Seasonality of Antarctic minke whale (*Balaenoptera bonaerensis)* calls off the western Antarctic Peninsula

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ABSTRACT

The Antarctic minke whale (*Balaenoptera bonaerensis)* is a difficult species to study because of its low visual detectability and preference for living within the sea ice habitat, accessible only by ice-strengthened vessels. Recent identification of the Antarctic minke whale as the source of the seasonally ubiquitous bio-duck call has allowed the use of this sound, as well as downsweeps, to investigate seasonality trends and diel patterns in Antarctic minke whale call production, and their relationship to sea ice cover. Passive acoustic data were collected using an autonomous Acoustic Recording Package (ARP) off the western Antarctic Peninsula. Bio-duck calls were classified into four distinct call variants, with one variant having two subtypes. Bio-duck calls were detected between April and November, with increasing call duration during the austral winter, indicating a strong seasonality in call production. Downsweeps, which were also attributed to Antarctic minke whales, were present throughout most months during the recording period, with a peak in July, and an absence in March and April. Both bio-duck and downsweeps were significantly correlated with sea ice cover. No diel patterns were observed in bio-duck calls or in downsweep call production at this site.

Key words: passive acoustics, minke whale, *Balaenoptera bonaerensis*, western Antarctic Peninsula, bio-duck, vocalizations, seasonality.

Passive acoustic monitoring (PAM) is an indispensable tool to study marine mammal distributions (Van Parijs *et al*. 2009). One tribulation, however, is that it lacks the visual identification component for linking unknown sounds to a specific species. However, even without confirmed knowledge of the sound source, much can be learned about the distribution and seasonality of a sound occurrence (*e.g.*, Thompson and Friedl 1982), and once sounds have been attributed to a particular species (Rankin and Barlow 2005), this information can greatly augment our understanding of the biology of a species. An example of one regionally common sound with unknown origin was the bio-duck call, first recorded in 1964 in the Ross Sea in the presence of leopard seals (*Hydrurga lepton*yx) preying upon penguins.

The bio-duck occurred at a rhythmic interval with regularly repeated groups of three pulses separated by a time interval equivalent to two pulses. These features, highly stereotyped sequence of frequency modulated short duration pulses and bouts lasting many hours, were shared with calls recorded from minke whales elsewhere

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(Mellinger *et al.* 2000), thus the bio-duck call is thought to be produced by minke whales (Mellinger *et al.* 2000, Van Opzeeland 2010). Antarctic minke whales (*Balaenoptera bonaerensis*) are known to be regularly sighted in Antarctic waters, so the Antarctic minke whale was thought to be a good candidate for production of the bio-duck call (Van Opzeeland 2010). However at the time, no specific evidence existed to rule out fish or other species as the source of the call (Van Opzeeland 2010). The conclusive link was obtained after a tag deployed on an Antarctic minke whale in Wilhelmina Bay off the western Antarctic Peninsula, recorded the bio-duck (Risch *et al.* 2014*a*). The calls recorded on a tag consisted of a series of 5–12 pulses, produced in regular sequences at an interval between sequences of 3.1 s. The individual downswept pulses making up the bio-duck had a mean duration of 0.1 s and mean peak frequency 154 ± 13 Hz (Risch *et al.* 2014*a*). The presence of the bio-duck in long-term recordings can shift between months, although it always occurs during the austral spring and winter, and monthly call rates differ between years in the western Antarctic (Van Opzeeland 2010). The bio-duck call has also occurred during the same time period off Western Australia (Matthews *et al.* 2004).

Antarctic minke whales also produce low frequency downsweeps (Schevill and Watkins 1972, Risch *et al.* 2014*a*). These sounds consist of a single downsweep from 130 Hz to 60 Hz. In one study, downsweeps were produced just before or after surfacing while animals were within pack ice (Schevill and Watkins 1972). Despite downsweeps having been known and recorded from minke whales for a number of years, little is known about their functionality (Edds-Walton 2000, Gedamke *et al.* 2001). Downsweep calls from other baleen whale species are suggested to serve a social function or to maintain spacing and contact with separated individuals (Edds-Walton 1997, 2000).

