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ABSTRACT

A variety of cetacean species inhabit the productive waters near the South Shetland Islands/Islas Shetland del Sur in the western Antarctic Peninsula. Cetacean acoustic activity was monitored at three different sites and three consecutive years. Acoustic time series were generated for a variety of cetacean acoustic signals, including mysticete (blue whale D and Z calls, fin whale 20 Hz calls, and humpback whale calls) and odontocete signals (killer whale clicks, long-finned pilot whale clicks, sperm whale clicks, and a variety of unknown beaked whale (BW) FM pulse types (BW29, BW37, and BW58)). Acoustic recorder deployments covered between 131 and 353 days of effort per year, fin whales, blue whales, humpback whales, long-finned pilot whales, sperm whales, BW29, and BW37 seemed to be visiting the sites seasonally with spatial preferences and variability. The time series were compared to sea ice data from the respective period and site, to make observations between sea ice coverage and cetacean presence. When no sea ice was present, there tended to be higher acoustic signal densities of sperm whales, pilot whales, BW29, and BW37. When sea ice coverage began to decrease, humpback whale occurrence appeared to increase. These trends could be further explored by using statistical models to quantify the relationships between environmental covariates and cetacean acoustic presence. Understanding seasonal and spatial trends in cetacean occurrence in this region is key for conservation of these populations, some of which have historically been decimated by whaling and all of which may be vulnerable to impacts from anthropogenic climate change.

KEYWORDS: ACOUSTICS, MONITORING, ECHOLOCATION, VOCALIZATION, HABITAT, ICE, ANTARCTIC, SOUTHERN OCEAN

INTRODUCTION

Complex oceanographic processes contribute to a set of unique physical conditions that sustain biodiverse ecosystems in the Southern Ocean (SO).The SO plays a crucial role in meridional overturning circulation, facilitating the intermixing and flow of water between ocean basins (Sverdrup, 1933; Toggweiler & Samuels, 1995; Döös & Webb, 1994). Strong winds drive the fastest current in the world, the Antarctic Circumpolar Current, around the continent (Deacon 1984). Drastic seasonal variations in light and weather play an important role in the formation of sea ice, the dynamics of which help drive nutrient-rich water to the surface and sustain localized zones of primary productivity (Treguer & Jacques 1992; Griffiths 2010).

Large whales historically constituted an integral element of SO ecosystems until the decimation of their populations through whaling. Since the cessation of whaling, investigations into the spatiotemporal dynamics, population abundances, and ecological significance of cetaceans in the SO have become increasingly relevant (e.g., Širović et al. 2004; Thiele et al. 2004; Friedlaender et al. 2006; 2016; Friedlaender et al. 2009; Širović & Hildebrand 2011; Attard et al., 2016; Shabangu et al., 2020; Herr et al., 2022b; Pallin et al., 2022; Johannessen et al., 2022) especially considering concerns that the region is experiencing rapid transformations driven by anthropogenic climate change (Montes-Hugo et al., 2009). Escalating temperatures have exerted notable effects on species reliant on sea ice such as Antarctic krill (*Euphausia superba*) and Antarctic silverfish (*Pleuragramma antarcticum*), both species which occupy low trophic levels crucial for sustaining ecosystems (Loeb et al., 1997; Ducklow et al., 2007; Knox 2007). These impacts are likely cascading up the food web to influence their cetacean predators (Thiele and Gill 1999; Pallin et al., 2023). The climate-induced shifts facilitate profound modifications to the evolved ecosystems in which krill link primary producers to the upper trophic levels (Schofield et al., 2010). A deeper understanding of presence and habitat associations of a variety of cetacean functional groups in the SO is essential to interpret these environmental transformations.

Many species of baleen and toothed whales occupy the western Antarctic Peninsula, with notable differences in their life histories and preferred habitats within this region. Baleen whales include blue (*Balaenoptera musculus*), fin (*B. physalis*), sei (*B. borealis*), humpback (*Megaptera novaeangliae*), southern right (*Eubalena australis*), and Antarctic minke whales (*B. bonaerensis*) (Kasamatsu et al. 1988; Širović et al. 2004; Thiele et al. 2004; McDonals et al 2005). At least ten odontocete species occur also here: killer (*Orcinus orca*), southern bottlenose (*Hyperoodon planifrons*), Arnoux's beaked (*Berardius arnuxii*), goose-beaked (*Ziphius cavirostris*), long-finned pilot (*Globicephala melas*), and sperm whales (*Physeter macrocephalus*), as well as hourglass dolphins (*Lagenorhynchus cruciger*) (Kasamatsu et al. 1988; Kasamatsu and Joyce 1995; Santora and Brown 2010; Martin et al. 2021, Santora 2012). Although no recent sightings have been reported of Gray's beaked (*Mesoplodon grayi*), strap-toothed beaked (*M. layardii*), or Shepherd's beaked whale (*Tasmacetus shepherdi*) their known distributions include the Antarctic Peninsula region (Jefferson et al. 2008; Van Waerebeek et al. 2010). Most baleen whales conduct extensive seasonal migrations to feed in productive high-latitude waters during the summer and calve in lower latitudes during the winter (Kellog 1929). However, minke whales are known to occur in the region year-round (Friedlaender et al., 2006; Dominello and Širović 2016) and blue whales can also be found at the ice edge year-round (Širović et al., 2004). The migratory behavior of odontocetes is less understood; both killer whales and sperm whales likely migrate north during the winter months (Pitman and Ensor 2003; Durban and Pitman 2012; Van Waerebeek et al. 2010). Knowledge of beaked whale and dolphin seasonality in this region is scarce.

