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Tusâven aivik and utjuk? Observing bearded seal and walrus seasonal presence and underwater sounds from year-round ocean acoustic recordings in the Torngat Area of Interest, Nunatsiavut, Canada

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Tusâven aivik and utjuk? Observing bearded seal and walrus seasonal presence and underwater sounds from year-round ocean acoustic recordings in the Torngat Area of Interest, Nunatsiavut, Canada

A Thesis submitted in partial satisfaction of the requirements
for the degree Master of Science

in

Marine Biology

by

Nina Marie Folz

Committee in charge:

Kaitlin Frasier, Chair
Simone Baumann-Pickering
John Hildebrand
Joshua Jones

2024

The Thesis of Nina Marie Folz is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

University of California San Diego

2024

DEDICATION

I dedicate this thesis to my mom, dad, and brother: thank you, each of you, for being my foundation and for filling my life with love and encouragement. Your unwavering support and belief in me have turned every challenge into a step forward and every dream into something I could reach.

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LIST OF ABBREVIATIONS

TAOI	Torngat Area of Interest
PAM	Passive Acoustic Monitoring
SIC	Sea Ice Concentration
HARP	High-frequency Acoustic Recording Package
XWAV	wav File Format
LTSA	Long-term Spectral Average
AMSR2	Advanced Microwave Scanning Radiometer 2

ACKNOWLEDGEMENTS

I would first like to thank my mentor and committee member, Joshua Jones, whose expertise and encouragement have been pivotal throughout my journey in the field of marine mammal acoustics. From my early days as his undergraduate student in marine mammal biology class to his role as my thesis advisor and lab supervisor, he has been a constant source of guidance and support. I would also like to thank Kaitlin Frasier for her consistent support and encouragement through this process. I would also like to thank my committee members John Hildebrand and Simone Baumann-Pickering for their insightful feedback on this project. Additionally, I would like to thank Rodd Laing and Michelle Saunders at the Nunatsiavut Government Department of Lands and Natural Resources for funding my work throughout the year and providing me with the opportunity to travel up to Nain where I gathered valuable fieldwork experiences and got to witness the beauty of the Torngat Mountains with my own eyes. My gratitude also goes to Joey and Sid for skillfully facilitating the acquisition of acoustic data for this project.

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ABSTRACT OF THE THESIS

Tusâven aivik and utjuk? Observing bearded seal and walrus seasonal presence and underwater sounds from year-round ocean acoustic recordings in the Torngat Area of Interest, Nunatsiavut, Canada

by

Nina Marie Folz

Master of Science in Marine Biology
University of California San Diego, 2024
Kaitlin Frasier, Chair

Bearded seals (*Erignathus barbatus*) and walrus (*Odobenus rosmarus*) are Arctic species that rely on sea ice for essential life functions such as mating, pupping, and foraging. Inuit have extensive knowledge of these animals in the waters of Nunatsiavut, Canada, but there is a paucity of information regarding their seasonal distribution and behavior in the northernmost areas of the region, particularly off the Torngat Area of Interest (TAOI). Both species produce distinctive underwater sounds that are readily detected and identified, making them ideal for studies using passive acoustic monitoring (PAM). This study provides observations of the seasonal acoustic presence and behavior of walrus and bearded seals using underwater recordings collected 20 km east of Saglek Bay in the TAOI, from October 2022 to September 2023. Analyses of acoustic data were conducted to detect bearded seal and walrus vocalizations at a temporal resolution of one-hour. Relationships between acoustic presence and environmental factors, such as sea ice concentration and time of day are examined. Bearded seal trills associated with male mating displays were detected from November through June, increasing with sea ice formation and continuing weeks after sea ice retreat and open water. Walrus knocks were detected primarily during ice cover from mid-January to early May, with vocal activity also peaking during 100% ice-covered period. Bearded seals exhibited diel patterns in vocalization with significantly fewer vocalizations detected during daylight hours during November to March. These findings contribute to a baseline understanding of the acoustic presence and behavior of walruses and bearded seals in the TAOI and provide valuable insights for marine spatial planning in the waters of Nunatsiavut.

INTRODUCTION

Bearded seals (*Erignathus barbatus*) and walrus (*Odobenus rosmarus*) are highly ecologically important species in the Arctic, serving essential roles in balancing the marine ecosystems as well as providing sustenance and supporting the cultural well-being of coastal indigenous communities (Gadamus &Yakoubian, 2015; Cameron et al., 2018). Despite their significance, very little is known about the abundance and seasonal distribution of these species. It is necessary to understand their movements, natural behaviors, and relationships with sea ice to better manage and protect ice-adapted seals in the changing Arctic. Studying ice-breeding pinnipeds in the Arctic has been limited due to the region's remoteness and extreme environmental conditions. Passive acoustic monitoring (PAM) has helped to improve the understanding of Arctic pinniped species in other regions during the times of the year when aerial, ship-based, or on-ice operations are not feasible (Stirling et al., 1983; Risch et al., 2007; Jones et al., 2014). PAM allows for the non-invasive collection of continuous data, making it well-suited to monitoring the seasonal acoustic presence of Arctic marine mammals in this seasonally ice-covered subarctic region.

Bearded seals and walrus are ice-associated pinnipeds that inhabit circumpolar Arctic and sub-Arctic waters, including along the Labrador coast. While both species are dependent on sea ice for critical life functions such as resting, mating, pupping, and molting, they exhibit some differences in their habitat preferences and seasonal movements (Cameron et al., 2010; London et al., 2024). Bearded seals primarily occupy areas with drifting pack ice over shallow continental shelves, where they can access benthic prey such as crustaceans and mollusks (Burns, 1981). Walrus are highly gregarious and are strongly associated with coastal regions and ice edges, foraging in shallow waters for benthic invertebrates and often hauling out on ice floes or coastal beaches (Fay, 1982; Hamilton et al., 2015). Both bearded seals and walrus rely on shallow waters (less than 100m deep) to feed and typically follow the yearly advance and retreat of sea ice, making them sensitive to changes in sea ice conditions, which can influence their distribution and access to suitable foraging grounds (Fay, 1968; Kovacs et al., 2012). However, much remains unknown about the specific habitat preferences and movement patterns of these species, particularly in the context of the rapidly changing Arctic environment.

