Atlas of Vulnerable Marine Ecosystem (VME) indicators observed on Bottom Trawl Surveys in Greenland waters during 2015-2019

Martin E. Blicher

Nanette Hammeken Arboe

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Authors: Martin E. Blicher and Nanette Hammeken Arboe

Survey taxonomists:
Alexey Golikov, Alexey (Kazan University, Russia)
Ámundur Nolsø (Kaldbak Marine Biological Laboratory/BIOFAR, Faroe Islands)
Anna Kari Sveistrup (Institute of Marine Research, Tromsø, Norway)
Birna Trygvadóttir (Kaldbak Marine Biological Laboratory/BIOFAR, Faroe Islands)
Denis Zakharov (Knipovich Polar Research Institute of Marine Fisheries and Oceanography, Russia)
Heidi Gabrielsen (Institute of Marine Research, Tromsø, Norway)
Igor Manushin (Knipovich Polar Research Institute of Marine Fisheries and Oceanography, Russia)
Jan Yde Poulsen (Greenland Institute of Natural Resources)
Jógvan Fróði Hansen (Kaldbak Marine Biological Laboratory, Faroe Islands)
Laure De Montety (Université Laval, Quebec, Canada)
Lis Lindal Jørgensen (Institute of Marine Research, Tromsø, Norway)
Natalia Zhuravleva (Saint-Petersburg Zoological Institute)
Natalya Anisimova Strelkova (Knipovich Polar Research Institute of Marine Fisheries and Oceanography, Russia)
Olga Zimina (Murmansk Marine Biological Institute, Russia)
Steinunn Hilma Ólafsdóttir (Marine Research Institute, Iceland)

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Cover photo: Sponge garden on the continental shelf in East Greenland (credit: Martin E. Blicher)

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Contact address: Pinngortitaleriffik, Greenland Institute of Natural Resources
Kivioq 2, P.O. Box 570
3900 Nuuk
Greenland

Phone: +299 361200
E-mail: mabl@natur.gl; nanette@natur.gl
Web: www.natur.gl

The report is only available in electronic format. You can download a PDF-file of the report at GINR's homepage: https://natur.gl/forskning/rapporter/

Contents

Abstract

This report is intended to provide an overview of *Vulnerable Marine Ecosystems* (VME) indicator taxa identified as bycatch in bottom trawls on stock assessment surveys conducted by Greenland Institute of Natural Resources during 2015-19. Catch weights of indicator taxa representing different VME habitat types are mapped, covering an area from the southern tip of Greenland up to 76°N in West and 67°N in East Greenland, and a depth range from 50m to 1500m. Several areas and single localities stand out, and regions of immediate concern are identified due to potential overlaps with bottom trawl fisheries. Data are available to management authorities for use in marine spatial planning.

Introduction

The seafloor around Greenland is central for Greenland's economy, as demersal fisheries, especially for prawns (*Pandalus borealis*) and Greenland halibut (*Reinhardtius hippoglossoides*), account for more than 80% of the national export value (The Economic Council 2017). It is also a habitat with an extraordinary richness of species with a total of more than 2000 *benthic* invertebrate species registered (Tendal & Schiøtte 2003). A healthy benthic ecosystem is crucial to sustain this productivity and biodiversity.

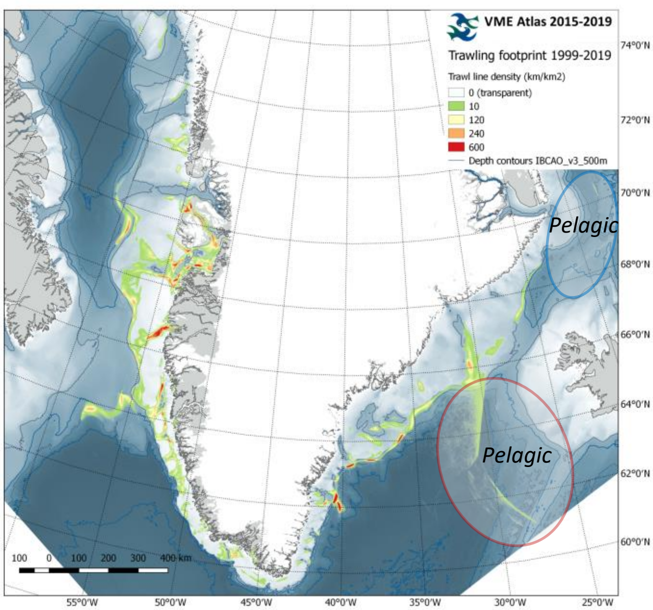


Fig. 1. Overview of trawl fishing in Greenland waters. This representation of fishing effort is based on haul-by-haul logbook data from the Greenland Fishery Licence Control (GFLK) from fisheries employing trawl gear from 1999 to 2019, all species and vessels inclusive. The data set was further processed to establish line vectors from start and end haul positions. The line vectors were interpolated with a 5 km search radius to a 1 km grid. The resulting density raster represents the distance trawled per unit area (km trawled per km^2) (for more details see Long et al. 2020). The vast majority of fishing represent demersal trawl hauls for prawn, Greenland halibut, cod and redfish. However, a pelagic fishery for mackerel and herring has developed rapidly in East Greenland waters since the late 2000s (Jansen et al., 2016). The main fishing effort for herring has been north of 68°N (blue circle), while the effort for mackerel has been focused south of 66°N (red circle) with minimal overlap with demersal fisheries.

Credit: Karl Brix Zinglersen

Motivated by a large gap in knowledge about the benthic ecosystem in Greenland waters in general, and the influence of climate changes, demersal trawling, oil exploitation and other potential stressors, the Greenland Institute of Natural Resources (GINR) has integrated a "trawl bycatch-program" on national stock assessment surveys in Greenland waters since 2015.

The approach is suggested as a minimum-standard for large-scale and long-term monitoring of marine bottom-living invertebrate fauna (benthos) in Greenland (Blicher et al. 2017) and the Arctic (CAFF 2017), and has proven effective for documenting large-scale patterns in benthic species distribution and community structure. The data can feed directly into management supporting sustainable development as agreed in the Convention on Biological Diversity in 1992 (CBD 1992), and the Sustainable Development Goals adopted by United Nations (UN) member states in 2015 (UNGA 2015).

The trawl bycatch-program enables the initial detection of potential *Vulnerable Marine Ecosystems* (VME's), which is the focus of this report. The VME concept was introduced to facilitate the spatial management of deep seas, identifying benthic habitats vulnerable to anthropogenic disturbance (FAO 2009). UN's Food and Agriculture Organization (FAO) defined VME's as exhibiting one or more of the following criteria: 1) unique or rare; 2) functionally significant, 3) fragile, 4) containing component species whose life-history traits make recovery difficult; or 5) structurally complex.

United Nations General Assembly (UNGA) Resolution 61/105 has called upon states to take specific action to protect VME's (UNGA, 2006).

Both the Northwest Atlantic Fisheries Organization (NAFO) and North East Atlantic Fisheries Commission (NEAFC) have adopted the VME concept, and are largely aligned in what is considered *VME indicator taxa*, i.e. organism records that suggest the presence of a VME with varying degrees of certainty dependent on the quantity and quality of data available. But they differ slightly in their approach in the sense that NEAFC consider main VME habitat types represented by indicator taxa at *family* level, while NAFO refer to a list of indicator taxa at higher taxonomic resolution (i.e. *species* or *genus*). In both cases, cold-water corals and large-sized sponges dominate the list of VME indicator taxa and habitat types. In this report we refer to the VME guidelines with respect to both NAFO, NEAFC and wider literature.

The intention with this atlas is to give a geographical overview of VME indicator taxa recorded as bycatch in demersal trawls during fishery assessment surveys conducted by GINR in Greenland waters during 2015-19.

Material and Methods

Bottom Trawl Surveys

GINR's stock assessment surveys with bottom trawl are conducted annually from June to September on the continental shelf and slope off the Greenland West coast from 59°30'N up to 72°30'N, and off the East coast from 59°30'N up to 67°N. Two types of surveys are conducted in both West Greenland and East Greenland: 1) Combined shrimp-fish surveys using a Cosmos 2000 trawl with a 20 mm mesh size in the cod-end with 'rock-hopper' ground gear comprising steel bobbins and rubber disks on depths from 50m down to 600m (Fig. 2 left photo). Towing time is 15 minutes and towing speed is between 2.0 and 2.5 knots (average swept area *c.* 0.03 km^2). Stations are positioned using 'buffered random' sampling, and about 50% of the stations included in the preceding year's design have been repeated as fixed stations in the following year; 2) Greenland halibut surveys using an Alfredo III trawl with a mesh size of 140 mm and a 30 mm mesh-liner in the cod-end. The depth interval surveyed is from 400m to 1500m. Towing time is 30 minutes and average towing speed is 3.0 knots (average swept area *c.* 0.07 km^2). Station positions are based on random allocation with a buffer zone around each station.

In 2016 an additional survey outside the standard survey area was conducted in Melville Bay, Northwest Greenland using Cosmos trawl.

All trawls are equipped with trawl sensors (Furuno Marport) sending live information about depth, temperature, bottom contact, and pitch and roll for most effective trawling. For all stations metadata (position, depth, bottom temperature, wire length, gear type etc.) are entered directly into GINR's Access database.

Upon completion of a trawl set, the catch is moved onto a conveyor, visually sorted, and recorded in a catch database. Fish and shrimp species are weighed and measured, while the remaining catch of primarily benthic invertebrates is identified to the lowest possible taxon and weighed. We followed the recommendation of Blicher et al. (2015) and implemented the INAMon benthos protocol for sampling, sorting, species identification, photo documentation, preservation of focus taxa and data entry into the standard routines on bottom trawl surveys. For this purpose 2 to 4 benthos taxonomy specialists from the INAMon network attended each survey. By doing so, all steps in the process from sampling to data entry could be completed onboard, with the result of being able to retrieve a complete dataset shortly after the ending of surveys.

Fig. 2. Left: Cosmos trawl with a large bycatch of *Geodia* sponges. **Right:** Example of small bycatch sorted in taxonomic groups.

Overall, we completed 1506 sampling stations between 2015 and 2019, of which 981 were from Cosmos trawl, 525 from Alfredo trawl (Fig. 3). Besides additional beam trawl sampling (see Blicher et al. 2017), visual surveys with a towed video sled and bottom-triggered drop camera has also been carried out at targeted locations in a partnership with Institute of Zoology at Zoological Society of London and others (Yesson et al. 2016, Gougeon et al. 2017, Long et al. 2020) However, for the purpose of producing a geographical overview of observations of VME indicator taxa, only trawl bycatch data are included in this report. All information is stored in GINR's 'Malotus' database (MS Access).

