A new baleen whale song type described for the Western Indian Ocean off Oman and northwest Madagascar

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Background

We report in this brief document a baleen whale song type that, to the best of our knowledge, has not been previously described. The song was recorded at two disparate locations in the western Indian Ocean separated by approximately 3500km during two independent efforts of long-term passive acoustic monitoring, off Oman in the western Arabian Sea and northwest Madagascar in the Southwest Indian Ocean. The purpose of this paper is to introduce this new song type to the IWC Scientific Committee, query members on the possible documentation of this signal in other datasets, and discuss implications for our understanding of baleen whale populations in the Indian Ocean. Although it is impossible to definitively attribute this song to a species, we suspect it is almost certainly a new blue whale (*Balaenoptera musculus ssp.*) song type, and briefly discuss how this impacts our current understanding of blue whale population structure and behavior in the Indian Ocean.

During 2011/2012, a passive acoustic monitoring effort was conducted off Oman in Hallaniyats Bay targeting Arabian Sea humpback whales; results of work pertaining to humpback whales has been reported to the IWC-SC in a previous and the current meeting (Cerchio et al. 2016, SC/66B/SH/32; Cerchio et al. 2018, SC/67B/CMP/19) and details of the recording effort can be found in those papers. Three recorders were placed in shallow water at depths ranging from 16m to 33m; two recorders were placed in close proximity to the shelf break, and therefore had an acoustic "view" of nearby deep water. One site in particular, labeled Hal 3 in Cerchio et al. (2016, 2018), was placed within <1km of the shelf break at 16m depth, and all data presented here were recorded at that site (17.40°N, 55.31°E). During the analyses conducted for humpback whales, low-frequency signals of an apparent different baleen whale species were detected on a few occasions; since the humpback whale analysis was not ideal for detection of signals below 100Hz, for the current analysis a systematic low-frequency manual browse of spectrograms was conducted. The original wav files were down-sampled to 2kHz sample rate to reduce size and increase manageability of the data set for low-frequency analysis. A scan of continuous spectrograms was conducted in Raven Pro 1.5, at parameters optimized to detect signals of low frequency baleen whales such as blue and Bryde's whales (0-60Hz bandwidth, 30min per spectrogram line, 4096pt FFT, 50% overlap, Hanning window).

During 2016/2017, an independent passive acoustic monitoring effort was conducted off northwest Madagascar in the Nosy Be region targeting southern hemisphere blue whales and other baleen whales; a

progress report of this work is reported to the IWC-SC in the current meeting (Cerchio et al. 2018, SC/67B/SH/14) and details of the recording effort can be found in that paper. Three 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. The resulting 24kHz 16bit wav files were down-sampled to 2kHz sample rate to reduce size and increase manageability of the data set for low-frequency analysis. Manual browsing of spectrograms from one of the sites (at 13.28°S, 48.01°E) for the first three deployments (December 2016-November 2017) was conducted for review of baleen whale vocalizations and logging for hourly presence (0-60Hz bandwidth, 30min per spectrogram line, 4096pt FFT, 50% overlap, Hanning window). Review of data revealed extensive documentation of both SWIO (Madagascar) pygmy and Antarctic blue whale song-types, as well as fin whale and Antarctic minke whale song. In addition, NIO (Sri Lanka) blue whale song was detected during two isolated events in December 2016 and January 2017.

Song type description

The new baleen whale song type reported here was first detected during the low frequency browse of the Madagascar data. In all cases it was detected at low signal to noise ratio (SNR) indicating distant animals heard on the deep water recorders. During the assessment of humpback whale song on the Oman recorders, the same signal was detected somewhat opportunistically, prompting the systematic low frequency browse of that dataset at the same standardized parameters used for the Madagascar assessment. Ultimately, the Oman data revealed higher SNR examples and more frequent rate of occurrence of the song type, despite the very shallow water deployment of the hydrophones; the Oman detections were still relatively low SNR, as would be expected from a nearby deep water source propagating up onto the shelf to be detected by the shallow water hydrophone after substantial propagation loss.

