Interim report: Deep-sea benthic habitats and the impacts of trawling, Davis Strait, West Greenland

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Purpose

This report outlines activities and preliminary findings of ongoing research. This research has principally been conducted as part of an IUCN Best 2.0 project in which the Zoological Society of London and Sustainable Fisheries Greenland (SFG) are partners. Contributions from Greenland Institute of Natural Resources' (GINR) benthos monitoring programme, *INAMon,* are included separately in Appendix II. The purpose of the report is to inform SFG of progress to date. We understand SFG may subsequently use this to inform the Marine Stewardship Council (MSC) audit of the West Greenland offshore Greenland halibut (WGOGH) fishery. Thus SFG may elect to share this with the Conformity Assessment Body (CAB) conducting the audit. Some of this material was presented and discussed at a meeting between ZSL and SFG (18/07/18).

Survey work

In October 2017 the annual stock assessment cruise conducted by the Greenland Institute of Natural Resources in the southern area of the fishery and adjacent areas (NAFO areas 1C and 1D), provided an opportunity to conduct a benthos survey. Surveys were conducted between 63˚11.01' N and 65˚15.92' N at depths of 649 to 1,479m (fig. 1). Bad weather at the start of this cruise meant we were not able to survey at all the intended stations, hence poorer coverage in the northern portion of the survey (fig. 1).

There were two survey types:

- Benthic video sled (23 stations)
- Beam trawls, with video (8 stations)

Beam trawl stations conducted with video had two purposes: 1) to obtain physical samples of benthos to be analysed by GINR's taxonomic specialists on-board, providing a detailed description of species composition of macro- and megafauna, and 2) to use this as a taxonomic reference to aid the identification of benthic megafauna from imagery of all stations.

Additionally, bycatch of benthic invertebrates has been recorded during the annual stock assessment surveys by GINR in surveys of 2015, 2016 and 2017 (190 stations).

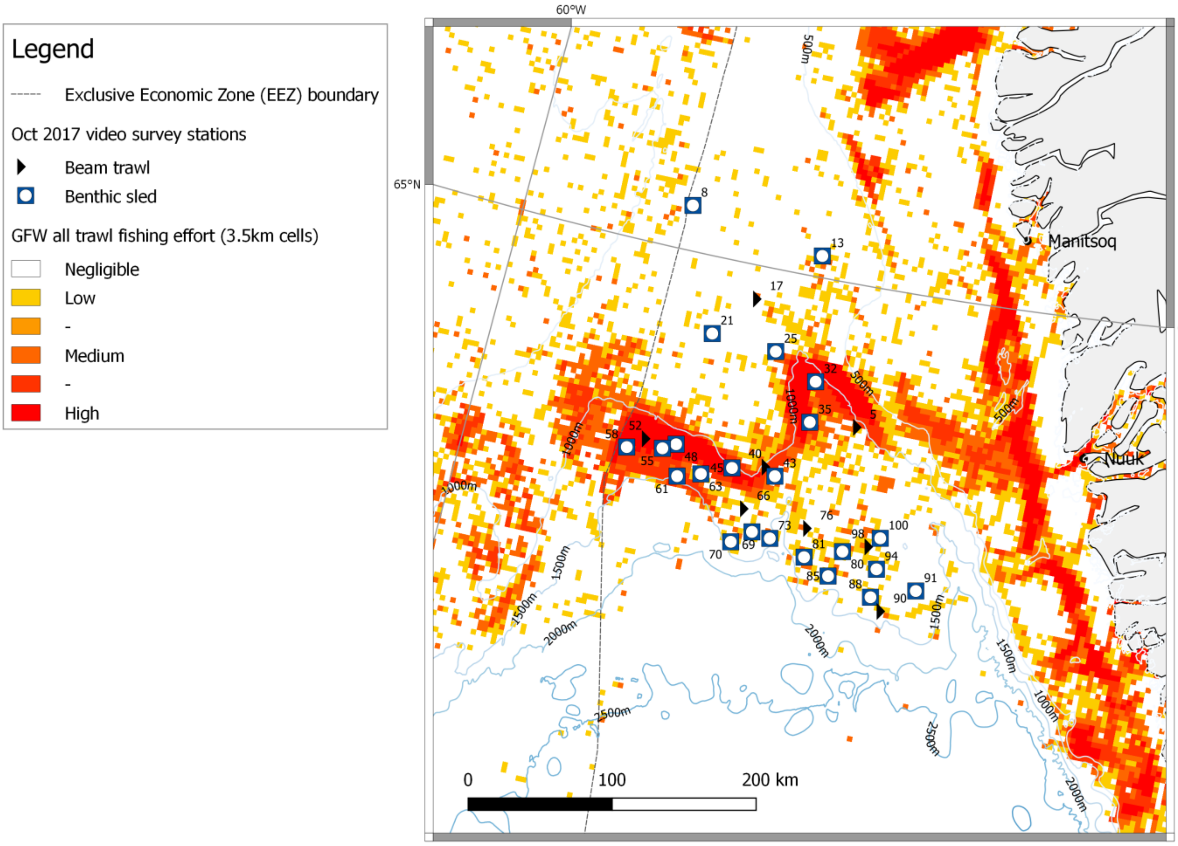

Figure 1: Map showing locations of video surveys conducted using a beam trawl and benthic sled, stations were sub-sampled from the 2017 Greenland halibut stock assessment survey stations. Many of the northern stations were omitted from the stock assessment survey (and thus the benthic video survey) due to adverse weather at the start of the cruise. Fishing effort data was obtained from Global Fishing Watch (GFW) and represents hours of all trawling effort, from 2012 to 2016 inclusive, aggregated into grid with 3.5 km cells. Depth contours are drawn at 500m intervals.

Fishing effort data

Raw fishing effort data was initially obtained from Greenland Fishery and License Control (GLFK) from 2000 to 2016. This haul by haul dataset is obtained from logbooks and transcribed manually into a database. It was evident that this data set contained some errors, and more work is needed to clean this dataset. An alternative source of effort data is Global Fishing Watch (GFW) (http://globalfishingwatch.org/) which is based on automatic identification system (AIS) position data from vessels. A machine learning approach is used to identify fishing activity including specifically identifying trawling (de Souza et al., 2016). The GFW approach offers some advantages from a research perspective:

- Spatial coverage, it can be used to determine fishing effort in Greenlandic and Canadian EEZ.
- Near real-time data, from 1st January until 72 hours prior to data download date.
- Publically available, which means our research is more readily reproducible.
- Produced by a systematic, consistent, methodology, which is detailed in the literature.

Note the GLFK data is exclusively halibut fishing effort, whereas the GFW data represents all trawling effort. Despite the advantages of the GFW data there are merits of the GLFK data, notably it is a longer time series. We continue to explore the options with regards the processing and utility of both datasets. Preliminary analyses and figures included in this report use 2012-2016 GFW data aggregated to a 3.5km grid.

Analytical approach

Video surveys are designed to sample across a spectrum of fishing effort (see above), subsequent analysis thus aims to determine the impact of trawling on abundance and structure of communities, accounting for the effect of environmental variables.

