Determining the correlation between call frequency and matriline density in Southern Resident killer whales (*Orcinus orca*)

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Introduction:

Orcinus Orca, also known as the killer whale or orca, is found in oceans worldwide making it one of the most widespread marine mammals. Killer whales are seen living in closely related matrilines called “pods”. A matriline, which is composed of a mother and all her offspring, and her daughters offspring, is the smallest unit of hierarchical organization within the pod (Weiland, 2007). A matriline can extend back as far as five generations (Weiland 2007). There are three different ecotypes of killer whales; resident, transient, and offshore (Ford et al., 1999). The different types of killer whales are distinguished based on their physical characteristics, diet, habitat, and behavior (Ford, 1989). The primary focus of this study are the resident killer whales, which are classified into two communities, the Northern Residents and the Southern Residents. The Northern Resident population is composed of 16 pods which equates to about 220 whales, and resides off the northeast side of Vancouver Island in British Columbia. The Southern Resident Killer Whales (SRKW) include three pods J, K, and L which total to about 86 whales. This study will observe the SRKW's, which inhabit the southern tip of Vancouver Island and the coastal waters ranging from Washington to California (Center for Whale Research 2006).

Analyzing the dynamics of different killer whales calls, can provide valuable insight to killer whale behavior and social structure. Killer whales produce three different sounds; clicks, whistles and pulsed calls (Ford 1989). Clicks are typically employed in echolocation and are characterized as a brief series of pulses. The pulses can vary in structure with frequencies as high as 85kHz. Whistles feature either a nonpulsed or continuous waveform and can vary from frequencies of 1.5-18kHz (Ford, 1989). Lastly, the most profusely used killer whale sounds are the pulsed calls. The pulsed calls are classified as discrete, variable, and aberrant (Ford, 1989). A variable call is one that lacks repetition and fails to fall into a structured category. The discrete call is repetitive in occurrence and has a characteristic fundamental structure. This study will focus on discrete calls used in killer whale communication. Clearly, acoustic communication plays a crucial role in killer whale behavior and better understanding their intricate methods of communication would play a critical role in helping us conserve this symbolic animal.

The matrilines in resident killer whales are highly vocal, exhibiting group specific dialects, which reiterate the importance of intra-group communication. A repertoire is defined as the total range of distinct calls made by an individual or population (Weiland, 2007). Each pod has its own vocal repertoire that is unique and shared among the group (Ford, 1989, 1991). It has been speculated that there is a great significance in having a collective repertoire. By having multiple shared discrete calls, killer whales can increase the efficiency of communication within the pod (Ford, 1989). Living in stable matrilineal groups, a killer whale will travel with its mother its entire life (Bigg et al., 1990). This makes for a strong mother-offspring bond and even as adults, the offspring can be seen swimming next to their mothers. These killer whale behaviors of shared repertoires and staying close together, emphasize the strong bonds among related whales and support the premise that such close groups would want to evolve an effective and reliable way to stay in contact when out of visual range. Evaluating the complexity and detail of a killer whale pod reveals how important communication is in their society and can provide us with valuable information on how to improve our conservation efforts.

A study conducted by Monika Weiland in 2007, discloses the significance of killer whale communication by looking at the repertoire usage in the SRKWs. Weiland used hydrophones to record the current repertoire usage in all three of the SRKW pods. The results yielded a detailed spread of the call types, frequency, and duration, used by the pods, see figure 1.

Comparing her findings to Ford's 1989 paper, revealed that the discrete call S1, has been the J-Pod's dominant call since at least the 1970's. Building on previous data that this call is used solely by the J-Pod, the S1 call could serve as a contact call for the pod to keep track of each other and stay organized. The hypothesis of this study is that J-Pod uses their discrete call S1, as a contact call to maintain group cohesion and will use it more frequently when they are separated from one another. By testing this, one can measure the frequentness of the call to support the use of a contact call and emphasize the benefit of vocal localization in killer whale pods.

This concept of using discrete calls to keep in contact among pods is no new feat to the animal kingdom. In the past decade, many species including elephants, dolphins, and birds, have been identified using a unique contact or "cohesion" call to keep in touch with their group when they are beyond visual range (Janik and Slater, 1998; Maccomb et,al.,2001; Ford, 1991). Such studies have been done with a close relative of the killer whale, the bottlenose Dolphin (*Tursiops truncatus*), by removing a single dolphin from the main pool into an isolation pool out of sight and sound of the other dolphins (Janik et al., 1997). The results revealed that the isolated dolphin significantly increased the use of its signature whistle (figure 2). As well, the dolphins that were together in a separate pool, increased their signature whistle use when one member was separated from the group (Janik et al., 1997). These findings support the hypothesis that killer whales may also use a cohesion call when they are separated.