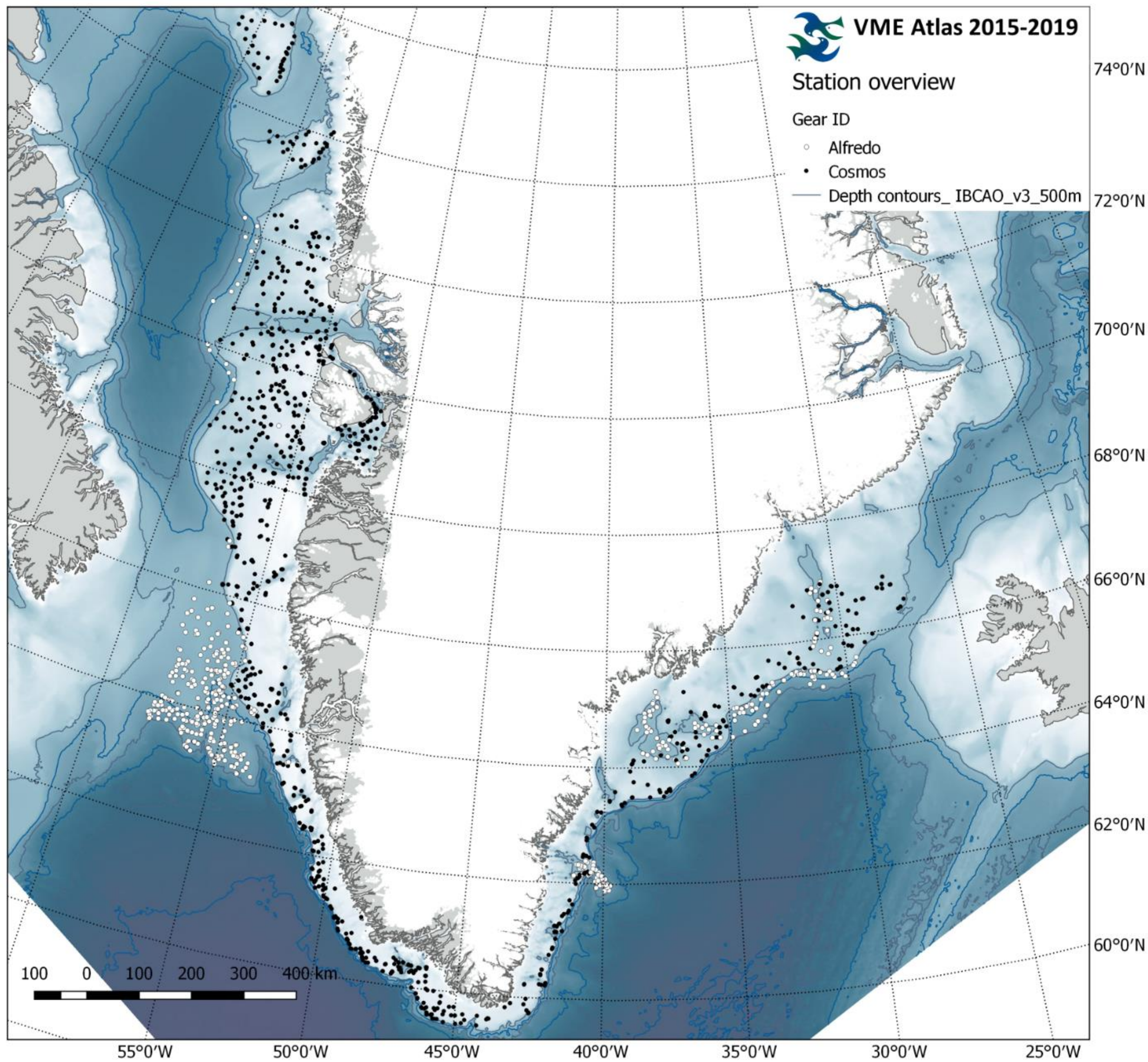


Fig. 3. Overview of bottom trawl stations on GINR's stock assessment surveys conducted in 2015-19.

VME indicator taxa and habitat types

For this report we have combined NAFO's and NEAFC's lists of VME indicator taxa (ICES 2013) with the additions in (Buhl-Mortensen et al. 2019). For the description of VME habitat types we use the NEAFC definitions with the addition of the sponge category, *Deep Arctic Sponge Aggregation*, and the division of the NEAFC's *Sea Pen Field* into *Sublittoral* and *Bathyal* subcategories as suggested in Buhl-Mortensen et al. (2019) (Supplementary table). Only VME indicator taxa that have been observed as bycatch in GINR's bottom trawl samples are included.

Mapping VME trawl data

Our observations of VME indicator taxa and VME habitat types in Greenland waters was mapped using QGIS 2.18 software. The maps display the catch weight of VME indicator taxa in trawl hauls at station level as compiled from database records. Catchability of benthic invertebrates in demersal trawls is generally low. Therefore, the recorded catch weights do not represent the actual biomass present on the seabed but should instead be regarded as a relative measure of abundance. For the biomass maps, different value ranges were used, as catches of some taxa were much smaller than others, with catch weights varying from <0.0001 kg to several tons. The trawl sets are presented as stations using the point coordinates at the beginning of each tow at the sea bottom. For the maps in this report, we have not distinguished between the two trawl types (but see Fig. 3). Both NAFO and NEAFC have set threshold values of catches of VME indicator taxa in the commercial fishery, above which specific actions needs to be taken (NAFO 2017, NEAFC 2014, Table 1). These thresholds represent total bycatch weight per haul irrespective of trawl type or swept area. As such, our catch weight values can be compared to the NAFO and NEAFC Encounter Threshold values for VME indicator taxa, but it should be kept in mind that commercial trawl hauls usually last several hours. Also, the question of the applicability of common threshold values across all taxa has been questioned. The threshold for sponges is most relevant for massive sponges such as *Geodia* spp. (Ostur), but seems too high for other lighter sponges, e.g. glass sponges (Murillo et al. 2020). The same seem to be the case for coral thresholds that favor only the largest types, such as *Paragorgia arborea* (bubblegum coral), while other species, can be found in high densities on the seafloor, enough to qualify as VME habitat, without exceeding threshold values in trawl hauls (Long et al. 2020).

Therefore, the maps presented in this report should be used to indicate where VME indicator taxa and VME habitat types are present in relatively high and low densities. High-density areas, or areas with presence of unique or rare habitats or taxa, may need special consideration by management authorities. The information can be used directly in VME assessments, i.e. as a basis for a VME designation, or as means of identifying geographical areas where more detailed research is needed.

In that respect, it is relevant to mention the limitations in the geographical coverage, which is defined by the framework of GINR's bottom trawl surveys as described above. And while areas outside the existing footprint of commercial fisheries are well represented within the survey area, the station lay-out strategy does indeed cause some areas and depths to be under-represented or absent in the data set (see Fig. 3 and Discussion).

Fisheries management organization	Encounter threshold for move-on requirement (per haul)
Northwest Atlantic Fisheries Organization (NAFO)	Sponges: 300 kg Sea pens: 7 kg Corals (other): 60 kg
North East Atlantic Fisheries Commission (NEAFC)	Sponges: 400 kg per haul Corals: 30 kg

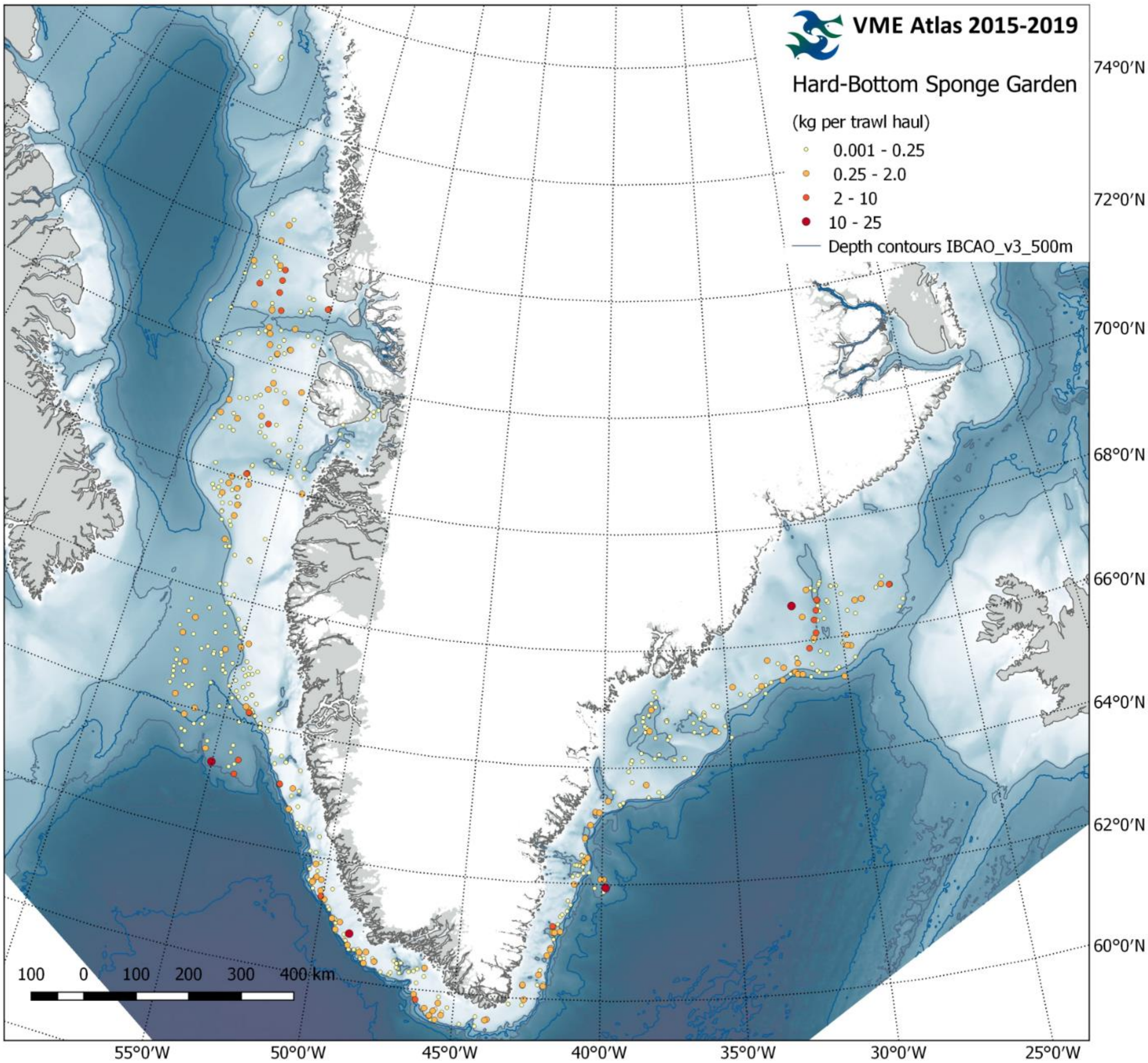
Table 1. Encounter threshold values to activate move-on requirement in the commercial trawl fishery in NAFO and NEAFC.

Results

We present maps of observations of the *VME habitat types* described in the supplementary table. For most habitat types this includes several individual VME indicator taxa pooled into one catch weight value per station. The segregation of taxa into pre-defined habitat types should be regarded an attempt to simplify complex patterns in ecological composition for management purposes. Species follow their environmental niches and form 'sub'-habitat types or co-exist in ways that do not always match these simplified habitat types. This may be important in relation to more specific research or management questions but is not the scope of this report. For more information about occurrences of individual species or taxa, or restricted areas, please contact the authors of this report.

VME habitat type – Sponges

The catch weight of identified taxa belonging to four different VME habitat types are plotted: 1) Hard-Bottom Sponge Garden, 2) Ostur Sponge Aggregation, 3) Deep Arctic Sponge Aggregation and 4) Glass Sponge Community, referring to the list of taxa in the supplementary table.



