Sounds recorded in the presence of Blainville's beaked whales, *Mesoplodon densirostris*, near Hawai'i (L)

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During a combined visual and acoustic cetacean survey of the Hawaiian Islands in 2002, four midfrequency sounds were recorded in close proximity to a group of Blainville's beaked whales, *Mesoplodon densirostris*. These sounds included one frequency-modulated whistle, and three frequency- and amplitude-modulated pulsed sounds, with energy between 6 and 16 kHz. Until recently, little was known of the acoustic behavior of beaked whales, and early descriptions of audible sounds made by beaked whales are incomplete [Caldwell and Caldwell, Cetology **4**, 1–5 (1971); Lynn and Reiss, Marine Mammal Sci. **8**(3), 229–305 (1992); T. C. Poulter, "Marine mammals," in Animal Communication; Techniques of Study and Results of Research, edited by T. A. Sebeok (Indiana University Press, Bloomington, 1968)]. Recent recordings of high-frequency clicks (>20 kHz, [Johnson *et al.*, Proc. R. Soc. London, Ser. B (Suppl.) **271**, 5383–5386 (2004); Zimmer *et al.*, J. Acoust. Soc. Am. **117**(6), 3919–3927.]) were above the frequency response of our equipment, and therefore not detected. Sound production within the midfrequency range of sounds described here suggests that the hearing of *M. densirostris* is sensitive at frequencies used in some types of active sonars. [DOI: 10.1121/1.2743159]

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I. INTRODUCTION

The connection between mass strandings of beaked whales with U.S. Navy midfrequency sonar has led to an increased interest in the acoustic behavior and physiology of beaked whales (Cook *et al.*, 2006; Johnson *et al.*, 2004; Madsen *et al.*, 2005; Zimmer *et al.*, 2005). At present, the cause of strandings remains unclear (Cox *et al.*, 2006). Sounds produced by beaked whales provide insight into their hearing sensitivity and frequency bands important for communication and foraging. Visual and acoustic monitoring for the presence of beaked whales can minimize exposure to sonar and other anthropogenic sounds; however, acoustic monitoring of beaked whales requires an understanding of their vocal repertoire (Barlow *et al.*, 2006; Barlow and Gisiner, 2006).

Until recently, little has been known of the acoustic behavior of beaked whales. Recordings of a stranded Blainville's beaked whale (*Mesoplodon densirostris*) consisted of pulsed and tonal calls in the frequency range of 1–6 kHz (Caldwell and Caldwell, 1971). Poulter (1968) described *Mesoplodon* calls as including "roars" and "lowing and sobbing groans." Lynn and Reiss (1992) recorded broadband pulsed sounds and midfrequency whistles (1.4 to 10.7 kHz) from stranded *M. carlhubbsi* held in captivity. Recently, research using acoustic recording tags has increased our understanding of echolocation of beaked whales (Johnson *et al.*, 2004; Zimmer *et al.*, 2005). Johnson *et al.* (2004) did not detect sounds with significant energy below 20 kHz in either *M. densirostris* or *Ziphius cavirostris*, and no calls of any kind were detected when the animals were within 200 m of the surface. In this paper, we present sounds recorded in the presence of *M. densirostris* during a recent cetacean survey off the Hawaiian Islands.

II. METHODS

The 2002 Hawaiian Island Cetacean Ecosystem and Abundance Survey (HICEAS) survey (Fig. 1), aboard the R/V *David Starr Jordan* and *R/V McArthur*, included the exclusive economic zone of the Hawaiian Island chain and transit to and from San Diego, CA (Barlow *et al.*, 2004). This research project combined visual and acoustic detection of cetaceans using standard protocol designed by Southwest Fisheries Science Center (SWFSC). Visual observation of cetaceans was conducted during daylight hours and consisted of six experienced visual observers rotating between two "big eye" binocular (25×150) stations and one station observing with 7× binoculars and unaided eye (Kinzey *et al.*, 1999).

The acoustics team was on the *Jordan* only, and consisted of two rotating acoustic technicians monitoring a towed hydrophone array and a hull-mounted hydrophone aurally and visually using ISHMAEL real-time spectrogram display (Mellinger, 2001). A hydrophone was mounted to the bow of the *Jordan*, to detect bow-riding dolphins and other cetaceans in close proximity to the bow of the ship, where the towed array has limited detection ability. The bow hydrophone has a limited acoustic range due to high ambient noise levels, and during this survey they were occasionally monitored when animals were near the bow. The frequency response of the bow hydrophone was 500 to 25 kHz (±10 dB). Output from the bow hydrophone was recorded with the output from the towed hydrophone array. The hydrophone array consisted of two elements separated by 3 m, with a fre-

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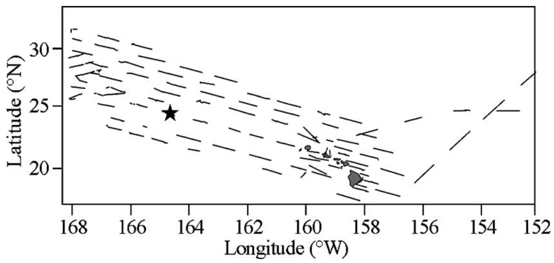

FIG. 1. Map of sighting and acoustic detection of *Mesoplodon densirostris* northwest of the Hawaiian Islands. Tracklines for the HICEAS survey are shown as solid lines, with the *M. densirostris* shown as a star.

quency response of 500 to 25 kHz (±10 dB). The array was towed 200 m behind the vessel at an average speed of 10 knots and an average depth of 6 m. Hydrophone output was passed through a Mackie CR1604-VLZ sound mixer for high-pass filtering of low-frequency noise (cut below 70 Hz). All recordings were made using a Tascam DA-38 digital recorder, sampling at 48 kHz.

