BEST 2.0
Interim Technical Report

**** All red text should be deleted before the report is submitted ****

This report should describe all of the work completed during the reporting period. It is important that the report is complete and accurate.

Project Details

Project title:		Sustainable fishing in the Arctic: Can the harvest of Greenland's biggest export be compatible with the conservation of benthic ecosystems?
Project reference number:		1586
BEST 2.0 region:		Polar/Sub-polar
Targeted OCT(s):		Greenland
Name of the lead beneficiary:		Institute of Zoology, Zoological Society of London
Project start date:		1st April 2017
Project end date:		31st March 2019
Value of BEST 2.0 grant awarded (€):		296,382.86
Total project budget (€):		324,759.18
Names of any associated beneficiaries:	**1.**	Sustainable Fisheries Greenland
	2.	
	3.	
	4.	
Names of any affiliated entities:	**1.**	
	2.	

Report Information

Date report submitted:	30th April 2018
Time period covered by this report:	1st April 2017 to 31st March 2018
Name of project contact person:	Chris Yesson
Email address of contact person:	chris.yesson@ioz.ac.uk

Table of Contents

1. Project overview....1
2. Assessment of continued relevance and feasibility of the project....1
3. Highlights from the reporting period....2
4. Progress towards achieving the project results and purpose....2
5. Progress in carrying out the project activities....3
6. Stakeholder engagement....3
7. Capacity building....4
8. Communication and project visibility....4
9. Sustainability and replicability....5
10. Lessons learnt....5
11. Safeguard policy assessment....6
12. Any other comments on progress....6
13. Progress and achievements against the project logical framework....7
14. Annexes....10

The table above should be updated – page numbers only – before the report is submitted. Left click on table and select 'update field' then 'update page numbers only'.

List of Acronyms and Abbreviations

MSC	Marine Stewardship Council
GINR	Greenland Institute of Natural Resources
SFG	Sustainable Fisheries Greenland
IoZ	Institute of Zoology (a department of ZSL)
ZSL	Zoological Society of London
VME	Vulnerable Marine Ecosystem
UCL	University College London
DFO	Department of Fisheries and Oceans (Canada)
MPA	Marine Protected Area
GFLK	Greenland Fisheries License Control Authority
GFW	Global Fishing Watch

1. ***Guidance:***

- *There is no word limit for the various sections. Responses should contain all of the relevant information in a concise way. It is important to ensure that the information included is complete and accurate.*
- *If you have already answered a question in one section do not repeat the information in another section but refer back to the previous section.*
- *When making statements of progress or impact please ensure you refer as much as possible to sources of evidence based on the indicators in your project logical framework.*

2. Project overview

Provide a brief overview of the project including:

- *The location of the project activities (with a map if possible).*
- *The target species, habitats, ecosystem services etc.*
- *A description of the problem the project aims to address.*
- *The project's approach to addressing the problem.*
- *What the project aims to achieve.*

As ice retreats in the Arctic, and polar waters are warming at unprecedented rates, there are significant challenges to Arctic communities. Warming sea temperatures are influencing the movements and distributions of organisms, including many commercially important species. Changing patterns of biodiversity lead to changing fishing effort, which can place new pressures on important but vulnerable marine ecosystems, such as benthic habitats. Polar nations dependent on income from fisheries have to adapt to changing conditions to ensure long term sustainability of their industry. Greenland is responding positively to these challenges by engaging with organisations such as the Marine Stewardship Council (MSC) to develop and implement sustainable strategies to safeguard natural resources.
The West coast of Greenland is home to commercially important coldwater prawn and halibut fisheries. Their entrance into the MSC sustainability scheme has highlighted a concerning lack of knowledge of benthic habitats (deep sea environments are logistically difficult and expensive to study). Benthic habitats play vital roles in the marine ecosystem, functioning as carbon sinks and providing nurseries and protection for juvenile fish. Trawl fisheries (such as the prawn and halibut) directly impact the local seabed environment, with removal of habitat-forming organisms, and consequently the marine ecosystem as a whole. This project will perform photographic surveys of the West Greenland benthos to document existing seafloor communities, their structure, function and diversity. One survey will examine the continental shelf around Disko Bay, revisiting locations where benthic images were taken in the 1980s. This will create a unique time series allowing investigation of benthic habitats in response to climate change and trawling impact over 30+ years and enabling an assessment of the recovery potential of impacted communities. A second survey will be conducted in the deeper off-shelf area of the existing halibut fishery, to document for the first time the benthic habitats in this region. From these benthic community data, and environmental data sourced from oceanographic models, we will build predictive maps of species distributions and Vulnerable Marine Ecosystems (VMEs).
Observations and information collected, along with our analytical interpretations, will be made publically available in the form of open-access data (image) sharing and publications, and will be used to develop and evaluate management plans for the sustainable use of marine resources in West Greenland. It is critical that we ensure effective and sustainable management of polar natural resources, particularly now as resource exploitation potentially

expands into new territory. Sustainable management of fisheries is a widely recognised priority for Greenland.
Specimens, images, interactive web resources, and educational games will be used in a series of outreach events designed to engage a broad spectrum of stakeholders including fishers, industry leaders, children and the general public in the drive to recognise the importance and conservation value of Greenland's precious and wondrous benthic habitats. These events will generate teaching resources (online and physical), a fixed scientific exhibit to be housed in Nuuk, and a legacy of engagement through education.

3. Assessment of continued relevance and feasibility of the project

- *Assess whether the project objectives are still relevant and achievable.*
- *Describe any changes to the external context that might affect your ability to achieve the project objectives or to implement the project activities in line with the work plan in your proposal.*

The continued reliance of the Greenland government on marine resources means the project objective to promote "Sustainable use of marine resources in the Arctic and conservation of benthic habitats" will be relevant for many years to come. Our project has made good strides towards meeting this objective and will continue to do so for the remainder of the project.

The 1-month delay to the survey of the Halibut fishery region has had a knock-on effect for the rest of the project, but this should not affect our ability to deliver the analysis. We have data from our surveys and expect to analyse and write-up the planned studies by the end of the project (details below).

4. Highlights from the reporting period

Please describe any noteworthy milestones or achievements that have occurred during the reporting period. These can be in the form of bullet points.

- April 2017 An independently funded PhD student, Stephen Long, joined the project, to examine the impact of the Halibut Fishery on the seabed. Representing a new 3-way supervisory relationship between IoZ, UCL and GINR
- May 2017 Mona Fuhrmann joined the project as a postdoctoral researcher
- May 2017 The Greenland Halibut fishery received provisional certification of sustainability from MSC, conditional on, amongst other things, the research results of our project (https://fisheries.msc.org/en/fisheries/west-greenland-offshore-greenland-halibut/@@view)
- May 2017 An MSC surveillance report is published for the West Greenland Coldwater Prawn fishery, with contributions from this project, demonstrating the fishery is meeting sustainability criteria (https://fisheries.msc.org/en/fisheries/west-greenland-coldwater-prawn/@@view)
- June 2017 Fieldwork conducted aboard R/V Paamiut (see cruise report in annex)
- October 2017 Fieldwork conducted aboard R/V Paamiut (see cruise report in annex)
- Successful development and deployment of our new video sled, taking video images down to 1500m.
- Jan 2018 An outreach event was conducted in Nuuk, the capital of Greenland, as part

of Kulturnat (Kulturnat is an annual event in Greenland where institutions and businesses open their doors to the general public and give exhibitions showcasing what they do).

- New area closures to the coldwater prawn fishery have been introduced in the Melville Bay region, after identification of potential VME species based, in part, on our project's assessment (http://naalakkersuisut.gl/da/Naalakkersuisut/Nyheder/2018/01/2301_melvillebugten)

5. Progress towards achieving the project results and purpose

Please describe the progress made towards the achievement of the project results and purpose (as contained in the logical framework submitted with your proposal).

- *Are they likely to be achieved by the end of the project?*
- *If not, what action have you taken/will you take to ensure the situation can be improved?*

Result 1. Visual (photographic) surveys of benthic habitats of W Greenland

- Surveys have been conducted.
- Collated images will be made available by the end of the project

Result 2. Documentation and analysis of structure, distribution and change over time (40 years) of benthic habitats of West Greenland. Interpretation of this change in terms of response to disturbance impact (trawling) and climate change. Projection of potential future change under the existing impact regime.

- Analysis of survey data is underway and we are on course to complete these by the end of the project.

Result 3. Management plan for sustainable use of marine resources in West Greenland

- Management plans and all other documentation required for the fisheries to progress through the MSC certification process is on track.
- The Halibut fishery has received conditional certification.
- The Coldwater Prawn fishery should enter recertification in year two of the project.

Result 4. Engagement of fishers, children, industry, and public with the issue of conservation value of Greenland's benthic habitats. Long-term buy-in and interest amongst these stakeholders regarding the importance of these national resources and their sustainable management.

- Some elements of public engagement have already been achieved, such as engagement with school groups and exhibitions to members of the public. Further events are planned for the following year.
- A significant issue with certification has been the expansion of the fishery into Melville Bay. There has been a positive conservation outcome with the closure of 1,900km^2 of Melville Bay to the fishery and the adoption of the precautionary principle, requiring government approval for expansion of the fishery beyond the existing footprint. This is evidence of the long-term buy-in of the government and fishery to the sustainable management of marine habitats
- Other engagements events have met with some obstacles (see Section 6)

- Communication with Greenlandic organisations has been difficult at times. It is felt that a presence on-the-ground in Greenland would be beneficial for improving communications. To this end we plan to send a project member, Mona Fuhrmann to Greenland for summer 2018. This requires the reallocation of budget to cover accommodation costs. See budget reallocation request submitted with report.

6. Progress in carrying out the project activities

Describe the work completed during the reporting period for each of the activities foreseen in your proposal, indicating and explaining:

- *Any changes in approach from the original project design[1].*
- *Any deliverables/outputs as a result of the work.*
- *Any problems encountered (e.g. delays, cancellation of activities) and how they are being / will be addressed (if relevant).*

1 Any substantial change must be notified to the BEST 2.0 Secretariat and the relevant BEST 2.0 Regional Hub through a request for an addendum to the grant contract prior to the end date of the project. The BEST 2.0 Secretariat reserves the right to accept or to refuse the request.

Cruises

Two research cruises were conducted in 2017, in line with the original plan. Cruise reports and blogs were delivered on schedule (See section 9). However, the cruises were not without difficulties.

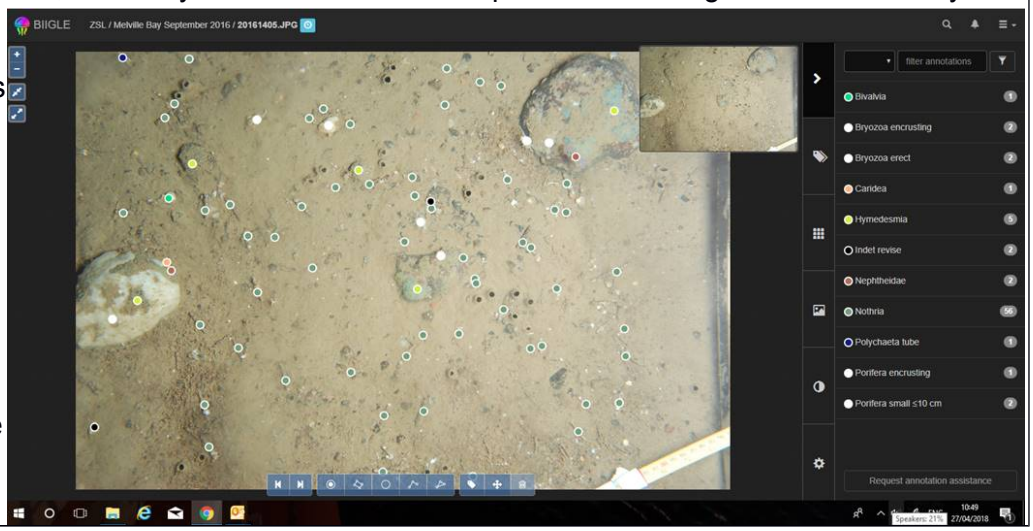
The survey of the West Greenland Coldwater Prawn Fishery region, in June 2017, met with significant sea-ice coverage, which limited the number of historical stations that could be surveyed with our drop-camera. GINR have offered us a space on the next available cruise to revisit the remaining stations.

The survey of the West Greenland Offshore Greenland Halibut Fishery took place in October 2017. Initially this cruise was scheduled for September, but was cancelled due to equipment failure on the vessel. However, repairs were complete quicker than expected and the cruise schedule was re-arranged at short notice to encompass a shortened survey. The consequence of the cruise occurring later in the season, meant severe weather conditions curtailed some activities and the full range of the fishery could not be visited. The original workplan was for 48 hours of ship time dedicated to our surveys, but 9 hours of these were unused due to adverse weather conditions. GINR have agreed to provide the remaining survey hours on the next Halibut survey.

Our project has relied on the cooperation of GINR and the use of their survey vessel M/T Paamiut. This vessel was constructed in 1971 and in recent years has been in need of a series of expensive repairs. In early 2018 GINR decided to decommission the vessel after it failed safety tests in preparation for the 2018 survey season. At present GINR, SFG and the Greenland government are in negotiations about finding a replacement vessel. As outlined above we have been offered places aboard subsequent surveys to supplement our sampling and enhance our datasets, but at present we do not know whether a vessel will be in place by summer 2018 that is capable of deploying our survey equipment. However, we have sufficient data to produce a robust set of analyses, and we will proceed with the original project plan. If a compatible vessel is found we believe the relatively small (travel) cost of participating on the survey would be a worthwhile expenditure as it would improve the quality of our datasets.

Image analysis

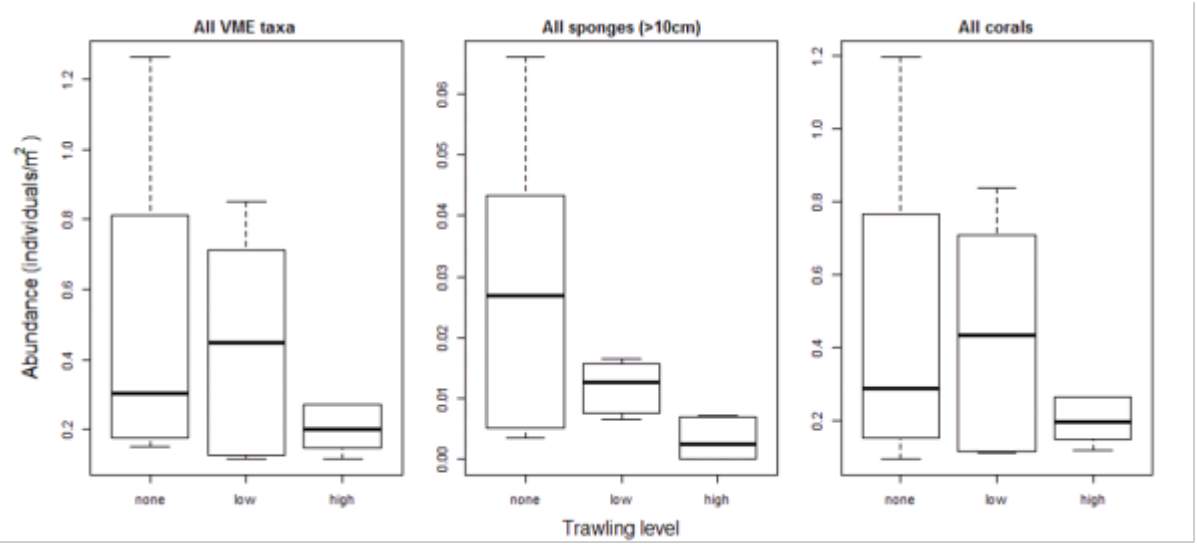
We have adopted the Biigle platform for image annotation. This platform is significantly more advanced than the Poseidon platform identified in the original proposal. The ability to review and edit groups of labels, read labels directly from the world register of marine species, and automatically detect scaling lasers have greatly improved our efficiency in processing images. Adopting this platform has involved a new collaboration with the Biigle developers at Universität Bielefeld, Germany. To date we have incorporated 901 images from our survey of the Greenland Halibut fishery, and 767 images associated with the Coldwater Prawn fishery. There are a total of 9514 annotations (faunal identifications) currently recorded on the system (example right).



We have developed a methodology for analysing the video sled data, involving taking stills from the video at regular intervals, and associating a location with each image by referencing the ship position and relative position of the camera to the ship.

