**Ground-truthing the impacts of prey abundance and ambient noise levels on foraging behavior in the Southern Resident Killer Whales:**

**A three-part study**

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**Background:**

Killer whales (Orcinus orca) are one of the most widely dispersed cetaceans on the planet, they can be found in all of the world’s oceans (Dahlheim and Heyning 1999). Populations of killer whales are distinctly different in their foraging tactics and acoustic communication. There are two known distinct foraging habits for killer whales, mammal eating and fish eating. Fish-eating killer whales forage using echolocation to target their prey. \*\*\*MORE ON ECHOLOCATION AND ECHOS HERE: HOW DOES IT WORK. \*\*\*Acoustic communication is vital for all killer whale populations, not only to communicate with one another, but also to travel, and most importantly, forage (CITATION). Echolocation clicks are believed to play a critical role in Southern Resident foraging activities, where as transient killer whales do not heavily rely on echolocation clicks to find their prey (CITATION..Bigg 1987?)\*\*\*

 The Southern Resident killer whales (SRKW) are an example of fish eating killer whales; they primarily feed on Chinook salmon (Hanson 2010). In 2005, The National Oceanic and Atmospheric Association (NOAA) listed the Southern Residents as endangered and declared the inland waters off the coast of Washington and southern Vancouver Island, B.C., commonly known as the Salish Sea, to be SRKW critical habitat. The Salish Sea is the summer home range for the Southern Resident killer whales and is a common route for Chinook salmon headed to spawn in the freshwater rivers.

The recovery plan for the Southern Residents addressed three primary concerns that are still considered to be the largest threats to the population recovery: scarcity of prey (Chinook salmon), exposure to contaminants from pollution, and vessel disturbance (NOAA/NMFS 2005)

A study done in 2009 by John Ford et. all correlated the population decreases of the 1990’s were directly correlated to decreases in Chinook salmon abundance. Decreases in Chinook salmon abundance were directly correlated to the decrease in SRKW population size during the 1990’s (Ford 2009). This suggests that the limiting factor in Southern Resident killer whale conservation is prey availability. Recent genetic studies have demonstrated that 80-90% of the Chinook salmon that make up the SRKW diet are Fraser River Chinook Salmon (Hanson et all. 2010). These studies both indicate that understanding Chinook salmon abundance, specifically that of the Fraser river Chinook salmon, is a vital piece in understanding killer whale foraging success.

Along with Chinook salmon abundance, masking affects from ambient noise levels from boats have also been proven to impact Southern Resident killer whale foraging. Griffin and Bain examined the affects of whale-watch boats on killer whale echolocation range in 2006. This study demonstrated that annual decreases in foraging space do to increased ambient noise levels are 15% to 20%. A decrease in carrying capacity for this increase in noise level and subsequent avoidance behaviors was estimated to be 18% to 23%. From these two studies it can be concluded that both prey availability and increases in ambient noise levels have the potential to negatively impact Southern Resident killer whale foraging.

\*\*STILL WORKING ON THE WASSER INTERPRETATION\*\*A recent pilot study conducted by Sam Wasser shows that the SRKW’s are leaving their summer range with increased levels of Glucocorticoids (GCs; also known as cortisol) than when they arrive in the early spring (….CITATION). This specific new information is contrary to the previous belief that the killer whales came in from the outer coast deprived of rich food sources and the Chinook salmon runs were fattening the whales for their winter activities of less food.

These results suggest that the Southern Residents are having a difficult time foraging successfully due to limited prey availability.

The current belief is that the amount of vessels are not increasing stress hormones in the whales, but making it more difficult for them to communicate and potentially impacting foraging activities by masking echolocation clicks. DEFINE MASKING Masking due to increased ambient noise levels from vessel/boat traffic is the biggest concern in terms of vessel/whale interactions at the moment. Particularly, masking of echolocation clicks. GRIFFIN AND BAIN RESULTS It is proven that killer whales raise their calls 1 dB for every dB of ambient noise (Holt et. all)

Correlating Chinook abundance to killer whale foraging surface behavior and click rates is vital step for determining when and where these whales are feeding. The goal of this study is to examine prey scarcity and vessel disturbance in relation to killer whale foraging behavior in an attempt to determine which factor most impacts the successful outcome of foraging activities and potentially establish important locations for killer whale foraging activity in the Salish Sea.

**Methods:**

This study incorporates multiple forms of data collection and analysis. In order to correlate fish presence and ambient vessel noise to echolocation click rates foraging success, it is necessary to ground-truth SRKW foraging behavior. As it is seen now, foraging behavior incorporates a wide-variety of surface behaviors, which makes it very difficult to define based on surface observations alone (NOAA/NMFS 2004). Defining foraging behavior is vital to killer whale conservation because it can be used to determine energy budgets, estimates of total time spent foraging, spatial and temporal foraging patterns and more. The Southern Resident killer whale behavior workshop conducted by NOAA and NMFS in 2004 concluded, “Ground-truthing the definition for foraging with prey and behavior studies conducted in unison was necessary”. In order to do this surface behavior observations must be correlated to echolocation click rates and Chinook salmon presence/absence during encounters. Determining foraging surface behavior is rarely looked at from all three of these dimensions, but it is vital for determining whether ambient noise from vessels or Chinook salmon abundance has the greater affect on foraging success.