Cetacean abundance estimates in the Southern Ocean (SO) rely on visual survey techniques, which have limitations due to their dependence on daylight and weather conditions. Conducting shipboard surveys in the tumultuous seas of the region may be difficult and is generally restricted to short time periods during the austral summer (Richardson et al., 2012). Acoustic methods for cetacean monitoring offer advantages such as higher sample sizes and year-round data collection regardless of weather or sea ice conditions (e.g., Širović et al. 2006; Posdaljian et al. 2022). Previous deployments of autonomous acoustic recorders around the Western Antarctic Peninsula (WAP) have contributed to our understanding of cetacean calling, distribution, and habitat preferences in the region, especially in time periods that are otherwise mostly unobserved (Širović et al. 2004; Širović et al. 2007; Širović et al. 2009; Širović and Hildebrand 2011; Baumann-Pickering et al. 2015; Van Opzeeland et al., 2013; Burkhardt et al., 2021; Trickey et al. 2015; Thomisch et al., 2016; Shabangu et al., 2017; Shabangu et al., 2020; Yun et al., 2021).

Cetaceans emit species-specific sounds related to feeding, spatial orientation, and social behaviors that are detectable using passive acoustic monitoring devices (Širović et al. 2004; Mellinger et al. 2007; Širović and Hildebrand 2011; Marques et al. 2013). Baleen whales primarily produce low frequency (mostly <1 kHz) sounds, with some species like humpbacks and southern right whales exhibiting a diverse range of calls (e.g., Cummings et al. 1971; Payne and McVay 1971; Clark 1982) while others have more stereotyped calls (Schevill and Watkins 1972; Leatherwood et al. 1981; Širović et al. 2004; McDonald et al. 2005; Rankin et al. 2005). Blue and fin whale calls may also be used to distinguish distinct populations (Hatch and Clark 2004; McDonald et al. 2006; Širović et al. 2009; Širović & Oleson, 2022; Archer et al., 2020). Odontocetes produce higher frequency (often > 5 kHz) echolocation signals, often species-specific, for spatial orientation and feeding (Au 1993; Mohl et al. 2000; Mohl et al. 2003; Au et al. 2004; Zimmer et al. 2005; Rankin et al. 2011; Baumann-Pickering et al. 2013a). Some species also produce species-specific whistles, likely for communication (Herman and Tavolga 1980; Norris et al. 1994; Dawson et al. 1998; Janik and Slater 1998; Rogers and Brown 1999; Janik 2000). Killer whales emit pulsed calls for communication

(Ford 1989; Deecke et al. 2005; Riesch et al. 2008) along with high-frequency modulated (HFM) signals (Samarra et al. 2010; Filatova et al. 2012; Simonis et al. 2012; Samarra et al. 2015; Reyes Reyes et al. 2017). Beaked whales, due to their extreme diving behavior, are challenging to observe visually and thus are well-suited for passive acoustic monitoring (Jefferson et al. 2008; Baumann-Pickering et al. 2013a). During a shipboard concurrent visual and acoustic cetacean survey conducted in 2014 between Elephant Island/Isla Elefante and the South Orkney Islands/Islas Orcadas del Sur, two previously unknown echolocation signal types, likely produced by unspecified beaked whale species and named BW29 and BW37, were described by Trickey et al. (2015).

Here, we provide insights from long-term, autonomous, passive acoustic data collected at three sites near Elephant Island/Isla Elefante, Antarctica, in 2014, 2015, and 2016. Time series of acoustic presence for a subset of baleen and toothed whale species were analyzed and put in relation to sea ice concentration to identify spatial and seasonal trends.