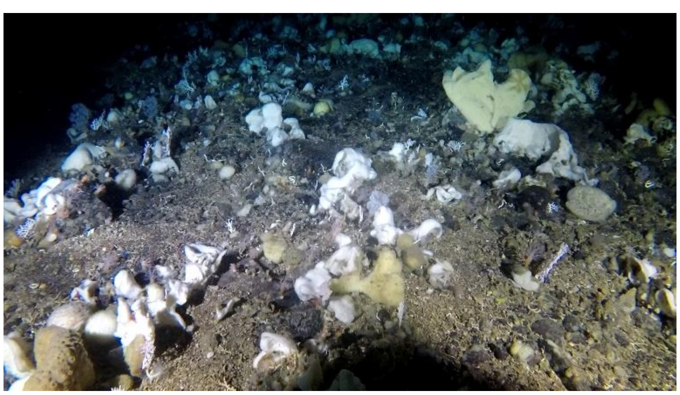
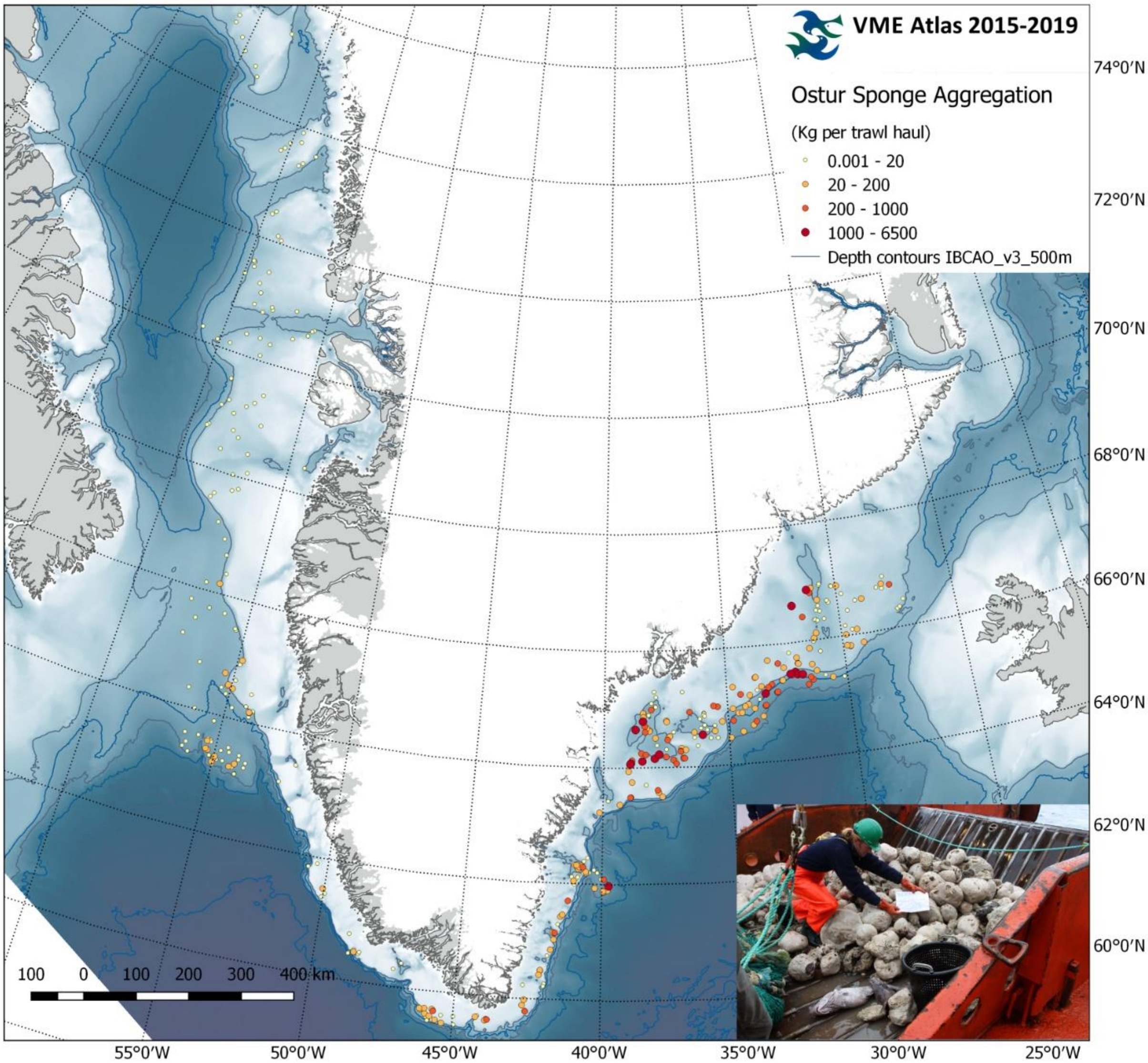


Fig. 4. The Hard-Bottom Sponge Garden habitat type includes VME indicator species from ten sponge families. Our observations do not suggest a core distribution area for this habitat type. Indicator taxa of this habitat type can be found across the entire depth range of GINR's surveys from 50 to 1500m depth. Areas with high-density observations are found in both East and West Greenland. Example still from the East Greenland shelf is shown.



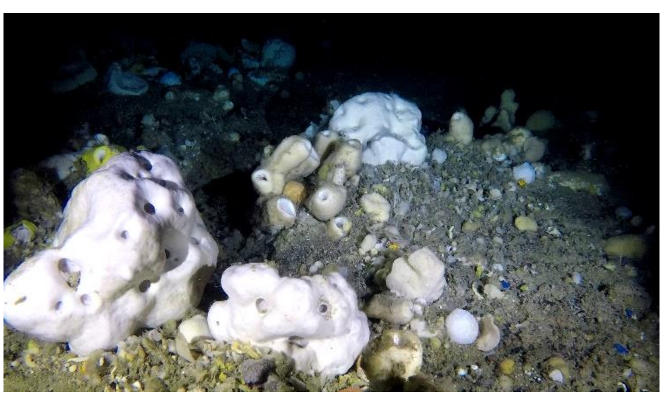
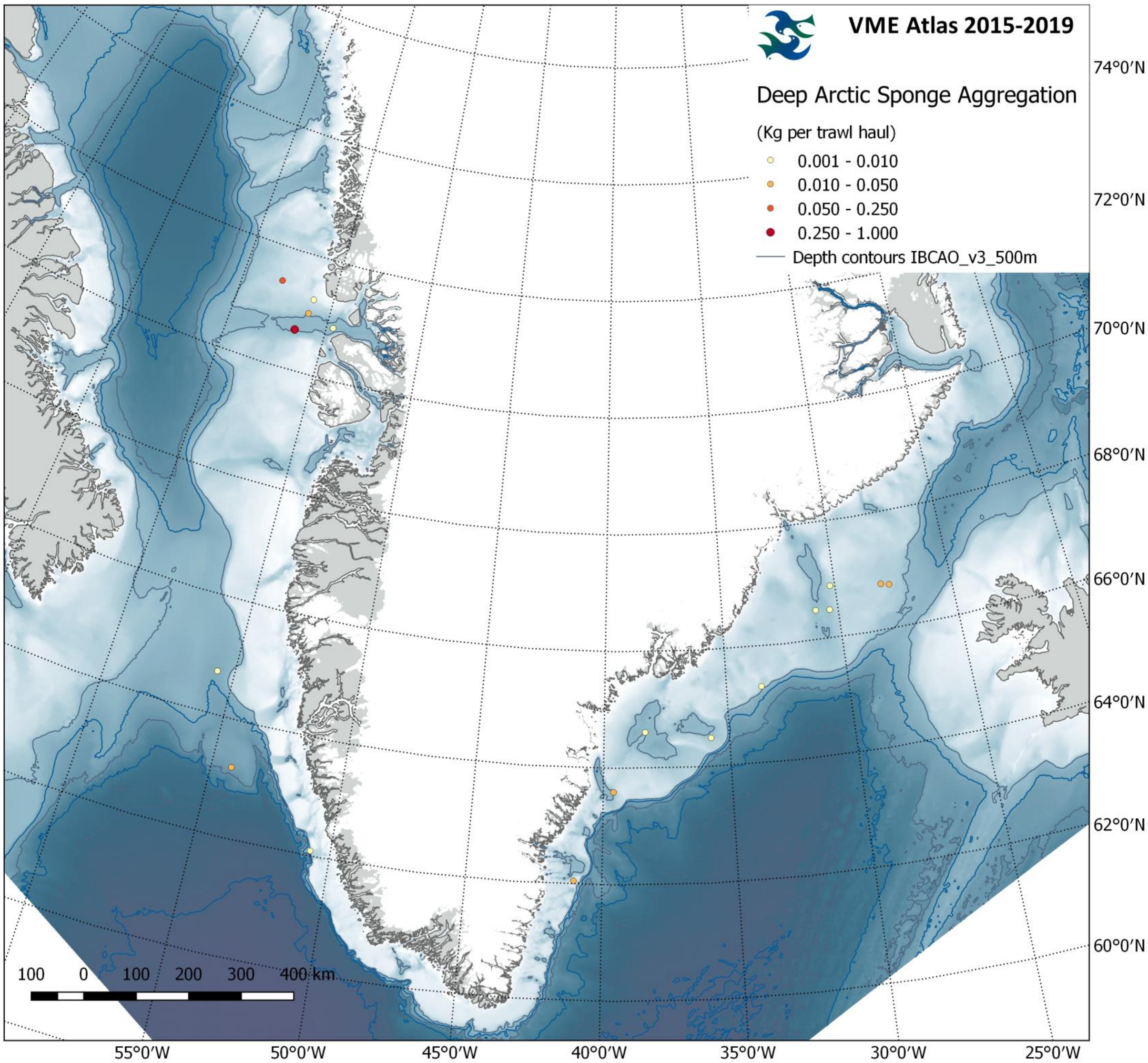
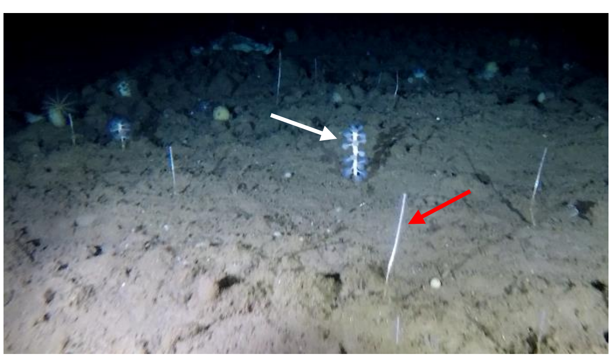


Fig. 5. The Ostur Sponge Aggregation habitat type is defined by the presence of several large tetractinellid sponges (up to 50 kg per individual). Indicator taxa have been observed deeper than 120m. The habitat type seems relatively rare in West Greenland becoming more common around the southern tip of Greenland. In East Greenland high-density observations are frequent north of 64°N, where trawl bycatch weights of >1000 kg have been observed at depths from 300 to 1450 m. Example still photos show a medium-size Ostur catch on deck (above), and an in-situ image from East Greenland of a locality dominated by *Geodia* spp. and *Stryphnus ponderus* (left).