The Atlantic subspecies of bearded seal, *Erignathus barbatus barbatus*, are distributed across the North Atlantic and adjacent Arctic regions, from the eastern Canadian Arctic and Greenland to the Barents and Kara Seas (Burns, 1981). Bearded seals generally migrate to remain associated with sea ice, causing them to move north in late-spring and summer as the ice retreats and then south in the fall as the ice begins to reform (Boveng & Cameron, 2013; Burns, 1967; Jefferson et al., 2008).They prefer regions in which the sea ice forms polynyas and leads, avoiding areas of heavy sea ice concentration (Kovacs et al., 2019). In the Eastern Arctic, pups are born on sea ice between mid-April and mid-May, and they are weaned by around 24 days old (Burns, 1967; Lydersen et al., 1994, 1996). Females come into estrus once their pups are weaned and, because they are aquatic mating phocids, they are diffusely spread at sea (Van Parijs et al., 2001). This dispersion of females requires male bearded seals to establish aquatic territories. Males typically are at the peak of rut in April and end in June (Burns, 1981; Cleator, 1996). During that period, males also produce loud trilling vocalizations from March to June that are associated with displaying fitness and protecting their territory (Cleator et al., 1989; Van Parijs et al., 2004).

The Atlantic subspecies of walrus, *Odobenus rosmarus rosmarus,* is distributed around the North Atlantic from Canada to the western Kara Sea (Born et al., 2001). Walrus are seasonally associated with pack ice and during the open water season mature males and females will amass on land at separate traditional haul out sites (*uglit*) (Loughrey, 1959; Mansfield, 1963). Male walrus go into rut November through late May (Mansfield, 1959). Females who are not preparing to give birth are in estrus from January-June with a peak in April. In order to attract females, male walrus produce knocks to advertise their reproductive fitness from January to April (Mansfield, 1959; Fay, 1982, Stirling et al., 1983, 1987; Sjare and Stirling, 2003). Mating season takes place from February to April (Fay, 1982; Sjare and Stirling, 2011; Stirling et al., 1983). Calves are born between April and mid-June with a peak in mid-May, and the mother nurses its young for two years (Mansfield, 1959; Born 2001; Burns & Frost 1979; Fay, 1982).

The Inuit territory of Nunatsiavut was established in 2005 and its territorial government has been tasked with the rapid assessment of natural resources and the need to develop monitoring to support environmental evaluation and management. One particular area in Nunatsiavut that is in need of environmental study is the Torngat Area of Interest (TAOI, Fig. 1 purple shaded area), a potential national marine conservation area and Inuit protected area off the Torngat Mountains National Park in the northern tip of Nunatsiavut. Forming a better understanding of where these pinnipeds seasonally reside in the TAOI through passive acoustic recordings will aid in the monitoring of their interactions with humans and the formation of this potential national marine conservation area.

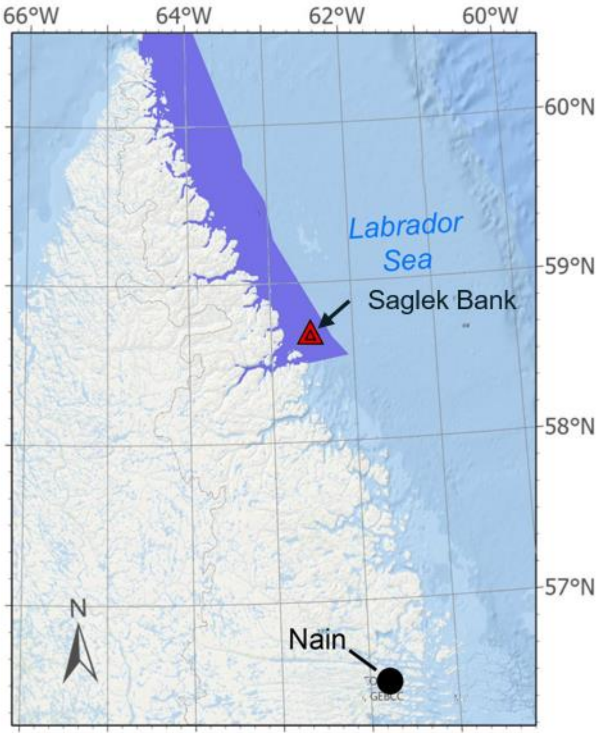

Figure 1: Map of study site. Acoustic data collection site approximately 20 km off the coast of the Torngat Mountains National Park along the Labrador Shelf. Red triangle is the HARP and the purple shaded region represents the TAOI.

The underwater calls of both bearded seals and walrus are distinct and easily identifiable, making them suitable candidates for using acoustic data to assess their seasonality. The detection of these species' vocalizations in passive acoustic data relies on them being vocally active within the study area of interest. Some factors that can influence call detection rate are: the proximity between the vocalizing pinniped and the recording instrument, vocal behavior, the frequency and amplitude of the vocalization, and ambient noise levels. This study aims to address the current knowledge gaps about pinniped presence in the Torngat Area of Interest using PAM. The specific goals of this paper are to: provide a baseline understanding of pinniped acoustic presence in the AOI based on underwater vocalizations, analyze how species interact with their environment by looking at seasonal and diel trends of calls, and explore the influence of sea ice concentration (SIC) on pinniped acoustic presence.

Acoustic recordings of pinnipeds were made during 2022-2023 on the Labrador shelf approximately 20 km off the coast of Saglek Bay in the Torngat Mountains National Park. The seasonal presence of the species' calls were combined with satellite-based measurements of sea ice concentration as well as solar elevation angle to gain insights into pinnipeds relationship with sea ice and daylight. Additionally, these results were compared to similar studies in other regions that documented timings of spatial distributions, behaviors, and reproduction.

METHODS

i. Acoustic data collection

Between October 12, 2022 and September 9, 2023, a High-frequency Acoustic Recording Package (HARP; Wiggins & Hildebrand, 2007) recorded underwater sounds at a depth of 153 m on the Labrador Shelf, 20 km off the coast of Saglek Bay (Table 1). The HARP sampled at 200 kHz continuously during the 2022 – 23 deployment. Acoustic recordings from the 2022 – 23 deployment had an effective hydrophone bandwidth of 10 Hz –5 kHz. During the recording period, the hydrophone consisted of six cylindrical transducers (Benthos AQ-1) wired in series for a hydrophone sensitivity of −187 dB re: V/μPa and with 55 dB of preamp gain. In 2021-22, a two-stage hydrophone was used. It included the low-frequency stage from previous years with six cylindrical transducers and approximately 50 dB of preamplifier gain. The additional, high-frequency stage consisted of a spherical omnidirectional transducer (ITC-1042, www.itc-transducers.com) with a relatively flat (± 2 dB) sensitivity response of −200 dB re: V/μPa from 1 Hz to 100 kHz and about 80 dB of preamplifier gain. The combined sensitivity of the two stages was consistent with published HARP specifications (Wiggins & Hildebrand, 2007). All acoustic recordings were converted into an adapted wav file format (XWAV) for analysis. XWAV files were decimated using an eighth-order Chebyshev type I filter to reduce the data to 10 k samples/s (new bandwidth: 10 – 5,000 Hz), minimizing further computational requirements. Analyses were conducted using the Triton program, based on MATLAB (mathworks.com), to calculate and display long-term spectral averages (LTSA) and standard spectrograms, to perform audio playbacks, and to log call detections (Wiggins & Hildebrand, 2007).

