An acoustic and behavioral analysis of the southern resident killer whales of British Columbia: How does gender and age affect behavior states and discrete calls?

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Introduction

The southern resident killer whale community of British Columbia is made up of three pods that collectively make up 90 individuals (Center for Whale Research 2007). A pod is defined as a social unit in which the whales spend at least 50% of their time together (Ford et al. 2000). They socialize regularly, share acoustic calls, and the pods made up of tightly knit matrilines. The offspring in these resident pods have never been seen to disperse from their mothers. Pods that share acoustic similarities belong to a clan. The J, K, and L pods which make up the southern resident community share some discrete calls, which place them in J clan (Ford et al. 2000). Although they have some acoustic similarities, there are calls that are pod specific. It is unknown if there are any individually specific calls, although a study has shown that there do, not seem to be signature whistles (Riesch et al. 2005).

The goal of this study is to 1- localize killer whale calls in order to identify specific individuals and investigate whether calls are age specific and 2- to collect surface behavior data in order to distinguish whether there are behavioral differences between different age classes. The answers to these questions are relevant to the current

management plans for the southern residents. It would be advantageous to have the ability to distinguish gender acoustically because it would provide insight into the male: female ratio when the whales are out of sight. It would also be beneficial to distinguish the call rate transmitted from calves to mothers in order to establish how anthropogenic noise could affect their communication.

It is unknown whether behavior and acoustic differences between genders are prevalent in killer whales. Killer whales produce three types of sounds: clicks, whistles and calls (Saultilis et al. 2005). Whistles are tonal sounds that last about 1.8 seconds and have an average frequency of 8.3 kHz (NMFS 2006). Discrete pulsed calls are the most common type of vocalization of the southern residents. Call frequencies are generally between 1-6 kHz, but can extend up to 30 kHz (NMFS 2006). Although it is unknown whether discrete calls differ between gender or age, there is evidence that the range of frequency is related to body size (May-Collado et al. 2007). It is believed that a large factor in intraspecific variation could be related to a morphological constraint such as body size or mass. There is a great size variation in the toothed whales, *Odontoceti* which is correlated with minimum frequency (May-Collado et al. 2007). The larger toothed whales have a greater range in reference to low frequencies when in comparison to smaller toothed whales (May-Collado et al. 2007). This may indicate that adult male killer whales are able to produce lower frequency calls due to sexual dimorphism, as males are approximately 10 meters whereas females range from 6-8 meters (Baird 2006).

It also may be possible that there are sounds or calls produced more frequently, or solely by males. These sex-specific acoustics have been proven in various animals such as the sperm whale and many species of birds (Jaquet et al. 2001, Alcock et al.

1998). In an isolated population of transient killer whales in southern Alaska, it is known that lone males make loud, discrete calls that last from 1-4 s, which is significantly longer than their average hunting call (Saulitis et al. 2005). These calls are thought to send multiple pieces of information during long distance communication (Saulitis et al. 2005). Although the social behaviors of resident and transient killer whales differ greatly, it indicates that there is a possibility that the southern resident males also have distinct calls. Foreman (2006) also found the southern resident males have higher frequency fundamentals and shorter calls than females. Due to these data I hypothesize that the southern resident adult males will produce shorter calls, and have calls that are somewhat distinct from the rest of the population.

Along with sex-specific calls, there may also be sexually specific behavior, which has been found in other delphinids (Kaplan et al. 2007). A population of over 600 bottlenose dolphins (*Tursiops truncatus*) in Western Australia exhibits a behavior known as contact swimming in which one dolphin places a pectoral fin on the flank of another dolphin (Connor et al. 2005). Two adult females exhibit this behavior even when they are in a group dominated by males (Connor et al. 2005). It is thought that since this position looks much like a mom and her calf, it is more commonly found in females because they provide parental care and males do not (Connor et al. 2005).

My second study question asks whether age plays a role in the behavior and acoustics of the southern residents. The birth of a killer whale is a group event for the whole pod (Baird 2002). The acoustic behaviors of three northern resident matrilines were observed after births of calves (Weib et al. 2005). All pods increased their family-specific call rates, and showed a very high rate of excitement calls, all of which peaked in

the days followed by the birth, and then dropped back to normal levels approximately two weeks after (Weib et al. 2005). It is known that infants learn their calls from their mothers, and tend to vocalize less in their first year of birth (Baird 2002). Infants tend to separate (more than 16 m) from their mothers more than once an hour (Baird 2002). One fourth of their time is spent either playing with siblings or by themselves (Baird 2002). During these times, are they communicating with their mothers and with other members of the pod? If they are in contact with their mother, what kind of calls are they producing?

