Localizing Vocalizations in Southern Resident Killer Whales: A look at Gender Differences

Peggy Foreman
Beam Reach Marine Science and Sustainability School

Introduction

The southern resident killer whales (*Orcinus orca)*, known as J, K, and L pods, forage in the inland and coastal waters of Washington State and British Columbia. The social and acoustic associations characterize the relatedness of this population. A pod is a primary social unit made up of stable matrilines that associate regularly (≥50% of observation time), and emigration of males or females has not been observed (Yurk et al. 2002). These stable kin groups are believed to share a unique repertoire of discrete call types; and pods that are acoustically related and share parts of these vocal traditions are called an acoustic clan (Ford, 1991). A community is a group of pods that have frequent associations with one another and have different distributions in relation to other communities (Ford, 1987). Hence, J, K, and L pods socially make up the southern resident community and are acoustically know as the J clan. There are approximately 86 whales: 29 are males (34% of the population and only 14 of the males are over the age of 15) and 56 are female (65% of the population and 41% of the females are of reproductive age). There are 7 whales with unknown gender, making up less than 1% of the population. In contrast, the northern resident community consists of 16 pods (about 200 whales) and is acoustically known as A, G, and R clans (Ford, 1991).

Killer whale vocalizations are grouped into three categories, clicks, whistles, and calls. Clicks are very short bursts of sounds (0.1-25ms), characteristically in series (Ford, 1987). Clicks are used as echolocation in the detection and pursuit of prey, as well as during social encounters (Barrett-Lennard et al. 1996). Whistles have tonal characteristics, commonly with a continuous waveform, which appears in spectrographic analysis as a narrow-band tone with or without harmonics (Thomsen et al. 2000). Whistles are believed to play an important role in the close range acoustic communication in northern resident killer whales (Thomsen et al. 2002). Calls have been classified as pulsed signals generated at high repetition rates; most fall into distinctive structural categories referred to as discrete calls (Ford, 1987). These discrete calls are the most common sound type during activities when individuals are widely spaced, like in foraging, suggesting that discrete calls help with cohesion or coordinate with members of the social group (Ford, 1991). These discrete call types are shared among pods, but are often seen in different forms specific to each pod or groups of pods. Variability in structure of these discrete calls is common in all categories. Also there appears to be variation in the sound production within matrilines of pods (Miller and Bain, 2000).

Furthermore, social dynamics and differences between males and females within a pod are quite extensive. For instance, there are large morphological differences like overall length (adult males ranging in size from 8-9meters and adult females about 7meters), and weight (adult males weighing between 10-11 tons and females 7-8 tons (Bigg et al. 1987). Often seen in foraging behavior, whales tend to spread out over an area of about 3-10 km^2 and have been seen in different social organizations (Osborne, 1986). Killer whales spatially segregate both horizontally and vertically while foraging and peripheral males have been seen milling on their own. (Felleman et al. 1991). It has also been documented that adult males dive deeper more often than adult females (Baird et al. 2005). Are these differences in foraging behavior and spatial distribution potentially a method for minimizing competition for food or are the males scouting for food and then determining where the pod travels next? Are they feeding on deeper, bigger fish (possibly Chinook salmon)?

The goal of my study is to localize vocalizations from individuals in the southern resident community with the intent of studying gender differences. By localizing the calls of males, females, and mixed gender groups, I hope to understand more about the communication of these animals and reveal more information about their social organization. Understanding killer whale acoustics in relation to individuals within a pod could potentially reveal a great deal about a species that is currently endangered. Thus, I will consider if there are any variations in calls (duration, high and low frequency, change in frequency, and the fundamental) in regards to gender. I hypothesize that lower frequency calls would travel further distances and due to the sexual dimorphism of this species, I would predict that males would have a lower fundamental frequency. I also predict that they will call more often because they are further from the rest of the pod. I would assume that call duration and amplitude would be correlated. A louder call might have a shorter duration; hence I am predicting that males will have shorter calls. I predict that the frequency modulations of the harmonics of calls will differ in regards to gender.

Such research is currently relevant due to recent population declines of southern resident killer whales and the recent Endangered Species Act listing (NMFS, 2005). Of the 86 whales in this population, only 14 males are sexually mature ($\geq$ 15 years of age) and approximately only 23 females are of reproductive age. It bears understanding the complex differences between genders in a population, especially if they have differences possibly in foraging/diving behavior (Baird et al, 2005). Understanding who is making the calls and the variations in vocalizations among individuals can reveal more information about behaviors and the complex interactions of this complex social species.

Materials and Methods

Data Collection:

To determine if calls and call characteristics change with gender, acoustic and surface behavior observations of the southern residents took place in the greater Puget Sound region, ranging from the north end of Stuart Island to the south end of San Juan Island. Fieldwork took place between October 2-22, 2006, and we encountered the whales on October 3rd , 10th, 11th, 13th, 19th, and the 20th. Recordings and observations were made during daylight hours from a 42' catamaran, known as the Gato Verde. This vessel is propelled primarily by the wind, but can also be powered by twin hybrid diesel-electric engines that burn biodiesel. We received assistance finding the whales using the Whale Watchers' pager system on most days except the 13th and 19th. We were diligent to abide by the voluntary Be Whale Wise Guidelines paralleling the whales and recording when whales were within about 500m of the vessel. When we encountered whales we took a GPS waypoint at the time of deployment of the towed hydrophone array, which was used to assist in localizing the calls of focal animals. There were continuous acoustic recordings throughout the time we saw whales and another waypoint was taken when we stopped recording.