Table 1: Recording times, sampling period, position, and depth for the HARP used to collect acoustic data. One single-channel HARP was deployed at this site.

Deployment Name	Start Date (UTC)	End Date (UTC)	Recording Duration (Days)	Sample Rate (kHz)	Depth (m)	Latitude (° N)	Longitude (° W)
NUNAT_SB_03	Oct 12, 2022	Sept 9, 2023	332	200	-153	58°41.93’	62°31.08’

ii. *Call detection and species identification*

A trained analyst visually scanned 1 hour LTSA windows with 5 s temporal and 10-4,500 Hz frequency range for the characteristic calls of the two species. We compared previously described vocalizations for bearded seals and walrus (Stirling, 1983; Watkins and Ray, 1977; Risch et al., 2007; Miksis-Olds et al., 2016; Van Parijs et al., 2004) with calls detected in the HARP recordings. To avoid misidentification, we accepted only characteristic trills of bearded seals and the pulsed, repetitive knocks of walrus as initial evidence of their presence. When likely calls were detected in the LTSA, a corresponding 90 s spectrogram (1000 point FFT, Hanning window, 0% overlap) was inspected to verify and log their presence. While analyzing the 2022 – 23 recordings, we logged one representative call detection for each hour for each species when vocalizations were present, thereby providing acoustic presence or absence at a temporal resolution of one hour. A box was drawn around the call in a 90 s XWAV time series and JPEG graphical file was saved for logged calls. Each JPEG image showed the 1 hour LTSA window from which the call was detected and a 90 s spectrogram of the call detection, often with additional calls (Fig. 2). In the final step, the analyst visually inspected the JPEG files of all logged detections to check for identification errors. Any misidentifications were reassigned to the correct species or removed from the detection database.

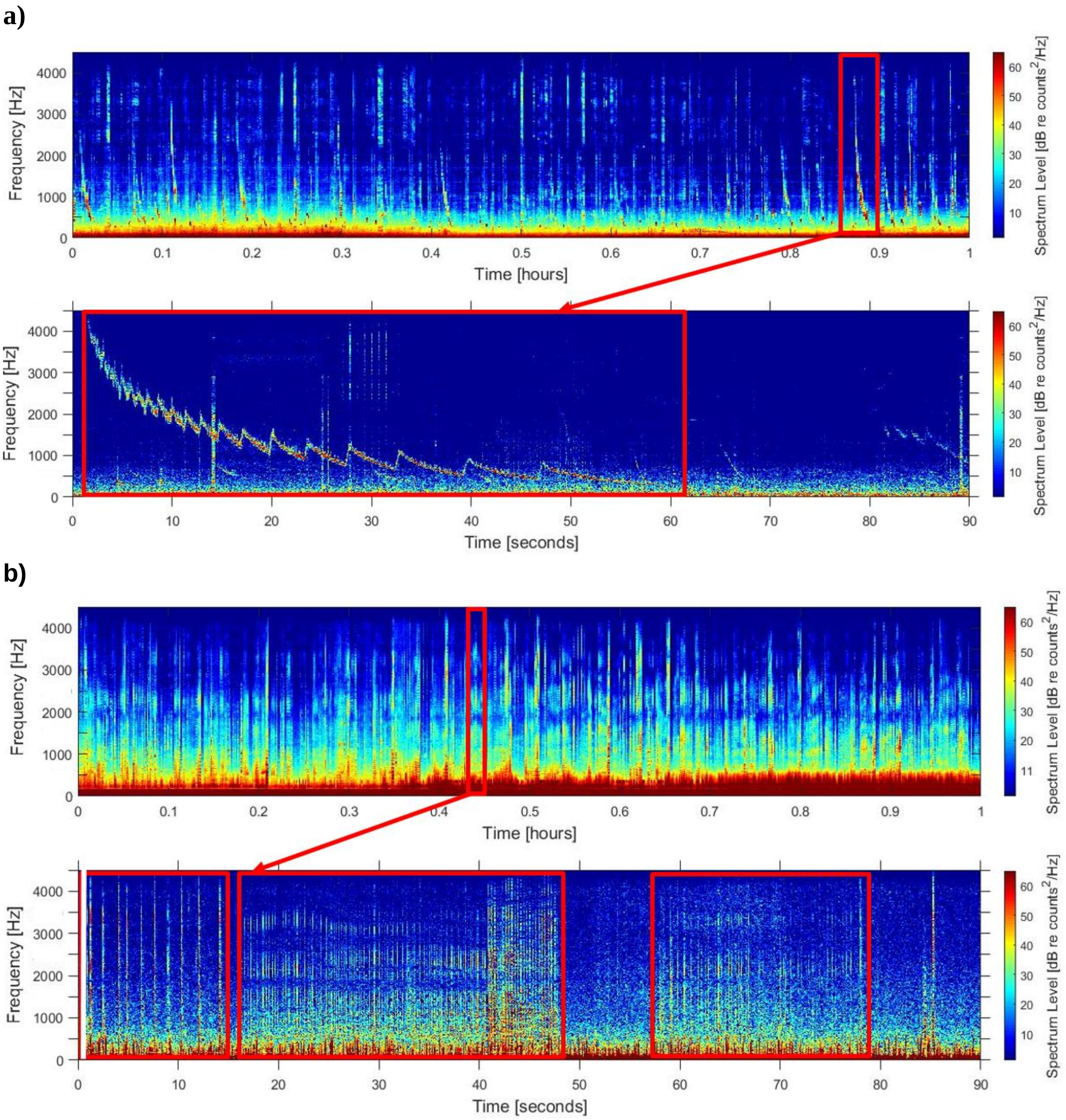

Figure 2: Spectrogram examples of recorded species-specific vocalizations: **(a) bearded seal trill and (b) walrus knocks**. Red boxes and arrows show the process of call identification between spectrogram windows.

iii. Acoustic analysis of call characteristics

All 90 s XWAV call detections in the 2022-23 recordings to identify the acoustic presence of each species. For each call, key parameters such as start and end times were recorded, as well as minimum, maximum, start, and end frequencies. Only calls with clearly visible parameters in the spectrograms were included in the repertoire and seasonal analysis. We identified signals that matched published call types based on their type and logged their key parameters (Table 2). A time series of the acoustic presence of each species to assess their seasonal presence in the TAOI was produced. This was coupled with a concurrent analysis and a time series of sea ice concentration and solar elevation angle around the survey site. The results were analyzed to determine the possible influence of sea ice presence on pinniped acoustic presence and behavior.