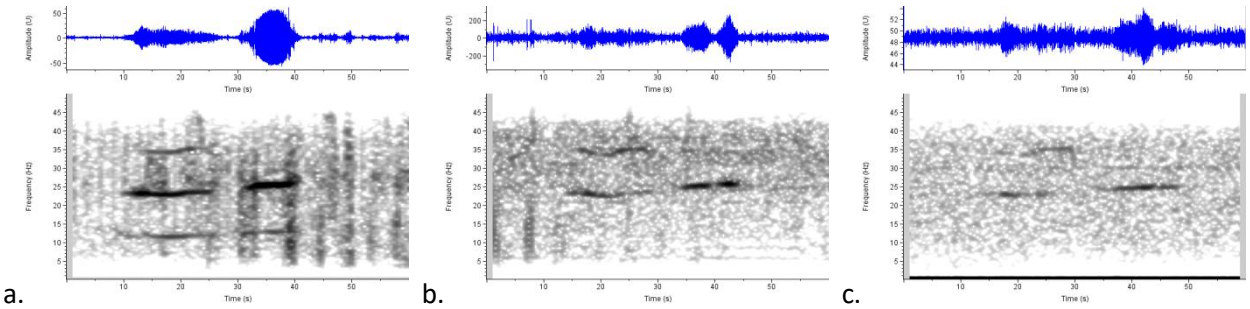

Figure 1. Example phrases for new song phrase recorded off Oman and Madagascar (2000Hz SR, 4096pt FFT, 75% overlap, bandpass filtered 5-40Hz). Illustrated are (a) Oman 3-band; (b) Oman 2-band; and (c) Madagascar 2-band examples. Also frequently recorded in both areas was a 1-band phrase that resembled (b) and (c) without the 35Hz band of the first unit, illustrated in Figure 2. Differences between these phrases are presumed to be primarily due to differential received levels, signal to noise ratios and effects of propagation loss.

The song phrase consisted of two tonal units arranged in a consistent simple pattern (Figure 1). In most detections each unit consisted of a single band in the 22-26Hz bandwidth, however higher SNR detections indicated a 2-band pattern in the first unit in both Oman (Figure 1b) and Madagascar (Figure 1c). Some detections, found only off Oman, indicated a lower frequency component in the 11-12Hz bandwidth, and thus a 3-band pattern for the first unit, and 2-band pattern for the second unit (Figure 1a). For these multi-banded examples, the first unit was relatively consistent, non-modulated, and had three apparently harmonically related bands: a first harmonic at approximately 11.5Hz, a second harmonic at 23Hz that is also the peak frequency, and a third harmonic at 34Hz. The second unit had a slight FM upsweep most evident in the second harmonic, of approximately 2Hz from 24Hz to 26Hz, and a lower amplitude first

harmonic at approximately 12Hz. In most observed sequences in both regions only the second harmonics were obvious (Figure 2b, Oman; Figure 2d, Madagascar). Unit duration ranged from at least 15-18sec for Unit 1 and at least 9-14sec for Unit 2; total phrase duration ranged from at least 32-39sec. The phrases were always detected in rhythmic series (Figure 2) with varying repetition rates, measured from the start of consecutive phrases, ranging at least from approximately 60sec (Figure 2b) to 116sec (Figure 2a), or approximately 1.8x to 3.6x the phrase length. In most sequences, several repetitions occurred at a consistent rate interspersed with occasional longer gaps (Figure 2b, c and d).

