MASTS Scotia-Canadian Ocean Research Exchange – Report

Acoustic target classification of Arctic Zooplankton

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Background

The Arctic Ocean is changing rapidly, with warming temperatures, reduced sea-ice cover, and the potential for increased human activity in the region. Quantifying the biomass, distribution and behaviour of zooplankton is important to understanding the ecological impacts of these changes. Zooplankton are typically surveyed using echosounders, but species identification can be a significant source of measurement uncertainty (Demer, 2004). It is the 'grand challenge' for acoustic methods (Korneliussen, 2018).

Measurements of backscattering strength at multiple frequencies can be used as an 'acoustic signature' for target classification (Martin *et al*., 1996). A widely used method involves measurements of backscattering strength collected at 2-3 discrete frequencies simultaneously. The difference in backscatter between the frequency pairs is used to classify aggregations into taxonomic groups (Madureira *et al*., 1993). However, there is concern that this approach may misclassify some targets (e.g. Fallon *et al*., 2016; Vacchi *et al*., 2017). Broadband echosounders offer the potential for improved target classification. Measurements of backscattering strength across a wide frequency range (frequency response) provide greater discriminative power for classification compared to multi-frequency methods (Benoit-Bird and Waluk, 2020). However, to classify unknown targets, it is first necessary to characterise the frequency response spectra of known species.

The MASTS SCORE grant supported the author's collaboration with Muriel Dunn (University of Newfoundland / Akvaplan-Niva) and Maxime Geoffroy (Memorial University of Newfoundland). The grant was used to pay for the author's travel to and from Svalbard on 1-19 January 2022, to participate in a field campaign within the Norwegian Research Council (NFR) funded 'Deep Impact' (NFR 300333, RIS 11640) and 'A Deeper Impact' (RiS 11640) projects, and NFR Arctic Field Grant funded project 'AZKABAN-Light' (RiS 11578) in Ny-Ålesund. As broadband fisheries acoustics is an emerging research field, the exchange facilitated a bilateral sharing of expertise and resources, as well as progress towards common research goals.

The primary objective of this work was to make frequency response, TS(f), measurements of Arctic zooplankton in a purpose-built cage ('AZKABAN') designed by Muriel Dunn with input from the author. The concurrent 'Deep Impact' cruise on research vessel (RV) *Helmer Hanssen* in Kongsfjorden enabled the collection of animals for these experiments. Trials of an unmanned surface vehicle (Maritime Robotics Mariner USV 'Apherusa', owned and operated by the University of Tromsø) from Ny-Ålesund provided an additional opportunity to collect acoustic survey data. The cage measurements will be used to train machine-learning algorithms for target classification of Arctic zooplankton, using the USV survey data as a test bed.

Due to Covid-19 travel restrictions, Maxime Geoffroy was unable to participate in fieldwork but contributed equipment and expertise remotely. Despite this, the exchange was highly successful, generating novel broadband data on Arctic zooplankton and fish.

Figure 1. *Left*: Cage and fish net (mid-assembly). *Right*: Cage and zooplankton net in deployment orientation.

Methods

Animals were collected during the January 2022 'Deep Impact' cruise in Kongsfjorden, Svalbard (78°56'N, 12°10'E) from RV *Helmer Hanssen* using a combination of Tucker and pelagic trawls. Catch samples were sorted into taxonomic groups. Due to limited abundances of zooplankton, measurements of fish were incorporated into the experiments. Five groups of animals were measured: krill (a mixture of *Meganyctiphanes norvegica* and *Thysanoessa* spp.), a mixture of zooplankton (predominantly *Calanus* spp., *Metridia* spp., krill and *Parasagitta* spp.), polar cod (*Boreogadus saida*), Atlantic cod (*Gadus morhua*), and a mixture of polar and Atlantic cod.

Acoustic data were collected using a purpose-built cage ('AZKABAN') deployed from the dock in Ny-Ålesund, Svalbard (78°55'N, 11°55'E). The cage comprises an 8 x 2 x 2 m aluminium frame with interchangeable fish (7 x 2 x 2 m) and zooplankton nets (500 μm, 3 x 2 x 2 m) (Figure 1). A Kongsberg-Simrad Wideband Autonomous Transceiver (WBAT) was mounted at the top of the frame with a 120 kHz (fish) or 200 kHz (zooplankton) split-beam transducer oriented downwards. Transmit pulse configurations are provided in Table 1. The WBAT was calibrated using the standard sphere method (Foote *et al*., 1987) adapted for broadband using multiple spheres (22 and 38.1 mm diameter, tungsten carbide). The resulting corrections were then merged.

The cage was suspended from a dockside mobile crane and fully submerged. Each group of animals was placed separately inside the cage for 3-4 hours of continuous measurement, with the WBAT transmitting 2.5 pings per second. Following recovery of the cage, samples were retained for species identification and length measurements. Example TS(f) data from preliminary processing of the mixed zooplankton dataset in Echoview 12 are shown in Figure 2.

Table 1. WBAT transmit pulse configurations.