Table 2: Bearded seal and walrus call type characteristics. Parameters based off previously published literature on bearded seal and walrus vocal repertoire.

Species	Call Type	Duration (s)	Minimum Frequency (Hz)	Maximum Frequency (Hz)	References
Walrus	Knock	1-15 pulses/s lasting for 60-80	500	4000	Ray & Watkins, 1975; Stirling et al., 1983, 1987
Bearded Seal	Trill	3-45	250	4000	Jones et al., 2014; Risch et al., 2007; Stirling et al., 1983; Van Parijs et al., 2004

iv. Sea ice measurements

Average daily sea ice concentration was estimated to evaluate the influence of sea ice on the acoustic presence of bearded seals and walrus. We estimated median daily sea ice concentrations within a 20 km radius around the recording site between 2022 and 2023 for comparison with the observed pinniped acoustic presence.

Advanced Microwave Scanning Radiometer 2 (AMSR2) 3.12 km spatial resolution sea ice maps were obtained from the University of Bremen (Melsheimer & Spreen, 2019; Spreen et al., 2008). Utilizing custom MATLAB code, median daily sea ice concentrations were estimated for all AMSR2 grid values within a circular mask of a 20 km radius centered on our recording location (Fig. 3). The 20 km mask radius was selected for comparisons of daily acoustic presence with sea ice cover based on two previous observations of maximum detection range for bearded seals and walrus in water less than 100 m deep (Stirling et al., 1983; Cleator et al., 1989). This estimate of maximum detection range for what we assume to be the highest amplitude vocalizations produced near the study site was intended to be conservative. To reduce the effects of terrestrial snow and ice on sea ice estimation, an additional mask was applied to remove all pixels within a 1 km distance from the nearest shoreline. The daily arithmetic mean, variance, and median of sea ice concentrations, expressed as a percentage of the total mask area, were computed using MATLAB. The median value for the sea ice measurements was used because the passive microwave data had greater ice concentration values at each grid point than expected, potentially due to the proximity of the recording site to nearby land on Torngat Mountains National Park. This issue was particularly noticeable during ice-free periods in the late summer. For example, during these periods, the mean values sometimes indicated greater than 5% ice cover, while the median values more accurately showed the correct 0% ice cover.

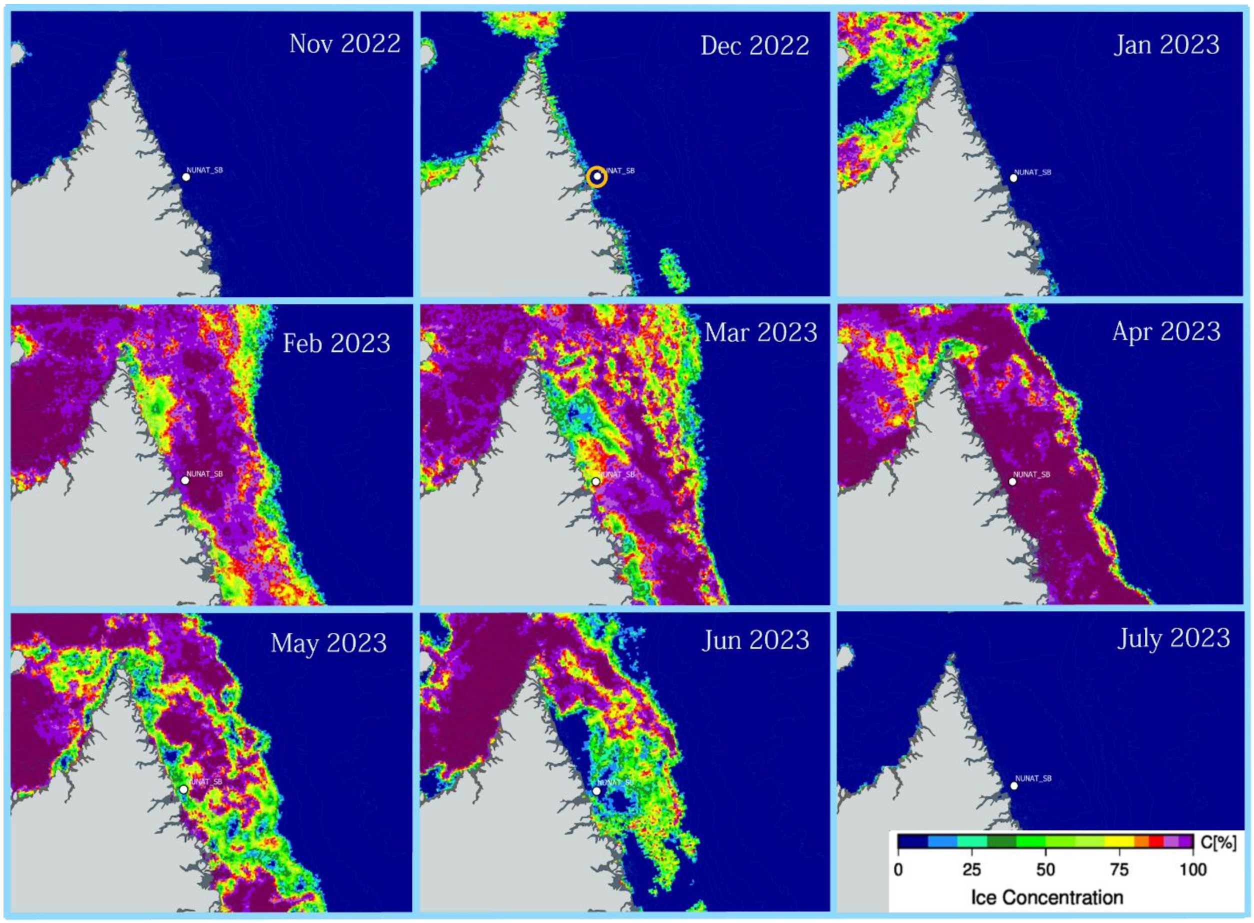

Figure 3: Map of monthly sea ice concentration around the recording site (Nov 2022- Jul 2023). Months with 0% SIC were not included. Site is labeled with a small white dot. Orange circle represents 20km radius around site. Percent SIC is shown on color bar scale.

v. *Solar elevation angle*

Solar elevation angle (accounting for atmospheric refraction) was obtained for the corresponding timing and coordinates of the deployment using the NOAA Solar Calculator (Astronomical Algorithms). The time of sunrise and sunset associated with the data is accurate for locations between +/- 72 degrees latitude The study site falls within the range of accuracy as it is situated at 58.70 degrees. This data was used to investigate the influence of solar elevation, representing day and night, on the hourly acoustic presence of bearded seals and walrus at the site.