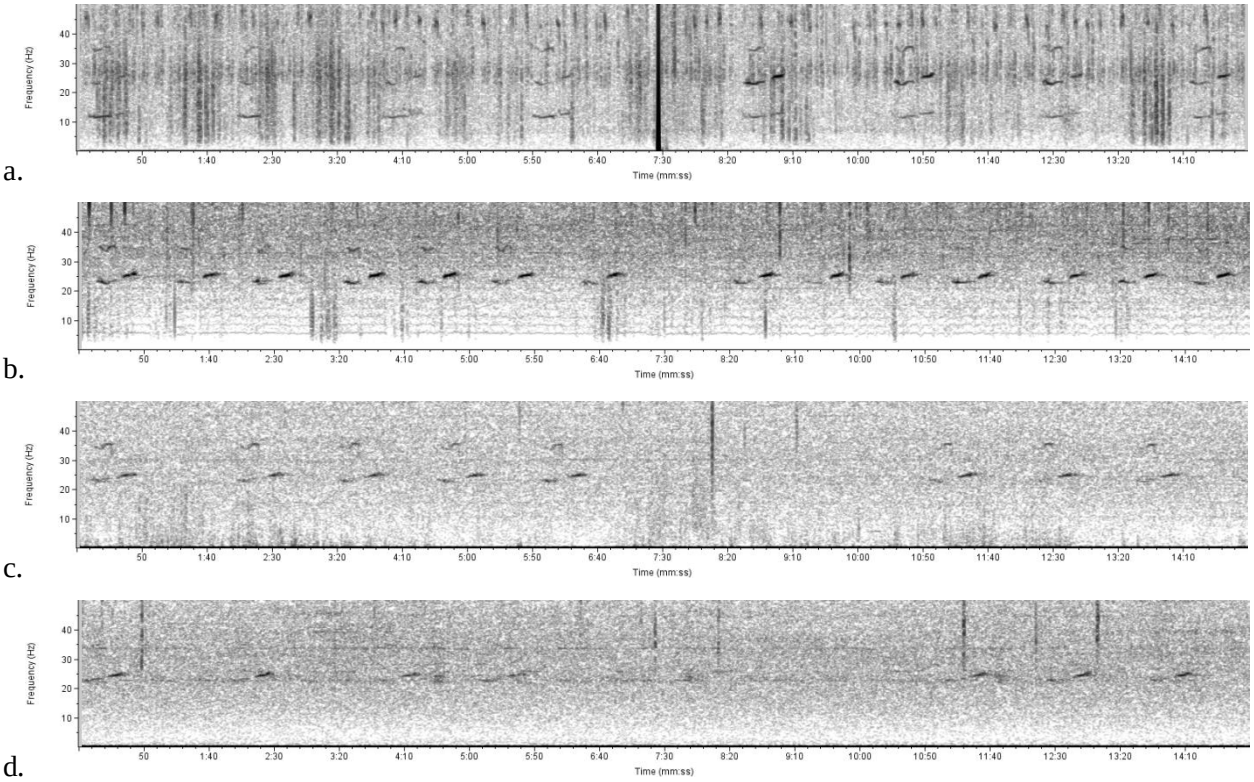

Figure 2. Example sequences of phrases for new song type recorded off Oman and Madagascar (2000Hz SR, 8192pt FFT, 75% overlap). Illustrated are sequences with varying SNR of (a) Oman 3-band; (b) Oman 2-band and 1-band; (c) Madagascar 2-band; and (d) Madagascar 1-band phrase sequences.

The temporal distribution of detections of the song type over the monitored period varied substantially at the two disparate sites (Figure 3). Off Oman the song was detected predominantly during December, with a more sparse distribution of detections during six months from late November to late May. Off Madagascar, the distribution of detections was much more limited during two months from early April to late May, and occurred in predominantly three distinct events of several days each. It is important to consider here the differences in propagation characteristics at each site and likely ranges that songs were detected. The deeper recorders deployed off the shelf at Madagascar had an acoustically unobstructed "view" of deep water habitat and could certainly detect signals at much greater distance than the shallow water recorders perched on the shelf above the break off Oman. As seen off Madagascar in Cerchio et al (2018a), there was much more extensive documentation and higher SNR detections of other baleen whale song types (Antarctic and SWIO pygmy blue, and fin whales). Therefore we surmise that the detections of the new song type off Madagascar were likely a few isolated events of relatively distant animals. Conversely, off Oman there would be extensive propagation loss of signals originating in deep water before they were detected on the shallow water shelf recorder; therefore, the low SNR detections likely represent relatively close individuals singing off the shelf edge in nearby deep water, and the observed