METHODS

Data collection

High frequency acoustic recording packages (HARPs, Wiggins and Hildebrand 2007) were deployed on three separate trips to three different sites near the South Shetland Islands/Islas Shetland del Sur, Antarctica (Figure 1; Table 1). All trips were conducted onboard the Prefectura Naval Argentina *SB-15 Tango*. HARP systems were bottom-moored and included an acoustic release system, data logger and battery cases, and a single hydrophone suspended approximately 10 meters above the sea floor. Recorders sampled at a rate of 200 kHz with 16-bit quantization. Those at sites EI and SSI were on a recording schedule while the recorder at EIE recorded continuously (Table 1). Recorders were equipped with six bundled cylindrical sensors (AQ-1, Teledyne Benthos, Falmouth, MA) designed to capture low frequency signals between 10 and 3000 Hz, as well as an omni-directional sensor (ITC-1042, International Transducer Corporation, Santa Barbara, CA) optimized for high frequency signals between 3 and 100 kHz. These sensors were connected to custom-built preamplifier boards, and calibrated system responses were applied to recordings during subsequent analyses.

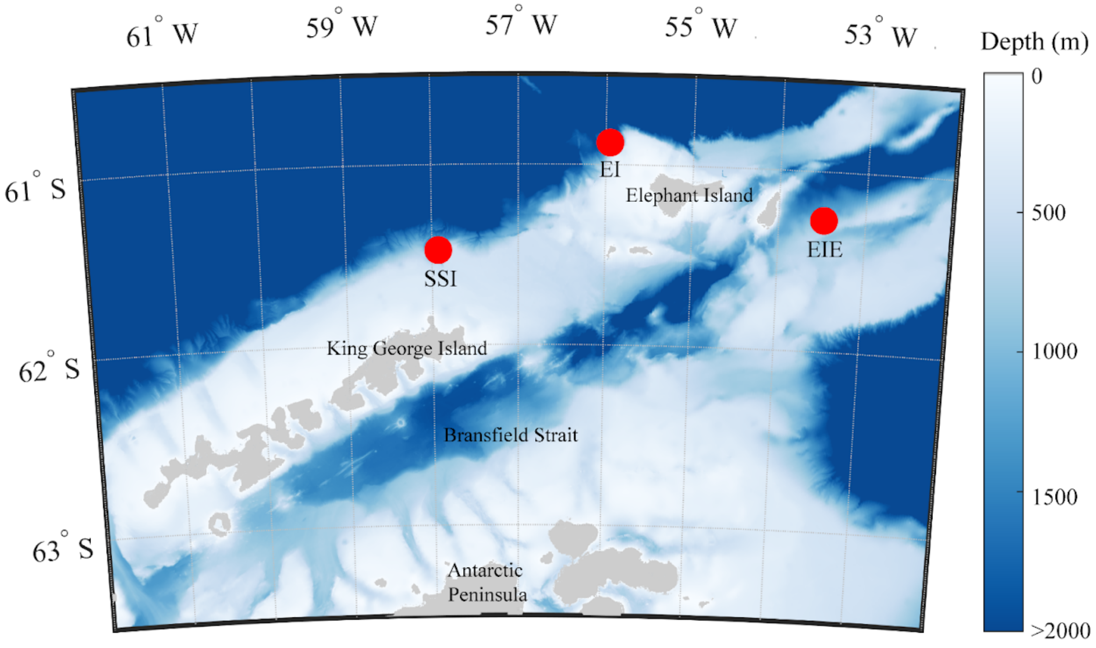

Figure 1. Bathymetric map of HARP deployment locations (red dots).

Table 1. Summary of passive acoustic monitoring effort at Antarctic sites between 2014 and 2016. Dates are in the format MM/DD/YYYY. Duty cycles are the recording period (minutes on)/pause period (minutes off).

Site	Location	Depth (m)	Recording Dates	Days with Effort	Duty Cycle
Elephant Island/ Isla Elefante (EI)	60° 53.214’ S 55° 57.238’ W	762	03/05/2014 - 07/14/2014	131	5/1
South Shetland Islands/ Islas Shetland del Sur (SSI)	61° 27.469’ S 57°56.515’ W	768	02/10/2015 – 01 29/2016	353	10/3.33
Elephant Island East/ Este Isla Elefante (EIE)	61° 15.112’ S 53° 29.006’ W	1033	02/03/2016 - 12/02/2016	303	—

Acoustic analysis

Acoustic signal processing was performed using the MATLAB-based (Mathworks, Natick, MA) custom software program *Triton* (Wiggins et al., 2010), as well as other custom MATLAB routines. Data were decimated by a factor of 100 for analysis of blue and fin whale calls, and by a factor of 20 for humpback whale calls, while high frequency odontocete signals were analyzed using the full bandwidth data. Long-term spectral averages (LTSAs), or long-term spectrograms, were calculated with each time segment consisting of an average of 500 spectra, which were created using the Welch algorithm (Welch 1967). The averages were formed from the power spectral densities of non-overlapped 1 s or 10 ms Hann-windowed frames and resulted in long-term spectrograms with a resolution of either 1 Hz or 100 Hz in frequency and 5 seconds in time for decimated or full bandwidth data, respectively.