After our research cruise of June 2017, we have now revisited and surveyed 43 stations previously surveyed by Per Kanneworff in the 1970s and 1980s. Images from these historic surveys have been scanned and prepared for analysis and comparison with present day images.

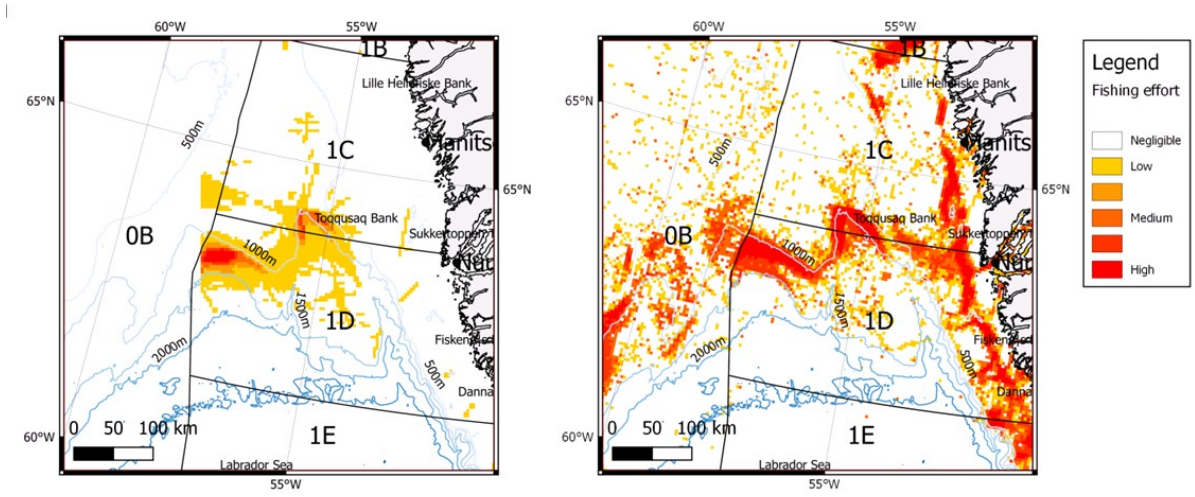
A provisional analysis of data from the benthic survey of the Greenland Halibut fishery has revealed a significant pattern of abundance linked to fishing effort, where lower abundance of populous taxa is seen in areas with higher fishing effort (see figure below).



Preliminary analysis of trawling impacts on benthic fauna at 20 video stations in the southern area of the Greenland halibut fishery and adjacent areas. Boxplots for abundance of all VME indicator taxa (as defined by NAFO), all sponges >10cm and all corals at three levels ('none', 'low', 'high') of fishing effort. Fishing effort data obtained from GFW estimates total hours of trawling, from 2012 to 2016 inclusive. Fishing effort at each station is determined by the log-transformed cumulative number of fishing hours in the 3.5 km cell where the estimated geographic centre of the video transect is situated. Effort was then divided into three levels, where; 'none' =0, 'low'<=median effort for the stations; and 'high'>median effort estimated for the stations.

Fishing data

Data on fishing effort in the West Greenland Offshore Greenland Halibut Fishery has been obtained from GFLK. These data are in the form of start and end positions and times of trawling events registered at GFLK (in theory this should cover all legitimate trawling activities in the area). However, upon examination of these data is was observed there were some 'gaps' in the data for several years that gave us cause for concern. Therefore we approached globalfishingwatch.org for an alternative dataset. We have compared both GFW and GFLK data (figure below) and will conduct analysis of impact using these data.



Fishing effort data obtained from GLFK (left) and GFW (right). Where GLFK represents hours of Greenland halibut fishery trawling effort within the Greenlandic EEZ, from 2000 to 2016 inclusive. Whereas, GFW represents hours of all trawling effort within map extent, from 2012 to 2016 inclusive. NAFO zones 0B (Canadian EEZ) and 1B-E (Greenlandic EEZ) are shown. Bathymetry is indicated at 500m intervals (blue lines).

Environmental data

Datasets which model marine environmental conditions have been downloaded from the Copernicus website. These are depth-tiered grids (so called 2.5D grids). The cookie-cutter upscaling method has been used to create high resolution seabed environment grids for the parameters Temperature, Salinity, Current Speed, Current Direction, for average winter and summer conditions over the last decade. These will be used in the analysis to assess the environmental influence on observed faunal patterns. These grids will be made publicly available as supplementary data with the first published paper that uses them.

Management plans

The MSC certification process requires extensive documentation of all aspects of the fisheries. These are all publicly accessible on the relevant MSC webpages. The Halibut fishery has received certification, demonstrating a credible management plan is in place for this fishery. The Coldwater prawn fishery will enter re-certification later this year. The announcement of new protected areas in Melville Bay, along with the introduction of the precautionary principle limiting expansion is evidence of conservation planning and stakeholder engagement of the conservation process.

Outreach events

A series of successful outreach events have been conducted, which are detailed in section 9.

We were unable to attend and present at the biennial ship's captain meeting due to the last-minute rescheduling of the cruise. We are seeking an alternative event where we can present to fishers (the next captains meeting will not be held until autumn 2019, after the end of this project).

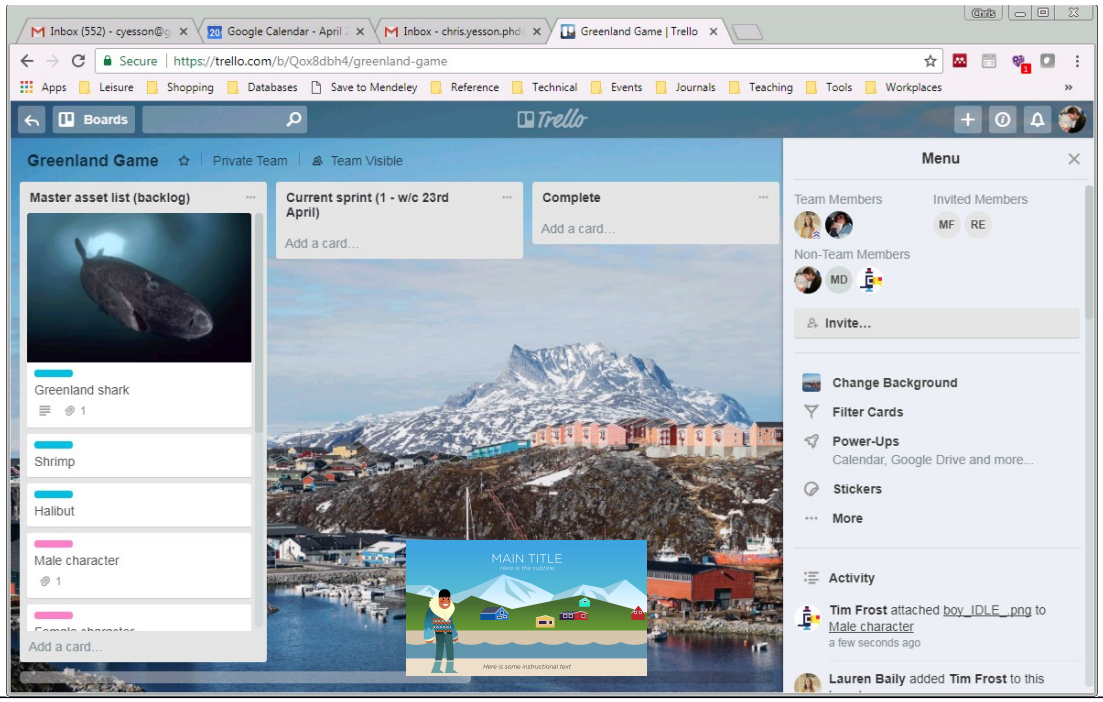
We have been unable to make progress with Skipper Skolen our attempts to contact the organisation have proved unsuccessful. We have found a reluctance to engage with an overseas organisation and feel that a face-to-face meeting is required to develop this further

(see revised plan to put staff in country below).

Whilst the pilot school engagement activity was successfully conducted around our first research cruise, the last-minute rescheduling of the October 2017 cruise meant we were unable to conduct a similar event around this survey. However, we feel that as rewarding as single-instance engagements may be, a longer-term legacy of school engagement will be achieved by our collaboration with the Learning Institute, University of Greenland. The ebook we are supporting with information and images should reach a much wider audience of Greenlandic school children and teachers with conservation and habitat information.

Game Development

Development of a game is underway. A draft outline has been constructed and third party developers have been enlisted to deliver the game by summer 2018. A project management page on the Trello website has been set up (screenshot right). ZSL digital department has been struggling with staff retention and has been short staffed for a significant period of the first year of the project. Therefore the game will be developed by a third party organisation, sub-contracted by ZSL. We have learned a lot about game development over the year. In a small departure from the original project plan, we have decided to focus on developing a single game that delivers both a conservation message about the impact of fishing on the seabed and snippets of information about key species in Greenland.



7. Stakeholder engagement

Describe the support or engagement between all key stakeholders and the project.

- *To what extent have stakeholders been involved in the project to date?*
- *Highlight any particular achievements, lessons learnt or challenges with regards to the engagement with/participation of the different stakeholders.*

- Chris Yesson participated in an MSC audit meeting for the West Greenland Coldwater Prawn fishery, at Polar Seafood offices in Aalborg, where he presented research findings and discussed the project with fishing industry executives, fishers and auditors in the MSC evaluation process. One issue raised at this meeting was the potential problem that would be caused by northward expansion of the fishery into Melville Bay. We raised the issue that this is a relatively unimpacted area that could be adversely affected by expansion, and it was agreed that a management strategy was required to ensure sustainability. Following this meeting there were a series of meetings between SFG, GINR and representatives of the Greenland government to reach a sustainable solution. We had additional input into this process through communication with our research collaborator Martin Blicher of GINR, who provided consultation to SFG and the government of Greenland in the process of decision making regarding regulation of fishery in Melville Bay. The result was the formal protection of areas in Melville Bay and adoption of the precautionary principle requiring evidence of impact before any future fishery expansion. This positive outcome, with a focus on sustainability, is evidence of stakeholder buy-in and will be a long-term legacy of the project.
- Our public engagement activities have delivered information directly to both the general public and schoolchildren.

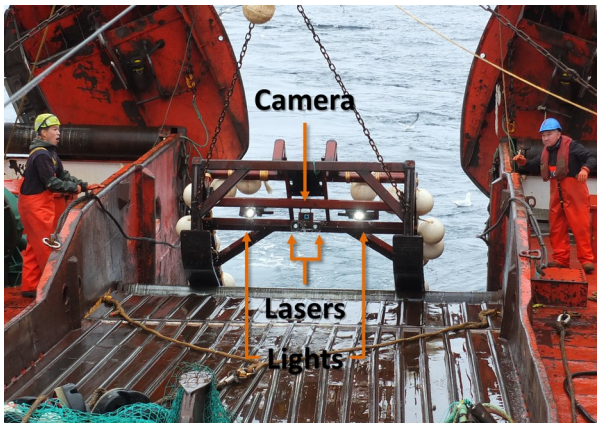
8. Capacity building

Provide details of any capacity building activities conducted, including:

- *Details of how the project has supported capacity building within the territory e.g. institutional/organisational development, training and human resources development, sustainable financing, enabling environment etc.).*
- *Tangible evidence (facts/figures) of increased capacity of institutions/individuals within the targeted territory(ies) and region.*

- We established a collaboration with Lars Port at the Learning Institute, University of Greenland, to assist the developing of training material provided for teacher students in natural sciences. Maps and seabed images from our project will be used in an interactive ebook, teaching students about benthic biodiversity and environmental parameters in the waters off West Greenland. The ebook is in development and should be released by the end of the project. This ebook will be a resource of training material delivering information about Greenland's habitats for years after the life of the project and constitutes a legacy of capacity building.

- We have worked closely with our collaborators at GINR to develop a new video sled for benthic surveys (image right). The first successful deployment was during our June 2017 survey, and this was followed by deployment down to 1500m during the research cruise of October 2017. This camera equipment is housed at GINR and will expand their ability to conduct benthic surveys in the future. New GINR-led surveys using this equipment are scheduled for August and October 2018, demonstrating the usefulness of these equipment beyond our project.



- We have introduced the Biigle image annotation platform to members of GINR, providing informal training in its use. This platform allows for easier collaboration between ourselves and GINR.

9. Communication and project visibility

Discuss the profile of the project within the territory(ies)and the region and describe any communication or visibility activities undertaken (e.g. events, workshops, media events etc.) to raise the profile of the project and the BEST 2.0 programme detailing:

- *The groups targeted by each activity.*
- *Any communication products produced (brochures, leaflets, videos, website, social media etc.), including figures for dissemination where possible. (Please add pdf copies in the annexes of your report)*

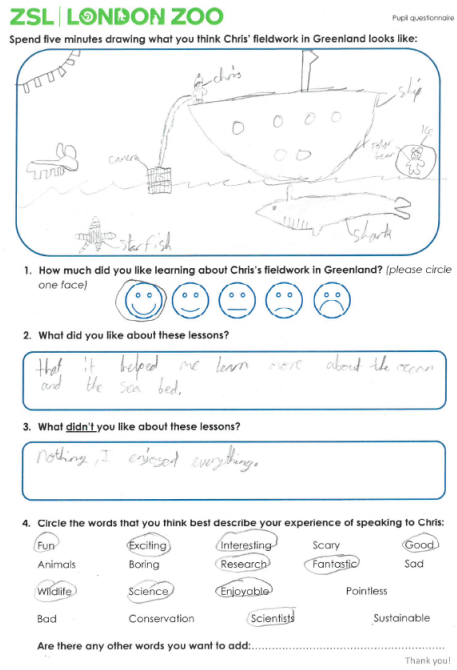
Multimedia

- A short video highlighting our project was produced by ZSL digital communications team (560 views as of 19/3/2018 - https://youtu.be/M4qODUKXbv0)
- A longer video highlighting our research was produced and translated into Danish (presented an exhibition at the "Kulturnat", 1046 visitors - https://drive.google.com/open?id=1q4SRToAynh09Njpu9-u3qOIl0VjoTS4U).
- The following blogs highlighting our project activities have been published on the ZSL webpage (website stats as of 27/3/2018)
    - https://www.zsl.org/blogs/wild-science/exploring-the-deep-seafloor (May 2017, 100 unique views)
    - http://www.zsl.org/blogs/wild-science/sea-cucumbers-carnivorous-sponges-and-other-deep-sea-creatures (Sep 2017, 167 unique views)
    - http://www.zsl.org/blogs/wild-science/diving-deeper (Jan 2018, 58 unique views)
    - https://www.zsl.org/blogs/science/new-protection-for-vulnerable-arctic-habitats (Feb 2018, 41 unique views)
- 5 project related tweets have been posted on the @ZSLScience twitter feed (18.5K followers). These have generated 10214 impressions, 93 engagements, 18 retweets and 18 likes (stats as of 20/3/2018).
- An article on our research cruise of October 2018 was published in the deep-sea science publication Deep-Sea Life (http://www.indeep-project.org/indeep/sites/indeep/files/documents/DSL10_Nov2017.pdf#page=3 – which is circulated to around 600 deep-sea researchers quarterly)

- The MSC published an article about our research on their website (25/9/2017 - http://greenland-seafloor-stories.msc.org/)
- The 2017 MSC annual report highlighted our research in their annual global impacts report (https://www.msc.org/documents/environmental-benefits/global-impacts/msc-global-impacts-report-2017#page=11)

Events

- Chris Yesson gave an outreach talk to the general public at the Grant Museum as part of the field adventures season (26/04/17 – 20 attendees)
- Chris Yesson, Mona Fuhrmann & Stephen Long conducted two half-hour interviews with 58 key stage 2 schoolchildren from Devonshire Hill Nursery & Primary School in North London on 19/5/2017 to speak about our research and upcoming cruise. We spoke about our work in Greenland and the upcoming research cruise. During the cruise we sent information about our activities. We held follow-up discussion with the school children on 28/6/2017. Evaluation questionnaires were completed by the children, 90% of children said they liked the sessions (see example right)


ZSL LONDON ZOO

Pupil questionnaire

Spend five minutes drawing what you think Chris' fieldwork in Greenland looks like:

1. How much did you like learning about Chris's fieldwork in Greenland? *(please circle one face)*
2. What did you like about these lessons?

That it helped me learn more about the ocean and the sea bed.

3. What didn't you like about these lessons?

Nothing I enjoyed everything.