distribution of detections is likely a substantial underestimate of presence. This effect of different propagation characteristics was documented in Madagascar for SWIO pygmy blue whale song, for which only several isolated detections during December were made from a shallow (37m depth) recorder on the shelf edge, whereas extensive daily detections were made throughout December and January when monitoring off the shelf edge (at 270m depth) at the same location. Therefore, it is possible if not likely that had monitoring been conducted off the shelf in deep water off Oman, the sparse distribution of detections of this song would have filled with much more extensive presence between December and June.

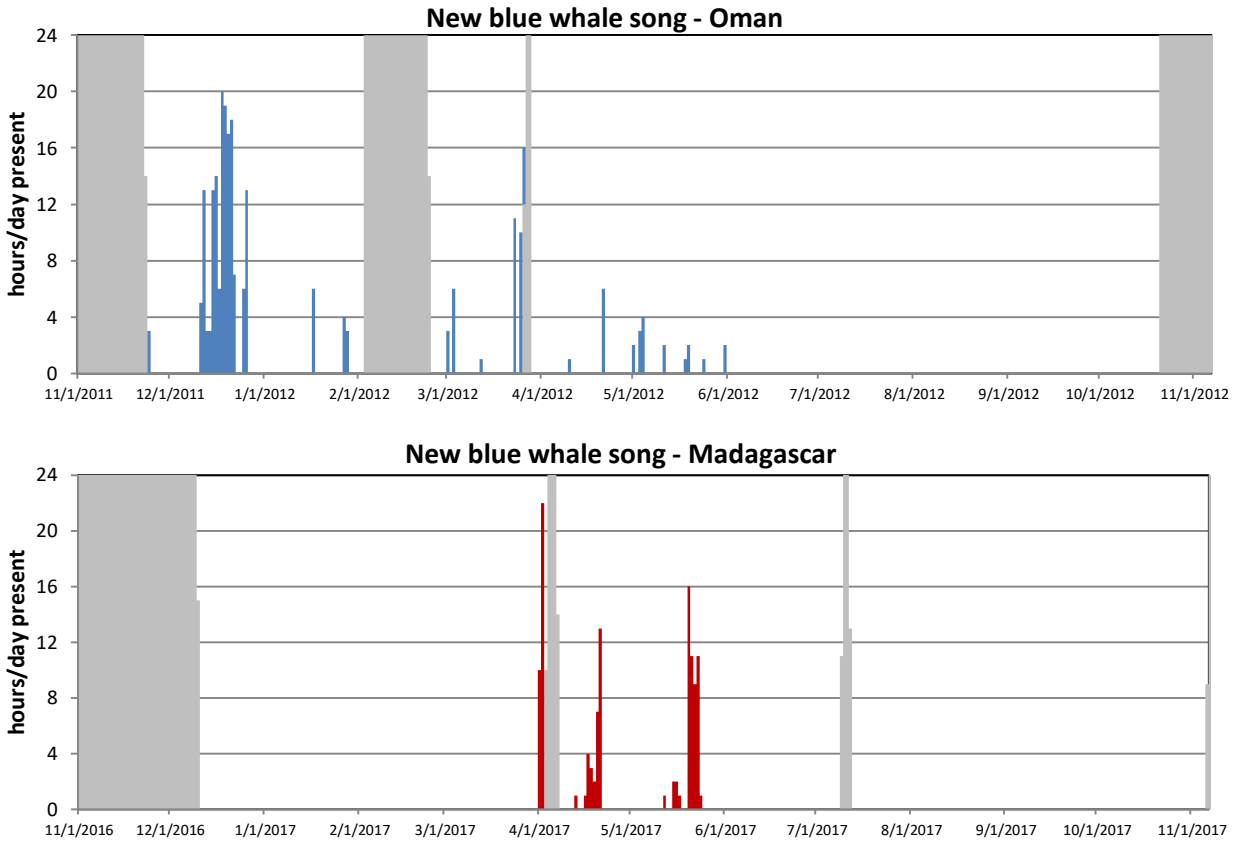

Figure 3. Hourly occurrence of low frequency baleen whale song detected off Oman (top line) and northwest Madagascar (bottom line). Data represent deployments from 24 November 2011 to 20 October 2012 off Oman, and from 10 December 2016 to 6 November 2017 off Madagascar; grey bars represent hours and 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.