The hydrophone array was in linear formation and attached to the hull of the catamaran. There were 6 different configurations used due to equipment failure (see table 1). Hydrophone #2 on the blue sea snake was calibrated using a National Institutes of Standards and Technology hydrophone. The hydrophone array was then attached to a National Instruments sound card which took the output from the four channels of the hydrophone array into a laptop. Series of sound files, which were time stamped and stored every 1 minute, were used to record the data using the software program, ISHMAEL 1.0.

When whales were present, I was located at the bow of the boat with my PDA (palm Tungsten E and software provided by Dr. James Ha, University of Washington), clipboard with paper and pencil backup for observational data, watch, bearing chart, and an assistant with a camera, range finder, and binoculars. I did not collect surface data if the whales were in close/ tight knit groups, or directly in front of or behind the array. Opportunistically, when whales were spread out I choose my focal groups who were swimming separate from other whales or were located on one side of the hydrophone to get acoustic and surface behaviors. My focal groups fell into different categories: lone males, more than one male traveling together, and matrilines with primarily only females that were acoustically isolated from other pod members. To decrease the possibility that my sample was dominated by one vocalizing individual, I tried to conduct at least another recording session of each focal group with more than one individual (Miller and Bain, 2000). Once I found my focal groups, I found the bearing from the center of the boat and determined their distance, either exact distance with a range finder or an estimate. Then I counted the number of individuals in the focal group (time stamped in the PDA).

To gain confidence with our bearing and locations of sound sources we conducted two experiments in a dinghy with known locations and bearings. We hit a metal pipe with a closed base and recorded using the hydrophone array and the red box. We then analyzed the pings from the pipe in Ishmael to see if the bearings were reasonable. The average degree difference from the experiments was 23.5°, however the highest difference occurred 15° either side of 0° and 180°. In eliminating data 30° degrees at either end of the array made the average 17° off of the original source. These experiments also revealed that if the sound source was further than about

350m, there was more variance in the bearing from ISHMAEL. However, in my analysis my largest difference in bearing was 16° and the average bearing of my data was off by 5.8°.

If the focal animal/s were not identified at the time of surface recording, we photographed each focal group and documented in writing which frame on the camera matched the calls recorded. We used the Center for Whale Research Field Guide, 2006 color edition to identify the individual whales. The last observation recorded in the PDA was the predominant behavior state, as described below (Osborne, 1986). When our data collection ended I would take another GPS waypoint, bring in the array, and prepare the sound recordings for acoustic analysis.

Behavior States:

Resting: Often a tight cluster of whales moving slowly often in synchronized formations. Traveling at speeds around 1-2 kts. Stationary resting, known as logging, are when whales hover at the surface of the water (up to 1.5 min. at a time).

Traveling: Directional movement at a steady pace (+3.5 kts) over a minimum distance of 2-3 km. Staying together as a pod, not necessarily synchronized, however it does occur.

Foraging/milling: Loose forward orienting; non-directional milling; percussive activity; spread out over a 3-10 km^2 region; sometimes sudden bursts of energy that appears like chasing.

Surface Active: Explosive surface acrobatics (breaches, porpoising, and cartwheels). There are also other low level activities such as tail lobs, pectoral slaps, dorsal fin slaps, spyhops, and any other splashing behavior. When whales are seen manipulating seaweed or any other object.

Other: This is a category where a behavior might be difficult to put into a category. Sexual behavior or courtship are a few examples that might fit into this category.

Data Analysis:

Information collected on my PDA (numbers in focal group, bearing, distance, predominant behavior state, and Pod I.D.) was downloaded and transferred to my data file stored in excel. First I looked at my behavior data and sorted by gender, then I focused on individuals that I recorded more than two or three times. I then categorized for individuals or small groups that were closer than 350m to the boat. I then looked for calls to localize within 1-2 minutes of the time I saw an isolated focal group. I listened to the one-minute files to determine if there were any calls. I selected and saved each call (in all four channels) that I thought was loud, pulsed, and had harmonics. Next, I analyzed each of the calls using ISHMAEL; which calculated the arrival time difference for pairs of phones and produced a bearing to the animal/s. I then compared my bearing to the localized calls from ISHMAEL. Vocalizations in which consistent angles to the sound source could not be verified with this program's locations were not used, because they likely came from outside the focal group. Calls were rejected if any of the following occurred:

1. The bearing didn't match the observed surfacing within 17°
2. There were more whales than the focal group present in the direction of the bearing.
3. The recorded call was faint or undetected due to background noise

Vocalizations recorded from a localized source were measured to estimate the variation in the call characteristics within three categories: male, female, or mixed gender. I used the software program, Raven (version 1.2.1) to analyze the structure of the calls (sampling rate of 22050 samples per second, and using an FFT rate of 512). Measurements of the frequency of the fundamental, call duration, and changes in the frequency of the 1^{st} harmonic were taken from each of the localized vocalizations. I then found the average and standard deviation of all the call characteristics in regards to male, female, and mixed groups. To statistically analyze the variations in calls I used a one factor ANOVA to determine if each of the physical measures of calls varied with gender.

