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Progress Report: Acoustic Monitoring of Blue Whales (Balaenoptera musculus) and other baleen whales in the Mozambique Channel off the Northwest Coast of Madagascar

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Progress Report: Acoustic Monitoring of Blue Whales (*Balaenoptera musculus*) and other baleen whales in the Mozambique Channel off the Northwest Coast of Madagascar

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Abstract

Migratory baleen whales of the Southern Ocean, particularly Antarctic blue (*Balaenoptera musculus intermedia*), pygmy blue (*Balaenoptera musculus brevicauda*), fin (*Balaenoptera physalus*) and Antarctic minke (*Balaenoptera bonaerensis*) whales, move each year into subtropical and tropical waters during the Austral winter, presumably for breeding; however, information for each is highly limited regarding migratory timing, population distribution, and potential breeding habitat. Recently, SC/66b/SH33 reported evidence for the presence of blue whales off northwest Madagascar, ca. latitude 13.3ºS, including a pair encountered in 1,800m depth water off Nosy Be, and distant recordings of Madagascar song-type from shallow water in December 2014 and 2015. These discoveries prompted an acoustic monitoring project in the deep waters off northwest Madagascar during 2017, in part funded by the IWC SC. Three passive acoustic recorders were deployed during four 4-month deployments starting in December 2016 and ending in April 2018, anchored just off the shelf break at depths ranging from 225-275m. Initial review of data from the first three deployments from December 2016 to November 2017 revealed extensive documentation of both SWIO (Madagascar) pygmy and Antarctic blue whale song-types, fin whales and Antarctic minke whales. SWIO pygmy blue whale song was present bi-modally with peaks of singing activity during May-July and October-January. This pattern suggests a previously unrecognized migratory corridor between summer feeding and winter breeding grounds south and north of Madagascar, respectively. Antarctic blue whale song was present throughout the Austral winter from June to September (overlapping with the first peak of SWIO pygmy blues), suggesting a previously unrecognized breeding season aggregation. NIO (Sri Lanka) blue whales song, as well as a potentially new, previously undescribed blue whale song were detected for short periods between January and May. Fin whale song was present during the late Austral winter, from early August to mid-September. At times high SNR series of fin whale 20Hz pulses were recorded, which included a single secondary frequency peak at 94-96Hz; this appears to be distinct from the different types previously reported from the Southern Ocean, however further analysis and direct comparisons are necessary. The timing of fin whale song suggests a later arrival than Antarctic blue whales and a lower rate of occurrence and occupancy, potentially representing the northern extent of breeding habitat. Antarctic minke whale pulse trains representing three distinct song types, were found to be very common in the higher bandwidth. Although a systematic browse above 100Hz has not yet been completed, Antarctic minke whales were present from at least early July to early November, so remaining seasonally later than Antarctic blue or fin whales. In addition, the monitoring has also documented the expected seasonal presence of humpback whales (*Megaptera novaeangliae*) and year-round presence of Omura's whales (*Balaenoptera omurai*).

Introduction

Migratory baleen whales of the southern ocean, particularly pygmy blue (*Balaenoptera musculus brevicauda*), Antarctic blue (*Balaenoptera musculus intermedia*), fin (*Balaenoptera physalus*) and Antarctic minke (*Balaenoptera bonaerensis*) whales, move each year into subtropical and tropical waters during the Austral winter, presumably for breeding; however, information for each is highly limited regarding migratory timing, population distribution, and potential breeding habitat. This report updates the IWC Scientific Committee on progress on a study of blue whale presence off Madagascar, in part funded by the IWC SC awarded during SC66. The project uses Passive Acoustic Monitoring (PAM) to document the presence and seasonality of blue whales and other baleen whales in the deep water habitat off the northwest coast of Madagascar, where they have been recently documented (reported in SC/66b/SH/33, Cerchio et al. 2016). The goal of the work is to extend monitoring previously conducted during 2015/2016 in shallow shelf habitat (at a depth of ca. 40m) into deep water, after the detection of Madagascar-type blue whale song during six days in December 2015 at a location positioned near the shelf break edge. The current work involves 16 months of acoustic monitoring off the shelf in deeper water at the same location, and we herein report on the first 12 months of those collected data.

Blue whales in the Southern Hemisphere are currently divided into four subspecies, including in the southern Indian Ocean the Antarctic blue whale (*B. m. intermedia*) and the "pygmy" blue whale (*B. m. brevicauda*). Populations of blue whales globally have been distinguished by stereotyped song-types. In the Indian Ocean there is one song-type from Antarctic blue whales, and at least three regional pygmy blue song-types (McDonald et al 2006, Stafford et al. 2011, Samaran et al 2013a). Antarctic blue whales are distributed around Antarctica during the summer and migrate to as-yet poorly documented regions in lower latitudes during winter (Branch et al. 2007). Acoustic monitoring in a few locations in subtropical waters of the central Indian Ocean indicated a strongly seasonal temporal distribution, inferring winter breeding habitat (Samaran 2010, 2013a, Leroy et al. 2017). Pygmy blue whales are distributed in tropical to temperate latitudes not much further south than 54ºS (Branch et al. 2007). In the SWIO, a population is defined by the "Madagascar" song-type, heard from the Madagascar Plateau to the central Indian Ocean (Ljungblad et al. 1998, McDonald et al. 2006, Samaran et al 2013a). There is a likely summer feeding region on the Madagascar Plateau, for which abundance was estimated at 424-474 (Best et al. 2003). There were also large numbers of winter catches north of Madagascar between 0º - 10ºS, and recent spring sightings off Kenya, suggesting a potential breeding area; although it is not clear if these represent the Antarctic, SWIO pygmy, or Northern Indian Ocean subspecies (Branch et al. 2007, Barber et al. 2016).