RESULTS

i. *Pinniped acoustic presence with sea ice concentration*

A timeseries was generated to illustrate the seasonal patterns of acoustic presence of bearded seals and walrus in relation to daily sea ice concentration, highlighting the distinct species-specific responses to sea ice variability around the site from October 2022 - September 2023. (Fig. 4). Acoustic detections of bearded seal trills began two months before sea ice was detected within 20 km of the site. When the sea ice began to form in mid-January, there was a distinct increase in the number of acoustic detections hours of bearded seal trills. The number of detection hours was variable from January to early March and then increased to nearly 24 hours/day from mid-March through late June. Bearded seal detection hours declined quickly over the course of two weeks from the middle to the end of June. Bearded seal trills were detected despite the lack of ice for a few days at the beginning of May. Additionally bearded seal acoustic presence remained consistent despite the absence of the sea ice at the site by early June.

Acoustic detections of walrus knocks began when sea ice started to form in mid-January. The number of detection hours varied from mid-January to the beginning of February and then increased to nearly 24 hours/day from early February to the beginning of April. At the start of April, walrus detection hours slowly declined over the course of the month until detections ended in mid-May. This decline coincided with the lack of consistent sea ice around the site for the short period of time at the beginning of May. When the ice returned to the site, the walrus detections did not resume. There were a few remaining sparse detections in June and September.

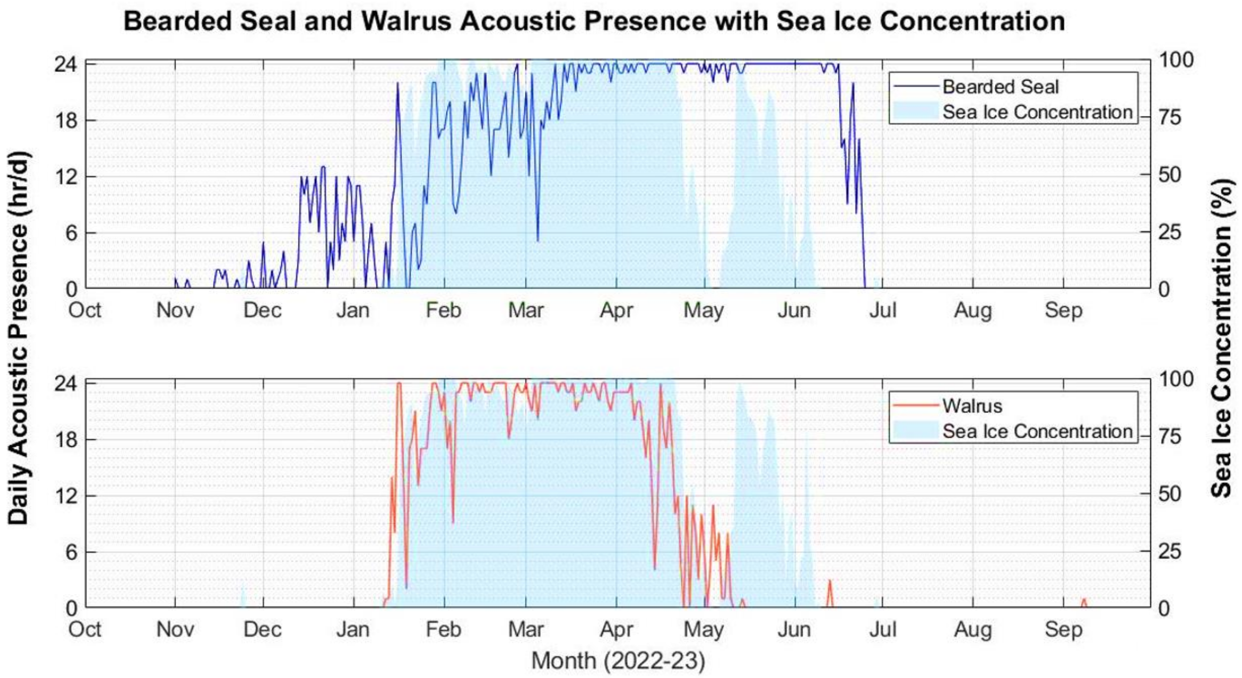

Figure 4: Pinniped acoustic detections in hourly bins per day with sea ice concentration. Data from October 2022 to September 2023 plotted against sea ice cover: top plot shows bearded seals (dark blue line) and bottom plot shows walrus (red line). Blue shaded areas indicate median daily percent sea ice cover (AMSR2 20 km radius).

ii. Pinniped acoustic presence with time of day

Bearded seal acoustic detections began at the start of November and continued until late June (Fig. 5). There was a nocturnal presence to their call detections from November until March but it was most distinct from November to mid-January. When the solar elevation angle was < 0 (indicating darkness), the number of hours with bearded seal acoustic detections was higher. This early marked nocturnal presence coincided with the open water period that extended until the sea ice started to form in mid-January. The trend remained after sea ice formed around the site, but it is much less pronounced. There was no pattern in their calling behavior once the sea ice disappears in early June.

