Project 12/29

Passive tools for monitoring endangered species in Svalbard: monitoring the distribution and relative abundance of Red Listed whales

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(Photo by Øystein Wiig)

Introduction

Sea ice in the Arctic has declined in recent decades at an alarming, unprecedented rate and although the physical models that predict sea ice extent still contain a lot of variability, continued sea ice declines are expected to produce a seasonally ice-free Arctic well before the end of this century. This would be a first for the Arctic in over 5+ M years. A summer-time ice-free Arctic Ocean will have significant effects on ocean circulation and our global climate system and it will have impacts throughout Arctic ecosystems. Predicted implications for the organisms that have become residents of the unique Arctic sea ice habitat have been described as "transformative". For its mammalian residents, Arctic sea ice has been a spatially extensive, virtually disease free habitat that is to a great degree sheltered from open-water predators (i.e. killer whales *Orca orcinus* and humans) and other human impacts (e.g. oil development, shipping). This habitat has been a low-competition environment that has provided a spatially predictable, seasonally-rich food supply and an environment that is sheltered from storm action for the mammals that have succeeded in dealing with the prevailing cold temperatures, risk of ice entrapment, dramatic seasonality and other aspects of an ice-associated lifestyle. All of Svalbard's resident whales have evolved within the Arctic sea ice environment, or joined it, over the millions of years of its existence, including the narwhal *Monodon monoceros*, the white whale *Delphinapterus leucas* and the bowhead whale *Balaena mysticetus*.

Although most projections of future impacts on Arctic marine mammals are quite negative, the reality is that our ability to predict impacts on ice-associated cetaceans is quite limited (Kovacs et al. 2011, Gilg et al. 2012). It is difficult to assess *a priori* the behavioural plasticity that might be displayed by Svalbard's ice-whales as their environment changes, in part because we lack base-line data on their current local abundance and seasonal distribution and concrete knowledge regarding the linkages between them and their sea ice environments (Laidre et al. 2015). Research has been conducted on Svalbard white whales, which are undoubtedly the most numerous of the resident whales in the Archipelago. These studies have discovered that: they remain very tightly associated with coastal regions through all seasons studied thus far; they spend a lot of their time, and concentrate their feeding, in front of glaciers (Lydersen et al. 2001), eating fat-rich polar cod (Dahl et al. 2000); and they have high contaminant burdens, which exceed those of polar bears in the case of many organochlorine compounds (Andersen et al. 2001, 2006). Svalbard white whales are very quiet in relation to their conspecifics elsewhere, but they do use clicks like all odontocetes when foraging so can be detected via these signals given that recorders are set such that they can detect the appropriate frequencies (Karlsen et al. 2002, Castellote et al. 2013). Less research has taken place with the other two species but occasional sighting (Wiig et al. 2007, 2019) and pilot studies involving satellite tracking (Lydersen et al. 2007, 2012) give us some insight about where to geographically target future efforts to know more about them. Their rarity, the vastness of the spaces they can occupy (and in the case of narwhals their boat-shy nature) demands "alternative" thinking when it comes to monitoring these Nationally Red Listed species.

We are attempting to answer the research challenge of monitoring the seasonal distribution and relative abundance of Svalbard's resident whales (and their summer competitors) via the establishment of a passive acoustic monitoring (PAM) array. This new technology has been implemented successfully elsewhere to collect data from rare whales - because it can be done with a minimal environmental-footprint and no disturbance to the animals themselves. We deployed our first PAM device during International Polar Year, when the research consortium involved in this Miljøvernfond project had an American-owned AURAL positioned in the Fram Strait (see Fig. 1 below), a placement that was strategically chosen because historical whaling records hinted that this area might be a wintering grounds (i.e. breeding area). We discovered that it was indeed a locale where animals from the Svalbard bowhead population spent the winter (during 2008 and 2009), despite "100%" ice cover in this area, or perhaps because of it (see Moore et al. 2012, Stafford et al. 2012). At this site the animals sang complex songs, indicating that this was a breeding site in the 2007-2008 winter season.

Additionally, we learned many fascinating things about the environment in which this critically endangered whale stock lives, such as the fact that they are exposed to an extremely high frequency of air-gun blasts. From July to September such noise was recorded daily, and on average more than 50% of the daily records from the remaining months of the year also included this source of anthropogenic noise. This finding was very unexpected given the remoteness of the AURAL (at about 80º N), but it demonstrated that even during the middle of the winter, deep into heavy ice cover, at high latitude, this potentially sensitive breeding habitat of a critically endangered whale population is exposed to significant amounts of man-made noise (see Reeves et al. 2014). Human activities are increasing the level of noise in the world's oceans, causing widespread concern about potential effects on marine mammals and marine ecosystems. Major human-induced sources of sound include the seismic surveys for oil and gas exploration (and scientific research) documented in the first year of study, but also commercial shipping for transportation of goods, sonar systems for military purposes, fishing, and research vessels. Marine cruise tourism and small vessel research and pleasure traffic are also increasingly common in Svalbard waters and all of these sources of noise are likely to increase as sea ice becomes less prevalent in the Northern Barents Sea/Svalbard area. This is a potential threat to marine mammals that are very sensitive to sound (Nordtvedt Reeve 2012, Williams et al. 2014); the very nature of the physical properties of sound-travel in water has made it an important sensory modality for animals living in marine habitats. Sound is important to marine mammals for communication, individual recognition, predator avoidance, prey capture, orientation, navigation, mate selection, and mother-offspring bonding. Potential effects of anthropogenic sounds on marine mammals include physical injury, physiological dysfunction (for example, temporary or permanent loss of hearing sensitivity), behavioural modification (for example, changes in foraging or habitat-use patterns, separation of mother-calf pairs), and masking (that is, inability to detect important sounds due to increased background noise).

The IPY AURAL also documented the seasonal arrival of migratory whales such as blue whales and fin whales to and from the north. Unfortunately, this recorder was recalled by its owners (NOAA), despite the exciting results, because of

Norwegian/American import/tax laws. It was replaced the following year, but this instrument along with the whole oceanographic mooring was lost, presumably ripped from its anchor by ice bergs. So, our consortium applied to SMF and also Svalbard Science Forum (SSF) for grants to re-establish the recorder at this site and expand our PAM array. Both grants were successful and our acoustic array currently consists of four AURAL (Autonomous Underwater Recorder for Acoustic Listening) recorders (Multi-Électronique AURAL M2), two of which were purchased by this Svalbard Environmental Protection Fund grant. These two AURALs were deployed in Fram Strait and at a site north of Noraustland (ATWAIN); the other two SSF devices were placed at nearshore sites in Kongsfjorden and in Rijpfjorden (Fig. 1).