Recently, Cerchio et al. (2016) reported evidence for the presence of blue whales in the northern Mozambique Channel off northwest Madagascar, including a pair encountered in 1,800m depth water off Nosy Be, and distant recordings of Madagascar song-type from shallow water in December 2014 and 2015 (Figure 1). Prior to this, socio-ecological interview surveys with local fishermen had indicated reports of blue whales from several locations along the west coast of Madagascar, from Ifaty in the southwest, latitude 23.2°S, to Nosy Be in the northwest, latitude 13.3°S (Cerchio et al. 2012, 2014).

Fin whales and Antarctic minke whales are distributed around Antarctica in the Southern Ocean and like blue whales exhibit seasonal breeding and migratory movement into as-yet poorly defined lower latitudes. Acoustic data indicate geographic variation in fin whale song, defined by a varying frequency peak above 80Hz; it was speculated that this geographic variation may indicate population identity and structure (Gedamke 2009). Limited data from PAM indicates that fin whale singing and presence in sub-tropical waters is highly seasonal and correlated with breeding season, inferring seasonal migration into low latitudes during the Austral winter (Samaran et al 2013b).

Very little is known about distribution of Antarctic minke whales in low latitudes, with scattered reports of minke whales in the SWIO from Kenya (Wamukoya et al. 1996) to Reunion Island (Dulau-Drouot et al. 2008), and 2 reported sightings from aerial surveys off northwest Madagascar with an ambiguous species designation (Laran et al. 2012, 2017). Recently, Risch et al (2014) described the vocalizations of acoustically tagged Antarctic minke whales, definitively attributing the "bioduck" sound to the species, and describing the currently understood acoustic repertoire of the species. During surveys offshore of Nosy Iranja in northwest Madagascar in 2012, we made a boat-based recording of the "bioduck" sound while in deep water of approximately 2000m, thus indicating the presence of Antarctic minke whales in the region (Cerchio, unpublished data).

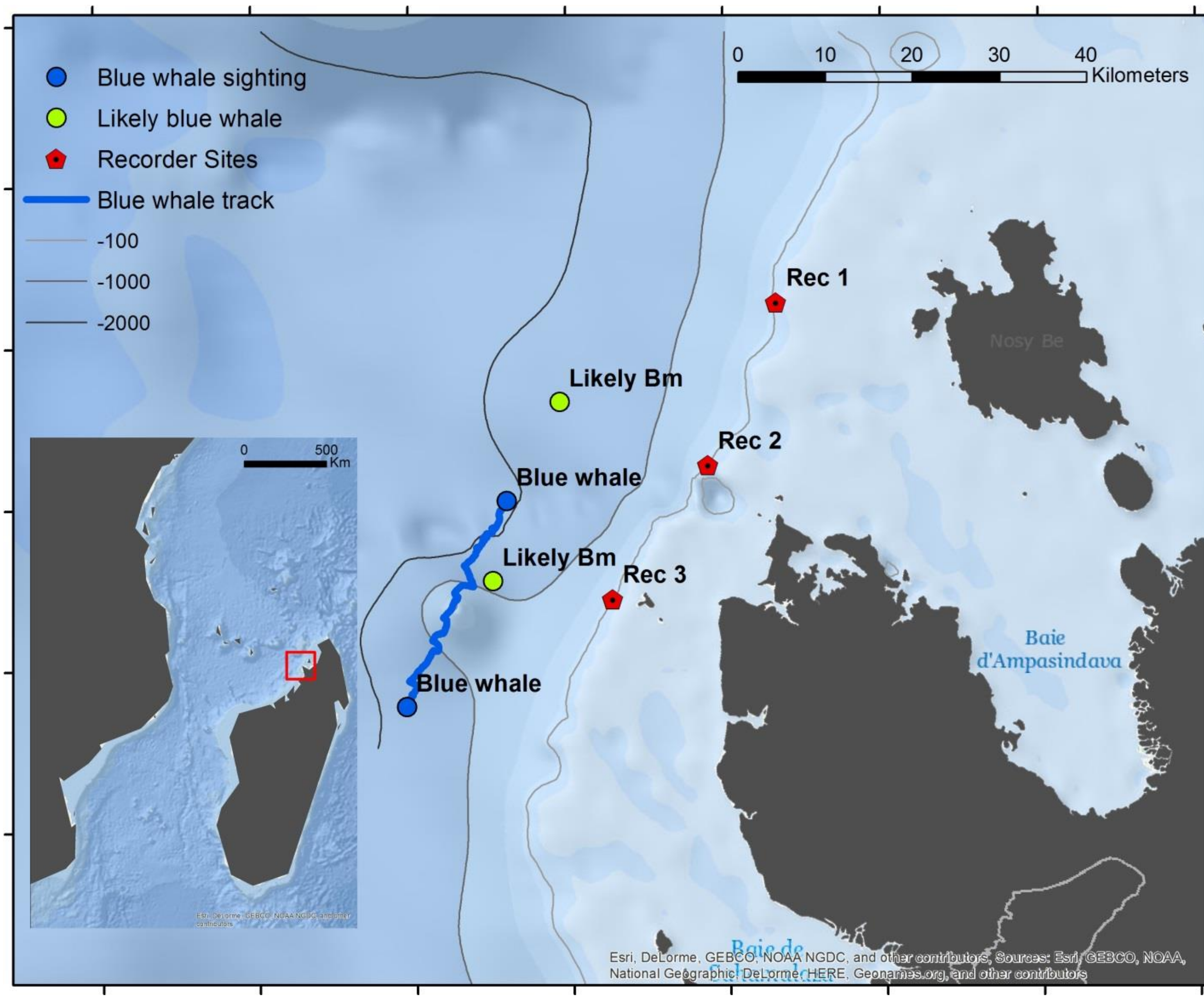

Figure 1. Map of field site showing Nosy Be (base of small boat work) and positions of three acoustic recorders deployed during 2017 immediately off the shelf break at 225-275m depth. Illustrated are the position and track of a pair of blue whales encountered and followed over a 4-hour period on October 11, 2012, and additional positions of two likely blue whale sightings during 2012 offshore surveys. These data document the proximity of blue whales within 25km of the Madagascar coast and within 15km of recorder positions. Inset shows the positon of the detail map relative to Madagascar and the east African coast.

