Title
Acoustic Interactions with the Endangered Vaquita

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Acoustic Interactions with the Endangered Vaquita

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Capstone Project

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I. Introduction to Vaquita

Vaquita (*Phocoena sinus*), or Gulf of California Harbor Porpoises, belong to the order Cetacea, a taxonomic order that includes dolphins, whales and porpoises. The vaquita is the world's smallest cetacean. Individuals average 110 pounds in weight, and five feet in length. This animal is unique because it is the world's most endangered cetacean. It is endemic to the northernmost portion of the Gulf of California, and has the most limited range of habitat of any cetacean (Brownell, 1982).

The vaquita is a recently discovered species, described by Kenneth Norris and William McFarland in 1958 (Norris & McFarland, 1958). For almost as long as scientists have known about this species, it has had protected status. In 1978, just 20 years after its discovery, it was placed on the Mexican Endangered Species List, and in 1985 it was added to the United States' Endangered Species List (Brownell, 1988). Population surveys from the last 15 years estimate as many as 500 (Mungia et al, 2007) to as few as 150 individuals left in the population (Jaramilla Legoretta et al, 2007).

II. Introduction to Acoustics

Odontoceti is a suborder of Cetacea, which includes all toothed whales. Vaquita, included in this classification, share characteristics with other toothed whales, including the ability to echolocate. Echolocation is the behavior in which animals use a biological sonar to investigate their environment. Echolocating animals emit calls and receive the reflections from objects in their environment. They use these echoes to locate, range and identify the objects. Echolocation can be used to navigate and forage in certain environments. Studying marine mammals by their acoustic characterizations is important because there is a diversity of acoustic signatures across cetacean species. In addition, visually observing marine mammals can be difficult because of their diving behavior and often wide ranges. Acoustics allow scientists to study these animals' behavior, biology and population dynamics more easily.

The vaquita have unique vocalizations. Figures 1 and 2, taken from Silber (1991), describe the vaquita click. Figure 1 illustrates the power spectrum of a click. Relative to many other marine mammal species, the vaquita has a relatively narrow spectrum of frequencies. In addition, relative to many other marine mammal species, the vaquita has a high peak frequency between 130-142 kHz.

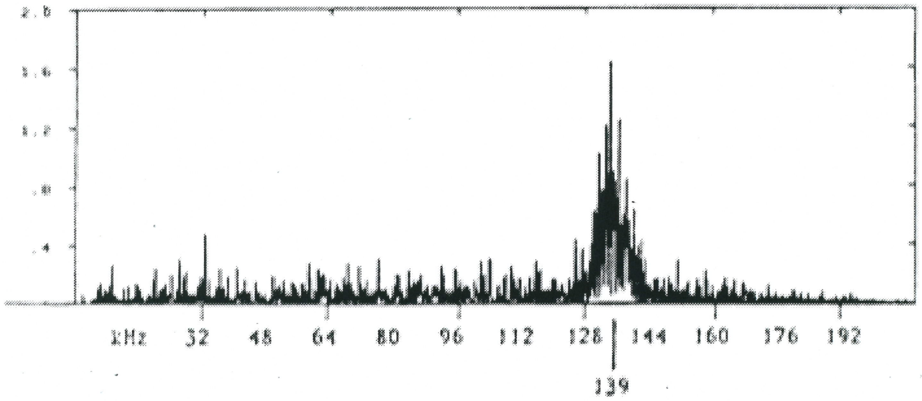


Figure 1. Example of a power spectrum of a *Phocoena sinus* click. Most energy in the pictured click was concentrated between 130 and 142 kHz, with peak energy around 139 kHz.

