

Relationship between Vocalizations and Social Activity in Southern Resident Killer Whales, *Orcinus orca*

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June 6th, 2008

Literature Review: The killer whale, also referred to as the Orca whale is the largest member of the Delphinidae family. Within the species Orca, three distinct groups exist: offshores, transients, and residents (Holt 2008). The transients feed primarily on marine mammals and typically travel in smaller pods than the residents. Residents feed primarily on fish like salmon. Little is known of offshore diets but it is known to include fish (Krahn 2004). In the waters off of Northern Washington State and British Columbia the two primary groups are the Southern Resident Killer Whales and the Northern Resident Killer Whales (Krahn 2004). Despite the close overlap in range, they do not associate with each other.

Orcas as a species make several types of calls. These include clicks, whistles, and pulsed calls. Although considerable work has been done on pulsed calls in Orcas, less is known about the use of whistles in Killer Whales. The reason for the predominance of literature on pulsed calls is because clicks require high frequency equipment and whistles are not as commonly made by wild Orcas. A whistle is a tonal sound with an average bandwidth of 4.5 kHz, an average dominant frequency of 8.3 kHz (Thomsen et al. 2001). Clicks on the other hand are used for echolocation. Clicks can be made singularly or in click trains (Holt 08). They are relatively short, broadband, and range in frequency from 8 to 80 kHz

(Au 2004). The most common call orcas use is the pulsed call which can contain harmonics up to 30 Hz (Ford 1989). The source levels of the calls often range from 135 to 168 dB re 1 μ Pa (Miller 2006).

Of the studies done with whistles in resident killer whales, differences exist between Northern Resident Killer Whales and Southern Resident Killer Whales. Studies done with the Northern Residents showed that the whistle was primarily used during socializing (Thomsen et al. 2002). During the course of the study researchers found that whistles were used 43% of the time during socializing events as opposed to 29% and 28% for discrete and variable calls respectively (Thomsen et al. 2002). The full statistics from Thomsen et al's study can be seen in table 1.

Behavioural category/sounds	Socializing (12/15/33)	Social-travelling (16/18/49)	Foraging (5/17/31)	Mixed foraging (10/10/21)	Slow-travelling (7/14/22)	Mixed slow-travelling (7/8/14)	Travelling (5/5/7)
Whistles	43%	26%	3%	6%	6%	2%	2%
Discrete calls	29%	54%	94%	85%	85%	89%	96%
Variable calls	28%	20%	3%	9%	9%	9%	2%

Table 1: Results from Thomsen et al. study on Northern Residents

However, in a 2006 study done by Colleen Barry, a former student of Beam Reach, on Southern Resident Killer Whales off of San Juan Island, she found that whistles were used least frequently during socializing events (Barry 2006). Research has suggested vocal differences in the different populations and ecotypes of orcas (Ford 1991) and these conflicting results support those findings. Although the Northern Residents and Southern Residents habitat sometimes overlap, this supports the theory that they are still distinct populations.

Apart from whistles there has also been work done on the behavior of the Southern Resident Killer Whales. Nicole Lee, a 2005 Beam Reach student, studied the

correlation between breaches and vocalization (Lee 2005). She found that within one minute of a breach, the call most often heard is S10 (Lee 2005). However, the correlation between S10 and breach was not sufficient to say that there was a strong relationship between S10 and breaching.

Another study done comparing behaviors to vocalizations was Heather Hooper's 2007 study *Discrete Call-Type and Behavioral Event Associations of Southern Resident Killer Whales (*Orcinus orca*) in the Salish Sea*. Heather looked at the call types made in association with specific behavioral events including peckslap, breach, change of direction, tailslap, and porpoising. Her study showed many different calls used within a two minute period of these specific events (Hooper 2007). In addition to these studies, a 2006 research project done by Juliette Nash examined a link between killer whale acoustics and killer whale behavior. Unfortunately, Juliette's results were inconclusive (Nash 2006).

When doing behavioral work it is important to define various behaviors such as social behaviors for the purposes of the research project. Most socialization definitions are very similar in nature. Socializing is tactile interactions between two or more orcas. The individual behaviors of socializing can vary greatly from percussive events such as breaching and tailslapping, to physical contact, such as rubbing, rolling over, and sexual interactions, as well as acoustic calls such as whistles or pulsed calls. During social interactions the group is stationary or nearly stationary (Bain 1986, Barry 2006, Nash 2006, Thomsen 2002). It is also important to note that the entire group of orcas might not be socializing at the same time. Sometimes only a smaller group of orcas socialize while the others display other behaviors nearby (NMFS 2008). The purpose of these definitions

is to clearly separate observed behaviors in the wild into specific categories. Another of the categories that is defined is social travel which is traveling at a fairly constant rate and course (Barry 2006, Thomsen 2002).