Methods

Passive acoustic monitoring was conducted at three locations each separated by 20km, just past the shelf break from north to south: Rec Site 1, Sakatia-DW at 226m depth; Rec Site 2, Ankazoberavina-DW at 276m depth; and Rec Site 3, Iranja-DW at 270m depth (Figure 1). Four approximately 4-month deployments starting on December 10, 2016 were conducted. The central recorder of the three (Ankazoberavina-DW at 276m) was placed just 420m offshore of the site of the shallow recorder that had detected blue whale song in December 2015 at a depth of 38m, indicating a very steep drop-off. The fourth deployment was recovered on 9 April 2018, resulting in over 16 months of monitoring.

Archival recorders used were SoundTrap 300STDs with external battery pack (oceaninstruments.co.nz), which provides up to 76day battery-limited recording endurance. The SoundTrap recorder has a flat response from 20Hz-60kHz (+/- 3dB) with a 34dB re 1 µPa noise floor and a full scale response of 174.1 dB re 1 µPa including system gain. Recording parameters were a sample rate of 24kHz (for an analysis bandwidth of 12kHz) and a 50% duty cycle recording 30min every 60min, yielding a 139day (4.6month) estimated maximum recording period per deployment. The 24kHz SR was chosen because it is the lowest rate available on the SoundTrap, and does not limit endurance due to storage space (i.e., endurance is entirely determined by battery limitations and therefore maximises temporal sampling performance of recorder). The units were deployed attached to a locally constructed anchor with an acoustic release, the Vemco Ascent system (http://ascent.vemco.com) and a hard deep water float. The PAM rigs had a system maximum depth rating of 500m, so 250-300m was conservative, and recorders were floated approximately 5m off the sea bottom. Although the SoundTraps are not designed to be synchronized when duty-cycled, synchronization signals were produced at the beginning and end of each deployment, which can be used to assess clock drift between units. If possible, with the assistance of engineers, the synchronization signals will be used to time-shift/stretch the paired acoustic data streams, in order to "pseudo-synchronize" them; however this has not been attempted for the current report. This would allow for determination of rough bearings of recorded vocalizations through time-of-arrival delay, which may be accurate enough to estimate northward vs southward movements of animals.

Upon retrieval, the Soundtraps were downloaded and the archival acoustic files decompressed into wav files (a lossless compression algorithm is used by the SoundTrap software that provides on average 3x compression dependent on broadband noise amplitude, Johnson et al. 2013). The resulting 24kHz 16bit wav files were then down-sampled to 2kHz sample rate to reduce size and increase manageability of the data set for low-frequency analysis. The chosen 2kHz sample rate has been found convenient to assess presence and distribution of a wide range of baleen whale vocalizations, from low-frequency blue and fin whales to mid-frequency minke and humpback whales.

Manual browsing of spectrograms was conducted for review of baleen whale vocalizations and logging for hourly presence. Although manual browsing spectrograms and logging of individual vocalizations for large data sets can be prohibitively time consuming, we have found that a rapid browse in order to log simple presence is an effective means to provide an overview of the data for moderate size datasets as in this study. The results are informative and the process is indispensable for exploration of the dataset and detecting unusual, previously unknown, or unexpected vocalization types or other acoustic signals. Raven Pro 1.5 (Bioacoustic Research Program, Cornell University) was used to generate continuous spectrograms of multiple consecutive 30 minute samples, allowing several hours of data to be scanned on a single screen. Two separate scans are being conducted for low frequency blue and fin whales (0-60Hz bandwidth, 30min per spectrogram line, 4096pt FFT, 50% overlap, Hanning window) and mid-frequency minke, humpback and other species (0-500Hz bandwidth, 10min per spectrogram line, 512pt FFT, 75% overlap, Hanning window). In order to document hourly presence, the presence of each species' song encountered is being logged once for every 30min sample period.

Results and Discussion

Four deployments of the three recorders were successfully completed during: 10 December 2016 to 3 April 2017 (114 days); 7 April to 9 July 2017 (93 days); 12 July to 6 November 2017 (117 days); and 10 November 2017 to 9 April 2018 (150 days) (Figure 2). All recorders contained complete datasets and in all but one case were still recording upon retrieval. The most southern-most recorder at site Nosy Iranja had stopped recording during the first deployment on 14 February 2017 after 66 days due to battery failure; need for repair resulted in that recorder not being deployed for second deployment (Figure 2). A total of 15,340hr of recording was collected during 1,281 recorder days for all sites combined.

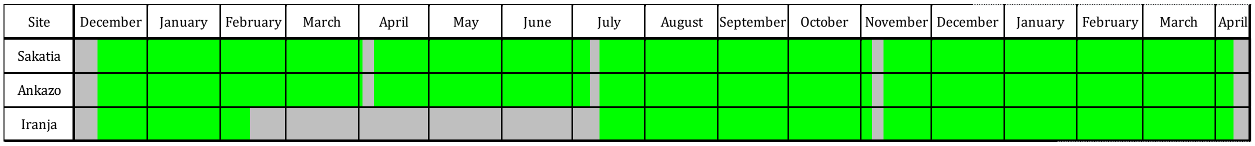

Figure 2. Schematic of recording effort at three sites off Northwest Madagascar for 16 months from 10 December 2016 to 9 April 2018; complete 24hr recording days are indicated in green (at 50% duty cycle, 30min every 60min), and grey represents periods of no data. Recorder malfunction at the Nosy Iranja site on 14 February 2017 resulted in a truncated deployment 1 and loss of deployment 2 during recorder repair for that site. Gaps between deployments for recorder download and refurbishment were 3 to 4 days.