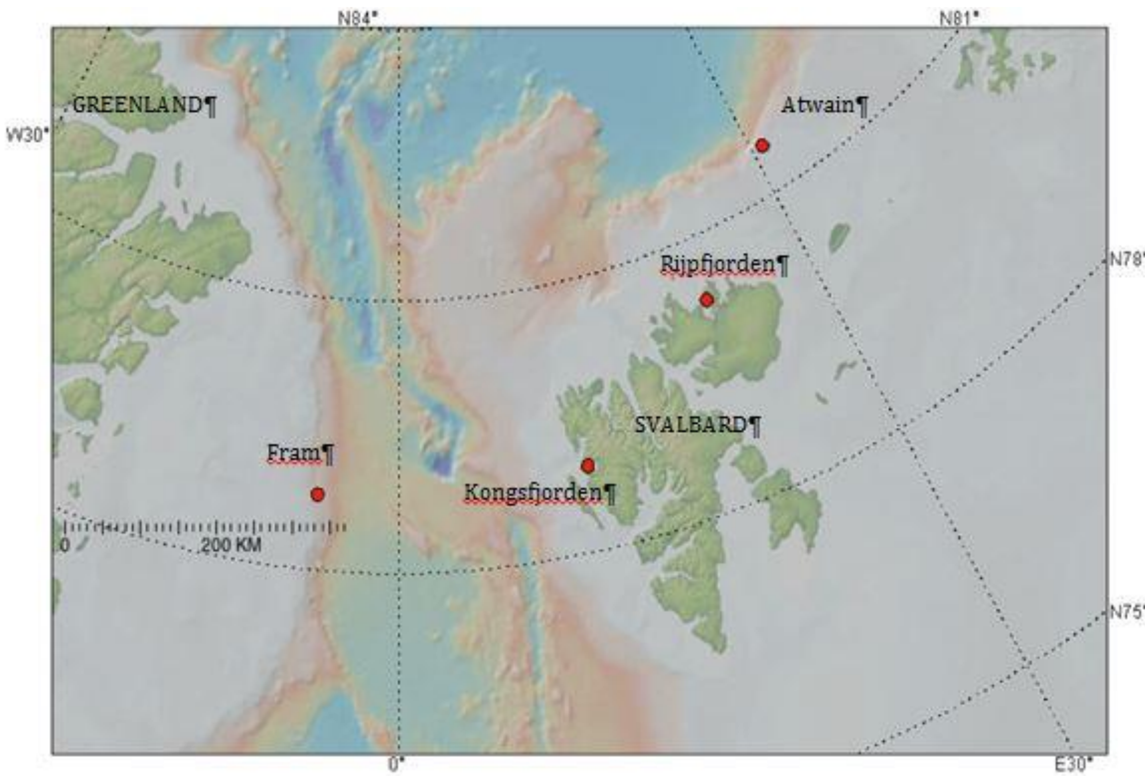

Figure 1. Locations of moorings on which AURAL hydrophones have been deployed. SMF financed the purchase of the Fram and Atwain instruments.

Description of data and preliminary results

All of the instruments are programmed to record an acoustic sample at the beginning of every hour over the period of one year. The instruments are programmed to record data from 10 Hz-16 kHz which is an appropriate acoustic bandwidth to record key arctic marine mammals species, as well as shipping and oil and gas seismic activity. Data records collected up to an including the 2014 season are summarized in Table 1.

Table 1. Data record durations for each AURAL in the Svalbard array and current status of data treatment. (HF = high frequency, AN = Antropogenic noise, LF = low frequency).

Instrument	Start recording	End recording	Water depth (m)	Status
Fram	25.9.2010	23.7.2011	1117	Data summary complete for HF, AN; LF to do
Fram	2011-2012			Whole mooring lost
Fram*	2.9.2012	11.4.2013	1014	Data summary complete for HF, AN; LF to do
Fram*	8.9.2013	27.4.2014	939	Data summary complete for HF, AN; LF to do
Fram*	2014/15			Currently deployed
Atwain*	18.9.2012	1.5.2013	850	Complete for HF, AN; LF to do
Atwain*	2014			Not recovered due to ice cover
Kongsfjorden	9.10.2013	24.3.2014	236	AN; HF, LF to do
Kongsfjorden	2014/15			Currently deployed
Ripfjorden	-	-	236	This instrument did not record in 2013-14 and was sent back to manufacturer. It has been repaired and is currently on Lance for shipment to Svalbasrd. It will be redeployed September 2015.

*AURALS purchased on funding from SMF.

Overall ambient noise levels for Fram, Atwain and Kongsfjord have been were measured using custom-built software written by JASCO, Inc. Our preliminary analyses show that each site in our AURAL network is exposed to quite different levels of anthropogenic activity (including shipping and oil and gas exploration). Each region also experiences different sea ice coverage and concomitantly animal use of the areas also vary markedly.

Biological sound records – general results

Different marine mammals produce species-specific signals that allow them to be identified, and distinguished, from other species. Acoustic signals from the ice-loving cetacean species, bowhead whales (calls and song, Figs 2 and 3) and narwhals (buzzes and echolocation clicks, Fig. 4) were the most commonly recorded biological signals on both the Fram Strait and the Atwain instruments. Detections of each of these species were more numerous at the Fram Strait site than at Atwain. Bearded seals (Fig. 5), which like broken drifting ice, were also recorded at both locations, but were most common on

Atwain. Other species detected in the data records included fin, blue, sperm and humpback whales (sperm and humpback whales at Atwain only).

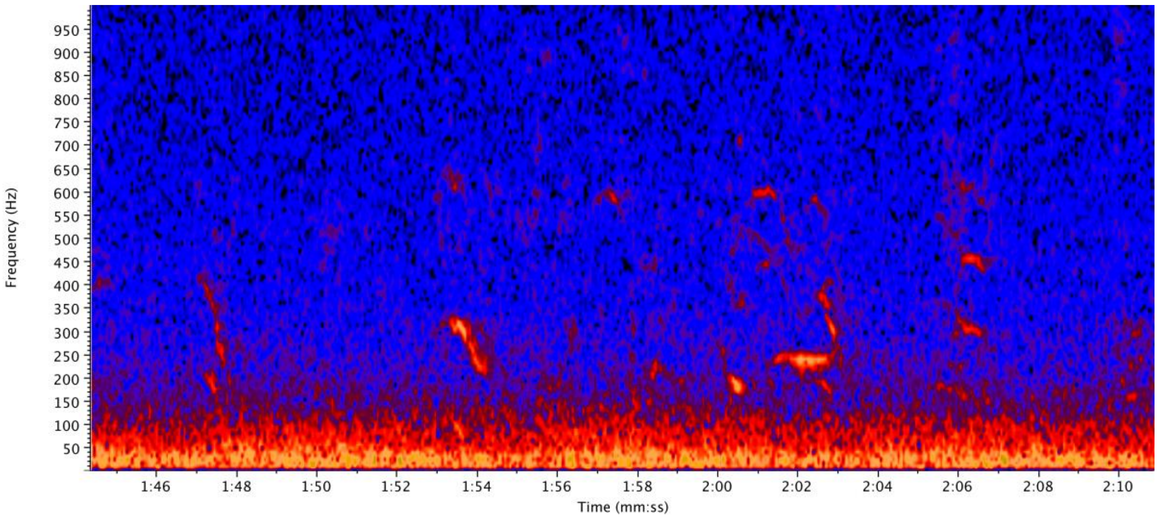

Figure 2. Four bowhead whale simple calls recorded at Fram Strait 8.4.2014.

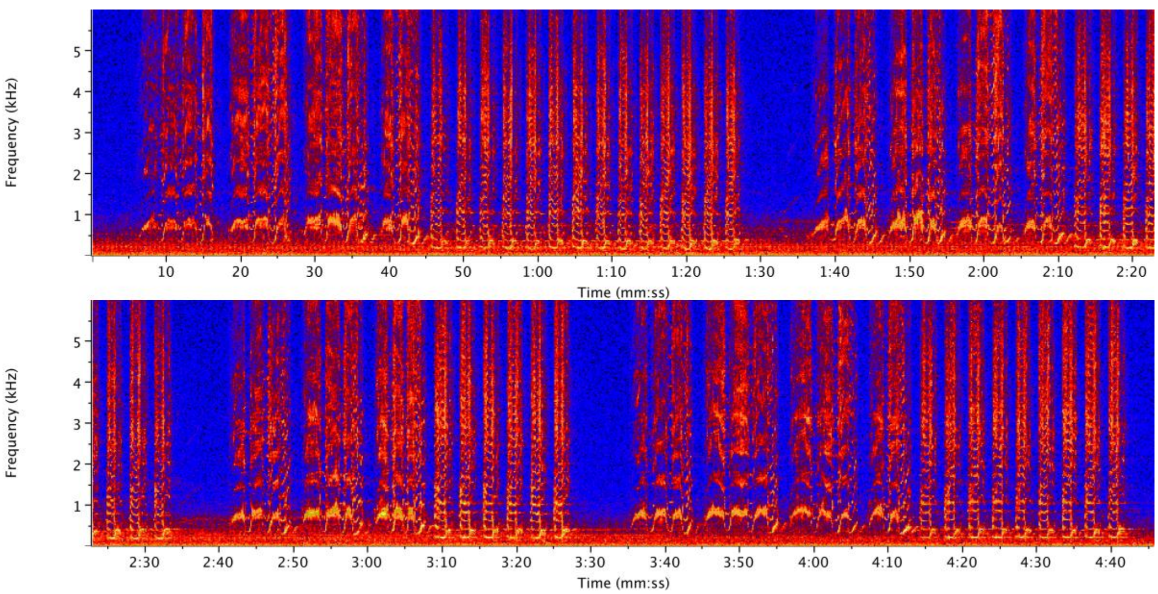

Figure 3. Four iterations of a bowhead whale song recorded on the Fram Strait instrument 9.1.2013.

