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NOTE

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Unique morphological and acoustic characteristics of beaked whales (*Mesoplodon* sp.) off the west coast of Baja California, Mexico

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Three new species of beaked whales (Ziphiidae) have been described in the past three decades: the pygmy beaked whale (*Mesoplodon peruvianus*; Reyes et al. 1991), Perrin's beaked whale (*Mesoplodon perrini*; Dalebout et al. 2002), and Sato's beaked whale (*Berardius minimus*; Yamada et al. 2019). Perrin's beaked whale has never been identified alive and was discovered accidentally through genetic analysis of stranded whales in California that had been misidentified as Hector's beaked whale (*Mesoplodon hectori*; Dalebout et al. 2002). However, before they were formally described, field naturalists had identified the pygmy beaked whale as a new species and given it the interim name *Mesoplodon* sp. A (Pitman et al., 1987; Pitman & Lynn, 2001). Sato's beaked whale was known to whalers and given the colloquial name *kuro-tsuchi* or black Baird's beaked whale before its existence was known to science. Based on this recent history, more beaked whale species may be awaiting discovery and are likely to be recognized in the field before they are formally described. Here we present photographic and acoustic features of an unidentified *Mesoplodon* seen off the west coast of Baja California, Mexico, that are distinct from any of the mesoplodonts known to regularly occur in the northeast Pacific. These observations may therefore represent the first record of a new taxa.

Previous acoustic studies characterized a unique beaked whale echolocation signal (called BW43) that, based on its limited distribution off southern California, was believed to be made by Perrin's beaked whale (Baumann-Pickering et al., 2013). An acoustic survey in 2018 used drifting buoy recorders and identified an area with a high density of BW43 signals off the Pacific coast of Baja California, Mexico (Simonis et al., 2020). During November 15–28, 2020, we surveyed this area in the 24 m sailing vessel *Martin Sheen* of the Sea Shepherd Conservation Society in an attempt to observe, photograph, and acoustically record Perrin's beaked whale at sea for the first time.

At 06:08 PST on November 17, 2020, a group of three beaked whales was encountered approximately 100 km SW of San Quintín, Baja California, Mexico. The sighting location (Figure 1) was above an undersea ridge at a water depth of ~900 m. When the vessel stopped, the animals approached it several times, coming within ~30 m, allowing 953 above-water photographs and below-water video to be taken. One whale gave several tail slaps, but no breaches or other surface-active behaviors were observed. A launch was deployed to follow the group but was unable to obtain additional photographs or a skin biopsy. Water samples were taken in the whales' "flukeprints" for

