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"Spot" call: A common sound from an unidentified great whale in Australian temperate waters

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Abstract: Underwater passive acoustic recordings in the Southern and Indian Oceans off Australia from 2002 to 2016 have regularly captured a tonal signal of about 10 s duration at 22–28 Hz with a symmetrical bell-shaped envelope. The sound is often accompanied by short, higher frequency downsweeps and repeated at irregular intervals varying from 120 to 200 s. It is termed the "spot" call according to its appearance in spectrograms of long-time averaging. Although similar to the first part of an Antarctic blue whale Z-call, evidence suggests the call is produced by another great whale, with the source as yet not identified.

[DRD]
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1. Introduction

Cetaceans rely heavily on acoustical cues for communication. The frequency, duration, and inter-call interval of vocalizations provide important sources of information. Baleen whales ("great whales") produce low to mid frequency sounds lasting from fractions of a second to more than 10 s which are used for long-distance communication (Edds-Walton, 1997) and can be heard up to tens or even hundreds of kilometers away (Bannister, 2008).

Passive acoustic monitoring (PAM) provides an efficient and relatively low cost alternative to visual monitoring (Mellinger and Barlow, 2003). It is particularly useful in remote offshore areas and areas of unfavorable environmental conditions where the opportunity for visual observations is limited (Mellinger and Barlow, 2003; Salgado-Kent *et al.*, 2012; Erbe, 2013), such as the Southern Ocean. To provide adequate data on the population dynamics and migration patterns of a species of interest, PAM requires an understanding of a species' vocal repertoire.

The Antarctic blue whale (ABW) (*Balaenoptera musculus intermedia*) is one of the largest and most endangered species on the planet, with the population estimated to have been reduced to less than 1% of the original abundance during the whaling era (Branch *et al.*, 2007). Moreover, the ABW is one of the least investigated great whale species in terms of its current population, distribution, and migration patterns. This is primarily due to the remoteness and large extent of the ocean areas these whales mainly inhabit, where PAM is the only means to monitor seasonal variations in the presence of ABWs over long periods of time.

ABWs are recognized in ocean noise recordings by their characteristic, so-called Z-calls (Ljungblad *et al.*, 1998). It is also believed that ABWs produce a variant of those calls where the second and third parts are omitted and the call consists of a single tonal sound of about 10 s length produced at 26–28 Hz (Rankin *et al.*, 2005). Similar sounds have been observed at several locations in the Southern and Indian Oceans off Australia. They are typically 8–10 s long and produced in a series of calls with an interval varying from about 120–200 s. Because of their spot-like appearance in spectrograms of long time averaging window, these sounds will be referred to as spot calls further on in this paper. Tripovich *et al.* (2015) used these tonal sounds as a proxy to analyze the seasonal presence of ABWs in the Southern Ocean south of Portland, Victoria, using data from a passive acoustic observatory of the Integrated Marine Observing System (IMOS, 2017). Balcazar *et al.* (2017) included this type of sound in their analysis of the ABW distribution in the southwest Pacific and southeast Indian Oceans. In this paper we present strong evidence that the spot call is in fact produced by another great whale species, not ABW.

2. Methods

2.1 Data collection

Sea noise data collected from nine sites in the Southern and Indian Oceans (Fig. 1) were analyzed in this study. These sites include (1) three IMOS passive acoustic