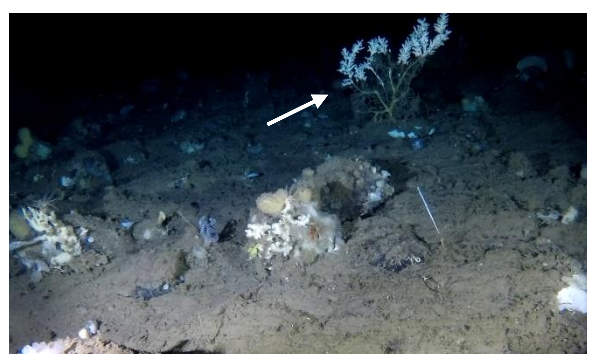
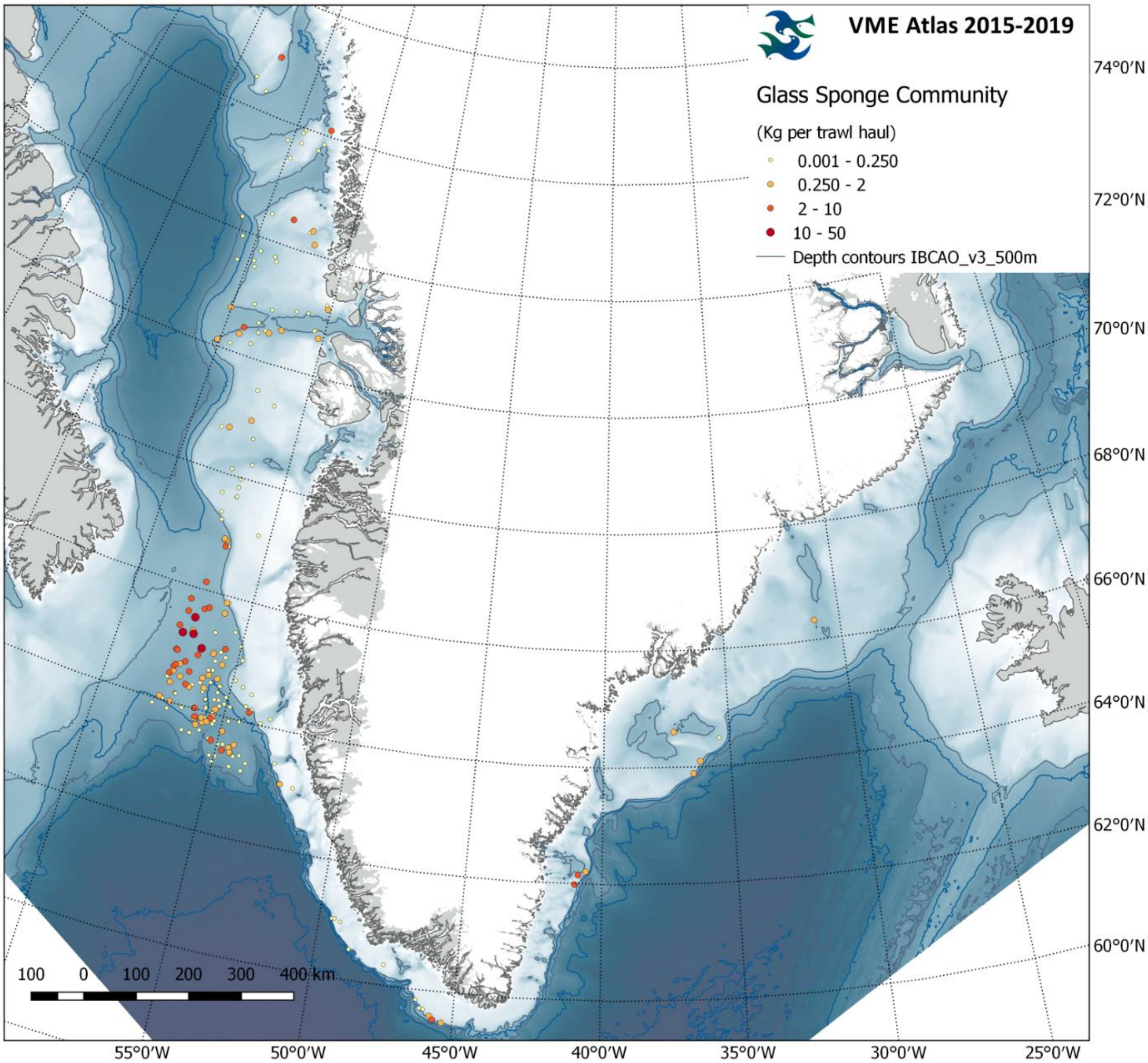


Fig. 6. VME indicator taxa from the **Deep-Arctic Sponge Aggregation** habitat type are rarely caught in demersal trawls, and only in low amounts. Most observations in the trawl bycatch are from 200-600m depth. Video surveys in East Greenland have shown areas with high abundance of *Asbestopluma* sp.(red arrow, left photo), *Chondrocladia* sp. (white arrow, left photo) and *Cladorhiza* sp. (white arrow, right photo) in the northernmost part of the survey area.



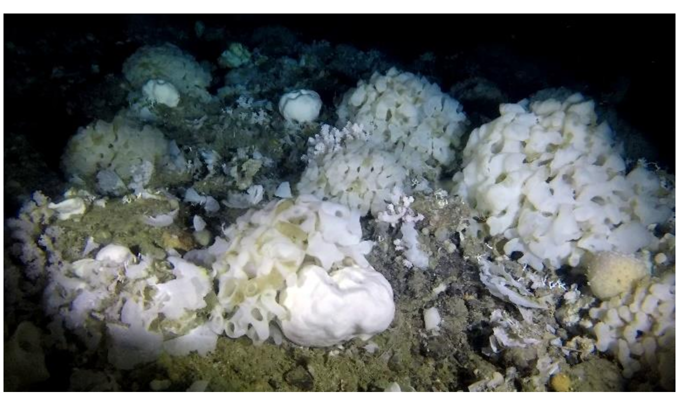


Fig. 7. *Asconema foliatum*, is the only VME indicator of the **Glass Sponge Community** habitat type identified in the survey. Most frequent observations and highest catch weights are found in West Greenland north of 64°30’N at depths >500m in the Davis Strait sill region, but dense Glass Sponge Communities have been video documented both in West and East Greenland, see example still photo, where indicator taxa for the Ostur Sponge Aggregation and Hard-Bottom Sponge Garden habitat types are also present, e.g. *Geodia* sp. and *Weberella bursa,* besides Cauliflower corals.

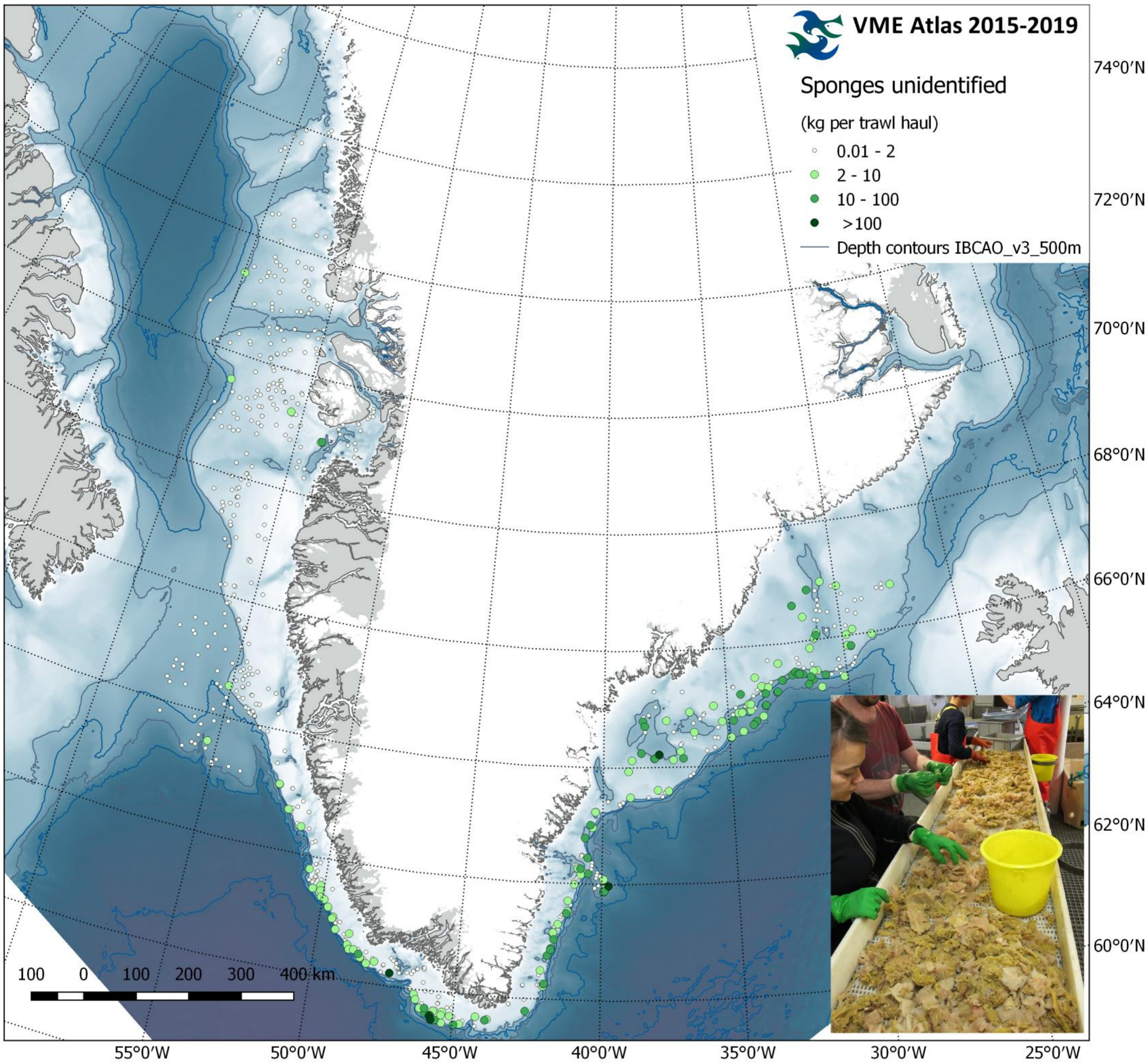


Fig. 8. Unidentified Sponges. In many cases there is a significant, sometimes dominant, fraction of sponges in the trawl catch that cannot be identified, mainly due to the damage caused by the trawl gear and the initial handling of the catch onboard. There is a bias in these observations towards the more fragile types, such as branching, vase- or leaf shaped taxa, e.g. Axinellidae and Chalinidae belonging to the Hard-Bottom Sponge Garden habitat type. These observations, registered as 'Porifera *indet*', are plotted here. There is a tendency of relatively high catch weights on the narrow shelf-slope area in SW and SE Greenland, which may be related to the hard substrate types dominant in this high-energy environment (strong currents), see (Gougeon et al. 2017). Further north in East Greenland the amount of unidentified sponges correlate with the very large catches of Ostur Sponge Aggregation indicator taxa.

VME habitat type – Corals

The catch weight of identified taxa belonging to six different VME habitat types are plotted: 1) Hard Bottom Gorgonians and Black Corals, 2) Soft Bottom Gorgonians, 3) Cauliflower Coral Field, 4) Seapen Field Bathyal, 5) Seapen Field Sublittoral, 6) Cup Coral Field, referring to the list of taxa in the supplementary table.