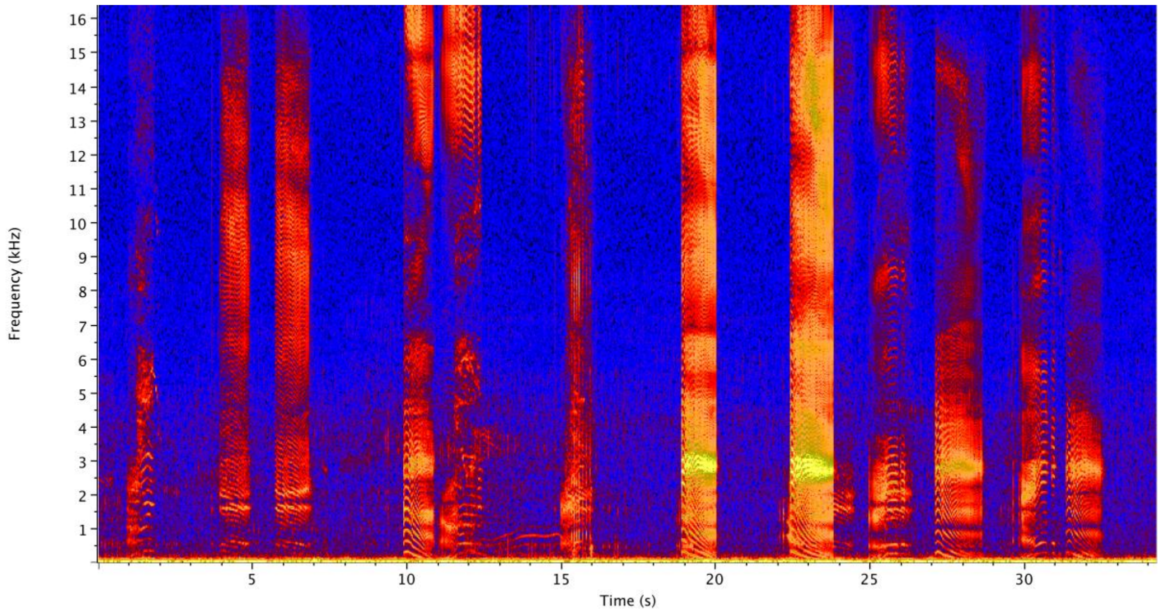

Figure 4. Narwhal buzzes and echolocation clicks recorded on Fram Strait instrument 8.9.2012.

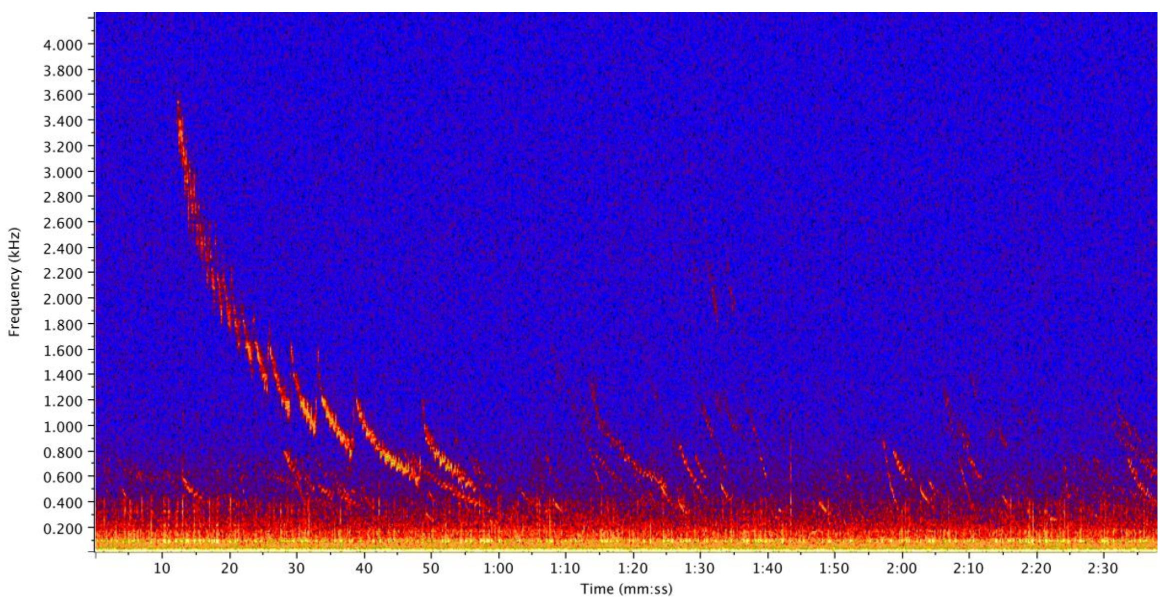

Figure 5. Bearded seal trills recorded at Atwain 23.4.2013.

Anthropogenic sources of noise – general results

The most common source of anthropogenic noise in Fram Strait was low frequency signals from seismic airguns. These generally occurred on 10-20 second repetition rates. Often, the signals were coming from distant surveys (Fig. 6a) but on occasion the signals received indicate that the survey had to be in the vicinity of the instrument (Fig. 6b,c).

