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Acoustic signals of the Vaquita (*Phocoena sinus*)

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Summary

This report describes the first sounds recorded from the phocoenid porpoise, vaquita, (*Phocoena sinus*, Norris & McFarland, 1958). High-frequency recordings were obtained near free-ranging vaquita in the northern Gulf of California in 1986 and 1987. All *P. sinus* clicks were sharp, intense, and narrow-band ($\chi = 17.1 \pm$s.d. 5.38 kHz) signals that ranged in frequency from 122.2–146.9 kHz, and dominant frequencies ranging from 128.0–139.0 kHz. Click duration ranged from 79–193 µsec. *Phocoena sinus* acoustic signals were similar to those described for other members of the Phocoenidae as well as the distantly related delphinids,* *Cephalorhynchus spp.* Similarities in sound structure among these species are probably linked to the utilization of analogous habitats.

Introduction

The phonations of only three species of the family Phocoenidae have been described (Kamminga, 1988; Watkins & Wartzok, 1985). This includes accounts of sounds produced by *Phocoenoides dalli* (Awbrey *et al.*, 1979; Kamminga, 1988; Ridgway, 1966) and *Neophocaena phocaenoides* (Kamminga, 1988; Kamminga *et al.*, 1986; Mizue *et al.*, 1968). Descriptions of *Phocoena phocoena* echolocation signals were provided by Busnel *et al.* (1963), Busnel *et al.* (1969), Schevill *et al.* (1969), Zaslavsky *et al.* (1969), Dubrovskii *et al.* (1971), Møhl & Anderson (1973), Kamminga & Wiersma (1981), and Kamminga (1988). However, due to recording system limitations prior to the 1970s, only Møhl & Andersen (1973), Kamminga & Wiersma (1981), and Kamminga (1988) described the ultrasonic (125–135 kHz) component of *P. phocoena* clicks.

Phocoenid vocalizations consist of clicks that are high frequency (100–160 kHz), narrow band (10 kHz), short duration (100–150 µsec.) (Kamminga & Wiersma, 1981; Møhl & Andersen, 1973), and are formed into a narrow (30° wide) forwardly directed beam (Møhl & Andersen, 1973). Unlike most delphinids, whistles have not been reported in phocoenids.

To date, there are no accounts of sounds produced by the remainder of the phocoenid species, *P. sinus*, *P. spinipinnis*, and *Australophocaena dioptrica*. There have been few opportunities to record vaquita vocalizations because the species is endemic to the Gulf of California, Mexico, and it is seen infrequently (Brownell, 1986; Silber 1988, 1990). A description is provided here of pulsed signals recorded near free-ranging vaquita in the northern Gulf of California in 1986 and 1987.

Materials and Methods

High frequency recordings of *P. sinus* were obtained from an 8 m vessel, using a Racal Store 4DS reel-to-reel tape recorder, an ATC high-frequency hydrophone, and a University of California fabricated pre-amplifier. High-pass filters were used to filter out noise in the sonic frequency ranges. When used at a tape speed of 30 ips, the system had a flat frequency response from 50 Hz to 150 kHz, and at 60 ips the frequency response was flat from 100 Hz to 300 kHz. During all recordings the hydrophone was deployed at a depth of approximately 2 m.

Seven recordings were attempted within 200 m of *P. sinus*. However, phonations from *P. sinus* were recorded on only three occasions, when the animals were close (< 50 m) to the hydrophone. One recording, obtained when a vaquita adult/calf pair were seen within 50 m of the boat, was made on 25 March 1986. The location (31°07′N; 114°42′W) was within 10 km of San Felipe, Baja California Norte, in 15.0 m of water. The second recording was made on 27 March 1986, 9 km NE of San Felipe (31°05′N; 114°45′W) also in a water depth of 15.0 m. During the recording session, a vaquita adult/calf pair surfaced within 20 m of the vessel, while swimming toward us. Both of these recordings were made at 30 ips and using a 500 Hz high-pass filter. A third recording was made 16 km ENE of San Felipe (31°03′N; 114°40′W) on 7 May 1987 when at least two adult *P. sinus* were seen less than 30 m from the vessel. The water depth was 29.0 m and recordings were made at 60 ips, using a 20 kHz high-pass filter.

