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VOCALIZATIONS OF THE SEI WHALE *BALAENOPTERA BOREALIS* OFF THE HAWAIIAN ISLANDS

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ABSTRACT

Little is known about the sounds produced by the Sei Whale *Balaenoptera borealis* and no recordings have been made in their presence in the Pacific Ocean. This research presents sounds recorded in the presence of Sei whales near the Hawaiian Islands in November, 2002. A total of 107 vocalizations, including two variations of low-frequency downswept calls, were measured. Two of these calls were sweeps from 100 Hz to 44 Hz, over 1.0 seconds. The second call type (n=105) consisted of low-frequency calls which swept from 39 Hz to 21 Hz over 1.3 seconds. These calls are different from sounds attributed to Sei whales in the Atlantic and Southern Oceans, where recordings were made only in the summer months. These sounds are similar, however, to sounds attributed to fin whales in Hawaiian waters. Additional studies are needed in order to understand the spatial and temporal variation in the vocal repertoire of Sei and Fin whales in the Pacific Ocean.

INTRODUCTION

The vocal behaviour of the Sei Whale *Balaenoptera borealis* is poorly known. Thompson *et al*. (1979) recorded pulse trains of 7-10 metallic pulses, with peak energy at 3 kHz, in the presence of Sei whales between Nova Scotia and Newfoundland. Low frequency cable noise prevented the detection of low frequency sounds during these recordings. Knowlton *et al*. (1991) recorded similar pulse sounds in the presence of Sei whales off of Nova Scotia. More recently, recordings were made near a group of Sei whales off the Antarctic Peninsula (McDonald *et al*. 2005). These recordings included broadband "growl" and "whoosh" sounds (100-600 Hz, 1.5 s duration) and tonal and upsweep calls that often appeared "stepped" (200-600 Hz, 1-3 s duration). Previously, there were no known recordings of Sei whales in the Pacific Ocean.

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During a 2002 cetacean survey of the U.S. waters off the Hawaiian Islands, several groups of Sei whales were encountered approximately 60 km NNE of Maui. Here we describe the calls we recorded from one of those groups on November 20, 2002.

The Sei Whale is found primarily in temperate waters and is easily confused with the more tropical Bryde's whale, especially in the southern regions where their distributions overlap (Leatherwood *et al*. 1988). A mid-winter southward migration of Sei whales appears to coincide with a peak in sexual activity and calving for this species (Jefferson *et al*. 1993). In the North Pacific Ocean, the summer distribution of the Sei Whale extends from California westward to Japan and northward to the Aleutian Islands. In the eastern North Pacific, their winter distribution is shifted south, from Piedras Blancas in California to the Revillagigedo Islands off Mexico, but in the rest of the North Pacific their winter distribution is largely unknown. Sei whales had not previously been known to inhabit the waters surrounding the Hawaiian Islands (Shallenberger 1981; Mobley *et al*. 2000; Mobley 2002).

METHODS

The Hawaiian Island Cetacean and Ecosystem Assessment Survey, HICEAS, was a combined visual and acoustic survey of cetaceans in the exclusive economic zone (EEZ) surrounding the Hawaiian Islands from July to December, 2002 (Barlow 2006). The visual observation team consisted of six experienced biologists rotating between two "big-eye" (25x150) binocular stations and one station observing with 7x binoculars and unaided eye. The acoustics team monitored cetacean vocalizations using a towed hydrophone array for odontocetes and sonobuoys for baleen whales.

Between November 20-22, five groups of Sei whales were sighted by the visual observation team; the only other cetacean sightings during these three days was a group of sperm whales on November 20. At 16:32 local time on November 20, 2002, a navy-surplus type AN/SSQ-53A sonobuoy (frequency response 10 Hz to 2.4 kHz) was deployed within 100 m of a group of three Sei whales at 21º 25.32 N, 156º 00.57 W (Figure 1). The identification of this group as Sei whales was made by an experienced team of marine mammal observers and was verified genetically from several biopsy samples (R. LeDuc, Pers. Comm.). Two hours were spent in the vicinity of this group of Sei whales; no other cetaceans were detected in the immediate area. The sonobuoy signal was transmitted to a radio receiver on the ship, and recordings were made on a Sony DAT PCM-R500 (sample rate 48 kHz). Measurements of the high frequency, low frequency, frequency shift, spectral peak frequency, and duration were made from all calls

of sufficient intensity. Frequency measurements were made using SpectraPlus digital signal processing software at a sampling rate of 5512 Hz (8,192 FFT size, Hanning window). Signal duration was measured from the spectrogram using a sampling rate of 44.1 kHz (32,768 FFT size, 90% overlap). Intense low frequency noise caused by the close proximity of the R/V *McArthur* precluded measurements of signal intensity or use of the waveform for analysis.