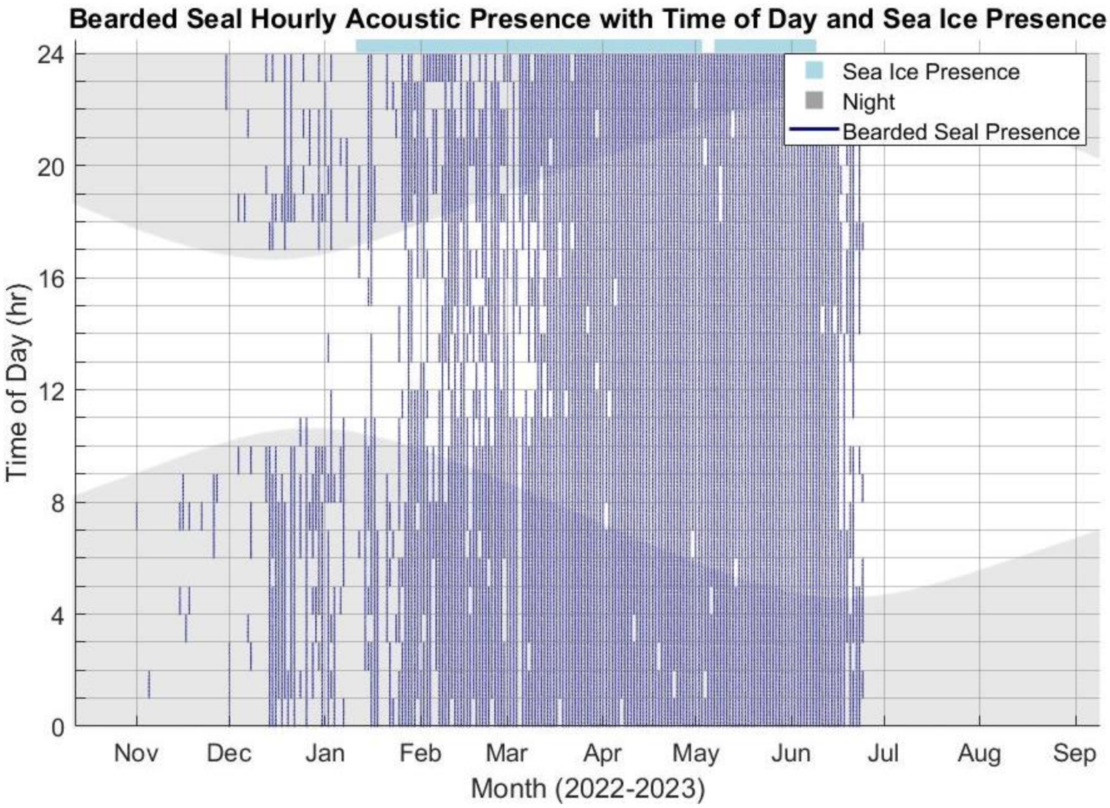

Figure 5: Diel plot of bearded seal trills (dark blue). Night time (horizontal elevation <0) is represented by gray shading.

Walrus acoustic detections began in mid-January and continued until early May (Fig. 6). There was no clear pattern in the detection of their calls between the day and night. When the solar elevation was < 0 (indicating darkness), there was no apparent increase or decrease in the presence of acoustic detections.

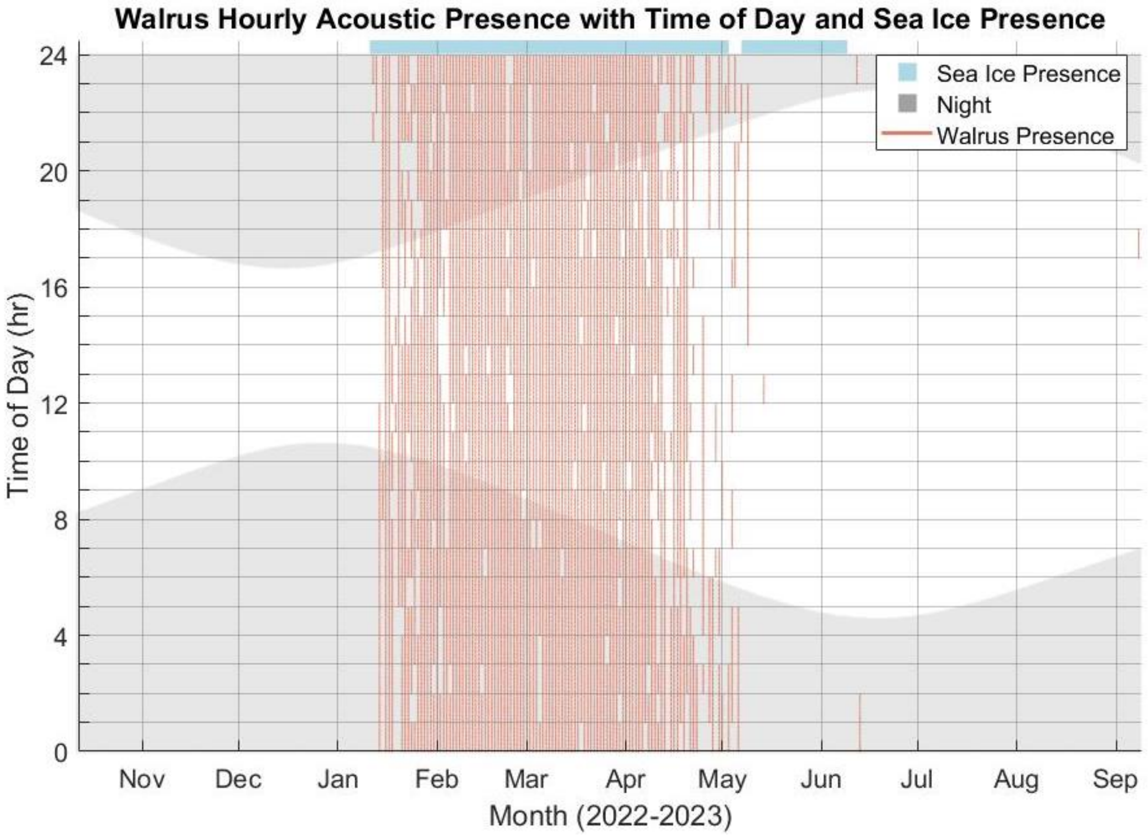

Figure 6: Diel plot of walrus knocks (red). Night time (horizontal elevation <0) is represented by gray shading. Sea ice presence is represented by the blue bar.

DISCUSSION

This study provided year-round acoustic information on bearded seal and walrus vocalizations from Saglek Bay in Nunatsiavut, Canada, where earlier acoustics studies of this species in this region had taken place in the Canadian High Arctic, Svalbard, Bering and Okhotsk Seas, and Alaskan territories.

i. Bearded Seals

i. Seasonal presence

Our analysis of bearded seal acoustic presence demonstrates a clear seasonal pattern with few detections in October and November, followed by a gradual increase through December and February, peaking from mid-March to mid-June before a quick decline by the end of June (Fig. 4). This nearly continuous peak calling period in the spring corresponds to the species' breeding season in the Arctic (March- June) (McLaren, 1958; Burns et al., 1981; Cleator et al., 1989). An increase in the number of calls has been linked to an increased number of males being present rather than just a rise in the call rates of individuals (Van Parijs et al. 2001). Therefore, it is probable that the observed increase in the number of hours with acoustic detections reflects a rise in the number of bearded seals present and vocalizing within the range of the hydrophone. Additionally, other studies have highlighted temporal variations in bearded seal vocal activity, generally showing peak activity during the mating season. There is typically significant variation in vocal activity before this period, with multiple peaks and drops occurring prior to the mating season (Stirling et al., 1983; MacIntyre et al., 2013, 2015; Frouin-Mouy et al., 2016). The slow and variable ramp up period of calls in late fall and early winter at the site can be attributed to male pinnipeds, both aquatic and land-breeding needing to establish territories and display their dominance months in advance of females giving birth and coming into estrus (Van Parijs et al., 1999; Van Opzeeland, et al. 2010). Following the mating period there was an abrupt ending to the calls that occurred irrespective of other environmental variables, which has been documented by multiple other studies (Crance et al., 2022; Burns, 1981; Van Parijs et al., 2004; Jones et al., 2014; Frouin-Mouy et al., 2016). This may be because males have completed their breeding period, which spans from April to July, and no longer need to expend energy on vocalizing, as they have already successfully found a mate and defended their territory (Burns, 1981; Cleator, 1996; Van Parijs et al., 2001).

