

**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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Spring 2012

Background:

Killer whales (*Orcinus orca*) are one of the most widely dispersed *Cetacean* species; they can be found in all of the world's oceans (Dahlheim and Heyning, 1999). In the inland waters of Northern Washington and Southern Vancouver Island, B.C. there are three recognized types of killer whales: residents, transients (Bigg's killer whales), and offshore

(Ford et. al 2000). Residents and transient killer whales are the most studied ecotypes. Residents are known to forage on fish, primarily salmon, whereas transients forage on other marine mammals (Bigg 1987). This difference in prey leads to the subsequent differences in foraging behavior, specifically acoustic behavior. The resident killer whales are known to use echolocation while foraging to target their prey. Transient killer whales, however, rarely produce echolocation clicks (Barret-Lennard 1996)

The Southern Resident killer whales (SRKW) are one of the resident populations in these northern inland waters. Residing in the Salish Sea during the summer months, these whales forage predominately on Chinook salmon (*Oncorhynchus tshawytscha*) most likely because of their high lipid content (Ford et. all. 1998). In 2005, The National Oceanic and Atmospheric Association (NOAA) listed the Southern Residents as endangered. 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 2008)

The Southern Resident killer whale population decreased 17% during the 1990's due to high mortality rates (NOAA/NMFS 2008). These population dynamics were correlated to decreases in Chinook salmon abundance with a one-year lag time (Ford 2009). This suggests that the limiting factor in Southern Resident killer whale conservation is prey availability, and it takes one-year time for the limitation to affect the population dynamics of the SRKW's. 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 al. 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 effects from boat noise have also been proven to impact Southern Resident killer whale foraging. Echolocation clicks have been observed to be present during assumed foraging behavior suggesting that echolocation plays a significant role in foraging for the SRKW's (Ford 1989). Ambient noise levels can mask killer whale vocalizations. (Szymanski *et. al.* 1998). A study conducted in 2006 by Griffin and Bain suggests that masking of echolocation clicks is a significant problem for the Southern Residents. This study demonstrated an annual decrease in foraging space due to increased ambient noise levels of 15% to 20%. Ambient noise levels can mask killer whale vocalizations. A decrease in carrying capacity for this increase in noise level and subsequent avoidance behaviors was estimated to be 18% to 23%. Veris and Veirs demonstrated that the ambient noise level in Haro Strait, an area frequented by foraging

killer whales, is dominated by ships (vessels upwards of 60 m) noise. These ships add approximately 20-25 dB to the ambient noise level, contributing to an average sound pressure level (SPL) of 118.5 dB during summer days (Veirs and Veirs 2005).

From these two studies it can be concluded that both prey availability and increases in ambient noise levels from vessels have the potential to negatively impact Southern Resident killer whale foraging.

A recent pilot study conducted by Ayers et. al (In Press) examined hormone levels, proving that in fact the SRKW' s are leaving their summer range more nutritionally stressed than when they arrive. Increased levels of Glucocorticoids (GCs; also known as cortisol) at the end of the summer months indicate both nutritional and physiological stress. Decreases in thyroid hormones indicate nutritional stress. The SRKW' s demonstrate this pattern as well suggesting they are better fed upon arrival than after a summer of foraging for Fraser River Chinook salmon. These studies suggest that the Southern Residents are having a difficult time foraging successfully due to either limited prey availability or limited ability to acquire scarce prey.

The goal of this study is to examine both factors of prey scarcity and inability to acquire prey to determine which factor is most limiting to foraging success. There will be three primary parts to this study: ground-truthing foraging behavior, monitoring Fraser River Chinook salmon densities in relation to killer whale foraging activity, and modeling the potential masking effects of ship noise on killer whale echolocation clicks. It is expected that this three-part analysis will demonstrate a combination of prey scarcity and masking echolocation clicks from ship noise limits Southern Resident killer whale foraging.

Methods:

This study incorporates multiple forms of data collection and analysis. In order to correlate fish presence/absence 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 potential masking of echolocation clicks. 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. The field methods for presence/absence of Chinook salmon is based off a pilot study examining the potential prey of the SRKW's conducted by Horne and Gauthier in 2004.

Part I: Ground-truthing the foraging behavioral state

All field data will be collected from the Gato Verde, a 42' hybrid electric-biodiesel catamaran. The study period will be a total of 23 days from April 30th, to May 24th.

1. 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. To conduct an unbiased study, those conducting the observations will have no knowledge of the fish finder data.

2. Acoustic Recordings

An array of hydrophones (Labcore 40's Array with peak sensitivity at 5 kHz) will be used to record the SRKW acoustics. The hydrophone will be towed from the aft starboard side of the vessel so as to get the clearest recordings. Recordings will begin upon sighting the Southern Resident killer whales or once they are believed 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 2.0.0 to count the echolocation

clicks per minute that were produced, if any. Through collaboration with fellow students, the density of S1 calls in a minute's time will also be examined. If echolocation click rates prove to have a greater density in a minute's time than the S1 call, the acoustic behavior will be deemed indicative of foraging.

3. 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. 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 backscatter images contain a large target at a certain depth (to be determined) it will be deemed Chinook salmon. Ultimately these 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.

4. 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. The overall behavior state will be declared foraging if all of these conditions are met: the individual behaviors recorded are consistent with previous definitions of foraging surface behavior; echolocation click rates are typical of acoustics produced during foraging (greater density than S1 calls); and Chinook salmon presence is confirmed, then

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. 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 fish finder 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. Source levels of the various vessels that pass through the geographically significant shipping lanes will be obtained from Scott Veirs. Ships can be cargo ships, tug boats, containers, ocean liners, coal ships, etc. The deemed foraging locations for the SRKW's will be marked on a map. The distance from these "foraging spots" to the nearest shipping lanes will be calculated. The echo that killer whales experience from the click they produce will be calculated from this data using modeling methods similar to those used by Au et. Al (2004) and those discussed by Erbe (2002). This will model the masking effect of echolocation clicks that the killer whales experience could experience, potentially making it more difficult to forage.

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