Results

To determine if calls and call characteristics change with gender, acoustic and surface behavior observations of the southern residents were recorded on 6 out of the 19 field days. We gathered 19.5 hr of acoustical recordings and I recorded 16.95 hr of PDA data, then looked through 115 one-minute files to isolate and save calls. I localized 122 calls, 19 of which were at bearings consistent with my visual bearings. Data from October 10^{th} was unusable because of equipment malfunction and therefore was excluded from further analyses. The predominant behavior state in which localized calls were recorded occurred during slow directional travel, 95%, and foraging, 5%. The localized calls in Ishmael were on average 5.8° off of my documented surface observation (Table 2). To look at gender differences in localized calls, I considered 4 male calls (one from a "sprouter" in J-pod and three from K21), three female calls (L47 and a juvenile from J-pod), and 12 calls from two mixed gender groups (L21, L47, with two males and 1 male, K40, another female and juvenile). Average fundamental frequency, call duration, low frequency, high frequency and the change in frequency of the first harmonic of calls are summarized in Table 3.

Analysis of variance showed no significant gender differences with respect to fundamental frequency (Figure 1, $F_{[2,16]}$=2.4212, p= 0.1206). There was no significant gender difference with respect to call duration (Figure 2, ANOVA: $F_{[2,16]}$=1.8183, p= 0.1943). Analysis of variance showed no significant gender difference with respect to low frequency of 1^{st}

harmonic of calls (Figure 3: $F_{[2,16]}$= 0.4785, p= 0.6283). There was no significant gender difference of high frequency of the 1st Harmonic of calls (Figure 4: ANOVA: $F_{[2,16]}$= 1.2457, p= 0.3142). Lastly, analysis of variance showed no significant gender difference with respect to change in frequency of 1st harmonic of calls (Figure 5: $F_{[2,16]}$= 3.5752, p= 0.0521).

Discussion

Although call types have been studied in the southern residents extensively (Ford, 1987, Ford, 1991, and Miller and Bain, 2000), these data are among the first in which localization of calls by gender has been studied. My predictions of differences in call characteristics in regards to gender were partially correct. First of all, I predicted that males would have lower frequency fundamentals, because males are often foraging further from the pod or on the periphery of the overall group and lower frequencies travel over longer distances. Also due to sexual dimorphism, I would predict larger animals to have lower frequency fundamentals and possibly more variation in their harmonic structure. I was incorrect on the average fundamental frequency; it is higher in females than males. This might be attributed to the fact that the higher frequency is heard over the ambient noise. I also predicted that males would call more often, because they were further from the rest of the pod. This was not tested, but would make a great study. I also assumed that call duration and amplitude would be related. A louder call might have a shorter duration; hence I predicted that males would have shorter calls. I was correct in my prediction; the males I localized had a shorter call duration. The harmonic differences were quite similar, males being on average having a little higher frequency. Females had the higher frequency of the first harmonic, but I was surprised to see that the change in frequency was higher in males than females. Looking at the mixed gender group, the frequency modulations of their calls might reflect two pods traveling together that day. When pods mingle and interact, there might be a calling response between individuals, mating communication or courtship calls, or even perhaps calls that might reflect emotion. I would like to note that the calls analyzed were of different call types and quite possibly a combination of pulsed calls and variable calls. If you look at the first harmonic of calls, the average low frequency isn't as varied as compared to the high frequency. I speculate that certain calls have sidebands or a multi-component call characteristic that accounted for the difference in the high frequency of the first harmonic of calls and due to my sample size wasn't able to localize the same call. A previous study by Miller and Bain (2000), showed the relevance of call types containing multi- components, noting that the duration of the terminal component was the most distinctive feature. The mixed gender groups were higher than both genders individually when looking either at fundamental frequency or the harmonic structures. This difference might also be contributed to the fact that there were two pods present on that day. If the pods had been separated for a length of time, this time together might have evoked changes in vocalizations. Increasing sample size might reveal more of a pattern between isolated genders and looking at different configurations in respect to pods.

It was common in my recordings for calls to be repeated. Typically they were within 5-7 sec apart, corresponding to a repetition rate of as little as two times to as many as 10 times in a few recordings. So, in one of my male samples, (K21), a call was repeated 3 times. In one of the female samples, (L47), a call was repeated 2 times. However, in the mixed gender group both samples had repeated calls. There is no certainty that all the calls came from one individual or if there were two individuals calling back and forth to each other. Also they occurred during slow directional travel. However, within 3 minutes of every localized call that was categorized as slow directional travel, there was foraging behavior documented. It is possible that these calls are related to foraging behavior, and as such, have a biologically relevant aspect to maintaining population viability.

There are a few potential sources of error that may have contributed to the lack of statistical significance between call characteristics and gender. The program used to localize, ISHMAEL, is capable of phone pair bearing, hyperbolic, cross pair correlation, and beamforming. However, I was only confident in using the bearing for my analysis, because when testing ISHMAEL in the dinghy experiment the locations and bearings did not match using the other three. Due to the fact that ISHMAEL gives you two bearings, it is possible that when one of the bearings that matched my behavioral data, the sound still could have come from the other side of the boat. If I had the hyperbolic location to verify my results it would add strength to my work. Two component calls were particularly difficult to analyze in Raven; it was hard to tell if two calls were overlapping or if they were the same call. Correctly isolating the contour of the first harmonics vs sideband structures was difficult on 1/3 of the calls selected. Another challenge analyzing the first harmonic was the background noise of boats, tankers, and other environmental noises.

