kong Karls Land. Red area 9 and 10 were established to protect the seabed in areas used as reference areas for scientific purposes. All these areas are relatively unfished compared to their surrounding areas, indicating a more pristine condition than other areas containing the same VME indicator species. These areas may be described as representative of the respective types of nature. To protect a representative selection of nature types - both terrestrial and marine - is a

[14] www.mareano.no

key element of Norwegian environmental policy. The protection of these areas serves to implement this policy.

4.3 The proposed regulation

Based on the above data, the Directorate of Fisheries concluded that the 2011 regulation prohibiting bottom trawling below 1000 m depth did not offer the needed protection of vulnerable marine ecosystems in the assessed area. An amended regulation was therefore drafted.

4.3.1 The concept of "New fishing areas"

The new, amended regulation (see green area 1, Figure 2) for the Northern Barents Sea should ban bottom trawling below 800 m depth and the delineation line should follow this depth line for new fishing areas. The outer line of the delineation (above waters deeper than 800 m) follows the Norwegian Fishery Protection Zone around Svalbard in the north and east towards the central Arctic Ocean and in the west towards the Greenland Sea. The Yermak Plateau, north-west of Svalbard, is shallower than 800 meters and was delineated by coordinates instead of the depth-gradient (green areas in Figure 2). These large areas was thus closed and preliminary protecting the high species diversity, the species susceptible toward trawling the VME indicator species.