Implications and questions regarding blue whales in the Indian Ocean

Although it is impossible to definitively attribute a new baleen whale song type to a species when recorded only from remote recorders, there are only two feasible candidates for this song type: blue whales and Bryde's whales. Both species have been documented in the area where recording was conducted off Oman during surveys conducted during March of 2011 and 2012 based upon the Oman Cetacean Database (Figure 4). When considering only days in 2012 when the song was recorded: there was a Bryde's whale sighted 20km to the north on 2 March, but this was likely too far to be detected by the recorder unless the individual moved south; on the 26-27 March there was a blue whale sighting within 2.5km and two unidentified *Balaenoptera* sightings within 3.5km and 4.3km of the recorder

(Figure 4 Detail). Off Madagascar, Bryde's whales have never been documented off the northwest coast study region despite extensive effort, however, they do occur regionally in the SWIO to the south of Madagascar. The acoustic attributes of the song type, including the tonal characteristics of the units, the relatively long duration of the units and the phrase, and the repetition rate of the phrases in the song sequence (which is on the order to 2-3x the length of the phrase), are more congruent with all identified song types of blue whales. Existing knowledge of Bryde's whale song suggests that phrases tend to be much shorter without long tonal units, and repetition rates much longer, such that this song type would be much more unusual for a Bryde's song than a blue whale song. Given the acoustic attributes of the song type, and the documented close proximity of a blue whale to the recorder in Oman when it was recorded, we believe that this is almost certainly a blue whale song.