There was another trend I found in the data having to do with energy distributed either in the fundamental or observed in one of the harmonics. I can't make quantitative energy level comparisons because that was not the focus of my study, however maybe interesting for future research. Killer whales have the ability to produce two different signals simultaneously, such as harmonic sounds with different frequencies (Dahlheim and Awbrey, 1982). In spinner and spotted dolphins, the relative amplitude of harmonics and the high sensitivity of dolphins to equivalent frequencies suggest that harmonics are biologically relevant spectral features

(Lammers et al. 2003), and this would be an interesting area of continued research with killer whales.

Next steps might include a full summer season with more opportunity to study the pods over longer periods of time. Ideally, if you could motor to groups that were isolated from the rest of the pod and were in distances of less than 350m localizing might be more fruitful. However, the more important task would be to increase the sample size of all three categories. I would also calculate calling rate, find the source levels, and measure the distance from the rest of the pod more consistently. Also it would be valuable to see if there are significant differences in calling rate in regards to gender. I am also interested in call type versus surface behavior. Do males and females use the same discrete calls and at what rate? Do individuals have signature calls that identify them within the pod or community? Are there variations in calls in regards to gender? Do the attributes of male and female calls differ? Do males and females make different calls?

Acoustic studies of gender differences in whales can also help us understand their potential differences in behavior and ecology. The calls given by males might direct where other whales eat or don't eat. If food sharing occurs in males who are diving deeper for Chinook, a call must be given to the rest of the pod. Knowing that cue call might be significant to researchers and policy makers; impacting conservation and recovery plans. Knowing the results of acoustic localizations of certain individuals or differences between genders of southern resident killer whales will further the understanding of a complex social organization and communication system. Being able to acoustically recognize individuals would allow acoustic tracking throughout the year and provide researchers another way to identify individuals that have been isolated from their pods (like A-73 or L-98). Acoustic monitoring is quite limited to the summer core area on San Juan Island and we have a few hydrophones that are located further south (i.e. Vashon Island, Port Townsend). However, increased monitoring could help researchers understand more about their range; where they frequent in the late fall through early spring and how diet selection varies seasonally. If researchers could study these animals throughout the year, they might be able to detect when the addition or loss of individuals occur in the population and support conservation and management.

Acknowledgements:

I would like to acknowledge the Puyallup Tribe for their generous contribution toward my funding for this class. In addition, I would like to say thank you to all of my instructors for their time, expertise, and patience. Jason Wood, I have appreciated so much your commitment to Ishmael, your steadfast patience, and your enthusiasm for "SCIENCE". Donna Hauser, your encouragement and positive attitude have allowed me to push forward and stay focused on why I came out here in the first place. Val Veirs, I can't tell you how much I have appreciated your time and commitment to the Blue Sea Snake and Willy. Your dedication to our project was heartwarming and we want you to know how much we appreciated every new version of the hydrophone array. Scott Veirs, thank you for your constant reminders that we are pioneering and making great strides in the field of killer whale acoustics. Your vision and constant support are what make this program strong and I look forward to seeing the program grow and flourish. To Dr. James Ha for creating my specialized PDA program for my behavioral data collection. I greatly appreciated your time and expertise. To my colleagues, who have inspired me in more ways than I can count…Thank you! Emily Pierson, for your outstanding teamwork on the hydrophone array and constant guidance with the computers, Ishmael, Raven, and so much more.

Rena Escobedo, for your constant smiles and laughter, you have been my rock and I can't tell you how much that means to me. Juliette Nash, thanks for sharing your enthusiasm with me every time we saw wildlife. Erin Soucy, for your love of sailing and your constant positive attitude. Colleen Barry, for your "October" kindred spirit we share and your playful sense of humor. Lastly, to friends and family who have given their support throughout this quarter.

References

Baird, R.W., M.B. Hanson, and L.M. Dill. 2005. Factors influencing the diving behavior of fish-eating killer whales: sex differences and diel and interannual variation in diving rates. Canadian Journal of Zoology 83:257-267.

Barrett-Lennard, L.G., J.K.B. Ford, and K.A. Heise. 1996. The mixed blessing of echolocation: differences in sonar use by fish-eating and mammal-eating killer whales. Animal Behavior 51:553-565.

Bigg, M.A., G.M. Ellis, J.K.B. Ford, and K.C. Balcomb. 1987. Killer Whales: A study of their identification, genealogy, and natural history in British Columbia and Washington State. Phantom Press and Publishers Inc., Nanaimo, British Columbia. P.13.

Dahlheim, M.E. and F. Awbrey. 1982. A classification and comparison of vocalization of captive killer whales (Orcinus orca). The Journal of the Acoustical Society of America 72: 661-670.

Felleman, F.L., J.R. Heimlich-Boran, and R.W. Osborne. 1991. The Feeding Ecology of Killer Whales (*Orcinus orca)* in the Pacific Northwest. Dolphin Societies: Discoveries and Puzzles. University of California Press, Berkley, California. P.113-147.

