# Jumping for Joy: Understanding the acoustics of percussive behavior in Southern Resident killer whales of the Salish Sea

Lindsay Delp
Beam Reach Marine Science and Sustainability School
Friday Harbor Laboratories

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I. Title and By-Line

II. Literature Review

Percussive behaviors of cetaceans include pectoral fin slaps, fluke slaps (lobtailing) (both fluke slaps and pectoral fin slaps may be inverted), dorsal fin slaps, and breaching. While these behaviors have a visual component, they may be more stimulating to marine mammals in terms of the sounds they produce. In southern resident killer whales, percussive behaviors have been recorded and observed more frequently during summer, and in the presence of whale watching boats versus land-based observations (Williams 2002). This suggests that the behaviors are not random and therefore must serve some purpose. This study attempts to determine whether that purpose has the potential to be communicative.

In a study of Norwegian killer whales (Simon 2005), underwater tail slaps, used as a hunting method to stun herring, were recorded with source levels of around 186dB (figure 2), with a frequency of 150 kHz for peak to peak measurements. Under water, these powerful tail slaps are thought to produce cavitation, which occurs when the vapor bubbles within a liquid implode under pressure. The sound produced by this underwater "thud" is beyond the hearing capabilities of orcas when compared with the audiogram for two captive orcas (figure 1). Of course, the purpose of these behaviors is for hunting rather than communication, so it is unnecessary for orcas to be able to detect such a loud sound after the prey has already been detected. However, replicated surface percussive behaviors have thus far resulted in amplitudes well within the auditory capabilities of an orca ( average of replicated fluke-slap behavior = 166.02 dB re 1 µ Pa).

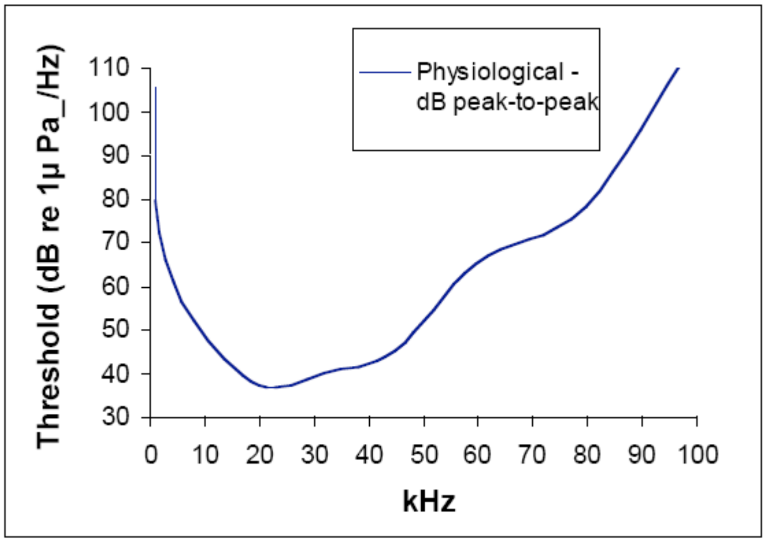


Figure 1. Killer whale audiogram showing physiological threshold (simplified from Szymanski *et al.* 1999)

Figure 1: Reproduced from (Hunt 2007).

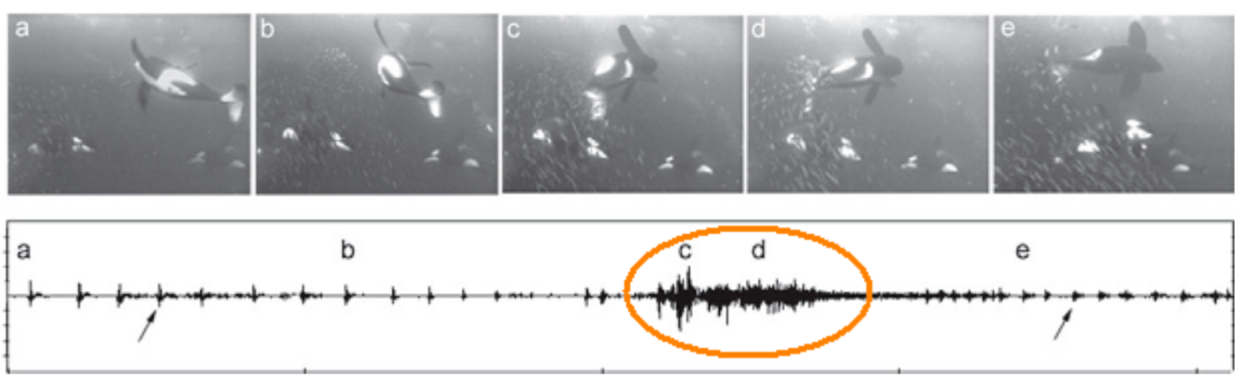


Figure 2. (Simon, M. et al. 2005) shows the acoustic progression of an underwater tail slap. a, b and e are echolocation clicks, c and d show the acoustic impact of the tail slap.