A preliminary analysis of the videos taken from the benthic video sled involved counting occurrences of 34 megafauna taxa (Appendix I) as they crossed a midline superimposed onto the videos. The selected taxa were a combination of potential vulnerable marine ecosystem (VME) indicators, fish, large and/or common epifauna. Macrofauna and infauna could not be quantified with this approach. Each fauna observed was counted only once and recorded in the most taxonomically detailed of the 34 taxa. Using the speed of the sled, the estimated width of the field of view at the midline and the duration video footage, the 'swept area' was calculated. This meant abundance per area of each of these 34 taxa could be estimated. Trawling intensity for each station was estimated, see 'Fishing effort data'. The fishing effort for each station (n = 20) was categorized into 'none' (effort = 0, n = 10), 'low' ($0 <$ effort $\leq$ median effort value, n = 5) and 'high' (effort $>$ median effort value, n= 5).

A more detailed analysis (in progress) will annotate all fauna from stills sampled from videos. A systematic process for sampling the most in focus stills at regular intervals has been developed. Accordingly 901 images have been uploaded to a browser based annotation platform, BioImage Indexing, Graphical Labelling and Exploration (BIIGLE) (Langenkämper et al., 2017) (fig. 2) .

Occurrence data from video sled, beam trawl and bycatch data will be combined with environmental data (depth, slope, temperature, salinity current) to model habitat suitability for VME indicator species in relation to the footprint of the fishery.

Habitats

According to a historical 1899 survey the dominant underlying substrate is a grey clay (Jorgensbye, 2017). Review of footage suggests that, per the EUNIS Habitat classification scheme, the principal habitat is 'A6.5 deep-sea mud'. Glacial drop stones/rocks are an important component providing a hard substrate for attachment of fauna, including VME indicator species. The availability of rocky, materials varies across the area surveyed. These are broad level classifications based on abiotic features. A more nuanced classification of the habitats would have incorporated a hierarchical classification of biotope with reference to cold-water corals (Davies et al., 2017) and/or other habitat forming species.

The work to date has not estimated the total area of habitat(s) in relation to the footprint of the fishery, and we consider the present dataset too limited to make such a calculation.

Vulnerable marine ecosystems (VMEs)

Vulnerable marine ecosystems are defined by FAO guidelines (FAO, 2009). For this area, there is neither; definitive guidelines as to which species should be considered VME indicators, nor a consensus as to what level of abundance and/or diversity of VME species constitutes a VME. There is an existing list of VME indicator species for the NAFO Regulatory Area (NRA) (NAFO, 2012). Those taxa on this list encountered to date are presented below (Table 1). Additionally we include taxa which based on our interpretation of the FAO guidelines and wider literature should be considered VME indicators in the study area. The estimated density of some VME indicator species at particular stations was notable and is highlighted (Table 2). These included cup corals (*Flabellum alabastrum*), bamboo corals (*Acanella arbuscula*) and sea pens (*Halipteris finmarchica*). A high density of any indicator species may potentially be considered a VME, for example see discussion of *Flabellum alabastrum* meadows (Jorgensbye, 2017).

Table 1: List of observed benthic VME indicator species within the southern West Greenland offshore Greenland halibut (WGOGH) fishery and adjacent area (NAFO 1C and 1D). Benthic VME indicator species list per the NAFO Regulatory Area list, amended to include additional species where it was considered appropriate. Additions of VME indicator species to the list are indicated with '*'. Observations are bycatch from annual stock assessment trawl surveys and/or video surveys (includes beam trawl and benthic sled) , indicated by an 'x'. Adapted from: (NAFO, 2012)

Common name of taxonomic group	Taxon	Family	Phyllum	Bycatch from trawl surveys (2015-17)	Video surveys (2017)
Large-sized sponges	*Geodia spp.*	Geodiidae	Porifera	x	
	Mycale (Mycale) lingua	Mycalidae		x	x
	Thenea muricata	Pachastrellidae		x	x
	Polymastia spp.	Polymastiidae		x	x
	Asconema foliatum	Rossellidae		x	x
	Craniella cranium	Tetillidae		x	x
Stony corals	*Flabellum alabastrum* *	Flabellidae	Cnidaria	x	x
Black corals	*Stauropathes arctica**	Schizopathidae	Cnidaria	x	x
Small gorgonian corals	*Acanella arbuscula*	Isididae	Cnidaria	x	x
Large gorgonian corals	*Acanthogorgia armata*	Acanthogorgiidae	Cnidaria	X	
	Paragorgia arborea	Paragorgiidae		x	
	Paramuricea spp	Plexauridae		x	
Sea pens	*Anthoptilum grandiflorum*	Anthoptilidae	Cnidaria	x	x
	Halipteris finmarchica	Halipteridae		x	x
	Pennatula sp	Pennatulidae		x	x
Sea lilies (Crinoids)	*Poliometra prolixa**	Antedonidae	Echinodermata	x	
	*Heliometra glacialis**	Antedonidae		x	
Sea squirts	*Boltenia ovifera*	Pyuridae	Chordata		x

Table 2: Maximum observed densities of selected VME indicator species. Estimated at the station level from October 2017 benthic video sled survey, Davis Strait, west Greenland.

Common name of taxonomic group	Taxon	Family	Phyllum	Density (individuals/m^2)	Station ID
Stony corals	*Flabellum alabastrum* *	Flabellidae	Cnidaria	6.5	21
Small gorgonian corals	*Acanella arbuscula*	Isididae	Cnidaria	0.5	8
Sea pens	*Halipteris finmarchica*	Anthoptilidae	Cnidaria	4.7	61

Impact of trawling

This preliminary analysis is based on video stations for which adequate footage was obtained (n = 20). For this limited dataset boxplots showing abundance of selected taxa at differing levels of trawling effort were produced (fig. 2) Taxa selected were those for which there were adequate observations for a statistically valid comparison. For most taxa the lowest median abundance was observed at the highest fishing effort. This was the case when aggregating: all VME indicator species ('all_vme'), all sponges ('all_sponge') and all corals ('all_coral') (see Appendix I for definition of aggregated groups). The overriding trend would appear to be that epifaunal abundance is reduced by trawling. This is seen clearest in those taxa which were common and found across the survey area, for example *Acanella arbuscula* ('A_arbuscula'). Trends are less clear for rarer taxa, such as *Anthoptilum grandiflorum* ('A_grandiflorum') and *Halipteris finmarchica* (H_finmarchica), likely a consequence of the limited data. Not all epifauna appears to be effected, for example the sea urchin, *Phormosoma placenta* ('P_placenta'), was common throughout the surveyed area, with its abundance seemingly unimpacted by trawling effort.