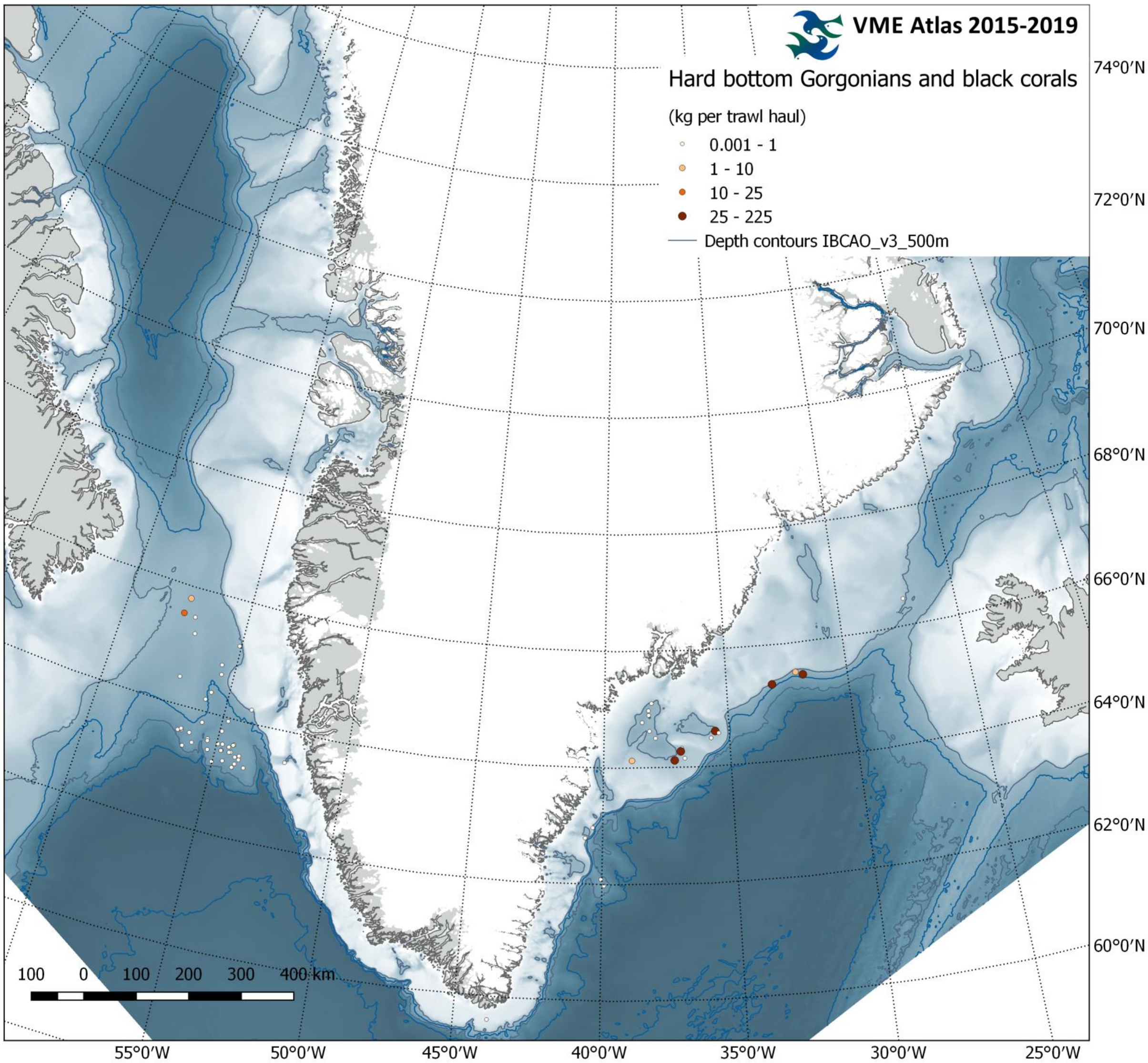
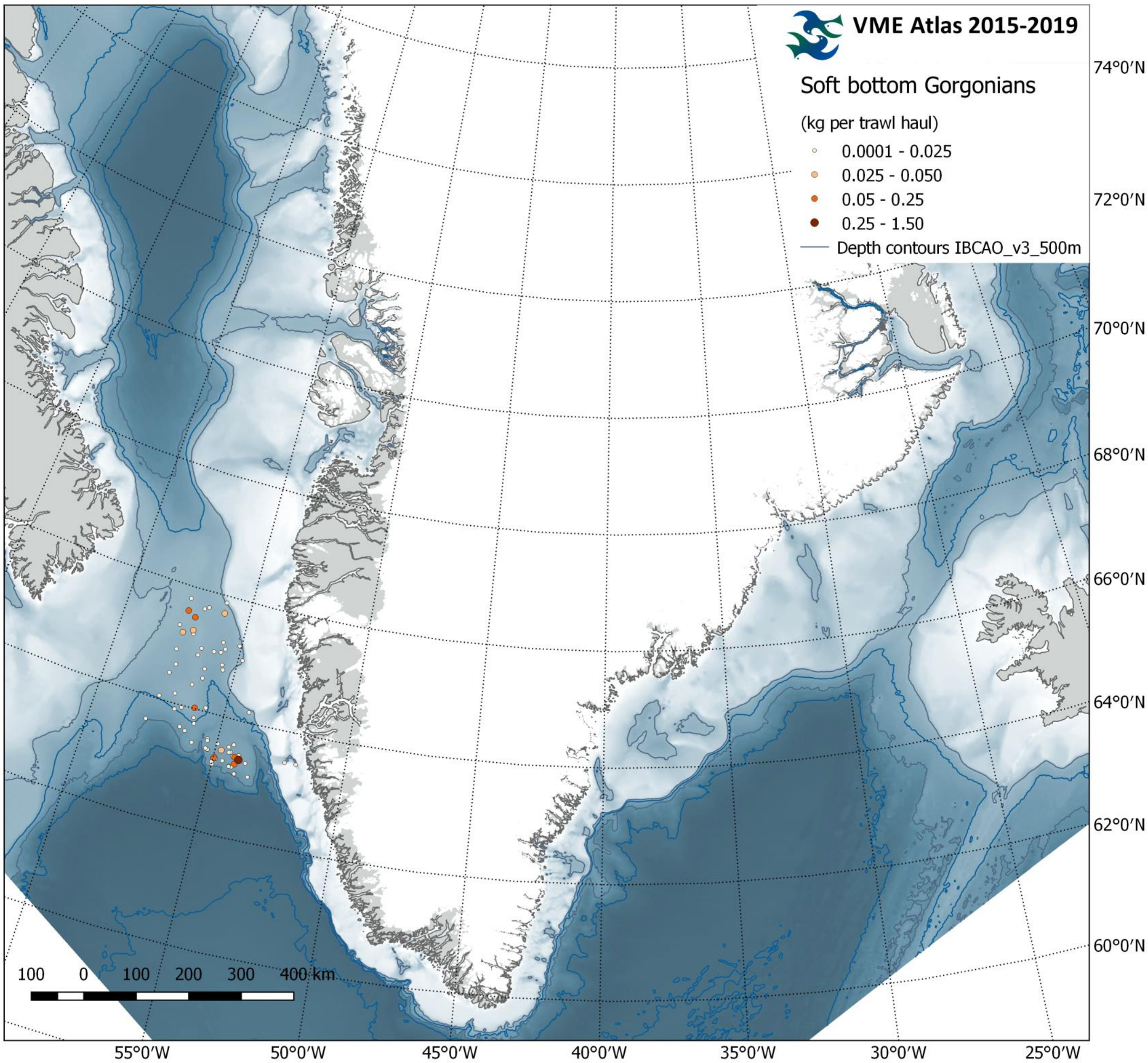


Fig. 9. The **Hard-Bottom Gorgonians and Black Corals** habitat type is represented by five different species (supplementary table), mainly found >300m depth. The only species exceeding 1 kg catch weight is the bubblegum coral, *Paragorgia arborea,* which is observed between *64 and 66°N* in both West and East Greenland waters (up to >200 kg). Black coral *Paramuricea* sp. is observed frequently at depths >1000m in an area south of 64°N in West Greenland. The remaining indicator species belonging to this habitat type are only caught sporadically. Left photo show *Paragorgia arborea* with large *Geodia* sp. sponge in a rocky habitat at c. 570m depth off Toqqusaq Bank (c. 64°30′N) in West Greenland. This occurrence is not documented with trawl bycatch samples.



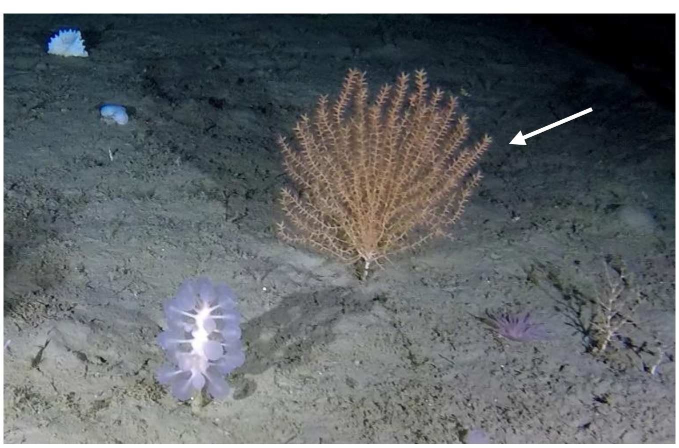
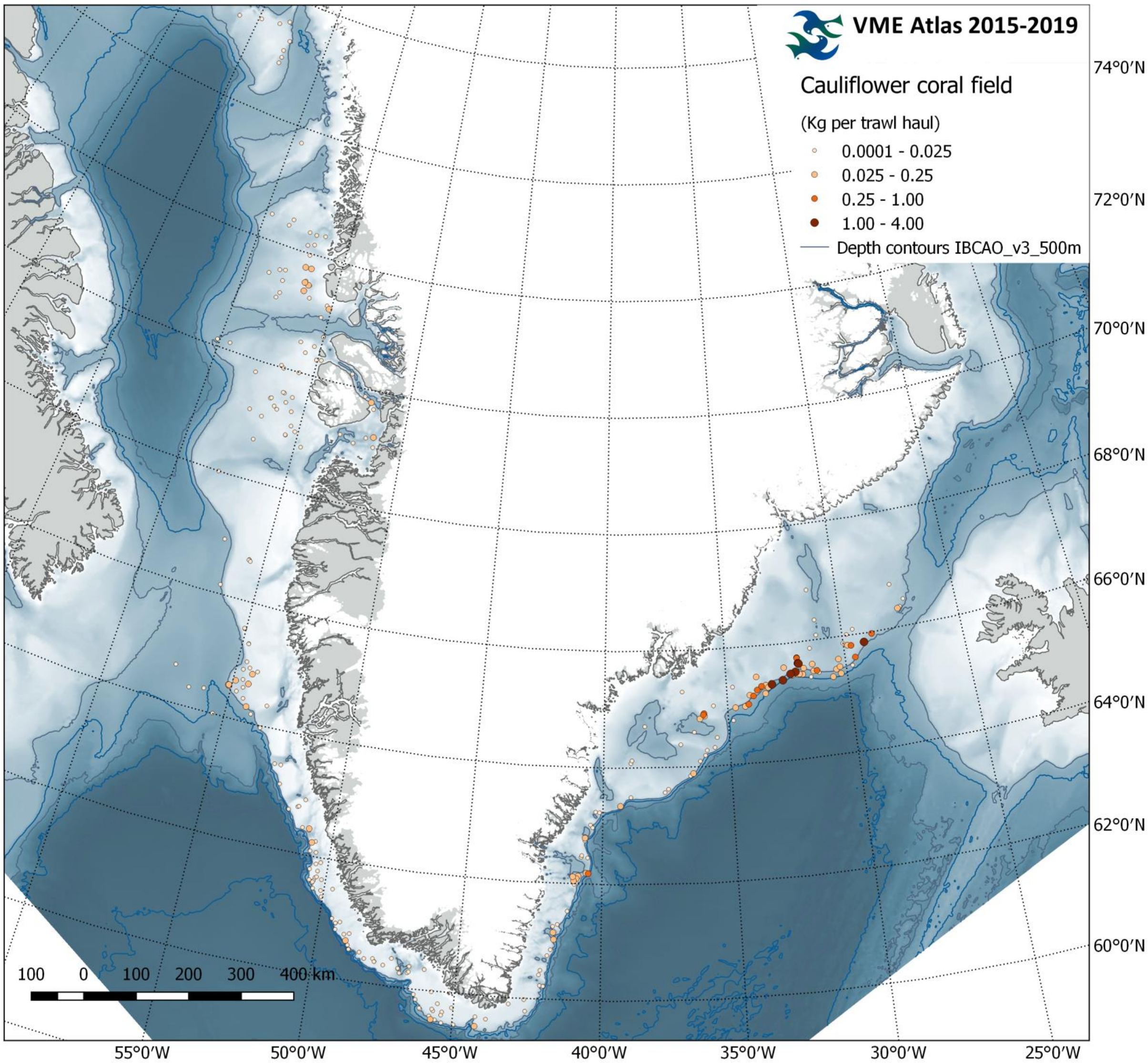


Fig. 10. Bamboo coral, *Acanella arbuscula* is the only VME indicator of the **Soft-Bottom Gorgonians** habitat type found in the survey area. It is exclusively observed in West Greenland between 63 and 66°N at depths >500m most frequently in the areas south and north of an existing fishing ground for Greenland halibut. Example still photo from the area show *Acanella arbuscula* (white arrow), cup coral *Flabellum alabastrum*, and the Cladorhizidae sponge, *Chondrocladia grandis*.