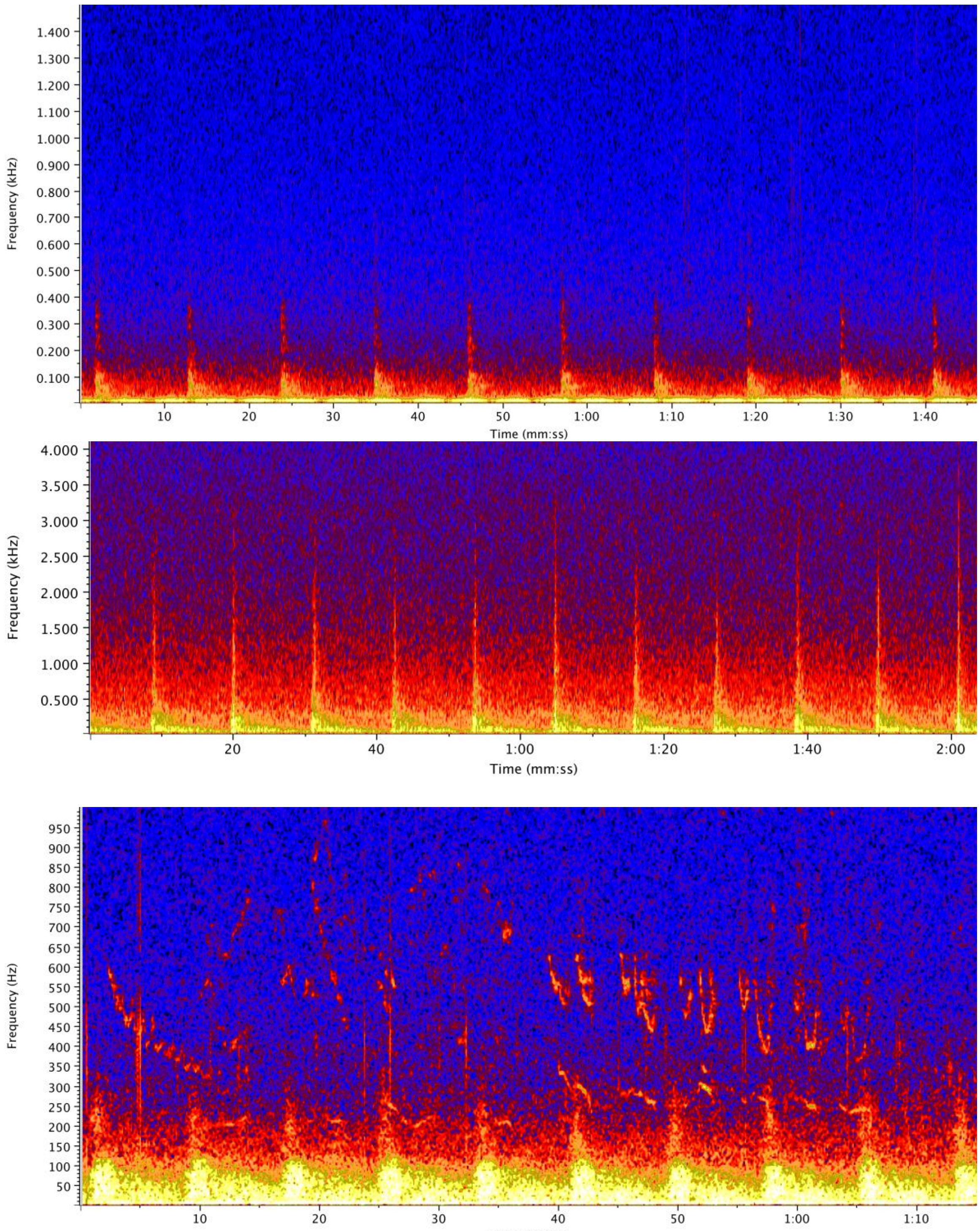

Figure 6. Airgun pulses recorded on the Fram Strait AURALa) signals from 4.10.2012;b)Very loud airgun pulses from 27.9.2013; and c) Airgun pulses with underlying bearded seal and bowhead signals recorded 7.4.2014. Note the different frequency axes in the three panels. Also note that the louder, closer airgun pulses from 2013 cover nearly 3 kHz, while the less loud signals only span 400 Hz.

Fram Strait

Arctic marine mammals

Similar to the IPY project deployment period, the signals of bowhead whales were the most commonly recorded biologic signal in all of the recent years of monitoring at the Fram Strait site. This confirms that it was not simply an irregular data record in 2008-2009, but rather that this area provides important habitat for this species and is a regular breeding site in winter. Bowhead whale sounds were recorded every day, often for many hours a day from late fall through until early spring (Fig. 7), with peak occurrences of vocalizations during midwinter. Both bowhead whale “calls” which are simple signals likely used for social communication and navigation, and “song”, which are almost certainly breeding displays, were recorded at this location. The extensive occurrence of this species highlights the importance of Fram Strait as habitat for this critically endangered population and the diversity of songs recorded suggests that a significant number of animals are likely present (Stafford et al. in prep).

The second-most commonly recorded marine mammal sounds at the Fram site were those of narwhals (Fig. 8). Both low-frequency echolocation and pulsed calls of this species were recorded. During preliminary analysis, these types of signals were assigned a generic “odontocete” tag because signals from other small odontocetes such as white-beaked dolphins can be confused with narwhal, white whales and other small-midsized toothed whales during this preliminary phase of data analysis. Further analysis should clarify what proportion of the odontocete signals are indeed narwhals; given the ice cover at this site it is likely the majority of these signals. Odontocete signals were recorded year-round with September and October having nearly twice the mean hours per day with signals compared to the other months.

Bearded seal trills were recorded mostly in spring (April-June), when they are in their breeding season, although a few signals were recorded for this species in almost every month of the data records (Fig. 9). In contrast with other regions of the Arctic, bearded seals were not the greatest contributor to spring-time ambient noise. The location of the Fram Strait instrument in deep water off the shelf break is likely reason for this as bearded seals prefer relative shallow shelf regions for easier access to benthic prey (Kovacs 2002).

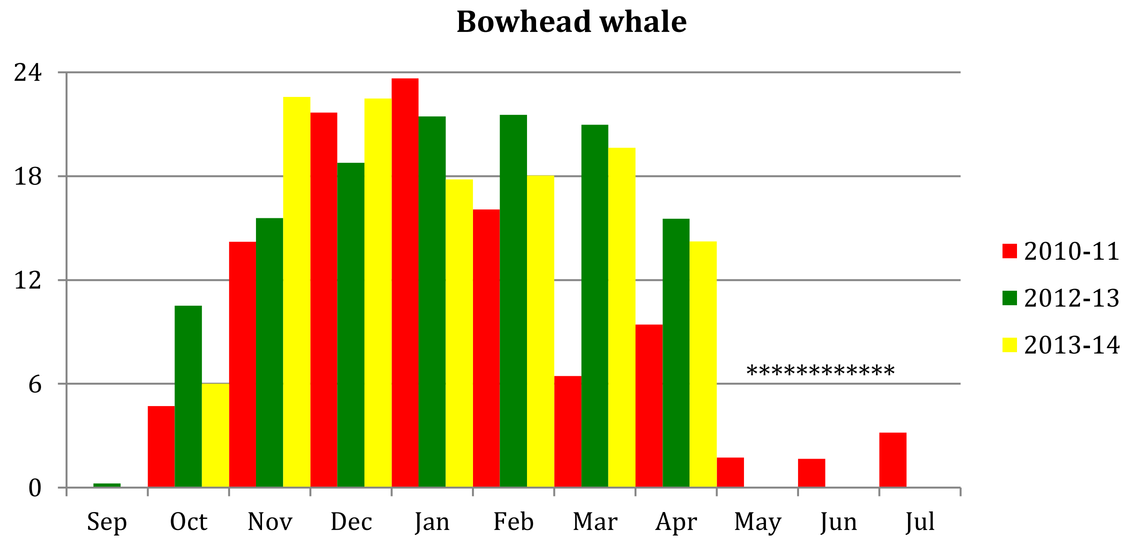

Figure 7. Seasonal detection in mean number of hours per day with bowhead whale signals at Fram Strait by year (* indicate no data for 2012-2014).**

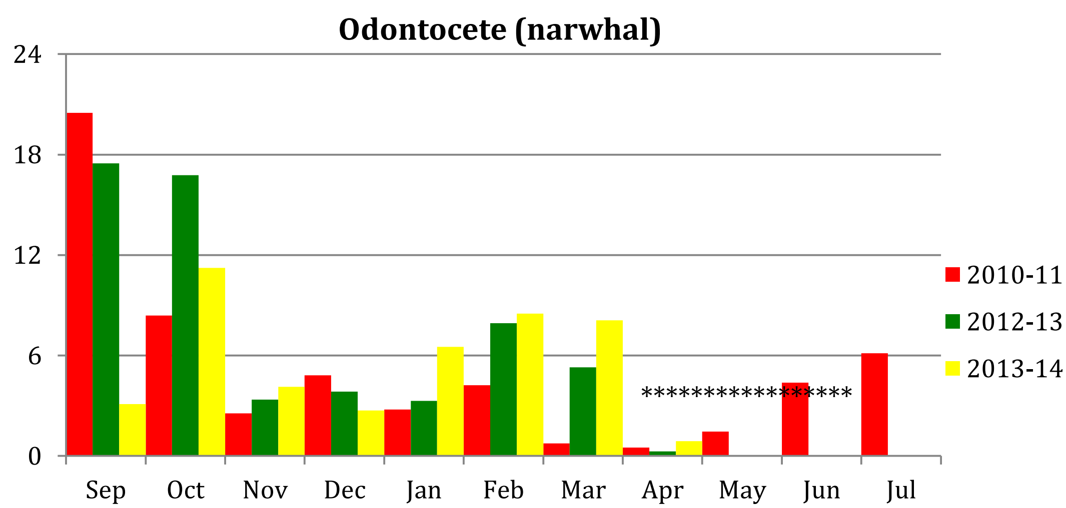

Figure 8. Seasonal detection in mean number of hours per day with toothed whale (almost all narwhal) signals at Fram Strait by year (* indicate no data for 2012-2014).**