4. Circle the words that you think best describe your experience of speaking to Chris:

Fun, Exciting, Interesting, Scary, Good, Animals, Boring, Research, Fantastic, Sad, Wildlife, Science, Enjoyable, Pointless, Bad, Conservation, Scientists, Sustainable

Are there any other words you want to add:.....

Thank you!

- Chris Yesson, Stephen Long and IoZ colleague Matt Bennion presented a stand at the Natural History Museum's Science Uncovered evening outreach event, with Chris Yesson participating in the associated European Researchers Night (29/9/17 – 4320 came to entire event – 83% of attendees said experience was good or excellent)
- Stephen Long presented a talk on his research at Institute of Making, University College London (12/12/17 – c.20 attendees)
- Mona Furhmann presented a poster on this project to the Arctic Frontiers Science conference (25/1/17 – see annex)


Deep impact: low-cost technology to determine effects of fishing on deep-sea benthic ecosystems

Stephen Long[1,2]

[1]Department of Geography, University College London, Gower Street, London, WC1E 6BT
[2]Institute of Zoology, Zoological Society of London, Regent's Park, London, NW1 4RY

Problem

- Little is known about the deep-sea – earth's largest habitat
- Fisheries are expanding into virgin deep-seas
- Studies require often prohibitively expensive equipment
- Unknown impact of fisheries on deep-sea benthic habitats
- Can commercial action cameras (e.g. GoPro) provide a low cost solution?
- Approaches trialled in Arctic deep-seas, W. Greenland

Benthic video sled

Temperature and depth sensor, Light, Video camera

New imagery

Furrows in seafloor from trawling seen at 209m, Scan to see video clips, Coral garden at 390m, Grenadier fish at 872m

Image analysis and annotation

- Using the BIIGLE platform to analyse stills captured from video

3D Modelling

- Structure from motion (SFM) approaches to produce 3D models from video footage

Video, VisualSFM, 3D model

Next steps

- Add lasers to benthic sled to assist scaling and quantification of organism abundance
- Video sample across a spectrum of fishing effort in the Greenland halibut (*Reinhardtius hippoglossoides*) deep-sea fishery
- Analyse to determine impact of trawling

NERC, UCL, ZSL LONDON ZOO

- Mona Furhmann presented a talk on this project to school children at the Arctic Frontiers science for schools event, Tromso, Norway (25/1/17 – c. 40 attendees - https://www.apecs.is/news/apecs-news/2308-being-a-real-scientist-at-the-science-for-schools-event-at-arctic-frontiers.html)
- Mona Furhmann presented an exhibition at the "Kulturnat" annual event at Greenland Institute of Natural Resources, Nuuk. Mona showcased our research to members of the public (20/1/18 - 1046 people visited to the event – see annex). Evaluation forms were handed out at the event, but only 2 were completed, both gave positive feedback.
- Stephen Long presented a poster at the London

NERC-DTP annual conference: “Frontiers in Natural Environment Research” (24/8/2017 – image right)

- Stephen Long presented talk on our research at IoZ annual student conference. The talk was highly commended by the panel of judges and received a small prize (21/2/2018)

10. Sustainability and replicability

- *How do you plan to ensure a sustained legacy (e.g., social, economic, ecological, technical etc.) of your project outcome; is your planned exit strategy still valid; are you planning to make changes to what was originally proposed?*

There are a number of products from this project that will provide a sustained legacy beyond the life of the project:

- Teacher training material (details in section 8) will provide a long term training resource
- Capacity building at GINR (see section 8) including new benthic survey equipment which will be permanently housed at GINR after the project. This new approach has already been incorporated into other projects (ghost gear survey, inshore cod survey and habitat mapping in Disko Bay)
- Establishment of closed areas and the adoption of precautionary principle in management of expansion into Melville Bay provide a long term legacy of sustainable management of habitats (see section 7)
- Entrance of fisheries into MSC scheme ensures sustainable management of the fisheries for at least the lifetime of the assessments (a 5 year cycle). In the case of the Halibut fishery, this entered the 5 year assessment cycle in 2017. The coldwater prawn fishery will enter reassessment in 2018.
- There are direct economic benefits resulting from MSC certification: I) a higher price can be achieved for sustainable produce II) certification ensures access to markets (such as UK supermarkets), which are increasing closed to non-certified products. These increase profitability and resilience for the fishing industry, which remains the major source of foreign income for the nation of Greenland.
- Our research findings, survey data and impact assessments will provide a publicly accessible baseline of information on seabed habitats in the area.
- Our survey methods will be published and in the public domain, facilitating repeat surveys and assessments of change.
- All seabed images will be made publicly available. This will be a permanent resource of deep-water benthic fauna.
- This project has provided study opportunities for PhD and masters students. Training the next generation of marine researchers of the value of Greenland’s habitats. These studentships have helped to further supervisory linkages between ZSL, GINR and UCL
- Collaborative links between ZSL and GINR have been enhanced by the project. We have created new collaborations on the back of this project which will result in further research of Greenland’s seabed habitats.

11. Lessons learnt

This can include lessons from all levels including administrative, management, technical, and M&E. E.g.

- *What has worked well, and what has not worked so well during the reporting period?*
- *If you had to do it again, what would you do differently?*
- *What recommendations would you make to others doing similar projects?*
- *How are you going to build this learning into the project and future plans?*

Worked well

- *Video surveys* – We have developed, tested and successfully deployed our video sled system, in collaboration with GINR. This new system has collected valuable video survey data at depths ranging from 30-1500m.
- *Biigle* – The adoption of the Biigle platform for image annotation has proved a significant improvement on the Poseidon system. Our image processing is now much more efficient.
- *Kulturnat* – The exhibition at the 2018 Kulturnat at the GINR offices in Nuuk was a successful event, showcasing our project to the Greenlandic public. This has enhanced our collaboration with GINR (who waived any fees associated with this event).
- We have found displaying *360° video* of our research activities with virtual reality headsets to be an effective science communication tool. These have proved very popular at our outreach events and give a sense of 'being there' to our audience.
- Our *contact with schools* has been a rewarding experience and we were pleased by the excellent feedback we received.
- *Raising our project profile* – We have articles publicising our research published by Deep-Sea Life & MSC.
- *Enhanced collaboration with GINR* – We have worked closely with collaborators at GINR, creating new supervisory links and developing plans for ongoing benthic research collaboration
- *Capacity building of marine research at IoZ* - As a result of this project we now have a postdoctoral researcher, PhD student and a masters student working on marine research at IoZ.

Issues, Recommendations & Future plans

- We were frustrated by the delays with the research cruise. This was entirely outside our control. Initially the cruise was scheduled for September 2017, was subsequently cancelled in August due to failure of the main trawl-winch. Repairs were expected to take several months, but were completed early and the cruise was hastily re-scheduled in September to be carried out in October. This was disruptive for our timetable, as we had to cancel meetings with SFG and fishers planned for October, as the fieldwork had to take priority. Cancelling our presence at the Biennial captains meeting has set back some of our engagement plans.
- With hindsight we would have factored in more flexibility around the fieldwork dates
- Flights to Greenland are expensive. Booking well in advance gives cheaper tickets, but the cheapest tickets are inflexible. Purchase of tickets at the last minute for the

hastily rescheduled cruise was significantly more expensive. Flexible plane tickets are more expensive, but maybe worth the investment.

- The ZSL digital team have had difficulties with staff recruitment and retention, leading to limited resources available to work on our project. This meant we have had to spend more time on this project than we expected. We have now sub-contracted game development to a third party (at no extra cost) to ensure delivery on time, without disrupting our other activities.
- We were initially naive in our approach to game development. We have learnt a lot about the process. The initial plan to develop 2 games in parallel was not workable, so we have restructured our plans to produce a single game that delivers a conservation message and information about Greenland habitats in a fun and friendly way. This has been a steep learning curve, but we are on course to produce the game on time and on budget.
- We have faced difficulties contacting people in Greenland, when out of country. Email communication is not reliable and we have found face-to-face communication to be the most effective for positive outcomes. We believe it is a much better approach to have a presence in-country to facilitate communication, collaboration and data management. To this end we have requested reallocation of funds to have Mona Fuhrmann spend a significant period of time in Greenland this summer. We also feel that it would be beneficial to have other staff visit Greenland over the summer to enhance our collaborations.
- Our original plan to staff a 3 day exhibit with 2 people underestimated the amount of work required to create a successful engagement event. After discussions with the Royal Society at training for the summer science exhibition and experience operating shorter engagement events, we feel it is more realistic to budget for 6 people to run our exhibition at Polar Fish 2018. To this end we have requested reallocation of funds to cover more people to run this event. Furthermore, it has proved difficult to arrange the transport of a large screen to this event, so we feel that large hand-held tablet computers would provide a suitable alternative. We have requested additional funds for these devices.

12. Safeguard policy assessment

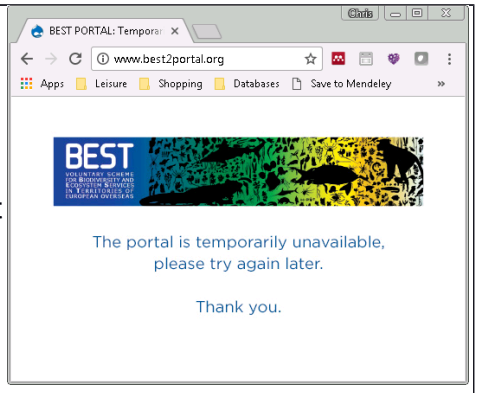
Provide a summary of any environmental and social safeguard issues that have arisen and any action taken to address them (if relevant).

Nothing has arisen

13. Any other comments on progress

Add any additional comments/information not covered by the other sections in this report.

The BEST web portal has been “temporarily unavailable” (see image right) for at least a week in the run-up to the reporting deadline (I write this on 27/4/18 and I have been unable to access the site since 20/4/18). This has been disruptive for the reporting process, as the website is required to submit our reports. With the site down I cannot check any details about submission requirements beyond the documents I have previously downloaded. At the very least I would expect to be contacted by BEST with some information about when the site will be back up and to provide an alternative access to reporting documents.



There have been several positive outcomes stemming from this project:

- *Additional research cruises* – our collaboration with GINR has expanded. We have been invited to conducted benthic surveys on other GINR funded research cruise. For example Stephen Long will conduct video surveys aboard M/T Sanna in October 2018 in the region of the inshore cod fishery.
- *New collaboration* – We have begun a new collaboration with DFO Canada to investigate the habitats of the Halibut fishery in waters contiguous with the Greenland fishery, but on the Canadian side of the border. We have been awarded a NERC grant to conduct a benthic survey in this region.

We would like to take this opportunity to express our delight at the positive outcome of the implementation of a new MPA in Melville Bay, which was facilitated by our research and collaborations with SFG and GINR. To have this outcome within the lifespan of project is beyond our expectations.

14. Progress and achievements against the project logical framework

Report of achievements against the project logical framework (repeat the logical framework from your proposal and include the necessary reporting)

Project summary	Indicator(s)	Progress and Achievements for the reporting period	Actions required/planned for the next reporting period
Overall Objective Sustainable use of marine resources in the Arctic and conservation of benthic habitats		The project has made a substantial contribution towards the overall objective. New information on benthic habitats has been collected. New protected areas have been set up in Melville Bay.	

Purpose Forward and promote sustainable fishing in Greenland by surveying, studying and informing stakeholders about the regions benthic habitats	1) MSC Re-certification of the Cold Water Prawn fishery by end of the project 2) MSC certification of the Greenland Halibut Fishery by Dec 2017 3) Surveys of the seabed (Jun/Oct 2016) 4) Stakeholder meetings conducted by IoZ throughout the project 5) Teaching fishermen on identification of key species (IoZ Nov 2017/Aug 2018) 6) Analysis of benthic habitats in relation to fishing effort and environment (IoZ researchers to submit 3 manuscripts in year 2 of project) 7) Publication of web-based resources (games, interactive map, website and educational materials - IoZ/ZSL Digital Outreach Jul 2017 & Jun 2018 deadlines)	1) The fishery is scheduled to enter re-certification in mid 2018 2) The Halibut fishery has been conditionally certified. 3) Cruises have been completed and the data is ready to work up. 4) Meetings have been conducted, further meetings to take place 5) Not yet achieved 6) Analysis ongoing 7) Material in preparation	[redacted]
Result 1. Visual (photographic) surveys of benthic habitats of W Greenland	Open access image library/ data resource (IoZ & ZSL Digital Outreach Team Jun 2018) Cruise report (IoZ Jul 2017, Nov 2017) Cruise blog (IoZ Jul 2017, Nov 2017)	Cruises were successfully conducted in June 2017 and October 2017.	

Activity 1.1 Photographic survey of benthic habitats at sites where historical shrimp surveys were conducted (continental shelf west of Disko Island)	Cruise reports documenting activities of surveys (by IoZ researchers published within 1 month of cruise) Approximately 1000 images of the seabed taken during two cruises (IoZ - make web-accessible by the end of the project)	The cruise was conducted successfully. The cruise report is provided as an annex A blog of the cruise is here (http://www.zsl.org/blogs/wild-science/sea-cucumbers-carnivorous-sponges-and-other-deep-sea-creatures)	Images to be made web-accessible by the end of the project.
Activity 1.2 Photographic survey of benthic habitats in the region of the Halibut fishery (off the continental shelf in NAFO region 1C & 1D)	Cruise reports documenting activities of surveys (by IoZ researchers published within 1 month of cruise) Approximately 1000 images of the seabed taken during two cruises (IoZ - make web-accessible by the end of the project)	The cruise was conducted successfully. A cruise report is provided in the annex. A blog detailing the cruise is here (https://www.zsl.org/blogs/wild-science/diving-deeper)	Images to be made web-accessible by the end of the project.
Activity 1.3 Scanning & digitising reels of images of the seabed taken in the 1970s and 1980s	Digitisation of approximately 500 images of the seabed taken during the surveys of the 1980s (IoZ - make web-accessible by the end of the project)	A total of 430 historical images have been scanned, covering all 430 areas we have been able to revisit.	Images to be made web-accessible by the end of the project.

Result 2. Documentation and analysis of structure, distribution and change over time (40 years) of benthic habitats of West Greenland. Interpretation of this change in terms of response to disturbance impact (trawling) and climate change. Projection of potential future change under the existing impact regime.	Minimum of 3 peer reviewed publications (Submissions by IoZ in year 2 of project) End of project report (IoZ/SFG)	Primary image data has been collected. Fishing effort data has been collected and processed. Environmental data has been collected. Examining images to identify organisms is ongoing. Analysis of these data will form the basis of the proposed publications.	
Activity 2.1. Identification of benthic organisms observed in photographs	Seabed images will be tagged with metadata identifying taxon observations using the image processing software Poseidon (IoZ – completed in the 3 months after each survey)	A start has been made on identifying taxa in images. Note we have decided to process these images in the software platform Biigle, not Poseidon as originally planned. The Biigle platform offers greater functionality and enables faster processing.	Identification is ongoing and should be complete by the end of summer 2018
Activity 2.2. Assimilation of environmental and fishing impact data for the region	Fishing effort data will be provided by SFG to document trawling activities in the region (SFG – 1st month of project) Environmental data, including seabed temperature, current speed and bathymetry data will be assembled for the regions of interest by examining oceanographic models from the http://marine.copernicus.eu/ web portal (IoZ – 1st month of project)	Fishing effort data has been collected both from the local regulator (GFLK) and the Global Fishing Watch Program Environmental data has been collected for temperature, salinity, current speed, bathymetry, slope and terrain ruggedness.	GIS layers will be made available at the end of the project.