There are two genetically distinct populations of Antarctic minke whales. The two populations overlap with no sharp boundary between them, but one predominates in the east and the other in the west (IWC 2013). The use of bio-acoustics in remote areas has the potential to help identify a more distinct line (Van Parijs *et al.* 2009). A particularly high abundance of minke whales has been identified in the northwestern Weddell Sea, in the pack ice bordering the Scotia-Weddell Confluence (Ainley *et al.* 2012). Additionally, Antarctic minke whales off the western Antarctica Peninsula (WAP) are found in high densities year-round very close to shore, with the population estimated at 1,544 individuals (95% CI: 1,221–1,953) (Thiele *et al.* 2004, Williams *et al.* 2006). Recent IWC surveys show an overall decrease of 30% from the late 1980s population estimates across the entire Antarctic (Branch and Butterworth 2001, IWC 2013). This decrease may be reflecting differing year to year ice conditions which may affect the total number of animals counted, or it may indicate a real decline. Bioacoustics may be an alternative method for density estimation of this highly-mobile species in these ice locked habitats (Marques *et al.* 2009, Williams *et al.* 2014).

Most baleen whales undergo seasonal migration between breeding and feeding grounds. The breeding season of southern baleen whales, generally, is considered to be austral winter with conceptions occurring from July to December, with a peak from August to October (Best 1982, Kasamatsu *et al.* 1995). Some groups of minke whales may leave the Antarctic for northbound migration by February and reach waters between 30°S and 40°S in March (Best 1982, Kasamatsu *et al.* 1995). Genetic evidence suggests, however, that tropical and temperate regions are likely not a major destination (Glover *et al.* 2010). Exact locations of breeding areas of the Antarctic minke whale populations remain unknown, but they may not be as concentrated as

those of more coastal distributed baleen whale species, such as humpback whales (*Megaptera novaeangliae*) (Kasamatsu *et al*. 1995).

Antarctic minke whale habitat preferences are influenced by ice cover and prey densities (Thiele *et al*. 2004, Murase *et al*. 2013). Off the WAP, Antarctic minke whales were found in greater numbers during seasons where a sea ice boundary existed over shelf areas (Thiele *et al*. 2004). Year-to-year changes in areal extent, sea ice concentration and its formation could cause a change in spatial distribution of Antarctic minke whales in open sea (Thiele *et al*. 2004, Murase *et al*. 2013). Antarctic minke whales share prey with other baleen whales, thus they may be partitioning their foraging habitat to avoid direct competition (Friedlaender *et al*. 2006, Santora *et al*. 2010). In general, visual sightings data from these regions might indicate low detectability (Ainley *et al*. 2007) and create a challenge for the study of these animals (Williams *et al.* 2014).

As mentioned earlier, PAM has become an important tool for monitoring cetaceans. PAM is especially useful in remote areas, during nighttime, or in adverse weather conditions and in general for species that are difficult to study at sea (Mellinger *et al*. 2007a, Van Parijs *et al*. 2009). Long-term records of seasonal occurrence and distribution patterns that can be obtained from PAM provide valuable insights into the habitat utilization of vocally active species (*e.g*., Širović *et al*. 2004, Širović and Hildebrand 2011, Gallus *et al*. 2012, Mussoline *et al*. 2012). This method has proved to be particularly useful in the Southern Ocean, where visual surveys are mainly conducted in open sea, and the vast majority of areas covered by sea ice are not surveyed (Van Opzeenland 2010, Murase *et al*. 2013).

Identification of the source of the bio-duck call has allowed us to use this seasonally ubiquitous sound to investigate seasonality trends in Antarctic minke whale call production and augment our understanding of the biology for this difficult-to-study species. In this paper, we report on the occurrence of bio-duck call and Antarctic minke whale downsweeps from a year-long record in a coastal area in the WAP and compare the presence of calls to sea ice concentration. In addition, we used these long-term recordings to provide a more detailed description of the bio-duck call and offer insights into diel call production patterns.