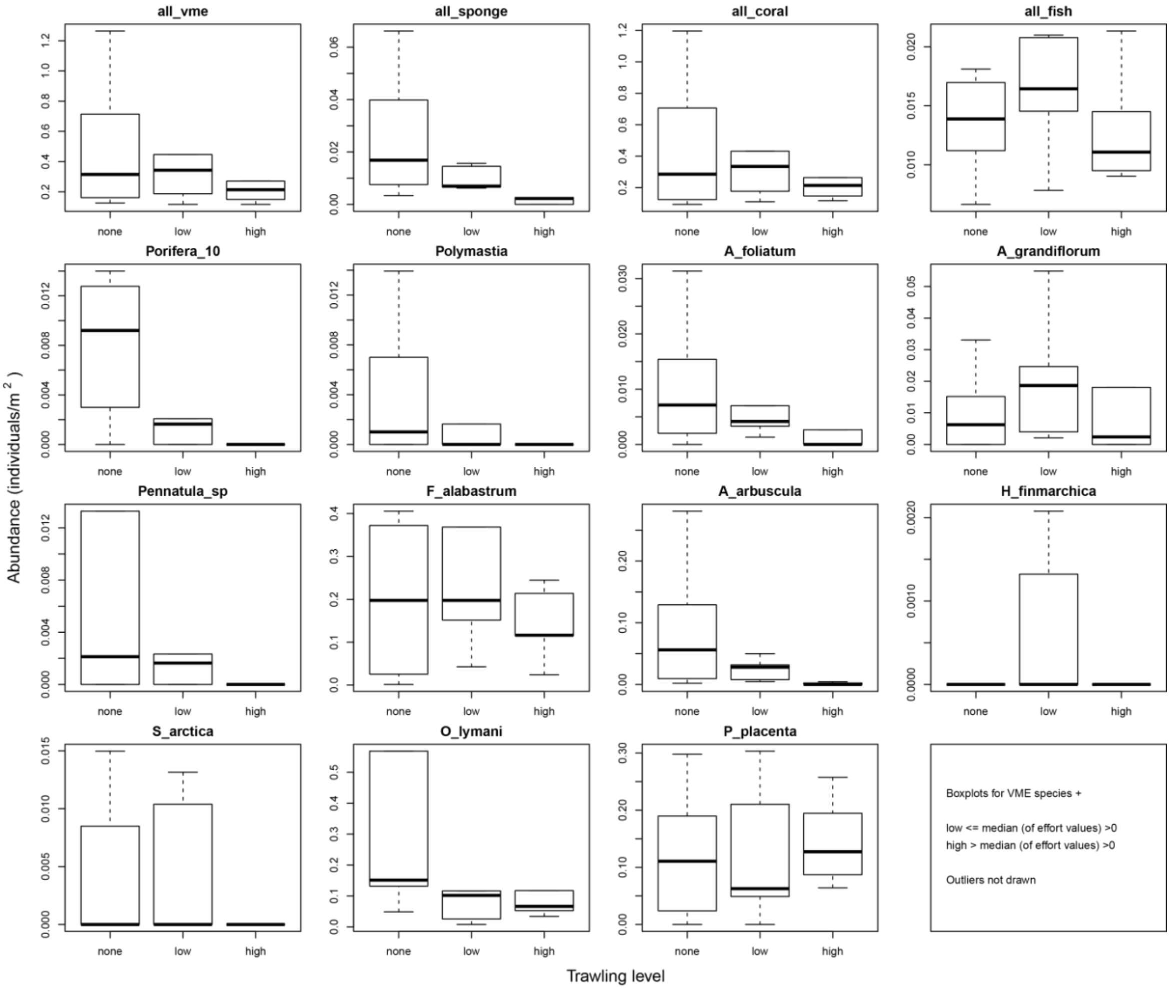

Figure 2: Abundance of benthic fauna against the level of trawling effort in the West Greenland offshore Greenland halibut (WGOGH) fishery and adjacent areas within NAFO 1C and 1D, Davis Strait, West Greenland. Trawling effort is from Global Fishing Watch (GFW) inferred trawling hours 2012 to 2016 inclusive aggregated in a 3.5km grid. Stations were assigned the effort value for the grid cell in which they were located. The 20 stations were then divided into three effort classes 'none' (effort = 0, n = 10), 'low' ($0 < \text{effort} \leq$ median effort value, n = 5) and 'high' (effort $>$ median effort value, n= 5), as per the bottom right-hand window. See Appendix for definition of aggregated group which have labels starting 'all_'. Porifera_10 is unidentified Porifera >10cm. For clarity outliers are not drawn.

It should be noted that this is a preliminary analysis, with a small sample size and does not account for environmental variability between stations (which may also explain differences in abundance). Further research (more stations) would allow a more sophisticated analysis adopting a modelling approach to determine the impact of trawling, whilst accounting for environmental effects.

The bamboo coral, *Acanella arbuscula* and the cup coral *Flabellum alabastrum,* are both VME indicator species observed across the spatial range of the survey and at the majority of stations. Their estimated density at each station is indicated (fig. 3 and 4 respectively). They are both observed in the shallower and deeper waters to the north and south of the core fishing effort. Similarly they are both observed at the highest densities outside the fishing footprint. This would support the preliminary conclusion that VME indicator species abundance has been reduced by trawling effort and that the observed patterns are unlikely to be accounted for by environmental factors alone.

