Comparing Vocalizations between Matrilines of Southern Resident Killer Whales (*Orcinus orca*)

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Vocalizations are an important part of the killer whale *(Orcinus orca)* species used in all aspects of their lives; communication, foraging, and traveling. It has been suggested that killer whales have different dialects to differentiate from one other, at least on the pod or matrilineal level. The goal was to identify a whale to a call and compare the calls across matrilines within the three Southern Resident killer whale pods. This proved difficult not having enough data to accurately make assumptions. But some evidence provided that there could be vocal learning in social situations between pods in the past couple decades, this could also supported due to the fact that the three southern resident pods (J K &L, making up J clan) have been starting to intermingle more in the most recent years. I was also about to see pod call structure similarities.

Introduction

Southern Resident killer whales (*Orcinus orca*) are a social species that travel together in pods, known as J, K, and L pod. With-in these pods there are matrilines which consist of a female, her sons and daughters, and offspring of her daughters. Matrilines can contain one to 17 individuals spanning one to five generations (Ford et al 2000). Matrilines have more cohesion than pods do, and rarely part for more than a few hours, while each matriline may separate from the pod for up to a couple months.

Vocalizations are an important aspect to this species; they are used in communication, foraging, and navigation. Killer whales have three types of vocalizations; clicks, whistles, and pulsed calls (Ford 1989). Clicks are brief pulsed sounds, and can sometimes be produced in a form called click trains. Clicks are generally used while echo locating for navigation and hunting/foraging. Frequency of these click are generally between 4-18 kHz but extend up to 50-85 kHz (Ford 1989). Whistles are generally recorded at 8.3 kHz, and last 1.8 seconds on average. Southern Residents produce whistles for both long-range communication (e.g., during foraging and slow traveling) and social interactions (Riesch et al 2006). Pulsed calls are the most commonly produced sound in killer whales which, to humans, sound like squeaks, squawks, or screams. The repetition rate can reach up to 4,000 pulses per second, last about two seconds, with frequencies of one to six kHz, but can reach up to 30 kHz. There are three different types of pulsed calls that are distinguishable; discrete, variable, and aberrant (Ford 1989). Variable and aberrant calls are less common but usually given after animals join together and interact in a social way (Ford 1991). Discrete calls are more common, therefore also studied more. Discrete calls are the dominant sound produced during foraging and traveling, and are used for maintaining acoustic contact with other group members, especially for those out of visual contact (Miller 2002).

As mentioned, killer whales have different call types, but to be able to distinguish the different dialects and individualize them has been an ongoing interest. Vocal dialects can be defined as differences in the structure of vocalizations among animals that come into acoustic contact (Deecke et al. 2010). Pods with similar dialects make up social groups defined as clans (ie J, K, and L pods make up the J clan). In the resident killer whales there are seven to 17 distinctive call types (Ford 1991). Along with categorical call types, there are calls that are non-repeated vocalizations defined as aberrant calls. (Wieland et al. 2009)Dialect variation has been identified and documented in complex species from a wide variety of taxonomic background such as; songbirds, parrots, bats, cetaceans, and primates. (Deecke et al. 2010). Similar dialects are likely to reflect on levels of relatedness within pods and matrilines (Miller and Bain 2000). It has been shown that while killer whale call repertoires are stable over long periods of time, they can have subtle changes due to frequently associating matrilines through vocal learning. This could be an after effect from older individuals dying, being hunted, or as pods and matrlines grow and split (Miller 2004). It is thought that younger individuals develop imitations of calls through learning from closely related individuals, instead of through genetics (Yurk et al 2002).

A study was done by Volker B. Deecke et. al (2010) that showed differences in call structure of six of the same call type in different matrilines in the Northern Resident population. One of the greater differences they found between matrilines was the abrupt drop in pulse-repetition rate towards the end of the N9 call (Deecke 2010). In other species vocal signals contain important information as well. It has been shown that greater spear-nosed bats (*Phyllostomus hastatus*) have group specific screech call, but are not individually distinctive (Nousek et al 2006). In other cases vocal signals can contain information about levels of social affiliation; such as in chimpanzees (*Pan troglodytes verus*) who share the same features of call between groups, but individuals will vary (Nousek et al 2006). In other cetaceans, such as the bottlenose dolphin (*Tursiops truncatus*), signature whistles can be individually distinctive, when in isolation. A study done by Stephanie Watwood et al. examined whistle production in 17 free-ranging bottlenose dolphins that were temporarily restrained. The results suggested that these signature whistles may be a way of both vocal learning and developing social relationships (Watwood et al 2004). Another species that has recognizable repertoires are humans. We learn our speech through a social atmosphere, and vocal learning just as suggests dolphins do. So, it would also be interesting to see this in the Orca community.