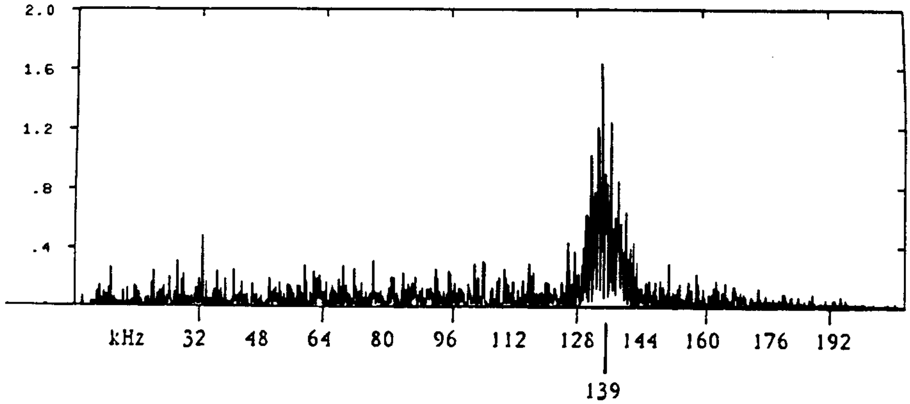

Figure 1. Example of a power spectrum of a *Phocoena sinus* click. Most energy in the pictured click was concentrated between 130 and 142 kHz, with peak energy around 139 kHz.

Table 1. Mean values of bandwidth, duration, and frequency ranges of *Phocoena sinus* clicks

	Dominant frequency (kHz)	Bandwidth (kHz)	Duration (μsec)
Mean	132.9	17.1	136
s.d.	3.86	5.38	41.09
Range	128.0–139.0	10.6–28.4	79–193

Overall frequency range of clicks: 122.2–160.0 kHz.

Several hundred individual *P. sinus* clicks were detected aurally when the tapes were played at slow speeds. Those with superior signal-to-noise ratios were analyzed on a Hewlett-Packard 5451C Fourier Analyzer and Hewlett-Packard 5466 analog to digital converter. Water depths at recording locations were determined using a JRC colour video depth sounder.

Results and Discussion

All *P. sinus* clicks were sharp, intense, narrow-band ($\chi = 17.1 \pm$ s.d. 5.38 kHz) signals (Figure 1) that ranged in frequency from 122.2–146.9 kHz (although a few clicks had energy as high as 160.0 kHz), and dominant frequencies ranging from 128.0–139.0 kHz (Table 1). Click duration ranged from 79–193 μsec. (Figure 2, Table 1).

If low frequency components existed in the *P. sinus* sounds, they were not detected in this study due to high pass filters that were used during recordings, or to overriding ambient biological noise in the lower frequency registers. Whistles were not detected.

Sounds from *P. sinus* were arranged in trains of pulses, which contained from 3 to 57 individual clicks ($\chi = 19.4 \pm$ s.d. 19.23, n=9). The interclick interval was highly variable and ranged from 0.019 to 0.144 second ($\chi = 0.103 \pm$ s.d 0.0231 second, n=75). The repetition rate also varied, and ranged from 10 to 50 clicks per second ($\chi = 12.5 \pm$ s.d. 6.91, n=43) (Table 1).

Because of uncertainties of the position of porpoises with respect to the hydrophone, it was not possible to measure signal strength of clicks.

Phocoena sinus acoustic signals were similar to those described for other members of the Phocoenidae—particularly with respect to click duration, dominant frequency, and bandwidth—including those of *Phocoena phocoena* (Dubrovskii *et al.*, 1971; Kamminga, 1988; Kamminga & Wiersma, 1981; Møhl & Andersen, 1973), *Neophocaena phocaenoides* (Kamminga, 1988; Kamminga *et al.*, 1986), and *Phocoenoides dalli* (Awbrey *et al.*, 1979; Evans & Awbrey, 1988). The sounds are also similar to those of the distantly related delphinids, *Cephalorhynchus spp.* (Dziedzic & De Buffrenil, 1989; Kamminga, 1988; Kamminga & Wiersma, 1982; Watkins & Schevill, 1980). Among these species, there is apparently considerable inter- and intraspecific consistency in click structure, as well as a great deal of interclick similarity (Kamminga, 1988).