The National Marine Fisheries Service (NMFS) has done work to categorize and code the specific behaviors in Killer Whales. Their findings were published in the 2004 workshop on Killer Whale behavior. Key distinctions that they make in their paper include subcategorizing play behavior into three subcategories. These subcategories are object play, social interactive play, and solitary play. Object play is anything with inanimate objects such as kelp or logs. Social interactive play can include touching, breaching, or percussive events such as tailslaps and breaches (NMFS 2004). They also come up with a key definition of directionality for the purpose of defining traveling behavior. They refer to directionality as being less than or equal to 90 degrees of the whales previous direction of travel. Likewise any movements which are greater than 90 degrees from the previous direction of travel will be considered non-directional (NMFS 2004).

Other categories of behavior described by NMFS are rest, travel, forage and milling (NMFS 2004). Rest consists of the whales being close together, traveling at slow speeds if at all, and lacking percussive events. In foraging behavior the whales can be in tight or loose formations, traveling at various speeds, and often including behaviors like chasing, lunging, and porpoising. Traveling can be directional movement in any direction at any speed and the whales could be grouped close or spread out wide. Milling is repeated non-directional movement over any distance usually at slow or medium speeds (NMFS 2004).

Behavioral studies with other cetacean species in the Pacific have had similar definitions of social behavior. A study in 1986 on the behavior of Gray Whales in the Bearing Sea defined social behavior for the Gray Whales as being within one-half body length of each other and interacting with each other (Wursig 1986). For example if they were oriented towards each other at close range they would be considered socializing.

Problem Statement: Despite extensive studies on orca acoustics, there are still a great many mysteries about what various acoustic calls mean. Further complicating our understanding of orca acoustics is the fact that each of the various pods have their own unique dialect (Ford 1991). This was shown in the conflicting results of two acoustical studies of orcas. The first done by Thomsen showed that Northern Resident Killer Whales use whistles predominately during socializing activity. However, as mentioned above another study done in 2006 by Colleen Barry showed that Southern Residents use whistles during socializing activity the least. This leads to the question; if Southern Residents don't whistle as often during socializing, what calls do they make, and are they different from the calls made during periods of non-social behavior?

Previous studies have shown differences in calls by each separate pod of orcas and between the different types of orcas. Exploring what Southern Residents do in place of whistles during socializing might help us understand more about those pod-specific dialects. Furthermore, exploring the question of call usage by Southern Resident Killer Whales would give us a better and deeper understanding of them as a species. The fact is there is still a great deal about killer whales as a species and southern residents specifically that is not well understood. We know that they are a highly social species,

but why they perform specific behavioral events such as breaches is still beyond our understanding. By studying their acoustics in addition to their behavior we might begin to get a window into their world. This information could then be used to better understand their natural existence and how our presence on the water threatens that existence.

Since the Southern Residents, like all Killer Whales, are highly social species it is logical to assume that socializing provides an important part of their existence. When orphaned they often try and find new social interactions like Luna (L98) did near Gold River after getting separated from her pod. She tried to associate with humans and boaters until her death in 2006. Understanding social activity better will give us a better understanding to their social structure, group cohesion, customs and traditions, and larger traits on a whole. In the future a better understanding of social behavior and the whales need for it might help avoid another tragedy like was seen with Luna.

For the purposes of this study, social activity will be defined as any tactile interactions between two or more orcas such as rubbing, rolling over, and sexual displays, as well as aerial displays and percussive events over a prolonged period of time while being stationary or nearly stationary. This definition was formulated after looking at similar definitions by other behavioral studies. For the purposes of this study there will also be a separate behavioral definition for social travel. Social travel will be defined as swimming at a consistent speed and course with occasional social events while being grouped closely together.

After defining these behaviors and examining previous literature I was led to the follow question: Is there a relationship between vocalizations and social activity in Southern Resident Killer Whales?

Methods: All observations will be made aboard the *Gato Verde*, a forty-two foot, biodiesel-electric hybrid catamaran. Using its electric motors we will be able to record the Southern Residents with little to no acoustic interference from the research vessel. Trailing from the stern of the boat we will have a hydrophone array consisting of three LONS hydrophones off of the port stern. We will also have a high-frequency Cetacean Research Technologies (CRT) hydrophone trailing off of the starboard stern of the boat to record high frequency vocalizations made by the whales. A full diagram of the hydrophone array set up can be seen in figure 1.