Activity 2.3: Comparison of diversity and community composition in on-shelf habitats of West Greenland over the past 40 years in relation to changing environment and fishing impact	Analysis comparing diversity and taxonomic composition of benthic habitats in the region of the coldwater prawn fishery by comparing observations from surveys conducted by this project and those from the 1980s. (IoZ – submission of manuscript in 2nd year of project)	A provisional analysis is complete, base on data collected prior to the 2017 survey.	A full analysis will be completed in 2018 after images from the 2017 survey have been processed.
Activity 2.4: Analysis of the diversity and community composition of off-shelf seabed habitats in NAFO region 1C & 1D in relation to fishing effort in the region	Analysis of patterns of diversity and community composition in relation to environmental conditions and fishing activities in the region of the Halibut fishery (IoZ – submission of manuscript in 2nd year of project)	A first pass analysis of taxonomic abundance and fishing effort has been carried out based on provisional results from the October 2017 survey of the Halibut fisher region	A full analysis will be conducted in year 2 of the project, after completion of 2.1 & 2.2
Activity 2.5: Create a classification of off-shelf seabed habitats and predictive habitat map of the region	Images of off-shelf seabed will be classified into EUNIS habitats. Environmental proxies will be examined to develop a predictive model of habitat class that will be used to create a predictive map benthic habitat that will made public at the end of the project (IoZ)	Data from the October 2017 survey has been collected for this purpose	An analysis will be conducted in year 2 of the project

Result 3. Management plan for sustainable use of marine resources in West Greenland	Reports to be submitted to the Marine Stewardship Council detailing plans for the management of the Halibut and Coldwater Prawn fisheries. To be submitted by SFG at the end of the project and supported by information gathered by IoZ	All plans have been delivered to MSC on schedule. The Greenland Halibut Fishery has achieved provisional certification. The Coldwater Prawn fishery is on course for re-certification.	
Activity 3.1. Create a management plan for the sustainable use of the Halibut fishery	SFG to submit a management plan for the sustainable use of the Halibut fishery to the Marine Stewardship Council by the end of the project. (IoZ to support with information on the impact of the fishery on benthic habitats)	Documentation of the West Greenland Offshore Greenland Halibut Fishery can be found on the MSC website (https://fisheries.msc.org/en/fisheries/west-greenland-offshore-greenland-halibut/@@view)	The annual audit of the fishery will be conducted in August 2018 where SFG, IoZ and stakeholders will discuss progress and outstanding conservation issues for sustainability certification. A revised management plan will be produced.
Activity 3.2. Create a management plan for the sustainable use of the Cold Water Prawn fishery	SFG to submit a revised management plan for the sustainable use of the Cold Water Prawn fishery to the Marine Stewardship Council by the end of the project (IoZ to support with information on the long-term impact of trawling on the benthos of the region).	Documentation of the West Greenland Coldwater Prawn Fishery can be found on the MSC website (https://fisheries.msc.org/en/fisheries/west-greenland-coldwater-prawn/@@view)	SFG will continue with their application for MSC re-certification which is on course for year 2 of the project. IoZ will continue to support this process with information and advice.

Result 4. Engagement of fishermen, children, industry, and public with the issue of conservation value of Greenland's benthic habitats. Long-term buy-in and interest amongst these stakeholders regarding the importance of these national resources and their sustainable management.	Workshop at Greenland Maritime Centre (Skipper Skolen) Teaching session at Grønlands Gymnasiale Uddannelser. (Secondary school, Nuuk) and others Lecture (x2) to Officers' conference of fishing industry leaders (Polar Seafood A/S, Royal Greenland A/S), Public exhibition at Polar Fish Trade show, Sisimiut Public exhibition and open day ("Cultural Evening") at GINR Permanent teaching resource and exhibition lodged in Nuuk Online publication of web resources: Food-web game and project website Educational video, interactive map and species identification materials	A series of outreach events have been conducted. These include talks to the general public, engagement with school children of various ages, and exhibitions at major institutions. These events have taken place in UK, Greenland and Norway. The rescheduling of the cruise has led to the cancellation of meetings with ships capatins. We will try to find alternative meetings in the upcoming year. Long term buy-in of stakeholders is evidenced by the adoption of new protected areas and restrictions on fishery expansion, requiring support from fishery representatives, scientists and government.	
Activity 4.1. Workshop to inform Greenlandic fishermen on benthic habitats and provide information on the identification of vulnerable marine organisms caught as bycatch	A workshop will be integrated into "Skipper skolen" to inform fishing crews on vulnerable marine organisms and provide training on how the identify vulnerable marine organisms in bycatch and inform on the correct procedures when encountered. (IoZ Nov 2017, Aug 2018)	We were unable to organise this event in 2017 due to the hasty rescheduling of the October 2017 cruise. We have failed to find a point of contact for this course willing to engage with us.	We will try to find a point of contact and arrange for training to be conducted in year 2 of the project.

Activity 4.2 Workshops on Greenland's benthic habitats and conservation efforts to protect them will be presented to the annual officers conferences of the main fishery operators Royal Greenland and Polar Seafood.	SFG have arranged for presentations by IoZ researchers at annual officers conferences held by Greenland's main fishery copmanies Polar Seafood (Autumn 2017) and Royal Greenland (Spring 2018)	The 2017 meetings of both Polar Seafood and Royal Greenland were conducted in October 2017 and unfortunately overlapped with rescheduled cruise. This meant we (IoZ) had to cancel our planned involvement.	The officers conferences are now on a two-yearly schedule, which means there will be no meeting until after the completion of the project (scheduled for autumn 2019). SFG are examining alternative opportunities for late 2018 or early 2019.
Activity 4.3 Education of school children about the seabed of West Greenland	A series of school events will be set up around research cruises include skype interviews before and after cruises, blogging of activities during cruises and a live Q&A with researchers (IoZ researchers and ZSL Discovery and Learning D&L team around research cruises Jun & Oct 2017) Educational material on the seabed of Greenland will be tailored to secondary school groups by ZSL D&L team to circulate to schools before/after the research cruises.	IoZ staff conducted skype meetings with 2 classes of primary school students before and after the research cruise in June 2017. Evaluation forms were completed by schoolchildren and teachers. Images and information were provided to the classes during the cruise. Unfortunately, no events were possible associated with the October 2017 cruise due to the last minute rescheduling.	The school events have been superseded by the production of teacher training material, which is felt to be a longer lasting teaching resource.

Activity 4.4 Exhibition showcasing Greenland benthic habitats will be presented at Polar Fish 2018	An exhibition presenting specimens, images and information of Greenland's seabed will be created by ZSLs D&L team. This will be presented by IoZ researchers at Polar Fish Greenland (September 2018)	The material developed for our other outreach activities will also be used for this event.	This event will take place in September 2018
Activity 4.5 Exhibition showcasing Greenland benthic habitats will be presented at the Royal Society Summer exhibition, 2018	An exhibition will be given at Royal Society Summer exhibition by IoZ in 2018	We have been successful in our application to the Royal Society and we will be participating in the 2018 summer science exhibition of July 2018. We participated at an outreach training event, provided by the Royal Society, in preparation.	Preparations for this event are ongoing. This will include a 'trial-run' of our exhibition stand at ZSL London Zoo during the May school half term.
Activity 4.6 An evening outreach event will be given as part of the "Cultural Night" program held at the Greenland Institute of Natural Resources, presenting the project findings to the general public	An evening cultural event will present the findings of the project to an audience of the general public at a meeting room in the Greenland Institute of Natural Resources. (IoZ Summer 2018)	This event was successfully conducted in January 2018. A total of 1046 people visited "Kulturnat" at the GINR offices.	This event is complete.
Activity 4.7 Development of web resources to highlight the diversity of life in Greenland's benthic habitats	Publication and promotion of web resources (on www.zsl.org), an interactive map using benthic images to showcase and educate about habitats, teaching materials (IoZ/ZSL Digital Outreach July 2017)	Development of the interactive map has been delayed until images from the 2017 surveys have been fully processed (Activity 2.1). This will ensure a representative set of images will be used to cover all important taxa and habitats.	The map will be produced by the end of the project.

Activity 4.8 Development of a game using seabed video and images to inform, educate and entertain on the subject of Greenland's benthic habitats	Publication of i) a game to inform on food webs of Greenland's seabed (IoZ/ZSL Digital Outreach July 2017) ii) a game to identify key species based on images of bycatch and direct on the seabed (IoZ/ZSL Digital Outreach Jun 2018)	Efforts have been re-focussed on developing a single game to educate about the impacts of fishing on the seabed. This game will include snippets of information about key species. Game developers have been employed and a game outline has been drafted.	Development is ongoing, we expect this game will be ready for the Royal Society Summer Science Exhibition in July 2018.
Activity 4.9 Production of an educational video	Publication, presentation and promotion of an educational video documenting the diversity and conservation of Greenland's benthic habitats (IoZ/ZSL Digital Outreach Jun 2018)	A short video outlining our research was developed by ZSL digital An extended video with Danish translation was presented at the Kulturnat event.	The video will be revised and enhanced in time for the presentation at the Polar Fish exhibition in September 2018.

15. Submission Checklist

(Please ensure that you have included all of the following before submitting your report)

	Check
Standard request for payment	☐x
Financial report (signed) covering expenditure up to the end of the reporting period	☐x
All relevant documents as annexes	☐x

16. Annexes

Please include any relevant deliverables as annexes to this report.

Annex 1 – Monthly reports

Annex 2 – Cruise report for the survey of June 2017

Annex 3 – Cruise report for the survey of October 2017

Annex 1

Monthly Reports

First email report for BEST project 1586 "Sustainable fishing in the Arctic: Can the harvest of Greenland's biggest export be compatible with the conservation of benthic ecosystems?"

Project staff Chris Yesson (CY), Mona Fuhrmann (MF), Stephen Long (SL)

Preliminary work

- A postdoctoral researcher was recruited prior to the start of the project. Dr Mona Fuhrmann (MF) was selected from a set of 47 applicants. MF has moved from Tromso, Norway to join the project and has experience working with Arctic invertebrates including significant time working in Svalbard. Unfortunately, MF had prior commitments and was not able to join the project until early May, just 2 weeks before our first research cruise.
- We are delighted to report that Zoological Society of London (ZSL) have secured a fully funded PhD student, Stephen Long (SL), who is part of the London doctoral training programme. SL will be conducting his research on the Greenland Halibut fishery. Although we did not include a PhD as part of the original project plan, we feel this PhD allows us to enhance our research on the Halibut fishery by adding another full time researcher on the project.
- Dr Chris Yesson (CY from ZSL), Kristina Guldbæk (KG) and Peder Munk Pedersen (PMP - both from SFG) attended the final MSC audit meeting for the West Greenland Coldwater Prawn fishery, at Polar Seafood offices in Aalborg. CY presented the findings of ZSLs research over the past 5 years and discussing requirements for the final certification of the fishery and future requirements for recertification, under the more stringent conditions of the revised MSC standards.

April 2017

- Work begins gathering environmental data for the West Greenland area.
- April 21st. PMP and KG visited ZSL to discuss the project. KG is leading the application to MSC for the Greenland Halibut fishery. Provisional feedback was received from the auditors regarding this application and the conditions of certification were discussed. A plan was outlined resulting in feedback to MSC auditors.

May 2017

- MF starts work on the project.
- May 22nd. The Greenland Halibut fishery receives provisional certification (https://fisheries.msc.org/en/fisheries/west-greenland-offshore-greenland-halibut/@@view) conditional on, amongst other things, the research results of our BEST project.
- May 19th. Pilot of outreach to schools. CY, MF, SL and ZSL's Public Engagement with Conservation Science Coordinator Charlotte Cowan (CC) conducted two 30 minute interviews with children from Devonshire Hill Nursery & Primary School in North London. We spoke about our work in Greenland and the upcoming research cruise. This is a pilot for future contact with Greenlandic schools.
- May 30th. Blog post published describing upcoming research cruise (https://www.zsl.org/blogs/wild-science/exploring-the-deep-seafloor)

June 2017

- May 28th - June 12th. Research cruise aboard M/T Paamiut. CY/MF/SL Conducted benthic photography and video targeting sites in the region of the West Greenland Coldwater Prawn Fishery with imagery from the 1970 and 1980s for analysis of change. Unfortunately, do to extensive sea ice, only 9 of the 20 target stations were accessible. We have been offered a place on the equivalent survey next year and will participate on this cruise to try to obtain data for the remaining stations. A successful trial was performed of a new benthic sled camera, which will be used for the upcoming survey of the Greenland Halibut area. I have attached a draft of the cruise report. And a short blog describing our trip is here (www.zsl.org/blogs/wild-science/sea-cucumbers-carnivorous-sponges-and-other-deep-sea-creatures).

Upcoming activity

- Examination of images from cruise
- Follow up session with school
- Development of website to include more project information

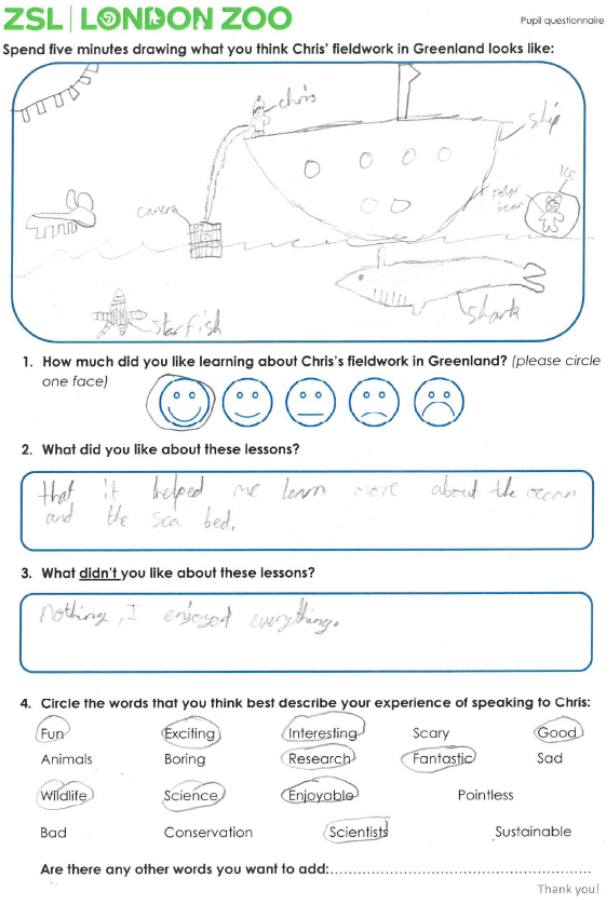
End of report

Email report for BEST project 1586 "Sustainable fishing in the Arctic: Can the harvest of Greenland's biggest export be compatible with the conservation of benthic ecosystems?" - July & August 2017

Project staff Chris Yesson (CY), Mona Fuhrmann (MF), Stephen Long (SL)

July 2017

- ZSL Public engagement produce feedback from our first school communication. Children were asked for their impressions of the event and drew pictures of what they imagined life was like on the research cruise (see example right).
- CY & MF met with London Zoo's presentation team. After discussions, presenters are now giving a daily talk to London Zoo's visitors describing our work with Greenland fisheries and the importance of ensuring sustainable fisheries
- Drop camera images and video sled data collected on the research cruise (June 2017) are being processed and taxa in the images identified (MF - ongoing)
- We are investigating new data management systems (specifically BIIGLE v2) to manage and mark-up our image data (SL, MF, CY)
- Our ZSL/SFG collaboration and research in West Greenland has been highlighted in the 2016/17 MSC annual report (https://www.msc.org/documents/environmental-benefits/global-impacts/msc-global-impacts-report-2017- page 18)


ZSL | LONDON ZOO

Pupil questionnaire

Spend five minutes drawing what you think Chris' fieldwork in Greenland looks like:

1. How much did you like learning about Chris's fieldwork in Greenland? *(please circle one face)*

2. What did you like about these lessons?

That it helped me learn more about the ocean and the sea bed.

3. What didn't you like about these lessons?

Nothing, I enjoyed everything.

4. Circle the words that you think best describe your experience of speaking to Chris:

Fun, Exciting, Interesting, Scary, Good, Animals, Boring, Research, Fantastic, Sad, Wildlife, Science, Enjoyable, Pointless, Bad, Conservation, Scientists, Sustainable

Are there any other words you want to add:.....

Thank you!

August 2017

- MF & ZSL Digital communications team have created a video highlighting aspects of this project (https://youtu.be/M4qODUKXbv0) which has been advertised on ZSL digital platforms
- Environmental datasets describing the oceanographic conditions of Davies Straight and Baffin Bay have been investigated and processed into analysis-ready GIS layers (CY)
- During the research cruise of June 2017, several issues were identified with the video sled (reliability of torches & need for lasers to get accurate scale). SL has been investigating solutions. Lasers have been purchased and low-cost housings are being developed
- Halibut trawling data has just been received from GFLK. We are investigating these data to convert into a gridded GIS layer of fishing effort in the region (SL)
- We have just been informed that the September research cruise to the Halibut area has been cancelled due to a significant failure of the winch equipment aboard M/T Paamiut. The Paamiut will spend the remainder of the season in port (in Iceland) undergoing repairs. The cruise will be rescheduled for September 2018. This will inevitably create some timing issues for our project.

