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A complex baleen whale call recorded in the Mariana Trench Marine National Monument

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Abstract: In fall 2014 and spring 2015, passive acoustic data were collected via autonomous gliders east of Guam in an area that included the Mariana Trench Marine National Monument. A short (2–4 s), complex sound was recorded that features a ∼38 Hz moan with both harmonics and amplitude modulation, followed by broad-frequency metallic-sounding sweeps up to 7.5 kHz. This sound was recorded regularly during both fall and spring surveys. Aurally, the sound is quite unusual and most resembles the minke whale "Star Wars" call. It is likely this sound is biological and produced by a baleen whale.

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1. Introduction

Passive acoustic monitoring (PAM) has become a common means of investigating vocal species in a variety of habitats. This is especially true in cetacean research, where acoustic surveys have become commonplace in most of the world's oceans. PAM's effectiveness depends upon a comprehensive understanding of the vocal repertoire of the species being studied. Cetaceans make a wide variety of sounds; animal-mounted recorders and localization via a towed hydrophone or sonobuoy array, coupled with visual survey data, have confirmed the source of many biological signals (e.g., minke whale bio-duck sounds—Risch *et al.*, 2014). Despite these advances, many "unknown" biological sounds are still recorded, especially in areas that are remote and have not been extensively monitored. Here we report a new, complex call likely produced by a baleen whale, which was recorded via passive acoustic ocean gliders in an area east of Guam that includes the Mariana Trench Marine National Monument (MTMNM).

2. Methods

2.1 Study area

In 2009, a 246 000 km^2 area east of the Mariana Archipelago (Fig. 1) was designated as the Mariana Trench Marine National Monument (U.S. Fish and Wildlife Service, 2016). This area also includes the Mariana Islands Range Complex (MIRC), which is the primary Western Pacific range for U.S. military training activities. Glider surveys were conducted east of the islands in support of the U.S. Navy monitoring program for cetacean species occurrence within the MIRC.

2.2 Glider specifications and survey design

Three passive-acoustic surveys in offshore waters east of Guam and Saipan were conducted using a Seaglider™ (Kongsberg Inc., Lynwood, WA). The glider was equipped with a custom-designed and -built passive acoustic recording system (Applied Physics Laboratory, University of Washington, Seattle, WA). Acoustic signals were received by a single omnidirectional hydrophone (type: HTI-99-HF, High Tech Inc., Gulfport, MS; sensitivity: −164 dB re 1 V/μPa), amplified by 36 dB, and recorded at 194 kHz sample rate and 16-bit resolution. The acoustic system was optimized for continuously collecting data in the frequency range 15 Hz to 97 kHz, and thus was well suited for the recording of both baleen and toothed whales. The glider repeatedly dove in a saw

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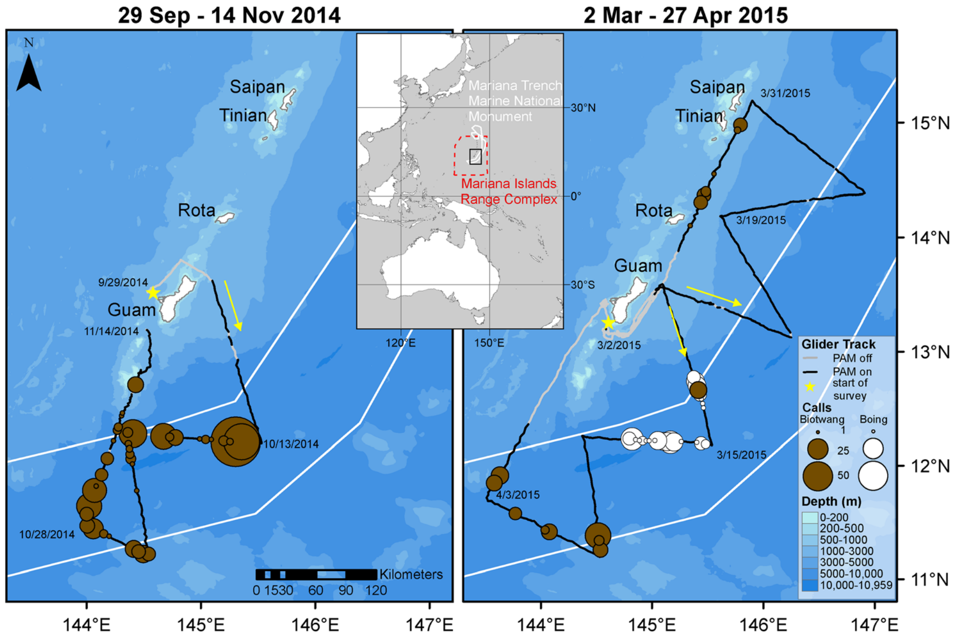