Baleen Whales

Calls from three species of baleen whales were used in this analysis: fin whales, blue whales, and humpback whales. For fin whales, 20 Hz calls were used as indicators of presence. In the WAP data, fin whale 20 Hz calls can be so abundant that they form a constant band of sound (Watkins et al. 2000; Širović et al. 2004). Although it is possible to distinguish individual calls from this band (Wood & Širović 2022), for easier processing a daily “acoustic index” was calculated instead. An energy detector was used to calculate this index, defined as the ratio between the signal (22 Hz) and noise (average energy between 10 and 34 Hz) power spectral density values from the LTSA (Custis et al., 1999; Širović et al. 2004; Nieukirk et al. 2012). Blue whale signals included both D and Z calls. D calls were detected using a modified version of the generalized power law (GPL) detector that was originally designed to detect humpback whale calls (Helble et al., 2012). These detections were manually verified by a trained analyst to remove false detections. Z calls were detected by manual scans of 1-h LTSAs with 5-s time and 1-Hz frequency resolution. Hourly call presence was noted by a trained analyst by viewing 60-s spectrograms of potential calls (1500-point fast Fourier transform (FFT) length, 90% overlap). Humpback whale signals that were analyzed included both song and non-song calls. Call candidates were initially detected using a generalized power-law detection algorithm (Helble et al., 2012) and then manually verified by an expert analyst.

Toothed Whales

All toothed whale presence was determined based exclusively on detection of echolocation clicks. Killer whale presence was visually searched for in full-bandwidth LTSAs, verified on spectrograms, and start and end of an encounter logged by an expert analyst using *Triton* and the remora *Logger*. For beaked whales, sperm whales, and long-finned pilot whales, echolocation signals were first detected using a two-step approach (Roch et al., 2011) and then verified by an expert analyst. For beaked whales at site EI, a previously published dataset of echolocation signals was used (Baumann-Pickering et al., 2015). These same data processing methods described in Baumann-Pickering et al. (2015) were replicated for beaked whales at sites SSI and EIE, as well as long-finned pilot whale signals at all sites. For sperm whales, the two-step modified algorithm is described in Solsona-Berga et al. (2022). An analyst then used the open-source *DetEdit* software (Solsona-Berga et al., 2020) to remove any false detections.

Sea Ice Data

Remotely sensed sea ice data was obtained for the region from the University of Brennen, Institute of Environmental Physics through the PANGAEA data publisher (Melsheimer & Spreen, 2019). A time series for the duration of the deployment was created for each site by averaging sea ice coverage measurements per day at the closest sample point (3.125 km grid resolution) to the acoustic recording site.

RESULTS

Acoustic signals produced by likely nine different cetacean species were identified from the long-term acoustic data and visually compared to mean daily sea ice concentration in a preliminary investigation to identify trends (Figure 2). Sea ice coverage differed between sites during the respective recording periods; there was no sea ice at site EI and variable sea ice coverage at sites SSI and EIE (Figure 2a) during the recording period, with site SSI having had highest coverage (Figure 2a).

Baleen Whales

Blue whale D calls exhibited a seasonal trend, with peaks around April-May and October-November at sites SSI and EIE, just before sea ice reached the site and after sea ice retreated. Site EI had relatively low D call presence with no clear seasonal peaks, possibly related to sea ice never reaching this recording location. Blue whale Z calls occurred throughout each deployment but seemed to slightly increase in May and November at sites SSI and EIE. At site SSI, which had the longest recording effort, blue whale Z calls clearly decreased into austral summer (Figure 2b).

Fin whale acoustic presence also had a clear seasonal peak at all three sites, with a high acoustic index during austral fall. Fin whale acoustic index was strongest at site EI and least strong at site EIE. Because of strong fin whale calling activity during these months, particularly at EI and SSI, some blue and/or humpback whale signals, if present, may have been masked (Figure 2b).

Site EI had the least amount of humpback whale calls, while site SSI had the most; however, recording effort at EI occurred from March to July and detection rates at SSI were similar during a comparable time of year. Humpback whale calls clearly increased at site SSI in austral spring, coinciding with the sea ice retreat and again in austral summer. Site EIE had less of a seasonal pattern, with sporadic increases in acoustic detections that seemed to align with breaks in sea ice coverage (Figure 2a; Figure 2b).

Toothed Whales

Killer whale clicks were detected at low rates at all three acoustic monitoring sites. The highest number of detections were at site EIE in May and June and seemed to coincide with increased levels of sea ice (Figure 2a; Figure 2c).

Long-finned pilot whale detections were highest at site EI towards late fall, a period without sea ice coverage, and all sites exhibited an increase in detections during late fall and early winter (Figure 2a; Figure 2c). Long-finned pilot whale detections also exhibited a clear nocturnal pattern at all sites (Figure 3).