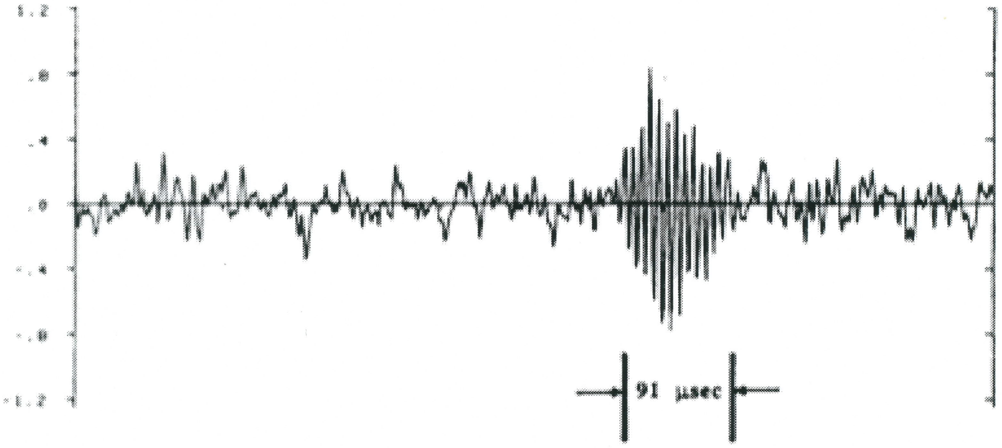


Figure 2. An example of a waveform of a *Phocoena sinus* click. The duration of the pictured example was 91 µsec.

The literature shows that the vaquita have similar vocalizations to other species of harbor porpoise. For example the clicks of a closely related species, *Phocoena phocoena*, are illustrated in Figures 3 and 4 taken from Villaadsgaard et al, 2007. These figures demonstrate that *Phocoena phocoena* have similar vocalization characteristics (click duration and peak frequencies) to that of *Phocoena sinus*.

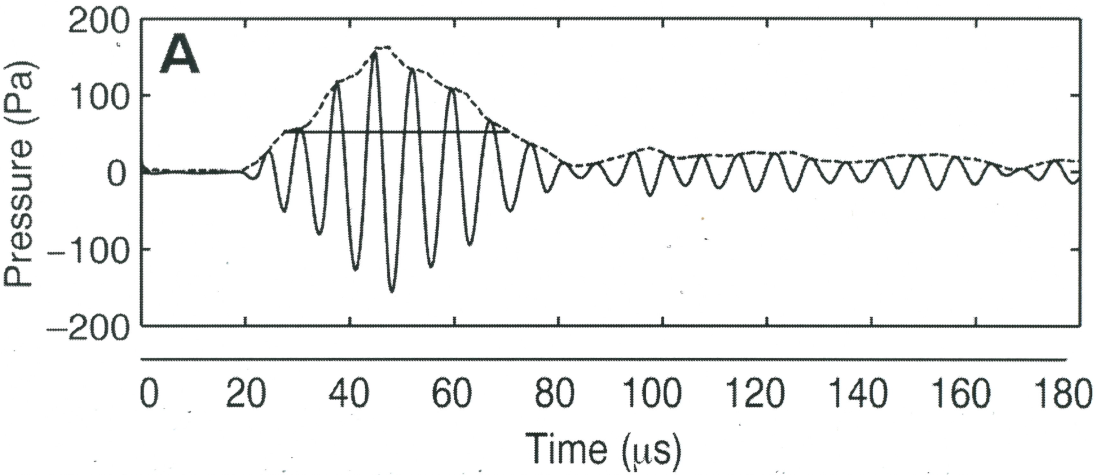


Figure 3. Harbour porpoise click with signal envelope (dotted line) and the -10 dB duration of the click (horizontal line)