Methods

Passive acoustic data were recorded using an autonomous Acoustic Recording Package (ARP), an acoustic recording device with a tethered hydrophone 10 m above a seafloor-mounted instrument frame (Wiggins 2003). The ARP consisted of a data logging system with a 16-bit A/D converter and 36 GB of storage capacity, a hydrophone (sensitivity 198 dB re: 1 Vrms/µPa and a 3 dB low-end roll-off at around 5 Hz), an acoustic release, two ballast weights, batteries, and flotation (Wiggins 2003). An ARP was deployed off the WAP ($65°22'$S, $66°28'$W) at a depth of 462 m, sampling continuously at 500 Hz from 26 February 2002 to 18 February 2003 yielding a total of 358 d of recordings over a bandwidth of 5–250 Hz.

Collected data were converted into WAV files and processed into 5 s averaged Long Term Spectral Averages (LTSAs) with 1 Hz frequency resolution using the MATLAB program (Mathworks Inc.) Triton (Wiggins and Hildebrand 2007). Data were reviewed visually by scanning LTSAs and spectrograms (fast Fourier transformation [FFT] 256 points, 80% overlap, Hanning window), as well as aurally, when a sound of interest was identified. Sounds of interest included bio-duck calls (defined as

series of downswept pulses) and individual downsweeps. The start and end time of each calling encounter was logged, with individual events delineated by a period of at least 30 min without calls.

In addition to marking the presence of calling encounters, nonoverlapping identifiable calls were further selected for detailed acoustic measurements of call characteristics. In an effort not to oversample calls from the same individual, only one call per calling event was used for measurements. Calls were measured from a spectrogram window of 10 s, 128-point FFT, 90% overlap and Hanning window. Frequency resolution and temporal resolution were 3.9 Hz and 0.26 s, respectively. The following parameters were measured manually for all call types using Triton: start and end time (s), start, end, and peak frequency (Hz) for each pulse in the sequence. Peak frequency was defined as the frequency at the highest spectrum level over the bandwidth of the call. Window lengths for spectral plots were 0.5 s for bio-duck variant B, 0.7–1 s for bio-duck variants A1, A2 and C, 3 s for bio-duck variant D and 5–10 s for downsweeps. Peak frequency of calls was the only parameter obtained from the power spectrum plot in Triton, others were measured from spectrograms. From the initial measurements, downswept pulse duration (s), number of pulses per series, bandwidth (Hz), interseries interval (ISI) and interpulse interval (IPI) were calculated. A series was defined as a cluster of downswept pulses separated by less than 1 s, and multiple series made up a call. ISI was defined as the time from the start of a downswept pulse in a series to the start of a downswept pulse in the next series. IPI was defined as the difference between the start of one downswept pulse and the start of the next pulse within the series. The mean and the standard deviation of each parameter were calculated. For bio-duck variants with frequency variability over the duration of the call, rate of change in pulse peak frequency over a series and rate of change in the ending frequency were also calculated.

Monthly encounter rates for bio-duck calls and downsweeps are reported. To investigate the relationship between sea ice cover and call occurrence, daily sea ice concentration estimates were made using Special Sensor Microwave/Imager (SSM/I) passive microwave data obtained from the National Snow and Ice Data Center (http://nsidc .org). Sea ice concentrations were binned to 25 km^2 cells in a polar stereographic projection. We extracted daily mean values for 75×75 km areas centered at the ARP using the imaging software WIM (Kahru 2015). For a more detailed description of sea ice concentration estimates see Širović et al. (2004). We calculated autocorrelation scales for each call type to ensure independence of samples. Days before the first and after the last occurrence of Antarctic minke whale calls in the recordings were not used in calculating autocorrelation scales. Percentage of time calling for bio-duck calls and downsweeps were binned into 9 d and 8 d averages, respectively, for correlation with the sea ice concentration.