Ford, J.K.B. 1987. A catalogue of underwater calls produced by killer whales (*Orcinus orca*) in British Columbia. Can. Data Rep. Fish. Aquat. Sci. 633:165p.

Ford, J.K.B. 1991. Vocal traditions among resident killer whales (*Orcinus orca)* in coastal waters of British Columbia. Canadian Journal of Zoology 69: 1454-1483.

Lammers, M.O., W.W.L. Au, and D.L. Herzing. 2003. The broadband social acoustic signaling behavior of spinner dolphins and spotted dolphins. The Journal of Acoustical Society of America 114: 1629-1639.

Miller, P.J.O. and D.E. Bain. 2000. Within-pod variation in the sound production of a pod of killer whales, *Orcinus orca*. Animal Behavior 60:617-628.

National Marine Fisheries Service. 2005. Endangered and Threatened Wildlife and Plants: Endangered Status for Southern Resident Killer Whales. National Marine Fisheries Service, Northwest Region, Seattle, WA.

Osborne, R.W. 1986. A Behavioral Budget of Puget Sound Killer Whales. Behavioral Biology of Killer Whales, Alan R. Liss, Inc. New York, NY. pp. 211-249.

Thomsen, F., D. Franck, and J.K.B. Ford. 2000. Characteristics of whistles from the acoustic repertoire of resident killer whales (*Orcinus orca)* off Vancouver Island, British Columbia. The Journal of the Acoustical Society of America, 109:1240-1246.

Thomsen, F., D. Franck, and J.K.B. Ford. 2002. On the communicative significance of whistles in wild killer whales (*Orcinus orca*). Naturwissenschaften, 89: 404-407.

Yurk, H., L. Barrett-Lennard, J.K.B. Ford, and C.O. Matkin. 2002. Cultural transmission within maternal lineages: vocal clans in resident killer whales in southern Alaska. Animal Behaviour 63:1103-1119.

Table 1: Different hydrophones specifications used between 10/03-10/20

Date	Equipment	working hydro-phones	Sampling Rate	Hydrophone locations (m)	Overall length (m)	Depth (m)	Calibrated
10/3	Blue Sea Snake (wired wrong, used Matlab to flip files)	4	22050	0, -16 0, -24.4 0,-33.4 0,-43.2	52.6 m	~2	yes
10/10	Blue Sea Snake 4 hydrophone configuration, and two sperms (ITC)	3 4 2	44100	0,-10 7,-10	52.6m		Blue Sea Snake and original sperm
10/11	Blue Sea Snake	3	22050	0,-24.4 0,-33.4 0,-43.2	52.6	~2	yes
10/13	Blue Sea Snake	3	22050	0,-24.4 0,-33.4 0,-43.2	52.6	~2	yes
10/19	Willy	4	22050	0, -9.38 0, -19.48 0, -29.42 0, -39.58	39.58	~3+	No
10/20	Willy	4	22050	0, -9.38 0, -19.48 0, -29.42 0, -39.58	39.58	~3+	No

Table 2: Comparison of my distance and bearing of call to Ishmael's bearing in order to localize.

Date	Gender/ID	Call Time	Predominant Behavior State	My Distance	My Bearing	Ishmaels Bearing	Degree Differences
10/3	M (J30?)	12:20:54	Forage	1850	5	**05**,355	0
10/19	M (K21)	1:10:14	SDT	110	270	91,**269**	1
10/19	M (K21)	1:10:32	SDT	100	270	91,**269**	1
10/19	M (K21)	1:10:57	SDT	100	270	89,**271**	1
10/19	F (L47)	12:46:01	SDT	100	90	**95**,265	5
10/19	F (L47)	12:46:08	SDT	100	90	**101**,259	11
10/20	F (L47)	12:35:44	SDT	100	330	31,**329**	1
10/19	2M/2F (L21 and L47) M?	1:06:44	SDT	50	90	**98**,262	8
10/19	2M/2F (L21 and L47) M?	1:06:45	SDT	50	90	**104**,256	14
10/19	2M/2F (L21 and L47) M?	1:06:47	SDT	50	90	**104**,256	14
10/19	2M/2F (L21 and L47) M?	1:06:56	SDT	50	90	**106**,254	16
10/19	1M/2F/J (K40)	1:11:02	SDT	200	45-90	**89**,271	1
10/19	1M/2F/J (K40)	1:11:03	SDT	100	45-90	**94**,266	4
10/19	1M/2F/J (K40)	1:11:05	SDT	100	45-90	**89**,271	1
10/19	1M/2F/J (K40)	1:11:16	SDT	100	45-90	**89**,271	1
10/19	1M/2F/J (K40)	1:11:30	SDT	200	45-90	**90**,270	0
10/19	1M/2F/J (K40)	1:11:38	SDT	100	45-90	**93**,267	**3**
10/19	1M/2F/J (K40)	1:11:40	SDT	100	45-90	**86**,274	**4**
10/19	1M/2F/J (K40)	1:11:42	SDT	100	45-90	**87**,273	**3**

Table 3: Average Call Characteristics including the relative strength of the fundamental tone, the call durations, low, high and change in frequency of the first harmonic of calls with standard deviations.