Fig. 1. (Color online) General location of glider surveys conducted in the Mariana Islands Archipelago. (Left) Glider survey flown 29 September to 14 November 2014. The line represents the trackline of the glider; the black line is the portion of the track when the passive acoustic monitoring (PAM) system was active and recording sound. Dark circles represent the number of WPB calls recorded during a dive. (Right) Two glider surveys flown 2 March to 27 April 2015. Both gliders were deployed southwest of Guam (star), continued south, and then transited to a location northeast of Guam with the PAM system off. Once northeast of Guam, one glider flew a southern survey and the other flew a northern survey (arrows) with the PAM system on. Dark circles represent the number of WPB calls recorded during a dive, while white dots represent the number of minke whale boings recorded during a dive. (Inset) Boundaries of the Mariana Trench Marine National Monument (solid lines) and the U.S. Navy's Mariana Islands Range Complex (dashed line).

tooth pattern to 1000 m depth and back to the surface at a typical horizontal speed of 25 cm/s. Dive durations were usually on the order of 4–6 h.

In 2014, a glider was deployed on 29 September 2014 off the west coast of Guam (13° 30.79′ N, 144° 35.04′ E). The glider was recovered about 24 nautical miles southwest of the deployment location (13° 10.81′ N, 144° 31.22′ E) on 14 November 2014. In March 2015, two gliders successfully surveyed this area again. Both gliders were recovered on 27 April 2015 (Fig. 1).

2.3 Data analysis

The FLAC files were decoded to standard WAV audio file format at 194 kHz sampling rate. Two datasets with reduced sampling rates of 10 kHz and 1 kHz were generated for baleen whale call occurrence analyses. Long-term spectral average (LTSA) plots were calculated using the Triton Software Package (version 1.81, Scripps Whale Acoustic Lab, Scripps Institution of Oceanography, La Jolla, CA). LTSA parameters were Δt of 2 s and Δf of 10 Hz (for 10 kHz data) and Δt of 1 s and Δf of 1 Hz (for 1 kHz data). The 10 and 1 kHz data were then time-aligned in the software package Raven Pro (version 1.5 beta, Bioacoustics Research Program, Cornell University, Ithaca, NY), and calls were logged for both datasets simultaneously. Analysts used the MATLAB based software Osprey (Mellinger, 2014) to measure calls. Calls selected for measurements ($n = 20$ calls) had a high (>20 dB) signal-to-noise ratio (SNR), did not overlap other calls, and were at least a few hours apart to maximize the chance that measured calls represented more than one animal.

3. Results

3.1 Call description

On numerous occasions, analysts observed a multi-part Western Pacific "Biotwang" (WPB) call, so named because of its unusual synthetic sound. WPB calls were complex and difficult to measure, lasting 2.5–3.5 s overall (Fig. 2). The call began with a brief 0.4 ± 0.3 s long tone (Part A) centered at 60.1 ± 6.0 Hz, followed by a 1.6 ± 0.1 s low-frequency moan (Part B) that swept from 44.5 ± 3.5 Hz down to 30.8 ± 2.7 Hz. The moan appeared to have both amplitude modulation and strong harmonics; the harmonic at ~410 Hz was typically one of the stronger components of the call, often