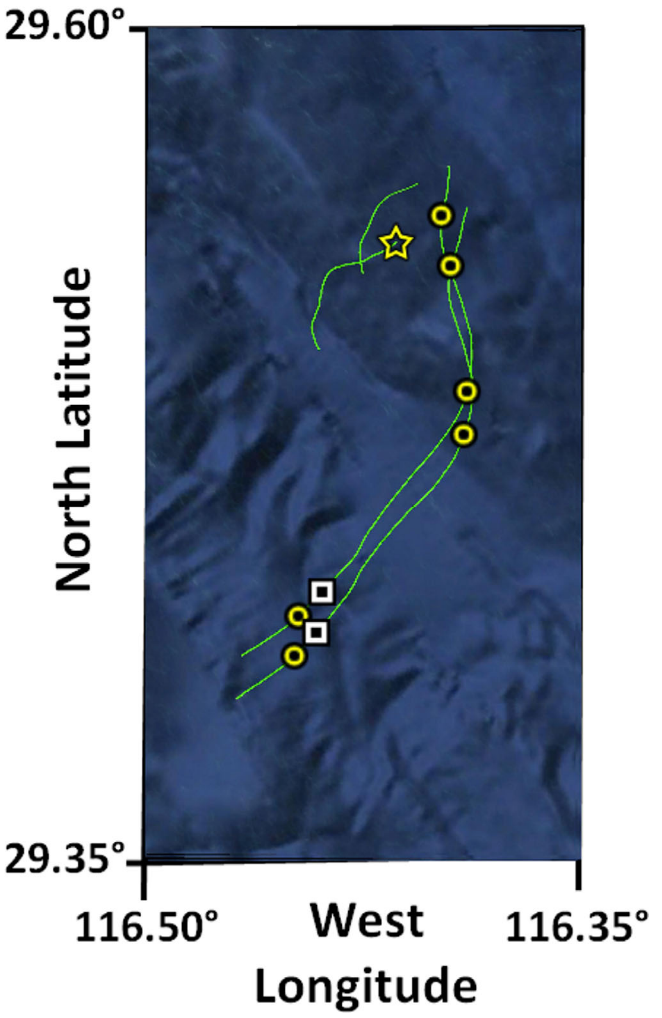

FIGURE 1 Sighting location (yellow star at 29.5369°N, 116.4142°W), drift tracks for four acoustic recorders, and acoustic detection locations for bouts of BWB (yellow circles) and *Z. cavirostris* (white squares) echolocation pulses. No beaked whales were detected on the two shorter drifts. Paired detections on the two longer drifts were concurrent and likely from a single animal or group on the same foraging dive.

future eDNA analyses. During the 72 min encounter, the group made frequent short dives of 5–11 min with 1–2 min surfacing periods. The group was last seen at 07:20 PST. Four drifting recording systems were deployed in the vicinity of the sighting at 06:25, 09:26, 11:03, and 11:26 PST (Figure 1). The first two hydrophone recording systems used a Soundtrap ST300HF at ~10 m depth with a 576 kHz sampling rate. The second two used a Soundtrap ST4300 multichannel recorder with a sampling rate of 288 kHz with input from two external hydrophones (one HTI-92-WB and one HTI-96-min, configured as a 5 m vertical array at ~150 m depth). All recording systems had a flat frequency response (±2 dB) from 100 Hz to 65 kHz and a useable frequency range from 20 Hz to 144 kHz.

A photographic catalog of the three whales was created composed of left- and right-side dorsal fin and left-side head images from all individuals, right-side headshots from two individuals, and scaring patterns on adjacent dorsal surfaces. The photographs show a beaked whale with a falcate dorsal fin and a short beak that is most similar to other beaked whales in the genus *Mesoplodon* (Figures 2 and 3). One of the whales had an elevated mandibular arch with a single, barely exposed tooth on top of the arch and is therefore presumed to be a male. The region immediately below the tooth was darkly pigmented. The color patterns include dark gray-brown shading along the dorsal side all the way to the tip of the upper rostrum, light coloration on the ventral side that extends from the tip of the lower rostrum to the insertion of the flukes and about halfway up the side body, and a distinct, irregular line separating the two regions. The lighter ventral coloration continues up around either side of the eye and along the full extent of the lower jaw. The eye area itself is dark, and a dark band extends upwards from the eye and over the head toward an area behind the blowhole. An irregular, lightly pigmented cheek patch is ahead of the eye patch. The gape line is very dark, creating a distinct line where the upper and lower jaws come together. Underwater video revealed the presumed male to be more robust than but similar in size to the other two whales. The male had a few, single, linear scars along the back that were relatively inconspicuous. All animals showed numerous white scars from healed and healing cookiecutter shark (*Isistius* sp.) bites.

The three animals displayed a distinctive set of external morphological features that do not match any known species in the genus *Mesoplodon*. Based on strandings, at least six *Mesoplodon* species are found in the eastern North Pacific (MacLeod et al., 2005), but five can be eliminated from consideration based on morphological features alone. Perrin's beaked whale has a pair of exposed teeth at the tip (not the middle) of the mandible (Dalebout et al., 2002). Pygmy beaked whale has a triangular (not falcate) dorsal fin, and the adult male has a conspicuous, and diagnostic, white "shawl" pattern and a larger exposed tooth. Blainville's beaked whale (*M. densirostris*) has a conspicuously flat head with a high-arching lower jaw, and the adult male a massive tooth raised above the level of the top of the head. Hubb's beaked whale (*M. carlhubbsi*) has a white-tipped beak and a white patch on top of its melon and also has a massive, exposed tooth. Stejneger's beaked whale (*M. stejnegeri*) occurs further north in the eastern North Pacific and would be extralimital off Baja California; also, the exposed tooth in the adult male is massive compared to the male we photographed. Gray's beaked whale (*Mesoplodon grayi*), a temperate beaked whale in the South Pacific, has a much longer, more slender beak than the whales we saw.