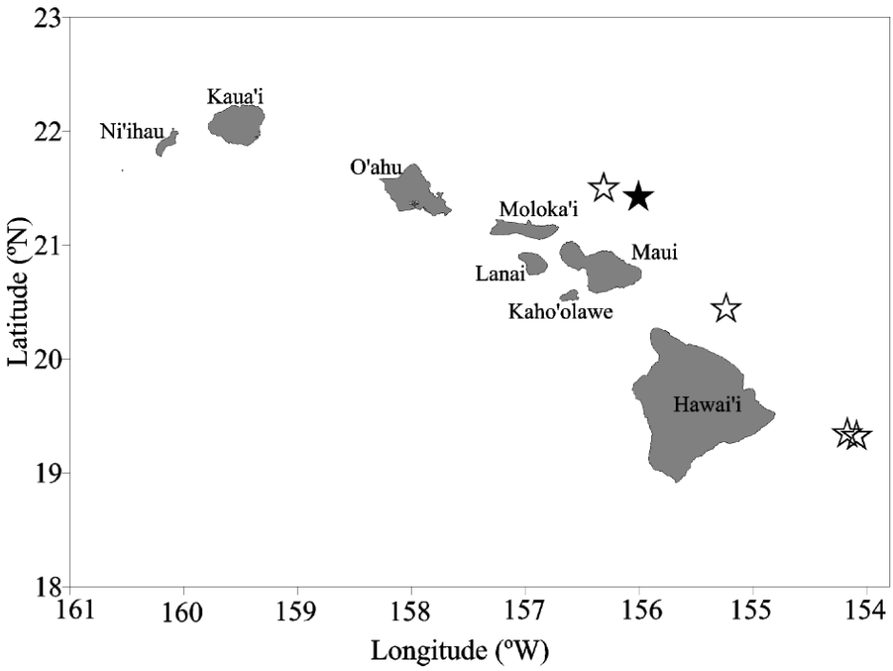

Figure 1. Map of the main Hawaiian Island archipelago, with the location of the Sei Whale recordings and associated sighting indicated by a black star. This corresponds to HICEAS sighting number 284. Additional sightings of Sei whales near the Hawaiian Islands during the HICEAS survey are indicated by the open stars.

RESULTS

A total of 107 vocalizations were measured from a total of 2 hrs and 22 min of recordings. All vocalizations were downswept tonal calls; however, the first two were significantly higher in frequency than the other 105 vocalizations (Figure 2). The two high-frequency downswept calls ranged from an average of 100.3 Hz down to 44.6 Hz over 1.0 s duration (Figure 2, Table 1). The 105 lower frequency downswept calls ranged from a mean high frequency of 39.1 Hz down to 21 Hz over 1.3 s duration (Figure 3, Table 1). We attributed all of these calls to the nearby Sei whales because of the high received

levels (as indicated by the signal-to-noise ratio) and because no other balaenopterids were seen that day. Due to the close proximity of the whales to each other and to the sonobuoys, we were unable to take advantage of the directional capacities of the DIFAR sonobuoys to distinguish individual calling whales.