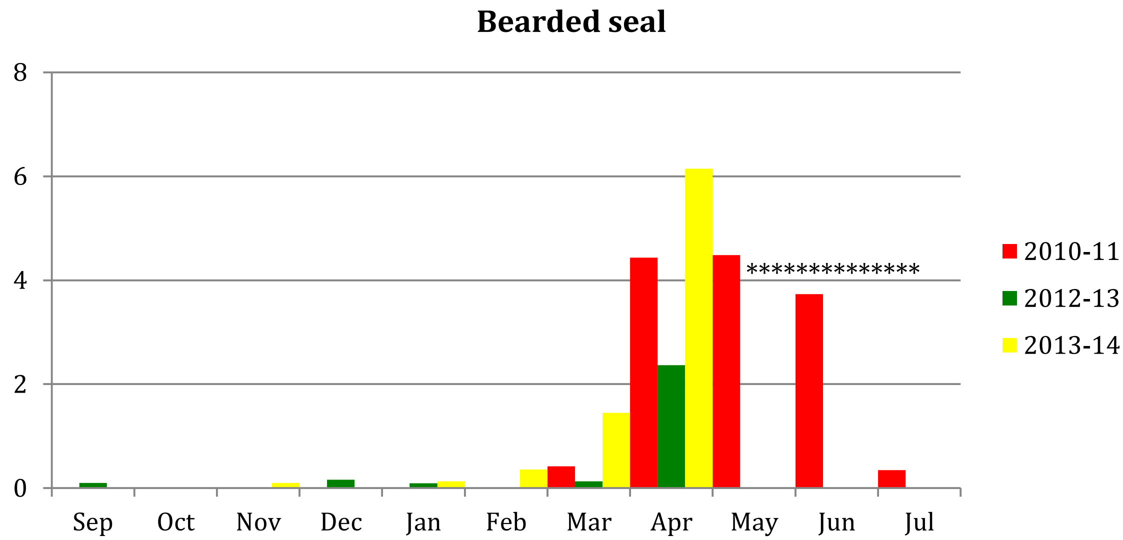

Figure 9. Seasonal detection in mean number of hours per day with bearded seal trills at Fram Strait by year (* indicate no data for 2012-2014).**

Other marine mammals

Analyses for blue and fin whale occurrences are on-going.

Anthropogenic noise

The signals of seismic airgun pulses were recorded year-round on the Fram Strait mooring with more hours per day with this type of signal from spring through fall (Fig. 10). Most seismic surveys recorded produced a low-frequency pulse every 10 to 15 s for hours to days at a time. Many of these surveys were likely distant as the signals were often restricted to very low frequency (< 50 Hz) pulses, although in some instances (e.g. Fig. 6b) the shooting ship had to be close to the hydrophone. Airgun surveys occur nearly year-round throughout the North and South Atlantic and contribute significantly to ambient noise levels even in the Arctic (Nieukirk et al. 2004, 2012; Klinck et al. 2012). These signals overlap with those produced by many baleen whale species (blue, fin, humpback and bowhead whales) and can propagate for hundreds to thousands of km (Nieukirk et al. 2004, Thode et al. 2010).

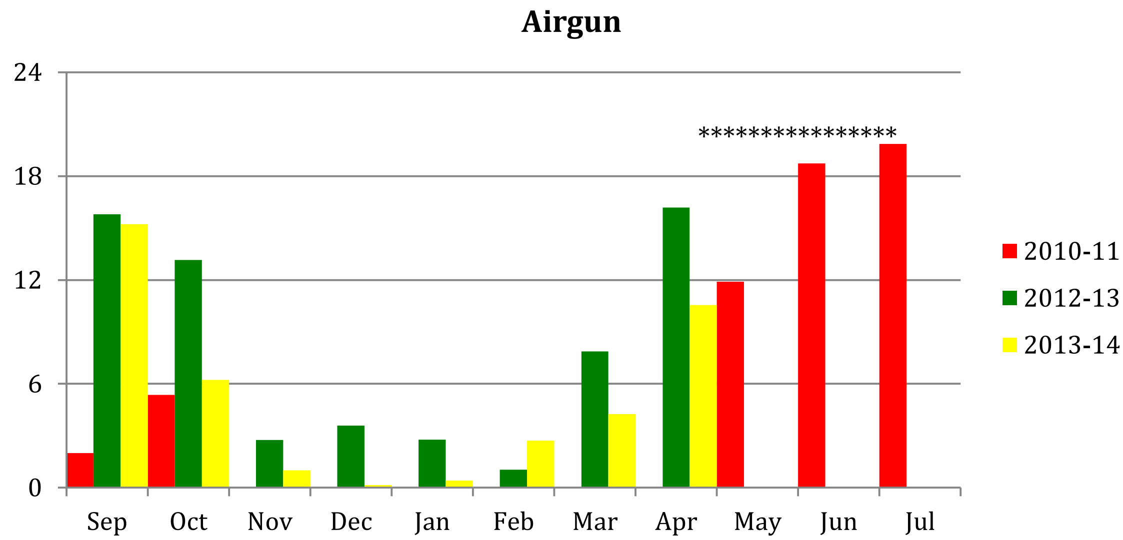

Figure 10. Seasonal detection in mean number of hours per day of seismic airgun signals at Fram Strait. By year (* indicate no data for 2012-2014).**

Atwain site

Data from the Atwain location were only available from September 2012- May 2013 as the mooring site was too ice-covered to retrieve the instrument deployed in 2013. The mooring at Atwain was exceptionally noisy due to mooring and self-noise therefore it was often difficult to detect signals, particularly low-frequency air gun signals during times of high self-noise. We are unsure of the source of this noise but it may be due to very high current in the region causing the mooring to vibrate. Therefore, the signals reported for this mooring should be considered minimum occurrences.

Arctic marine mammals

Bowhead whale signals were recorded seasonally on Atwain from late October 2012 until recording ended in May 2013. They were recorded much less often than on the Fram Strait instrument. However, both song and simple calls of this species were recorded at this site (Fig. 11).

Odontocete, presumed narwhal (see above), signals were recorded primarily in winter at Atwain, especially in February and March, but also at the beginning of May (Fig. 12).

A few detections of beluga whale whistles were confirmed on in November 2012 (Fig. 13). But, as noted above, these animals tend to produce few acoustic signals in this region of the High Arctic (Karlsen et al. 2002, Castellote et al. 2013) and their echolocation signals are too high frequency (~50 kHz) to be detected by the AURALS with the setting used in our deployments.

Bearded seals were the most commonly recorded marine mammal at Atwain (Fig. 14), with signal frequency increasing in occurrence from January thorough to May.

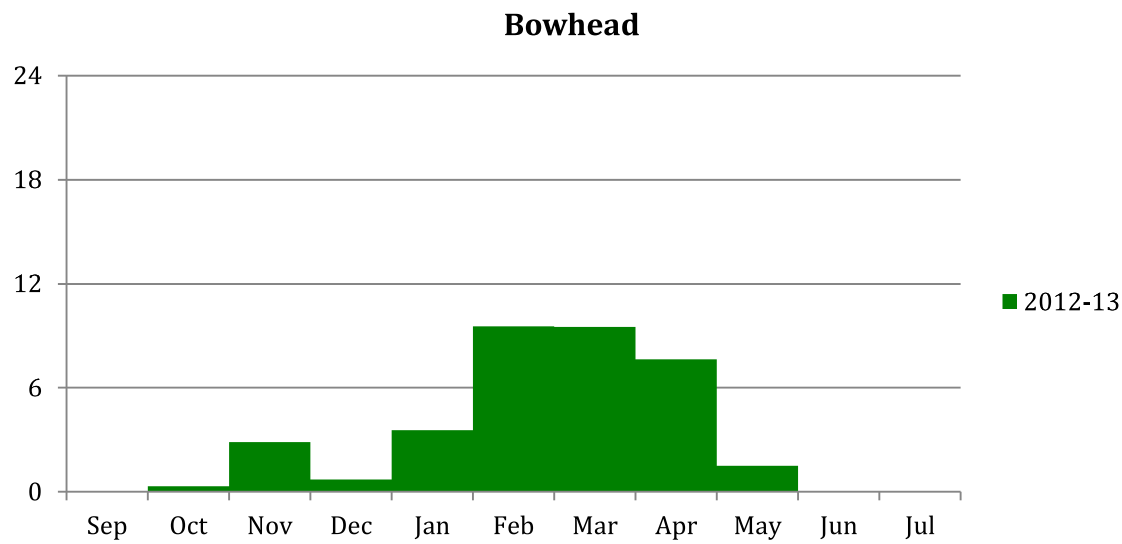

Figure 9. Seasonal detection in mean number of hours per day with bowhead whale sounds recorded at Atwain.