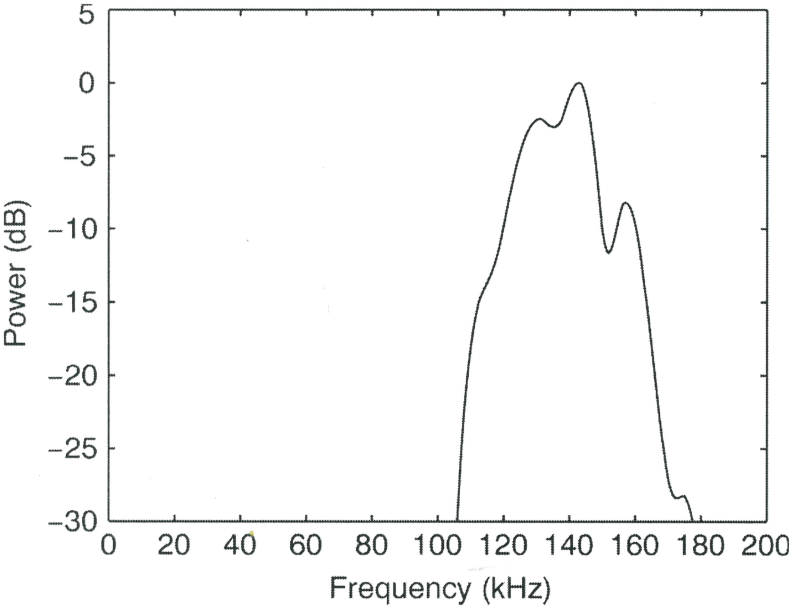


Figure 4. Power spectrum of a harbor porpoise click

While the vaquita is a rare and elusive species, the harbor porpoise is more widely studied. Since it is a closely related species, has similar vocalizations, and has been studied more extensively than the vaquita, much can be learned by bridging studies of the harbor porpoise and the vaquita.

Harbor porpoises and vaquita are both victims of bycatch. Fisheries operations, primarily those using monofilament gillnets, threaten populations of porpoises around the world. Studies of management strategies used to recover harbor porpoise populations might help inform the management of fisheries that threaten the vaquita.

One particular study (Kastelein et al, 2000) estimates the distance at which a harbor porpoise should be able to detect a monofilament net. In order to do so, these scientists played a simulated harbor porpoise click underwater and recorded the reflection off a monofilament net. The echo is represented in Figure 5. From these data the investigators were able to calculate 90% detection distances, represented in Figure 6. For the harbor porpoise, this ranges from three to six meters proximity to the monofilament net.

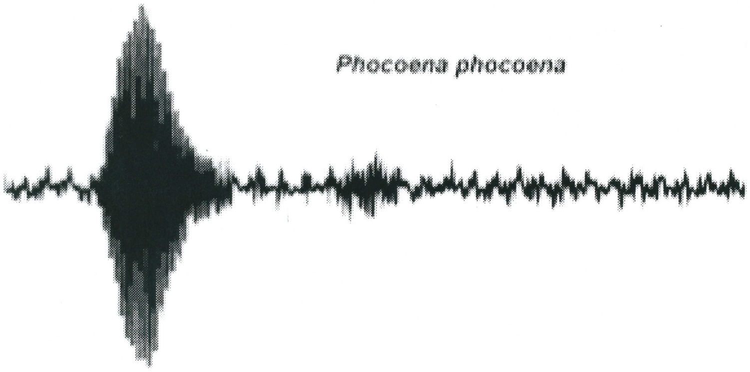


Figure 5. Example waveform of the echo of simulated harbor porpoise click

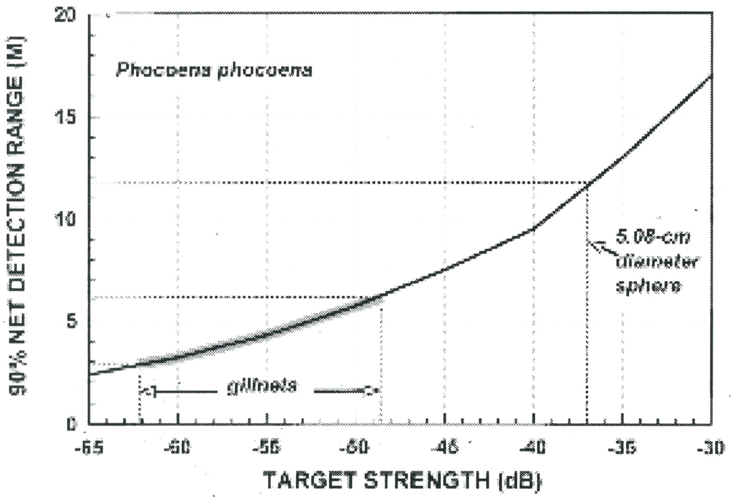


Figure 6. The Calculated 90% detection range of the gillnets used in this study by harbor porpoises when echolocating perpendicular to the nets.