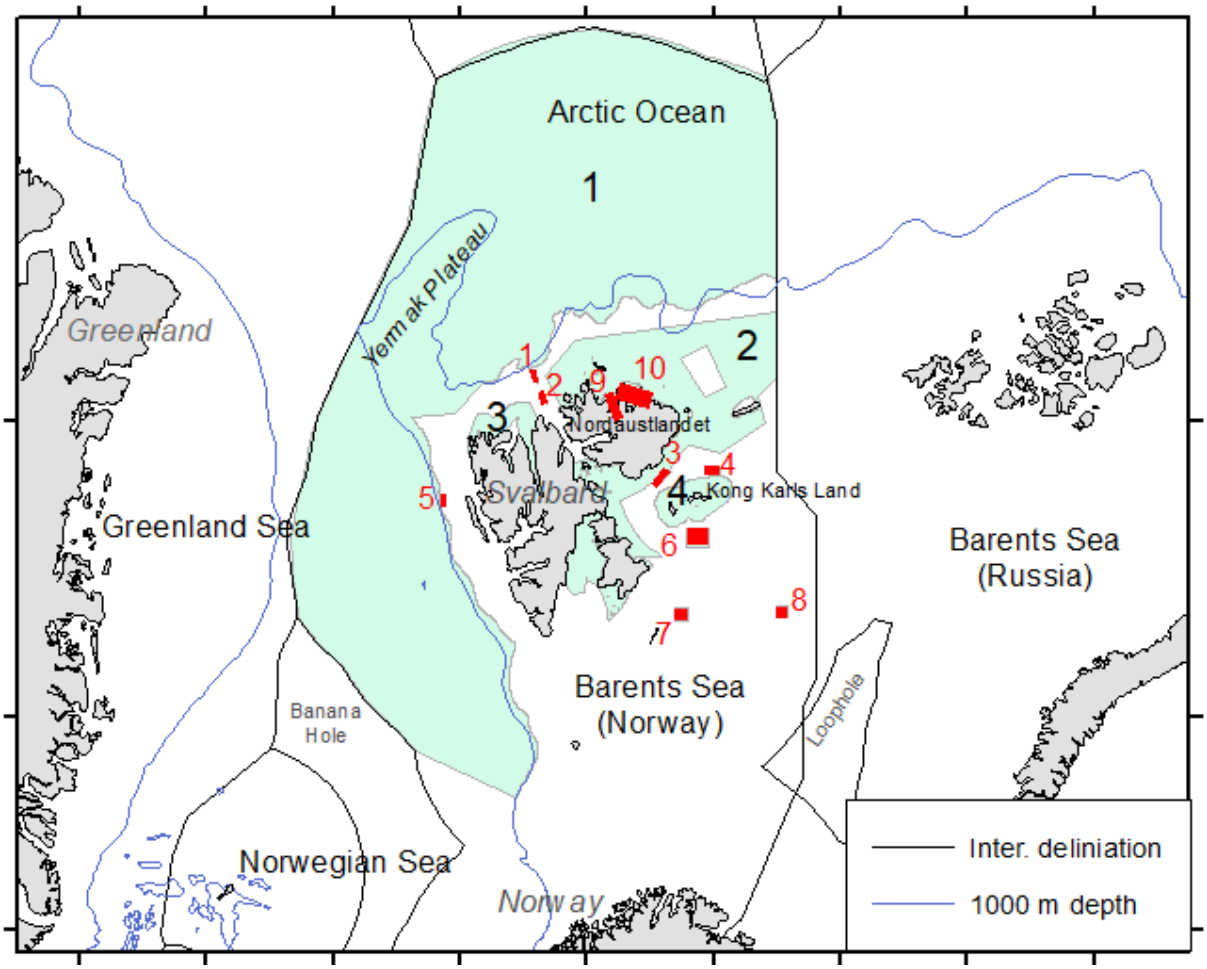

Figure 2. The Fisheries Protection Zone around Svalbard with the closed areas within existing fishing areas (red areas 1-10 covering 3260 km^2) and new fishing areas (green areas 1-4 covering 442022 km^2) areas. The black lines are the boundaries between different jurisdictions. The water column above the seabed in the Banana- and the Loop holes beyond national jurisdiction are international waters. The map is adapted from the map created by the Directorate of Fishery and available on: https://kart.fiskeridir.no/fiskeinrd.

In addition to the 800 m delineation area in the north and in the east, three other "new fishing areas" were suggested closed. These new areas included (see figure 2) one area surrounding the Nordaustlandet and the east coast of Svalbard (green area 2), another area is north of Svalbard (green area 3), and the third is around Kong Karls Land (green area 4). The territorial waters of areas 2 and 3 were previously designated as Marine Protected Areas (MPAs) under environmental legislation. The MPA regulations allowed bottom trawling for shrimp deeper than 100 meters and fishing with other types of gear. The new regulations goes

further as it prohibits *all* fishing. Areas outside 12 nautical miles were not previously trawled and therefore delineated by coordinates, interconnected with strait lines.

The narrow shelf west of Svalbard has been closed to fishing by another fisheries regulation since the early eighties. This regulation is still in force[15]. This area is therefore not covered by the new regulation discussed here, except for the small red area 5 (figure 2).

The green areas 1, 2 and 3 cover a total of 442022 km^2, preliminarily closed to all fishing. This area is almost as large as the North Sea (570000 km^2). If these areas are to be re-opened for fishing, a comprehensive mapping of the sea-bed biota will be required to identify vulnerable marine habitats (VMEs).

4.3.2 Existing fishing areas

For the existing fishing areas around Svalbard, a total of 10 protected areas, covering altogether 3260 km^2, were proposed. These areas were delineated as squares around the highest biomass records of VMEs (protected area 4, 5, 6, 7), as a triangle (protected area 3) or by following the seabed morphology and the fishing activity as identified by the VMS data and data from the electronic logbooks (protected area 1 and 2). These different shapes were first and foremost used because they are simple and easy to plot in navigational maps while at the same time serving offering effective protection, including areas functioning as a buffer zone contributing to biodiversity conservation. These protected areas, with biodiversity specific to the region, are also representative for a selection of Norwegian nature types.

[15] For the territorial waters as well as the waters beyond in the Fisheries Protection Zone §24 of a regulation pertaining to mesh size, bycatch, mimum sizes, etc was established several decades ago. See https://lovdata.no/dokument/SF/forskrift/1994-09-21-882?q=svalbards territorial and https://lovdata.no/dokument/SF/forskrift/1994-09-21-881?q=fiskevernsonen

The use of the terms "closed" and "protected" areas as described above, allows the managers flexibility in delineating area-based management measures within a complex seascape of new and already existing fishing areas.

Maps showing the locations of scientific trawl data, commercial trawling activity, the preliminary closed areas and the protected areas were made available on the webpages of the Directorate of Fisheries (https://kart.fiskeridir.no/fiskeinord) and the draft proposal developed by the Directorate[16] was subject to a public consultation in 2017-2018, seeking stakeholder input from other government agencies, industry organizations, non-governmental organizations (NGOs), the public and academic institutions.