Boye et al. (2020) documented the spatio-temporal distribution of vocalizing bearded seals in Baffin Bay and Davis Strait, showing a strong link between vocalization and sea ice concentration during a 6-month period from January to mid-June. This aligns closely with MacIntyre et al. (2015), who recorded vocalizing bearded seals in the Bering Sea from January through late-May, though the bearded seals at this site stopped vocalizing a few weeks earlier than in Boye et al. (2020). In Kongsfjord, Svalbard, Van Parijs et al. (2001) reported a restricted calling period from early April to mid-July, similar to the findings of Frouin-Mouy et al. (2016) in northern Baffin Bay. Comparing these findings with Saglek Bay, we observe that bearded seals at the site initiate calling in November, several months earlier than reported in Baffin Bay, Davis Strait, Bering Sea, and Kongsfjord. However, their vocal activity in Saglek Bay ceases by late June, which closely parallels observations in Baffin Bay and Davis Strait (Boye et al., 2020). Bearded seal detections in this study share the same pattern as those found in the Baffin Bay, Davis Strait, Bering Sea, and Svalbard, in that they have a clearly limited calling period that generally extends from winter through spring. This differs from the results of MacIntyre et al. (2015) which documented bearded seals calling year-round at multiple sites in the Beaufort and Chukchi Seas.

ii. *Sea ice*

Bearded seals were acoustically detected across a full range of SIC values from 0%-100%. The number of hourly acoustic detections peaked when sea ice was at 99%-100%, coinciding with their known mating season. However, sea ice around the site was disrupted briefly from late April to early May, and SIC dropped to 0% by early June; neither event prevented bearded seals from being detected 24 hours a day. Van Parijs et al. (2004) observed a similar trend in Svalbard when the rate of call detections in June decreased irrespective of the declining ice cover. Several previous studies have documented a much stronger positive correlation between sea ice cover and bearded seal vocal detections in the Chukchi, Bering and Beaufort Seas (MacIntyre et al., 2013, 2015; Frouin-Mouy et al., 2016). A key difference in the timing of the first bearded seal detections each year is that at Saglek Bay, the seals arrive before the sea ice, in contrast to the many other studies that found bearded seal calls to be closely coupled with the arrival and break up of sea ice (Fig. 4) (Hannay et al., 2013; MacIntyre et al., 2013, 2015; Frouin-Mouy et al., 2016). Llobet et al. (2021) documented bearded seal calls across all levels of sea ice concentration in Svalbard, while Simpkins et al. (2003) found that in St. Lawrence Alaska, bearded seals prefer sea ice cover from 70-90% and avoided areas with SIC any higher than 90%. There seems to be a lack of agreement as to what amount of sea ice cover bearded seals prefer. Because bearded seals are aquatic-breeding pinnipeds, they do not have a substrate-based territory to defend. Therefore, it is reasonable that at sites like Saglek Bay, males begin vocalizing and advertising fitness well before there is sea ice and females are in estrus. Additionally, there may be fewer vocalizations during the pre-ice period because there are less female bearded seals at the site due to a lack of ice to give birth on (Burns & Frost, 1979). The consistent peak in acoustic detections during periods of highest SIC across the bearded seal's circumpolar distribution underscores the importance of a stable sea ice platform during the mating season. The difference in bearded seal seasonal acoustic presence and sea ice concentration across various spatial and temporal scales indicates how future variations in suitable sea ice habitat may impact the future reproductive success of the bearded seal and other ice-dependent species.

iii. Diel patterns

During the time of year when the site experiences the fewest hours of daylight (November-mid January), bearded seals exhibited distinctly nocturnal calling behavior, vocalizing only during hours of darkness (Fig. 5). Daylight hours varied slightly across this period, however, bearded seals were consistently vocalizing from (0000) and 1000 and from 1700 to 2400 with a brief break in calls from 1000 to 1700 when the sun was up. The number of detection hours was higher from the early morning period from (0000) to 1000. This two-month period coincided with the time before any sea ice was present at the site, and although the pattern weakened, it continued through February and March until the breeding season began. Studies at various locations across the Arctic have documented a similar trend with a peak in vocal activity from (0000) to 0600, where the pattern is weaker in December and January and becomes stronger during March and April (Cleator et al., 1989; Van Parijs et al., 2001; Frouin-Mouy et al., 2016; Halliday et al., 2019). Our findings in Saglek Bay differ from other studies, as we documented a nocturnal pattern in bearded seal call detections before any sea ice was present at the site, with the pattern weakening as sea ice filled in by January, whereas previous studies observed this pattern only in the presence of near 100% SIC. It has been hypothesized that male vocal activity is correlated with the proportion of females in the water and that vocalization rates decrease when more of them are hauled out on the ice (Cleator et al., 1989). This theory would explain the diel patterns at the more Northern study sites that had a high percentage of ice cover by the time bearded seals started calling but Saglek Bay was ice free until early January. Bearded seals occasionally haul out on land in the summer, (Lydersen et al., 2008) but they generally prefer to haul out on ice at all other times of year not known to haul out on land in this region (Lairde et al., 2008; Burns, 1981; MacIntyre et al., 2013). Because this daytime haul out behavior, may not fully explain the diel vocal patterns of the bearded seals at the site in late fall (when sea ice is absent), we can consider the theory of predator avoidance. Killer whales are one of the main predators of bearded seals and they are predicted to have an increased predatory impact on marine mammals in response to reduction in Arctic ice cover (Lairde et al., 2008). Killer whales rely more on sight rather than echolocation when hunting seals to maintain stealth, making bearded seals more vulnerable to predation during daylight hours, especially during the open water period (Ferguson et al., 2012). Bearded seals could be more comfortable vocalizing at night because they are at much lower risk of predation.