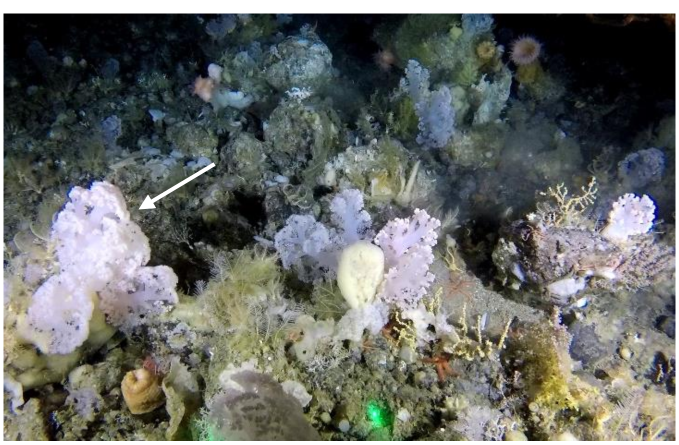


Fig. 11. Cauliflower corals, Nephtheidae, are observed across almost the entire survey area. In West Greenland relatively dense aggregations have been observed in the slope area off Toqqusaq Banke (64–65°N) and west of the Sigguup Nunaa Peninsula (71–72°N). But the densest aggregations are observed on the East Greenland slope between 65 and 66°N.

Example still shows the structural complexity of a Cauliflower Coral Field on rocky ground at a depth of 585m, on the continental slope off Toqqusaq Bank, West Greenland (c. 64°30'N). Cauliflower corals (white arrow), Feather stars, Gorgonians, Sponges and calcified bryozoans are present with a rich associated fauna. Laser dots (green) are 20cm apart, the left-hand dot is partially obscured (Long et al. 2020).

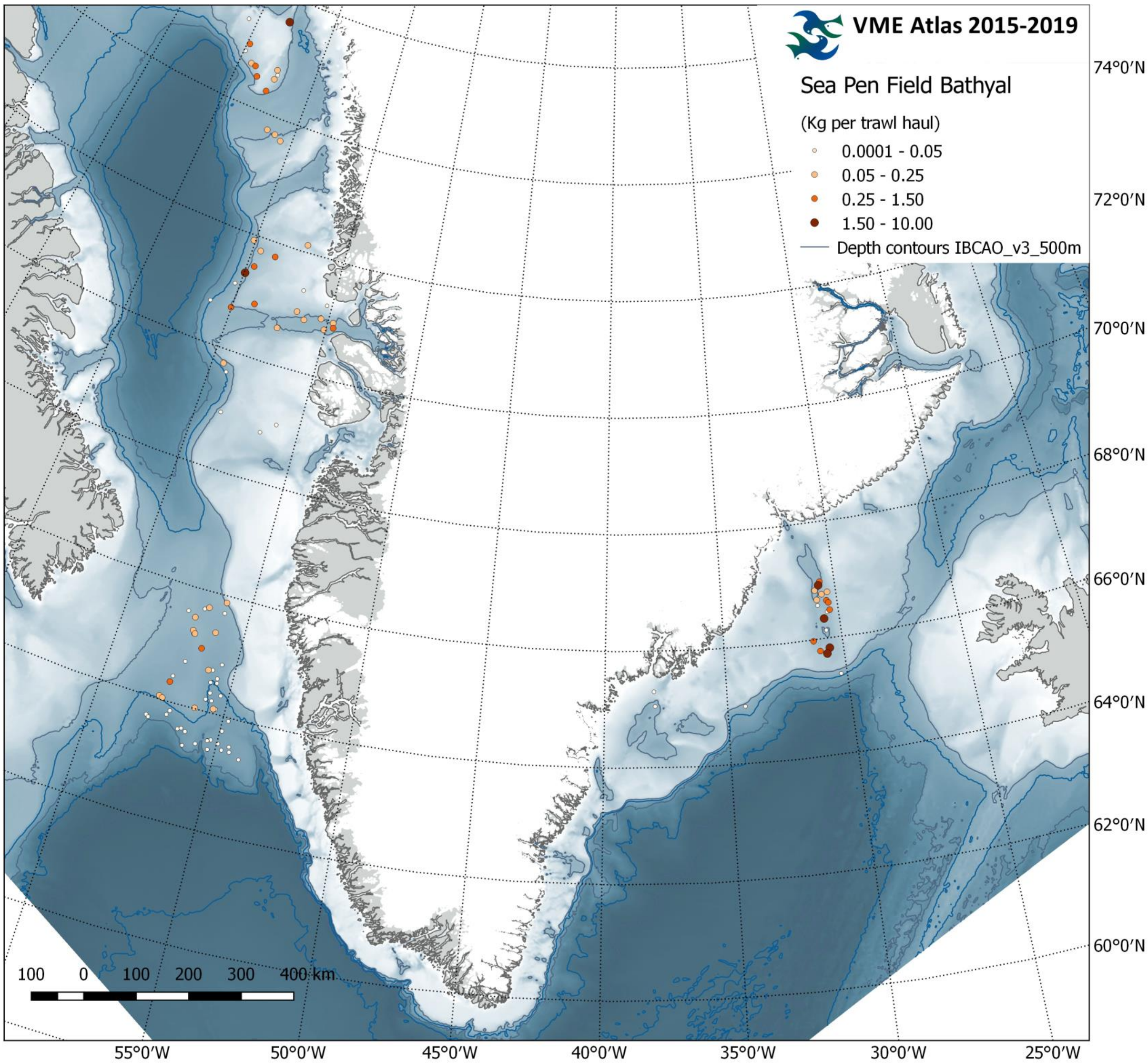
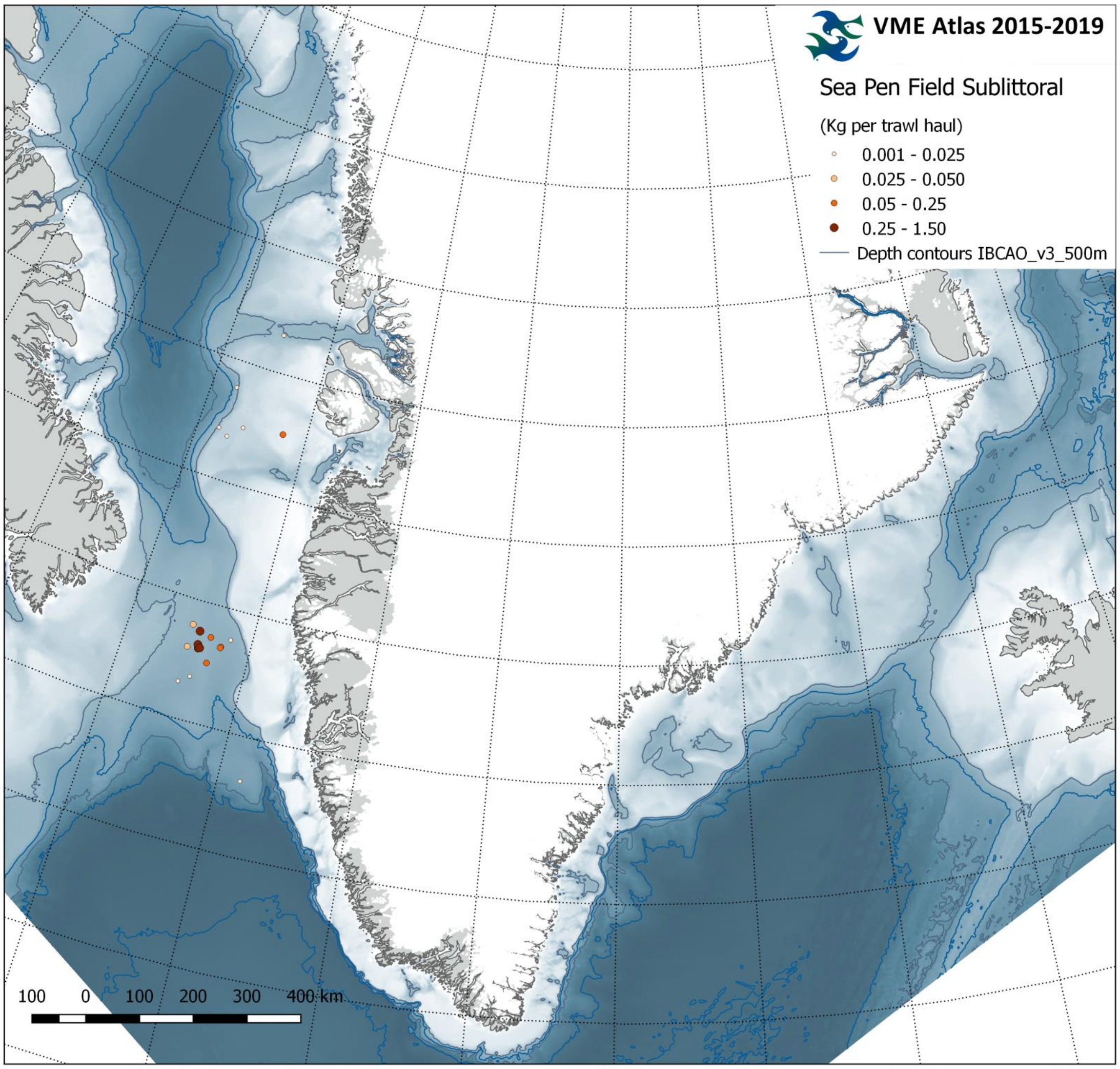


Fig. 12. The **Sea Pen Field Bathyal** habitat type is represented by *Anthopthilum grandiflorum* and *Umbellula* sp. with little spatial overlap in observations. The habitat type is found at mud bottom and almost exclusively >300m depth. *Anthopthilum grandiflorum* is generally observed more southerly (<72°N) than *Umbellula* sp. and only in West Greenland. Highest catch weights of *Umbellula* sp. are observed at localities in northern Baffin Bay in West Greenland, and a deep trough connected to the Kangerlussuaq fjord in East Greenland.
Example still photo shows *Anthopthilum grandiflorum* (white arrow), with sea anemone, brittle star, and sponges in the Davis Strait sill region.