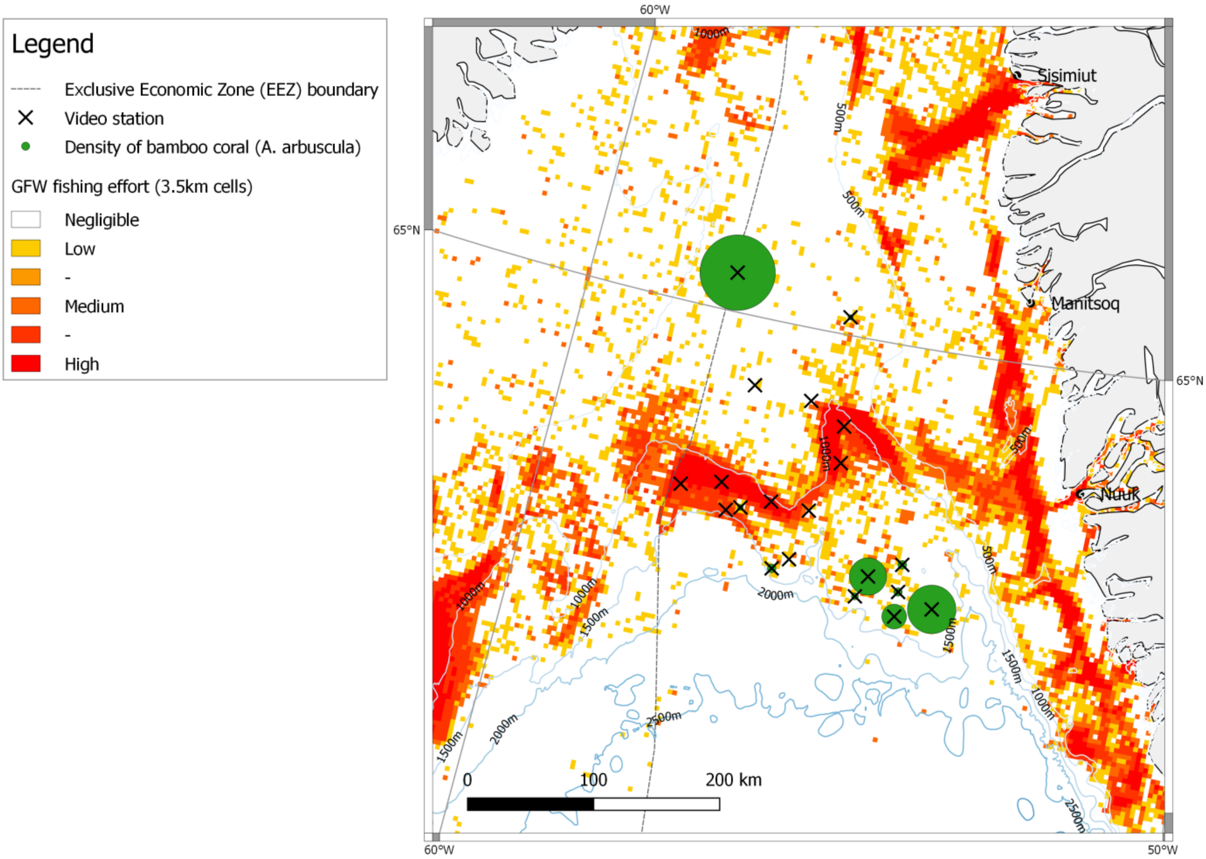

Figure 3: Bubble diagram showing relative density of bamboo coral (*Acanella arbuscula*) in the West Greenland offshore Greenland halibut (WGOGH) fishery and adjacent areas within NAFO 1C and 1D, Davis Strait, West Greenland. Density is indicated by green circles the areas of which are proportional to the estimated density. Video sled stations (n = 20) are indicated by black 'x's. The absence of a circle indicates *A. arbuscula* was absent (density = 0) from video at that station. Bathymetry is drawn at 500m intervals.

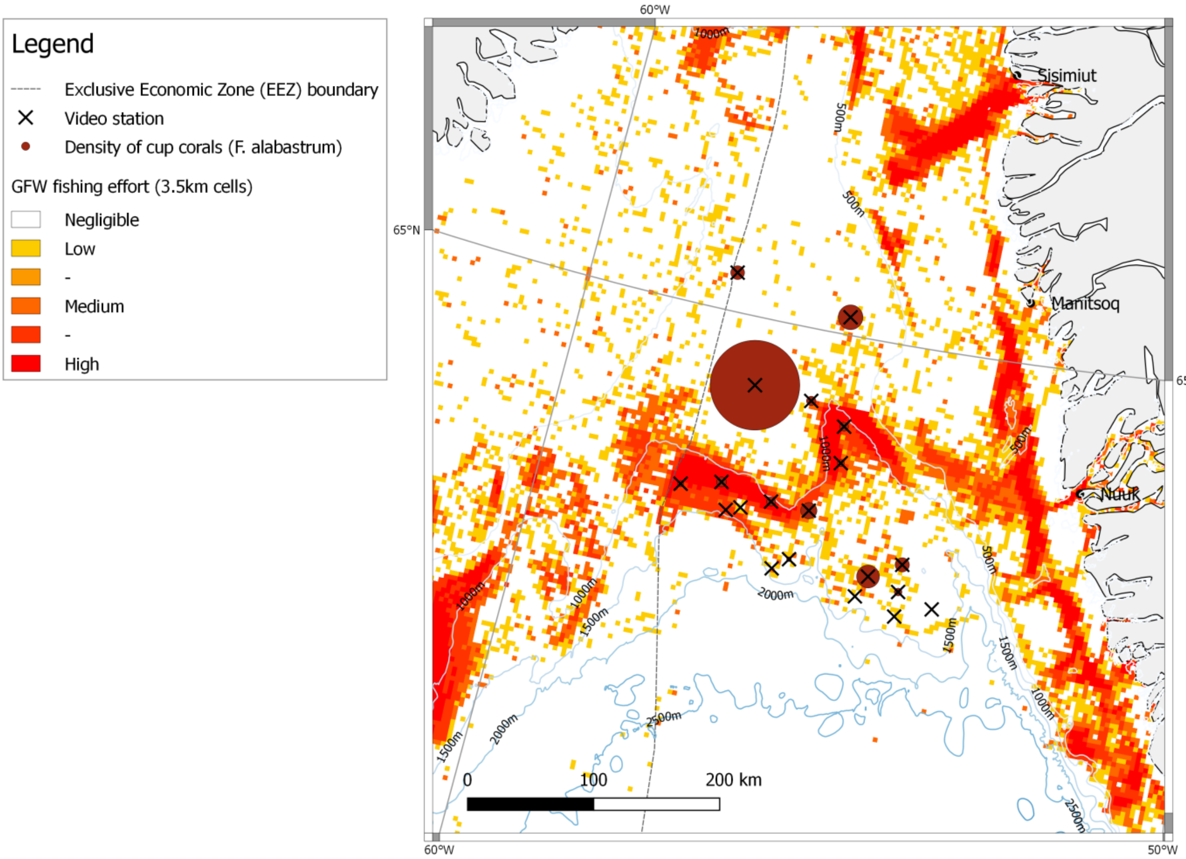

Figure 4: Bubble diagram showing relative density of cup coral (*Flabellum alabastrum*) in the West Greenland offshore Greenland halibut (WGOGH) fishery and adjacent areas within NAFO 1C and 1D, Davis Strait, West Greenland. Density is indicated by brown circles the areas of which are proportional to the estimated density. Video sled stations (n = 20) are indicated by black 'x's. The absence of a circle indicates *F. alabastrum* was absent (density = 0) from video at that station. Bathymetry is drawn at 500m intervals.

In summary, these provisional results are indicative of a negative impact of trawling on the abundance of VME indicator species. Similar conclusions can be drawn from the bycatch data from stock assessment hauls (see Appendix II). However, further work is required to confirm this and quantify the magnitude of the effect and the extent of these habitats in the wider region.

Future survey work

Work to date has been limited in terms of sample size (number of survey stations) and geographic scope. It currently has not been conducted at the scale of the entire fishery but only within the southern portion of the fishery. Future work should be undertaken to address this. The key aims of further surveys are to sample within the northern area of the fishery, increase the sample size (more stations across the whole area) and extend the geographic coverage to the Canadian exclusive economic zone (EEZ).

Options for conducting a survey in the northern area (NAFO areas 1A and 1B) of the WGOGH fishery aboard a Polar Seafood commercial vessel (Polar Princess) in October/November 2018 are currently being explored.

It is hoped that geographic coverage of the research can be extended to the Canadian EEZ. This would give a clearer impression of the total area of habitat(s) in relation to the footprint of fishing impact. Funding from NERC Arctic was secured in partnership with the Department of Fisheries and

Oceans Canada (DFO) to conduct this in 2018. Unfortunately due to the decommissioning of GINR'S R/V Paamiut, this did not occur. It is the intention to reapply for this funding in 2019.

Plans have been discussed to conduct further video sled surveys during the 2019 stock assessment survey programme led by GINR. This is pending a suitable survey vessel being identified.

Funding

Research presented here is part of the IUCN BEST 2.0 funded project (Reference number: 1586), led by Zoological Society of London (ZSL), with Sustainable Fisheries Greenland (SFG) as a project partner. The work is part of wider ongoing research collaboration between ZSL and the Greenland Institute of Natural Resources (GINR).