Tactile behaviors in Atlantic Spotted dolphins, *Stenella frontalis* have been proven to vary greatly with age class, mostly in regards to petting and rubbing (Kaplan et al. 2007). Juveniles engage in these behaviors much more frequently than adults (Kaplan et al. 2007). They also tend to play with other juveniles that are of the same sex (Kaplan et al. 2007). With this in mind, do juvenile killer whales exhibit certain behaviors more frequently than adults? I hypothesize that juvenile killer whales exhibit more tactile behaviors than adults.

The northern and southern resident killer whales have home ranges that greatly overlap, yet they belong to different acoustic clans and do not seem to interact (Riesch et al. 2005). Since the clans have specific dialects, and within clans there are pod specific calls, it seems possible that there are gender, age, or even individual calls that could be localized and identified. If these whales show age and gender specific communication, it could also be possible that they exhibit specific behaviors that coincide with their calls. I hypothesize that there are definitive differences between the call types, frequencies, duration and surface behavior of males and females, and between different age classes. I

also hypothesize that males will produce lower frequency calls because of sexual dimorphism and that females will exhibit a greater range of call types.

Materials and Methods

I collected two different sets of data, one for acoustic behavior and the other for surface behavior. All data was collected aboard the *Gato Verde*, a 42' electric powered catamaran, in the inland waters surrounding the San Juan Islands, Washington. The recordings and behavioral data were only collected from the J, K, and L southern resident pods. All of the data was collected between August 26, 2007 and October 21, 2007. We followed the Whale Watch Guidelines in order to ensure a minimal impact on the whales (The Whale Museum 2006).

For the acoustic part of my study, I analyzed the call rates of males, females, and different age groups to assess if there are differences. In order to collect this data, a four channel hydrophone array (Lab Core) was deployed off the port stern of the boat. The gain was set at 37dB and the samples per second at 44,100. The peak sensitivity was ~5000 Hz, down 20dB at ~200Hz- 10,500 Hz. **Specs** The array was continuously record when whales are present. While the whales were within our sight, a focal group was chosen. The group of whales closest to the boat was chosen so it was easier to photo identify the individual whales in the group. However, lone whales or whales in small groups took priority in order to increase accuracy of localization. When whales were present, the bearing of the animal in regards to the boat was calculated using a protractor. The distance of the whale from the boat was taken using a range finder (Newcon Optic), and pictures were taken for later identification.

The acoustic data was analyzed using the program Ishmael 1.0 (David Mellinger) which localizes calls through the hyperbolic method by producing a bearing to the whale and location in regards to the hydrophone array. The coordinates for the location produced by Ishmael were put into Excel (Microsoft) and compared to the bearing and location that was recorded with the protractor and range finder. From the Ishmael coordinates, the distance was calculated using the Pythagorean Theorem. The value produced is the distance, and from that number I obtained the bearing in radians, which is defined by sin=opposite/hypotenuse. The value in radians was then converted into degrees, which allowed it to be compared to the bearing and distance obtained on the boat. If the bearing was within 20 degrees and the distance was within 50 meters, the data was accepted and used for localization. The error range chosen for the degree and distance was due to potential large human error when using the protractor and estimating the distance of whales when I was unable to use the range finder. For the data that was accepted, the localized animal was identified.

Once the localization to a specific animal was complete, the call types were analyzed using the Catalogue of Underwater Calls Produced by Killer Whales (*Orcinus Orca)* in British Columbia (Ford 1987). Once the call types were identified, the lowest and highest frequency (KHz) of the fundamental frequency on each call was recorded. T-tests were used to analyze the frequencies. The call durations (s) of each localized call were recorded and differences between call durations of gender and age were be tested. The goal was to have results that indicated whether there are significant call type, frequency, and call duration differences between males and females, and age groups.

The second question of my study involved the differences in surface behaviors between genders and different age groups. The behavioral states that were used were taken from Ford et. al 2000 and listed in Table 1.