A chi-squared test was used to investigate diel patterns in bio-duck and downsweep occurrence. Total time spent calling (in hours) was calculated for daytime and nighttime, where durations of day and night were based on the sunrise and sunset times for our deployment location obtained from the U.S. Naval Observatory. If an encounter start and end spanned across sunset or sunrise, the encounter was split appropriately into a portion that occurred during each day period. First, daily data were tested for homogeneity using the chi-square test of homogeneity. If the sample was homogenous, we applied a chi-squared test on the pooled total.

<center>Results</center>

The bio-duck call was the most common Antarctic minke whale call found at this location in the WAP during 2002/2003, occurring during 22.8% of the recorded time (1,956.3 h). These calls were detected primarily from June to October, although a few calls were recorded in April, May, and in November (Fig. 1). Downsweeps occurred during 2.8% of the total effort (237.3 h). They occurred intermittently between May and February and were absent in April and March, but there was a peak in calls in June and July (Fig. 1). Bio-duck calls recorded in the WAP could be classified into four distinct variants based on their frequency and pulse rates, with one variant having two additional subtypes (Fig. 2, Table 1).

Bio-duck "A" type calls consisted of a series of about four pulses with peak frequency between 130 Hz and 150 Hz. They were further classified into two variants, A1 with a consistent number of pulses in a series and A2 with a variable number of pulses and also of variable end frequencies. Bio-duck A1 was the most common call found and is the call described in previous literature (Matthews *et al.* 2004, Risch *et al.* 2014*a*). Bio-duck A2 often had the end frequency of downswept pulses increase and/or decrease within the same series unit, while A1 end frequency tended to only increase within the same series unit. We consider A1 and A2 subsets of A because on rare occasion, A2 changed into A1 or *vice versa*, and was seemingly produced by the same individual based on the amplitude and timing of the call variants. This type of gradual change was not seen in other call types.