In November 2005, killer whales were listed as endangered under the Endangered Species Act of 1973. Since then, researchers have focused their efforts to better understand killer whale habitat and behavior in hopes of conserving this iconic animal. Scientists in the field have been observing and gathering acoustic recordings of killer whales, but still little is known about their communication and behavior. This is partially due to the fact that killer whales spend only 5% of their lives above the surface, which is where we can confidently study them (NFMS, 2008). As well, killer whales spend a significant amount of time close together in their pods, which makes it difficult to gather data on individual killer whale vocalizations. Despite the obstacles, researchers have managed to associate specific calls to the three different pods J,K, and L, that frequent the Salish Sea. Scientists have identified and cataloged the different call types for the SRKWs, but there are no present links between killer whale discrete calls and behaviors. Linking killer whale behaviors to calls would be helpful because then we could experimentally quantify that killer whales are in fact reliant on their discrete calls and outline parameters, such as reducing vessel noise or expanding protected habitat to improve our attempt to conserve these marine mammals.

Methods:

To investigate the use of a contact call in killer whales, we will observe and record SRKWs in the Salish Sea from mid April to late May. We will use a hydrophone array to record the killer whales acoustic communication. All recordings will be made from a 42–foot hybrid electric-biodiesel catamaran called the *Gato Verde*. The *Gato Verde* is equipped with a battery pack that allows it to motor silently for as long as 3 hours continuously. The *Gato* also has a biodiesel generator that can supply enough electricity to power the electric motors, should we need to motor for an extended period. This will allow us to motor silently and record the whales without disturbing them or disrupting our hydrophones.

For this study, data will only be collected from the Southern Resident J-Pod. Specifically, we will be searching for S1 calls as they are recorded via the hydrophones (see figure 3). Simultaneously, we will be measuring the killer whale's degree of distribution by taking wide angle photos of the whales when they surface for air. A paper by John Durban in 2006, used laser metrics to determine and catalog each whales dorsal fin length. From the photos, we will identify the whales by their unique dorsal fin markings. We can then use the laser metric determined length and to calculate how far apart the whales are from each other in the photos. When analyzing the photos, we will rely on a software program called ImageJ, to measure the whales group spread from the dorsal fin calculation. We will be assessing the distribution with respect to call rate as well as call density. We have defined the call density as the number of calls per minute, per group size. We will also measure the salinity, depth, and temperature, of the water.

By measuring visibility levels in the water, we can account for the killer whales sight range. When calculating killer whale calls and group spread, it will be useful to note the visibility of the water with respect to our results. To evaluate visibility we will use a Secchi disk and sample phytoplankton density in different predetermined zones. We constructed a Secchi disk equipped with LED lights so we can measure visibility during day and at night. The 8 inch diameter Secchi disk has alternating black and white quadrants and is rigged with a 10lb weight so it sinks. We plan to approach this measurement by lowering the disk over the shady side of the boat and calculating the depth at which we can no longer see it. The procedure will be the same for night tests except, we will be measuring the depth at which we lose sight of the LED lights on the disk.   As well, we will be measuring plankton density as a contributing factor to visibility levels. To collect and measure plankton samples, we will tow a 15 mircon and 150 micron net behind the boat in specific zones defined by figure 4. To assess how much water has been filtered through the nets, we will attach a flow meter. The flow meter will measure the velocity of water that passes through the net and enable us to know how much water we filtered.

Multiple hydrophones will be used to account for the variable that there may be multiple groups of killer whales in a wider region than visible to the crew. Using multiple hydrophones and pointing them in different directions, will facilitate a better idea of which whales are vocalizing and how far apart they are. The hydrophones will be distanced by 10ft increments and towed behind the boat. A hydrophone array of 4 LAB-core hydrophones and one Cetacean Research Technology C54 XRS/266 (CRT) high-frequency hydrophone will be towed behind the boat. The LAB-core hydrophones exhibit a peak sensitivity at 5,000Hz and decrease 30dB at 200Hz and 10,5000Hz. The sampling rate will be set to 44,000 samples/sec and the gain setting will be adjusted to 37dB. To keep the hydrophones parallel to the surface and below the upper layer turbulence, we will attach an 8lb weight to sink the array to a depth of about 5m. Using Audacity 1.3.12 Beta, a sound recording and analyzing program, we will also note the date, file name, and time of each recording made to help us keep the data organized.

Alternate Methods:

Should we not gather sufficient whale data, I will have an alternate experiment planned. In this experiment, I will look at the S1 discrete call use in J-Pod as it varies for day and night. The hypothesis for this experiment is that the killer whales will vocalize equal amounts during the day and night. This experiment will be completely based on archival data. I will analyze the killer whale recordings acquired from the Lime Kiln hydrophone. One idea I am considering would be to look at the recordings made from April 2006 to May 2006. Specifically, I will be looking at the percentage of calls for the different bouts during day and night to determine how often they use the S1 call. Using the data from WHO_Listener Data Central, the calls from Lime Kiln can be organized into spectrograms and analyzed.

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