Glider-based monitoring of Sperm whale (*Physeter macrocephalus*) vocal activity in an Arctic feeding ground

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Sperm whales produce at least four types of clicks, each with a seemingly specific purpose: usual clicks – long range echolocation, buzzes (also called "creaks") – prey capture, codas – social cohesion, and so-called slow clicks (or clangs) – long range communication. All clicks are sharp-onset broadband impulses with the main energy centered between 2 and 25kHz (Madsen et al., 2002). Though slow clicks are only known to be produced solely by males, codas are mainly produced by females in social groups with rare displays from males (Frantzis and Alexiadou, 2008). At the level of the ocean basin, sperm whale social units can be assigned to vocal clans with their own coda repertoires (Rendell and Whitehead 2003). It is unknown where the codas can be traced back to their original social units in breeding areas, though some studies have attempted to document their occurrence in relation to behavioural context. In Norway, male sperm whales inhabit continental slope areas from northern Norway to Svalbard year-around (Rødland and Bjørge, 2015) though are predominantly found in deep-water canyons north of 65° N during the summer months. The males tend to be mainly solitary, though group behaviour has also been documented (Lettevall, 2002). Groups may arise from scattered food resources or from a combination of reduced predation risk, benefits of practicing jousting with other males and cooperative behaviour against other males (Oliveira et al., 2013).

Given the importance of sperm whale social structure to population stability, we aimed to test the capabilities of an autonomous underwater vehicle to conduct studies of animal behaviour in northern Norway. Autonomous underwater vehicles (AUVs) have been at the forefront of ocean monitoring as cost-effective solutions for monitoring the marine biosphere and oceanic physical properties.

Methods

We equipped a SeagliderTM deployment with a JASCO AMAR G4 hydrophone. The glider was deployed in May 2019 and was operational for a period of 2 weeks.

The hydrophone had a sampling frequency of 128 kHz and recorded continuously in 10-minute segments/files.

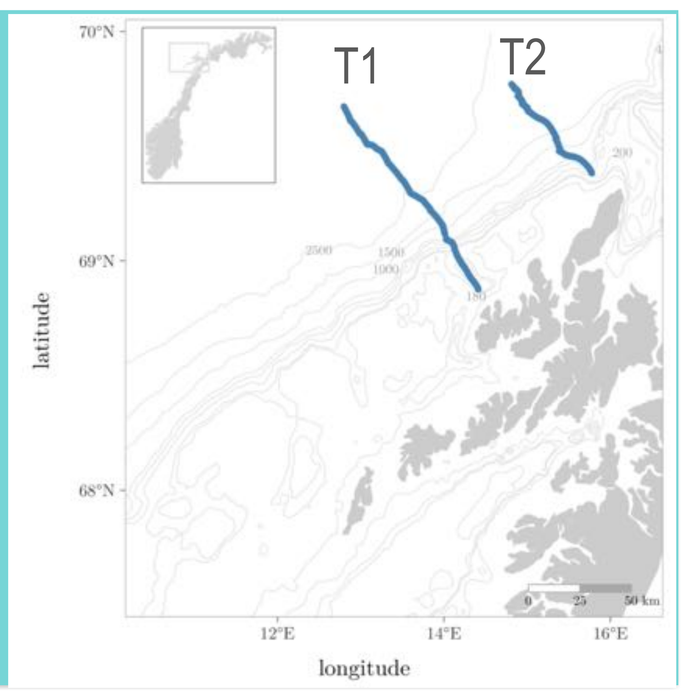
Glider position data are used to allocate individual hydrophone data files correctly to time, depth and geographic position. The glider was also equipped with a CTD (SeaBird GPCTD).

The Seaglider performed two transects, transiting between on and off-shelf areas.

The audio files were processed to obtain whale presence, species identification, and call type using RavenPro 1.5 (Cornell Lab of Ornithology, Ithaca, NY, United States), with Hamming window, 2048 DFT size, 125 Hz grid spacing, with 50% overlap. Detection of multiple individuals was conducted through analyses of their short Inter-Click-Intervals in spectrograms.

We calculated long-term spectral averages for each of the transects. Furthermore, we removed glider self-noise using Seadash software and calculated spectrum density values for a subset of data without whale sounds using PAMGuide (Merchant et al., 2005), at 1 Hz resolution and 60 second time steps. The Seadash splicer was set with a bandpass filter from 10 Hz to 10kHz.