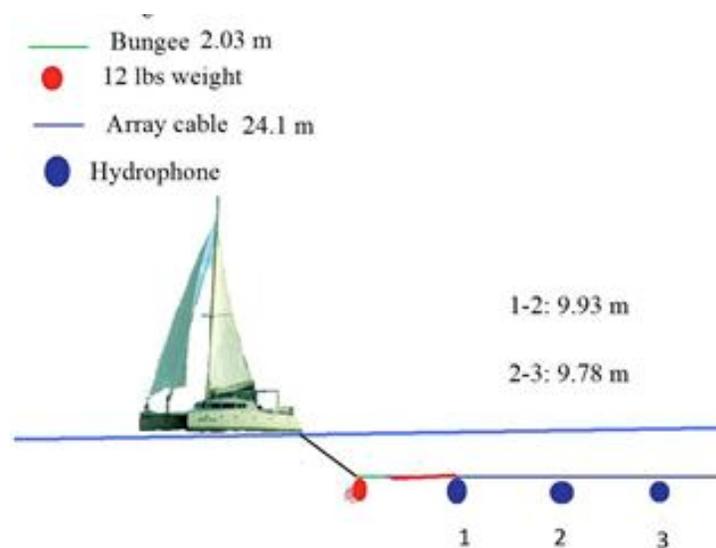


Figure 1: The hydrophone array trailing behind the *Gato Verde*. Photo courtesy of Dominique Walk

As you can see the distance of the whole cable is 24.1 meters and the distance from hydrophone 1 to hydrophone 2 and hydrophone 2 to hydrophone 3 is 9.93 and 9.78 meters respectively. Also, a weight will be deployed with the array to keep it below the surface. The recordings will be made at 192 kHz. For analysis they will be down sampled to 44.8 kHz.

The area of interest for this study will be the waters of the Salish Sea in and around the San Juan Islands. The general area our research vessel will be in is west and south of San Juan Island and Lopez Island. We will extend as far south as the Straights of Juan de Fuca and as far north as The Straights of Georgia. We will be on the water a total of five weeks time.

During Killer Whale sightings I will also be on the deck of the *Gato Verde* making behavioral observations. Unless conditions are too rough to safely allow it, I will be making my observations from the ship's catwalk or foredeck for the best 360 degree field of view. For those times where conditions do not allow for me to make observations from the catwalk or foredeck, I will be making my observations from the ship's cockpit. I will be observing what behavioral state or states they are in during our time with them as well as behavioral events such as breaches. The behavioral states I will be interested in are social, social travel, and non-social. I will be using a digital stopwatch to record times elapsed. Acoustic recordings will be made on two Sound Devices 702 solid state digital recorders time synced in a master-slave format. The gains on the Sound Devices were generally set at 22 for the CRT hydrophone and 37 for the LONS array. Latitude and Longitude information will also be recorded using a GPS unit. Behavioral notes made during the sightings will be noted on a data sheet which can be seen in appendix A. I will also be using several types of cameras to make photo documentation of the social events and 7 X 35 binoculars to assist during observations.

After recording all the data I will perform acoustic analysis on a Dell Inspiron 1200 laptop using several types of acoustic analysis software. I will be using Audacity and Syrinx for data analysis, as well as Ishmael to localizing calls to known social groups

from the sighting. Calls localized to a social group will then be separated from calls made by non-social animals. During analysis I will be comparing the call rate of social periods to social-travel, social travel to non-social, and non-social to social to see if the whales call more often during social periods than non-social periods. I will also be listening for any calls used during socializing events which are not used during non-social events to see if certain calls might be used predominately for a certain behavior.

Results: In the course of the five weeks on the water, 11 sightings were made with the Southern Residents. Of the 11 sightings, all of them came from J Pod. No data was collected for K and L Pods as they had not returned as of the first of June when our time on the water ended. Within these 11 sightings six social encounters were observed; four socializing periods and two social travel periods. From this a total of 43 minutes and 57 seconds of social time was recorded. This time is further broken down into 31 minutes and 37 seconds for socializing behavior and 12 minutes and 20 seconds for social travel periods.

For the 43 minutes 57 seconds call rates were gathered. No clicks were heard from the social groups therefore click rates were not calculated. 43 minute and 57 seconds of non social recordings were also recorded for comparison purposes. These non-social files were chosen at random using a random number generator. The call rates from the 12 minutes and 20 seconds of social travel were zero calls per minute due to the fact no calls were localized to social travel animals. Only one social period which lasted 9 minutes and 42 seconds had a call rate of zero. The other social periods had call rates of .98, .744, and 1.5 respectively for an average call rate during socializing of 1.07 calls/minute without the period where the whales were silent. It is .806 calls/minute with

the silent social period included. The social period with no calls was not included in the further statistical analysis and will be discussed later in the paper.

For the six non-social periods which were selected for comparison purposes the average call rates were 2.97, 1.02, 0, 4.5, 4.51, and 6.18. This gave an average call rate for non-social behavior as 3.74 calls/minute. The one non-social period with a call rate of zero occurred during a foraging period where a click rate of 41.3 was calculated. The call rates can be seen in figure 2 below.