III. Problem Statement: Southern Resident Killer Whales (SRKW) use a complex variety of calls, whistles and signals to communicate with one another. Many of these sounds have been recorded, analyzed and catalogued, yet the percussive sounds made by common SRKW behaviors such as breaching and tail slapping has not been thoroughly investigated. Percussive behaviors are much more common in Resident orcas than in transient orcas, which is most likely because such sounds may have negative effects on foraging success since marine mammal prey would easily be able to detect this behavior (Baird 2000).  Southern Resident orca whales prey mainly on salmon, specifically Chinook. Because Chinook which are found deeper than other species of salmon, detection of these percussives  by the orcas' prey is not a concern. This study will be useful because the acoustic properties of percussive behaviors in Southern Residents killer whales have not been examined or assessed in their feasibility as a potential means of communication. Southern Resident killer whales undergo anthropogenic environmental stress through call masking (Erbe 2002). In my research, I will attempt to find a connection of such percussive behaviors as a means of communication through analysis and comparison of the amplitude and frequencies of percussive with those of known communicative signals. . Additionally, percussive behaviors could be  more likely to be masked in the presence of high boat traffic. If potentially communicative signals are being masked, there may be implications for policy and further restrictions regarding vessel proximity to orcas. Further suggestions have been made that percussive behavior are an aggressive or irritated response and have the potential to be used for interspecies communication as well as communication among orcas. Do SRKW percussive behaviors have the potential to be used as a form of communication?

Methods:

To determine whether orca whale percussive behaviors have the potential to be used as a form of communication, seven synthetic samples of "splash" data were recorded. Three of the samples (A23_1prevost, A24_1prevost, and A25_1prevost), were recorded at the dock in Prevost Harbor in the San Juan Islands. The other four samples (A09fhl, A10fhl,A11fhl, and A14fhl), were recorded at the Friday Harbor Laboratories' dock in Friday Harbor, San Juan Island. The first three samples were recorded using the high frequency CRT hydrophone with distances of 30 meters, 20 meters, and 8.5 meters respectively. A flat wooden slab was slapped against the water by a colleague for each of the recordings. This slab is intended to simulate a pectoral slap, and the conditions at Prevost Harbor made this type of data collection ideal as little neither natural nor anthropogenic noise interfered. The gains for the first three samples were set to 37, 20 and 20 respectively.

The second set of samples recorded at Friday Harbor Laboratories were recorded using the high frequency Cetacean Research Technologies hydrophone and channel 2 of the 4 channel array. However, the data for the second channel was very poor due to ambient noise and were therefore not analyzed.. For these recordings, a four foot by one and a half foot wooden "fluke" was made and slapped against the water in similar fashion as before by another colleague. The distances of these recordings were 62 meters, 39 meters, 25 meters, and 10 meters, respectively. The greatly increased amount of natural (wind and wave), and anthropogenic (speed boats) noise interfered with the data collection and compromised the quality of the recordings. The gains for all four recordings at Friday Harbor Laboratories were set to 28.4

To measure frequency content, the OVAL May 2008 analyzer software was used and the zoom feature was utilized to isolate the highest peak of a single waveform within a slap. The frequencies and RMS values for these wavelengths were individually recorded and analyzed using the following formulas:

dB with no sensitivity= $20\log_{10}$(RMS)

dB re 1 μ Pa= dB no sensitivity + sensitivity of CRT (142)+the difference in gain settings from the calibrated CRT gain (calibrated gain for CRT=28.4)

Spherical Spreading Loss (Transmission Loss)= 20 ($\log_{10}$ (range/1m)