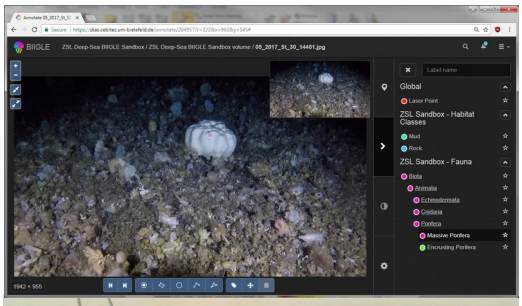
- CY & MF contributed to a meeting with GINR & SFG discussing the issue of sustainable fishing in Melville Bay by the West Greenland Coldwater Prawn Fishery
- SL has been exploring options to produce 3D reconstructions of the seabed from videos for science communication and analysis purposes
- We have been invited by SFG to present at annual industry meeting for fleet captains in October

End of report

Email report for BEST project 1586 "Sustainable fishing in the Arctic: Can the harvest of Greenland's biggest export be compatible with the conservation of benthic ecosystems?" - September & October 2017

Project staff Chris Yesson (CY), Mona Fuhrmann (MF), Stephen Long (SL)

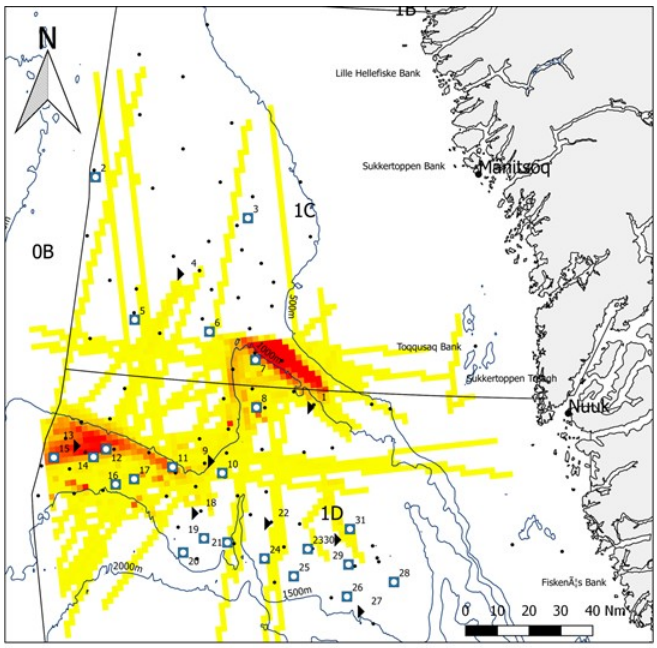
September 2017



- The research cruise scheduled for September 2017 was initially cancelled due to winch failure, then subsequently rescheduled for October 2017
- CY, MF, SL met with developers of the BioImage Indexing, Graphical Labeling and Exploration (BIIGLE) image annotation platform to investigate its potential for image analysis on this project. We have begun collaboration with Dr Tim Nattkemper and the University of Bielefeld to use this system for our analysis (screenshot right)
- SL constructed deep water housings for lasers (with assistance from UCL's Institute of Making), to be added to the towed video sled on the upcoming cruise
- CY, SL and IoZ colleague Matt Bennion presented at the Natural History Museum's Science Uncovered evening outreach event on 29th September. This involved showing specimens, images and videos to members of the public and informing them about the BEST project (see photo of stand - right). CY attended an associated discussion event at European Researchers Night at Natural History Museum (29th September)
- MF and colleagues at ZSL prepared an application to present our project work at the 2018 Royal Society Summer Exhibition (London, UK).
- MF arranged for a stall allowing us to present our research at the 2018 Big Bang Science Fair (Birmingham, UK)
- MF met with the digital team at ZSL to start developing the digital outreach game.

October 2017

- CY, MF, SL met with Martin Blicher (Greenland Institute of Natural Resources – GINR) to discuss ongoing collaboration on Greenlandic benthic research, outreach activity and the upcoming cruise
- MF met with Lars Poort (Ilisimatusarfik University, Greenland) to discuss outreach collaboration, specifically providing information on Greenland's benthic habitats to contribute to ongoing training of teachers in Greenland. We believe that providing teacher training material is a more effective outreach activity that one-off school visits and will provide a long-lasting legacy for our project
- We were unable to attend / present at the annual Polar Seafood fleet captains meeting as this coincided with the research cruise. This meeting will be rescheduled for 2018



- SL obtained log book data for the West Greenland offshore Greenland halibut fishery, and created provisional fishing effort maps for the region. SL cross referenced this with data from Global Fishing Watch (http://globalfishingwatch.org/), finding strong agreement between logbook data and inferred fishing effort from AIS data.
- CY, ML, SL conducted a research cruise aboard M/T Paamiut, taking benthic video and beam trawl surveys in the region of the West Greenland offshore Greenland halibut fishery (see attached cruise report & cruise map right). We successfully sampled 31 stations at depths of 650-1500m, collecting more than six hours of seabed video spanning 300 km. These data will form the basis of the habitat mapping and impact assessment
- After the cruise SL was able to conduct 4 interviewees with actors in Greenland fisheries representing scientific and fisher perspectives. In accordance with ZSL ethics procedures interviewees are anonymised. The interviews offered new insights into the history, management and governance of the Greenland halibut fishery and the role of the Marine Stewardship Council (MSC) certification. This will feed into SL's PhD research and future academic publications related to fishery governance, principally working with SL's supervisor Dr Peter Jones (Department of Geography, University College London)
- CY, MF, SL presented a summary of survey videos from the cruise to Martin Blicher, Nanette Hammeken and Rasmus Nygaard (GINR). All were enthused about how well the video sled worked, the potential for analyses of the data collected and the potential to do further video survey work to address questions in this and other fisheries
- A video presentation detailing our research was prepared by MF and shown at the Institute of Zoology annual research conference at the Zoological Society of London (16th October)

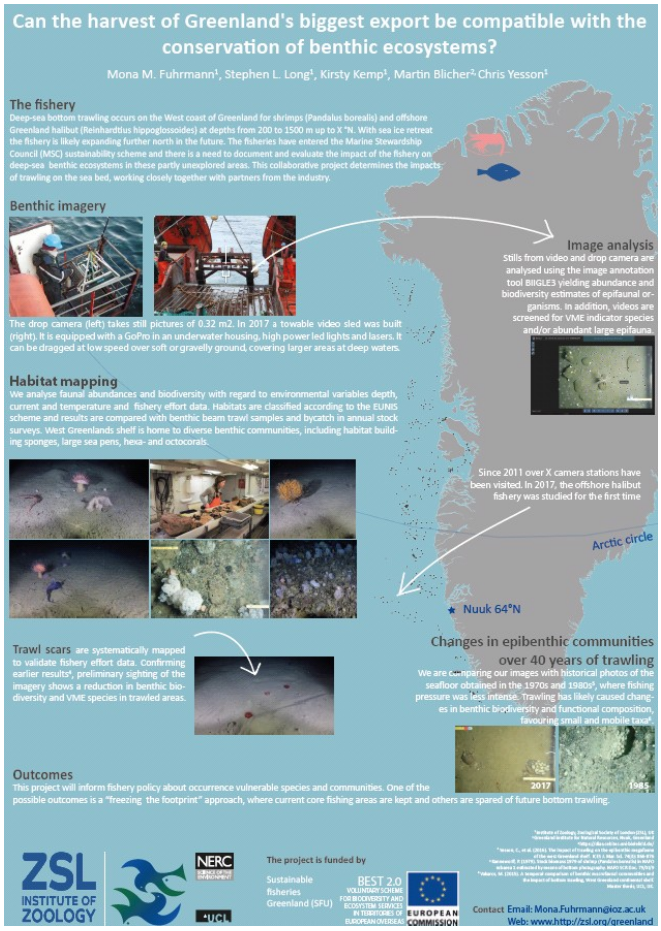
November 2017

- We received notification from the Royal Society that our application to present at the Royal Society Summer Summer Science Festival was successful. This event will take place in July 2018.
- Kristina Guldbæk (KG) of Sustainable Fisheries Greenland visited ZSL on 8th November for a project meeting with CY and MF to discuss progress and future plans. MF & CY presented initial findings and video highlights from the cruises. KG presented a progress report on the MSC certification process for the Halibut and Prawn fisheries.
- CY put forward plans to GINR for ZSL participation in two stock assessment cruises in 2018. These were provisionally accepted by GINR.
- MF met with ZSL digital communications team to discuss plans for the computer game.
- SL began assessment of seabed video footage taken during the October cruise.
- MF worked with developers of the Biigle image annotation platform and successfully uploaded a pilot dataset on the system.
- MF wrote and published a blog providing outreach highlights from the October cruise (https://www.zsl.org/blogs/wild-science/diving-deeper)
- MF wrote and published a note on the October cruise in Deep Sea Life (http://www.indeep-project.org/indeep/sites/indeep/files/documents/DSL10_Nov2017.pdf#page=3)
- MF, CY & SL wrote a cruise report detailing activities for the October cruise (see attached)
- The Marine Stewardship Council published a story about our research on their website (http://greenland-seafloor-stories.msc.org/)
- MF has continued collaboration with Lars Poort (Ilisimatusarfik University, Greenland), to develop teaching material for Greenlandic schools

December 2017

- MF attended an OceanTeacher Global Academy Training Course: Research Data Management at UNESCO/IOC Project Office, Oostende, Belgium (4-8 December). This was an opportunity to discuss our project with an international audience and learn about best practice for data management, including online portals for making project data publicly accessible.
- CY attended a coral identification workshop at the University of Plymouth (6/12/17)
- SL presented his research at Institute of Making, University College London (image right), where he showcased the home-made laser housings used during the 2017 field season (12/12/17).

- MF, SL & CY drafted, discussed and improved our protocol for image annotation.
- SL met with Wojciech Walkusz of the Department of Fisheries and Oceans, Canada, to discuss expanding our benthic surveys into the Greenland Halibut fishery in the Canadian EEZ.
- MF, SL & CY attended a planning meeting at ZSL discussing the Royal Society Summer Exhibition.
- MF, SL & CY discussed ideas for a video game with fellow marine researchers at ZSL. The game will highlight the issues of sustainable fishing and trawling impacts.



January 2018

- MF & SL attended a planning meeting at ZSL discussing the Royal Society Summer Exhibition.
- MF travelled to Nuuk, Greenland to present at the "Kulturnat" annual event at Greenland Institute of Natural Resources. Mona showcased our research to members of the public (20/1/18 - images below, 1046 people visited to the event)
- MF presented a poster at the Arctic Frontiers event in Tromso, Norway (image right)
- MF gave a presentation of our research to the Arctic Frontiers-science for schools event, Tromso, Norway (25/1/18)
- MF took part in the Arctic froniters/Arctos workshop, Tromso, Norway (23/1-1/1/18) https://www.arcticfrontiers.com/program/session/?id=AY006
- SL carried out annotation of video footage from the survey conducted in October 2017
- CY examined seabed images from the survey of May/June 2017
- MF examined benthic images from Melville Bay
- MF met with Peder Munk Pedersen of Sustainable Fisheries Greenland to discuss project progress
- MF met with Lars Poort (Ilisimatusarfik University, Greenland) to discuss teaching materials and contributed to an ebook of educational material on Greenland's benthic habitats to be used for teacher training
- New closures to the Shrimp fishery in Melville Bay have been introduced, after identification of potential VME species based on our analysis of our 2016 survey (http://naalakkersuisut.gl/da/Naalakkersuisut/Nyheder/2018/01/2301_melvillebugten)

Kulturnat – Outreach event at GINR offices, Nuuk, Greenland (20 Jan 2018)

February 2018

- Chris Yesson (CY) published a blog on the new fishing regulatory areas in Melville Bay (https://www.zsl.org/blogs/science/new-protection-for-vulnerable-arctic-habitats)
- In early February, we learnt that the research vessel Paamiut, used to conduct annual stock assessments of the Coldwater Prawn and Halibut fisheries is unsafe to operate and has been decommissioned. This has major implications for fieldwork planned for 2018, as we planned to conduct surveys aboard Paamiut this year.
- CY, Mona Fuhrmann (MF), Stephen Long (SL) met with Martin Blicher of GINR to discuss plans for the 2018 field season. It remains uncertain whether a vessel suitable for our surveys will be in place for this year.
- MF continued identification of benthic fauna from drop camera images
- SL presented work on the halibut fishery at the Institute of Zoology Annual Student Conference (21st February)
- SL examined benthic videos from Halibut fishery region and produced counts of the main fauna, focussing on vulnerable marine ecosystem (VME) indicator species

March 2018

- CY attended public engagement training at the metal Society, as part of preparation for the Royal Society Summer Science Exhibition (14/03)
- SL successfully went through the PhD upgrade process (21/03)
- CY attended a training workshop, hosted by the London Ocean Group, on using remote sensing data in marine environments (23/03)
- SL attended a course on Species Distribution Modelling (SDM) in marine environments hosted by the International Oceanographic Data and Information Exchange (IODE)
- MF met with game developers to discuss specifics of the outreach game we are developing (23/03)
- SL received a new substantial dataset (2012-2016) of fishing activity (trawling) from Global Fishing Watch for the Baffin Bay and Davis Strait regions
- SL conducted a preliminary exploration of the fauna count data from the Halibut fishery videos to assess impacts of trawling in this area
- CY developed a method for extracting standard interval stills from our benthic videos and uploaded these to the Biigle platform

Annex 2

Cruise Report June 2017

Cruise report

M/T Paamiut SFW RejeFisk Survey Togt 1

27th May – 13th June 2017: Nuuk-Ilulissat

Personell

Dr Chris Yesson, Dr Mona M. Fuhrmann, Stephen Long (ZSL)

Cruise leader: Nanette Hammeken (GINR)

Objectives

1. Collection of sea bed photos in areas of shrimp fishery in West Greenland. In order to investigate the long term impact of trawling in this area, priority was given to remaining stations of which there were images taken between 1977 and 1985 (by Per Kanneworff and colleagues) to continue our study of historical change of the benthic community.
2. Testing and collection of video footage of the sea bed using a new developed benthic sled with a mounted GoPro and new torches.
3. Collection of benthic bycatch data from cosmos shrimp trawls (GINR project supported by Stephen Long)
4. Collection of abundance and biomass data of the benthic community using a beam trawl (INAMON project supported by Stephen Long)
5. Conduct first survey (beam and video sled) in the MabHab area in Disko bay.
6. Inform and educate by conducting outreach activities around the cruise.

Summary of work

The survey was a joint venture between the Greenland Institute of Natural Resources (GINR) and Zoological Society of London. We had effective ship time of 14 nights for our camera activities. Night-time sampling was shared between the camera survey conducted by ZSL and beam trawls conducted by the INAMon project. The benthic habitat mapping during the cruise leg 1 onboard Paamiut was successful and resulted in over 200 pictures of the sea bed from 15 stations and more than 9 hours of video footage from 36 stations between the latitudes 64º15 and 69 º49 (between Nuuk and Disko Bay), at depths ranging from 29 to 872 m. Bottom substrates ranged from muddy to mixed rocky ground. Our primary object was to re-sample areas with historical imagery available, and we managed to resample 9 of these. Due to ice

conditions the northernmost target stations with historical imagery (13) were not accessible.

Equipment

Drop camera

ZSL's benthic drop camera was used for imaging the seabed (Fig. 1). The camera was additionally equipped with a GoPro and one standard torch in a GB-PT underwater housing (we tested two torches as well which resulted in a slight overexposure). 15 to 20 pictures were taken per station with an interval of 1 min. To obtain video coverage of a larger area, we tested drifting the camera ca. 1 m above the seabed with help of a trawleye (mounted on the frame), which provides live feedback on the distance to the seabed. A computer was set up in the winch room to give real time information on the depth of the camera using the trawl eye data. The team viewer software was used to provide a view of the bridge computer via a new network cable set up during the cruise. The video obtained helped in getting an impression of the habitat and aided identification of animals, but did not provide additional quality footage for quantitative analysis, mostly because precise estimation of the distance to the sea bottom could not be achieved. Furthermore, an experiment was performed deploying the camera in area with extreme high sloping seabed, where trawling gear could not be deployed. This provided footage of the seabed which could not be gathered with our other survey methods, including video footage of a vertical rockface.