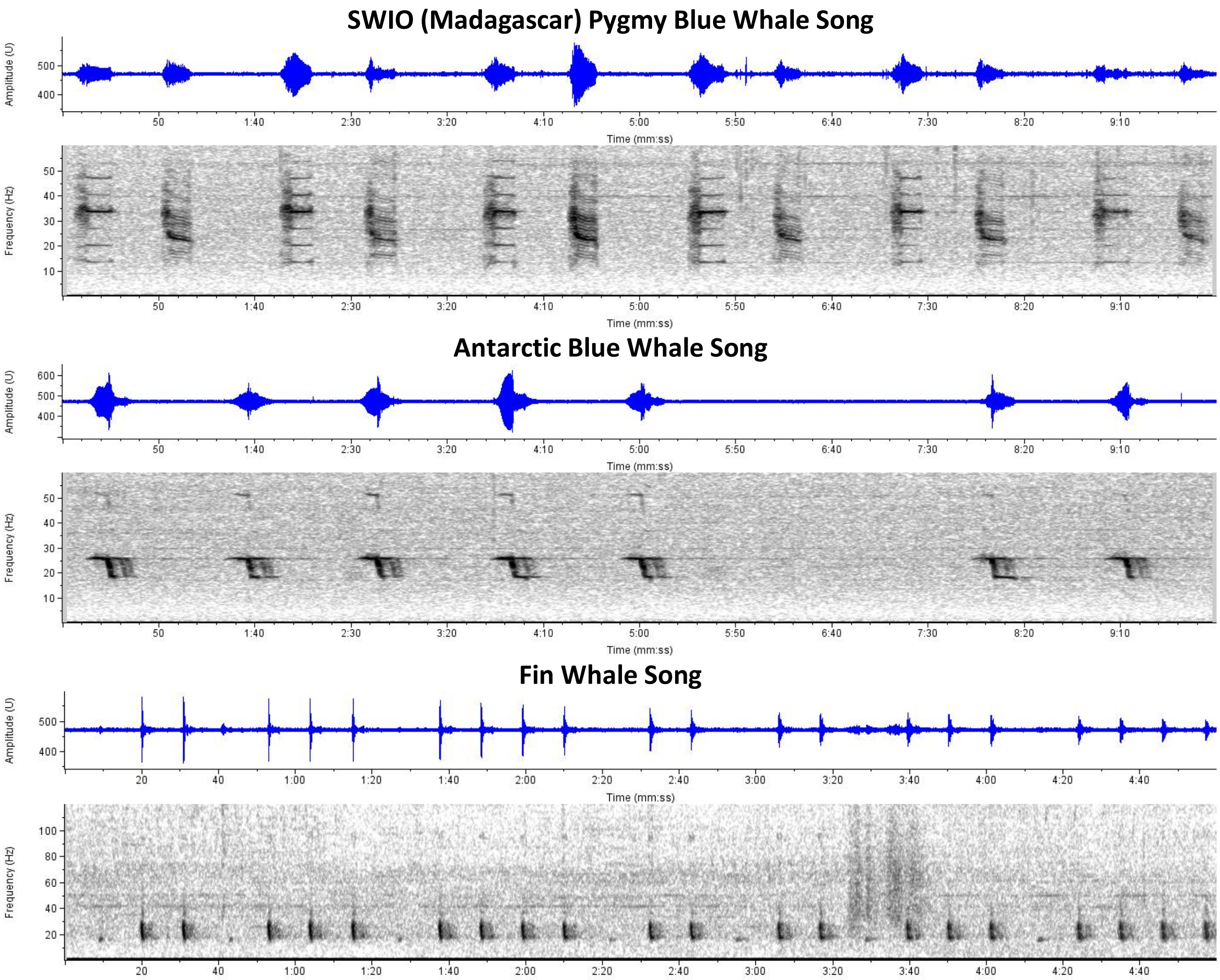

Figure 3. Example spectrograms and waveform envelops (in blue) of high signal-to-noise ratio recordings of blue and fin whale song recorded off Sakatia-DW (Rec Site 1, Figure 1). Represented, top to bottom, is Antarctic blue whale song, Madagascar pygmy blue whale song (2kHz SR, 8192pt FFT, 95% overlap, Hann window), and fin whale song sequence (2kHz SR, 2048pt FFT, 95% overlap, Hann window).

Initial review of data from December 2016 to November 2017 revealed extensive documentation of both Antarctic and pygmy blue whale song-types (Figures 3 and 4), fin whale song (Figure 3) and Antarctic minke whale song (Figure 5). In addition, humpback whale and Omura's whale song was also detected (not shown). For particularly the Antarctic blue, SWIO (Madagascar) pygmy blue, and fin whales, the highest signal-to-noise ratio (SNR) songs are shown (Figure 3); the singer in each case was possibly within 10km or a few 10s of km of the recorder, given the received signals' clean, non-degraded quality, high amplitude and clear presence of sidebands (SWIO blue) and harmonics (Antarctic blue). Most detections reported in the hourly presence analysis were lower SNR of much more distant animals, however it is likely that many if not most were within 100 or 200km, which will eventually be tested with propagation modelling. Currently, to assess hourly presense throughout the year, only the low frequency browse has been completed for one site (Sakatia-DW, Rec 1 in Figure 1) for the first three deployments from 10 December to 6 November 2017.