These data suggest that harbor porpoises should be able to detect gillnets meters before reaching them. Why then, are the vaquita being caught at a rate that suggests they will be extinct in a short amount of time?

III. Methodology

To further study the acoustics of the vaquita, this project aimed to use Finite Element Modeling (FEM) to understand the interaction between acoustic stimuli and the anatomy of the vaquita. The Finite Element Method is applied for design of a variety of structures such as buildings, ships and airplanes. This method is a numerical procedure for analysis of structures and continua. In other words, FEM is a technique used in structural engineering to mathematically simulate the propagation of disturbances in complex structures. For example, it could be used to simulate the effects of an earthquake on a planned building. In the case of this project, it was used to simulate the interactions between sound waves and the anatomy of the vaquita. This allowed us to estimate whether the vaquita sonar system could receive echoes from monofilament nets.

The model is constructed of two parts, a detailed map of density gathered using X-ray CT scanning, and data on the elastic properties of the various tissues. For this project, the values for the elastic properties of tissue were estimated from those reported in the literature. The model was constructed and operated by Drs. Petr Krysl and Giovanni Castellazzi at the Jacobs School of Engineering at UCSD. Simulations for acoustic frequencies between 60-100kHz were performed presenting the stimuli at two different angles. There are plans to continue the frequency range up to 150 kHz.

IV. Results

Stimuli ranging from 60-100kHz were simulated at two different angles to the body of the animal (Figure 7). Figure 8 shows the skull and ear bones, illustrating the orientation of the results. In the first simulation, the results of which are presented in Figure 9, the stimuli were presented straight on to the body. The second set of stimuli were presented at the angle of the tip of the rostrum to the base of the cranium (basicranial) (Figure 10).

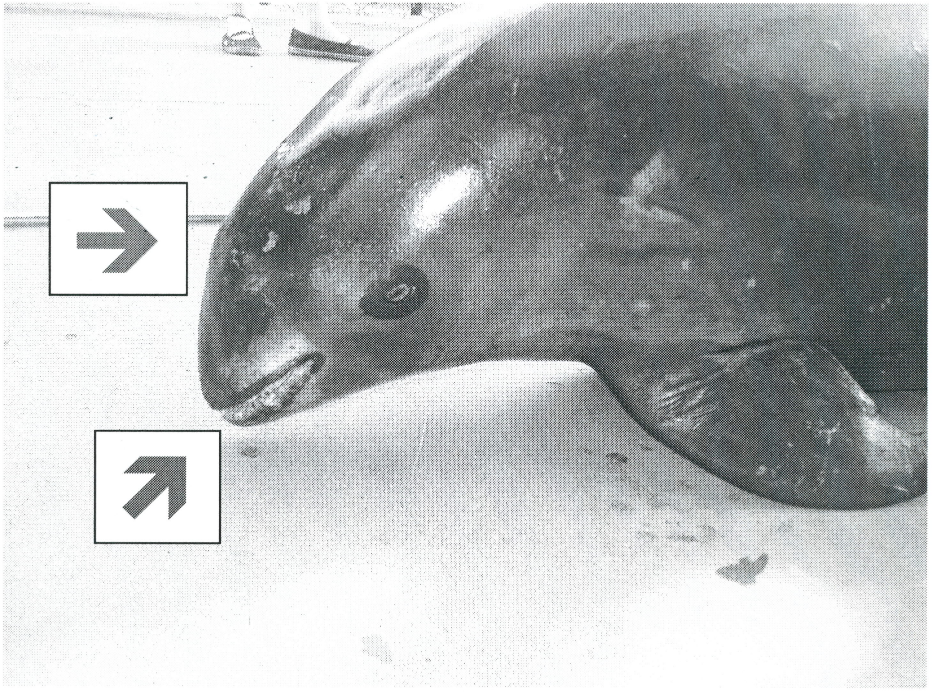


Figure 7. Vaquita head. Pink arrow represents straight on direction of stimuli in first simulation. Green arrow represents basicranial direction of stimuli in second simulation.

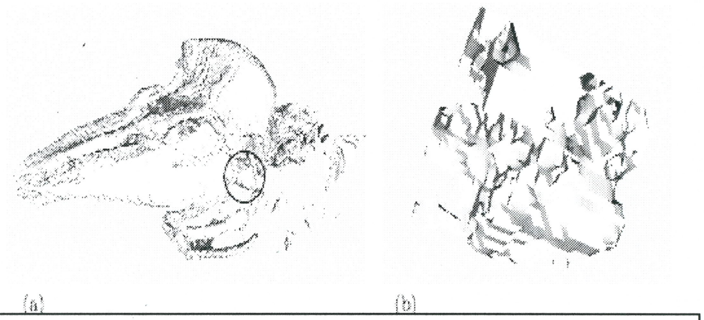
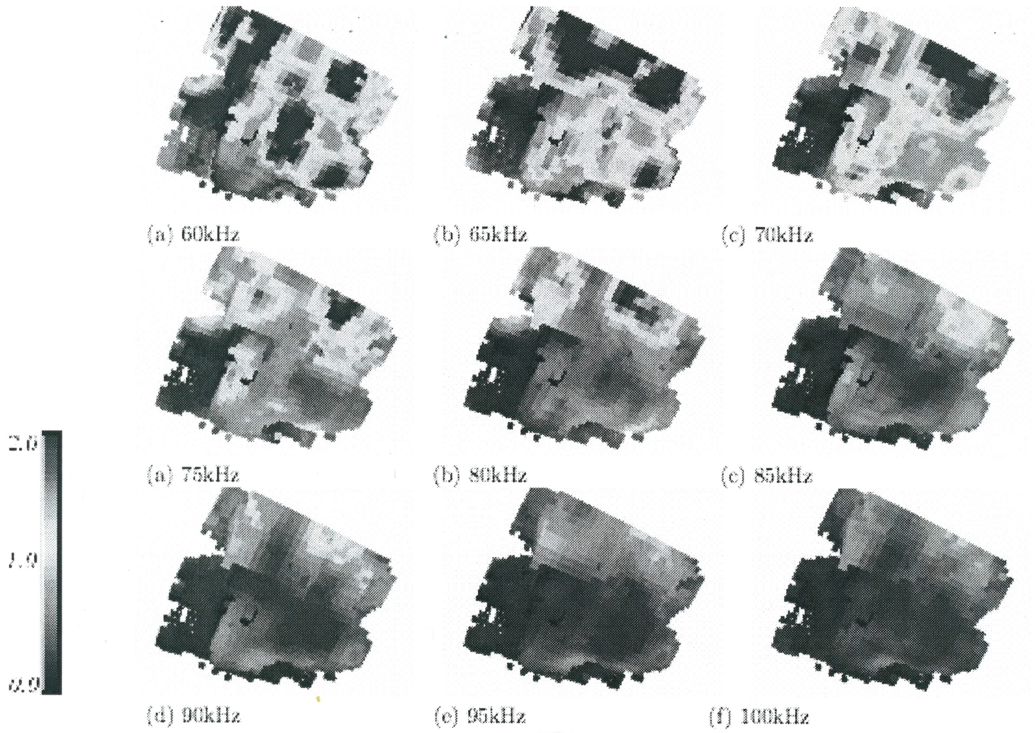
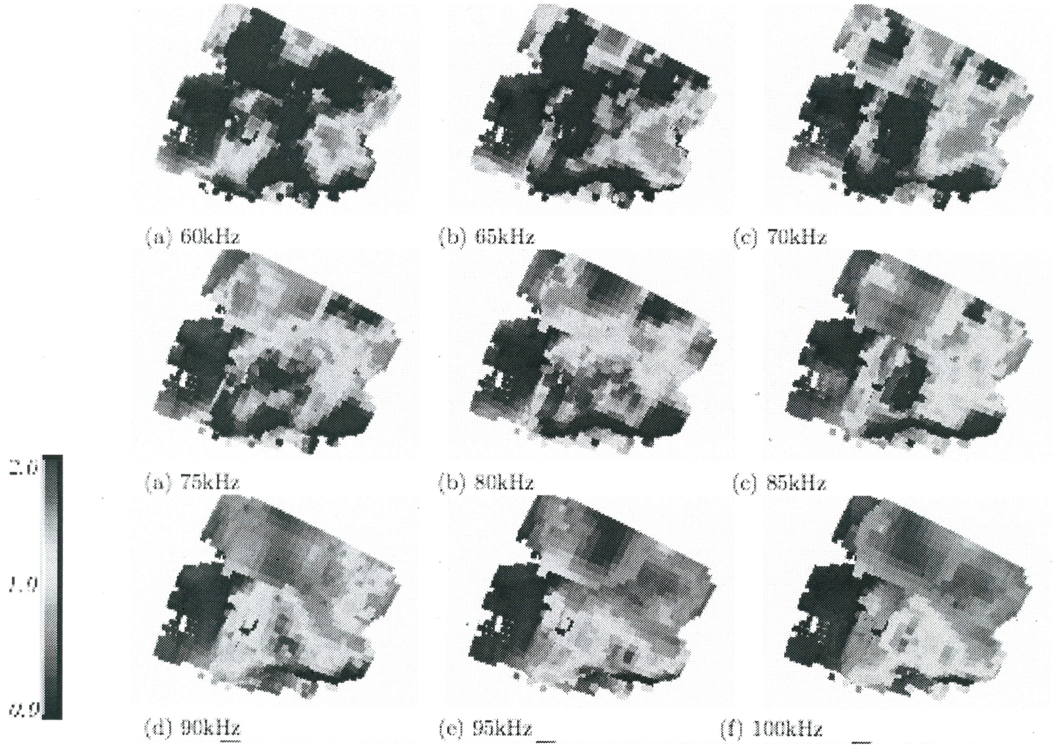

(a)
(b)

Figure 8. Skull of vaquita (a), with emphasis on ear bones (b).



(a) 60kHz
(b) 65kHz
(c) 70kHz
(a) 75kHz
(b) 80kHz
(c) 85kHz
(d) 90kHz
(e) 95kHz
(f) 100kHz

Figure 9. Ear bones and results of first simulation. Stimuli presented straight on to body.



(a) 60kHz (b) 65kHz (c) 70kHz

(a) 75kHz (b) 80kHz (c) 85kHz

(d) 90kHz (e) 95kHz (f) 100kHz

Figure 10. Ear bones and results from second simulation. Stimuli presented at basicranial angle.

The results are presented as relative pressures on the ear bones. Warm colors represent relatively high pressure, cold colors represent relatively low pressures. The scale, cold to warm colors, is zero to two times the pressure outside the body, respectively.

V. Discussion

The results show a disparity in the signals that place pressure on the ear bones, depending on the angle of directionality. A comparison of Figures 9 and 10 suggest that for lower frequency signals, 60-70kHz, higher pressures are reaching the ears from both directions. However, Figure 9 illustrates that relatively high frequencies, 90-100kHz, place relatively low pressures on the ear bones, where as the corresponding frequencies in Figure 10 place relatively higher pressures on the ear bones. The implication of this disparity is that the angle of direction of the stimulus is an important factor influencing whether the signal reaches the ear bones.

These data help to explain why vaquita continue to be entangled in fishing gear when other data suggest that they should be able to detect the echo off the gear from three to six meters away. One possibility is that these animals are not using their echolocation to detect the nets. However, if they are using their echolocation around the nets, the angle at which the reflection is approaching the body may have great implications for whether that animal detects the net in time to avoid being entangled in it.

Currently, there are many efforts underway to remove gillnets from the vaquita's habitat. Significant amounts of money, time and other resources have been dedicated to relieving the fishing pressure that threatens the survival of the species. The conservation and management implications of this project recommend that acoustic detection devices should be used to alert the animals to the nets' presence. Since most of these devices emit lower frequency signals, and these data suggest that lower frequencies reach the ears regardless of directionality, there is a greater likelihood that the animals will detect the gear in time to avoid entanglement.

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