Among mesoplodonts recorded in the North Pacific, the tooth size and location in the adult male in the Baja whale most closely resembles that of the ginkgo-toothed beaked whale (*M. ginkgodens*) and the recently recognized Deraniyagala's beaked whale (*M. hotaula*; Dalebout et al., 2014). Both are known only from stranded specimens, and neither has been reliably identified at sea. The ginkgo-toothed beaked whale is believed to have a tropical and warm temperate distribution throughout most of the Indo-Pacific (figure 2(i) in MacLeod et al., 2005). There has been only one stranding in the eastern North Pacific (Del Mar, California, 1954; Leatherwood et al., 1982). Photographs of freshly stranded specimens typically show black dorsal and dark ventral coloration with a white tip on the upper and lower sides of the beak (Reeves et al., 2002; Dalebout et al., 2014). However, the California specimen showed lighter overall coloration, a lightly pigmented lower jaw, and a darkly pigmented upper rostrum (Leatherwood et al., 1982), similar to the observed animals. Despite these physical differences, the control region of the mitochondrial DNA of the California specimen was nested within other ginkgo-toothed beaked whales from New Zealand, Taiwan, and Japan in a phylogenetic tree (Dalebout et al., 2007). Deraniyagala's beaked whales are known to occur only in tropical waters from the Seychelles, in the central Indian Ocean, to Palmyra Island in the central tropical Pacific (Dalebout et al., 2014). Their overall

FIGURE 2 Photographs of the unidentified *Mesoplodon* encountered off Baja California, Mexico, on November 17, 2020. Markings include a slightly darker band that travels up and back from the dark eye spot, dark gape line, lighter ventral coloring extending up the side of the body with a darker lateral band, and lighter coloring in front of and behind the dark eye spot. The tooth (yellow arrows) in the male is located midway along the moderately arched lower jaw with dark pigmentation below it, and the dorsal fin is falcate. Pock marks and pale oval areas are cookiecutter shark bite scars; linear scars are presumably tooth rake marks from other males and are not paired as in some beaked whale species. Photographs (a), (c), and (f) are of the mature male; photographs (b), (d), and (e) are of the other two whales (females or juvenile males).

coloration is described as dark dorsally and grading to lighter pigmentation ventrally and with a lightly pigmented eye patch and a lightly pigmented throat and lower jaw (Baumann-Pickering et al., 2010; Dalebout et al., 2014). Although the observed animals may exhibit a geographic variation of the color patterns of ginkgo-toothed or Deraniyagala's beaked whales and we cannot rule out either species, their external features do not match any published descriptions of these species. Superficially, the whales we saw closely resemble a group of *Mesoplodon* beaked whales (described as either *M. ginkgodens* or *M. hotaula*) photographed recently in the South China Sea (Rosso et al., 2020) but differ in the shape of the cheek patch and the presence of dark pigmentation below the tooth in the male.

Acoustic recordings provide additional evidence of the distinctiveness of the observed animals. Two of the drifting systems recorded a novel beaked whale echolocation pulse type (referred to here as BWB, following the

