**Methods**

This study implements a three-part data collection and analysis with the ultimate goal of determining if a relationship exists between the Southern Resident killer whales’ echolocation click rate and shipping traffic in the Salish Sea.

I. Determining ambient noise level in relation to shipping traffic

The purpose of this portion of the study is to determine how the number of ships and range of ships affect the received noise level at various locations around Haro Strait, see below in Figure 1.



Figure 1: Data collection waypoints

A= Salmon Bank

B= Hein Bank

C= Eagle Point

D= Pile Point

E= Lime Kiln

F= Kellett Bluff

G= Turn Point

I= East Point

H= West Bank

*Calibrated hydrophone recordings*

Calibrated hydrophone recordings will be made at approximately 10 different waypoints during the data collection period of May…. to May 24th. A minimum of three recordings was collected at each of the waypoints. Data collection will be conducted from a 42’ long catamaran. Recordings were made on a laptop using Audacity 2.0.0, recording from an InterOcean Systems Blue Box, Model 902 Acoustical Listening Calibration System. The blue box is vital to these recordings because the recording can be calibrated to the varying ambient noise level. The calibration tone will be interjected into each recording at the start and finish for approximately 1-2 seconds. Audacity will also be used to contrast the calibrated gain setting to the recorded ambient noise level. The amount of difference in dB… between the two will be used to calculated the received level, using the equation:

*CGS – CD = RL*

Where CGS is the Calibrated gain setting (dB), CD is the Contrast difference (dB) and RL is the Received level (dB).

*AIS Vessel Data*

Ship data was collected using an AIS receiver mounted on the catamaran. The receiver was connected to a computer which outputs ship data. Screen shots were taken at the start of each calibrated hydrophone recording to collect the AIS data. The receiver was set to pick up ship radar within a 26-nautical mile (nm) radius. This specific radius was chosen because it is approximately half the length of the region of interest, Haro Strait and the surround shipping lanes. Data collected was the name of the ship, the type of the ship, and the range of the ship. Ship data was only collected if the navigational status was declared to be “underway”. This was to ensure that ships, which may not be underway, are not included as contributing to the received level. However, this could impact the data because some ships that may be underway just might not have it declared as their navigational status. This potential error could explain some of the variability seen in the results. The ship data collected was then used to determine the number of ships present during each recording and the maximum, average, and minimum distance of ships from the Gato Verde during the recordings.

*Received Levels in relation to AIS vessel data*

The received levels and AIS ship data above were used to determine whether the number of ships or range of ships most affects received noise level. The data sets were tested using linear regression analysis and T-tests in the statistical program R.

*II. Echolocation Click Rate in Relation to AIS Ship Data*

This part of the study aims to look at the echolocation click rate of the Southern Resident killer whales compared to the number of ships and ranges of ships around them at various times. For the purposes of this study, echolocation click rate is defined as clicks per minute.

*Hydrophone Array Recordings and Click Rate*

An array of hydrophones (Labcore 40’s Array with peak sensitivity at 5 kHz) was used to record the SRKW acoustics. Recordings were made on May 4th during the field study that was conducted from April 30th to May 24th 2012. The hydrophone was towed from the aft starboard side of the vessel so as to get the clearest recordings. Recordings typically began once the boat was positioned approximately 200 m to the front and side of the Southern Resident killer whales to ensure the quality of the recordings. The recording time continued for the length of the encounter.

*Archived Hydrophone Array Recordings*

Archived hydrophone array recordings from Beam Reach Fall 2011 were also analyzed to determine Southern Resident killer whale echolocation click rate. The recordings were chosen based on the correlating location of the recordings. If the recordings were conducted near Lime Kiln State Park the recordings were chosen for analysis. This is because the only archived AIS ship data available is from Lime Kiln lighthouse.

*Lime Kiln Lighthouse Reson Hydrophone Recordings*

Recordings made by the Reson hydrophone located in front of Lime Kiln State Park Lighthouse were also analyzed to determine Southern Resident killer whale echolocation click rate. These recordings were chosen for analysis again because of the location of the hydrophone and the AIS ship data that correlates to the recordings, but also because of the hydrophone itself. The Reson hydrophone has a stronger crystal and therefore higher sensitivity than the previously mentioned hydrophone array. This is advantageous because it picks up a wider range of frequency of noise.