Foraging	Traveling	Resting	Socializing
includes feeding or searching for food. It Is the most common activity. The pod is usually spread out with small subpods that are generally swimming together. There are usually 2-3 short dives made, followed by a loner diver (1-3 minutes). Foraging is thought to compromise 65% of the southern resident behavior.	Traveling is considered when a group of whales is consistently swimming in a specific direction. Usually there is a tight formation, and there cannot be ay signs of feeding or searching for food. They usually travel faster than when they forage, and they often surface and dive simultaneously. They are usually very vocal while traveling.	This behavior is very easily recognized because the whales swim slowly, in a tightly knit group, usually abreast. While swimming abreast, the offspring usually surround their mother. They are very quiet and make longer dives. Resting is thought to make up 13% of southern resident behavior.	Socializing includes many different physical interactions, displays, and percussive events. Socializing behavior includes sexual interactions, kelping, aerial displays (breaching, tail slapping, spyhopping, etc.) This is thought to account for 15% of the southern resident's time.

Table 1. The four behavioral states of killer whales

I recorded the behavior and took pictures for later identification. Each whale can be identified by their distinguishable saddle patch shape, dorsal fin shape, and specific nicks or scratches. The Orca Survey has left and right identification pictures of each whale and the pictures I take were identified using this guide (The Center for Whale Research 2007). My observation period was in ten minute intervals, and during these periods the focal group's behavioral state was recorded. The surface behavior data was organized by creating a table that includes the duration of the 10 minute interval, behavior, gender, bearing, distance, and identification. Gender between adults is very easily distinguishable due to the different sizes and shapes of the dorsal fin. The total duration (seconds) that each individual has spent in the four different behavioral sates were calculated. After the individuals were grouped by sex and age, total durations for each behavior were averaged

to obtain a final result that indicated the proportion of time males, females, and juveniles spent in the different states.

Results

The acoustic portion of my study was limited by the number of calls that I was able to localize to a specific individual. Two juveniles, four females, and six males were identified and they are listed in Table 2 along with the frequency of calls by those individuals. The results for the acoustic portion of my research was partially supported by my hypotheses, however other portions were inconclusive. Three Anovas were run using a general linear model and a square root transform in order to fit the assumptions of the test. For the mean duration of calls (Figure 1) were $F_{2,33}$=1.34, P = 0.275 indicated that there were no significant differences between the call durations of females, juveniles, or males. The next Anova run was for the differences between high frequency. The results (Figure 2) were $F_{2,33}$=1.34, P = 0.067 therefore no differences between high frequencies were detected. The last Anova was for the differences between low frequencies of calls and results (Figure 3) were $F_{2,33}$=4.19, P = 0.024. This P value indicates that there is a significant difference between the mean low frequencies of females, juveniles, and males. Since significant differences were found, a Tukey's pairwise comparison was run. The results are listed in Table 3. These results show that there is a significant difference between the low frequency of females and juveniles, but no significant differences between males and females, or males and juveniles.

ID	Male	Female	Juvenile	Number of Calls
L84	X			1
L95	X			1
J30	X			1
K21	X			1
?	X			2
L83		X		2
K27		X		6
J22		X		4
L47		X		3
J38			X	14
J juvenile			X	1

Table 2. The individual whales that were localized and the frequency of the calls that were localized

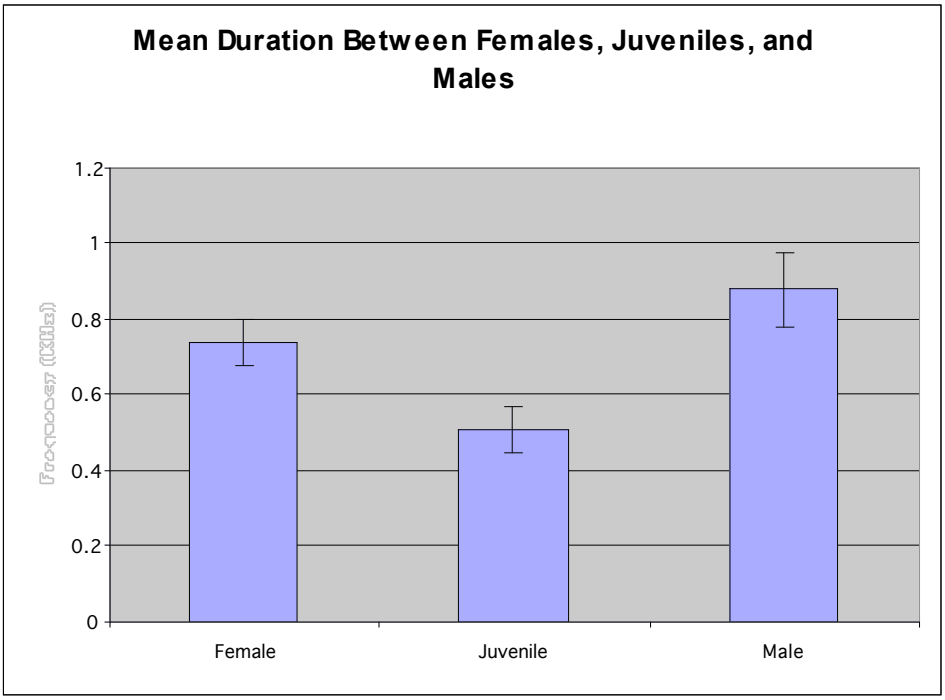

Figure 1. Anova results for the duration of calls between females, juveniles, and males