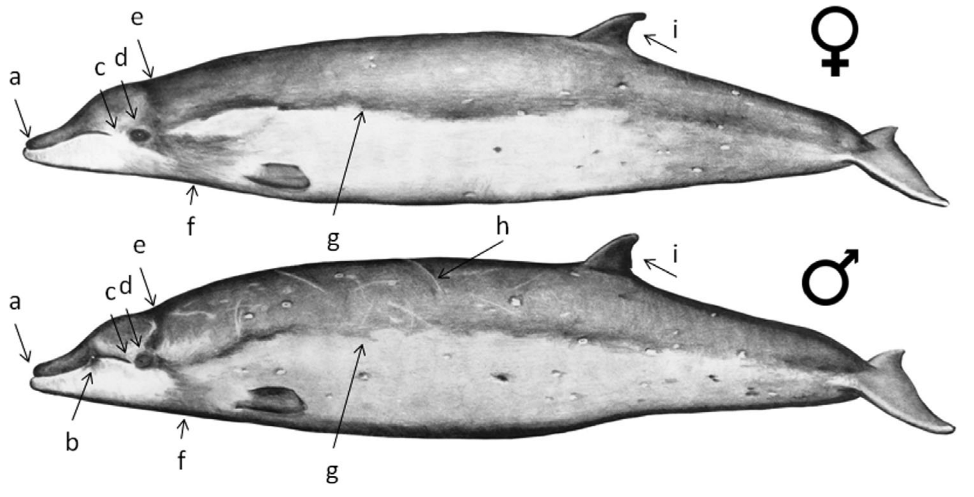

FIGURE 3 Features seen on an unidentified *Mesoplodon* from still and video images. Features include (a) an upper rostrum that is darkly pigmented to the tip and a lightly pigmented lower rostrum, (b) a small tooth in the mid-jaw position of the male with dark pigmentation below, (c) a light cheek patch forward of the eye that bifurcates dorsally, (d) a dark eye patch, (e) a darkly pigmented band from behind the blowhole towards the eye patch, (f) an irregular shaped dark patch posterior to a light throat patch, (g) an irregular, but sharp delineation between a darkly pigmented dorsal surface and lightly pigmented ventral surface, (h) unpaired linear scars on the male, and (i) a falcate dorsal fin varying in shape among individuals. Note, the sex of the presumed female was not confirmed. Drawings by B. Taylor.

nomenclature used by Baumann-Pickering et al., 2013) on three occasions at ~8, 15, and 27 hr after the initial sighting and at initial distances of 1.8 and 2.0 km from the sighting location (Table 1). Echolocation pulses from a Cuvier's beaked whale (*Ziphius cavirostris*) were also recorded on one occasion by both recorders. The novel pulses (Figure 4) had a frequency upsweep, as is typical for beaked whales, and often had two distinct frequency peaks. Peak frequencies, 3 and 10 dB bandwidths, and interpulse intervals were measured separately for 19 bouts of what appeared to be continuous echolocation pulses. The means (and standard deviations) for the two frequency peaks are 40.6 ($SD = 1.6$) and 23.6 ($SD = 0.9$) kHz. The 3 dB bandwidth is 35.7–47.1 kHz ($SD = 0.8$ and 1.9 kHz, respectively). The 10 dB bandwidth is 32.4–54.4 kHz ($SD = 1.1$ and 3.2 kHz, respectively). The mean interpulse interval (IPI) is 0.217 ($SD = 0.029$)s.

The recorded echolocation pulses do not match previously described pulse types for any beaked whale species. The secondary frequency peak is similar to the secondary 24 kHz peak seen for True's beaked whale (*M. mirus*) (figure 5 in DeAngelis et al., 2018). Although the primary frequency peak and IPI are within the ranges reported for the BW43 echolocation pulse,[1] the secondary frequency peak is not seen in BW43 pulses (Baumann-Pickering et al., 2013). Baumann-Pickering et al. (2013) also described another beaked whale echolocation pulse type, BW40, with a peak frequency near 40 kHz, but that signal also did not show secondary peaks at lower frequencies and had a much longer mean interpulse interval (0.435 s). The presumed echolocation pulses of ginkgo-toothed beaked whales (BWC) are much longer and have a higher peak frequency (46.9 kHz; Baumann-Pickering et al., 2013) than the pulses we recorded. The echolocation pulse of Deraniyagala's beaked whale also has a higher peak frequency (47.3 kHz; Bauman-Pickering et al., 2013). Although FM-pulses have only rarely been recorded in the presence of a known *Mesoplodon* species, the beaked whales that have been studied to date are believed to produce a single species-specific type of frequency-modulated pulse (Baumann-Pickering et al., 2013); therefore, our acoustic data alone are sufficient to suggest the existence of an undescribed beaked whale species in our study area.

The combination of photographic and acoustic evidence supports the possible existence of an undescribed beaked whale species off Baja California. Although the color patterns seen in our photographs could represent a

TABLE 1 Times and durations of bouts of BWB echolocation pulses on two drifting recording systems in the vicinity of the beaked whale sighting (Figure 1) and distances from that sighting location at the start of each bout. Based on the times and durations, each bout likely represents a portion of a foraging dive, and three foraging dives were detected on both recorders.