The second part of the study is plotting out Chinook salmon runs based on archived data. This data will provide information on how many salmon there are in the Salish Sea during the study period, as well as the spatial and temporal patterns of the salmon runs this spring. The objective is to gauge the abundance of Chinook salmon in these initial runs.

The third and final aim of this project is to incorporate the previously mentioned data along with known ship acoustic data to model the potential masking effects that the ambient noise level (dominated by large ship noise) may have on Southern Resident killer whale echolocation. Ultimately, this investigation seeks to determine whether Chinook salmon abundance or ship noise levels most impact the echolocation click rate of Southern Resident killer whales and the outcome of their foraging activities in the Salish Sea.

Methods for examining Chinook salmon presence and absence both during killer whale encounters and through archived data are based off of methods used in a study conducted in Fall 2011 by Charla Basran. Charla’s methodology is based off of a pilot study examining prey of the SRKW’s conducted by Horne and Gauthier in 2004????. CHECK THIS CITATION!

*Part I: Ground-truthing the foraging behavioral state*

1. Surface behavior observations

Surface behavior observations will be recorded during each encounter with killer whales. The protocol for these observations will be cohesive with those determined in 2004 at the previously mentioned NOAA/NMFS workshop on Southern Resident killer whale behavior, including the post-data analysis instructions. To conduct an unbiased study, those conducting the observations will have no knowledge of the fish finder data.

1. Acoustic Recordings

An array of hydrophones (TECH INFO HERE) will be used to record the SRKW acoustics. Recordings will begin upon sighting the Southern Resident killer whales or once they are believe to be within acoustic recording range. The recording will continue for the length of the encounter. Someone listening to the recording hydrophones will actively note killer whale acoustic communication. The recordings will be analyzed using Audacity 2.00 to count the echolocation clicks per minute that were produced, if any. Other aspects of echolocation clicks to be analyzed are: duration and frequency of the clicks. The echo that killer whales experience from the click they produce will be calculated from this data??? FIND OUT HOW YOU CALCULATE ECHOES

1. Chinook salmon presence and absence

 Field data to determine Chinook salmon presence and absence with whales present will be collected using a GP-1650 WF fish finder. I am using part of Charla’s methods. The fish finder will run continuously throughout each killer whale encounter. Images of the fish finder will be taken using a Go-Pro Hero camera, set to capture an image once every minute during the encounters. This will allow a constant stream of fish abundance data to be collected while the killer whales are being observed. If the images contain a large image at a certain depth, it will be deemed Chinook salmon. Ultimately this data will help determine whether the surface behavior observed and echolocation clicks recorded are indicative of the foraging behavior state based on Chinook salmon presence or absence.

1. Determine foraging behavior

Post-data analysis of the surface behavior observations, echolocation click rates, and Chinook salmon presence/absence will be used to determine whether the whales were actively foraging or not. If the individual behaviors recorded are cohesive with previous definitions of foraging surface behavior, and echolocation click rates are typical of acoustics produced during foraging, and Chinook salmon presence is determine, then the overall behavior state will be declared foraging.

*Part II: Chinook salmon spatial and temporal abundance*

 I plan to determine Chinook salmon distribution during the runs, regardless of killer whale presence by examining two different sources: the local fishermen and the Albion test fisheries on the Fraser River.

 1. The local fishermen have some of the best insight into of the Chinook salmon abundance based on their catch amounts and locations. Bob Wilson, a member of the Puget Sound Anglers will provide reports from any anglers willing to share details of their Chinook salmon catch for the month of May. The reports from the fishermen will ideally consist of the amount of Chinook salmon they are catching and the location of largest Chinook catches. \*\*\*I am open to suggestions on coordinating with the Puget Sound Anglers, I am not sure if this is the exact kind of data I need from them, but it seems to be a good place to start? \*\*\*

 2. Archived data used to determine Chinook salmon abundance will be collected from the Albion test fishery. The Albion test fishery on the Fraser River conducts daily counts for Chinook salmon. This data will be vital in determining Chinook abundance because killer whale population dynamics have been directly correlated to Chinook abundance. Collecting data on Chinook salmon spatial and temporal abundances is not only important for ground-truthing foraging behavior, but also in answering the question of whether it has a greater affect on echolocation click rates and foraging outcomes than large vessel acoustics.

*Part III: Modeling Methods*

 I plan to model the potential masking effects of ambient noise levels produced by ship traffic on killer whale echolocation clicks. The forage fish data as well as the foraging behavior data will both be used in this model. The locations where whales are deemed to be foraging (see part I) will be examined more closely in terms of vessel traffic. I plan to measure the proximity from the foraging points to the nearest shipping lanes (logR). Acoustic data on the various vessels that pass through the geographically significant shipping lanes will be obtained from Scott Veirs. These ships could vary from cargo ships, to tug boats, and coal ships, etc.. After I have marked known foraging locations for the killer whales I will calculate the distance between these spots and the shipping lanes. This will allow me to determine the potential masking affect that the killer whales. \*\*\*Need to talk about the echoes that the whales receive from their clicks\*\*\*

Masking is when a backrground (masking) sound causes the hearing for another sound to be raised (Erbe 2002)

M=SLn-SLo [dB]