4.4 The decision for new area-based measures in the northern Barents Sea and the waters north of Svalbard (Yermak plateau)

The final regulation was adopted by the Ministry of Trade, Industry and Fisheries the 29th of March 2019, as a regulation amending the 2011 regulation, which again has its legal basis in the 2008 Living Marine Resources Act.[17]

The title of the regulation is "*Regulation of fishing to protect Vulnerable Marine Ecosystems*" and its objective is "*to protect vulnerable marine ecosystems*" (section 1). The regulation defines and delineates the "new fishing areas" and the "existing fishing areas" with 10 protected areas, specifies the move-on rule if VMEs indicator species are taken in excess of threshold values, and stipulates the requirements for data collection and reporting. In

[16] https://www.fiskeridir.no/Yrkesfiske/Dokumenter/Hoeringer/Forslag-om-endringer-i-forskrift-om-regulering-av-fiske-med-bunnredskap-i-Norges-oekonomiske-sone-fiskerisonen-rundt-Jan-Mayen-og-i-fiskevernsonen-ved-Svalbard

[17] https://lovdata.no/dokument/LTI/forskrift/2019-03-29-416

respect of the new fishing areas the regulations specify to terms and conditons that apply if a vessel owner applies for a permit to do exploratory fishing, (section 4). The new regulation applies to all fishing vessels operating in the area covered irrespective of which country´s flag they fly. It applies to all types of fishing gear. Vulnerable marine ecosystems on the seabed is however the main focus and it is thus reasonable to assume that an application for permission for exploratory fishing with gear solely operating in the water column may be granted. In Norwegian fisheries the only gear in such cases would be purse seine. All other gear requires some kind of bottom contact or poses a risk for such contact during fishing.

There are also requirements for collection of new data during exploratory fishing. For opening a portion of a *new fishing area*, a permit is required in order to start exploratory fishing. The new regulation will require that data from exploratory fishing, relevant seabed mapping such as MAREANO, and future ecosystem surveys are assessed. The intent is to ensure that potential effects on vulnerable bottom habitats are assessed in advance of any commercial fishing activities. Since the original regulation was adopted in 2011, no applications have been received by the Directorate of Fisheries for permits for exploratory fisheries anywhere. This seems to indicate that interest in such deep-waters fisheries is low.

5. Discussion and conclusion

Global warming has triggered rapid and extensive sea ice loss in the Barents Sea (Lind et al. 2018; Onarheim et al. 2018). Together with poleward expansion of commercially important

fish species (Kjesbu et al. 2014, Landa et al. 2014) there are concern that new fishing activity in new ice free parts of the northern Barents Sea around Svalbard can have an impact on marine ecosystems (Misund et al. 2016).

Facing this situation and committed to act on internationally agreed fisheries management measures, the Norwegian *Ministry of Trade, Industry and Fisheries* contacted the Directorate of Fisheries and the Institute of Marine Research (IMR) to recommend regulatory action to protect potentially vulnerable areas to fishing.

The Directorate of Fisheries and the IMR were able to respond quickly the request due to an already existing time long-term monitoring program resulting in a decade of benthos data from the Barents Sea. On the basis of these benthos data, Jørgensen et al (2019) identified multiple locations shallower than 1000 m in the Northern Barents Sea with complex habitats of sessile, upraised, large bodied species easily damaged by a bottom trawl. The data were then used for identifying the quantitative distribution of species indicating the presence of vulnerable marine ecosystems (VMEs).
This information was combined by data from national and international Vessel Monitoring Systems (VMS) and electronic logbooks, allowing for delineation of areas with and without fishing. Such data are generally used to track the activities of national and international fishing vessels fishing in the area irrespective of the gear they use. Even though all fishing has been included, it goes without saying that bottom trawling received the greatest attention since it has a greater potential than other fishing gears in affecting the bottom habitats.

These spatially delineated areas of protection within new and existing fishing areas in the Barents Sea fall within the Convention of Biological Diversity (CBD) Aichi Biodiversity Target

11 and the UN Sustainable Development Goal 14.5. These targets call for sustainable use of the oceans, and a conservation strategy of well-connected systems with protected areas and "Other Effective area-based Conservation Measures (OECMs)", integrated into wider seascapes. The approach discussed here was intended to achieve positive and sustained long-term outcomes for conservation of biodiversity, and particularly seabed invertebrate diversity and associated ecosystem functions and services[18]. The area-based management measures described here offers long term in-situ protection to vulnerable marine ecosystems in areas where fishing is the only significant human activity. No other human activity is foreseeable future. The measures should therefore be regarded as an OECM. The development of the regulation and its adoption is therefore also a contribution to achieving the Aichi target 11 and SDG targets of 10% coverage of marine protected areas and other effective area-based management measures.

The 2019 regulation by the Ministry of Industry, Trade and Fisheries, limits the potential damage to vulnerable benthic species by bottom fishing activities in new and existing fishing areas. Also, from the point of view of the economic efficiency of fishing, the regulation also prevents trawl gear from being filled with unwanted by-catch. Together with the quota system, technical requirements to fishing gear, and temporal area closures due to presence of juvenile fish below minimum sizes, the regulation constitute the basis for sustainable harvest in Norway´s Fishery protective zone around Svalbard.