Source Levels dB re 1 μ Pa @ 1 meter = dB re 1 μ Pa + Transmission Loss

The significance of this data depends on its comparison with those source levels and frequencies of calls and whistles already known to be used for communication. If the source levels and frequencies of percussive behaviors are comparable, the sounds produced by percussive behaviors underwater have the potential to be used as a form of communication for orca whales.

| **Sound File** | **Gain settings** | **Gain during calibration** | **Gain difference** | **Sensitivity @ 28.4 for CRT** | **RMS for recordings** |
|---|---|---|---|---|---|
| A23prevost | 37 | 28.4 | 8.6 | 142 | 1.97 |
| A24prevost | 20 | 28.4 | -8.4 | 142 | 0.57 |
| A25prevost | 20 | 28.4 | -8.4 | 142 | 0.44 |
| A09fhl | 28.4 | 28.4 | 0 | 142 | 0.69 |
| A10fhl | 28.4 | 28.4 | 0 | 142 | 0.58 |
| A11fhl | 28.4 | 28.4 | 0 | 142 | 0.82 |

| | | | | | |
|---|---|---|---|---|---|
| A14fhl | 28.4 | 28.4 | 0 | 142 | 1.31 |

Table 1: Gain settings, sensitivity, and recorded RMS for seven sound samples of simulated percussives

| dB re 1 µPa | Distance to Source (m) | Transmission loss | Source Level dB re 1 µ Pa | Frequency of instantaneous simulated slaps (Hz) |
|---|---|---|---|---|
| 156.49 | 30 | 29.54242509 | 186.03 | 442.4 |
| 128.72 | 20 | 26.02059991 | 154.74 | 369.9 |
| 126.47 | 8.5 | 18.58837851 | 145.06 | 941.2 |
| 138.78 | 62 | 35.84783379 | 174.62 | 239.4 |
| 137.27 | 39 | 31.82129214 | 169.09 | 275.9 |
| 140.28 | 25 | 27.95880017 | 168.24 | 245.5 |
| 144.35 | 10 | 20 | 164.35 | 446.5 |
| 138.91 | | | 166.02 | 422.9714286 |

Table 2: Amplitude, distance, Spherical Spreading(Transmission Loss), Source Level, and Frequency data for seven sound samples of simulated percussives. The average amplitude, source level, and the average frequency are listed below the column.

The data from the dock recordings was compared with the following known communicative forms : Average Call Source Level =133-147 dB re 1 µ Pa, Average Call Frequency=1-10kHz, Average source level for whistles =140 dB re 1 µ Pa, Average frequency for whistles=0.5-10.2 kHz (Holt 2008). Thus far, the simulated frequency measures have not been comparable to these levels.