Characteristic:	Males	Females	Mixed Gender
Sample size	12	3	4
Avg. fundamental frequency in Hz ± SD	960.2 ± 207.379	744.233 ± 265.101	1200.358 ± 382.776
Avg. call duration in sec ± SD	0.823 ± 0.343	1.17 ± 0.112	0.907 ± 0.233
Avg. Low Frequency of 1st Harmonic in Hz ± SD	2329.4 ± 950.494	2474.233 ± 138.254	2970.808 ± 1435.333
Avg. High Frequency of 1st Harmonic in Hz ± SD	2117.075 ± 271.177	2905.67 ± 738.048	3245.233 ± 145.293
Avg. Δ Frequency of 1st Harmonic in Hz ± SD	1029.625 ± 344.324	692.9 ± 272.617	2187.191 ± 1232.064

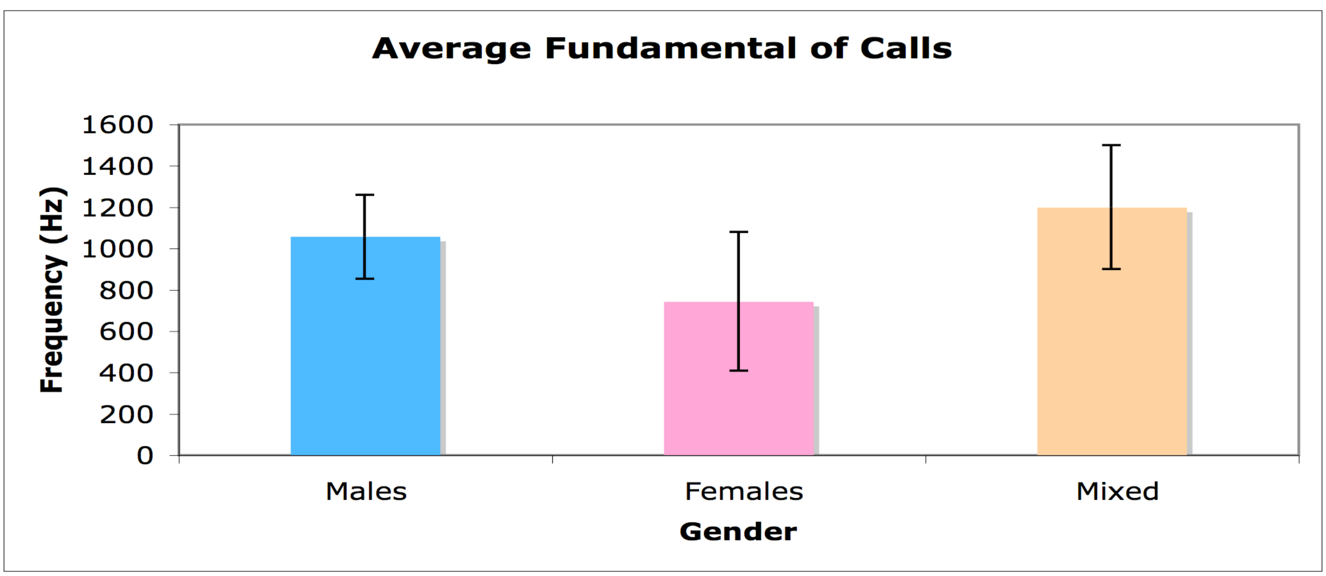

Figure 1: Average fundamental frequency of calls from 3 gender categories of the southern resident killer whales (*Orcinus orca*) with error bars showing 95% confidence intervals.