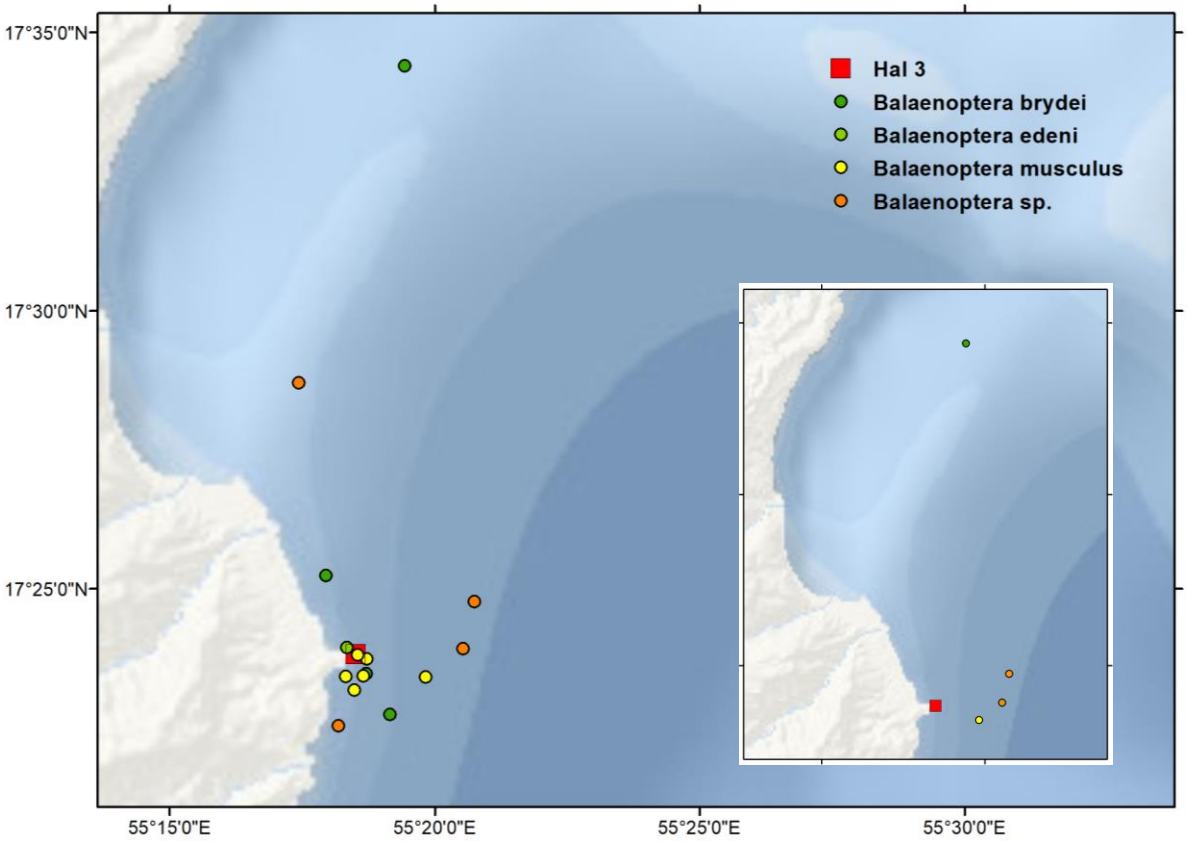

Figure 4. Positions of blue whale and Bryde's whale sightings relative to position of the Hal 3 recorder site during surveys in March 2011 and March 2012. Detail: positions of sightings on specific days when the new song type was recorded: during 26-27 March 2012 there was a blue whale in close proximity to the recorder (at 2.5km) along with two unidentified *Balaenoptera* sightings; a Bryde's whale was sighted on 2 March 2012, 20km to the north, and likely out of acoustic range of the recorder.

Assuming this is a correct species attribution, and this song is ultimately attributed to a blue whale, then these observations raise several implications and questions in regard to our understanding of blue whale population structure in the Indian Ocean:

- Different song types have been used to distinguish between populations of blue whales in the Indian Ocean. Given that this song type has not been reported before (pending review by other acousticians), then this song would represent that of a previously undefined population of blue whales in the western Indian Ocean.

- The patterns of presence suggest that this song type was detected more extensively and during a more extended period of the year off Oman than off Madagascar. This suggests this population may be more associated with the North Indian Ocean and the Arabian Sea, and only an occasional visitor in the Southwest Indian Ocean and the Mozambique Channel.
- Given the North Indian Ocean population of blues whales is currently characterized by the "Sri Lanka" song type, these observations suggest that there may be two NIO blue whale populations. Furthermore, given that this song type has not been previously reported in studies that documented the Sri Lanka song type, and that no Sir Lanka song types were detected in our analysis of the data off Oman, then there may be a longitudinal division of these populations between (a) the Western Arabian Sea and western Indian Ocean in general, and (b) the eastern Arabian Sea / Bay of Bengal and central Indian Ocean in general.
- The presence of this population off the coast of Oman during the Boreal winter, from November through June, is congruent with the timing of Soviet catches in the region (Mikhalev 1996) and observations off Oman. The large numbers of blue whales caught in Soviet whaling operations in the Gulf of Aden and Arabian Sea, may represent a population of blue whales that is distinct than that represented by the Sri Lanka song type, or a combination of two distinct populations.

The observation and initial assessment of this new song type should have several follow ups. Efforts to conduct deep water acoustic monitoring off the coast of Oman are critical to validate these observations and combined with boat-based surveys and recording in the vicinity of blue whales will allow definitive attribution to species. Existing acoustic datasets throughout the Indian Ocean should be evaluated for the presence of this song type, particularly for datasets for which only automated detection of targeted song types has been conducted (i.e., for which lack of manual browsing would have hindered discovery of unexpected or previously undescribed vocalization). Current data and discussions on Northern Indian Ocean pygmy blues (e.g., Branch et al 2018, SC/67B/SH/23) should be reconsidered in light of the possibility of two distinct populations in the NIO.

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