Bearded seals are known to be tactile foragers, using their vibrissae and mouths to root through sediment and find their prey, however, it is possible that some aspect of daytime conditions make it more optimal for their foraging (Marshall et al., 2006). The illumination of the water column during the daytime may facilitate bearded seals’ ability to navigate as they are foraging, although once they reach the depths of the shelf to feed (100 m), nearly all light will have attenuated (Burns & Frost, 1979; Cota et al. 2003). If male bearded seals are actively foraging during the day, they may not want to simultaneously expend energy producing trills, so they call more frequently at night prior to mating season.

ii. Walrus

i. Seasonal presence and sea ice

Acoustic detections of walrus knocks in our study began with the arrival of sea ice at the site in mid-January, fluctuating through late January and early February before stabilizing into near-continuous 24-hour detections from early February until the beginning of April (Fig. 4). This pattern suggests a potential link between walrus presence and the availability of sea ice, which is consistent with findings from other studies that highlight the reliance of walrus on ice for resting, molting, and as a platform for social interactions (Jay et al., 2012). As the sea ice diminished in April, there was a gradual decline in acoustic detections until they eventually ended in mid-May, a period characterized by fragmented ice cover. The absence of walrus following the return of sea ice suggests that they had already migrated out of the area, likely to regions with more stable ice conditions, as observed in other studies where walrus are known to follow the receding ice edge (Fay, 1982; Laidre et al., 2008). In May and June, walrus are known to enter their molting period, which requires them to haul out for long periods of time, resulting in fewer documented hours of underwater vocalizations (Kastelein, 2009). The few sparse detections in June and September could be attributed to transient individuals, a pattern also noted in other research where isolated walrus occasionally wander into previously vacated areas. Walrus seasonal acoustic presence coincided with sea ice availability and underscores the importance of stable ice platforms for the walrus population's seasonal activities and overall survival in the Arctic. The observed patterns in walrus acoustic behavior are challenging to equate to other studies, as full-year time series analyses of their acoustic presence have not yet been conducted at comparable latitudes.

ii. Diel patterns

Our study documented the acoustic presence of walrus from mid-January through early May. During this time, walrus acoustic detections were randomly dispersed across all hours of the day. There was no evident pattern of hourly acoustic detections being higher at night versus during the day. Comparable acoustic studies in the region have not observed a distinct diel trend in walrus calling behavior. The only known behavior that may influence acoustic detections of walrus throughout the day would be during their molting period that takes place from May to June (Kastelein, 2009). Data from studies using visual observations, acoustic recordings, and satellite telemetry, have demonstrated that during this time of year, walruses have a clear preference towards hauling out during the time of day with the most sunlight to trigger their molt (Salter, 1979; Stirling et al., 1983; Born & Knutsen, 1997). When walrus are hauled-out on land or ice, they are not in the water, meaning that their vocalizations are not able to be detected by underwater hydrophones. Their haul out behavior is heavily influenced by the weather conditions such as wind and cloud cover, as observed in Stirling (1983), which documented walrus in the High Arctic preferring to haul out on calm clear days from late March to early May. In this study, we did not document any diel pattern in walrus underwater vocalizations, but if we had, further investigation into the daily weather conditions at our site during this time period would help reveal if weather and molting behavior are the drivers of this decrease in walrus call detections during daylight hours observed in the data.

CONCLUSION

i. Limitations of the study

Autonomously recorded passive acoustic data is useful for filling the gaps of knowledge surrounding pinniped acoustic activity at sites during times of year when the region is difficult to access. However, it lacks the benefit of direct visual observation of the animals that are producing the vocalizations. The identification of species rather relies on prior acoustic descriptions from different regions and periods of time in which different analysis methods were used. Bearded seals and walrus are known to have distinct and stable acoustic repertoires. Despite this, there are very few comprehensive and continuous acoustic time series that exist for these species at comparable latitudes, or anywhere in the Eastern Canadian Arctic for that matter. This makes it difficult to predict results and compare findings to similar studies.

A significant challenge is the uncertainty surrounding the absence of the species. Lack of acoustic detections does not mean the species is necessarily absent, they could be present and silent. Seasons in which vocalization are low could be a result of many other factors including sea ice conditions, diel behavior patterns, and predator activity.

Additionally, the effectiveness of call detection is impacted by source level, transmission loss, and bathymetry. Ice covered regions also increase the rate of scattering, which alters propagation conditions and can alter detection distance and ability to correctly identify calls. Masking from ships, floe noise, and weather events can also impact the acoustic data by overpowering the species vocalizations and making them difficult to detect. The impact of the fluctuating Arctic soundscape on this manual detection process still warrants future work.

ii. Recommendations for collaborators

To complement PAM and address these current limitations, we recommend the incorporation of visual surveys, especially during the summer and fall months when sea ice concentration and vocal activity are both low. Additionally, this study has provided the unique opportunity for our research to be informed by the local expertise of Inuit who have inhabited this region for generations. Partners at the Nunatsiavut Government have conducted extensive surveys of Inuit knowledge on all types of wildlife in this region meaning that next steps would include the further gathering and incorporation of this knowledge to help strengthen the inferences drawn from this work. Collaborative efforts that integrate acoustic data, visual observations, and local knowledge will provide a more comprehensive understanding of the seasonal distribution and behavior of these species. Future studies could focus on developing combined methodologies to enhance the ability to monitor these species spatial occurrence through a combination of methodologies of year-round marine mammal monitoring in the Arctic.

iii. Key findings

The findings from this study provide important insights into the year-round acoustic presence of bearded seals and walrus in the Torngat Area of Interest (TAOI). Passive acoustic monitoring (PAM) proved to be an effective tool for documenting the seasonal and diel patterns of these pinnipeds, particularly during winter when visual surveys are hindered by harsh weather conditions, ice cover, and limited daylight. Although this study examines species acoustic presence, sea ice concentration, and solar elevation angle across a single year of data, the results demonstrated increased pinniped vocal activity coinciding with sea ice concentration at the site. This suggests that increased calling during periods of higher ice coverage are likely driven by both seasonal breeding activity and shifts in species distribution associated with the ice, however, examining multiple consecutive years of data would serve to verify the impact of these variables on one another.

The study also highlights the utility of PAM in filling a knowledge gap regarding the southern range of these Arctic species, as most previous studies have focused on populations in the Canadian High Arctic, Svalbard, the Bering and Okhotsk Seas, and Alaskan territories. By combining PAM with traditional boat-based and aerial surveys during the open-water season, researchers can obtain a more comprehensive understanding of the spatial and temporal distribution of bearded seals and walrus in the TAOI. Furthermore, the acoustic data generated offers valuable information on the vocal behavior of these species, including call type characteristics and their relationship to environmental changes, such as sea ice dynamics. As sea ice conditions continue to change in the Labrador Sea from year to year, PAM will be a critical tool for monitoring how these shifts affect the distribution, behavior, and mating patterns of ice-dependent pinnipeds in this region.

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