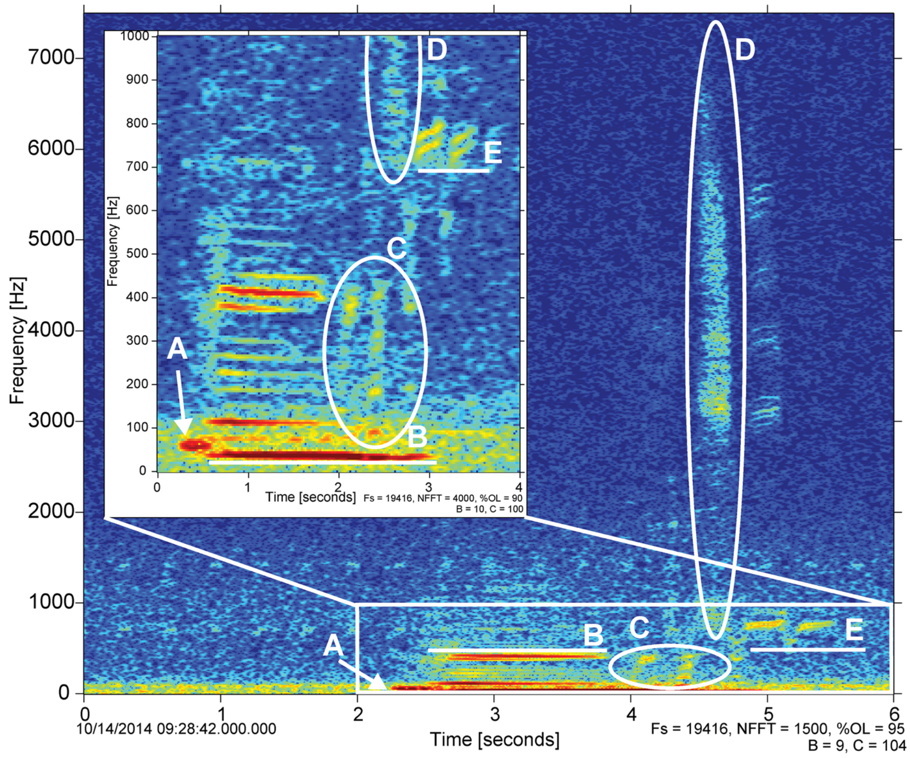

Fig. 2. (Color online) Example of the WPB call recorded 14 October 2014 (NFFT = 1500, Overlap 95%). The call consisted of five distinct parts: a 0.4 ± 0.3 s tone (Part A) centered at 60.1 ± 6.0 Hz; a low-frequency moan (Part B) lasting 1.6 ± 0.1 s and sweeping down from 44.5 ± 3.5 Hz to 30.8 ± 2.7 Hz. The moan appeared to have both amplitude modulation and strong harmonics; two ~60–150 Hz upsweeps lasting 0.5 ± 0.1 s (Part C) that often had diffuse energy up to 1000 Hz; a ~0.2 s long noisy burst of sound with energy up to 7.5 kHz (Part D); and finally, metallic-sounding upsweeps (Part E) lasting 0.66 ± 0.03 s with most energy between 700 and 800 Hz, but up to 7.5 kHz. (Inset) Same WPB call, but showing the 0–1000 Hz portion and detail of lower-frequency components.

appearing above the background noise level in the LTSA, making it useful for finding WPB calls in long recordings. The moan was followed by two ~60–150 Hz upsweeps lasting 0.5 ± 0.1 s (Part C) that often had diffuse energy up to 1000 Hz. Part D of the call started with a ~0.2 s long noisy burst of sound with energy up to 7.5 kHz. The call ended with metallic-sounding upsweeps (Part E) with most energy between 700 and 800 Hz, but up to 7.5 kHz, and lasting 0.66 ± 0.03 s. In calls with low SNR, Parts A, C, D and E were often not visible or audible.

3.2 Call occurrence

Between 14 October and 6 November 2014, 326 of these WPB calls were recorded during 38 glider dives (Fig. 1). Calls were typically 5–6 min apart and often occurred in long sequences. In data from March–April 2015, analysts identified 29 WPB calls during seven glider dives in the northern survey and 81 calls during nine dives in the southern survey (Fig. 1). Calls were recorded during both nearshore and offshore portions of the survey, in shallow and deep water and during all portions of a dive.

4. Discussion

In an ocean soundscape, sounds originate from anthropogenic, geophysical, and biological sources (Pijanowski *et al.*, 2011). The sounds reported here are not similar to known anthropogenic sources such as noise produced by ships or seismic airguns. They also do not resemble geophysical sources such as the very low-frequency sounds produced by earthquakes and ice, nor the sounds produced by wind or rain (Hildebrand, 2009). Using the spectral and temporal criteria long established in the bioacoustics community (Stafford *et al.*, 1999), the authors hypothesize that these complex sounds were produced by a biological source.

Given the call characteristics and low-frequency components of this sound, it is likely produced by a baleen whale. The MTMNM study area may be inhabited, at least seasonally, by numerous species of baleen whales that produce low-frequency vocalizations, including blue (*Balaenoptera musculus musculus* and *B. m. brevicauda*), fin (*B. physalus*), sei (*B. borealis*), Bryde's (*B. edeni*), minke (*B. acutorostrata*), and humpback (*Megaptera novaeangliae*) whales (Department of the Navy, 2005). Blue whale calls can be quite diverse in different acoustic populations, and all calls contain low frequency (<150 Hz) components, but the duration (10–30 s) of blue whale calls (Stafford *et al.*, 2001; Thompson *et al.*, 1996) exceeds the duration of our call. This sound also does not share temporal or aural characteristics with sei whale downsweeps (Rankin and Barlow, 2007), or with the very short, impulsive 20-Hz (Thompson *et al.*, 1992; Watkins, 1981) and 40-Hz (Širović *et al.*, 2013) calls produced by fin whales. Humpback song consists of many complex and diverse sounds repeated in predictable sequences (Payne and McVay, 1971) and does not match the stereotypy we observed in these call sequences.