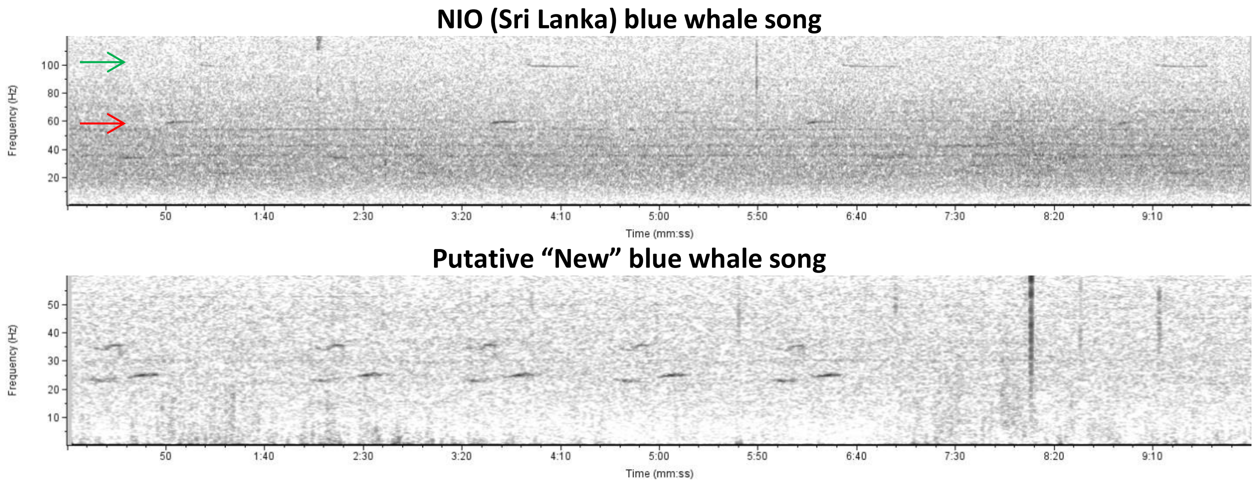

Figure 4. Low SNR detections of Sri Lanka type blue whale song (upper panel) recorded off Ankazoberavina-DW (Rec Site 2) on 13 December 2016, with the 60Hz (red arrow) and 100Hz (yellow arrow) units of four consecutive phrases evident; and a previously undescribed song of a putative blue whale recorded off Sakatia-DW (Rec Site 1) on 2 April 2017, illustrating five consecutive phrases of approximately 45sec duration, and energy between 21Hz and 36Hz. (2kHz SR, 8192pt FFT, 95% overlap, Hann window).

SWIO Madagascar-type blue whale song was initially detected on all recorders in a cursory browse throughout December and into January. Frequently multiple individuals were audible in a chorus of song. The systematic manual browse revealed that song was present throughout the year with clear bi-modal peaks of singing activity during May-July and October-January, and sporadic detections in the intervening periods (Figure 6). During the heights of the peak periods, song was detected nearly 24 hours/day for several days in a row. This pattern suggests a clear migration signal and therefore a previously unrecognized migratory corridor in the northern Mozambique Channel. The first yearly peak commenced in late April/ early May, peaking in late May / early June, and then declines by late July; this would presumably be attributed to animals moving north in the Austral autumn/winter coming from a summer feeding area (i.e., the Madagascar Plateau, Best et al. 2003) and moving towards a winter breeding area to the north of Madagascar (i.e., off the east African coast, Seychelles and the west Indian Ocean between 0º - 10ºS, Branch et al. 2007, Barber et al. 2016). The second peak commences in mid-October, appears to peak in early December (although we are lacking data from the month of November in the current scan) and ends by late January; this is presumably the southward passage of animals as they move from a breeding area back to the Madagascar plateau in the south. Final analysis of the fourth deployment from December 2017 to April 2018 will provide an uninterrupted record of this putative southward migration period. The sporadic detections in between the peaks, at times for most hours during a several day period (e.g., 25 February – 1 March 2017) suggests that the migration is prolonged or there are regular stragglers throughout the year.

Antarctic blue whale song was present throughout the Austral winter from June to September, overlapping with second half of the SWIO pygmy blue whales putative northward migration (Figure 6). The appearance of Antarctic blue whale song commenced in early June, with the total number of hours containing song peaking rapidly. The daily occurrence is not as consistent as for SWIO pygmy blue song, with several gaps of no detected song ranging from 6 to 15 days throughout the 3.5 month period until it drops off in mid-September. Also the frequency of occurrence in terms of number of hours per day present does not reach the levels observed for SWIO pygmy whales. This suggests that there may be fewer Antarctic blue whales visiting this area, or that they are further offshore, although the SNR of some examples (as in Figure 3) indicates that individuals of both subspecies at times come very close to the shelf break. Regardless, this presence during the winter suggests that the northern Mozambique Channel may host a previously unrecognized breeding season aggregation.