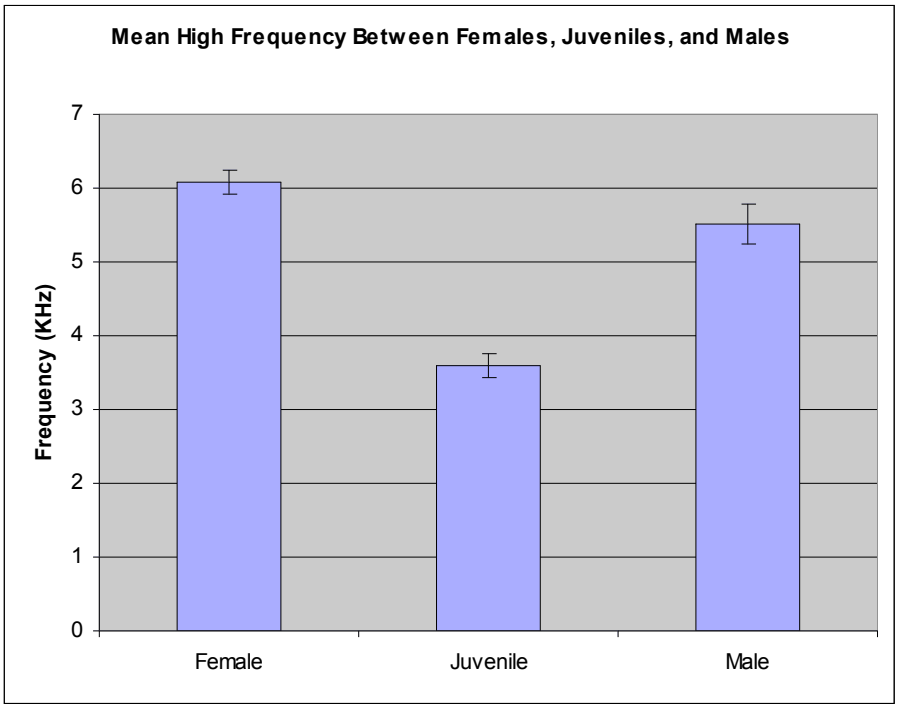

Figure 2. Anova results for differences in high frequency of calls between females, juveniles, and males

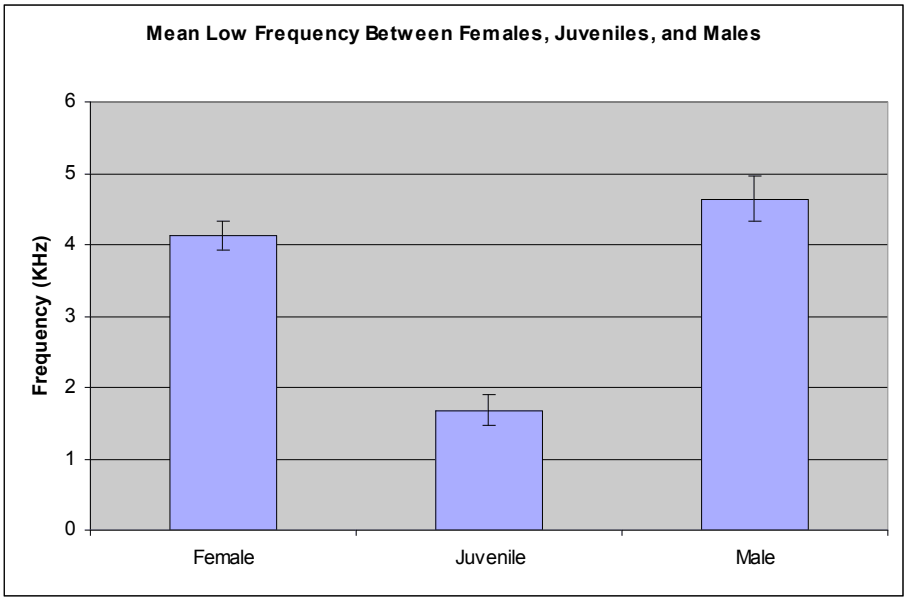

Figure 3. Anova results for the differences in low frequency of calls between females, juveniles, and males