Benthic sled with GoPro camera

High quality video footage was obtained using a new custom made benthic sled (dimensions 3m x 2m x 1m, weight approximately 1 ton), constructed to take video of the sea bed from a fixed distance (Fig. 2). A GoPro camera and two Nautilux torches in GB-PT 1750 group binc underwater housings were mounted on the sled pointing forwards and allowing for a larger area to be surveyed than with the drop camera. Each video sled trawl was deployed for 15 mins of bottom-contact time, and recorded using the same datasheets used for beam trawl and cosmos trawl deployment. These were entered into the database as “video sled” deployments.

Early deployments involved experimentation with the angle of the camera and lighting, along with settings for the camera. We settled on a strategy of an angle of approximately 31° from horizontal for the camera, providing a balance between distance visible in the video and the area covered by the lighting. These settings have been permanently marked onto the sled. An experiment with time-lapse photography, rather than video, was attempted at one station, but the still images were often blurred and it was felt that the video produced more reliable and usable images. The system

is sensitive to the speed of the sled over the ground. It was felt a speed of around 0.8 knots was optimal. Too much faster and it is difficult to get a clear image, especially in the area of the image closer to the camera, which appears blurry at faster speeds. It is difficult for the ship to go reliably slower than this, with the additional difficulty of slower speeds increasing the potential for the winch wire to droop and touch the ground ahead of the sled, causing sediment clouds to obscure the image. This was more of an issue on soft ground, deeper water and uneven seabed. In order to reduce seabed contact, 4 floats were mounted on the chain at the point it links with the main winch wire. We recommend these are attached before each deployment. Another factor in this issue is the amount of winch wire let out during deployment. We have used a ratio of wire length = 1.5x depth (i.e. 1500m of wire for deployment at 1000m), it is worth considering reducing this ratio at deeper deployments.

The sled occasionally became stuck on rocks, but generally coped well in rocky terrain.

There were issues with the deployment of the Nautilux torches. The cables inside the housing were regularly twisted by the screwing/unscrewing of the housing and bent by the movement of the battery. The cables frequently either became loose or snapped. Several methods were attempted to reduce the twisting (changing the section of housing to unscrew, placing the torch light-down while screwing), but the lights would partially fail every 4 or 5 deployments (typically one wire would detach causing one led to fail at initial deployment). Although there is a time-delay for switching on the torches, this function was not used because it was important to check the lights were functioning before deployment. Although it is recommended not to turn on lights out of water, the risk of overheating seems minimal in such cold conditions. We are working on an internal housing for the wiring to try to reduce this problem in future.

A starmon temperature sensor was mounted on the sled.

Beam trawls

If ship time allowed, after each camera survey was complete, a beam trawl survey was carried out at the same station. The beam trawl samples mostly epibenthic organisms larger than 5mm. These trawls were conducted as part of the INAMon benthic survey of the Greenland shelf currently being conducted by Martin Blicher (GINR). Specimens were identified and documented by a team of benthic taxonomists.

A GoPro camera and 2 GPH 1750m torches were fitted to the beam trawl in a similar setup to the video sled, only the camera and torches are not adjustable on the beam trawl and are inclined at a steeper angle. This setup produced good video at the start of deployment, but on soft sediments in particular, the video would become obscured

by sediment stirred up by the trawl. Additionally the speed required for beam trawl can lead to blurred video.

Results

Imaging

In a continuation of previous year's activities, 15 drop camera stations (Table 1, Fig. 3) were resampled and produced liable images of high quality which can be compared to historical images available. A highlight was the second observation of the carnivorous sponge *Chondrocladia gigantea* (Fig. 4). The camera was also deployed in slopy rocky bottom and the mounted GoPro managed to capture a vertical wall with sponge and anemone assemblages.

36 stations were covered by the benthic video sled (Table 1, Fig. 3), the deepest deployment was 872 m. At station V030 at 390 m depth, we discovered a diverse species assemblage including Nephtheid corals (Fig. 5). The picture and video material will be sighted and analysed for species abundance data.

Bycatch processing and beam trawls

GINR documented and collected all benthic fauna taken as bycatch from cosmos trawls as a reference collection of benthic fauna for the area. On the first leg of this year's surveys, this was conducted by the scientists and students conducting the shrimp stock assessment. Additionally samples of benthic invertebrates were collected and dried for use during public engagement and outreach activities.

There was limited benthic bycatch from Cosmos shrimp trawls in terms of biodiversity and biomass. Mostly these were non-target shrimp species.

Combined sampling of stations by camera/video and beam trawls, together with the taxonomic expertise on board, proved extremely useful in identification of fauna seen in images and video.

MapHab area

Three nights of sampling were conducted in an area in Disko Bay known as the "MapHab" area. This region is the focus of an ongoing project to map benthic habitats in the area using a combined approach of multibeam, mud sampling, biological sampling and imaging. Sampling in this area involved 7 video sled stations, 5 beam trawls (all at areas with video footage) and 2 drop camera stations at high-sloping areas where it was impossible to put down trawling gear (Fig 6). These data will form part of the larger MapHab project.

Outreach

As part of previous outreach to the Devonshire Hill Nursery & Primary School in North London school, we send pictures and short summaries to the pupils, telling them about our work and life on board. Other digital communication comprised twitter feeds (example https://twitter.com/MonaFuhrmann/status/873737435666149376) and a blog at the ZSL wild science portal (https://www.zsl.org/blogs/wild-science/exploring-the-deep-seafloor). We produced a highlight video from collected footage which was distributed to the crew and will be developed further for showcasing at outreach events. In addition, specimens for culture night in January (Nuuk) were collected by GINR.

Fig. 1 Setting up the drop camera

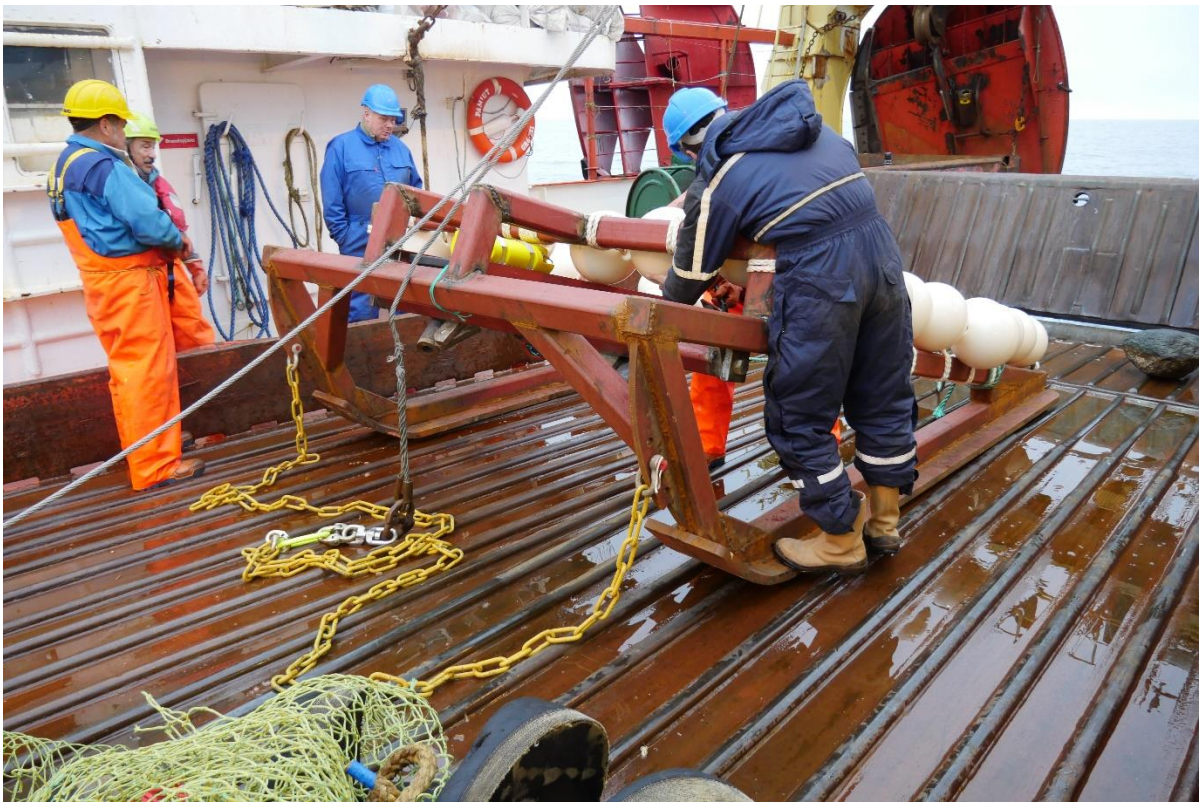


Fig. 2 Deployment of the benthic sled

Table 1 Station list

Station ID	Type	Latitude	Longitude	Depth	Date
1	Camera	64°32.45	52°51.956	435	28.05.17
2	Camera	64°16.098	53°14.428	366	29.05.17
3	Camera	64°15.971	52°57.922	392	29.05.17
4	Camera	64°54.109	53°07.023	351	30.05.17
5	Camera	64°35.076	55°07.328	399	31.05.17
6	Camera	64°56.345	53°34.455	75	31.05.17
7	Camera	64°57.907	53°18.180	35	01.06.17
8	Camera	66°29.475	56°02.505	168	02.06.17
9	Camera	66°21.987	56°24.099	293	02.06.17
10	Camera	66°17.673	56°30.340	487	02.06.17
11	Camera	66°40.450	56°41.342	564	05.06.17
12	Camera	66°48.413	55°08.257	230	06.06.17
13	Camera	68°26.986	54°17.702	443	07.06.17
14	Camera	68°55.321	53°07.368	262	10.06.17
15	Camera	68°51.595	53°10.412	279	10.06.17
V015	Sled	64°36.853	53°56.376	150	29.05.17
V017	Sled	64°51.130	53°17.394	131	30.05.17
V024	Sled	64°21.430	53°45.900	138	30.05.17
V026	Sled	64°25.238	54°07.551	160	30.05.17
V027	Sled	64°29.143	54°27.697	266	31.05.17

V030	Sled	64°34.837	55°07.0716	390	31.05.17
V038	Sled	64°54.279	54°05.572	137	31.05.17
V040	Sled	64°56.527	53°36.01	79	31.05.17
V042	Sled	64°57.608	53°17.6575	29	01.06.17
V050	Sled	66°12.840	54°42.15	97	01.06.17
V059	Sled	66°37.237	55°03.611	119	02.06.17
V061	Sled	66°49.770	54°41.7234	47	03.06.17
V062	Sled	66°52.8454	54°10.3999	71	03.06.17
V072	Sled	67°00.4209	56°27.7191	258	04.06.17
V080	Sled	67°45.3143	55°41.9859	87	04.06.17
V082	Sled	67°51.7400	54°38.0224	29	05.06.17
V084	Sled	67°57.7074	54°16.2692	96	05.06.17
V085	Sled	68°00.0855	54°10.1455	168	05.06.17
V091	Sled	68°25.6868	55°09.9966	468	05.06.17
V093	Sled	68°48.4231	55°08.1638	232	06.06.17
V094	Sled	68°45.828	54°42.280	209	06.06.17
V102	Sled	68°29.532	55°07.5822	470	06.06.17
V106	Sled	68°36.1292	53°50.1651	872	06.06.17
V113	Sled	68°58.5166	52°59.1480	137	06.06.17
V114	Sled+Beam	68°56.5472	53°22.1250	674	08.06.17
V124	Sled+Beam	68°55.1017	53°00.3260	86	08.06.17
V125	Sled	68°54.5934	53°11.7499	759	09.06.17
V126	Sled+Beam	68°51.8604	53°20.1899	868	09.06.17
V128	Sled+Beam	68°50.5060	53°09.1520	315	09.06.17
V137	Sled+Beam	68°53.7444	52°57.8394	443	09.06.17
V145	Sled	69°41.7532	51°46.9780	124	10.06.17
V147	Sled	69°42.208	51°28.779	430	11.06.17
V149	Sled	69°49.327	51°36.404	614	11.06.17
V150	Sled	69°34.468	51°37.551	249	11.06.17
V157	Sled	69°20.3871	51°42.9881	330	11.06.17
V159	Sled	69°30.5685	52°01.2982	331	12.06.17
V160	Sled	69°15.1025	51°50.2847	429	12.06.17

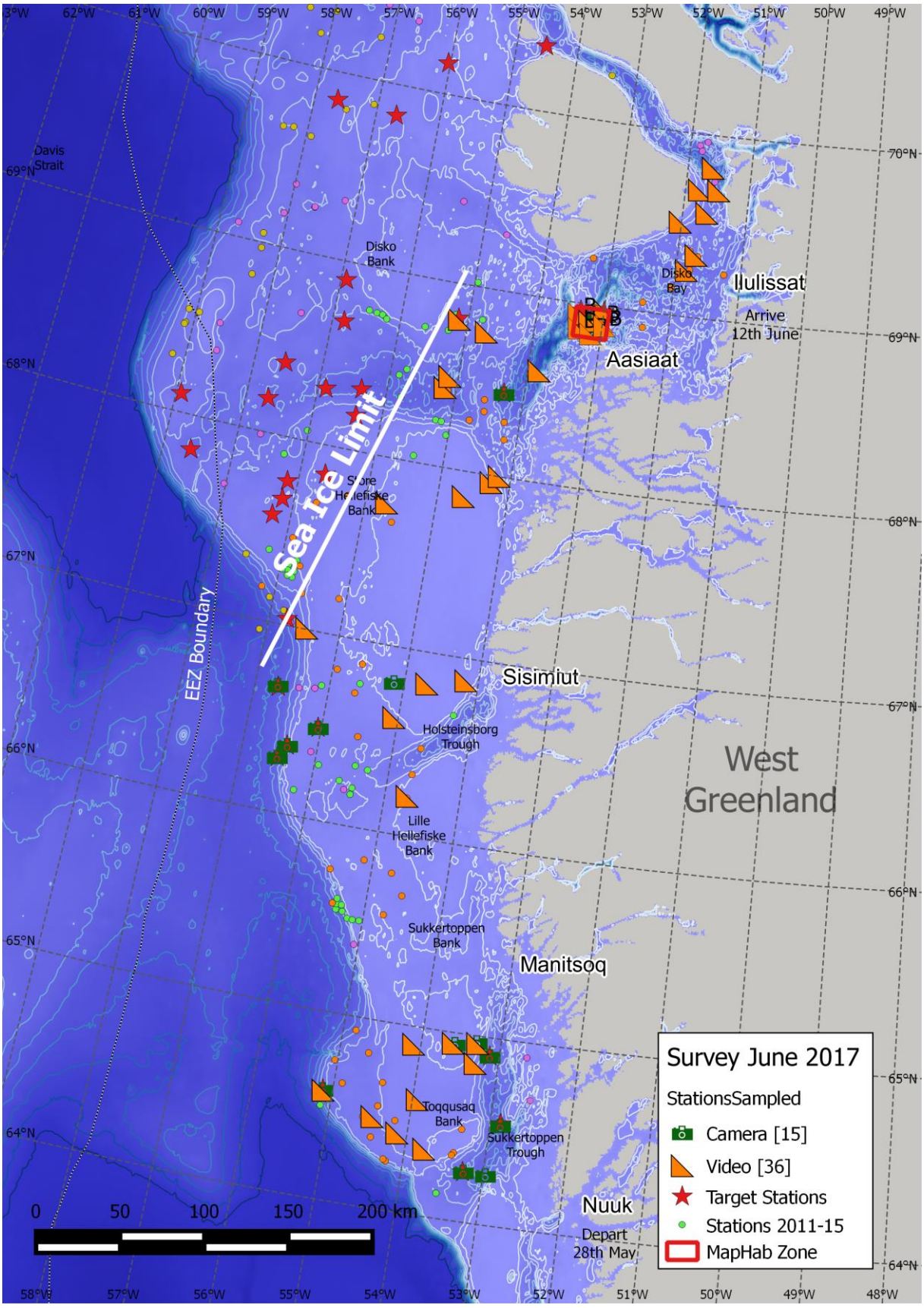
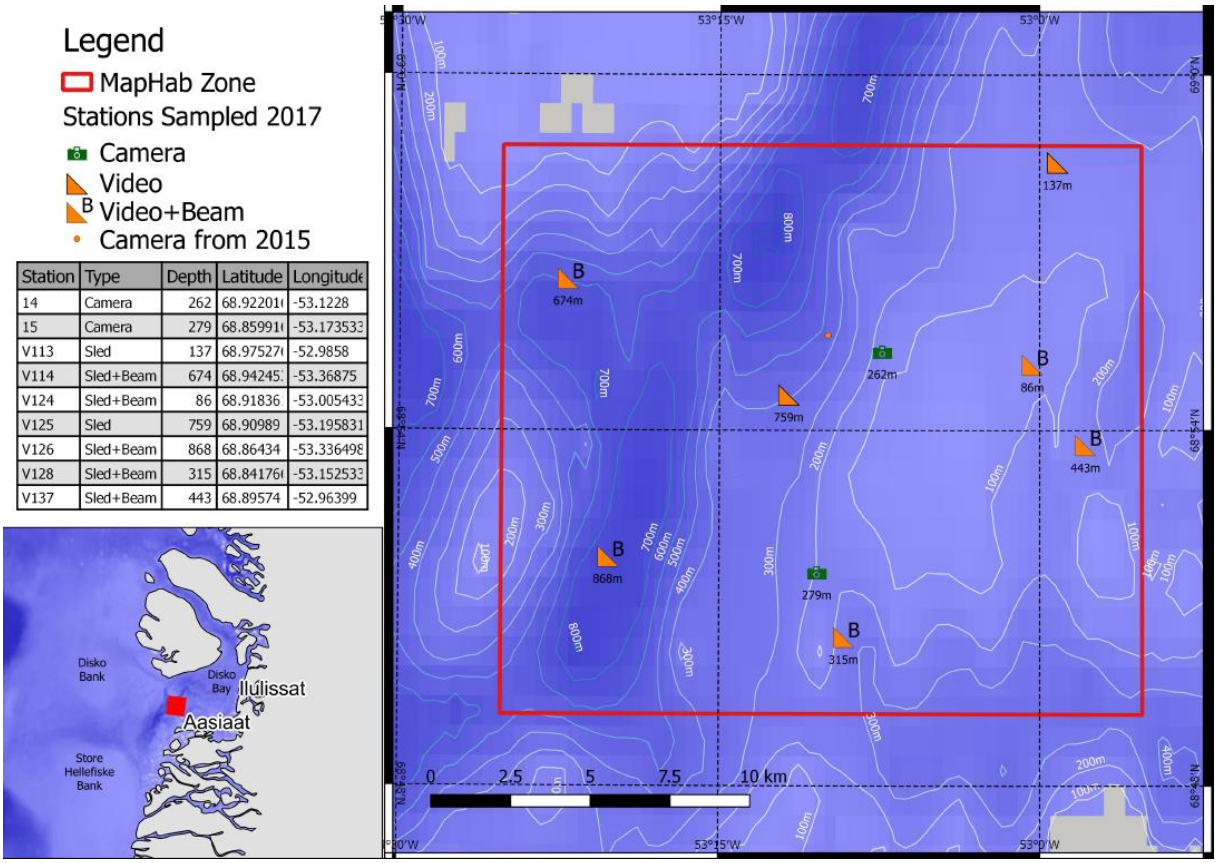