Sperm whales had the highest presence at site EI, with no acoustic presence at site SSI and a small level of detections at site EIE (Figure 2a; Figure 2d). Sperm whale acoustic presence peaked at site EI during austral summer (Figure 2a; Figure 2d). Slow clicks, typically displayed for communication, showed a possibly nocturnal pattern, with most of these events occurring at night (Figure 4).

Of the three beaked whale species present in the acoustic data, FM pulse type BW29 had the most detections. BW29 detections were highest at site EI followed by site EIE, with very little acoustic presence at site SSI. BW29 presence peaked in late fall, early winter at site EI and had strongest presence in austral spring at site EIE. There was an obvious absence of BW29 at EIE during periods with sea ice coverage. The FM pulse type BW37 was less often detected overall but had higher presence at sites EI and SSI compared to site EIE. BW37 peaked during May at site EI, during time periods of low BW29 detections. At site SSI, BW37 presence was highest in November and December. The final FM pulse type, BW58, was only detected in a few encounters at sites EI and SSI. The site EI detections took place during March, and the site SSI detections took place during December. Encounters at both sites occurred at times when no sea ice was present at the acoustic recording sites (Figure 2e).

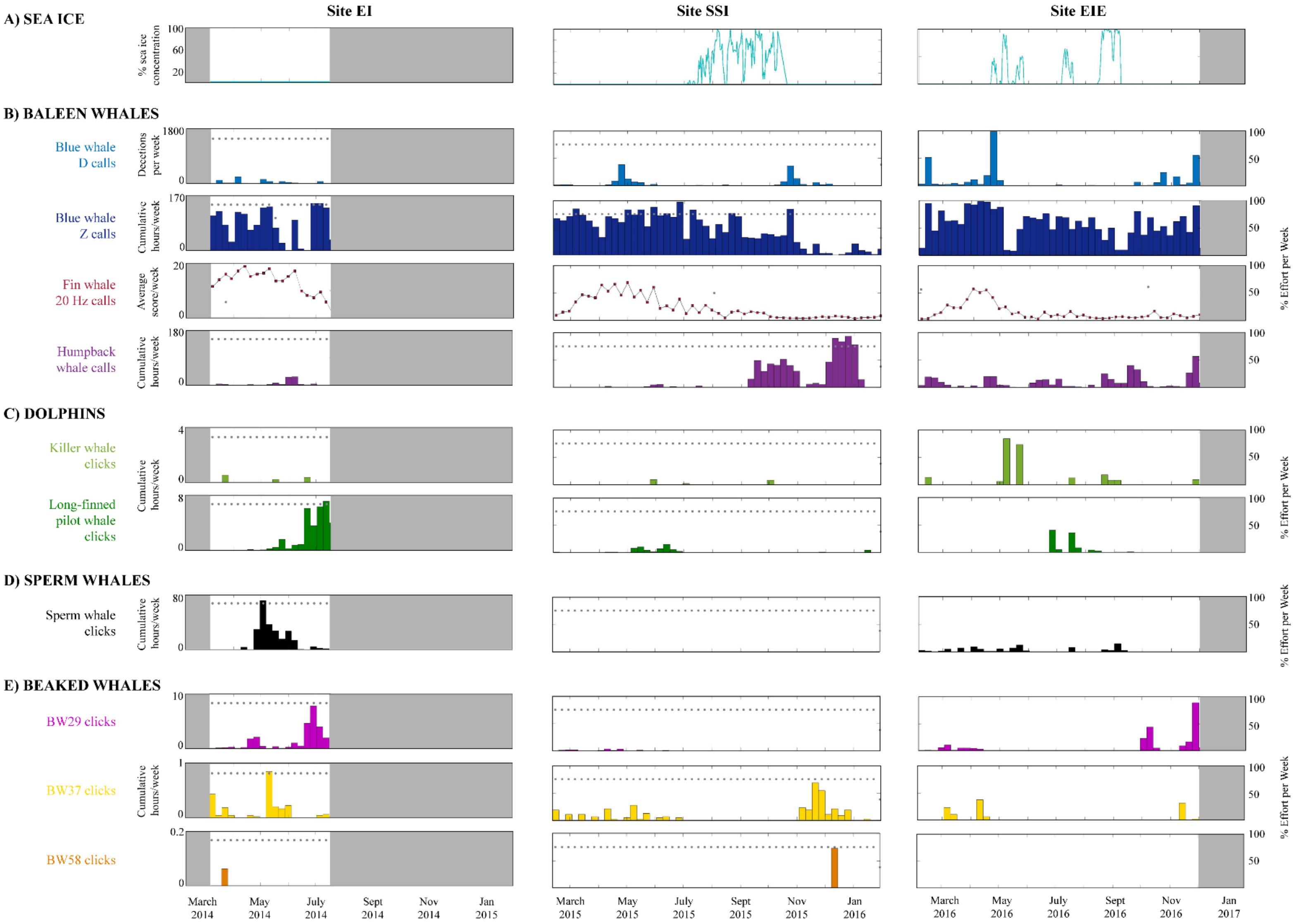

Figure 2. Cetacean acoustic detections and sea ice cover at recording sites EI, SSI, and EIE. A) Mean daily percent sea ice cover (AMSR2, 3.125 km grid resolution). B-E) Weekly presence of cetacean call types. Gray dots represent percent of effort in weeks with less than 100% recording effort. Gray shading denotes periods of no recording effort.