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Appendix I – Taxa table for preliminary video counts

Common name for group	ID #	Phylum	Class	Order	Family	Genus	*G. species*	Label shown for those in fig 2
Fish	1	Chordata	Elasmobranchii	Squaliformes	Etmopteridae	Centroscyllium	*C. fabricii*	
	2	Chordata	Actinopterygii					
	3	Chordata	Actinopterygii	Anguilliformes	Synaphobranchidae	Synaphobranchus	*S. kaupii*	
	4	Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Reinhardtius	*R. hippoglossoides*	
	5	Chordata	Actinopterygii	Notacanthiformes				
	6	Chordata	Actinopterygii	Gadiformes	Macrouridae			
	7	Chordata	Actinopterygii	Gadiformes	Macrouridae	Coryphaenoides	*C. rupestris*	
	8	Chordata	Actinopterygii	Gadiformes	Moridae	Antimora	*A. rostrata*	
	9	Chordata	Actinopterygii	Scorpaeniformes	Liparidae			
	10	Chordata	Actinopterygii	Scorpaeniformes	Psychrolutidae	Cottunculus	*C. microps*	
	11	Chordata	Actinopterygii	Scorpaeniformes	Psychrolutidae	Psychrolutes		
Sponges	12	Porifera	Large (>10cm)					Porifera_10
	13	Porifera	Demospongiae	Polymastiida	Polymastiidae	Polymastia		Polymastia
	14	Porifera	Demospongiae	Haplosclerida	Chalinidae	Haliclona		
	15	Porifera	Hexactinellida	Lyssacinosida	Rossellidae	Asconema	*A. foliatum*	A_foliatum
Corals	16	Cnidaria	Anthozoa	Pennatulacea	Anthoptilidae	Anthoptilum	*A. grandiflorum*	A_grandiflorum
	17	Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	*H. finmarchica*	H_finmarchica
	18	Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula		Pennatula_sp
	19	Cnidaria	Anthozoa	Scleractinia	Flabellidae	Flabellum	*F. alabastrum*	F_alabastrum
	20	Cnidaria	Anthozoa	Antipatharia	Schizopathidae	Bathypathes		
	21	Cnidaria	Anthozoa	Antipatharia	Schizopathidae	Stauropathes	*S. arctica*	S_arctica
	22	Cnidaria	Anthozoa	Alcyonacea	Isididae	Acanella	*A. arbuscula*	A_arbuscula
	23	Cnidaria	Anthozoa	Alcyonacea	Chrysogorgiidae	Radicipes		
	24	Cnidaria	Anthozoa	Alcyonacea	Nephtheidae			
Corallimorpharians	25	Cnidaria	Anthozoa	Corallimorpharia	Corallimorphidae	Corallimorphus		
Anenomes	26	Cnidaria	Anthozoa	Actiniaria				
	27	Cnidaria	Anthozoa	Actiniaria	Actinernidae	Actinernus	*A. nobilis*	
	28	Cnidaria	Anthozoa	Actiniaria	Actinostolidae			
	29	Cnidaria	Anthozoa	Actiniaria	Hormathiidae			
	30	Cnidaria	Anthozoa	Spirularia	Cerianthidae			
Echinoderms	31	Echinodermata	Ophiuroidea	Ophiurida	Ophiolepididae	Ophiomusium	*O. lymani*	O_lymani
	32	Echinodermata	Ophiuroidea	Euryalida	Gorgonocephalidae	Gorgonocephalus		
	33	Echinodermata	Echinoidea	Echinothurioida	Phormosomatidae	Phormosoma	*P. placenta*	P_placenta
	34	Echinodermata	Crinoidea	Comatulida	Antedonidae			

Boxplot groups	ID #'s used
all_fish	1-11
all_sponge	12-15
all_coral	16-24
all_vme	12-24 and 34

Appendix II – Stock assessment bycatch data

Benthic invertebrate bycatch from Greenland halibut stock assessments hauls was recorded by Greenland Institute of Natural Resources (*INAMon*) from 190 stations during three cruises in 2015, 2016 and 2017. The location of trawl stations is shown (Appendix II, fig. 1)

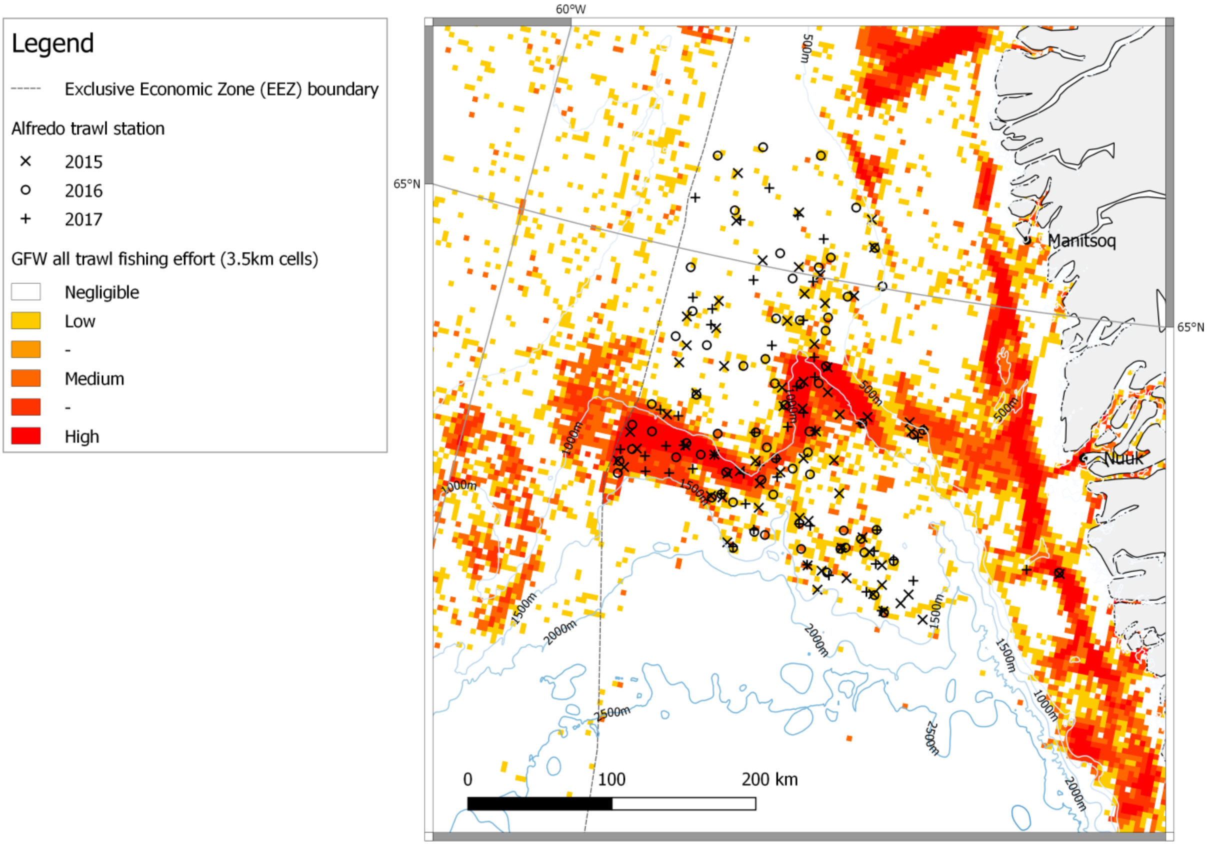

Figure 1: Locations of Alfredo trawl stations (n = 190) conducted by GINR in 2015,2016 and 2017, for the annual Greenland halibut stock assessment. Fishing effort data was obtained from Global Fishing Watch (GFW) and represents hours of all trawling effort, from 2012 to 2016 inclusive, aggregated into grid with 3.5 km cells. Depth contours are drawn at 500m intervals.