Bio-duck B typically had more pulses per series, and an overall higher start and end frequency compared to the other variants (Table 1). Since its start frequency was
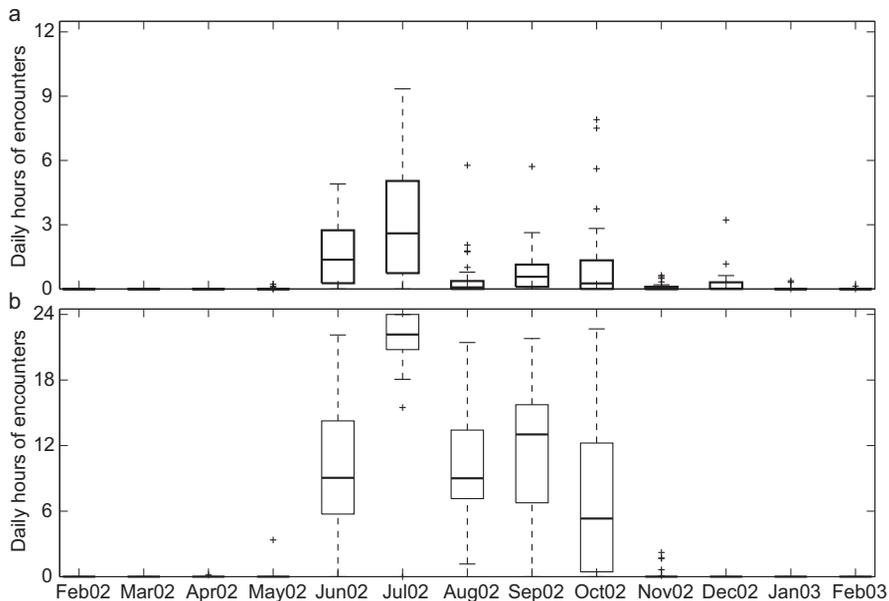
Figure 1. Average daily encounter durations (in hours) per month for minke whale (a) downsweeps and (b) bio-duck calls. Note the difference in *y*-axis scale between the plots.
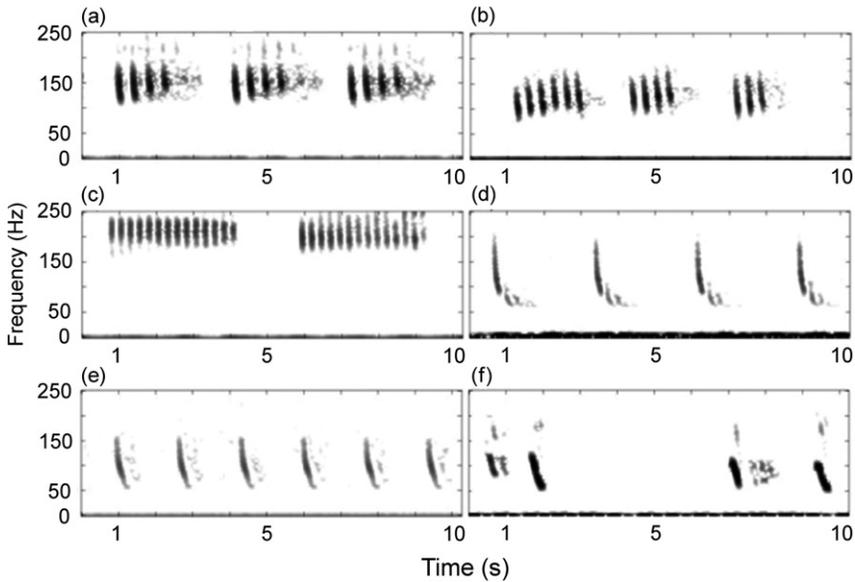
Figure 2. Spectrograms of Antarctic minke whale (a) bio-duck A1, (b) bio-duck A2, (c) bio-duck B, (d) bio-duck C, (e) bio-duck D, and (f) downsweep (128 point FFT with 90% overlap and Hanning window) recorded off the western Antarctic Peninsula in 2002. Note (f) downsweeps have been concatenated in time, to represent the variability of the call, and the irregularity in the production of this call type.

very close to the recording Nyquist frequency, it is likely that the true start frequency was not measured. While duration of the downswept pulse of variant B was similar to those of A variants, B had a shorter IPI than A1 and a longer ISI than both A1 and A2 (Table 1). Many B calls were detected, but most of them were faint, or overlapping with A1. Therefore, not many events were available for call characteristic measurements (Table 1). Bio-duck C was the only bio-duck variant that had a start frequency that decreased over successive pulses in a series as well as an end frequency and peak frequency which decreased with each pulse. Bio-duck C was not frequently encountered. Bio-duck call D consisted of regularly repeated individual pulses, not forming a series. Type D was the least frequently encountered call type. Because of its infrequency, not many events were available for measurements. We consider type D to be a bio-duck call type and not a downsweep sequence because of its regularity and repetitive structure, which was similar to other bio-duck calls. While type D only consists of a single pulse per series, the pulses are regular and are repeated upwards of 120 pulses per call. Of the bio-duck variants, type D downswept pulses had the longest duration (Table 1).

Minke whale downsweeps were individually occurring calls. Frequency and temporal characteristics measured during this work (Table 1) were similar to those reported previously (Schevill and Watkins 1972). There was no evident repetitive pattern and the number of downsweeps per event ranged from single, two, or three downsweeps to several downsweeps (Table 1).

Bio-duck calling was homogenous (χ^2 = 164.02, df = 150, P = 0.79), but there was no significant difference between nighttime and daytime calling over the entire

Table 1. Measured parameters of Antarctic minke whale bio-duck call types and downsweeps, including means (± standard deviation) of call start and end frequency, pulse duration, peak frequency, rate of change in peak and end frequency, ISI and IPI, are shown. Rate of change in peak frequency and ending frequency are calculated as (end value − start value)/number of pulses. Total number of samples, N, and number of pulses per series are also given.