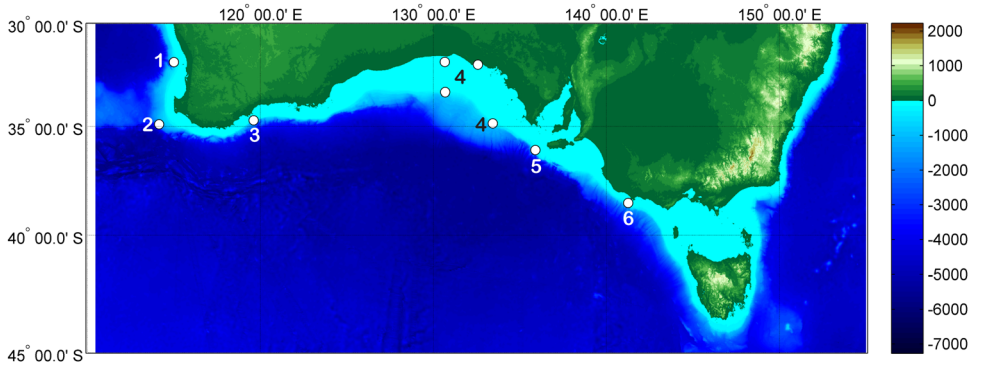

Fig. 1. (Color online) Locations of underwater noise recorders where individual spot calls and/or spot call choruses have been recorded: 1—IMOS Perth Canyon; 2—CTBT H01; 3—Bremer Bay; 4—GAB; 5—IMOS Kangaroo Island; 6—IMOS Portland.

observatories, in the Perth Canyon area in the Indian Ocean, off Portland and near Kangaroo Island in the Southern Ocean, (2) four sites in the Great Australian Bight (GAB), (3) one location near the Bremer Canyon in the Southern Ocean off southwestern Australia, and (4) the H01 hydroacoustic station deployed about 150 km southwest of Cape Leeuwin in Western Australia as part of the International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty (CTBT). All sea noise recordings except the H01 station were made on autonomous underwater sound recorders designed and built at the Centre for Marine Science and Technology (CMST, 2017 www.cmst.curtin.edu.au/products), Curtin University, and deployed on the seafloor for long time periods varying from a few months to more than a year. Deployments of non-IMOS recorders were not regular; at some sites we had just one (Bremer Bay) or a few deployments (GAB). Data collection at the IMOS site off Kangaroo Island only began in 2015. Most of the CMST sound recorders were programmed to make recordings of 200 to 600 s length repeated with 900 s intervals between recording start times. The sampling frequency was 6 kHz with a 2.8 kHz anti-aliasing filter. All instruments were calibrated for system frequency response by recording white noise of known spectral level applied in series with the hydrophone. Hydrophones used were Massa TR 1025C or High Tec HTIU90 types with factory supplied sensitivities of around −196 dB re 1 μPa/V.

The H01 hydroacoustic station is cabled to shore and transmits underwater sound to the IMS data collection center in real time, with data collected since 2002 barring a few short interruptions. Three hydrophones of H01 are on moorings and placed at about 1100 m below the sea surface near the axis of the SOFAR ocean sound channel. The sampling frequency is 250 Hz with an anti-aliasing filter set at 100 Hz. H01 data collected over ten years from 2002 to 2011 were available for analysis in this study.

2.2 Data analysis

A simple automatic detector, similar to that described in Gavrilov and McCauley (2013), was employed to find spot calls in sea noise recordings. As the call frequency changed over years, which will be discussed in Sec. 3, the detection frequency was also adjusted according to the calendar year of the dataset collected. Because the complexity of the spot call sound is rather low and it is similar to the first part of the ABW's Z-call, the detection algorithm resulted in a relatively high percentage of false detections. For this reason, ambiguous detections were checked using MATLAB based toolbox "CHORUS" (Gavrilov and Parsons, 2014). For each true detection, the detection time was reported with the call frequency calculated with high (0.05 Hz) resolution.

In addition, high frequency resolution (0.05 Hz) spectrograms were calculated for each dataset which comprised spectra of sea noise averaged over each individual recording. This allowed us to extract a chorus of spot calls from many remote whales singing at the same time, and to distinguish this chorus from a similar chorus formed by the first part of the ABW's Z-calls (Gavrilov *et al.*, 2012).

3. Results

3.1 Call description

A spectrogram of three spot calls of high intensity accompanied with frequency downswept impulses is show in Fig. 2. The background chorusing is also seen in Fig. 2. The