Drift ID	Start date, time (UTC)	End date, time (UTC)	Echolocation duration (min)	Number echolocation pulses	Time after sighting (hr)	Distance from sighting (km)
5	November 17, 2020, 22:05	November 17, 2020, 22:19	14.18	43	8.0	1.99
5	November 18, 2020, 05:36	November 18, 2020, 05:44	7.55	122	15.5	6.79
5	November 18, 2020, 17:20	November 18, 2020, 17:25	4.25	80	27.2	14.20
6	November 17, 2020, 21:55	November 17, 2020, 22:20	24.60	403	7.8	1.81
6	November 18, 2020, 05:43	November 18, 2020, 05:43	0.02	4	15.6	5.50
6	November 18, 2020, 17:18	November 18, 2020, 17:22	4.02	28	27.2	12.88

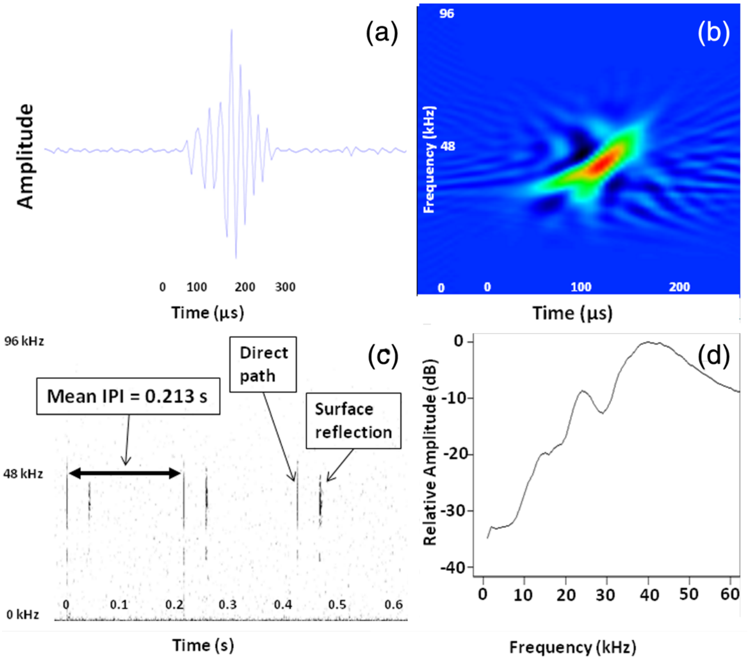

FIGURE 4 Acoustic characteristics of the BWB echolocation pulse recorded in the vicinity of the beaked whale sighting. Waveform and Wigner-Ville transformation for a typical high-SNR pulse are given in panels A & B (respectively). The spectrogram (C) illustrates three strong echolocation pulses with associated surface reflections and a typical interpulse interval (IPI). The frequency spectrum (D) was calculated as the mean of 403 pulses from the first encounter of drift 6 (Table 1) with a 288-pt FFT size (1 ms) and a resolution of 1 kHz. Panels C & D show a primary frequency peak at ~39 kHz and a secondary frequency peak at ~23 kHz.

geographic variation within one of the described species of beaked whale, the recordings of a novel beaked whale echolocation signal in the immediate vicinity make that less likely. Following the nomenclature guidelines of Horton et al. (2021) for unidentified species, we propose the interim name *Mesoplodon* sp. Baja2020 *aff. Ginkgodens* in referring to this morphotype. The full description of a new species would require a holotype specimen, either a skull or a complete genetic sample. We hope to motivate researchers to obtain these needed data.

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AUTHOR CONTRIBUTIONS

Jay Barlow: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; resources; software; validation; visualization; writing - original draft; writing-review & editing. **Gustavo Cárdenas-Hinojosa:** Conceptualization; funding acquisition; investigation; methodology; project administration; resources; writing-review & editing. **E. Henderson:** Conceptualization; data curation; funding acquisition; investigation; methodology; project administration; resources; supervision; visualization; writing - original draft; writing-review & editing. **Dawn Breese:** Investigation; methodology; resources; writing-review & editing. **Diana López-Arzate:** Data curation; investigation; writing-review & editing. **Eva Hidalgo Pla:** Funding acquisition; project administration; resources; writing-review & editing. **Barbara Taylor:** Visualization; writing-review & editing.

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ENDNOTE

[1] A partial reanalysis of the Simonis et al. (2020) data showed that some of the beaked whale pulses that were identified as BW43 and motivated this study to find Perrin's beaked whale were actually this newly recognized BWB pulse type. Now recognizing the differences, a reanalysis of all the 2018 data is needed to identify the distributions of these similar signals.

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