However, some aspects of *P. sinus* clicks differed slightly from the click structure in other phocoenid species, and a larger sample of *P. sinus* recordings might resolve the discrepancies. The maximum frequency was somewhat greater and the average bandwidth was slightly less in clicks produced by *P. sinus* than in those reported in other phocoenids. Observed differences may present 'real' interspecific variation in echolocation signals, or they may be related to the context, or the manner in which the recordings were made. For instance, click structure may be influenced by the size or age of the individual(s) recorded.

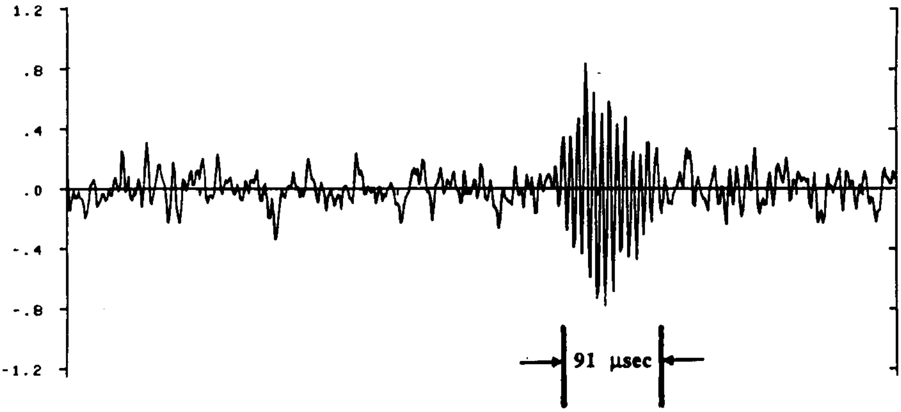

Figure 2. An example of a waveform of a *Phocoena sinus* click. The duration of the pictured example was 91 µsec.

Location of the hydrophone relative to the sound beam produced by vocalizing porpoises may result in small misrepresentations of clicks when reocrdings are obtained at sea (Watkins, 1980). Delphinid click structure can vary with the behavioural or environmental context in which they were emitted (Au *et al.*, 1974; Norris *et al.*, 1967). Similar flexibility in acoustic behaviour apparently exists in phocoenids (although to a much smaller degree than exhibited by delphinids). For example, *P. phocoena* may tune the frequency of its echolocation sounds with respect to a certain detection problem (Dubrovskii *et al.*, 1971; Kamminga & Wiersma, 1981; Møhl & Andersen, 1973).

Interspecific similarities in sounds produced by phocoenids and *Cephalorhynchus spp.* are probably linked to the utilization of analogous habitats (Evans *et al.*, 1985; Kamminga, 1988; Watkins *et al.*, 1977; Wood & Evans, 1980). Phocoenids and *Cephalorhynchus spp.* inhabit coastal regions and sounds produced by these animals are adapted to pursuing small prey associated with sea floor (Dubrovskii *et al.*, 1971; Kamminga *et al.*, 1986). A small wavelength signal permits the animal to focus sounds in a manner that minimizes competition with ambient noise and reverberation from the bottom and objects associated with it.

There are additional ecological implications to the structure of sounds produced by phocoenids. For example, Andersen & Amundin (1976) reported that *P. phocoena* vocalizations exceeded the auditory range of one of its principal predators, the killer whale; thereby limiting the ability of this predator to locate phonating porpoises. Phocoenid porpoises are able to remain undetected while searching for food, because the sounds also exceed the hearing of their prey. The sounds are adapted to turbid water habitats where limited visual detection by prey is enhanced by a concurrent reduction in acoustic detection, and the structure of the sounds allow porpoises to ensonify prey while remaining undetected during a predatory rush. Sounds produced by *P. sinus* are likely related to the same ecological factors.

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