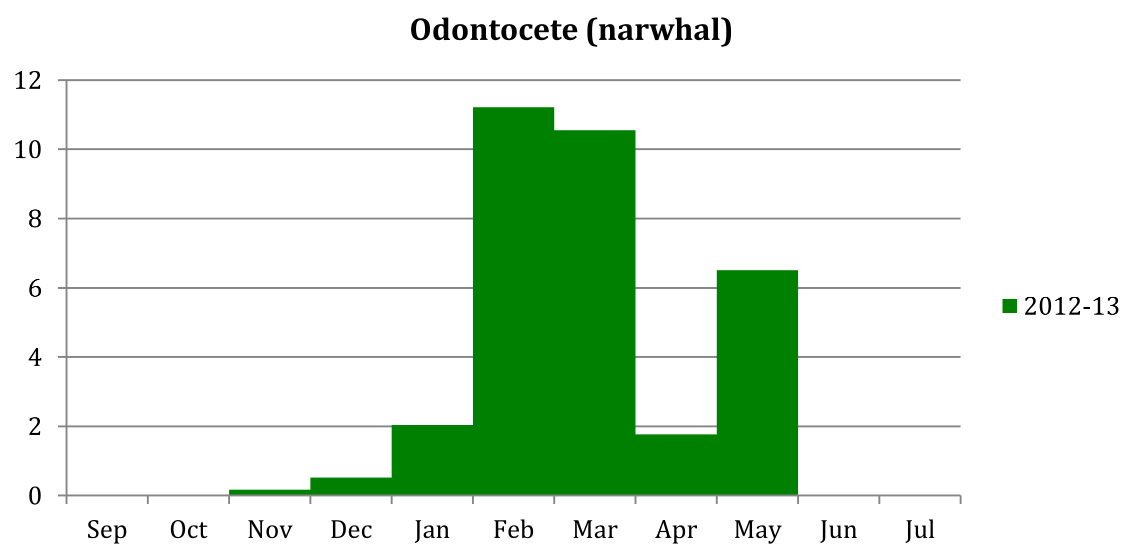

Figure 102. Seasonal detection in mean number of hours per day with odontocete sounds recorded at Atwain.

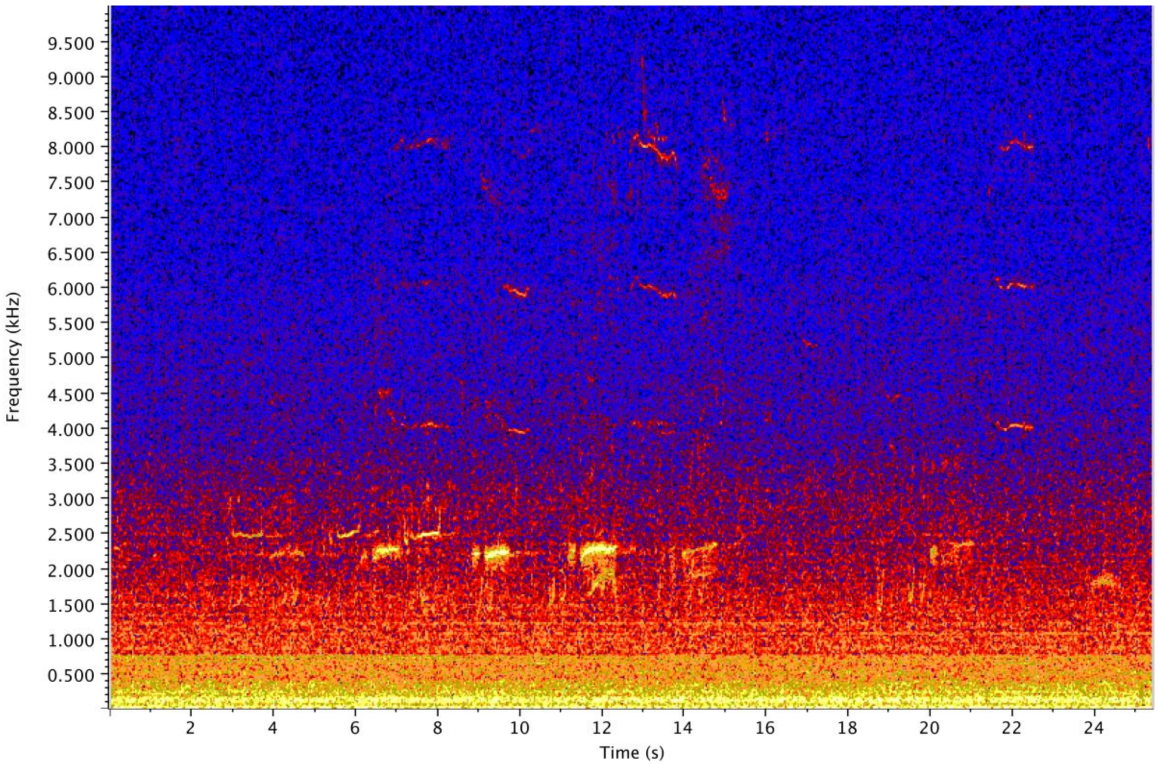

Figure 13. Beluga whale whistles recorded at Atwain on 19 November 2012.

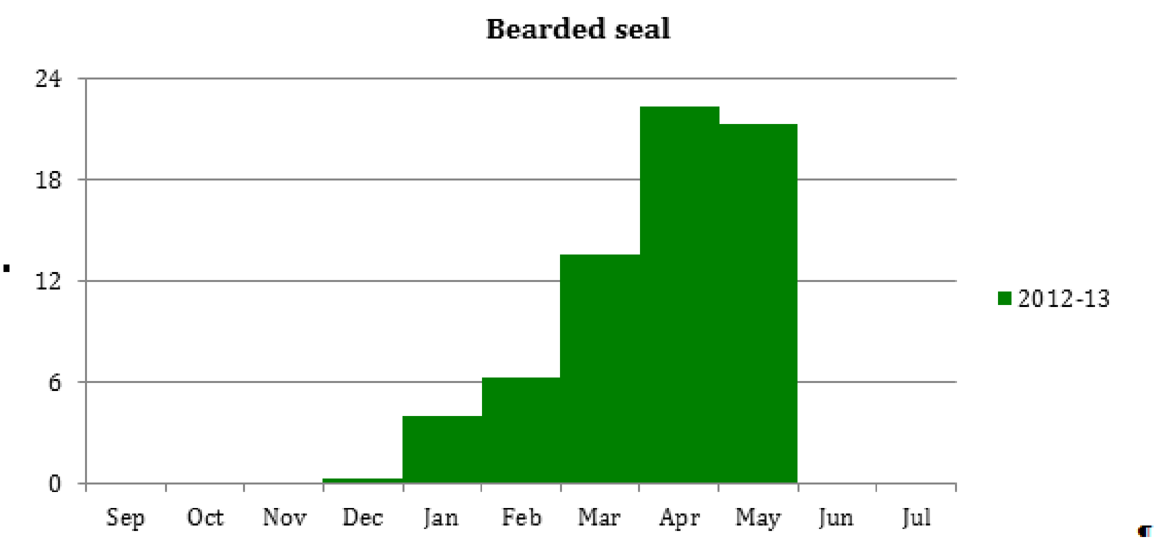

Figure 114. Seasonal detection in mean number of hours per day with bearded seal sounds recorded at Atwain.