The goal of this study was to examine the call structures between matrilines of Southern Resident killer whales, in the Salish Sea. In this study I was looking to find out more about their social dynamics as a whole as well as their communication with-in pods. Being able to indentify matrilines acoustically would contribute to knowledge and current ongoing research of how these animals communicate and if there is a certain meaning behind signature calls. It might also help track them in the winter months, when there is little information about where they go, and what they eat. We would also be able to start to see their vocal interactions between the different members of matrilines. Many of the vocal studies on killer whales have been done on the Northern Resident population; it would be valuable to do a study on the Southern Resident population, to be able to compare results of the two populations. The questions I focused on in my research were: Are there variations within the matrilineal calls, such as abrupt variations in pulse repetition, changes in frequency, or call duration? Does each matriline have a certain variation of calls to recognize each other? Can these features be seen on the individual level in this population? I hypothesize that there will be recognizable physical variations of the call structure on the matrilineal level in the Southern Resident killer whale population.

Experimental Design and Methods

Data was collected from a 42’ catamaran, the Gato Verde, from mid September 2010 through the end of October 2010 in the Salish Sea. During data collection we followed the

Washington State law which includes the Be Whale Wise guidelines by paralleling the whales by at least 100 meters. Hydrophones were be deployed and towed on both the port and starboard stern of the vessel. The four hydrophone array (Labcore 40's Array with a peak frequency of 5 kHz) was be towed on the port stern side of the vessel and the CRT (Single Cetacean Research Technology C54 XRS/266, a high frequency hydrophone with a flat response curve from one to thirty kHz) on the starboard stern side of the vessel. All hydrophones were calibrated using the Inter Ocean Systems Model 902 Listening Calibration System.

The total length of the array from the stern of the vessel was be 49.54 meters, which is where the fourth and final hydrophone is located. The first and third hydrophones are located at 16.40, and 38.34 meters, respectively. The CRT was be located 28.05 from the stern of the vessel. Both the CRT and the array were weighted to a depth of 1.85 meters in the water. The CRT took the place of the second hydrophone on the array during recording in order to record higher frequencies for other studies being done in the same time period; also the CRT took place of the second array hydrophone when plugged into the acoustic recorder. The four hydrophones being used were connected to ports of two Sound Devices (702 audio recording devices), which were connected to act as one unit recording. Hydrophone one and the CRT was plugged into the first sound device and hydrophone three and four in the second. The gain settings on the sounds devices for the three array hydrophones sere set at 43.5 and the CRT's gain setting was set at 37.5 in order to not clip any sounds.

Recordings were done at a speed of 2.5 knots unless under special circumstance, such as avoiding whales. During acoustic recordings of the whales there were a couple different things that need to be done. There was someone recording phonation data by listening to the hydrophones projected into headphones and speakers from the sound devices. Each minute was monitored for clicks and calls, if the array is straight, along with the orientation of the whales in relation to the boat, using a clock face reference with 12 o'clock at the bow of the vessel and 6 o'clock at the stern of the vessel (appendix A). There were also a couple people taking ID photos for later identification. At the end of each recording they were downloaded onto a hard drive in order to maximize space for the next recording. The photos were then downloaded daily and kept in folders by date they were taken. All of the cameras and watches used during data collection were synched to the time on the sound devices. The recordings that were collected in the sound devices were downloaded and spliced into the four hydrophone channels and minute by minute for a more successful and easier analysis. I first looked through the photos to identify a whale. Once I was certain of the animal identified I correlated the time of the photo with the time on the phonation sheet to first see if there are recordings during the time of the photo and second to see if there were any calls during that specific minute. If there were not calls in that minute I looked at the surrounding minutes (not more than a 2 minute on either side of the minute on the photo) to see if they had changed position drastically and if there were calls heard. If the whales changed position drastically I did not use those calls in my analysis. I then loaded the .wav file that had a call in it into Ishmael version 1.0 to localize the calls. Ishmael calculates the time delay to each hydrophone; produces a bearing to the animal and an estimated location using phone pairs and the hyperbolic method. I used 1485m/s as the speed of sound. If the call can be localized I compared the information that Ishmael gave me to the information from the phonation sheet, and photo. Information from the photo included general orientation that can be seen in the photo. This will help confirm that the localization from Ishmael gave accurate results or not.