*Acoustic Recording Analysis*

All acoustic recordings (mentioned above) will be analyzed using PAMguardBeta Version 1.10.00 December 2010 to determine the echolocation clicks per minute. A module, including sound acquisition, FFT spectrogram, and a click detector was created with specific settings. This module was used for each analysis to ensure that the click rates were being detected in a consistent manner. Click detection parameters that were changed for the purposes of this study are: Grouping, Channel, Threshold, Minimum Click Separation, and Maximum Click Length. Grouping was set to no grouping, Channel was set to Channel 0, and detection threshold was set to 18.0 dB. The minimum separation of samples was set at 5,000 samples, and maximum click length, which was manually measured in Audacity, was set to 25 samples.

These standards were chosen based on a trial and error test that was used to weed out aspects of acoustic recordings that are not of interest for the purposes of this study. For example acoustic buzzing sounds produced by the killer whales resemble click trains, but are not of interest for this study. Thus the detection parameters had to be tested until there was an amount of clicks being detected that fulfilled the purposes of this study without picking up on other acoustic properties that were not of interest.

*AIS Vessel Data II*

AIS ship data was collected and analyzed to correlate with all of the above acoustic recordings. The overall data that was calculated from each collection of AIS ship data was: the number of ships, and the maximum, average, and minimum distances of these ships from the Gato Verde at the time of the collection.

AIS screen shots were taken using the same protocol mentioned previously in AIS Vessel Data I. These shots were taken every thirty minutes while recordings were being made aboard the Gato Verde using the hydrophone array in the presence of the SRKW’s.

AIS data was also obtained from archives at Lime Kiln lighthouse. This AIS data will differ slightly from the data mentioned in AIS Vessel Data I. Ship data was collected by the AIS receiver when ships were abeam (90 degrees) of the lighthouse. Archived received levels were also collected from the Lime Kiln archives for this AIS data.

III. Categorizing Echolocation Click Rates by Surface Behavior

The specific interest of this study is to determine what type of affect, if any, underwater noise from shipping traffic has on Southern Resident killer whale echolocation while foraging. In order to determine this affect, click rates must be correlated with surface behaviors to demonstrate what click rates are when behavior is indicative of foraging.

*Surface Behavior Observations*

Surface behavior observations will be recorded during each encounter with killer whales. The protocol for these observations will be consistent with those determined in 2004 at the previously mentioned NOAA/NMFS workshop on Southern Resident killer whale behavior, including the post-data analysis instructions. The most important aspect of this data collection is that no behavioral states will be declared during data collection. Behavioral states, if present, will only be declared in post-data collection analysis to make the study as unbiased towards foraging behavior as possible.

*Correlating Click Rate and Surface Behavior*

Echolocation click rates were sorted into two categories based on the correlating surface behavior observations. Click rates where the surface behavior indicates foraging were used as one category. The second category includes click rates during all other behaviors, deemed the non-foraging category. These two categories were compared to determine the difference in click rate while foraging and not foraging.

*Relating Click Rate During Foraging and Ship Data*

The specific interest of this study is to determine what type of affect, if any, underwater noise from shipping traffic has on Southern Resident killer whale echolocation while foraging.

This portion of the study combines the above data of click rates while surface behavior indicates foraging, and the number and distance of ships present.

III: Modeling Potential Masking Effects of Ambient Noise on SRKW Echolocation Clicks

The final portion of this study focuses on demonstrating the potential masking effect of ship noise on Southern Resident killer whale echolocation clicks. The model will take into consideration the source level of the click, the transmission loss of the click, the received level of the echo, and the target strength (Chinook salmon). The received level of the ship noise will also be used, along with the range and number of ships.

This model is meant to demonstrate worst-case scenario with a received level greater than 130 dB due to close proximity of a ship as well as a large amount of ships within acoustic range.

Masking will occur if the received level (at the whale) of the echo is less in dB than the received level (at the whale) of the background noise, dominated by the shipping traffic.

Received level of ship/background noise

Ship

Received Level of Echo

Chinoook Salmon

Killer whale