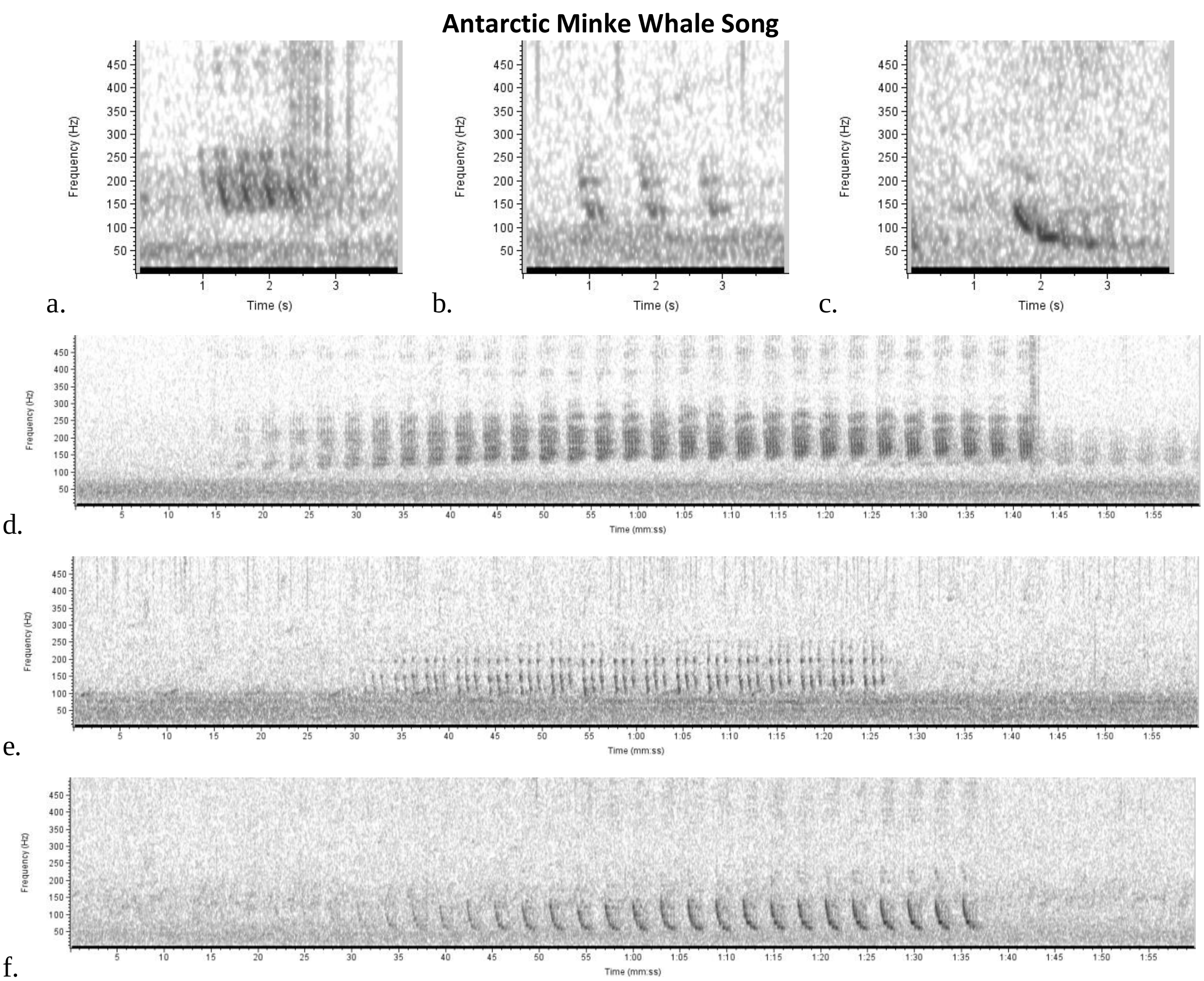

Figure 5. Example spectrograms of high signal-to-noise ratio recordings of Antarctic minke whale song recorded off Sakatia-DW (Rec Site 1, Figure 1). Represented are three different types of pulse train motifs including (a) 4-pulse motif (the “bioduck”), (b) three pulse motif, and (c) single pulse motif (downsweep) (2kHz SR, 256pt FFT, 95% overlap, Hann window). Each was recorded in a stereotyped series of varying length, with example series presented in (d), (e) and (f), respectively (2kHz SR, 512pt FFT, 95% overlap, Hann window).