Other marine mammals

Humpback whales were recorded on 16 different days from 3 October to 14 November. Distinct signals from sperm whales were recorded during a few hours on 12 October 2012 (Fig. 15). Analysis for blue and fin whale occurrence is currently on-going.

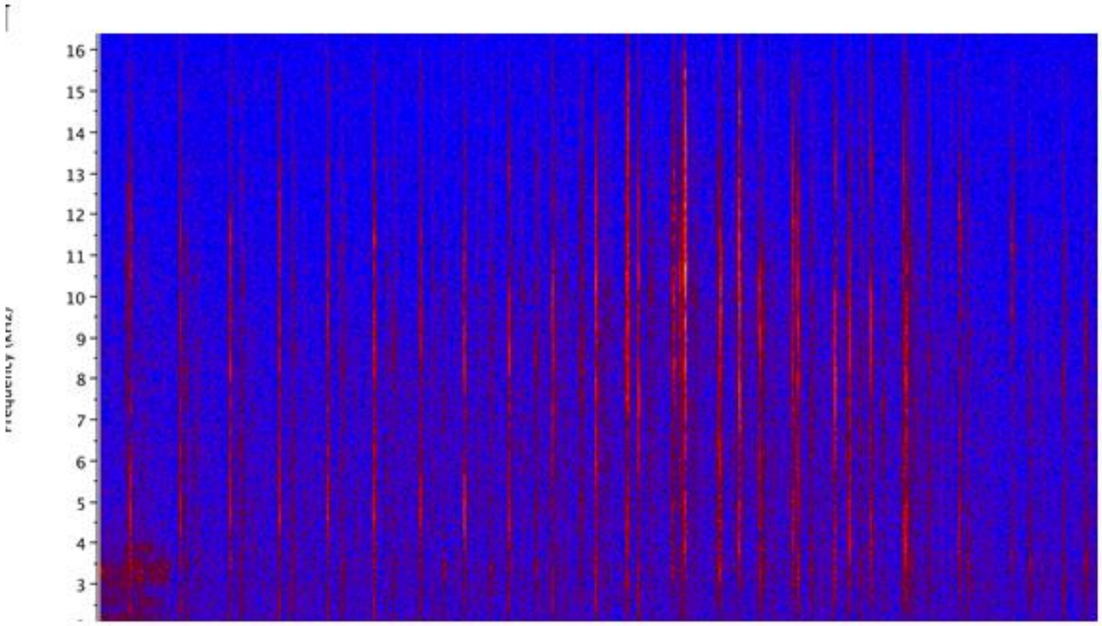

Figure 125. Echolocation clicks of sperm whales recorded at Atwain on 12 October 2012.

Anthropogenic sounds

Few seismic signals were detected at Atwain compared to the Fram Strait site (Fig. 16).

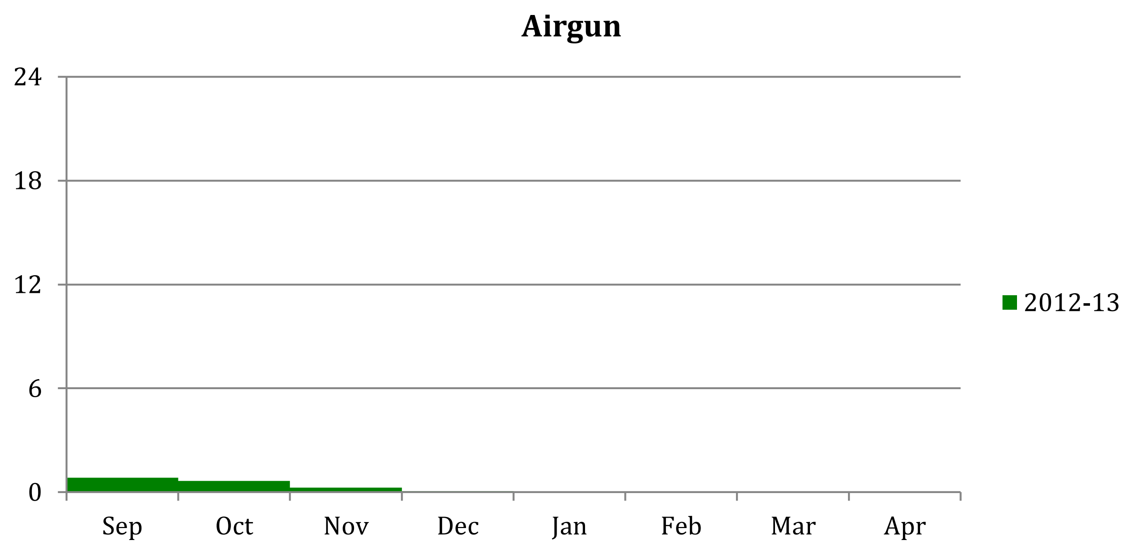

Figure 136. Airgun pulses detected on Atwain. These should be considered minimum detections as self-noise from the instrument at this location often obscured low frequency signals.

Ambient noise levels

We have also commenced analyses of total ambient noise levels by month at the Fram Strait mooring to create a base-line of noise for future time-series analyses. The three years of data are presented by month below (Figs 17, 18, 19) and a comparison of the three is also compiled (Fig. 20). These must be considered very preliminary at this point in time.

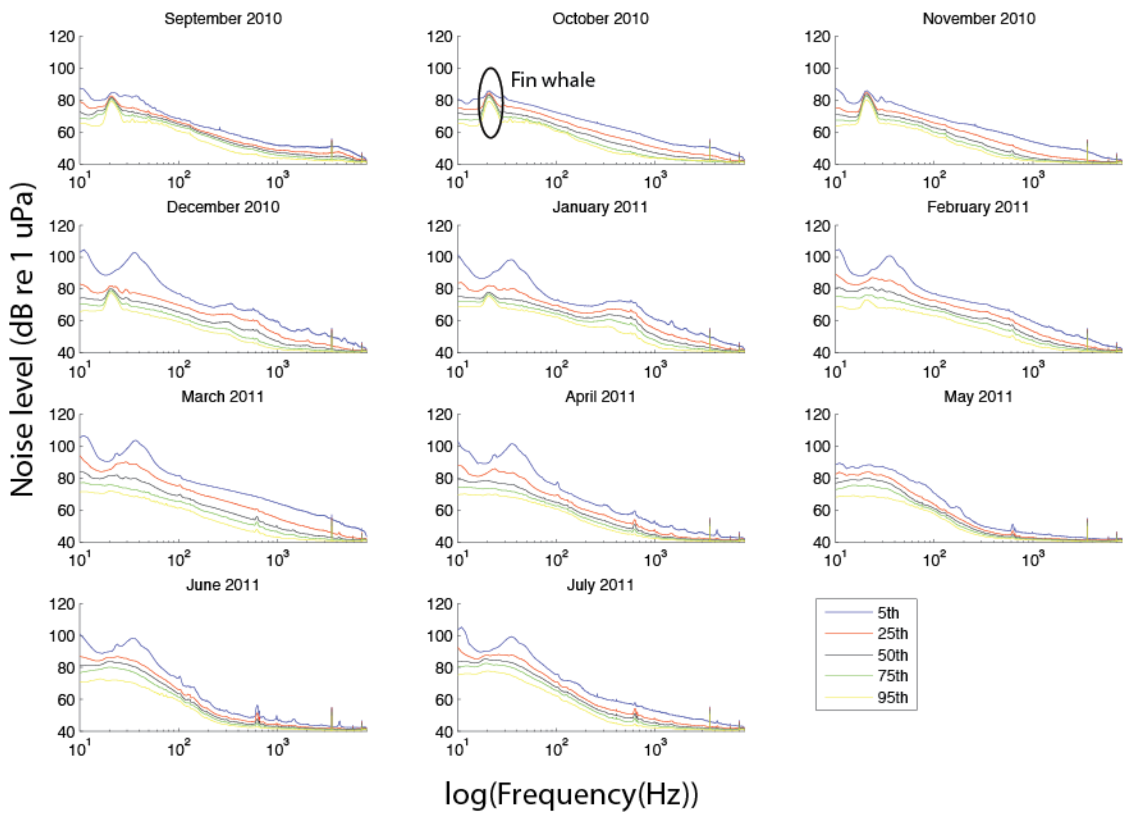

Figure 147. Mean power spectral densities by month for Fram Strait 2010-2011. 5th, 25th, 50th, 75th and 95th percentiles are shown for each month. From September into January a peak at 20 Hz (circled in October as an example) can be seen in the data that is an indicator of the presence of fin whale 20 Hz pulses.