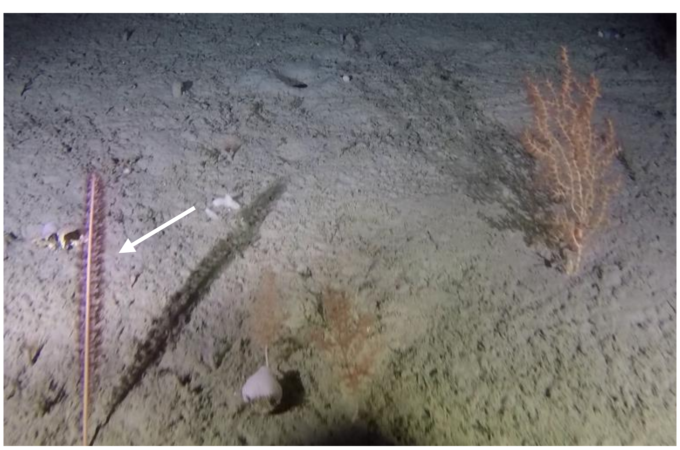
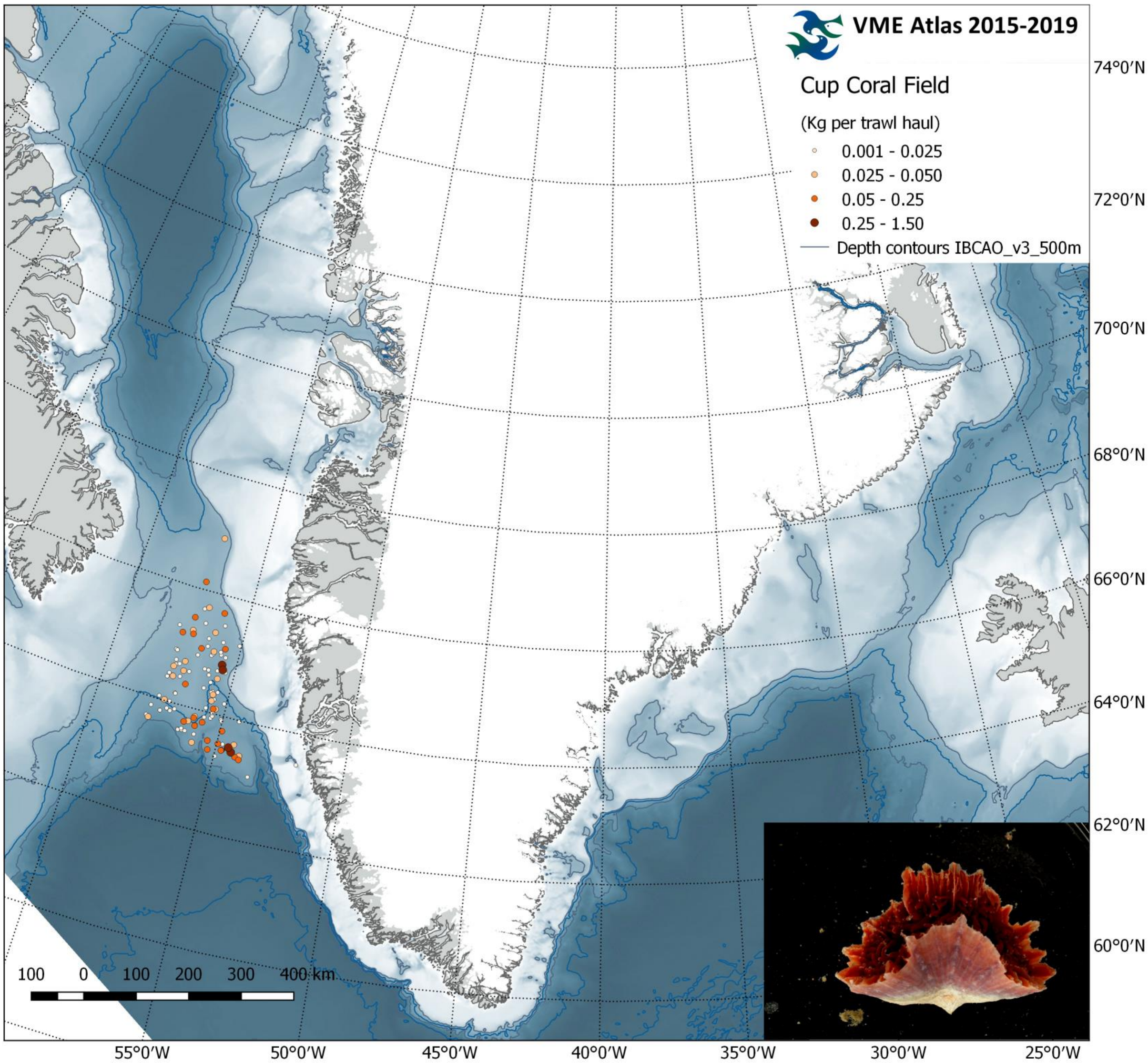


Fig. 13. The **Sea Pen Field Sublittoral** habitat type is represented by *Pennatula* spp. and *Halipteris finmarchica.* With a few exceptions, our trawl bycatch records are limited to an area in the Davis Strait sill region at 65-66°N and 600-800m depth. Video surveys have revealed a dense occurrence of *Halipteris finmarchica* at two deeper localities south of 64°N in the same region (Long et al. *In prep*).
Example still photo show *Halipteris finmarchica* (white arrow) together with bamboo coral *Acanella arbuscula* on typical muddy substrate.



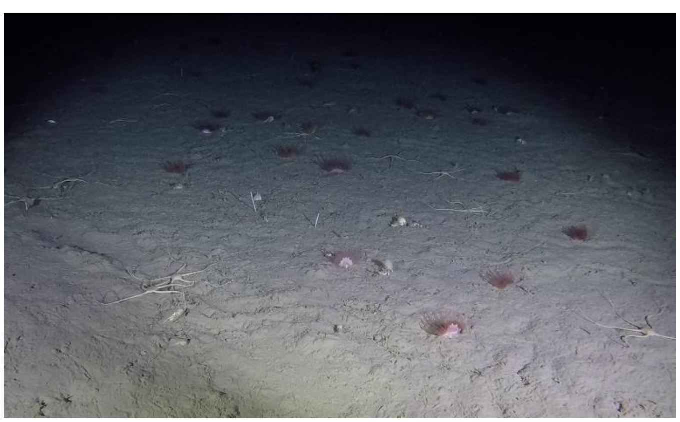


Fig. 14. A single species, *Flabellum alabastrum*, represent the **Cup Coral Field** habitat type. *Flabellum alabastrum* are only caught in the Davis Strait sill region at depths >500m.

Despite low catch weights, video surveys have documented local densities of >1 individual per m^2 (Long et al. *In prep*), which underlines the poor retention in trawls, and the fact that the trawl catch weight can only be regarded as a relative measure of the actual abundance.

VME habitat type – Feather Stars

The catch weight of identified crinoid (feather stars) taxa is plotted. The **Mud- and sand-emergent fauna** habitat type is represented by species from the two NEAFC indicator families, Antedonidae and Bourgueticrinidae. It is noted that NAFO's VME list includes only *Trichometra cubensis* from the Antedonidae family. We have not observed *Trichometra cubensis* in Greenland.

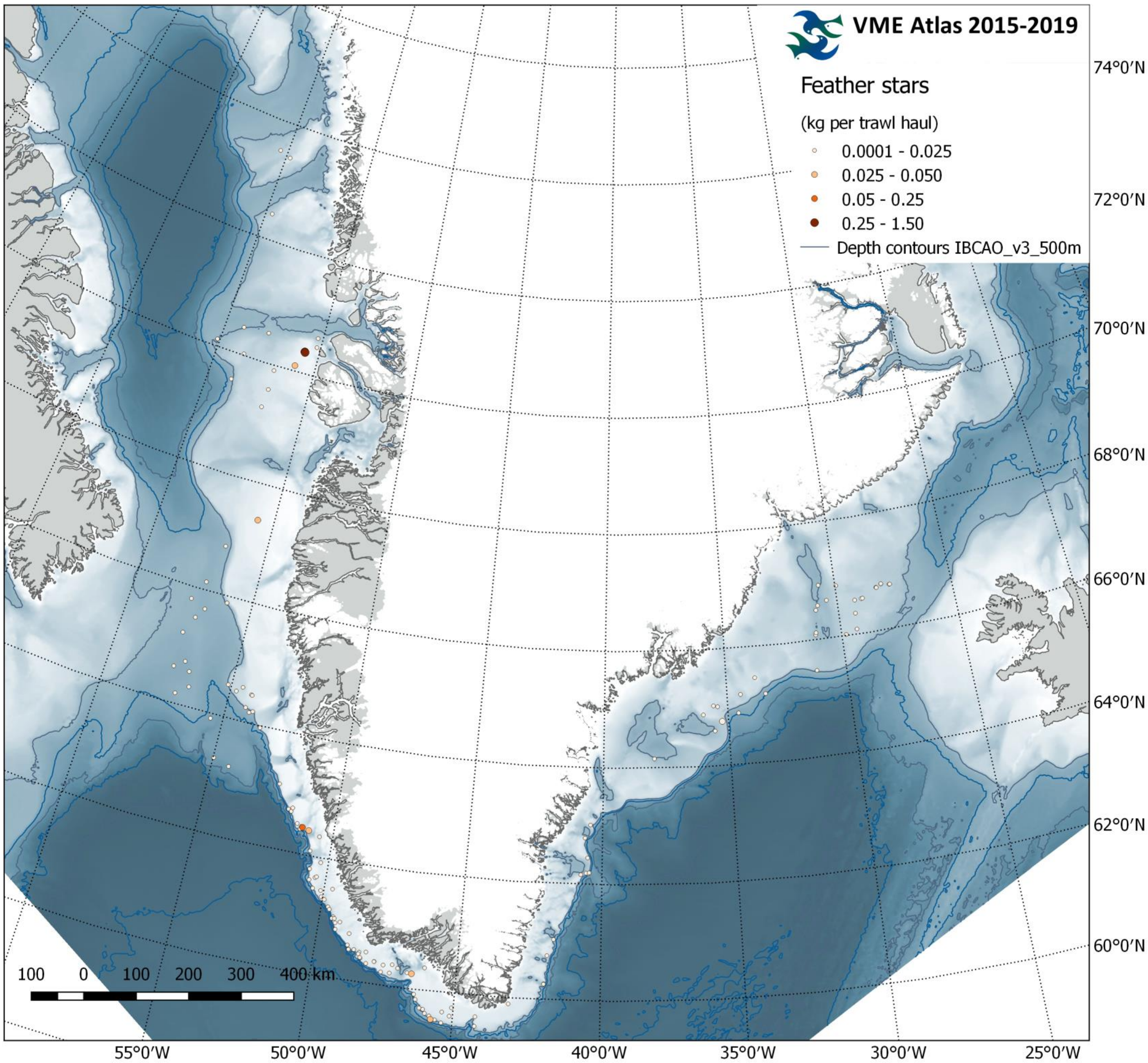


Fig. 15. Feather stars (Crinoidea) represent the **Mud- and Sand-emergent Fauna** VME habitat type. This name is however not a good description of the feather star habitats in Greenland, which are mainly found on hard ground on the shelf and slope. Feather stars are most commonly present in the bycatch in Southwest Greenland. However, very dense concentrations of feather stars have been observed further north, around Store Hellefiskebanke and west of Qeqertarsuaq (c. 69°N). Example still photo shows rocky habitat west of Qeqertarsuaq, with dominance of *Heliometra glacialis.* Brittlestars, mainly *Ophiopholis aculeata*, are also present in large numbers. Laser dots (green) are 20cm apart.

Discussion

The catch data presented here show that a wide range of VME indicator taxa, here integrated into VME habitat types, are distributed throughout Greenland waters. Some seem concentrated in restricted areas and/or depth ranges, while others have a broader distribution. Some are only observed at a few localities. As such, the data provides a basis for pointing out areas of specific concern in a management context.

However, it needs to be kept in mind that such conclusions are limited to GINR's bottom trawl survey area, and to bottom types that are trawlable. This limits the access to for example: 1) near-shore shallows and off-shore banks, 2) Depths >1500 meters, 3) very soft and very rough bottom, 4) steep cliffs. All of which may provide suitable conditions for some of the VME indicator taxa described here. In some cases, this has been confirmed by visual surveys (video sled, drop camera), which also reveal the patchy nature of the benthic fauna communities. This recently resulted in Greenland's first discovery of reef-forming *Desmophyllum pertusum* (previously named *Lophelia pertusa*) on a steep part of the continental slope in South Greenland (Kenchington et al. 2017), and the documentation of a Cauliflower coral garden VME candidate on the edge of Toqqusaq Bank in Southwest Greenland (Long et al. 2020).