The low-frequency (<200 Hz) components of this call superficially resemble the short and variable sounds from Bryde's whales. In the Pacific, at least six low-frequency calls have been attributed to Bryde's whales (Heimlich *et al.*, 2005; Oleson *et al.*, 2003). Hill *et al.* (2015, Fig. 16, p. 57) and Oleson *et al.* (2015) report finding sounds similar to the lower parts (Part A and B) of the WPB vocalization in their acoustic data recorded in the Mariana Islands and conclude their sound is similar to a Bryde's whale Be3 call (Oleson *et al.*, 2003). However, the call we report here contains components above 200 Hz, including some components exceeding 7 kHz, and to date there are no published accounts of Bryde's whale calls with anything like the Part D and E components of the WPB vocalization.

When all five parts of the call reported here are examined, including frequencies up to 8 kHz, this sound most closely resembles the "Star Wars" (SW) sound produced by dwarf minke whales on the Great Barrier Reef (Gedamke *et al.*, 2001). The complex structure of the WPB sound, the frequency sweep, and the metallic nature of the final part of this call are all very similar to characteristics of dwarf minke whale SW calls.

Minke whales are found in most of the world's oceans and produce a wide variety of regionally specific calls, including the SW call in northeastern Australian waters, low-frequency pulse trains in the Atlantic (Winn and Perkins, 1976) and boings in the North Pacific (Rankin and Barlow, 2005). Coincidentally, minke whale boing calls were also recorded during our southern survey in March 2015 (Fig. 1). Boings are produced by the common minke whale (*Balaenoptera acutorostrata*) across the North Pacific (Rankin and Barlow, 2005), while SW vocalizations are produced by dwarf minke whales, a conspecific of *B. acutorostrata* occurring in the southern hemisphere close to the equator (International Whaling Commission, 2001; Pastene *et al.*, 1994; Wada *et al.*, 1991). Two additional stocks of common minke whales are known in the western North Pacific, the "J stock," found in the Yellow Sea, East China Sea and the Sea of Japan, and the "O stock" found in the Sea of Okhotsk (Reilly *et al.*, 2008); calls produced by these whales have not been identified. Very little is known of minke whale and dwarf minke whale distribution at low latitudes in the Pacific (Reilly *et al.*, 2008), primarily because the species is the smallest of the baleen whales, produces an inconspicuous blow, spends little time at the surface, and often occurs in areas where high sea states make sighting this species difficult. Given that there are several types of minke whales with unknown vocal behavior in close proximity to our survey area, and that many species of baleen whales, including minke whales, produce regionally distinct calls, the WPB could have been produced by a minke whale.

Seasonal patterns in calling behavior are often used to infer the function of a baleen whale call and the potential source of the call (e.g., Oleson *et al.*, 2007). In this study, WPB calls were recorded during glider surveys in September–November 2014 and March–April 2015, indicating the presence of this species during fall, winter, and early spring. This is similar to the pattern reported by Hill *et al.* (2015), in which their "unidentified whale - tonal calls" were recorded off Tinian in most months of the year. Thus, the species making the WPB call is vocalizing and in the area during both the breeding and feeding season for most baleen whales, indicating that this call may have a complex function similar to blue whale vocal behavior in the Eastern Tropical Pacific (reviewed in Stafford, 2016) or the bio-duck calls recorded in Antarctica (Risch *et al.*, 2014). Interestingly, the J stock of minke whales breeds in fall, which is different from other North Pacific minkes and most other baleen whales that breed in the winter (Reilly *et al.*, 2008). The year-round presence of this call in MTMNM and surrounding waters may facilitate the identification of the species making this sound.

Here we have presented a first report of recordings of a novel call we believe to be from a baleen whale, most likely a minke whale. We have provided a quantitative and qualitative description of the acoustic features and location and timing of detections. In publishing these data, we hope others will be able to identify this call in past and future data, and in time identify the source of this sound. More data are needed, including genetic, acoustic, and visual identification of the source to confirm the species and gain insight into how this sound is being used.

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