The benthos and VMS data were entered into a ArcGIS program where maps was developed. These maps were discussed among the scientists, managers and stakeholders.

[18] https://www.cbd.int/sp/targets/rationale/target-11/

Because the cooperation between the Directorate of Fisheries, the IMR and the Government traditionally has been close, the communication lines are short and therefore efficient. This discussion was welcomed among the fishing organizations because monitoring of benthic habitats and resources may have direct economic consequences. For example, the non-governmental organization "the Marine Stewardship Council" (MSC) has launched the MSC eco-label which is intended to be the consumers' guarantee that a fish or seafood product meets certain fisheries standards of sustainability. For bottom fisheries, documentation and mitigation of the potential impact on seafloor habitat and its associated biological communities are essential for achieving MSC certification (www.MSC.org). Fishing activity must be managed carefully so that other species and habitats within the ecosystem remain sustainable. Lack of relevant data, or, lack of data presented in such way that is usable for the evaluation process, is preventing certification.

Based on this research, the suggested regulatory changes from the Directorate of Fisheries to close a total of 442022 km^2 was adopted 29th March 2019 by the Ministry of Industry, Trade and Fisheries, and entered into force on 1st July 2019. In order to obtain a permit for exploratory fishing within a closed area, a plan for avoiding VMEs and for collect data, is needed. Regular commercial fishing may not commence as long as the status of the area remains unchanged.

Acknowledgements

We acknowledge the valuable data collected in Ecosystem cruises of the Institute of Marine Research (IMR) in Norway and Knipovich Polar Research Institute of Marine Fisheries and Oceanography in Russia (PINRO) and the efforts of colleagues and staff on the ships, in the

laboratories, and the offices in this regard. We are also grateful to colleagues in the Norwegian Fishery Directorate and at the University of Tromsø who have commented on a draft of this article. Thanks to the two anonymous referees and to Jake Rise for editing and providing valuable comments. Thanks also to the Fram Centre for funding the ICE-EVA project (Flagship: Sea ice in the Arctic Ocean, technology and agreements), the Research Council of Norway for funding SI_ARCTIC (228896) and TIBIA (228880), projects that have supported field work and writing of this manuscript.

References

Aune M, Aschan M, Greenacre M, Dolgov A, Fossheim M, Primicerio R. (2018) Functional roles and redundancy of demersal Barents Sea fish: ecological implications of environmental change. *PLOSOne* 13 (11), e0207451.

Cheung W, Lam V, Sarmiento J, Kearney K, Watson R, Pauly D. (2009) Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries* 10(3), 235 - 251.

FAO (2006) Report on Expert Workshop on Marine Protected Areas and Fisheries Management. FAO Fisheries Report No 825, FAO, Rome. http://www.fao.org/tempref/docrep/fao/010/a1061e/a1061e.pdf

FKD 2013: https://www.regjeringen.no/no/aktuelt/ny-side13/id2638777/

546

547 Fossheim M, Primicerio R, Johannessen E, Ingvaldsen R, Aschan M, Dolgov A. (2015) Recent
548 warming leads to a rapid borealization of fish communities in the western Arctic. *Nature*
549 *Climate Change* 5: 673-677. doi: 10.1038/nclimate2647.

550

551 Frainer A, Primicerio R, Kortsch S, Aune M, Dolgov AV, Fossheim M, Aschan M. (2017)
552 Climate-driven changes in functional biogeography of Arctic fish communities.
553 *Proceedings of the National Academy of Sciences PNAS* 114: 12202-12207. doi:
554 10.1073/pnas.1706080114.

555

556 Garcia S, Rice J, Charles A. (2014) Governance of marine fisheries and biodiversity
557 conservation – convergence or co-evolution? Pp. 18-36 in: Garcia, S., Rice, J., and Charles,
558 A. (eds.) 2014: Governance of Marine Fisheries and Biodiversity Conservation. Wiley-
559 Blackwell, Chichester.

560

561 Gullestad P, Blom G, Bakke G, Bogstad B. (2015) The "Discard Ban Package": Experiences in
562 efforts to improve the exploitation patterns in Norwegian fisheries. *Marine Policy*, *54*, 1-9.
563 Gullestad P, Abotnes AM, Bakke G, Skern-Mauritzen M, Nedreaas K, Søvik G. (2017) Towards
564 ecosystem-based fisheries management in Norway–practical tools for keeping track of
565 relevant issues and prioritising management efforts. *Marine Policy*, *77*, pp.104-110.