Trawls (n = 190) were conducted using Alfredo gear with a 140 mm mesh, 30 mm liner in the codend and rockhopper ground gear. Towing time varied from ~15 to 30 minutes at a towing speed of ~3 knots. For each haul the benthic bycatch was identified to the lowest taxonomic level possible and the total weight of each taxon was recorded. Bycatch observations were standardized to kg/km^2, using the exact wingspread, towing speed, and duration for each tow to calculate the swept area. As the catchability of each taxa is not known this kg/km^2 value does not provide a true abundance estimate. It does however allow comparisons to be drawn between stations across the spectrum of fishing effort.

The bubble plots (Appendix II, figs. 2 – 6) below present data for selected taxa which were commonly encountered and are considered VME indicators. These data appear to support the preliminary conclusions drawn from the analysis of the benthic video sled surveys. The highest densities of VME indicators is seen outside of the core fishery footprint suggesting trawling may be responsible for reduced abundance (or absence) of some VME indicator taxa.

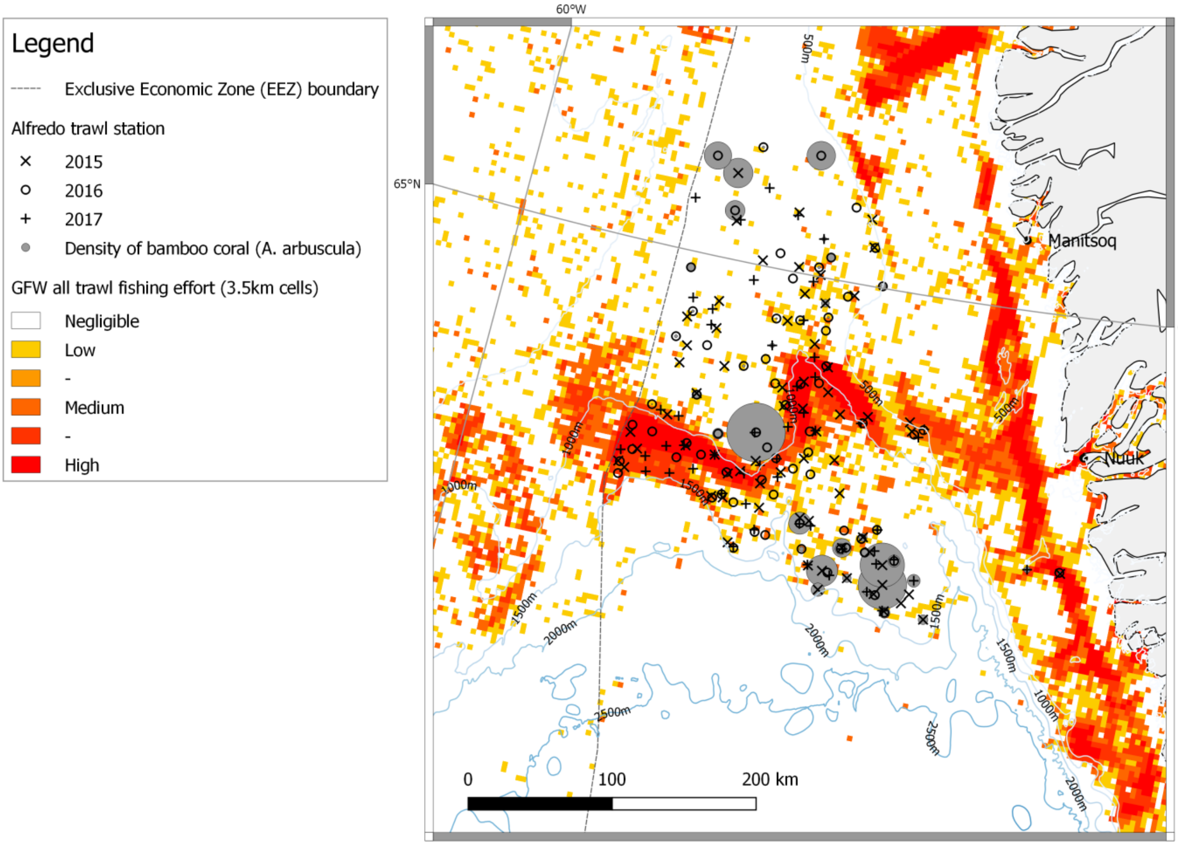

Figure 2: Bubble diagram showing relative density of bamboo coral (*Acanella arbuscula*) in the West Greenland offshore Greenland halibut (WGOGH) fishery and adjacent areas within NAFO 1C and 1D, Davis Strait, West Greenland. Determined from bycatch in stock assessment survey hauls (n = 190), where density (kg/km^2) is estimated from total weight of *A. arbuscula* and the swept area for each station's haul. Relative density is indicated by grey circles, the areas of which are proportional to the density. Note the density value has been log-transformed and a scaling factor applied to improve visual clarity, thus size of circles should not be compared between figures. Stations (n = 190) from each year are indicated. The absence of a grey circle indicates *A. arbuscula* was absent (density = 0) from the station's bycatch. Bathymetry is drawn at 500m intervals.