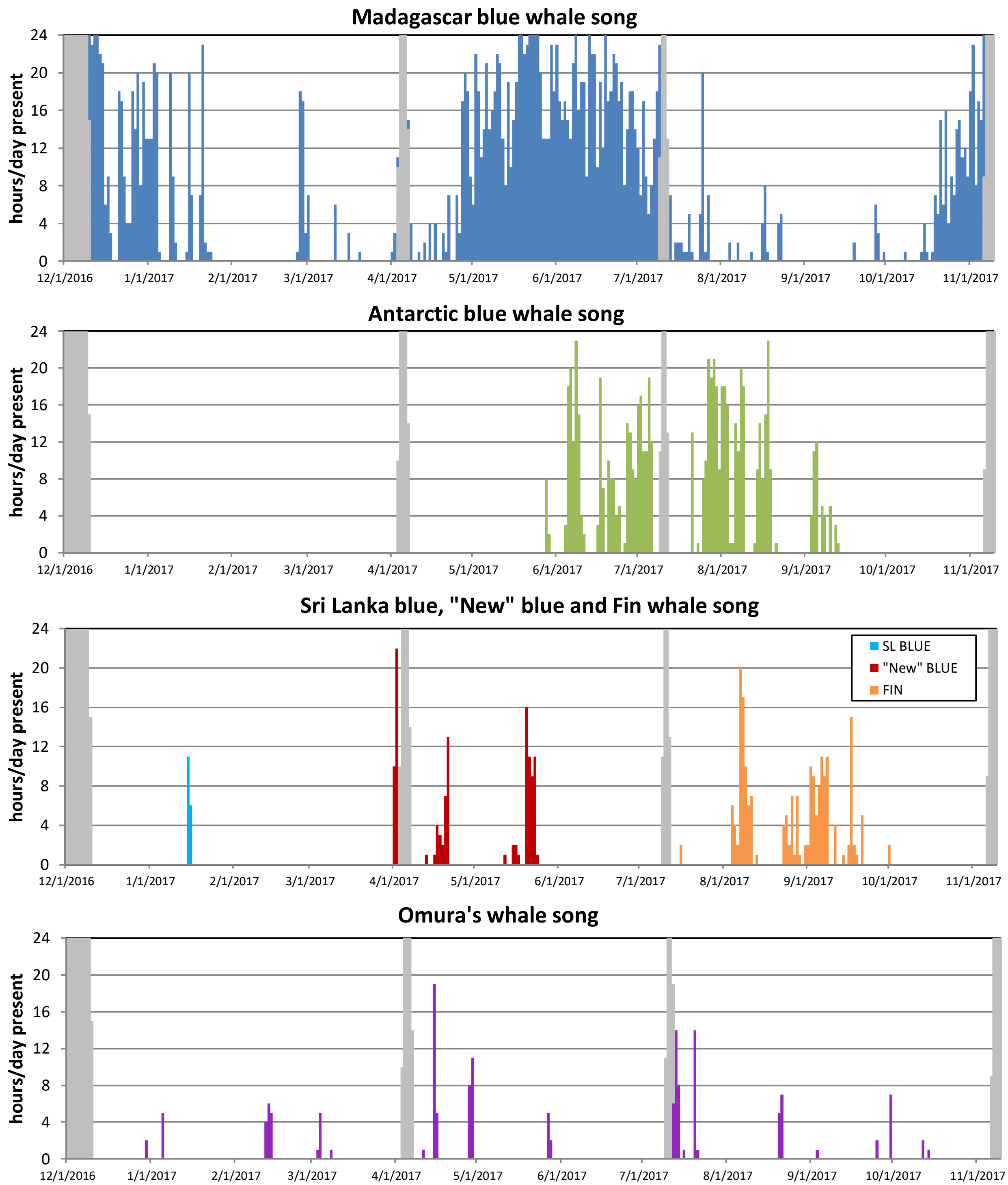

Figure 6. Hourly occurrence of low frequency baleen whale song detected on Sakatia-DW site (Recorder 1). Data represent first three of four deployments, from 10 December 2016 to 6 November 2017; grey bars represent hours and days of no data before, between and after deployments. For each day, bars represent the number of hours in which whale song was detected based upon a manual browse of spectrographic data from 0-60 Hz. Represented from top to bottom are: Madagascar pygmy blue whale song; Antarctic blue whale song; Sri Lanka blue/a “New” blue/fin whale song; and Omura’s whale song.

In addition to SWIO pygmy and Antarctic blue whale song, two other low-frequency song types were heard at low SNR (Figure 4). NIO Sri Lanka-type blue whale song was also recorded, first heard on 11 December 2016, the day after deployment, on the Ankazoberavina-DW (Rec Site 2), and was consistently detected for at least two days (Figure 4). During the systematic browse of the Sakatia-DW (Rec Site 1) data, this event was not detected; however a second event was detected during 15-16 January 2018. In each case it appeared to be a single animal and very distant so at the edge of perception on the manual browse. Primarily the second and third units of the NIO (Sri Lanka) song, at approximately 60Hz and 100Hz respectively, could be clearly discerned. This suggests that although very infrequent, NIO whales singing the Sri Lanka song type travel south into the Mozambique Channel; vagrancy of NIO whales has also been documented off the coast of Angola in the tropical South Atlantic (Cerchio et al. 2010).

A second song type was recorded that to the best of our knowledge has not been previously recorded (Figure 4). It was only ever recorded at low SNR, so there exist no clear examples. It appears to be a 2 unit phrase with a first tonal unit approximately 18sec duration with a peak frequency of 22-24Hz and an apparent sideband at 33-34Hz. In most detections the higher sideband of this unit was not visible. The second tonal unit was approximately 16sec duration and had a slight frequency modulation from 23.5 to 25.5Hz. The entire phrase was approximately 35 to 39 sec duration, and repeated at a regular interval typical of blue whale song. Although the species attribution of this song type cannot be confidently known, it has many of the characteristics of a blue whale song, and we believe it most likely to be a blue whale. Further documentation and study is required to confidently attribute species identity. The song was recorded off the Sakatia-DW site on three separate occasions spanning early April to late May 2017, and each time heard for several days, always at low SNR (Figure 6). Passive acoustic monitoring off Oman in the Arabian Sea for humpback whales (Cerchio et al. 2018a; CMP subcommittee, this meeting) indicated the detection of this same song type in the Arabian Sea, indicating a long distance connection between Northern and Southern Indian Ocean sites; this will not be covered in this report, but discussed elsewhere if time allows.

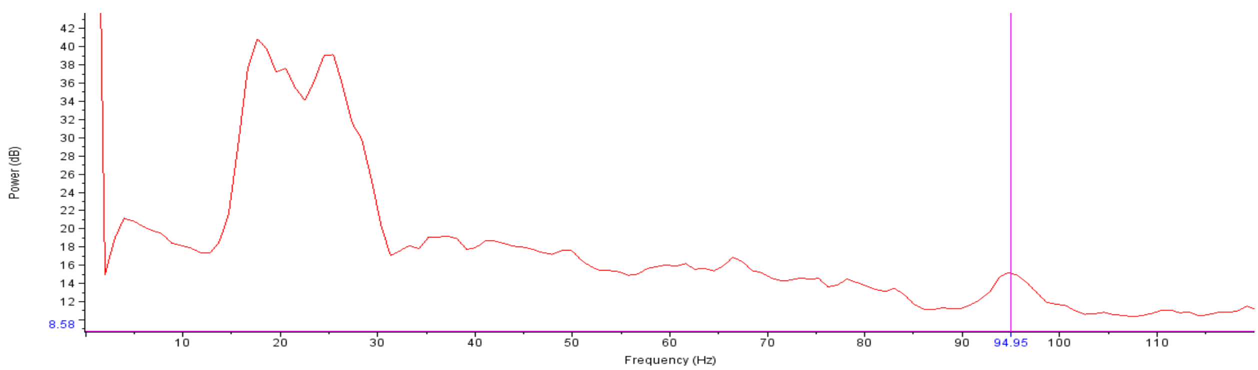

Figure 7. Average Power Spectral Density vs. frequency plot of a 6min sequence of detected fin whale song, showing energy spread of the main pulse component between 15-30Hz and the secondary peak at 94-96Hz.

Fin whale song was present during the late Austral winter, from early August to mid-September. At times high SNR series of 20Hz pulses were recorded, which included a single secondary peak at 94-96Hz (Figure 7); this appears to be distinct from the three different song types described by Gedamke (2009) that each differed in the frequency of this secondary higher frequency peak. It is possible that this song type may represent the same as previously detected off Western Australia and Antarctica (at ~75-80°E) with a peak at 99Hz (Gedamke 2009), but after several years of progressive decrease in frequency; further analysis and direct comparisons are necessary to clarify. The timing of fin whale song suggests a later arrival than Antarctic blue whales and a lower rate of occurrence and occupancy, potentially representing the northern extent of breeding habitat.