566

567 Hiddink JG, Jennings S., Kaiser M J, Queirós AM, Duplisea DE, Piet GJ. (2006) Cumulative
568 impacts of seabed trawl disturbance on benthic biomass, production, and species

569 richness in different habitats. *Canadian journal of fisheries and aquatic sciences*, *63*(4),
570 721-736.
571
572 Jørgensen LL, Planque B, Thangstad TH, Certain G. (2015) Vulnerability of megabenthic
573 species to trawling in the Barents Sea. *ICES Journal of Marine Science*, *73*(suppl_1), pp.i84-
574 i97.
575
576 Jørgensen LL. (2017) Vurdering av sårbare bunnhabitater i det nordlige Barentshavet;
577 trålfangete bunndyr fra det årlige «øko-toktet» (Evaluation of vulnerable benthos
578 communities in the northern barents sea; trawl-caught benthos from the "ecosystem-
579 survey") Rapport fra Havforskningen Nr. 19-2017. ISSN 1893-4536 (online).
580
581 Jørgensen LL, Primicerio R, Ingvaldsen RB, Fossheim M, Strelkova N, Thangstad TH, Manushin
582 I, Zakharov D. (2019) Impact of multiple stressors on sea bed fauna in a warming Arctic.
583 *Marine Ecology Progress Series* 608: 1-12.
584
585 Kaiser MJ, Ramsay K, Richardson CA, Spence FE, Brand AR. (2000) Chronic fishing disturbance
586 has changed shelf sea benthic community structure. *Journal of Animal Ecology*, 69(3),
587 494-503.
588
589 Kjesbu OS, Bogstad B, Devine JA, Gjøsæter H, Ingvaldsen R, Nash RDM, Skjaeraasen JE.
590 (2014) Synergies between climate and management for Atlantic cod fisheries at high
591 latitudes. Proceedings of the National Academy of Science, 111: 3478–3483.
592

593 Kovalev YA, Bogstad B. (2011) The scientific basis for management. In: Jakobsen, T. and
594 Ozhigin, V.K. (eds.) 2011: The Barents Sea – Ecosystem, Resources, Management. Tapir
595 Academic Press.
596
597 Landa CS, Ottersen G, Sundby S, Dingsør GE, Stiansen JE. (2014) Recruitment, distribution
598 boundary and habitat temperature of an arcto-boreal gadoid in a climatically changing
599 environment: A case study on Northeast Arctic haddock (*Melanogrammus aeglefinus*).
600 *Fisheries Oceanography.* 23, 506–520.
601
602 Lind S, Ingvaldsen RB. (2012) Variability and impacts of Atlantic Water entering the Barents
603 Sea from the north. Deep Sea Research Part I: *Oceanographic Research Papers*, 62, 70-88.
604
605 Lind S, Ingvaldsen RB, Furevik T. (2018) Arctic warming hotspot in the northern Barents Sea
606 linked to declining sea-ice import. *Nat Clim Chang* 8: 634−639.
607
608 Michalsen K, Dalpadado P, Eriksen E, Gjøsæter H and others (2013) Marine living resources
609 of the Barents Sea − ecosystem understanding and monitoring in a climate change
610 perspective. *Mar Biol Res* 9: 932−947.
611
612 Onarheim IH, Eldevik T, Smedsrud LH, Stroeve JC. (2018) Seasonal and regional
613 manifestation of Arctic sea ice loss. *Journal of Climate*, *31*(12), 4917-4932.
614
615 Sciberras M, Hiddink JG, Jennings S, Szostek CL, Hughes KM, Kneafsey B, Clarke LJ, Ellis N,
616 Rijnsdorp AD, McConnaughey RA, Hilborn R. (2018) Response of benthic fauna to

617 experimental bottom fishing: A global meta-analysis. *Fish and Fisheries*, *19*(4), pp.698-
618 715.
619
620 Shin YJ, Rochet MJ, Jennings S, Field JG, Gislason H. (2005) Using size-based indicators to
621 evaluate the ecosystem effects of fishing. *ICES Journal of marine Science*, *62*(3), 384-396.
622
623 van Denderen PD, Bolam SG, Hiddink JG, Jennings S, Kenny A, Rijnsdorp AD, Van Kooten T.
624 (2015) Similar effects of bottom trawling and natural disturbance on composition and
625 function of benthic communities across habitats. *Marine Ecology Progress Series*, *541*, 31-
626 43.
627
628 Årthun M, Eldevik T, Smedsrud LH, Skagseth Ø, Ingvaldsen RB. (2012) Quantifying the
629 influence of Atlantic heat on Barents Sea ice variability and retreat. *Journal of*
630 *Climate*, *25*(13), 4736-4743.
631
632