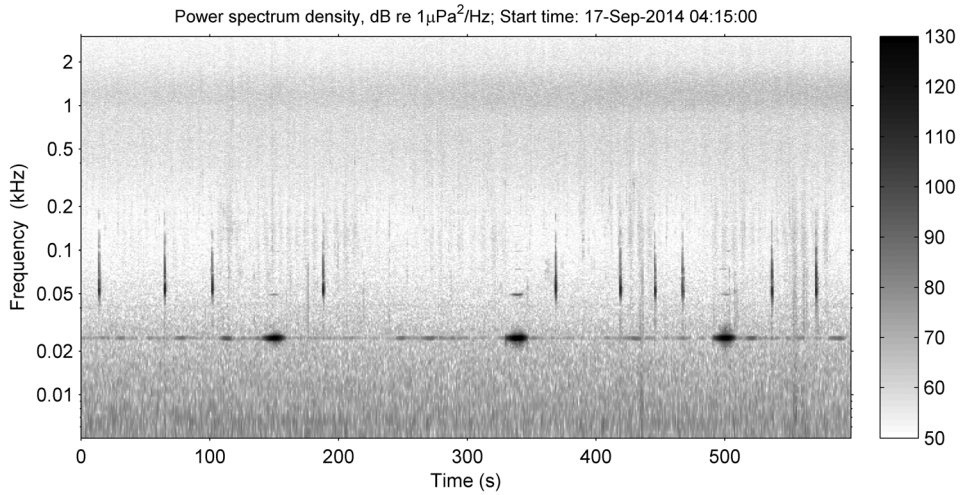

Fig. 2. Spectrogram of a series of three spot calls accompanied with frequency down-swept impulsive sounds recorded at Fowlers Bay in 2014. The FFT window length is 2 s with a 50% overlap.

waveforms and spectrograms of the ABW's Z-call and the spot call are compared in Fig. 3. A high frequency resolution spectrogram over 361 days of sea noise recorded in the area near the Bremer Canyon is shown in Fig. 4. It reveals two spectral lines corresponding to two different whale choruses. The upper line is formed by the first part of the ABW's Z- call, whereas the lower spectral line corresponds to spot calls from remote whales of the unidentified species. It is important to notice that (1) the call frequency of both whale species gradually decreases over the season of their presence in the monitored area and (2) the time period of the vocal activity of these whales is different: from early February to late October for ABWs and from early May to early December for the unidentified whale making the spot call.

Similar spectrograms were obtained from other datasets recorded off Portland, near Kangaroo Island and in the GAB. In sets recorded in shallow water deployments in the coastal zone near the Head of the GAB, the spectral line of the ABW chorus was absent.

3.2 Inter-annual frequency variation

The frequency of spot calls have been gradually decreasing over the observation period of 15 years, with the exception of the 2006–2007 seasons when a rapid transition from lower to higher call frequency took place at the Cape Leeuwin site. During these two years some whales remained calling at around 23 Hz, while an increased number of whales switched to a significantly higher frequency of around 28 Hz (Fig. 5). The frequency of the spot calls recorded in the Perth Canyon area in 2005 was also about 23 Hz, whereas in 2008 it was approximately 27 Hz similar to that at the Cape

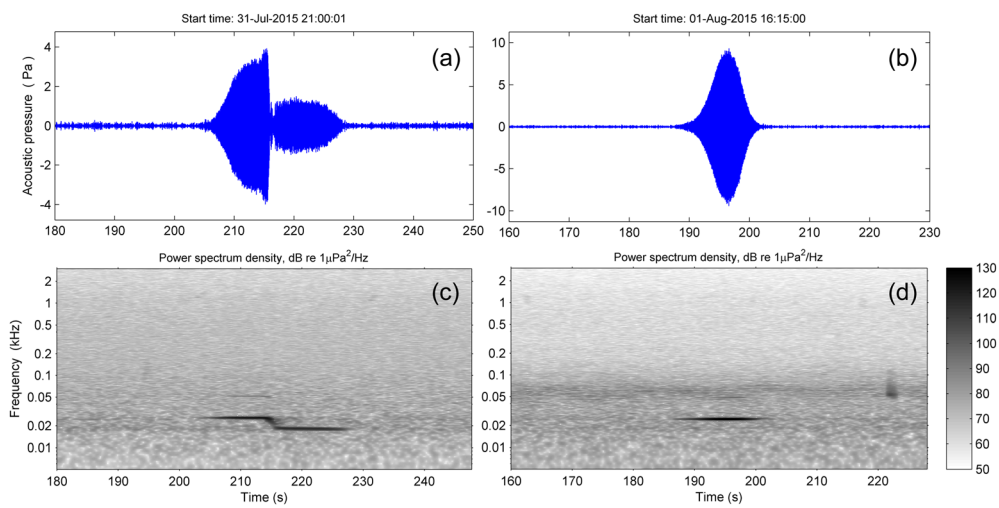

Fig. 3. (Color online) Waveform [(a), (b)] and spectrogram [(c), (d)] of the ABW Z-call [(a), (c)] and the spot call [(b), (d)]. The frequency of the first unit of the ABW call is 25.7 Hz, and the spot call frequency is 24.4 Hz.