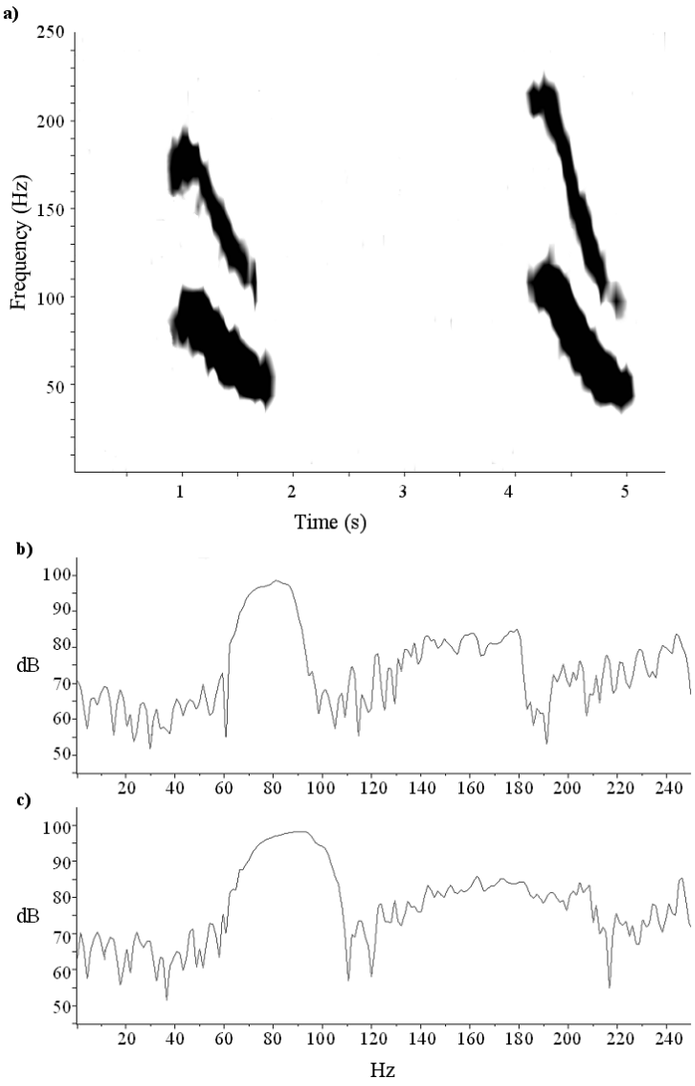

Figure 2. Spectrograph (a) of high-frequency Sei whale vocalizations with harmonics (5512 Hz sample rate, 512 FFT, Hann window). Spectrum (b, c) are associated with the two spectrographs shown in (a), respectively.

TABLE 1

Summary statistics for Sei Whale vocalizations. Two calls were detected, a high frequency downsweep (n=2) and a low frequency downsweep (n=105).

	Sample Size	High Frequency (Hz)	Low Frequency (Hz)	Frequency Shift (Hz)	Duration (s)
High Frequency Sweep	2				
mean		100.3	44.6	55.6	1.2
standard deviation		11.1	2.9	14.0	0.07
range		(92.4-108.0)	(42.6-46.6)	(45.7-65.4)	(1.12-1.22)
Low Frequency Sweep	105				
mean		39.4	21.0	18.4	1.2
standard deviation		3.4	2.4	3.6	0.11
range		(31.3-49.4)	(15.7-27.3)	(8.2-29.6)	(0.85-1.44)

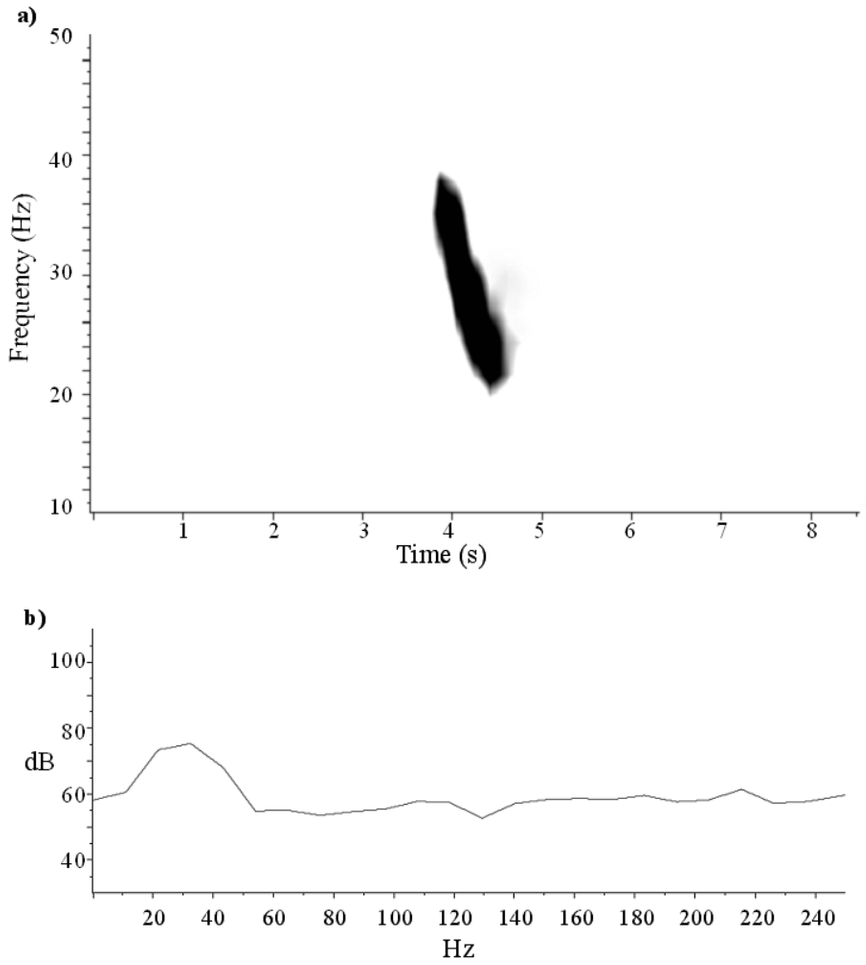

Figure 3. Spectrograph and spectrum of low-frequency downswept Sei whale vocalization (5512 Hz sample rate, 2048 FFT, Hanning window).