Visual surveys have also confirmed the low catchability of commercial-type trawls. The catchability is taxon-specific and likely to be affected by substrate type and rugosity. Therefore, the interpretation of VME catch weights presented here should be done with caution. The absence of VME indicator taxa in a single trawl haul does not necessarily reflect an absence of these taxa on the sea bottom on the locality. But presence data are indisputable and, given the large number of trawl hauls on annual stock assessment surveys, the approach is considered effective for documenting broad distribution trends and areas with unusual concentrations of VME indicator taxa.

Overlap with demersal trawl fisheries

The intergovernmental fisheries management bodies, NAFO and NEAFC, have adopted FAO's VME definition. The concern about the impact of bottom trawling on benthic habitats is also clearly formulated in the sustainability definition of Marine Stewardship Council (MSC 2014). In Greenland the off-shore fisheries for Greenland halibut (*Reinhardtius hippoglossoides*) and cold-water prawns (*Pandalus borealis*) in West Greenland are MSC-certified, but in both cases a general lack of knowledge about habitat distribution and potential impact of trawling has been acknowledged, and research initiated (e.g. Yesson et al. 2016; Gougeon et al. 2017). Based on the overview maps of occurrences of indicator taxa belonging to pre-defined VME habitat types presented in this report, the Davis Strait sill region and the East Greenland shelf-slope region are identified as areas of potential interaction. This has direct implications for the spatial management of economically important trawl fisheries (see Fig. 1). An area in West Greenland between 64°30'N and 68°N is currently closed for trawling for Greenland halibut (Government of Greenland 2017), which will effectively prevent impact on potential VME's deeper than 600 meters, where trawling for Greenland halibut normally occur. Impacts of Greenland halibut trawling in Davis Strait south of 64°30'N and Baffin Bay north of 68°N are currently being analyzed in a PhD study based on video surveys (Long et al. *In prep*). In the context of concrete spatial management, geographic scale is an important factor when assessing interactions between fisheries and habitats. What could seem like an overwhelming spatial overlap in large overviews, may be less so when addressed at a higher geographic resolution (with accurate geo-referenced information). This is illustrated with an example in Fig. 16 showing Ostur Sponge Aggregations and trawling density in East Greenland in two maps of different scale. Therefore, we recommend management authorities in Greenland to apply geo-referenced information in marine spatial planning, and to implement a methodology where the geographical scale and resolution is adjusted to match specific cases under consideration. Several *GIS* tools are available and implemented by others (e.g. https://kart.fiskeridir.no/fiskeinord). Besides involving annual trawl bycatch data and commercial trawl logbook positioning data presented in this report, data from other benthic sampling activities, such as visual surveys (e.g. Long et al. 2020; Long et al. *In prep*) and beam trawls surveys (Blicher & Hammeken Arboe 2017) could be combined for integrated assessments. This would support a more accurate identification of existing and potential future conflict zones, as well as areas with a lack of information. A management plan for the seafloor in Greenland, which is under development, should act as a framework for sustainable management, ensuring a systematic and consistent approach to the conservation of benthic habitats in a balance with economic considerations.

Conclusion

This report presents for the time overview maps of the occurrence of VME indicator taxa aggregated into pre-defined VME habitat types based on trawl bycatch data from GINR’s stock assessment surveys in East and West Greenland waters in 2015-19. Several larger areas as well as single locations stand out. We call attention to potential conflict areas between existing bottom trawling and VME habitats. For management purposes, we underline the importance of applying such geo-referenced information on an appropriate geographic scale with respect to the data available and the question being asked. Future surveys will continue to build up GINR’s benthos database and improve the understanding of the distribution of VME habitats. This knowledge can contribute directly to sustainable development of human activities in Greenland waters. Geo-referenced information will be made available to management authorities on request. Explicit knowledge needs can act as a guide for future sampling activities to maximize the relevance of our sampling program in the context of marine spatial planning.

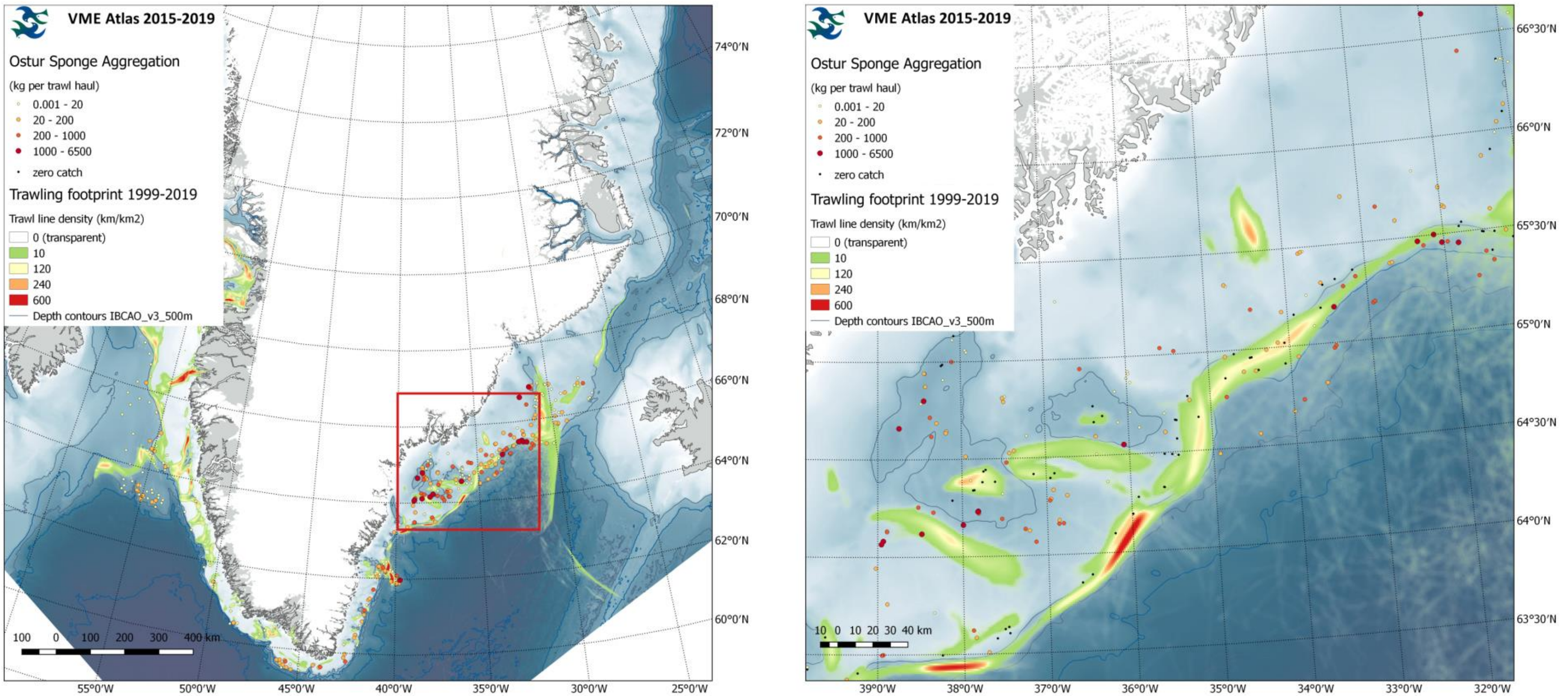


Fig. 16. Highlighting the importance of scale for the interpretation of spatial overlap between bottom trawling and VME's, in this case Ostur Sponge Aggregations. **Left:** Overview map combining Fig. 1 and Fig. 5. **Right:** Enlargement of an area in East Greenland (red square in left figure) with frequent observations of *Ostur* and intense bottom trawling.

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Supplementary table

SPONGES		
VME Habitat type	**Family**	**Identified taxa**
Hard-Bottom Sponge Garden	Axinellidae	Axinellidae *Phakelia powerbanki*, *Phakelia* sp.
	Chalinidae	*Cladocroce ventilabrum* *Cladocroce* sp. *Haliclona* sp.
	Acarnidae	*Iophon piceum* *Iophon* sp.
	Coelosphaeridae	*Forcepia* sp. *Lissodendoryx (Lissodendoryx) complicate* *Lissodendoryx* sp.
	Microcionidae	*Antho (Antho) dichotoma*
	Mycalidae	*Mycale* sp. *Mycale (Mycale) lingua* *Mycale (Mycale) loveni*
	Polymastiidae	Polymastiidae *Polymastia* sp. *Polymastia grimaldii* *Polymastia hemisphaerica* *Polymastia thielei* *Polymastia uberrima* *Quasillina* sp. *Quasillina brevis* *Radiella* sp. *Radiella sol* *Tentorium semisuberites* *Weberella bursa*
	Stylocordylidae	*Stylocordyla borealis* *Stylocordyla* sp.
	Tethyidae	*Tethya citrina* *Tethya* sp.
	Tetillidae	*Craniella cranium* *Craniella polyura* *Craniella* sp. *Tetilla* sp.
Ostur Sponge Aggregation	Ancorinidae	*Stelletta* sp. *Stryphnus ponderosus*
	Geodiidae	*Geodia* sp. *Geodia atlantica* *Geodia barretti* *Geodia macandrewii* *Geodia phlegraei*
	Theneidae	Theneidae *Thenea* sp. *Thenea muricata* *Thenea valdiviae*
Deep Arctic Sponge Aggregation	Cladorhizidae	Cladorhizidae *Asbestopluma* sp. *Asbestopluma (Asbestopluma) pennatula* *Chondrocladia* sp. *Chondrocladia (Chondrocladia) grandis* *Cladorhiza* sp.
Glass Sponge Community	Rossellidae	*Asconema* sp. *Asconema foliatum*

CORALS		
VME Habitat type	**Family**	**Identified taxa**
Hard Bottom Gorgonians and Black Corals	Acanthogorgiidae	*Acanthogorgia armata*
	Paragorgiidae	*Paragorgia arborea*
	Plexauridae	*Paramuricea* sp.
	Primnoidae	*Primnoa resedaeformis*
	Schizopathidae	*Stauropathes arctica*
Soft Bottom Gorgonians	Isididae	*Acanella arbuscula*
Cauliflower Coral Field	Nephtheidae	*Nephtheidae* *Drifa* sp. *Drifa glomerata* *Duva* sp. *Duva florida* *Gersemia* sp. *Gersemia fruticosa* *Gersemia rubiformis* *Pseudodrifa* sp. *Pseudodrifa groenlandica* *Pseudodrifa nigra*
Seapen Field Bathyal	Anthoptilidae	*Anthoptilum grandiflorum*
	Umbellulidae	*Umbellula* sp. *Umbellula encrinus*
Seapen Field Sublittoral	Halipteridae	*Halipteris finmarchica*
	Pennatulidae	*Pennatula* sp. *Pennatula grandis* *Pennatula inflata* *Pennatula phosphorea*
Cup Coral Field	Flabellidae	*Flabellum (Ulocyathus) alabastrum*

CRINOIDS (Feather Stars)		
VME Habitat type	**Family**	**Identified taxa**
Mud- and sand-emergent fauna	Antedonidae*	*Antedonidae* *Hathrometra tenella* *Heliometra* sp. *Heliometra glacialis* *Poliometra prolixa*
	Bourgueticrinidae	*Conocrinus lofotensis*

Supplementary table. List of VME indicator taxa identified on GINR's trawl assessment surveys with reference to VME habitat types as defined by NAFO and NEAFC with the additions of Buhl-Mortensen et al. (2019).

*NAFO's VME list includes only *Trichometra cubensis* from the Antedonidae family