Once I was able to rule out most errors and confirm information on Ishmael I put the information I have been able to use and the data from Ishmael into an excel sheet for organization. After I was able to localize, I identified the call type and measured the call duration, minimum frequency, and maximum frequency of the call in Ishmael. To measure frequencies I took one harmonic of the call, keeping the harmonic measured consistent within the call types (ie S16 measuring the whole 3rd harmonic, while an S19 measuring the up-swoop in the 3rd harmonic to get the min and max frequency). Due to a small sample size there is not enough data to compare call types between matrilines, therefore I was only able to compare the calls made to other calls of the same type from all pods. I was also able to compare all the calls made by one whale to find differences of frequency or call duration. In addition, there was no statistical test used due to such small sample sizes in each category.

Results:

During time at sea we were able to record the whales 12 different days in various regions of the Salish Sea. I was able to localize 26 different calls with an identified whale using Ishmael 1.0. Of these 26 calls 12 were from J-pod, seven from K-pod and seven from L-pod. With-in the 26 calls, there was a variety of 11 different calls; S1, S6, S7, S10, S11, S12, S15, S16, S17, S19, and one aberrant discrete call that was unidentifiable. Out of the 11 different call types, six were localized multiple times therefore those being the only calls comparable. Although there was not enough data to compare between matrilines, there were six call types from identified whales that were comparable (Table 1). With-in the same call types made by different individuals, I found that when a call made by the same pod they are more likely to be similar than the same call made by different pods. I saw this in both call durations and frequency measurements. K21's produced call S10 is an outlier in the call duration portion of this table because it was difficult to differentiate if it was a very long S10 or a variable call.

Table 1: *Measured call durations, minimum and maximum frequency differences within S16, S10, S1, S17, S19, and aberrant call types.*

S16					
Animal	**Matriline**	**M/F**	**Call Duration (sec)**	**Min Frequency (Hz)**	**Max Frequency (Hz)**
J19	J8	F	0.4881	3764.71	5019.61
J34	J10	M	0.465258	3948.05	4675.32
L87	L12	M	0.836103	2928.1	3869.28
K21	K18	M	0.550078	2337.66	3181.82
J16	J16	F	0.694841	3831.32	4675.32

S10					
Animal	**Matriline**	**M/F**	**Call Duration (sec)**	**Min Frequency (Hz)**	**Max Frequency (Hz)**
J27	J8	M	1.15807	4026.14	5751.63
J11	J8	F	1.966362	1974.03	3324.68
K21	K18	M	2.8065499	2077.92	4220.78

S1					
Animal	**Matriline**	**M/F**	**Call Duration (sec)**	**Min Frequency (Hz)**	**Max Frequency (Hz)**
J37	J2	F	0.911889	4248.37	5228.76
J46	J17	F	1.428548	3529.41	4705.88
J27	J8	M	0.96214	2141.85	4155.84

S17					
Animal	**Matriline**	**M/F**	**Call Duration (sec)**	**Min Frequency (Hz)**	**Max Frequency (Hz)**
K14	K3	F	1.921842	4000	5298.7
L88	L2	M	1.172242	4117.65	5882.35

S19					
Anima	**Matrilin**	**M/F**	**Call Duration**	**Min Frequency**	**Max Frequency**

l	e		(sec)	(Hz)	(Hz)
L88	L2	M	0.86679	4675.32	6103.9
L92	L26	M	0.923301	3660.13	7477.12
L92	L26	M	1.4534	4836.6	9150.33
L92	L26	M	0.6656	4901.96	6078.43
K21	K18	M	0.40569	5064.94	8181.82

Aberrant Call					
Animal	**Matriline**	**M/F**	**Call Duration (sec)**	**Min Frequency (Hz)**	**Max Frequency (Hz)**
K21	K18	M	0.914633	2405.23	5437.91
K21	K18	M	0.619212	3071.9	5555.56
K21	K18	M	0.868294	3896.1	5714.29

I was also able to compare call durations and frequencies of different call types within individuals (Table 2). In which I observed that there were no constants between variables. Again, the outlier is K21 with the S10 call duration being over a second longer than all the other calls made by that individual.