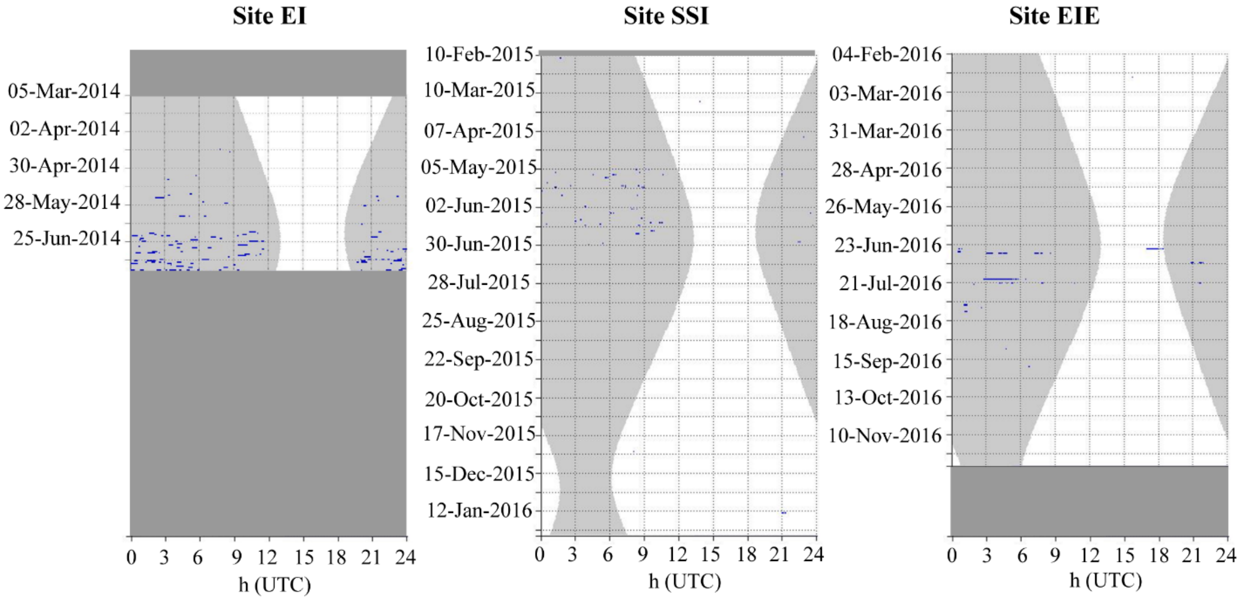

Figure 3. Diel presence of long-finned pilot whale echolocation clicks in one-minute bins. Light gray vertical shading denotes nighttime, and dark gray horizontal shading denotes periods of no recording effort.