Call type	N (events)	Number of pulses per series	Start frequency (Hz)	Peak frequency (Hz)	End frequency (Hz)	Pulse duration (s)	Peak frequency change (Hz/pulse)	End frequency change	ISI (s)	IPI (s)
Bio-duck A1	11	4 ± 1	231 ± 19	149 ± 19	116 ± 20	0.1 ± 0.1	+5.2	+8.6	3.1 ± 0.2	0.4 ± 0.1
Bio-duck A2	4	4 ± 1	191 ± 33	131 ± 22	101 ± 21	0.2 ± 0.1	—	—	3.1 ± 0.6	0.3 ± 0.1
Bio-duck B	3	13 ± 1	244[a] ± 7	216[a] ± 14	177 ± 12	0.1 ± 0.1	−0.3	+0.5	5.1 ± 0.8	0.3 ± 0.0
Bio-duck C	6	4 ± 1	122 ± 49	85 ± 22	64 ± 11	0.2 ± 0.1	−6.2	−12.7	2.7 ± 0.1	0.4 ± 0.1
Bio-duck D	3	1	155 ± 16	99 ± 13	52 ± 8	0.4 ± 0.1	—	—	—	1.7 ± 0.1
Downsweep	20	—	126 ± 18	97 ± 16	55 ± 8	0.3 ± 0.1	—	—	—	—

[a]For bio-duck B call, start frequency is not necessarily the call's true start as it is nearly at the maximum of the recording bandwidth.

calling period (χ^2 = 1.22, df = 1, P = 0.73). The downsweep calling was not homogenous (χ^2 = 51.67, df = 157, P = 0.0) and therefore chi-squared analysis was used for each individual day, but there was no significant difference between nighttime and daytime calling on any day. Both bio-duck calls and Antarctic minke whale downsweeps were found to be significantly positively correlated with the sea ice presence (r = 0.56, df = 21, P = 0.005 and r = 0.52, df = 35, P = 0.001, respectively; Fig. 3).

DISCUSSION

To our knowledge, this is the first record describing Antarctic minke whale calling seasonality in the WAP, including the first year-long analysis of minke whale downsweep occurrence. In previous studies on Antarctic minke whales downsweeps were
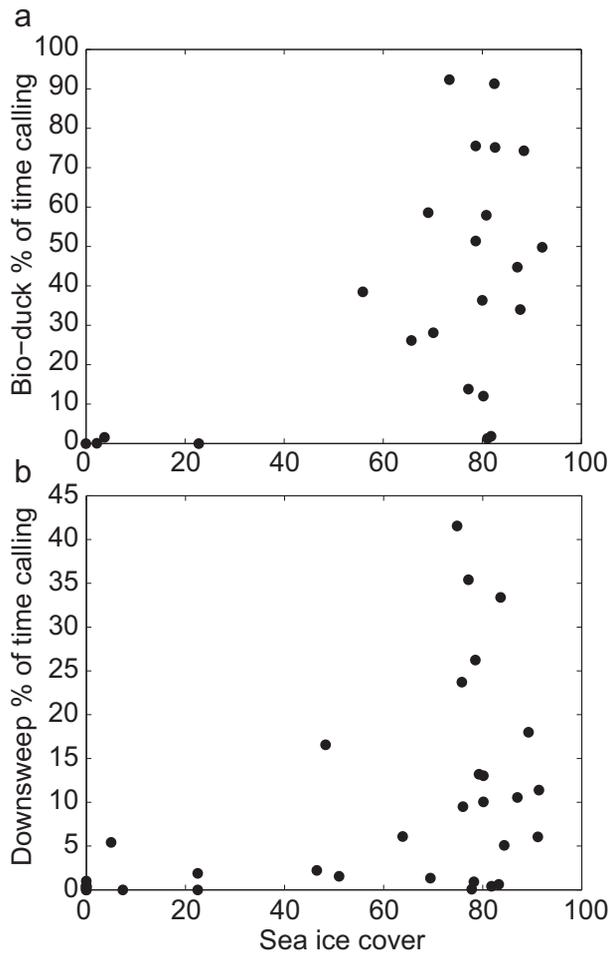
Figure 3. Sea ice concentration compared to (a) bio-duck and (b) downsweep percentage of time calling. Note the difference in *y*-axis scale between the plots.