III. RESULTS

At 15:57 on 17 October 2002, a group of six *M. densirostris* was detected 200 m in front of the ship 116 km southeast of Laysan Island at 24° 48.13 N, 171° 17.89 W (Fig. 1). The only other sightings within 30 miles were two sightings of sperm whales and two sightings of Bryde's whales. No other cetaceans were seen within three miles of the *M. densirostris*. Beaufort 0 weather conditions provided exemplary views of this group of three cow/calf pairs. During this encounter, 5–7 surfacings were observed before the animals dove within 50 m of the bow at approximately 15:58 local time. At 15:59, four calls were detected on the bow hydrophone with low signal-to-noise ratio (SNR). There was interference from wave noise on the bow and from the anchor knocking against the hull of the ship. No sounds were detected on the hydrophone array. Despite the poor SNR of these recordings, they may prove to be important in understanding the acoustic behavior of *M. densirostris*.

The first of the four calls was a frequency-modulated downsweep, with harmonics [Fig. 2(a)]. The other three calls exhibited both frequency- and amplitude-modulation [Fig. 2(b), Fig. 3]. Due to the low SNR, the pulsed nature of these sounds could not be detected in the waveform, but is evident in the banding found in the spectrogram. The poor quality required that approximations of the call characteristics were made using the spectrogram instead of the waveform (48 kHz sampling rate, 90% overlap, Hann window, 2048 FFT size).

The first two calls are of extremely poor quality, with wave interference separating what appears to be the first and the second call. The first call is a downsweep of at least 1.0 s duration and ranging from 12 to 6.3 kHz [Fig. 2(a)]. The wave noise appears to mask both the lowest frequency and end of the first call as well as the beginning of the second call. The second call appears to be pulsed in nature, with an interclick time interval of 1,474 s^{-1} and duration over 1.0 s [Fig. 2(b)]. The third and fourth calls are both 0.9 seconds in length, and have similar frequency-and amplitude-

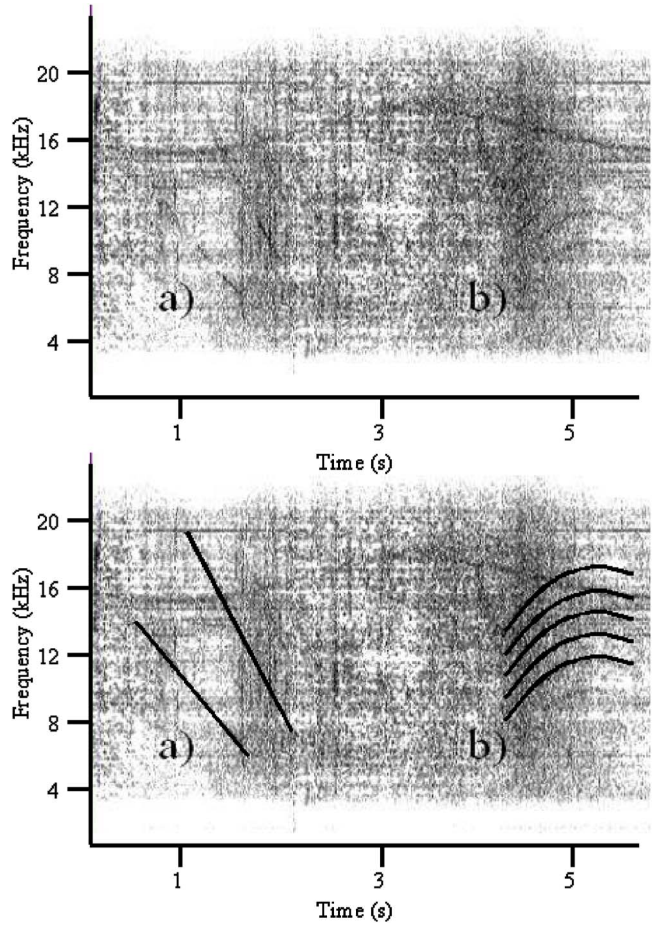

FIG. 2. (Color online) First and second of four vocalizations recorded in the presence of *M. densirostris*, with an outline of the interpreted signals shown in the bottom spectrograph (48-kHz sampling rate, Hann window, 512 FFT size). The first call is a frequency-modulated downsweep (A), and the second call exhibits both frequency- and amplitude modulation (B).

modulations to each other [Figs. 3(a) and 3(b)]. Both calls are pulsed sounds, with the greatest energy between 9.4 and 15.5 kHz. The pulse repetition rate is approximately 711 and 752 s^{-1} for the third and fourth calls, respectively. Due to the poor signal quality, it was impossible to obtain accurate measurements, and these values are intended as a general description of these calls.