Although a systematic browse above 100Hz has not yet been done, Antarctic minke whale pulse trains were noted as being very common in the higher bandwidth, and present from at least early July (recorded on Ankazoberavina-DW on 8 July 2017) to early November, so remaining seasonally later than Antarctic blue or fin whales. Three distinct song types of putative Antarctic minke whales were recorded, each differing in the motif of pulses used in the pulse train (four pulses, three pulses, and a single pulse; Figure 5). Each of these groupings of pulses has previously been attributed to Antarctic minke whales (Risch et al. 2017). In each case, a group of downswept pulses was repeated in a series that gradually increased in amplitude (Figure 5d, e, f). The number of pulse groups within a series varied considerably among different series of the same song type, as well as between different song types, with the single pulse series (Figure 5f) at times being very long in excess of 10min. These stereotyped patterns were consistently repeated, such that it appears that a single animal produces a string of pulse train series at a relatively regular repetition rate. These are all characteristics of typical balaenopterid song, and thus suggest a breeding display.

In addition, songs were also documented from humpback whales (*Megaptera novaeangliae*), and Omura's whales (*Balaenoptera omurai*). Although not presented here, the humpback whale song had the typical Austral winter distribution, as expected from the well documented migration and use of Madagascar waters as a breeding area. Extensive monitoring for Omura's whales on the shelf habitat of the Nosy Be regions is presented elsewhere (Cerchio et al. 2018b; this meeting, NH subcommittee). Those data indicate year-round presence in northwest Madagascar shallow water, extensive singing throughout the year, and marked variation in frequency of occurrence between two sites separated by 40km. The deep water monitoring presenting here indicates that Omura's whale are also heard off the shelf throughout the entire year, but sporadically, only 1 or 2 times each month (Figure 6). This suggests that while the resident population of Omura's whale clearly prefers shallow water habitat, singing individuals occasionally make their way at least to the shelf edge or into deep water. Given the high SNR of some of the detections, it is likely that at times they are off the shelf, as also indicated by satellite telemetry results (Cerchio et al. 2018b).

Next Steps

Manually browsing analysis of spectrograms will continue to complete the 16-month recording period for the Sakatia-DW site, as well as for the other two recorder sites, resulting in hourly presence across the entire period. Additionally, or alternatively for Rec Sites 2 and 3, the use of automated detectors will be explored to quantify number of song notes/unit time. We will seek to apply and compare several different existing detectors for the target species. The NOAA Northeast Fisheries Passive Acoustic Group has extensive experience working with the Low-Frequency Detection and Classification System (LFDCS, Baumgartner & Mussoline 2011), a contour-tracing algorithm successfully used for North Atlantic blue, fin and humpback whales in both archival and real-time detection scenarios. Alternative detectors, such template detectors and energy detectors, have also been explored in prior analyses of Madagascar datasets. Additionally, we are seeking input and collaboration from SORP colleagues and other experts for use of existing detectors (such as in Mellinger and Clark 2000, Širović 2016, Samaran et al 2008, 2013b) for Southern Ocean data sets. Efficacy of detectors will be assessed through expert analyst review of a portion of the data set (i.e., 5 or 10%) in which all occurrences are logged to assess rates of false detections and missed detections. Measuring the spectral energy in song unit frequency bands will also be explored. This method is a means to present a broad overview the presence of specific vocalizations in a long-term recording sequence by quantifying the Power Spectral Density (PSD) at the specific frequency bands of whale song units (as in Širović et al 2004, Samaran et al 2013c, and Leroy et al 2016 for a "Chorus to Noise-without-chorus-ratio"). Application of this methodology will be assessed, ideally with input from the SORP acoustic experts.

Detailed structure of song patterns can be compared within our sample, and between ours and Southern Ocean samples collected by SORP and others, to make inference into population identity and connectivity. This is already implicit in the classification of blue whale song types into Antarctic and

Madagascar pygmy (or other known pygmy blue whale song). However, particularly for fin whales, we will seek to quantify the high frequency component of the pulse units in the song (see Figure 7), as has been proposed to distinguish populations (Gademke 2009, Samaran et al. 2013c). We will assess if all fin whale detections are comparable, or alternatively if there is evidence for multiple fin whale song types in our dataset. Comparison with the SOHN database (van Opseeland et al. 2013) may provide information on what portion of the Southern Ocean the fins whales visiting the Mozambique Channel come from.

As currently proposed to the Southern Ocean Research Partnership, we are expanding the geographic acoustic sampling in the Mozambique Channel during 2018-2019, by deploying recorders at multiple sites along a 1300km stretch of the west coast of Madagascar. The work proposed to SORP involves deploying recorders off the shelf off Toliara at 23.3ºS, Mahajanga at 15.4ºS, and Nosy Be at 13.2ºS, from October 2018 to October 2019. The Nosy Be site is the position of the most northern of the three recording sites of PAM reported here between December 2016 and April 2018. We have been able to start this project ahead of the proposed schedule due to the acquisition of a small set of funds to monitor for humpback whales in partnership with the Reunion Island NGO Globice. In April 2018, recorders were successfully deployed at the two most northern and southern sites, off Nosy Be (on 11 April) and Toliara (on 19 April), to record for the 6-month period between April and October at a 33% duty cycle (20min every 60min). If the proposed project is funded, then this will extend sampling in the Nosy Be region an additional 16 months for a total 32 month period, and add additional sites on the Madagascar west coast for the second 16-month period. Together, the work presented here, analyses to be conducted on recently collected data, and the proposed extended work will add significantly to our understanding of Southern Ocean baleen whale occurrence, movements and habitat utilization in this region, including determining whether this area serves as a migratory corridor or potentially a seasonal breeding habitat for each species. In addition, the work will assess the occurrence of other key species that have been previously documented, including humpback whales and Omura's whales.

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