only mentioned briefly, as a way to confirm an Antarctic minke whale is vocally active (Schevill and Watkins 1972, Risch *et al*. 2014*a*). Fin whales *(Balaenoptera physalus)*, blue whales *(Balaenoptera musculus)*, and dwarf minke whales *(Balaenoptera acutorostrata)* are also known to produce downsweep calls (Gedamke *et al*. 2001, Širović *et al*. 2004, Rankin *et al.* 2005). Downsweeps produced by fin whales average 0.7 s and sweep from 27.6 Hz to 14.9 Hz (Širović *et al*. 2004), lower than downsweeps reported here. Blue whale downsweeps are in the frequency range of Antarctic minke whale downsweeps, but have a longer duration of about 2.7 s (Rankin *et al.* 2005). For these reasons we do not believe the downsweep calls we have identified to be attributable to these baleen whale species. Humpback whales are capable of producing downsweep like calls (Dunlop *et al.* 2007), and effort was made to exclude downsweeps in presence of other humpback whale calls when conducting our analysis. Dwarf minke whale distribution into the WAP is not known, therefore it is possible some of the Antarctic minke whale downsweeps we have identified could be attributed to dwarf minke whales. Antarctic minke whale downsweeps were present throughout most months during the recording period, with few downsweeps in January and February, none in March and April, and peaks in July (Fig. 1).

The bio-duck call was the more common Antarctic minke whale call found at this location in the WAP, but its occurrence was more seasonal. Bio-duck calls were detected between April and November with peak calling during July (Fig. 1). The bio-duck call was previously suggested to be found during the austral winter and spring in the western Antarctic (Van Opzeenland 2010) and our records extend that occurrence into fall. Recordings of the bio-duck call in Perth Canyon off Australia peak in July–August and again in December, suggesting the migration of this species is complex (Matthews *et al*. 2004, Erbe *et al*. 2015). Part of the population may undertake seasonal migrations while another part may remain in the ice, there could be a staggered migration with seemingly continuous presence in the Antarctic (Matthews *et al*. 2004, McCauley 2004, Erbe *et al*. 2015). However, the bio-duck calls produced in Perth Canyon during the winter included different bio-duck variants than the ones we encountered, suggesting the variants may represent subpopulations of the species (Matthews *et al.* 2004).

Even though bio-duck calls were strongly seasonal in this area, the near year-round presence of downsweeps suggests that there were Antarctic minke whales present in months the bio-duck call was absent. Visual surveys confirm year-round Antarctic minke whale presence in the area (Thiele *et al*. 2004, Ducklow *et al*. 2007) with highest occurrence close to shore and between islands (Thiele *et al*. 2004, Ainley *et al*. 2012). Some of these inshore sightings coincide with the location of our recordings. Thus our data in combination with the year-round visual sightings suggest that the seasonality seen in bio-duck call recordings is more likely the result of a change in calling behavior than an indication of migration or movement out of the area. Similarly, pulse trains from minke whales (*Balaenoptera acutorostrata*) occur year round, however, their seasonality can vary by location (Risch *et al.* 2014*b*).