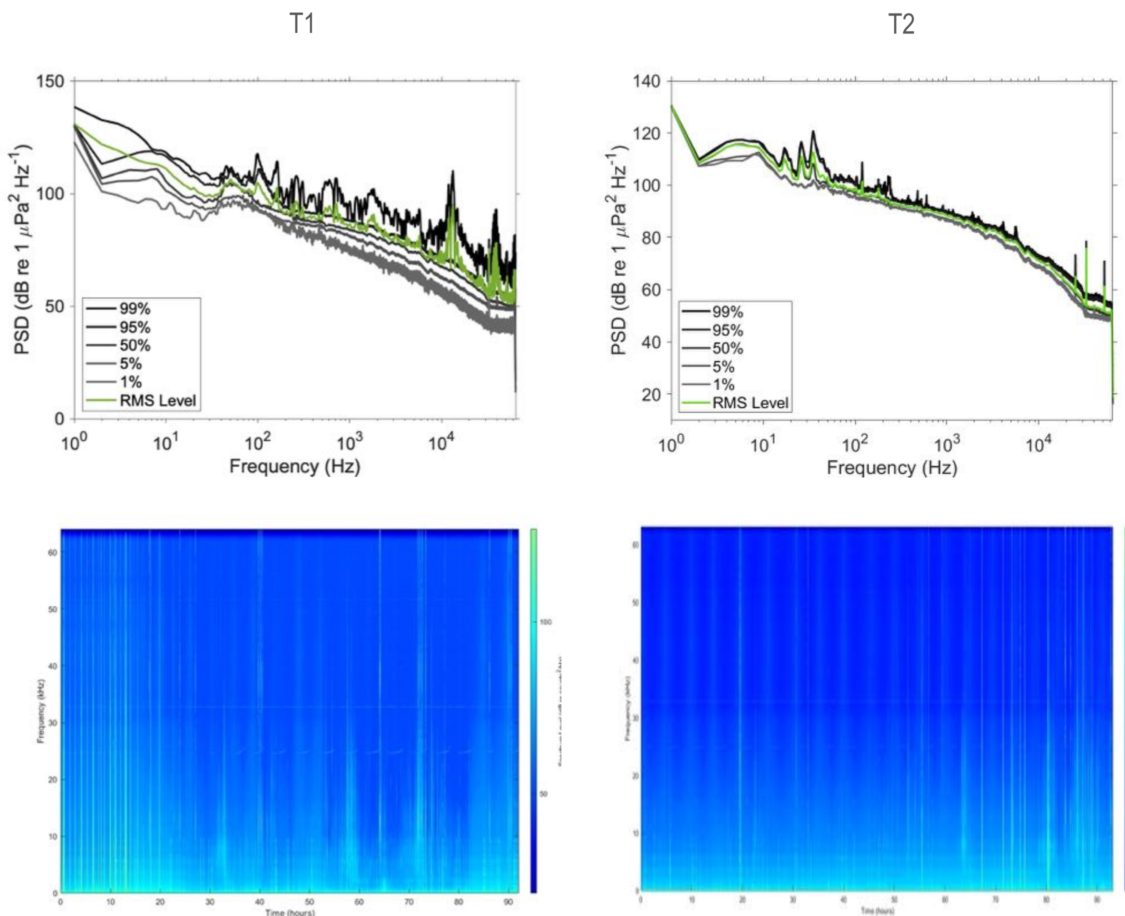
Animal length measurements were made using Rhinelander and Dawson (2004) regression.