Fig. 3 Map over the study area and stations sampled during the Paamiut cruise June 2017

Fig. 4 Observation of *Chondrocladia gigantea* and sea anemones at 445 m depth

Fig. 5 Coral garden at 390 m depth



Station	Type	Depth	Latitude	Longitude
14	Camera	262	68.92201(	-53.1228
15	Camera	279	68.85991(	-53.173533
V113	Sled	137	68.97527(	-52.9858
V114	Sled+Beam	674	68.94245	-53.36875
V124	Sled+Beam	86	68.91836	-53.005433
V125	Sled	759	68.90989	-53.195831
V126	Sled+Beam	868	68.86434	-53.336498
V128	Sled+Beam	315	68.84176(	-53.152533
V137	Sled+Beam	443	68.89574	-52.96399

Fig. 6. Sampling in the MabHab area

Annex 3

Cruise Report October 2017

Cruise report

M/T Paamiut
Hellefisk Survey Togt 7 (Leg 7, Greenland halibut stock assessment survey)
Benthic imaging survey
10th Oct – 24th October 2017
Greenland, Nuuk to Nuuk

Personnel

Benthic Imaging: Chris Yesson[1], Stephen Long[1,2], Mona M. Fuhrmann[1]
Cruise leader: Ole Jørgensen[3]

[1]Institute of Zoology (IoZ), Zoological Society of London (ZSL)
[2]University College London (UCL)
[3]National Institute of Aquatic Resources, Technical University of Denmark (DTU Aqua)

Objectives

The cruise was conducted in the southern area of the west Greenland offshore Greenland halibut fishery and adjacent areas, all within NAFO areas 1A and 1B. This report describes the benthic ecosystem research that was conducted alongside the annual Greenland halibut stock assessment survey. Specific objectives were to:

1. Conduct video surveys of seabed to map benthic communities and their habitat, in particular vulnerable marine ecosystems (VMEs) indicator species
2. Collection of video across a spectrum of fishing effort to analyse the impact of trawling.
3. Testing of scaling lasers added to the video sled rig.
4. Collection of benthic bycatch data from stock assessment trawls using Alfredo trawl.
5. Collection of benthic community abundance and biomass data using a beam trawl.

Summary of work

The survey was a joint venture between the Greenland Institute of Natural Resources (GINR) and the Institute of Zoology (IoZ). Our agreement with GINR was to conduct video and beam trawl surveys using 48 hours of ship time. Due to adverse weather conditions we were able to use 39 hours of ship time on this cruise. Sampling time was shared between the video survey (23 stations) and beam trawls (8 stations), with a focus on collection of seabed video footage at stations along a trawling effort gradient (fig. 1, Appendix I). Trawling effort was determined using digitised, anonymised fishing vessel logbook data (2012 to 2016, inclusive) provided by Rasmus Nygaard of GINR. A sub-sample of stations were selected from the Greenland halibut stock assessment survey stations. Typically these were conducted after trawls, taking care not to sample the exact location to avoid a disturbance bias. The use of the video sled was successful, seafloor videos were obtained from stations between 63˚11.01' N and 65˚15.92' N, at depths ranging from 650 to 1476 m. This was the first time we have used this equipment at depths exceeding 1000m. Bottom substrates sampled were dominated by mud with occasional dropstones (isolated rocks). Aside from the adverse weather conditions, our major challenges were optimising the drag speed and wire length during towed video deployment in variable conditions to ensure clear consistent video was

acquired. Beam trawls were taken at depths ranging from 720 to 1431m with the main purpose of complementing video stations and aiding identification. A camera was mounted to the beam trawl to obtain additional video, which resulted in short sequences providing additional information on sampling efficiency of the beam. GINR documented all benthic fauna taken as bycatch from Alfredo trawls as a reference collection and to support subsequent research.

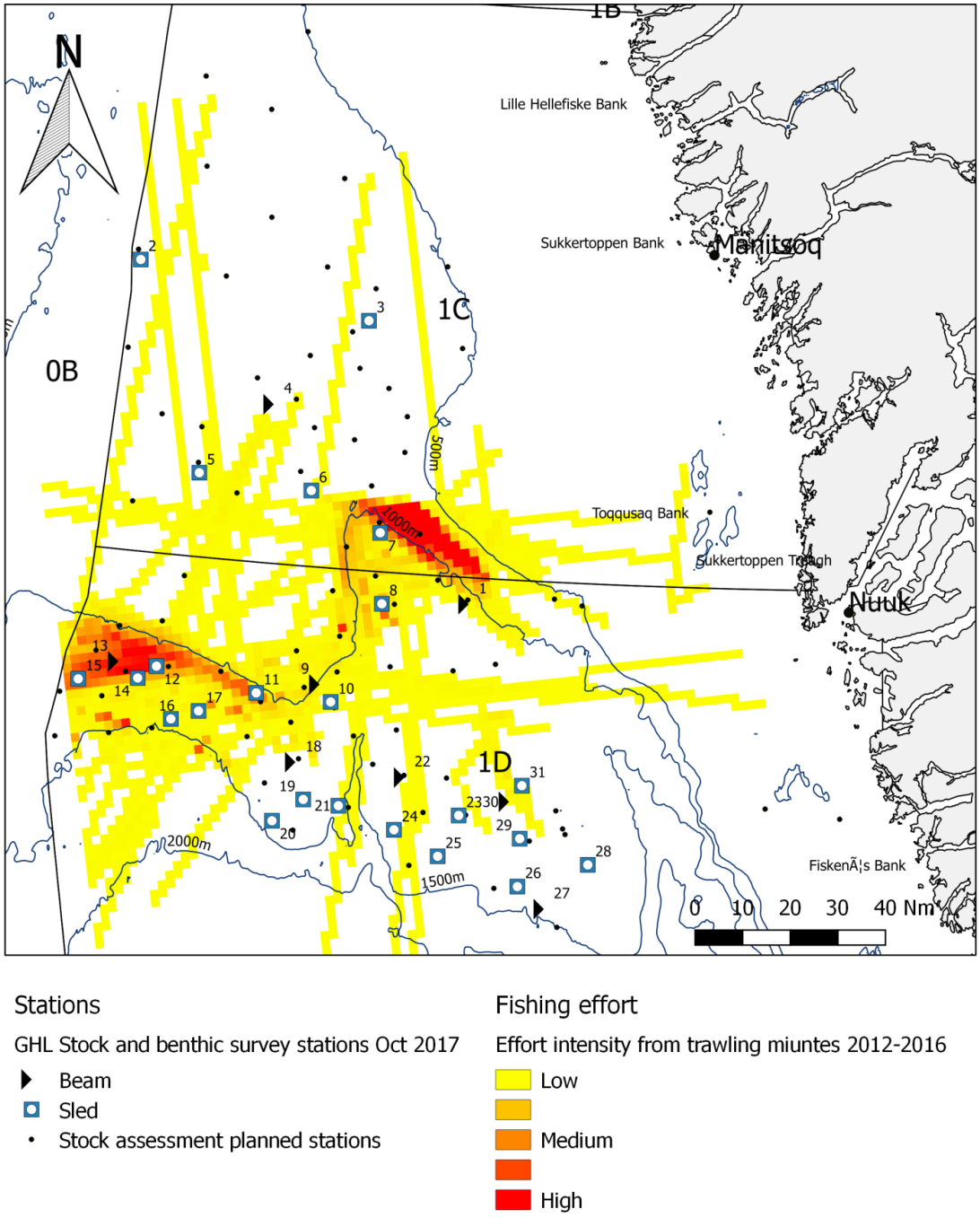


Figure 1: Map showing beam and video sled survey stations sub-sampled from the planned Greenland halibut stock assessment survey stations. Many of the northern stations were omitted from the stock assessment survey (and thus the benthic video survey) due to adverse weather at the start of the cruise. Preliminary representation of combined effort data from logbooks 2012-2016 inclusive, where total minutes between start and end of trawls are allocated to 3.5 km grid. Straight lines extending beyond the main footprint are thought to represent positional errors to be excluded in future analyses. Contours are drawn at 500m intervals. NAFO

areas are indicated. Survey designed to sample the southern area of the west Greenland offshore Greenland Halibut fishery and adjacent areas between 800 and 1500m in the Davis Strait, west Greenland.

Equipment and sampling

Adverse weather

The cruise was severely disrupted by adverse weather conditions. For the first 3 days (10th-12th October) and the final three days of the cruise (21st-23rd October) there were gale force winds (measured up to 26m/s) and high waves severely disrupting sampling. It was felt that these conditions were too dangerous for gear deployment. One beam trawl was attempted on October 11th, as this was felt to be a safer deployment in rough conditions. The first video sled deployment was on 13th October, at which point uninterrupted surveys began. The forecast for the final three days was so bad it was decided that no sampling could be attempted and the ship returned to port, curtailing the cruise.
The sampling began in the northern region of the survey and moved steadily southwards. The uncertainty caused by the extreme weather resulted in no sampling at many of the northernmost stations. In good conditions, the sampling proceeded apace, resulting in a higher density of stations in the southern region of the survey. It was hoped that some of the norther stations could be revisited at the end of the survey, but the reappearance of poor conditions meant this was not possible.

Sampling time

The cruise plan was for 48 hours of video sled/ beam trawl sampling time, to be taken throughout the cruise at a subset of the stock assessment stations. On agreement with the cruise leader, Ole Jørgensen, our sampling time was measured from the start of gear change (moving Alfredo nets) covered the gear setup, deployment, towing and gear retrieval and stopped when our video sled/beam trawl gear returned to the deck and we could begin transit to the next station. Our initial estimate was that this process would take on average 90 minutes (dependent on depth of deployment). As the crew became accustomed to the gear change procedure, the gear setup time reduced. On average, the deployment of the video sled at depths of around 1000 m took an hour and 15 minutes, breaking down to 30mins setup, 15 mins descent, 15 mins tow time and 15 mins retrieval. The ascent/descent of the video sled was approximately 60m per minute.
Of the 48 hours originally assigned to benthic sampling, only 39 hours were used, meaning that 9 hours of sampling time were unused on this cruise.

Benthic sled with GoPro camera

High definition video footage was obtained using GINR's benthic video sled system (fig 2). This is a towed forward-facing GoPro video camera in a deep water housing, coupled with Nautilux torches in GB-PT 1750 group binc underwater housings (see cruise report June 2017 for full specifications). Temperature was monitored by a Starmon sensor. Each video sled trawl was deployed for 15 min of bottom-contact time. Trawl data (depth, time, location etc) was recorded and entered into the common database (MS Access) designed and

maintained by GINR. These were entered as part of the station sequence for the cruise and identified by the gear type ‘video sled’.

The camera and lighting angles on the sled were set according to previous trials, from which permanent marks had been made on the sled. To prevent slippage issues these were spot welded to ensure consistency. In the past difficulties were experienced with the torch wires becoming detached during the process of screwing/unscrewing for setup. This was resolved by reconfiguring the arrangement of battery and circuit by adding an additional power cable to allow access without disturbing the circuit boards. Additional challenges were experiences with lights turning off when the sled made heavy contact with the ship or seafloor. This was resolved by soldering fragile wire connections and immobilizing circuitry using a rigid plastic sleeve and cable ties.

Initial use of the video sled used specifications based on trials in shallower areas (50-800m) during the cruise of June 2017. However, optimum towing speed for deployment at 1000m depths was adjusted to 1-1.2 knots, and the ratio of the wire length to depth was reduced to 1.2 (e.g. for 1000m stations 1200m of wire was deployed). As previously, net floats were added to the towing chain immediately in front of the sled. These modifications reduced the chance of slack wire stirring up sediment ahead of the camera. It is also preferable to tow against the seabed current (where this was known/guessed). It is noted that the sled tended hop along the seabed, or move in a stop/start motion, rather than the continuous motion observed in the original pilot. This may have been caused by wave action or the sled getting “stuck” in the sediment. Additional floats were attached to the sled to reduce friction with the seabed, but this had limited affect in remedying the issue.

There was an additional issue with the amount of winch wire let out during deployment. The counter on the wire spool experienced some slippage, resulting in uncertainty over the true wire length being deployed, typically resulting in too much wire being deployed. This resulted in excess wire touching the ground in front of the sled and stirring up a sediment cloud, obscuring the video. We recommend using the 1.2 wire length to depth ratio for deployments at similar or greater depths. Depending on the accuracy of the wire counter it may be appropriate to adjust this in future.

Scaling lasers

In order to improve video image interpretation and scaling a pair of 5mW Z-bolt green lasers were integrated into the video sled system. A custom underwater housing was designed and made by Stephen Long at University College London’s (UCL) Institute of Making, with assistance from the Department of Mechanical Engineering. The housings remained water tight at depths of ~1400m. Unfortunately the lasers were prone to weakening and turning off. This was thought to be due to the temperature and physical stresses. Nevertheless, it was possible to acquire video with two dots a known distance apart (20cm). This represented a significant cost saving as equivalent commercially available products are prohibitively expensive. This will aid subsequent analysis. In future a more rugged laser could be sought or the existing product could be customized to improve durability. The lasers were mounted directly beneath the camera (fig 2), to provide central positioning of the lasers on the image. However, the prominent position of the lasers meant they were repeatedly struck either on

deck or during deployment, this infrequently led to difficulties removing the camera as the casing for the laser housings warped on impact. It is recommended that the lasers are repositioned to avoid this issue.