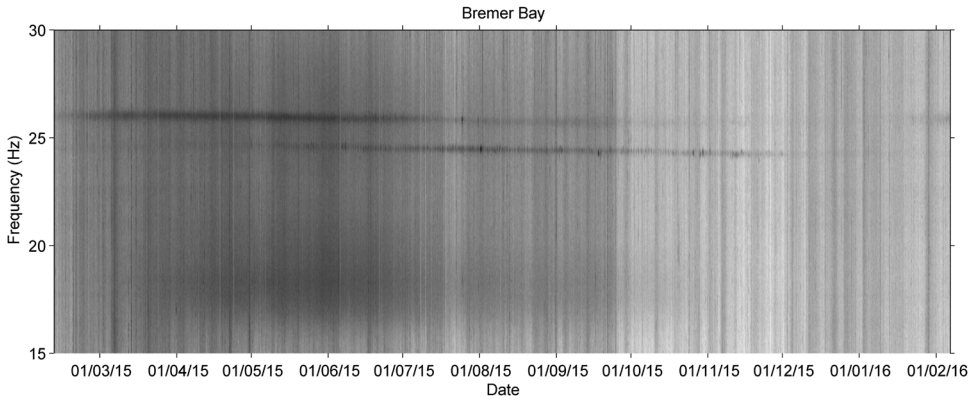

Fig. 4. Chorus from the first unit of ABW Z-call (top spectral line) and spot call chorus (bottom spectral line) recorded near Bremer Canyon in Western Australia.

Leeuwin site. It is particularly important to note that the rate of inter-annual decrease in the spot call frequency has been considerably higher than that of the ABW calls, also shown in Fig. 5. Moreover, the frequency decrease rate has been different at the sites in the Southern Ocean and near the Perth Canyon in the Indian Ocean. Also the intra-seasonal variations in the spot call frequency were noticeably larger than those of the ABW calls.

4. Discussion

The frequency of spot calls overlapped or was close to the frequency of the first unit of the ABW Z-calls in some years: 2007–2008 at the Cape Leeuwin site and 2007–2010 in the Perth Canyon area (Fig. 5). Moreover, the typical duration of the spot call is similar to that of the first unit of the Z-call. Due to this similarity, the spot call has been incorrectly attributed to ABWs in some studies, e.g., Tripovich *et al.* (2015).

In this paper we provided strong evidence supporting the conclusion that the spot call cannot be produced by ABWs, which is based on three essential facts:

(1) The vocal behavior, including the call frequency and its change over years, is different for the ABWs and the unidentified great whale species making the spot call.
(2) The seasonal presence of the ABWs and the whales making spot calls in the Southern Ocean off Australia is noticeably different.
(3) Finally, spot calls of high intensity and a prominent spot call chorus were recorded in relatively shallow water in the coastal zone near the Head of the GAB where blue whales have never been sighted by whale watchers, including yearly aerial surveys (Bannister and Double, 2016).

According to a few publications, e.g., Stafford *et al.* (2004) and Rankin *et al.* (2005), ABWs may produce single-tone sounds. So, care should be taken when