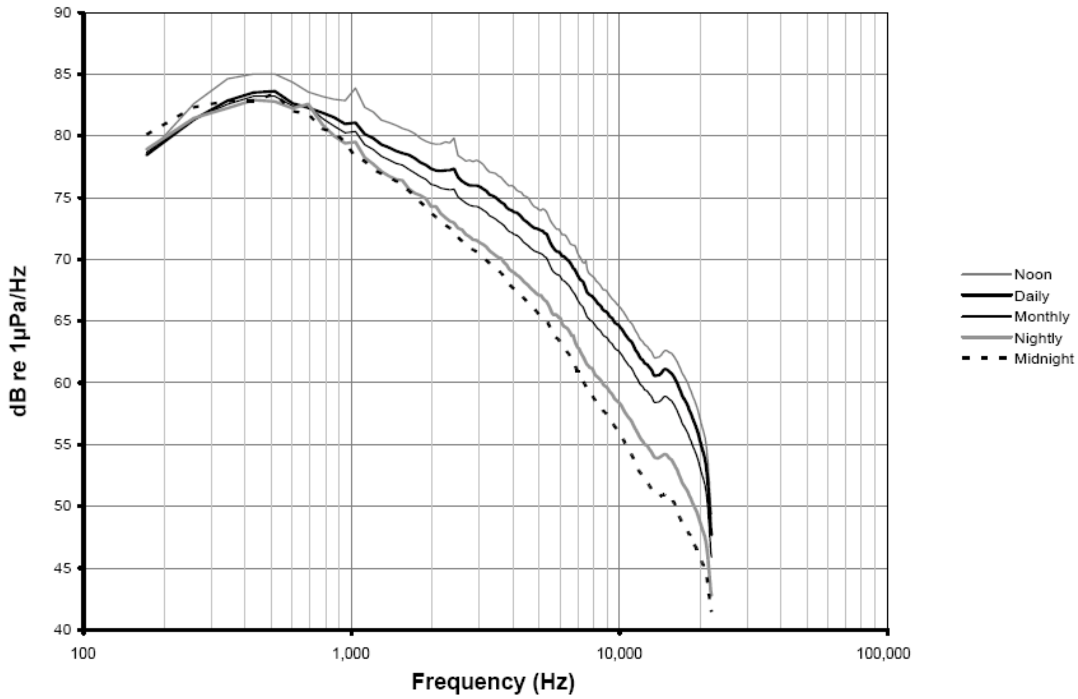


Figure 3- Analysis of ambient noise in Haro Straight, Washington in July 2005. (Holt 2008)

While the data present here is small sample and only represents simulated orca percussive behaviors, the results indicate that the percussive behaviors may have the potential to be used as a form of communication because the  decibels and source levels (Table 2) are similar to the source levels of both whistles and calls, which are known communication methods.

However, the extreme differences in frequency indicate that the transmission of percussive sounds as communication may be more easily masked in some circumstances (Figure 3). For example, in July the peak frequency of ambient noise was between 300 and 400 Hz which would make masking of percussive sounds in this instance much more likely.

Future recording of data will take place on the Gato Verde catamaran research vessel when the whales are sighted. The hydrophone array will be deployed and the hydrophone array will be used in localizing (figure 4). A 12 lb weight is attached to the hydrophone array so it will stay submerged in the water. Because of the difficulty in obtaining an audible percussive sound, every audible event will be used and a random sampling rate will not be necessary. Thus far, it has been unnecessary to localize as the recordings were taken sequentially from fixed locations on the docks, but will be necessary as the location of the orcas will be spontaneous. Recordings of the date, weather, distance to the whale (using the range finder), bearing (using a hand-held protractor), and whale ID (if attainable) will be taken for each percussive event. To localize the source of the percussives, Ishmael software will be used to analyze the sound file, which generates an image of the coordinates of the Gato Verde and the call source. The coordinates are used as (a,b) in the Pythagorean theorem, which gives the hypotenuse (distance) to the source. Next, the received level of sound is found using the OVAL software. The spreading loss is then calculated using the spherical spreading equation : Spherical Spreading Loss (Transmission Loss)= 20 ($\log_{10}$ (range/1m), which is added to the received level to attain the source level, which will be the amplitude of the percussive event at 1 meter from the origin of the source (whale). If the source level for the percussive event is similar to the known source levels for other communicative sounds, the percussive event has the potential to be used as a form of communication.

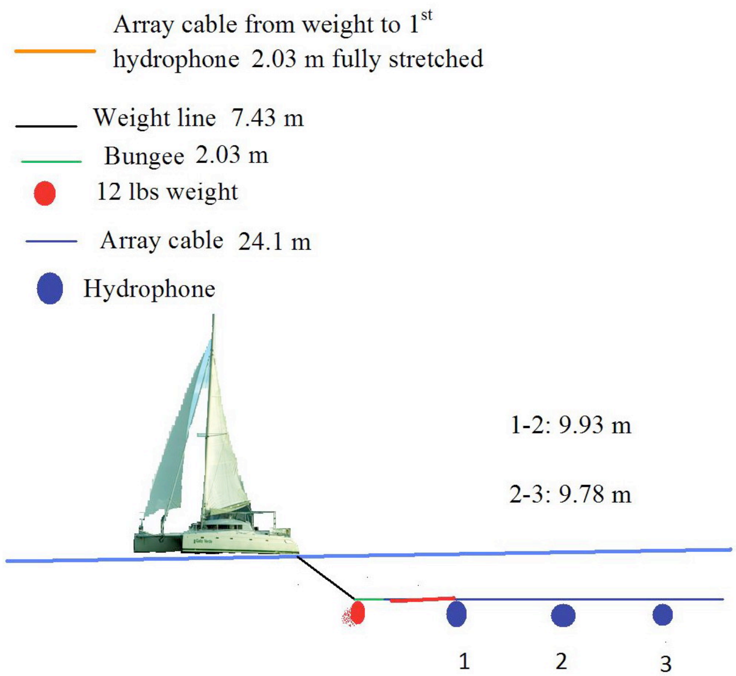


Figure 4: Diagram of the arrangement of hydrophones (Courtesy Dominique Walk 2008).

## IV. Literature

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