MAIN FINDINGS

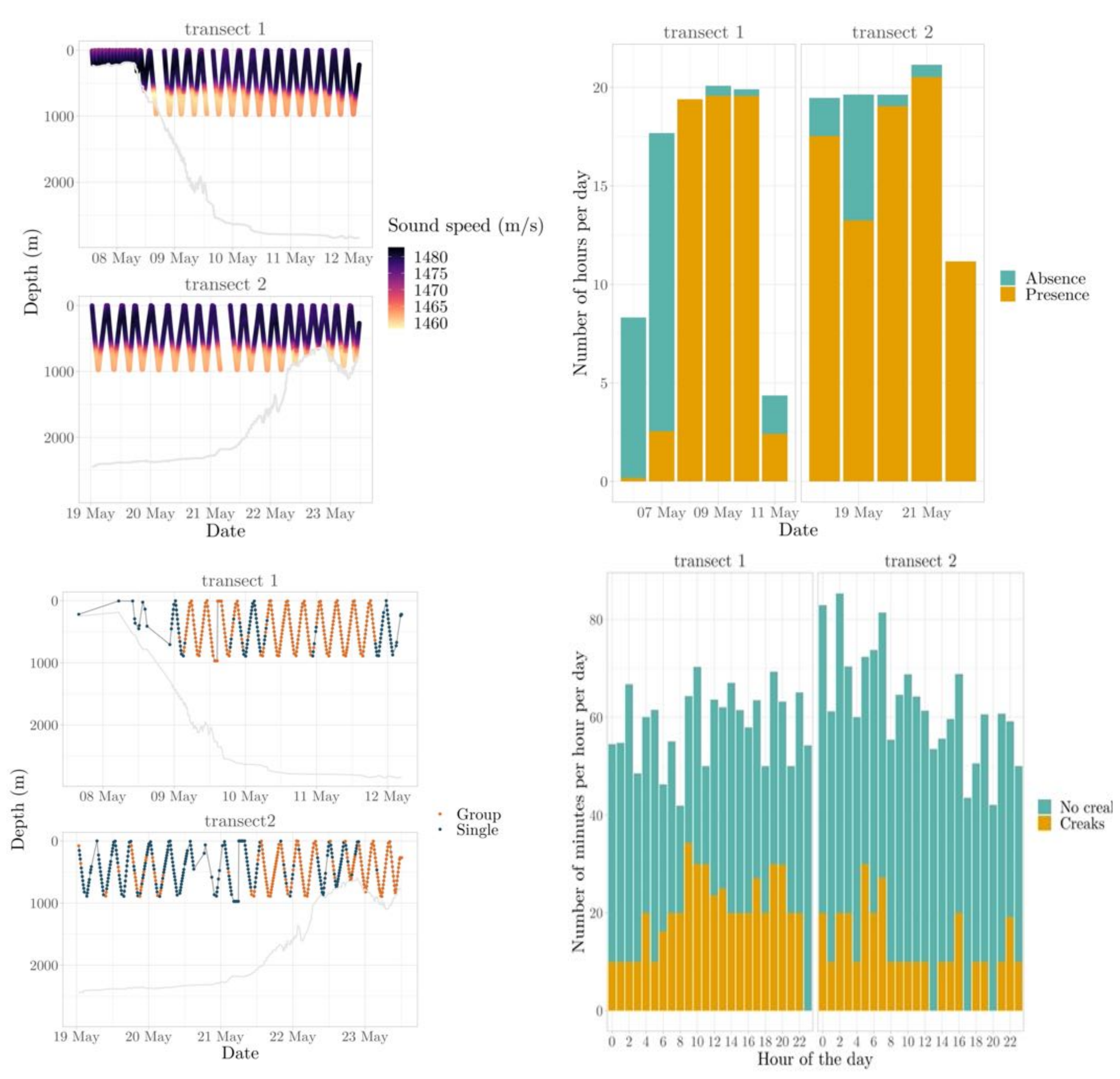
Background noise

The glider dove to a maximum of 1000 meters and recorded over 241 hours of acoustic files. Upon inspection of spectrograms, we observed the occurrence of vessel passage events, as well as noise generated by breaking waves. We detected delphnid vocalizations, but no baleen whales.