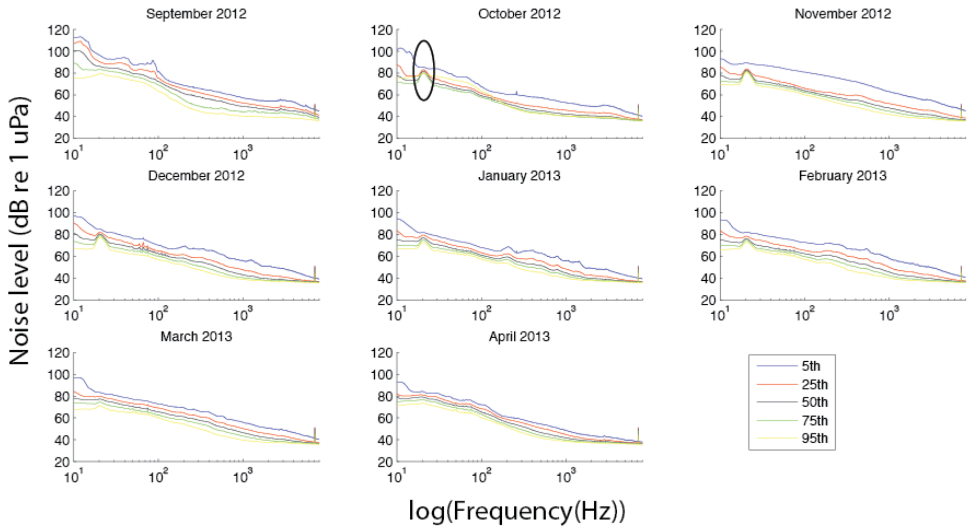

Figure 158. Mean power spectral densities by month for Fram Strait 2012-2013. 5th, 25th, 50th, 75th and 95th percentiles are shown for each month. From October into February a peak at 20 Hz (circled in October as an example) can be seen in the data that is an indicator of the presence of fin whale 20 Hz pulses.

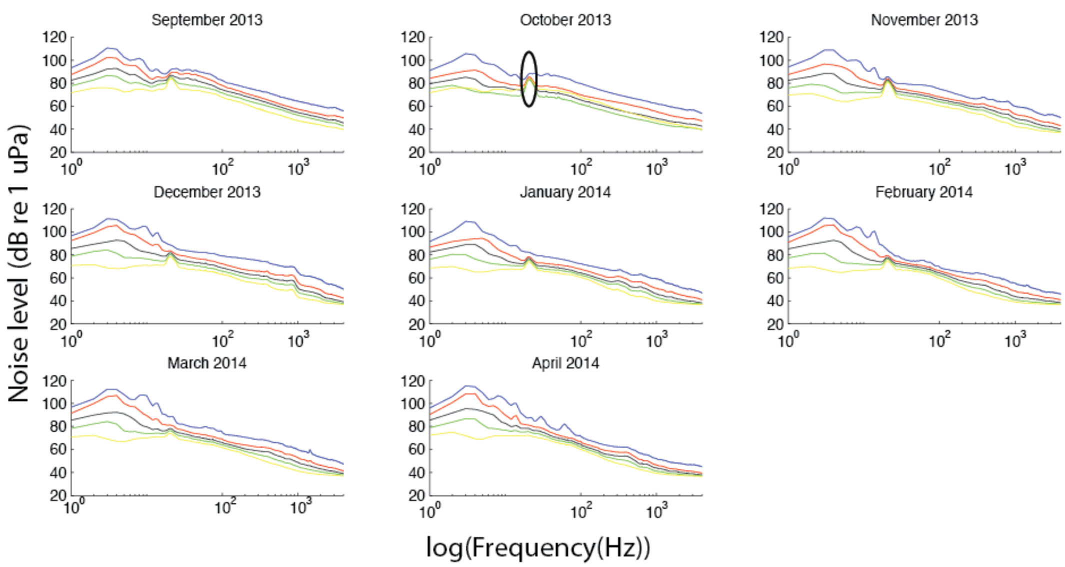

Figure 169. Mean power spectral densities by month for Fram Strait 2013-2014. 5th, 25th, 50th, 75th and 95th percentiles are shown for each month. From October into February a peak at 20 Hz (circled in October as an example) can be seen in the data that is an indicator of the presence of fin whale 20 Hz pulses.

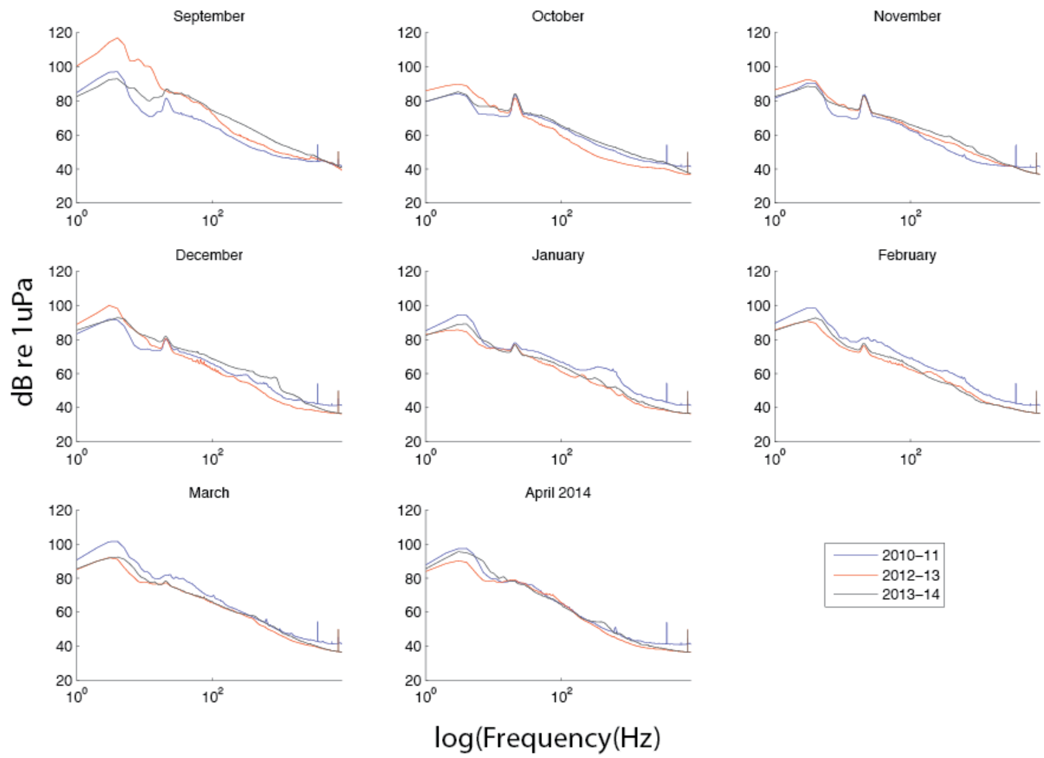

Figure 17. By month comparison of 50th percentiles from 2010-11, 2012-13 and 2013-14.

Next steps

The AURAL programme has considerable research potential and is providing vital management-related data on Svalbard's cetacean community and ocean noise in the Norwegian High Arctic. A manuscript on bowhead song from the Fram Stait site will soon be submitted to a scientific journal. We have now hired dedicated staffing for the research effort with these data for the coming 2-3 years to complete analyses and produce scientific papers and further management advice.

Acknowlegements

We thank the NPI oceanographers (Drs Arild Sundfjord and Laura de Steur) as well as Kristin Fossan and Rupert Krapp for their help with servicing our Fram Strait and Atwain instruments annually.

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