The functionality of the bio-duck call is not known. The bio-duck call is somewhat similar acoustically to the pulse train, another call commonly found for minke whales in the Atlantic Ocean (Mellinger *et al*. 2000, Risch *et al*. 2013). Pulse trains are also common in the winter and spring, and are believed to be a reproductive call, but this has not been conclusively shown (Edds-Walton 1997). Given their similar characteristics and temporal occurrence, the bio-duck call may also be a reproductive call. It is plausible that reproductive calling can happen in areas other than the breeding grounds based on prior findings in other species. Humpback whales and blue whales

are known to produce reproductive calls during migration and on feeding grounds (Mattila *et al.* 1987, McSweeney *et al.* 1989, Clapham and Mattila 1990, Norris *et al.* 1999, Clark and Clapham 2004, Oleson *et al.* 2007). North Atlantic minke whales also produce pulse trains on the feeding grounds and during migration (Risch *et al.* 2014*b*). It has been suggested that the bio-duck call may serve as a tool for navigating ice covered areas, however, this hypothesis would not explain its production in ice-free areas (Matthews *et al.* 2004, Van Opzeeland 2010). A broad-ranging breeding grounds or multiple functions of the bio-duck call would be more probable reasons for its wide occurrence.

An additional clue to the functionality of the bio-duck call may come from the fact that there are no significant diel patterns to this call. This may suggest this call is not involved in feeding, since most feeding occurs during the night in this area (Konishi *et al.* 2014). In the North Atlantic during the migration to feeding grounds, on the other hand, minke whale calls occurred most commonly at night (Risch *et al.* 2013). However these patterns are not consistent to all areas and diel patterns may be site specific (Norris *et al.* 2012). Site specific diel patterns have been observed in North Atlantic right whales (*Eubalaena glacialis*) (Mellinger *et al.* 2007*b*). Differences in diel patterns were hypothesized to be due to prey availability, where the site with no diel pattern observed was relatively sparse in prey availability compared to the site where a significant diel pattern was observed (Mellinger *et al.* 2007*b*). To our knowledge Antarctic minke whale prey studies have not been conducted during winter, but Antarctic minke whale distribution tightly matches their prey distribution between April and June (Friedlaender *et al.* 2006).

Downsweep call rates peaked in the winter during a time when sea ice forms rapidly. If downsweeps produced by other baleen whale species function to maintain spacing (Edds-Walton 1997, 2000) then Antarctic minke whales may utilize this call more when there are more individuals present or when sea ice cover is more prominent. Both bio-duck calls and downsweeps were found to be positively correlated to sea ice presence. This is in agreement with higher Antarctic minke whale visual sightings occurring in correlation with sea ice (Thiele *et al.* 2004, Ainley *et al.* 2012, Murase *et al.* 2013). The relationship, however, was not linear but step-like. There was a high relative frequency of time spent calling when sea ice cover was greater than 50% (Fig 3). However, increasing sea ice concentration is not linked to an increase in calling. On one hand, it is possible that a sea ice cover threshold needs to be reached to trigger a vocal behavioral response. On the other hand, our sea ice data covered a large spatial scale and may not provide a tight coupling to the location where calling minke whales occurred. A tighter coupling of calling whales to sea ice concentration at their location may provide a better insight to the real relationship between these two variables.

In this study, we showed year-round trends of the Antarctic minke whale bio-duck and downsweep calls. In the future, a more detailed look at distinct patterns of bio-duck variants, to investigate whether there are variant differences in diel patterns, seasonality, or relationship to sea ice cover, could be illuminating for learning more on the functional importance of those variants. Additionally, investigating different recording sites would help determine how much call variation occurs over different regions and potentially give insight into Antarctic minke whale population structure. Extending this analysis to more years and over a large temporal scale may also explain if the observation of few bio-duck calls produced during the austral summer (Risch *et al.* 2014*a*), not seen in our study, could be due to a change in sea ice cover. It is possible that ecological changes in the WAP (Ducklow *et al.* 2007) are also changing the calling behavior of Antarctic minke whales. Collecting more current, long-term data at this location would

offer insights into ways in which animals in this rapidly warming region may be responding to environmental changes. In any case, these findings add substantially to the paucity of data describing the acoustic behavior of Antarctic minke whales in the WAP and will provide a useful benchmark for future comparison studies.

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