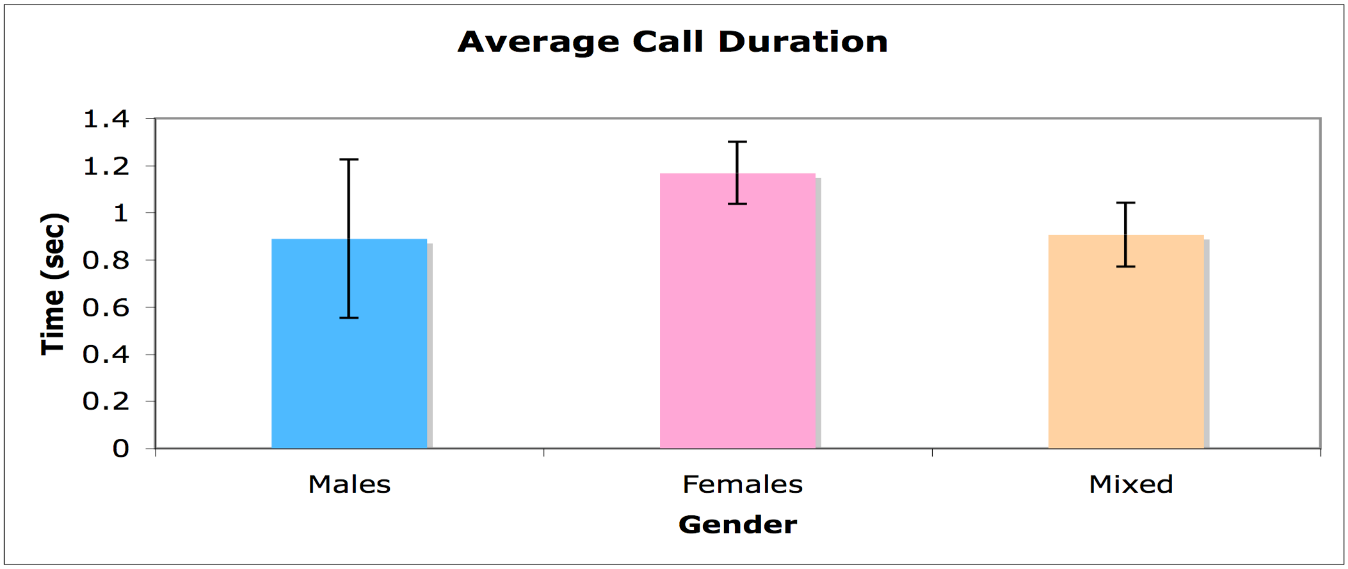

Figure 2: Average call duration of 19 calls from different genders among J, K, and L pods with 95% confidence interval as error bars.

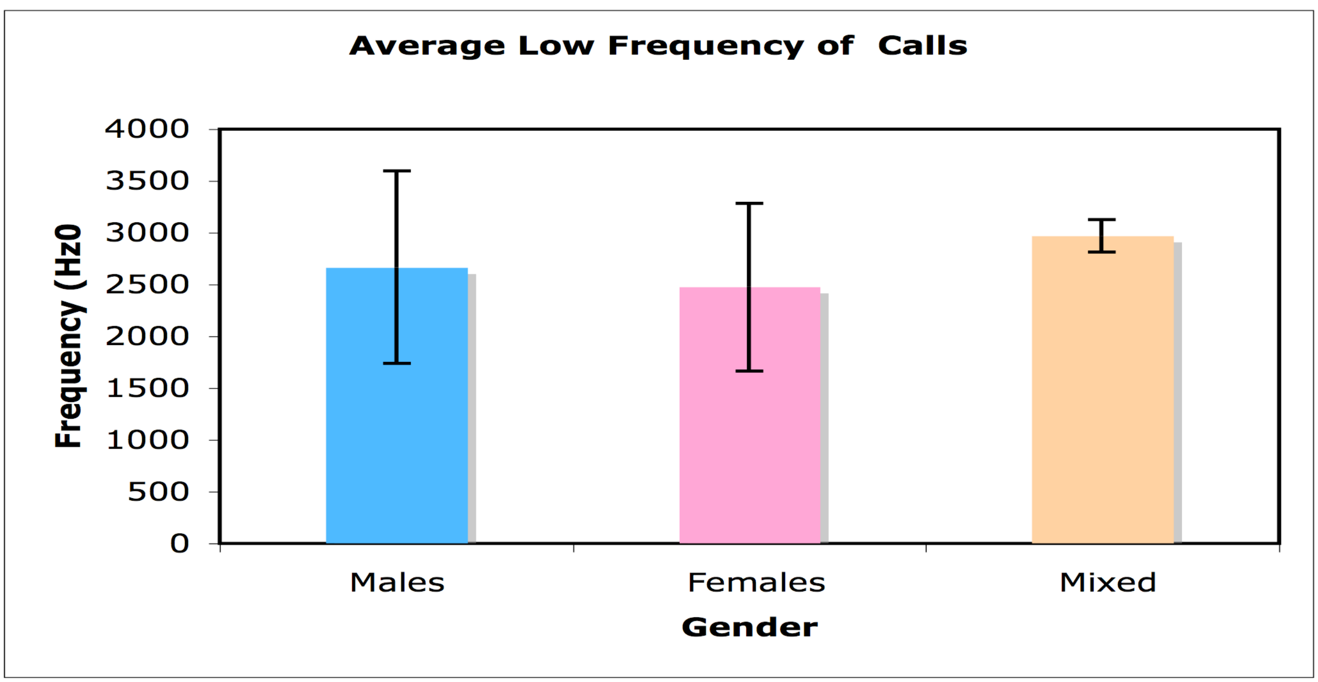

Figure 3: Average low frequency of the first harmonic of calls in different gender categories including error bars with 95% confidence intervals.