IV. DISCUSSION

The sounds described here were produced by a group of three cow/calf pairs in close proximity to the research vessel. The animals dove within 50 m of the bow at the approximate time of this recording, and no other cetaceans were detected in the near vicinity (3 nmi). Although a reasonable comparison cannot be made with the basic descriptions of published accounts of *M. densirostris* vocalizations (Caldwell and Caldwell, 1971; Poulter, 1968), these sounds do appear to be similar to some sounds produced by the highly vocal Baird's beaked whales, *Berardius bairdii* (Dawson *et al.*, 1998; Rankin and Barlow). Recent research using acoustics tags on Blainville's and Cuviers' beaked whales (*Z. cavirostris*) has detected click sounds while the animals were at depth (Johnson *et al.*, 2004). These animals appeared to be feeding,

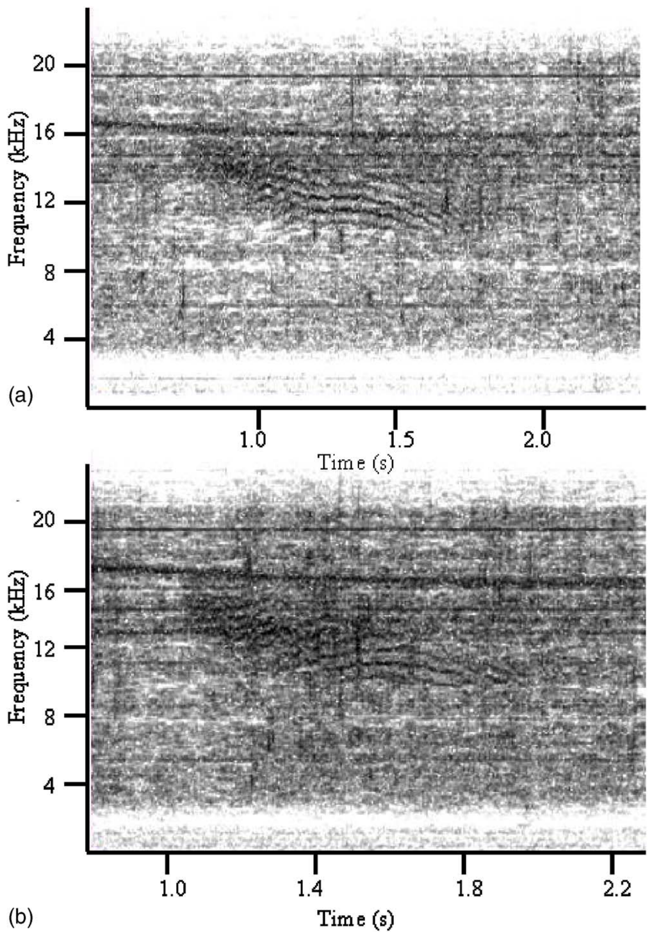

FIG. 3. (Color online) Third (A) and fourth (B) calls, exhibiting both frequency- and amplitude modulation, recorded in the presence of *M. densirostris* (48-kHz sampling rate, Hann window, 512 FFT size).

and no other sound types were recorded from these animals. While it is likely that the predominant sounds of *Mesoplodon* species are clicks produced while foraging, this study shows that they may at least occasionally produce midfrequency tonal sounds like those sounds that have been associated with communication in other species.

In five seasons of combined visual and passive acoustics cetacean surveys, including 51 964-km survey effort, sounds from only 2 of 72 beaked whale sightings have been detected on a towed hydrophone array (Barlow and Rankin). Both of these detections were of *B. bairdii* in Alaskan waters. The sounds of *M. densirostris* presented here were detected on bow hydrophones, and were not detected on the towed hydrophone array. Detection of sounds on the hydrophone array within 15 deg of the bow is negatively affected by the physical presence of the ship, and sounds detected with this range tend to have a high SNR (Rankin and Barlow). Beaked whales spend a relatively short time in surface waters, and most calls are high-frequency echolocation clicks produced at depth, far below the depth and above the frequency range of our towed hydrophones. We were unable to determine the source level of the sounds detected on the bow hydrophone; however, the poor SNR on the bow hydrophone and the fact that they were not detected on the hydrophone array indicate that they were likely low in intensity.

Despite the paucity of data concerning the hearing sensitivity of beaked whales, it is reasonable that they should have sensitive hearing at those frequencies that they utilize. Thus, it is expected that Blainvilles' beaked whales should have sensitive hearing in these midfrequency ranges. Cook *et al.* (2006) found that *M. europaeus* could minimally detect sounds between 5 and 80 kHz, with a similar hearing sensitivity at 5 kHz as the bottlenosed dolphin, *Tursiops truncatus*. The pulsed sounds presented in this paper provide verification that beaked whales do, indeed, use midrange frequencies which overlap in frequency with some naval sonar applications.

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