	T Value	P Value
Female- Juvenile	-2.543	0.0409
Male- Juvenile	2.244	0.0786
Female- Male	0.321	0.9448

Table 3. Results for the Tukey's pairwise comparison for low frequency differences between females, males, and juveniles

Discussion

In this study it was found that there are no significant differences between the call durations of males, females, and juveniles. However, it has been shown that juveniles and females have significantly different low frequencies. The mean low frequency of juveniles was lower than that of the females. Although there was no significant difference between the low frequency of juveniles and males, the p value was marginally above .05, indicating that there is a possibility that with a larger sample size a significant difference could be found. No significant differences found in low frequency between adult males and females, implicating that my hypothesis was incorrect. There were also no significant differences found in the high frequencies of females, juveniles, and males. A further study that investigated the age at which juveniles begin calling at the same frequencies as adults would be informative. Although my hypothesis about the frequencies of age groups was somewhat correct, my hypothesis for frequency differences between males and females was wrong. The gender differences in high and low frequencies, and duration were found to be statistically insignificant. These results could possibly be due to the much smaller n value in males (6) than in females (16).

The largest area for further research would be to have a much larger sample size. This would allow Anovas to be run for high frequencies, low frequencies, and call durations between different call types. The call types are highly variable in both frequency and duration, but unfortunately the sample size of this study was too small to

conduct tests within call types. The calls that I was able to localize to individuals and performs tests on consisted of 5 males, 2 juveniles, and 4 females. This is an extremely small sample size but my findings indicate that with further research significant differences between frequencies and call durations may occur.

The behavioral part of my study was completely inconclusive. A longer amount of time and a bigger sample size is needed to detect the subtle differences in behavior between individual whales. However, behavioral differences between juveniles and adults have been recorded in other species. For example the Atlantic Spotted Dolphin juveniles tend to play with other juveniles of the same sex, and they are more likely to engage in petting or rubbing behaviors than adults (Kaplan et al. 2007). Juvenile male killer whales have been seen in groups with erections, and this is thought to be a type of play (NMFS 2006). These encounters have not been quantified but it supports my hypothesis that there are possible behavioral differences between gender and age groups. These subtle behaviors were unable to be detected during my four weeks of data collection.

There were no significant differences for call duration or high frequency. However, the low frequency of the female adults differed from the juveniles. The results that were obtained from the juveniles could be due to a variety of biological or physiological reasons. Killer whales are thought to learn through cultural transmission (reference), and the complexity of their repertoire is not totally understood. The juveniles whose calls I was able to localize may be too young to make calls that are similar in frequency to the adults that they are learning from. The age at which calves use the entire repertoire of their pod is unknown. The calls that were collected from the juveniles were

different call types than the calls from the adults so it is unknown whether the frequencies would differ among the same call type.

If the results are not because of a biological reason, they may be due to a physical restraint that the juveniles have. They may not be able to produce sounds at as high of a frequency or for as long compared to adults. A study of captive and free ranging Bryde's whale (*Balenoptera edeni)* mother calf pairs were studied revealed that adult calls are shorter in duration, and the frequencies between adults and juveniles were similar (Edds et al. 1993). This study also had a limited sample size but call differences between juveniles and adults did exist (Edds et al. 1993). Although my study found a significant difference between juvenile and adult low frequencies but not for call duration, there is a possibility that definitive differences do exist between males, females, and juveniles. Foreman (2006) found that southern resident killer whale males had shorter call durations than females, and females had a higher frequency of the first harmonic. These results do not agree with my results, however, a bigger sample size would allow tests to be run within call types and that could allow different results.

The acoustics of killer whales is a vital part of their behavior and learning more about the differences between pods, matrilines, or even individuals can provide insight to their behavior, physiology, and ecology. Acoustic behaviors during different behavioral states, or even different stages of life could be important information while thinking about conservation. The southern resident killer whales are an endangered population, and future recovery plans rely on the information that is known about their ranges, behavior, foraging, along with many other factors. Their acoustic behavior is used for foraging and social complex social organization among pods, and matrinlines. Therefore,

any information known about their acoustic behaviors could be vital in their recovery in the Salish Seas.

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