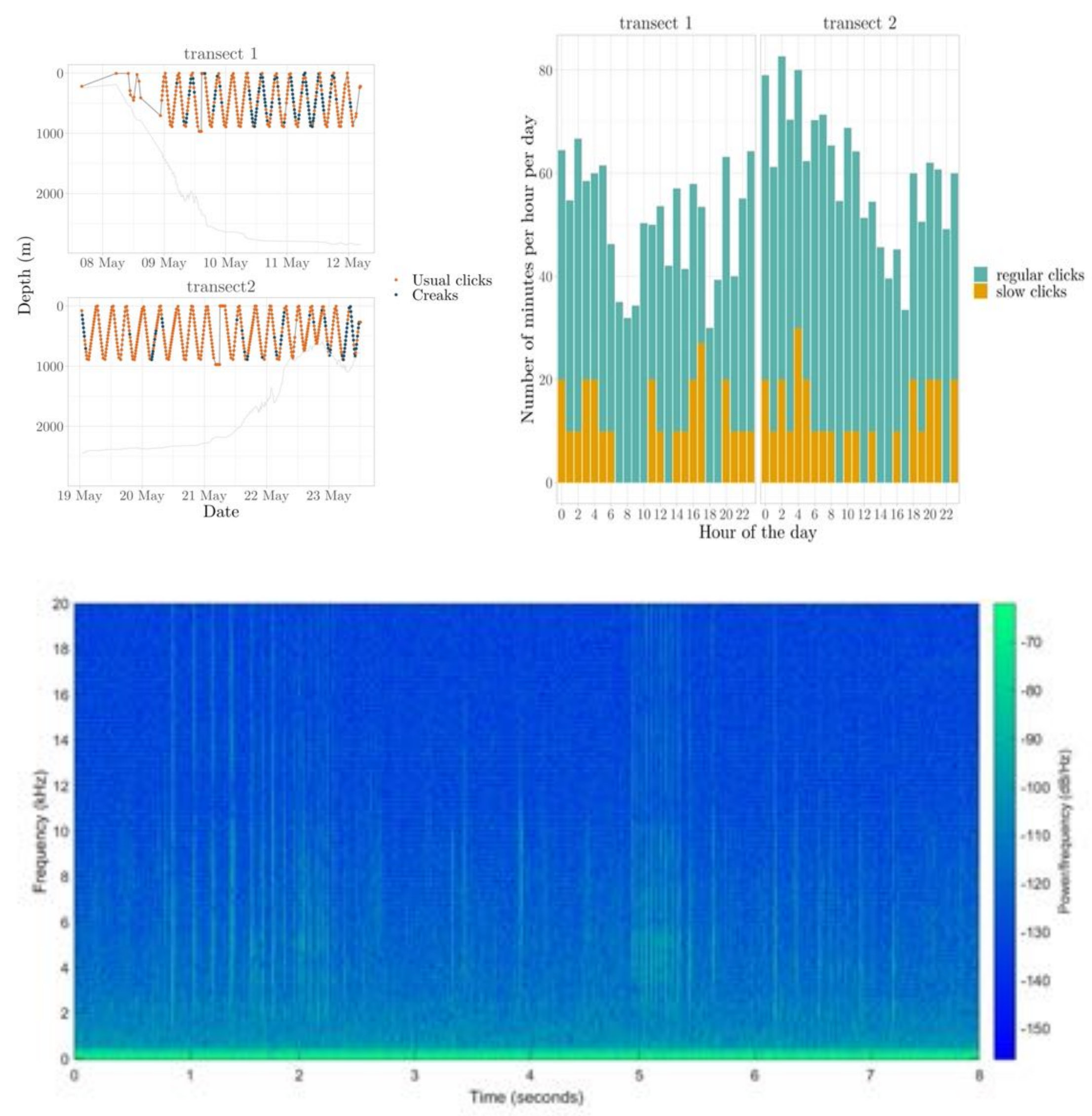
Whale spatio-temporal occurrence

The whales were found overall in the study area. However, a few animals ventured into more shallow waters and were detected in transect 1 (T1).
Most detections occurred beyond the shelf edge and multiple individuals which occurred 88.3% of the time. Furthermore, we observed indications of possible diel foraging activity.
From temperature, salinity, and depth sensors we calculated sound speed along the transects and for each glider dive, illustrated above.



Click types

Throughout the study period, we identified four click types: usual clicks, creaks, slow clicks, and codas.
Creaks were detected 21.3% of the total time. We found no distinguishable pattern in slow click distribution in space or time.
Finally, we detected one coda event lasting about 66 seconds, reflecting a communication line between two individuals with approximately 12 m length.



CONCLUSIONS

This short study shows the potential of glider-based acoustic sampling for assessments of marine mammal behaviour. We show that Sperm whales above the arctic circle are more social than previously believed, showcasing two types of social clicks that occurred in spring 2019.

The acoustic environment, excluding self noise, amounted to values below 150 dB re 1 μPa2/Hz. These levels provide an indication of the acoustic environment marine organisms are exposed to.

The social structure of sperm whales in Norway is poorly understood. We present the occurrence of a single coda event, which represents a communication exchange between two animals. This suggests that male sperm whales are more social in foraging grounds than previously believed, with known coda repertoires. This is a first step towards bettwe understanding male sperm whale social behaviour outside known breeding grounds.

Our analyses reveal variations in whale detections throughout the sampling season, which may reflect changes in behaviour and detectability.

Finally, we use CTD data to estimate sound speed. However, it is also possible to integrate other sensor data to provide more details on the ecological context of animal detections.

Though marine mammals are often challenging to survey in Norway, our study shows that the use of autonomous PAM systems provide new insights on animal behaviour that would otherwise be difficult to obtain. The use of oceanic gliders to investigate whale behaviour represents therefore a great technological advance that can improve ecosystem-based management and conservation decisions.

Acknowledgements

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