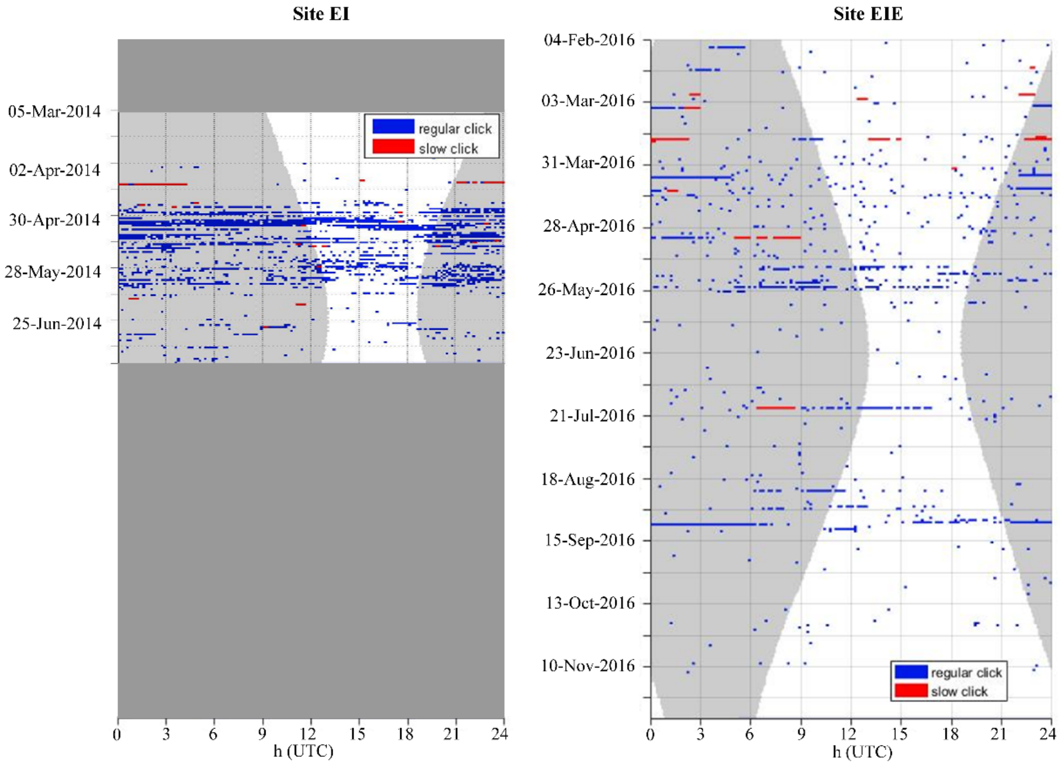

Figure 4. Diel presence of sperm whale regular (blue) and slow (red) clicks in one-minute bins. Light gray vertical shading denotes nighttime, and dark gray horizontal shading denotes periods with no recording effort. There were no sperm whale detections at site SSI.

DISCUSSION

Baleen Whales

All three species of baleen whales from this analysis are known to feed on dense patches of Antarctic krill along the Western Antarctic Peninsula (WAP) (Santora et al., 2010; Širović & Oleson, 2022). While these species have a shared preferred prey, tag data reveals that size preference in krill and differing migration behaviors provide some niche separation among the three species of krill-feeding baleen whales in the area (Friedlaender et al., 2009; 2021; Santora et al., 2010).

Two types of blue whale calls, D and Z, were recorded in the acoustic data. Both male and female blue whales produce D calls, which are believed to be related to foraging (Olsen et al., 2007). At sites SSI and EIE, D calls had seasonal peaks during May and November, coinciding with the appearance and disappearance of sea ice coverage (Figure 2b). These seasonal trends in D calls are likely related to seasonal changes in their prey distributions (Širović et al., 2004). Z calls are hypothesized to be produced only by males based on parallels to Northeast Pacific blue whale songs (Rankin et al., 2005; Shabangu et al., 2020; Olsen et al., 2007; McDonald et al., 2001). Z calls were recorded across almost the entire deployments at all three sites, indicating either a resident population of Antarctic blue whales that travel north around Antarctica as sea ice coverage changes or an area heavily trafficked by male blue whales passing through (Attard et al., 2016).

Across all three sites, high fin whale presence was recorded during the austral fall and early winter (April-June). Of the three sites, site EI had the highest cumulative hours of acoustic presence per week, with 20 Hz calls nearly constant during these months (Figure 2b). Visual surveys and net tows showed that krill size is a significant variable for describing fin whale foraging hot spots (Santora et al., 2010). Fin whales feed on larger, mature adult krill (44-65 mm), found in the oceanic, nutrient rich Antarctic Circumpolar Current (ACC) waters (Santora et al., 2010). Given the proximity to the ACC at site EI in comparison to sites SSI and EIE that are closer to the coastal waters of the Bransfield Strait/Mar de la Flota, the higher acoustic presence at site EI could be attributed to the more ideal oceanographic conditions favored by the adult krill. While the site EI recording effort ended prior to recording any seasonal drop in acoustic presence, both sites SSI and EIE show a decline after June. Previous acoustic monitoring in the western Antarctic also found similar strong seasonal trends in fin whale presence (Širović et al., 2004). The seasonal trends observed at sites SSI and EIE are likely explained by fin whales leaving their Antarctic foraging grounds to disperse north (Herr et al., 2022a), but further tracking efforts would be needed to confirm their exact migration paths.

Previous studies found humpback whale foraging to peak during the austral spring and summer (October-February) (Curtice et al., 2015). Tagged humpback whales have been shown to travel seasonally with krill as prey patches migrate inshore towards the sea ice coverage (Curtice et al., 2015). While humpbacks start the summer foraging offshore, they move closer to the shelf break as krill begin to move inshore to overwinter under the sea ice (Curtice et al., 2015). This migration pattern is consistent with the humpback whale calls recorded in our acoustic time series. At site SSI, the southernmost site, humpback presence followed a distinct seasonal trend and peaked during the austral summer (October-January). At site EIE, located at the entrance to the Bransfield Strait/Mar de la Flota off the eastern shore of Clarence Island, humpback whale presence also peaked during the earlier austral summer months but remained consistent into the late austral summer and even was found between breaks in sea ice coverage (Figure 2b). At site EI, minimal humpback whale acoustic presence may be related to the lack of sea ice coverage at that site and recording effort not covering optimal habitat conditions (Figure 2b).