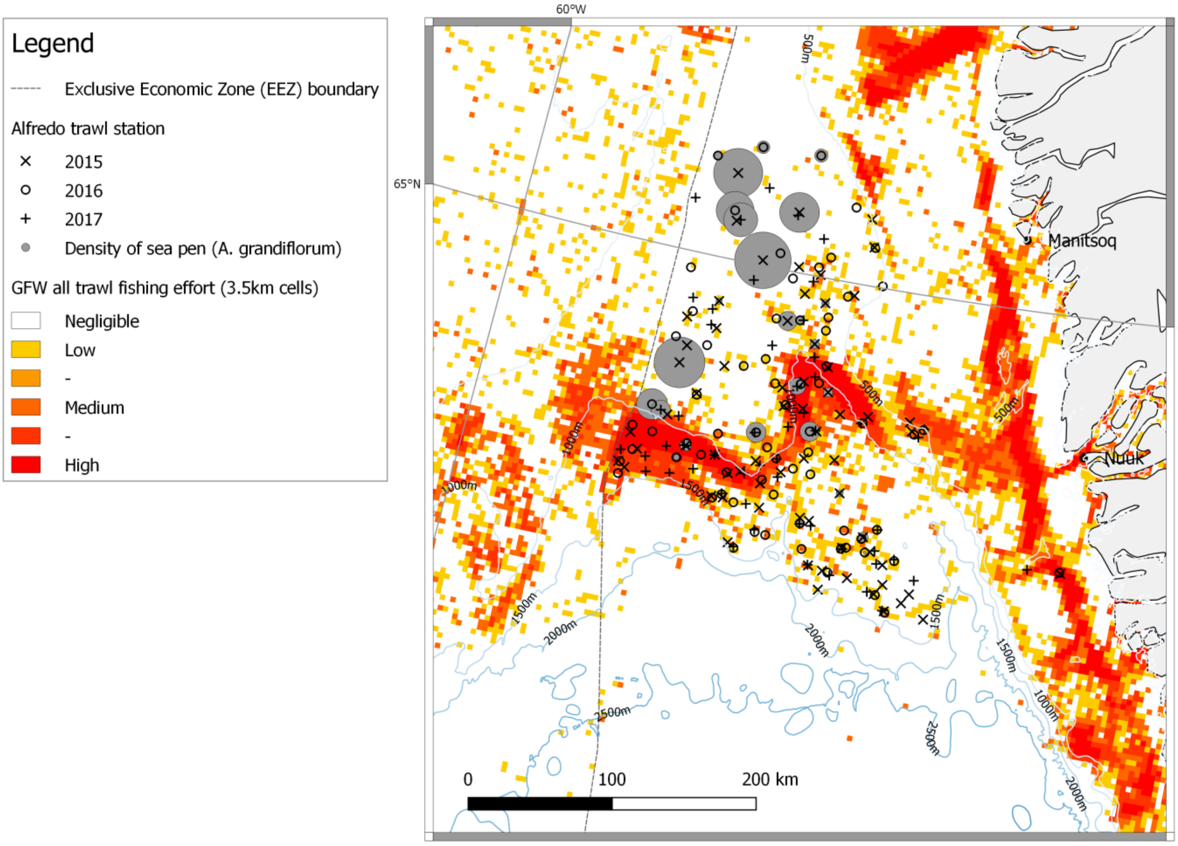

Figure 3: Bubble diagram showing relative density of sea pen (*Anthoptilum grandiflorum*) in the West Greenland offshore Greenland halibut (WGOGH) fishery and adjacent areas within NAFO 1C and 1D, Davis Strait, West Greenland. Determined from bycatch in stock assessment survey hauls (n = 190), where density (kg/km^2) is estimated from total weight of *A. grandiflorum* and the swept area for each station's haul. Relative density is indicated by grey circles, the areas of which are proportional to the density. Note the density value has been log-transformed and a scaling factor applied to improve visual clarity, thus size of circles should not be compared between figures. Stations (n = 190) from each year are indicated. The absence of a grey circle indicates *A. grandiflorum* was absent (density = 0) from the station's bycatch. Bathymetry is drawn at 500m intervals.

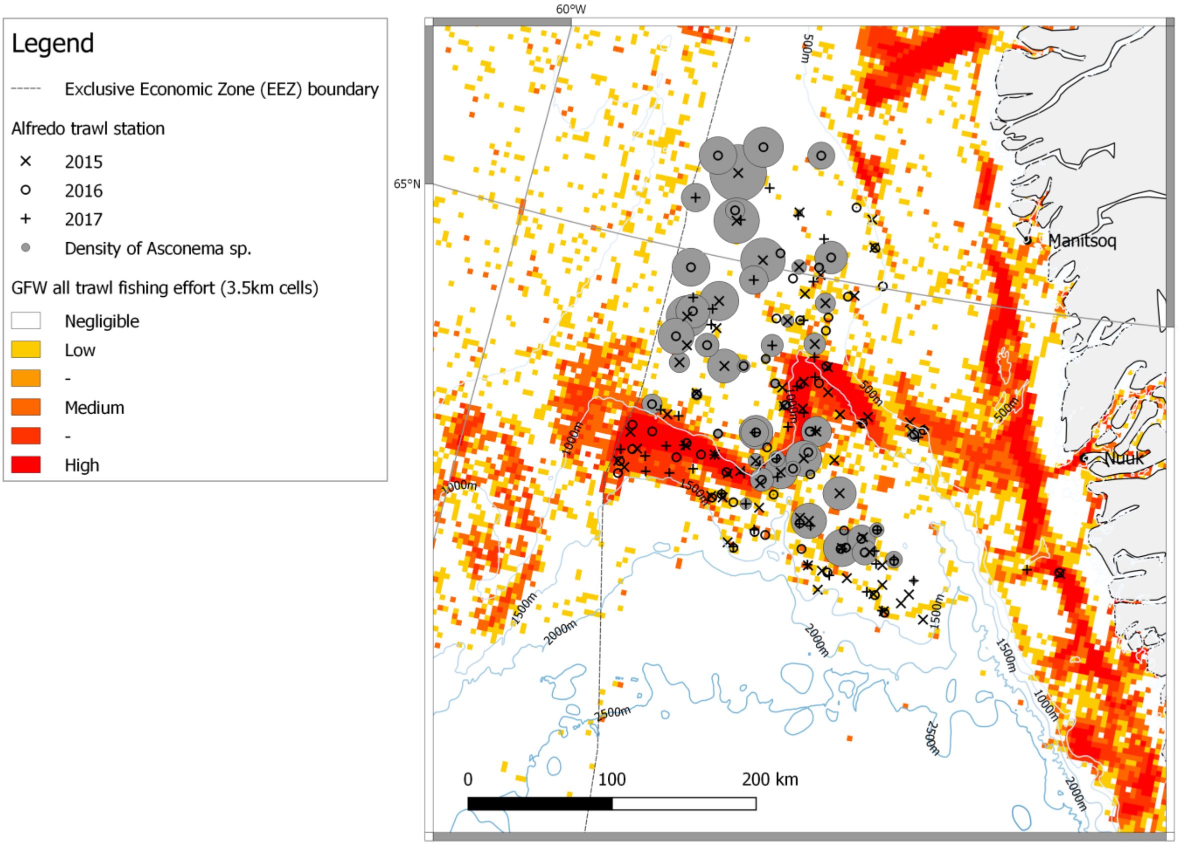

Figure 4: Bubble diagram showing relative density of sponge (*Asconema sp.*) in the West Greenland offshore Greenland halibut (WGOGH) fishery and adjacent areas within NAFO 1C and 1D, Davis Strait, West Greenland. Determined from bycatch in stock assessment survey hauls (n = 190), where density (kg/km^2) is estimated from total weight of *Asconema sp.* and the swept area for each station's haul. Relative density is indicated by grey circles, the areas of which are proportional to the density. Note the density value has been log-transformed and a scaling factor applied to improve visual clarity, thus size of circles should not be compared between figures. Stations (n = 190) from each year are indicated. The absence of a grey circle indicates *Asconema sp.* was absent (density = 0) from the station's bycatch. Bathymetry is drawn at 500m intervals.