Table 2: *Comparison of call durations and frequencies between different call types produced by the same animal.*

Animal	**Call Duration (sec)**	**Min Frequency (Hz)**	**Max Frequency (Hz)**	**Call**
J27	1.15807	4026.14	5751.63	S10
	0.511019	3816.99	6222.22	S15
	1.30985	4183.01	6209.15	S11
	0.96214	2141.85	4155.84	S1

Animal	**Call Duration (sec)**	**Min Frequency (Hz)**	**Max Frequency (Hz)**	**Call**
L88	1.172242	4117.65	5882.35	S17
	0.86679	4675.32	6103.9	S19

Animal	Call Duration (sec)	Min Frequency (Hz)	Max Frequency (Hz)	Call
L92	0.923301	3660.13	7477.12	S19
	1.4534	4836.6	9150.33	S19
	0.6656	4901.96	6078.43	S19

Animal	Call Duration (sec)	Min Frequency (Hz)	Max Frequency (Hz)	Call
K21	2.8065499	2077.92	4220.78	S10
	0.550078	2337.66	3181.82	S16
	0.914633	2405.23	5437.91	Aberrant
	0.619212	3071.9	5555.56	Aberrant
	0.868294	3896.1	5714.29	Aberrant
	0.40569	5064.94	8181.82	S19

While identifying calls during analysis I came across a couple differences to John Ford's Catalogue of Underwater Calls Produced by Killer Whales (1987). There were S16 calls produced by all three pods and S19's produced by some K-pod members. These both go against Ford's article stating the only K and L pod produce S16 calls, and L-pod is the only to produce S19 calls. I am confident in these findings due to the circumstances of the days these were found.

There is no statistical evidence of significance in this study because the lack of data available.

Discussion:

Even though the Southern Resident community is studied very well, there is very little evidence that supports defining individuals or matrilines by differences in call types. My hypothesis of there being recognizable physical variations of the call structure on the matrilineal level is not supported by the data in this study. First, there was not enough data to do a decent study on this topic due to the time constraint. Also, it proved to be very difficult to localize a call and have evidence that a certain whale made that call. Ishmael was not always consistent in the results it put out. I was able to find that within the same call types the pods seemed to be more likely to have similarities within the pod. For example, J-pod had similar call durations and frequencies in one call, as did K-pod, and L-pod, but there were larger differences between the pods. This proves promising that is there are differences between pod call structures, there might be slight differences on a matrilineal level as well. There were some findings in the Northern Resident community that support this (Deecke et al 2010), but this study was established over ten year. Therefore, I still stand by this hypothesis, but quite a bit more data would need to be collected over a longer span of time.

When comparing all the calls made by one individual I came across a couple individuals making the same call over and over again. I took a couple samples of about ten minutes apart, and after looking at the call structures they were quite different from each other. Being all from the same whale this could mean various things, maybe the whale was trying to get different individual’s attention, or exerting different amounts of energy while traveling making the calls different. When this came across in K21 (the aberrant calls) he was alone at the time, and a female had recently gone out of our view. This could proceed to mean maybe he was lonely and trying to find other members of his pod, but those conclusions cannot be supported.

I took the averages of call durations of the six repeated calls to compare to the average call durations from Ford’s call catalogue (1987) and found that they were pretty similar (table

3) therefore have stay constant over the years. While some characteristics of killer whale calls have stayed consistent this study suggests that the whales could be evolving in their calls. This would not be uncommon, considering they have been intermingling a lot more in the recent years. (Though this could have been happening a couple decades ago as well, the technology is just not starting to help us say what call came from what whale.) As mentioned S16 calls were identified to a couple J-pod members. This could suggest that killer whale dialects are being learned between members of the J clan (Deecke et al 2000).

Call Type	Call Duration (Sec)	Call Type	Call Duration(Sec)
S16	0.607	S16	0.729
S10	1.977	S10	2.1
S1	1.101	S1	0.884
S17	1.547	S17	0.863
S19	0.863	S19	0.73
???	0.801	???	unknown

Table 3: *My data call duration averages vs. John Ford 1987 call duration averages respectively.*

Further research of this topic is much needed. So many people in the public are looking for answers to questions of how to tell them apart acoustically, and although it proves impossible to the human ear, to have that information would be very valuable. This will be a difficult process until there is some way to guarantee that an individual whale made a certain call. Other research to be done would be to see how much the calls change over the years, and if they separate pods and starting to learn from each other in a social setting.

Acoustical studies have already proven to be a great asset to knowing where the whales travel throughout the day, but this is only limited to when they are near the San Juan Islands during the summer months. There is very little known about where they go between the late fall and early spring months, more acoustical research in other parts of the west coast, would be a great asset to know if they stay near the coast. Also some kind of standing hydrophone in various places further off shore might give us more information about where they go, or if they even use the same types of calls when they are not around these areas. Knowing where they travel would also help in figuring out what they eat during those months. Is there some kind of special fish migration patterns that they follow off shore?

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Appendix

Appendix A: