Southern resident killer whale vocal response to vessel noise

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Introduction

The southern resident population of killer whales is currently being reviewed by the National Marine Fisheries Service to determine their status under the Endangered Species Act. This population of killer whales has already been declared "depleted" under the Marine Mammal Protection Act. According to the Conservation Plan (2005), a potential threat to these killer whales is the noise generated by vessel traffic because it may affect their sensitive hearing and interfere with the sounds they use for "navigating, locating prey, and communicating with other individuals." Noise generated by vessel traffic overlaps with killer whale communication.

In the home range of the southern residents, Haro straight and the straight of Juan de Fuca, which is where this study was conducted, the number of private and commercial whale-watching vessels increased from an average of 13 to 80 boats between 1989 and 1998, along with the number of hours that the whale-watching vessels operate, (Osbourne et al, 2002). Thus, I infer that the amount of vessel-related noise has increased. Vessel traffic typically generates noise in the frequency range of 70 Hz to 10,000 Hz with motorboats at the high end and large ships/tankers emitting low frequency sounds (Richardson et. al, 1995). The noise generated by the boats largely depends on the size and speed of the motor. Large ships emit lower frequencies, however, their intensities are greater than the intensity of smaller vessels that emit higher frequencies (Hildebrand, 2000). For example, a 270m super tanker emits a source level of 198 dB re 1 _Pa with a peak frequency of 23 Hz, whereas a 12m long fishing vessel traveling at 7 knots emits a source level of 150 dB re 1 _Pa with a peak frequency of 300 Hz (Hildebrand, 2000). Killer whale hearing ranges between 1 to 120 kHz and much of their communication ranges between 500 Hz to 16 kHz (Sea World, 2002). As seen in other marine mammal species, intense and long lasting noise, possibly boat noise, may cause threshold shifts (Katsak, 1999), thus possibly decreasing the ability to communicate for foraging and social cohesion. A possible cause of depletion of the southern resident population of killer whales is the decrease in prey availability (NOAA/NMFS, 2005), and inhibited communication may add to the escalating problem of finding prey (Bain, 1994).

Various marine mammal species have shown evidence of changes in hearing, vocalizations, and behaviors in response to *boat noise and presence.* Harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), and northern elephant seals (*Mirounga angustirostris*) experienced temporary threshold shifts when exposed to noise of "moderate intensity and duration" under water (Katsak, 1999). Changes in calls have been exhibited by many cetaceans, including humpback whales and killer whales. Humpback whales (*Megaptera novaeangliae*) lengthened their song by 29% when exposed to the US Navy low-frequency active sonar (Miller et al, 2000). Foote and

Osborne (2004) found that the southern resident orca population increased the duration of their calls by 10-15% as vessel traffic increased over three decades. However, the northern resident population of killer whales did not exhibit changes in call duration in response to vessel noise (Talus, 2000). Talus (2000) did find that average frequencies of N4 and N5 northern resident calls were significantly different with vessel noise than without, indicating that a greater range of frequencies were used in the absence of boat noise. In addition to modification of acoustic behaviors, killer whales exhibited avoidance behaviors when approached by 'leapfrogging' vessels, which emit louder noise when motoring faster than whale watching boats that slowly parallel the orcas, indicating that the whales were disrupted by the presence of these boats (Williams, 2002).

While the southern resident killer whales have increased the duration of their dominant calls possibly in response to increasing vessel noise over 30 years (Foote et. al., 2004), it is unknown if they make short term, daily changes to their calls in response to vessel noise. With an increasing number of whale-watching boats and commercial ships, orcas possibly modify the duration of their dominant calls in response to short-term vessel noise exposure. I expect that the southern resident killer whales increase the duration of S1, S16, and S19 calls as vessel noise increases.

Materials and Methods

Technology and Setup

In collaboration with five other students and two Beam Reach professors, I recorded Southern Resident killer whale vocalizations in the waters off the west and south side of San Juan Island, Washington using a single International Transducer Corporation (ITC) hydrophone with a frequency response between 80Hz and 22kHz over a period of 19 days beginning October 3, 2005 and ending October 21, 2005. We connected the hydrophone to a high impedance instrumentation amplifier that offers a gain of x1 or x10. We used a Marantz PMD 660, a digital recorder, at a digitizing rate of 44.1kHz to record the sounds onto a compact flash card and then transferred the files to a computer for analysis.

Surface Observations

When killer whales were present I made observations every five-to-ten minutes noting the time, number of vessels within sight, the types of vessels (c.f. whale watching, fishing, large ships), and any vessels that were motoring.

Call Analysis

Through a procedure similar to Foot et. al. (2004), I used OrcaSound Analyzer to listen to sound files, create spectrograms, and identify the dominant call of each pod (S1 for J-pod, S16 for K-pod and S19 for L-pod) based on Johns Ford's call classification (Ford, 1987). Foote et. al., however, referred call classifications determined by Osbourne and Hoelzel and the calls are named call 1, call 6 and call 3 respectively. Foote et. al. (2004) compared call duration, measured to the nearest 0.01s, in the presence or absence of boat noise during the periods 1977-81, 1989-92, and 2002-03 to determine changes in call duration in response to increasing whale-watching traffic. I recorded many vocalizations in the presence of vessels (commercial ships included) over a short period of 19 days but made few recordings at times when vessels were absent due constraints, such as long commercial whale watching trips and uneasy tracking of whales at night.

I used OrcaSound Analyzer to view the spectrogram with an FFT size of 1024 samples. Because the fundamental and first harmonics of many calls were masked by background noise, I measured the duration of second harmonic for S1 and S16 calls (Figure 1a, 1b), the duration third harmonic for the low frequency component of S19 calls (Figure 1c) and the first harmonic of the high frequency component (Figure 1d). These harmonics were often less masked by the present boat noise. I determined the duration of the indicated harmonic to the nearest 0.01 seconds after adjusting the spectrogram gain to minimize masking of the harmonic by background noise in the spectrogram display. I categorized the calls according to the presence or absence of vessels and I did not include our research vessel, the Gato Verde, in determining presence of vessels because the engines were off during observations.

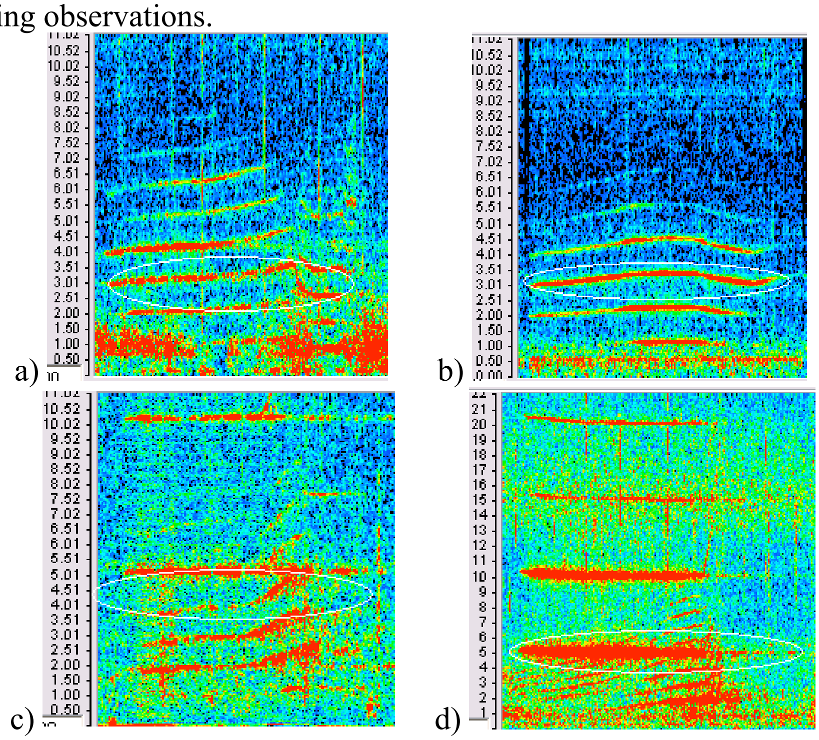


Figure 1. Spectrograms with white ovals indicating which harmonics are measured for a) S1, b) S16, c) S19 low frequency component, and d) S19 high frequency component.

Statistical Analysis

I used a two-sample t-test to compare the mean duration of S1 calls in the presence versus absence of boats (_=0.05).

Results

I found no significant difference between S1 calls in the presence of vessel and S1 calls in the absence of vessels (T=0.50, P=0.621). While not statistically different, in the presence of boat noise, the mean S1 call duration (x = 1.17±.0.29) was higher than without boats present (x = 1.11±0.37) (Figure 2). There is a weak correlation between the number of vessels present and duration of the second harmonic of S1 calls (Figure 3). With one boat present, the call duration focused at approximately 1.0s while call duration ranged between 1.43s to 1.69s when four to seven vessels were present (Figure 3).

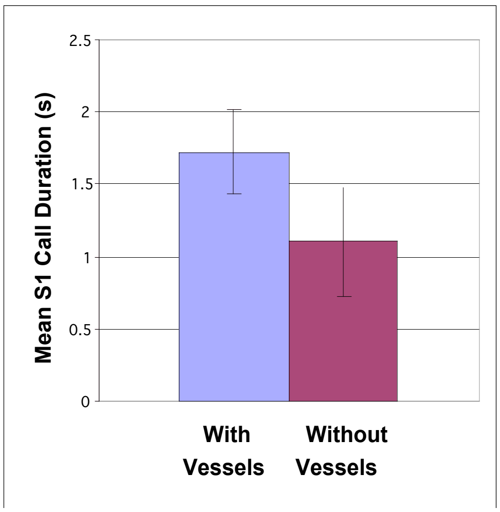


Figure 2. S1 mean call duration in the presence of vessels ("with vessels") and absence of vessels ("without vessels").

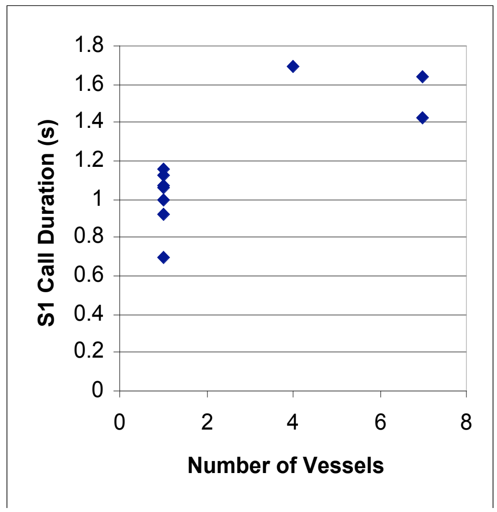


Figure 3. S1 call duration versus the number of vessels present.

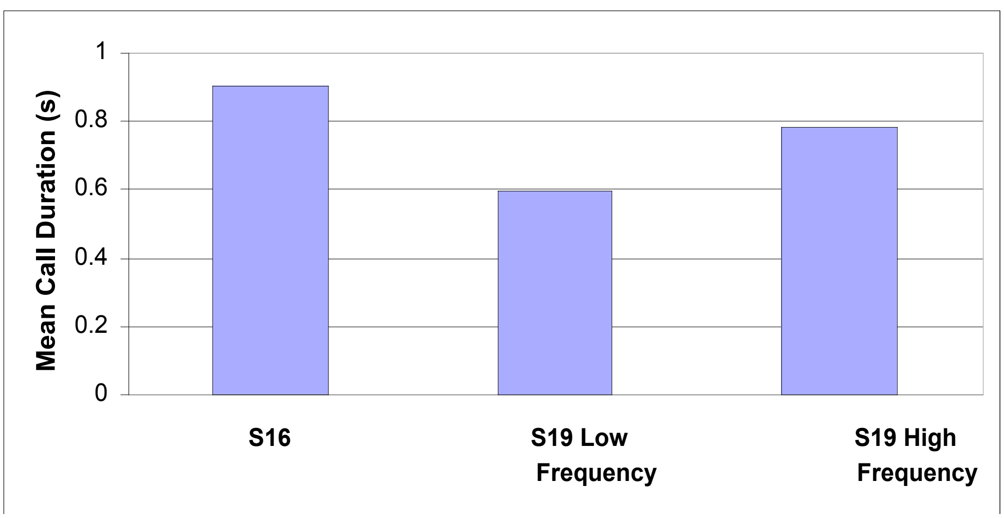


Figure 4. Mean call duration of S16, S19 low frequency components, and S19 high frequency components with vessels present.

I did not find S16 and S19 calls that could be quantified using the methods stated above and thus did not have comparisons to make. I found that the mean S16 call duration is

0.90±0.21s, mean S19 low frequency component is 0.60±0.21s, and the mean S19 high frequency component duration is 0.78±0.27s.