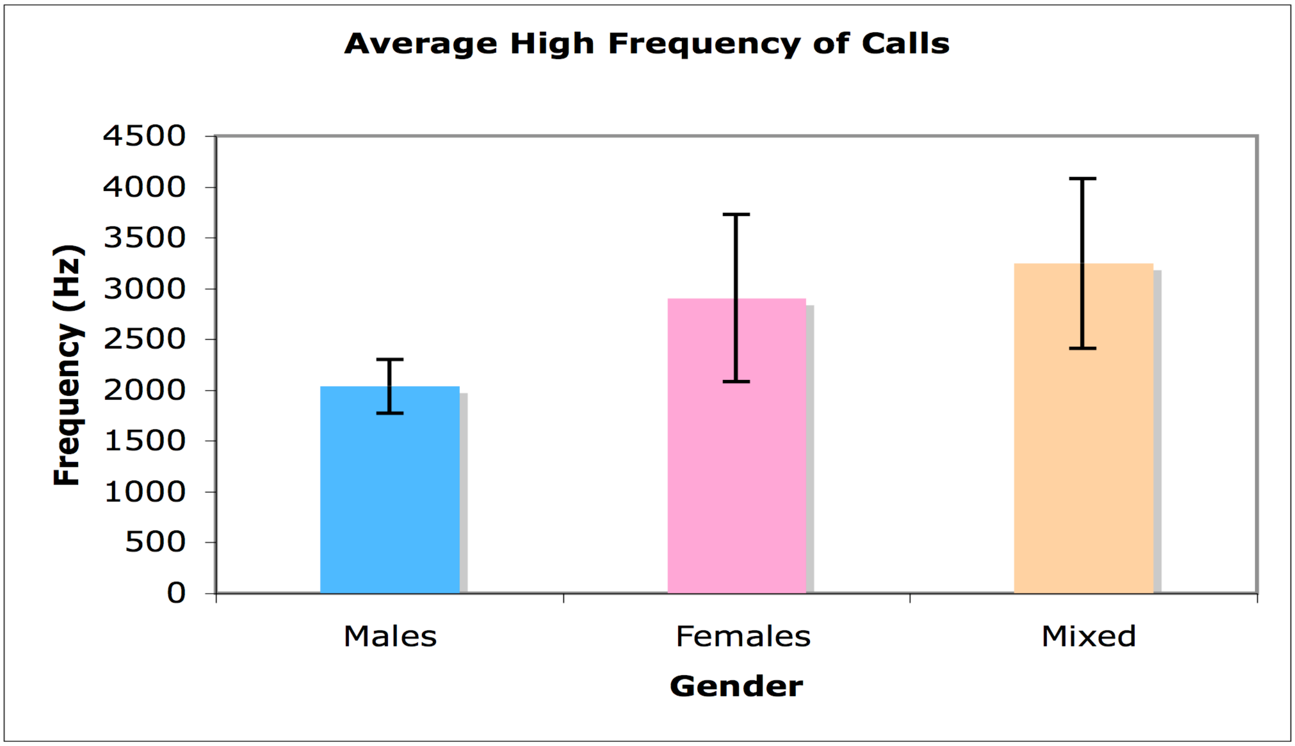

Figure 4: Average high frequency of the first harmonic of calls in regards to gender with 95% confidence intervals.

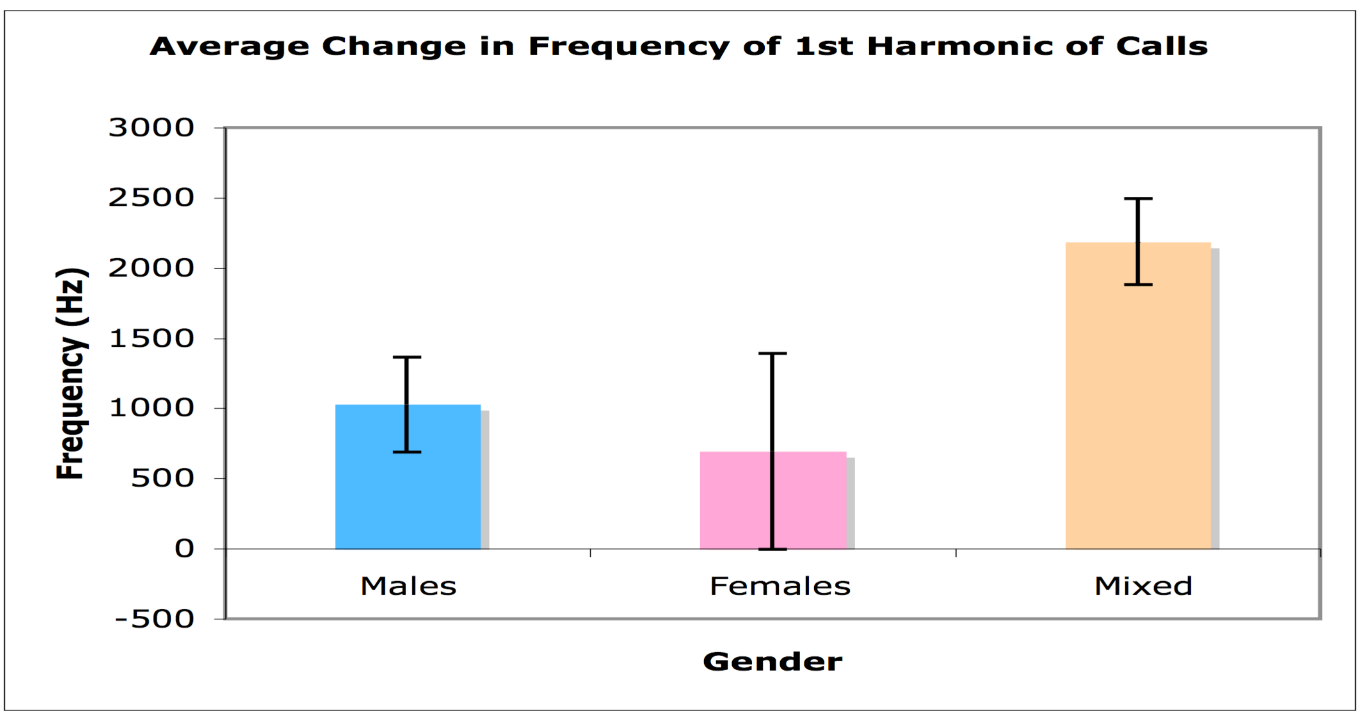

Figure 5: Average change in frequency of calls from southern resident killer whale genders.