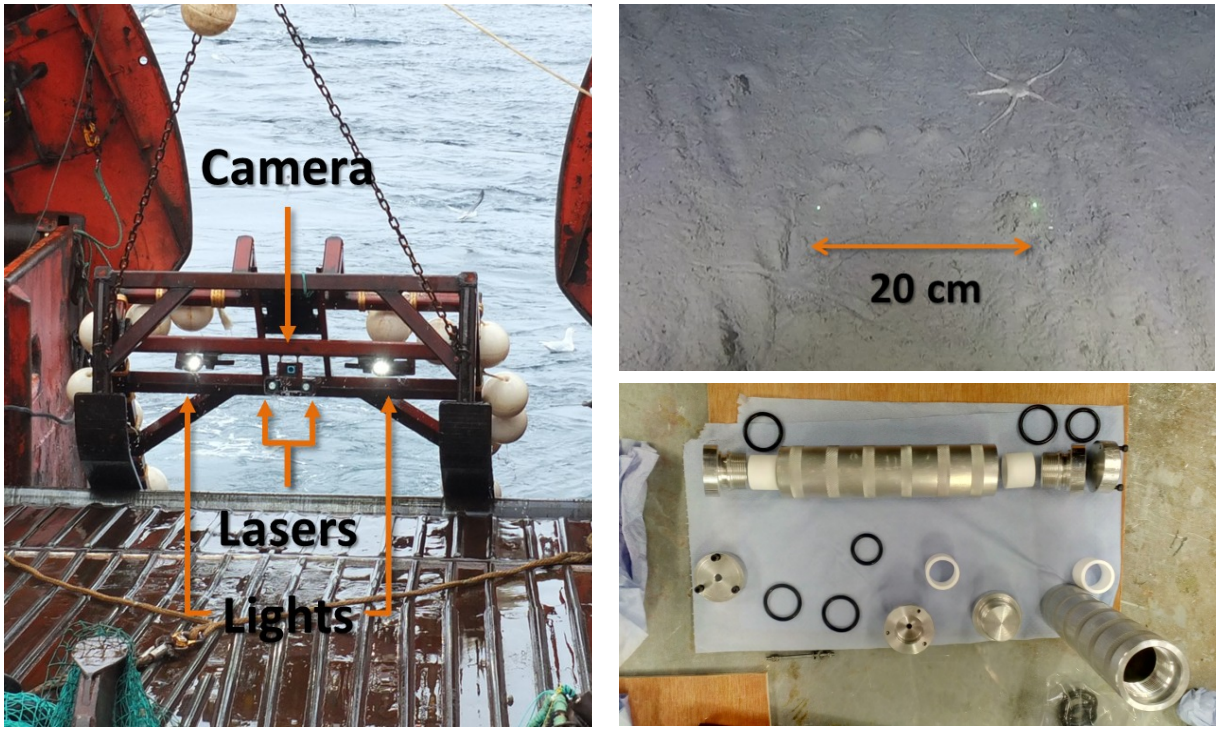


Figure 2: Clockwise from left, camera sled showing camera lights and laser postions, example still from video showing laser dots 20cm apart, purpose built laser housing.

Beam trawls and bycatch processing

A GoPro camera and two Nautilux torches in GPH-1750 Group Binc underwater houses were mounted on the beam trawl. Initial deployment of the beam trawl was for 10 minutes of bottom contact at 1kt, in order to maximise video footage. However, the sea conditions meant consistent deployment at 1kt was difficult and the first deployment collected a large amount of benthic fauna. Subsequent deployments were reverted to the 'typical' setup of 5 minutes tows at speeds exceeding 1 knot. Frequently, the disturbance of soft sediments obscured the view in the beam trawl videos, this meant that the quality of beam trawl video was not as good as the video sled and is unlikely to be suitable for quantitative analysis. However, typically the first minute of footage produced clear video, which may be useful for other purposes. Often the catch brought up a lot of muddy sediment, and it helped to rinse the net out in the water before bringing it on board (given that no large stones were in the catch, in which case this technique would additionally crush specimens). Catches were processed according to previous protocols designed by Martin Blicher (GINR) for the INAMon project. Specimens were identified and documented by Igor Manushin, Jan Yde Poulsen and IoZ participants. Some specimens were kept and dried for outreach purposes.

There were some technical issues with the Starmon sensor on the beamtrawl; it seems to have registered unrealistic temperatures that were out of step with other readings, which were therefore not entered into the database. GINR documented abundance and biomass of

all benthic fauna taken as bycatch from Alfredo trawls. Data was entered in the cruise database, described above.

Results

Video

Because of bad weather the more easterly high effort fishing area could was undersampled, it is hoped this can be addressed on a cruise in 2018. Beds of *Halipteris finmarchica* were found in the northern area and these were also caught in Alfredo trawls (see below). A few species were only observed on videos and not sampled by beam trawl, for example *Radicipes cf. gracilis*, and an unidentified anemone (Fig.3).

Figure 3: Left, *Radicipes cf. gracilis* (St 13, 822 m). Right, Unidentified sea anemone at St 80, 1129 m. Bottom, Unidentified sea anemone at St 35, 1102 m.

The cup coral *Flabellum alabastrum* was common at deeper stations, often at high abundances in assemblage together with the brittle star *Ophiomusiom lymani* (Fig.4). Cup corals were easily displaced by the video sled, but probably slipped through meshes of the Alfredo trawl since they were seldom caught as bycatch. They were also seen in higher fishing effort stations, but in lower abundance. The sea urchin *Phormosoma placenta* was encountered across the fishing effort spectrum.

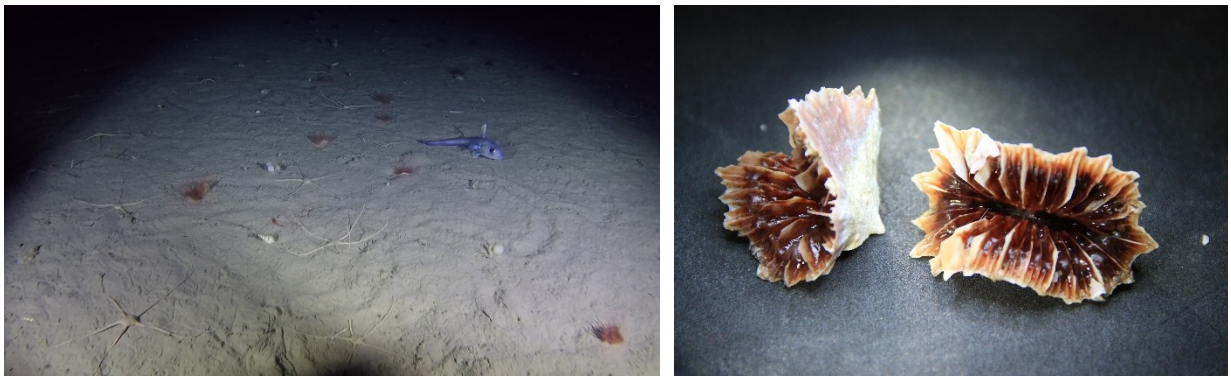


Figure 4: Left, High abundance of *Flabellum alabastrum* and *Ophiomusium lymani*. Right: *Flabellum alabastrum* specimens from beam trawls.

Whilst soft sediments were dominant, coral and sponges were often observed, associated with the hard substrate offered by rocks/dropstones (fig. 5).

Figure 5: Stones offer attachment to a variety of species, i.e black corals (Stauropathes spp) and an unidentified sponge at 1336 m.

Preliminary impressions of the footage showed a stark contrast between trawled and untrawled areas. Trawled areas were typically flatter seabed with less diverse fauna and fewer dropstones. Observable trawl marks were widespread, in addition to furrows caused by trawl doors, features consisting of a series of linear grooves were observed in areas subject to fishing effort. This rake like pattern of grooves (fig. 6) may be caused by rock-hopper gear, chains or roller 'clumps' position between pairs of nets.

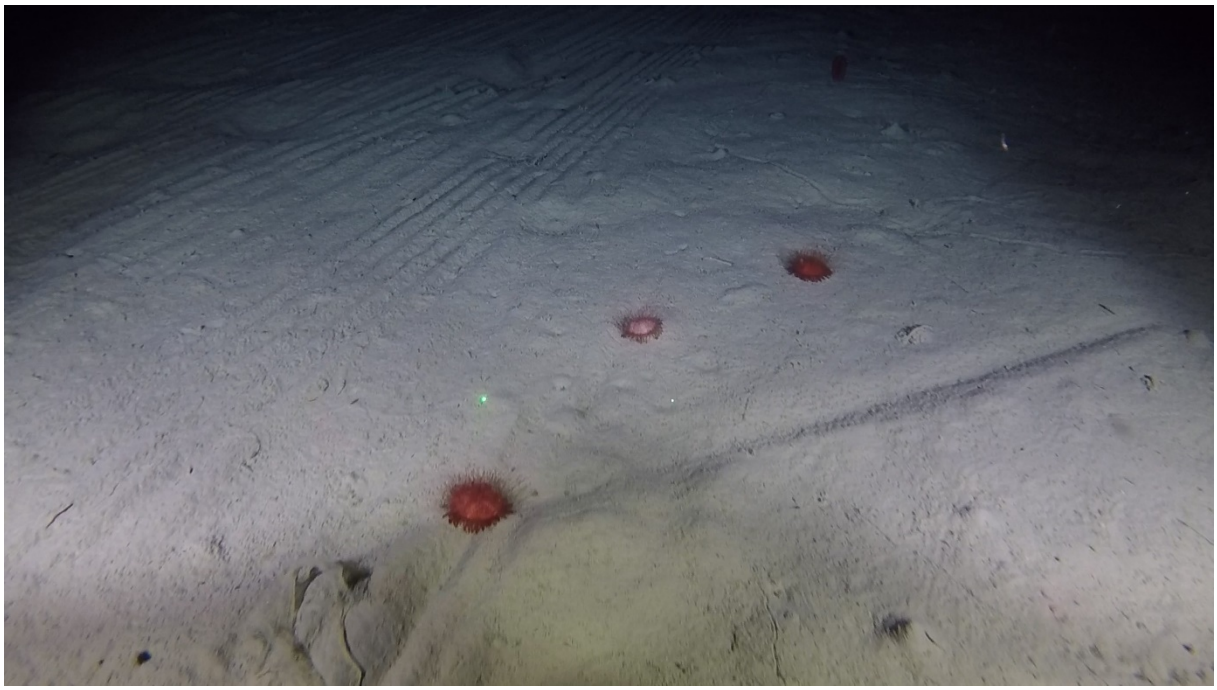


Figure 6: Trawl marks were frequently seen on the seafloor in areas of high fishing effort. Here at St 58 at a depth of 1250 m, next to the abundant sea urchin *Phormosoma placenta.*

Fish were frequently seen in videos, i.e. Grenadier fish (family: Macrouridae). However, Greenland halibut (*Reinhardtius hippoglossoides*) were rarely observed since they likely escaped the video sled which ran at low speed.

Combined sampling of stations by camera/video and beam trawls, together with the taxonomic expertise on board, proved extremely useful in identification of fauna seen in images and video. The video material will be analysed to identify species and estimate abundances using stills capture from the videos. Stills will be annotated using the online BIIGLE platform which was designed for reviewing and annotating benthic imagery.

Beam trawls and bycatch

Beam trawls in general reflected species composition seen in the area by video observations. Benthic biomass was in generally lower than in shallow (on-shelf) areas surveyed in the June 2017 survey. There was limited benthic bycatch from Alfredo trawls in terms of biodiversity and biomass. It was mostly dominated by jellyfish (*Periphylla periphylla*, *Atolla wyvillei*), sponge fragments (*Asconema foliatum*), shrimps (*Acanthephyra pelagica*, *Pasiphaea* spp.), *Gonatus* spp. and occasionally bamboo corals (*Acanella arbuscula*), echinoderms (most often *Ophiomusiom lymani* and *Phormosoma placenta*) and large octopus (Cirrotheutidae).

At station 82 (Southeastern region of fig 1), the Alfredo trawl failed but brought up a large amount of sponges, *Geodia* spp. (fig. 7). Another mentionable bycatch consisted of many large seapens (*Halipteris finmarchica*) at station 9 (Northern region fig 1).


Figure 7: Left, Bycatch of sponges in the Alfredo trawl at station 82. Right, Large seapens (*Halipteris finmarchica)* caught in Alfredo trawl at St 9, 628 m.

Conclusions

Video and beam trawl surveys were successfully conducted at 31 stations, covering areas of high and low trawling impact. There was a clear distinction between trawled and untrawled areas, with frequently observed trawl marks and reduced diversity in the latter. The cup coral *Flabellum alabastrum* was widespread, but observations of seapens, sponges and branching corals were predominantly restricted to untrawled areas.

Due to severe weather conditions, only 39 of the 48 hours allocated to benthic sampling were used.

Appendix I

Table 1: Video and beam trawl survey station data

#	Date	Ship time (hh:mm)		Tow time (UTC)		Midpoint (Decimal degrees)		Gear	Video?	Mean depth (m)	Mean speed (knots)
		Used	Total	Start	End	Latitude (N)	Longitude (W)				
1	11/10/2017	02:05	02:05	11:29	11:44	64.1574	54.7833	Beam	N	1063	1.62
2	13/10/2017	01:20	03:25	12:53	13:08	65.2620	57.6808	Sled	Y	649	1.88
3	14/10/2017	01:09	04:34	01:26	01:41	65.1210	55.7472	Sled	Y	823	1.86
4	14/10/2017	01:17	05:51	10:04	10:14	64.8035	56.4741	Beam	Y	719	1.40
5	14/10/2017	01:10	07:01	20:10	20:25	64.5425	57.0266	Sled	Y	828	1.26
6	15/10/2017	01:09	08:10	04:58	05:13	64.5147	56.1098	Sled	Y	908	1.10
7	15/10/2017	01:10	09:20	17:38	17:53	64.3859	55.5287	Sled	Y	1051	1.20
8	15/10/2017	01:15	10:35	22:54	23:09	64.1391	55.4755	Sled	Y	1103	1.24
9	16/10/2017	01:15	11:50	10:24	10:30	63.8423	55.9235	Beam	Y	1040	0.90
10	16/10/2017	01:00	12:50	15:21	15:36	63.7844	55.8241	Sled	Y	1150	0.96
11	16/10/2017	01:12	14:02	18:55	19:10	63.7951	56.4158	Sled	Y	1089	0.96
12	17/10/2017	01:17	15:19	00:23	00:38	63.8563	57.2191	Sled	Y	1183	0.64
13	17/10/2017	00:59	16:18	09:48	09:53	63.8596	57.5238	Beam	Y	1180	1.10
14	17/10/2017	01:20	17:38	13:59	14:14	63.8089	57.3577	Sled	Y	1261	1.14
15	17/10/2017	01:17	18:55	20:07	20:22	63.7846	57.8238	Sled	Y	1250	0.90
16	18/10/2017	01:30	20:25	02:35	02:50	63.6780	57.0665	Sled	Y	1476	1.08
17	18/10/2017	01:07	21:32	06:25	06:40	63.7147	56.8557	Sled	Y	1356	1.04
18	18/10/2017	01:20	22:52	12:54	12:59	63.5653	56.0648	Beam	Y	1267	0.90

19	18/10/2017	01:05	23:57	17:47	18:02	63.4378	55.9798	Sled	Y	1191	1.10
20	18/10/2017	01:15	25:12	19:23	19:38	63.3550	56.2094	Sled	Y	1409	1.14
21	19/10/2017	01:10	26:22	01:42	01:57	63.4253	55.7030	Sled	Y	1399	0.92
22	19/10/2017	01:25	27:47	07:37	07:42	63.5393	55.2062	Beam	Y	1148	1.10
23	19/10/2017	01:10	28:57	13:53	14:08	63.4191	54.7629	Sled	Y	1129	0.72
24	19/10/2017	01:10	30:07	16:20	16:35	63.3549	55.2585	Sled	Y	1337	1.10
25	19/10/2017	01:00	31:07	22:23	22:37	63.2724	54.9068	Sled	Y	1301	0.96
26	20/10/2017	01:13	32:20	05:30	05:45	63.1824	54.2776	Sled	Y	1300	1.22
27	20/10/2017	01:15	33:35	08:57	09:02	63.1083	54.0655	Beam	Y	1433	1.10
28	20/10/2017	01:09	34:44	12:38	12:53	63.2696	53.7408	Sled	Y	1102	1.00
29	20/10/2017	01:25	36:09	19:03	19:18	63.3498	54.2786	Sled	Y	1144	1.15
30	21/10/2017	01:10	37:19	02:14	02:19	63.4764	54.3773	Beam	Y	1133	0.90
31	21/10/2017	01:40	38:59	05:53	06:08	63.5349	54.2826	Sled	Y	1104	1.08