	Fish	**Zooplankton**
Transducer	ES120-7CD	ES200-7CDK
Nominal Beamwidth (º)	7	7
Transmit Power (W)	200	75
Pulse Type	FM	FM
Frequency (kHz)	90 - 170	185 - 255
Pulse Duration (μs)	512	512
Ramping	Fast	Fast

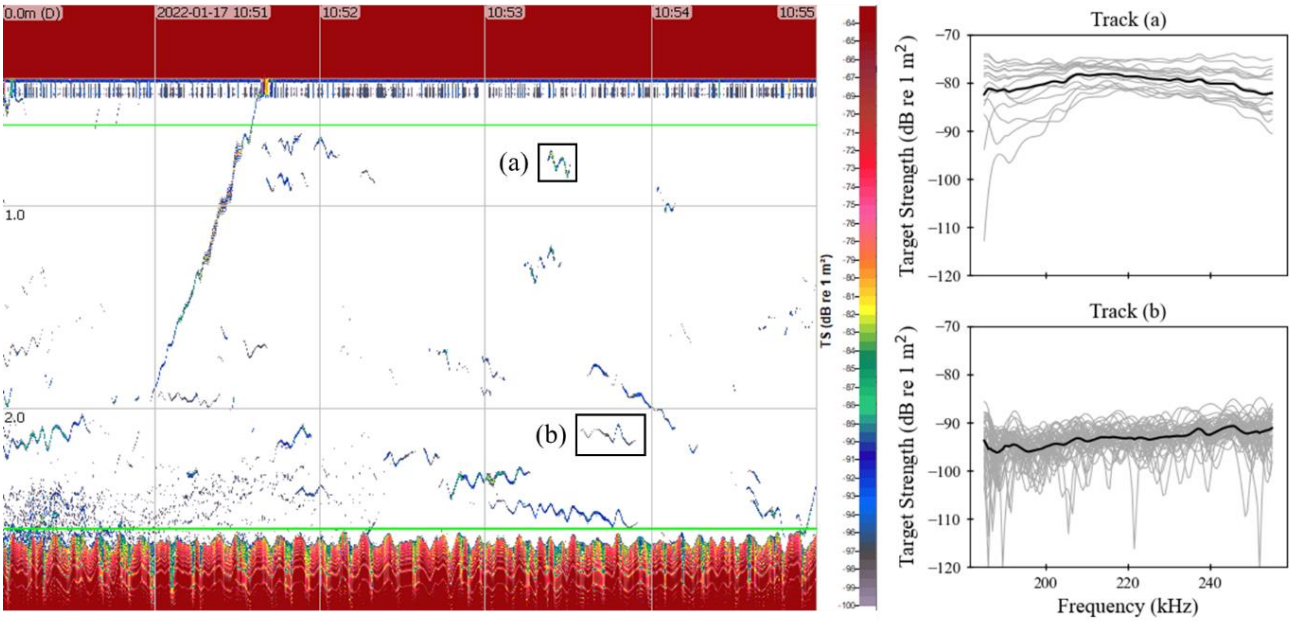

Figure 2. *Left*: echogram showing tracks of individual zooplankton within AZKABAN. *Right*: TS(f) of two tracked targets. Grey lines: TS(f) of each target detection within the track; black lines: track-averaged TS(f).

Future Work and Outcomes

The cage data will be processed to extract single targets and TS(f) for each group of animals. These will be used to train machine-learning algorithms for target classification. A range of unsupervised models will be tested on the mixed zooplankton data, including k-means, Gaussian mixture model and hierarchical agglomerative clustering. Supervised models, including random forest, support vector machine, and gradient boosting will be tested on the other datasets using methods developed on boreal zooplankton in Loch Etive, Scotland. The optimal target classification method will then be applied to the USV survey data from Kongsfjorden to provide new insights into behaviour.

This work has validated the use of 'AZKABAN' as a platform for acoustic experiments, and will form the basis for ongoing collaboration. It is anticipated that this work will result in multiple joint manuscripts for peer-review and publication in high-ranking journals. Additionally, results derived from this research will be disseminated at international conferences and working groups, such as the ICES Working Group on Fisheries Acoustics, Science and Technology (WGFAST). This project is aligned with the COP26 commitment to protecting and restoring ecosystems, and UN Sustainable Development Goals 13 (Climate Action) and 14 (Life Below Water). Methodological improvements in acoustic target classification will improve biomass estimates pertinent to sustainable management of Arctic marine ecosystems, and further our understanding of the ecological impacts of a changing Arctic Ocean.

Expenditure

Item	Cost per Unit (£)	No. of Units	Total (£)
MASTS SCORE Grant			
Return flights London – Tromsø (1st – 19th January 2022)	133	1*	133
Return flights Tromsø – Longyearbyen (2nd – 18th January 2022)	317	1	317
IN-KIND CONTRIBUTIONS			
NFR Project 'A Deeper Impact'			
Accommodation and board in Ny-Ålesund	165	14	2310
Return flights Longyearbyen – Ny-Ålesund	610	1	610
NFR Project 'Deep Impact'			
Covid-19 tests for entry to Svalbard	330	1	330
Ship time on R/V Helmer Hanssen for trawl sampling			N/A
NERC Changing Arctic Oceans Project 'Arctic PRIZE'			
Return flights London - Tromsø (1st – 19th January 2022)	149	1*	149
Accommodation in Tromsø	90	2	180
Accommodation in Longyearbyen	100	2	200
Accommodation in London	49	1	49
Additional travel costs (e.g. airport parking, taxis, Covid-19 tests)			180
NFR Arctic Field Grant Project 'AZKABAN-Light'			
Rent of Kings Bay Marine Laboratory, support from Kings Bay staff, mobile crane, shipping of equipment	TBC	TBC	TBC
Memorial University of Newfoundland			
Loan of equipment			N/A
British Antarctic Survey			
Loan of equipment			N/A

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