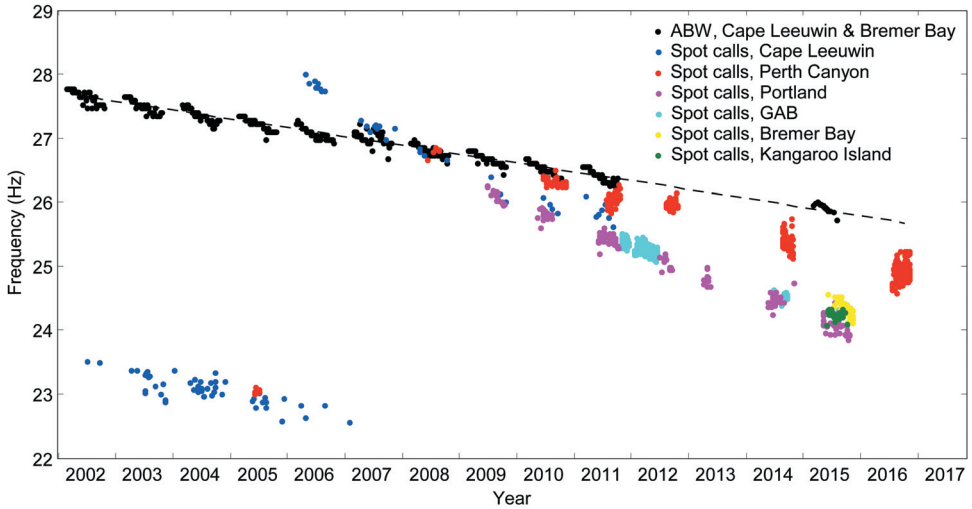

Fig. 5. Inter-annual variation in the fundamental frequency of the spot call and first unit of the ABW Z-call observed at various locations off the southern and south western coast of Australia.

detecting and identifying a whale producing such sounds. The difference in the call frequency and the shape of the signal envelope, when the signal-to-noise ratio is high, should be taken into consideration to distinguish the ABW and spot call vocalizations.

The spot call frequency has been steadily decreasing since 2007–2008 with an inter-annual rate considerably higher than that of the ABW calls (Gavrilov *et al.*, 2012). A steady inter-annual decline was also observed in the vocalization frequency of the Australian population of pygmy blue whales (Gavrilov *et al.*, 2011). The reason for such long-term trends is unknown; although it is hypothesized that it is driven by an increase in the population density (McDonald *et al.*, 2009). However, rapid transition from low (~23 Hz) to high (~28 Hz) frequency observed in the spot calls in 2006–2007 does not support this hypothesis. It is reasonable to expect a similar transition for the spot calls within a few years when the call frequency drops below 23 Hz. It would also be plausible to expect a similar transition to higher values in the ABW call frequency when it reaches a certain minimum.

The chorus of spot calls is seen almost year round in the GAB, with a peak from the austral winter to spring. This is presumably the result of species migration to warmer temperate waters to rest and breed, as is observed with other great whale species (Bannister, 1990; Clapham, 2000; Gavrilov *et al.*, 2012).

Individual high intensity spot calls and a spot call chorus have been observed in shallow waters nearshore to the Head of the GAB and Fowlers Bay, South Australia. Both areas are recognized as established aggregation grounds for southern right whales (*Eubalaena australis*, Department of Sustainability, Environment, Water, Population and Communities, 2012). Long-term visual monitoring surveys at both locations have regularly observed southern right and humpback whales during the austral winter to spring. Based on an extensive library of humpback whale sounds and songs collected off the western and southern coasts of Australia over several decades, it is very unlikely that the spot call is produced by the humpback whale. Consequently, the southern right whale is the most likely candidate to produce the spot call. However, further investigation is needed to finally identify the calling whale species, which will include visual observations accompanied with acoustic recordings on direction DIFAR sonobuoys to localize the calling whale. A field study implementing such an approach is planned to be conducted either in the Perth Canyon area or in the GAB during July–September 2017 or 2018. Additional H01 data beyond 2011 which were not available for this analysis, as well as data from other deployments of sea noise recorders around Australia will be analyzed to further clarify the inter and intra-annual variations in the frequency of the spot and ABW calls.

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Alec Duncan and Frank Thomas of Curtin University were instrumental in designing, building, and putting up with all the tribulations of proving the sea noise loggers used in this study. Mal Perry and RPS MetOcean have been of tremendous help in preparing and deploying moorings. The work would not have eventuated without the excellent and professional vessel crews required, in particular Curt and Micheline Jenner and their *RV Whale Song* vessels. Rod and Simone Keogh of Fowlers Bay Eco Whale Tours provided in-kind support and vessel use, as well as invaluable assistance during logger deployment and retrieval at Fowlers Bay in 2014–2016. IMOS supported Australia wide sea noise logger deployments from 2009. BP Australia provided funding for sea noise recordings in the GAB. Geoscience Australia and CTBT Organization provided access to data from the H01 IMS hydroacoustic station.

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