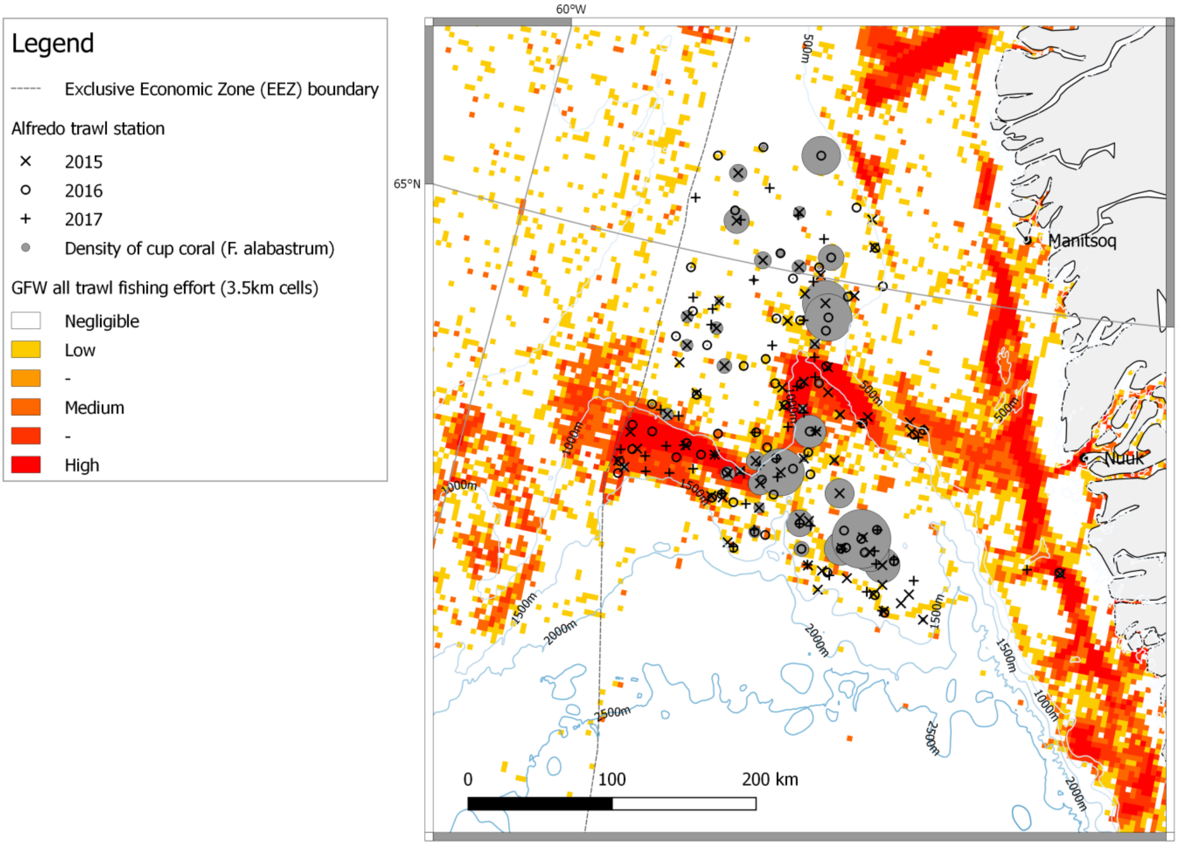

Figure 5: Bubble diagram showing relative density of cup coral (*Flabellum alabastrum*) in the West Greenland offshore Greenland halibut (WGOGH) fishery and adjacent areas within NAFO 1C and 1D, Davis Strait, West Greenland. Determined from bycatch in stock assessment survey hauls (n = 190), where density (kg/km^2) is estimated from total weight of *F. alabastrum* and the swept area for each station's haul. Relative density is indicated by grey circles, the areas of which are proportional to the density. Note the density value has been log-transformed and a scaling factor applied to improve visual clarity, thus size of circles should not be compared between figures. Stations (n = 190) from each year are indicated. The absence of a grey circle indicates *F. alabastrum* was absent (density = 0) from the station's bycatch. Bathymetry is drawn at 500m intervals.

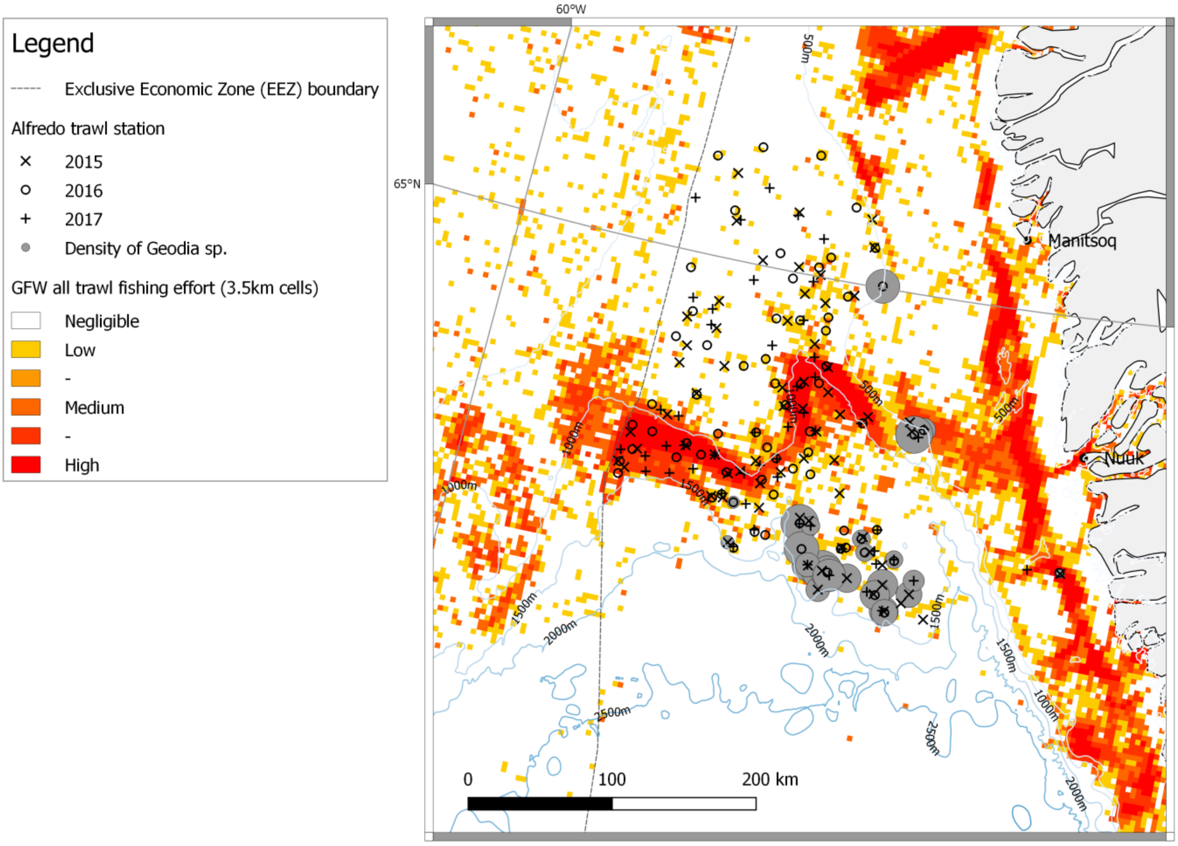

Figure 6: Bubble diagram showing relative density of sponge (*Geodia sp.*) in the West Greenland offshore Greenland halibut (WGOGH) fishery and adjacent areas within NAFO 1C and 1D, Davis Strait, West Greenland. Determined from bycatch in stock assessment survey hauls (n = 190), where density (kg/km^2) is estimated from total weight of *Geodia sp.* and the swept area for each station's haul. Relative density is indicated by grey circles, the areas of which are proportional to the density. Note the density value has been log-transformed and a scaling factor applied to improve visual clarity, thus size of circles should not be compared between figures. Stations (n = 190) from each year are indicated. The absence of a grey circle indicates *Geodia sp.* was absent (density = 0) from the station's bycatch. Bathymetry is drawn at 500m intervals.