DISCUSSION

These Sei whale calls are similar in frequency and duration to calls attributed to fin and Bryde's whales. These calls can be easily discriminated from all of the described call types for Bryde's whales (Cummings *et al.* 1986; Oleson *et al.* 2003; Heimlich *et al.* 2005). Fin whale calls are generally categorized into two types: 20-Hz stereotyped pulses and other higher frequency downswept pulses. The 20-Hz pulses are well-described in the literature and have been conclusively linked to fin whales in both the Atlantic and Pacific Oceans. Downswept calls with frequencies between 20 and 200 Hz have been found for most balaenopterids, including fin whales (Watkins 1981; Thompson

et al. 1992; Cummings *et al*. 1986), blue whales (Rankin *et al*. 2005; Thompson & Cummings 1996; Ljungblad *et al*. 1997), Bryde's whales (Cummings *et al*. 1986) and minke whales (Schevill & Watkins 1972). In general, these sounds are not detected in stereotyped patterns, and are typically detected near larger groups of whales.

The vocalizations recorded in the presence of Sei whales during this survey closely resemble the "20- to 35-Hz irregular repetition interval" downswept pulses described from seafloor recordings off of O'ahu, Hawai'i (Thompson & Friedl 1982; McDonald & Fox 1999). These sounds have been attributed to fin whales based on similarities to the 20-Hz pulses and based on recordings made in the presence of fin whales off of California (McDonald & Fox 1999). The Sei whale vocalizations presented here were longer in duration (1.2 s) than those recorded in the presence of fin whales (0.8 s), but cannot be distinguished from the "20- to 35- Hz" calls based on frequency characteristics.

Thompson and Friedl (1982) described a bimodal seasonal peak in the detection of 20-Hz fin whale pulses as well as the "20- to 35-Hz" calls, with a two-month delay in peak detection of the 20-Hz fin whale calls. Thompson and Friedl (1982) suggested that the bimodal detection of vocalizations reflect a local change in the detection of calling whales as they migrate past O'ahu. The two peaks in detection of "20- to 35-Hz" calls occurred in August and November. There was a marked decrease in detection of 20-Hz fin whale calls in November. Our sighting and recordings of Sei whales off O'ahu in November coincided with a peak in "20- 35-Hz" pulses (Thompson & Friedl 1982). Likewise, McDonald and Fox (1999) reported that 90% of purported fin whale calls recorded by seismology and military systems in the North Pacific were these "20- to 35- Hz" calls. Given the overlap in geographic and seasonal occurrence, as well as the frequency and temporal characteristics, it is possible that at least some of the "20-35-Hz" pulses described in these studies were produced by Sei whales.

The vocalizations recorded from the Hawaiian Sei whales are different from recordings made in the presence of Sei whales elsewhere in the world. The recordings off of Nova Scotia and the Antarctic Peninsula were made in high latitude feeding grounds during the summer months. The Hawaiian recordings were made in the late autumn (November 20) in lower latitudes. There are two likely explanations for the large differences in call characteristics. First, this variation may be due to geographic separation, suggesting that different Sei whale populations produce different stereotypic calls. A second explanation is that Sei whales may produce different types of calls in the low latitude wintering grounds than in the high latitude feeding grounds, as do humpback whales (Payne & McVay 1971). Low-frequency downswept calls have been recorded in the presence of most baleen whales species, and these sounds may serve a different

function from the geographically distinct stereotyped vocalizations considered to be "song".

Sei whales are listed as endangered under the U.S. Endangered Species Act and protected under the U.S. Marine Mammal Protection Act. Considering that these species are typically found in offshore waters, accurate population estimates are difficult to obtain using conventional ship and aerial methods. An understanding of the vocal repertoire of this species may allow for more accurate population information for the pelagic Sei whale. However, unless these Sei whale calls can be unambiguously distinguished from the "20- to 35- Hz" sounds attributed to fin whales, the use of these sounds in population studies is limited. Additional acoustic monitoring is needed in order to increase our understanding of the spatial and temporal variation in the vocal repertoire of Sei and Fin whales. This and other studies of balaenopterid vocalizations show the importance of using acoustic equipment, such as sonobuoys, that can detect very low frequency signals.

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