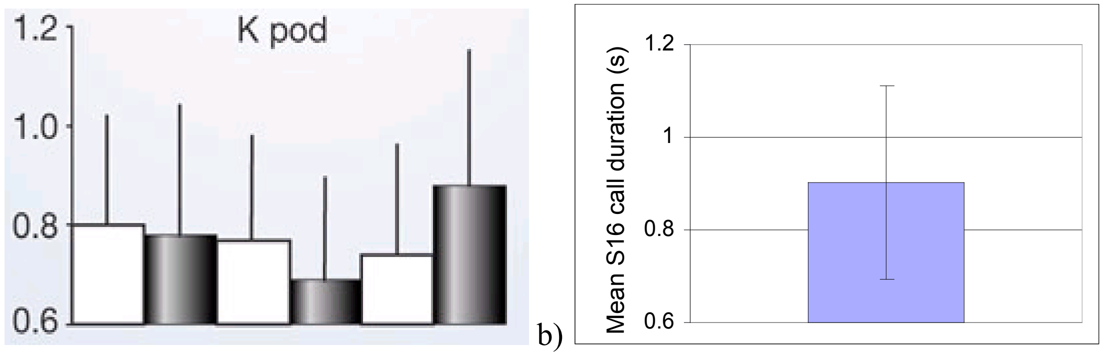
a) b)


Figure 5. a) Foote et. al. results for S16 calls. The bar on the right is the mean S16 call in the presence of whale-watching boats for the 2001-2003 period, b) the mean S16 call in the presence of vessels that I calculated.

Discussion

Southern resident killer whales have increasingly been exposed to anthropogenic noise over the past three decades (Foote et. al., 2004). Studies on any effects that this may have on the marine environment have only recently intensified. With this population of killer whales possibly being listed as endangered many steps will need to be taken to ensure their survival. Understanding their vocal response to man-made sound is one step toward helping the southern resident population increase.

S1 calls were longer in the presence of vessels indicating a possible change in duration due to vessel noise. However, the difference was statistically insignificant. Perhaps with more recordings over a longer period of time it would be possible gain a better understanding of the differences, or similarities, in call duration when vessel noise consumes the marine environment. Foote et. al. (2004) discovered that in the period between 2002-2003 there was a significant difference between the average call duration of S1 with whale-watching vessels present and absent. This indicates that there may be a threshold level of background noise before that needs to be reached before killer whales begin changing their vocalizations and that it may have been reached by 2002 (Foote et. al., 2004).

I did not compare the call duration of S16 and S19 in the presence and absence of boat noise. However, I calculated a mean call duration of S16 calls in the presence of vessels to be 0.90±0.21s which is similar to the mean calculated by Foote et. al (2004) (Figure 5). I, unlike Foote et. al., did not distinguish if the S16 calls were made specifically by K-pod, or by L-pod. This could also be a source of error because killer whales from different pods may make the same call with some small differences. Because I was unclear on what component of the S19 was measured in the experiment conducted by Foote et. al. I was unable to make a comparison between the mean I calculated and the mean they calculated. In the future, work could be done during the peak whale-watching season and finding more opportunities of recording killer whale calls without vessel noise in the background and making comparisons between the two situations.

Problems

The whale watching season consists of the summer months, usually ending in October. However, the whale-watching season has increased and the yearly time of boats with the whales has increased significantly (Osborne, pers. comm.). On an average day during the whale-watching season 30 boats may surround a group of killer whales (Koski, pers. comm.). We conducted our research in October when much of the whale-watching industry has regressed until the following year. Therefore, I may not have gathered recordings that will depict an accurate relationship between killer whale calls and vessel noise. Results may also have been distorted by other abiotic factors.

Like many animals, southern resident killer whales may have daily changes in activity and changes in their calls may depend on the time of day. Because the recordings I examined were not recorded over a 24 hour period I am unable to exclude the possibility duration changes being caused by killer whale activity and not by vessel traffic. The recordings that yielded results regarding S1 call duration were taken from only four different days. It is possible that the southern resident killer whales made changes in call duration in response to the day (temperature, lighting, time) and not only vessel noise. SRKWs also exhibit a variety of behaviors and activities throughout a day, such as traveling, socializing, foraging, and resting (Ford et. al., 1994). Perhaps SRKWs change the duration of their calls when engaged in the various activities just mentioned and not in response to boat noise.

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