Toothed Whales

Low acoustic presence of killer whales across the three sites (Figure 2c) make interpretations on seasonal and spatial trends challenging. Around the WAP, three types of killer whales have been identified to inhabit the area: Type A, typically found offshore in circumpolar waters preying on Antarctic minke whales, Type B, typically found in inshore waters preying on humpback whales, Antarctic minke whales, and seals, and Type C found in inshore waters feeding on Antarctic toothfish (Ensor et al., 2003). While lack of echolocation clicks could indicate lack of killer whale presence, Type A and B killer whales may very well be present but silent, given that they reduce acoustic output when feeding on other marine mammals to remain undetected (Deecke et al., 2005).

Long-finned pilot whales were recorded at all three recording sites. Long-finned pilot whale echolocation clicks followed a diel pattern, with most clicks recorded during the night (Figure 3). Increased echolocation click occurrences during the night likely indicates increased foraging at night. This diel pattern in foraging was also observed in tagged long-finned pilot whales in the Ligurian Sea (Baird et al., 2002). Increased foraging activity during the night is presumably related to the diel vertical migrations of their prey, squid and other cephalopods (Olson, 2018).

Sperm whale echolocation clicks were recorded at sites EI and EIE, with higher presence at site EI during the austral fall when there was no sea ice coverage (Figure 2d). Only male sperm whales are found at these higher latitudes, typically producing regular and slow clicks (Jefferson et al., 2008). Regular clicks are associated with sperm whale foraging while slow clicks are believed to be related to communication among groups (Miller et al., 2004; Oliveira et al., 2013). Stomach content analysis revealed that *Kondakovia longimana* (giant squid), *Mesonychoteuthis hamiltoni* (colossal squid), *Gonatus antarcticus*, and *Moreteuthis knipovitchi* made up the top four species of squid consumed by east Antarctic sperm whales (Miller & Miller, 2018). Of these four species of squid, three prey on krill that follow seasonal patterns (Miller & Miller, 2018). It is likely that the seasonal trends in regular clicks are a product of seasonal variability in sea ice influencing seasonality in krill patches, then cephalopod prey presence, and in turn sperm whale foraging. Slow clicks have been hypothesized to function as a method of communication, in the context of Antarctic sperm whales to maintain group cohesion among groups of lone males (Oliveira et al., 2013). Miller & Miller (2018) observed diel trends in regular and slow clicks, with increased regular clicks during the day and increased slow clicks at night (2018). They hypothesized that these trends are likely associated with increased foraging during the day and social communications to maintain group cohesion during periods of rest at night (Miller & Miller, 2018). Conversely, while a potential diel pattern in slow calls was observed in our study, possibly indicative of maintaining group cohesion during the night, there was no discernable diel trends in regular clicks, which is likely associated with continuous foraging.

Of the unidentified beaked whale echolocation clicks, BW29 is hypothesized to be produced by southern bottlenose whales (Baumann-Pickering et al., 2015). BW29 was recorded at all three sites, with increased presence at sites EI and EIE (Figure 2e). These spatial trends are similar to those observed by Santora and Brown during visual surveys (2010). Southern bottlenose whales were frequently observed along the shelf-break near Elephant Island, a highly productive area due to the influx of the ACC and bathymetry that aggregates prey (Santora & Brown, 2010). Along with the similarities between the echolocation pulse of BW29 and northern bottlenose whales, similar spatial trends in both visual and acoustic data add to the evidence BW29 is produced by southern bottlenose whales (Baumann-Pickering et al., 2015; Clarke et al., 2019).

Previous work has hypothesized that the BW37 and BW58 echolocation pulses could be produced by Gray's and strap-toothed beaked whales, respectively (Trickey et al., 2015; Baumann-Pickering et al., 2015; Barlow et al., 2021). Shepherd's beaked whale has also been a proposed candidate for these unidentified signals (Barlow et al., 2021). Further research is still needed to confirm the species producing these echolocation pulses.

CONCLUSION

Findings from this multi-site, multi-year analysis of acoustic data from WAP further our understanding of the seasonal and spatial trends in cetacean presence and demonstrate the benefit of long-term passive acoustic monitoring, particularly in remote and logistically challenging regions. Continued exploration of these trends via statistical modeling would provide a species-specific analysis of the significant oceanographic and biological factors that influence cetacean presence in the Antarctic, allowing further exploration of predator-prey dynamics via proxies such as sea ice coverage or sea surface temperature. Continued passive acoustic monitoring will be key in ensuring the conservation of these remote and highly sensitive areas in the face of climate change.

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