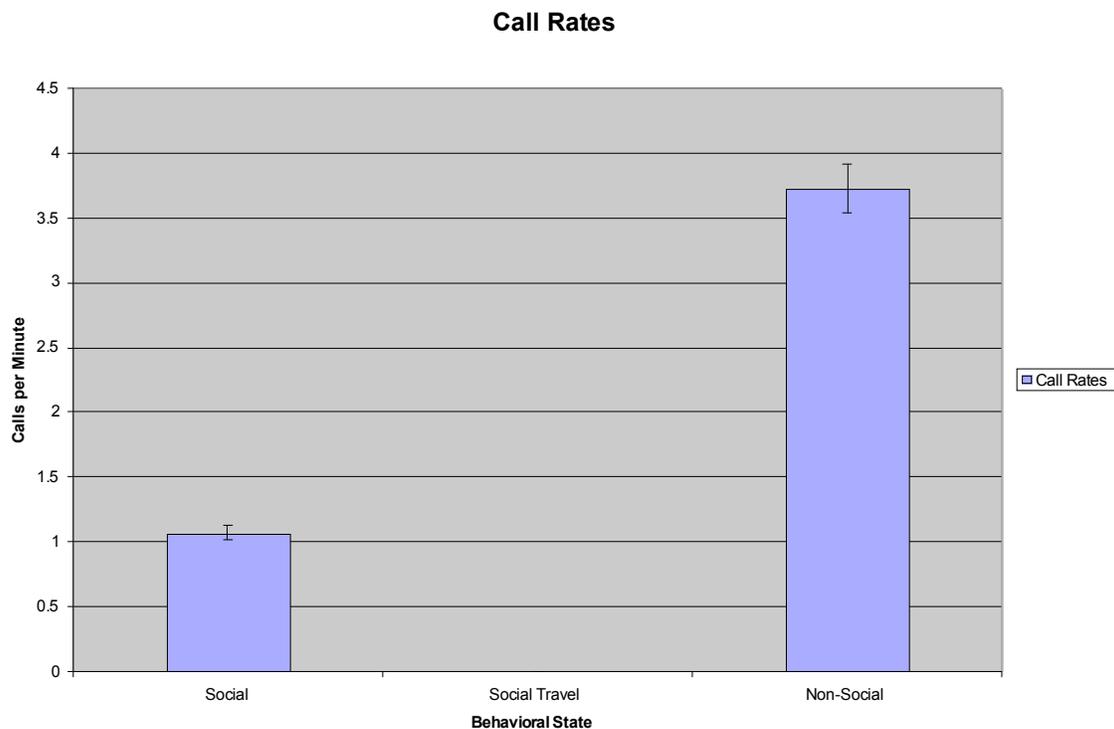


Figure 2: Average call rates by behavioral categories social, non-social, and social travel. Error bars show a 5% error margin.

After calculating the average call rates, the various call rates were also analyzed using a Kruskal-Wallis test, the non-parametric equivalent to an ANOVA. This was done due the small sample size (social-travel n=2, social n=3, non-social n=5). The results were: $H = 6.86$, $DF = 2$, $P = 0.032$. The medians for non-social, social, and social travel

were 4.5, .98 and 0 respectively. The averages show that they call the most during non-social behavior, call least during social travel, and social is in the middle. According to the Kruskal-Wallis test these differences were significant, however no significant differences could be found between the pairs.

As for looking for calls during one behavior category compared to another, no results were found. Calls heard in social clips were also heard in non-social clips. Because of this it is unlikely that there are any calls used only for one behavioral category.

Discussion: Previous studies that have been done to correlate certain behaviors with vocalizations have been met with mixed success and this study was much the same way. During actual observations behavior was determined based on surface observations. It is possible that their behaviors below water were not accurately reflected in what was observed at the surface and because of this it is possible certain behavioral states were missed. There were several occasions where two or more animals would surface very close together and might be tail slapping or breaching but any tactile interactions that happened did so out of sight while the animals were underwater making it difficult to classify as social.

Also, doing a behavioral study on a specific behavioral state is somewhat opportunistic by nature. Due to this fact the whales did not exhibit as much social behaviors as I was hoping. I only obtained data from two social travel and four social periods. Due the small amount of social interactions I had, generalizations were hard to make. Future studies should be done where more data can be obtained.

Difficulties were also experienced while localizing the calls that were recorded. Ishmael can only work under certain conditions and when recording from a noisy environment with lots of background noise it can be difficult for Ishmael to correctly localize a call above the background noise. Also, if a call is right on axis with the hydrophone array than it will prove difficult to localize accurately due to sound waves hitting the hydrophones head on, making it difficult for the time difference of arrival to accurately depict the calls location.

Analysis was further made difficult by the small sample size. In addition the few samples that I did get came from J Pod only. Nothing is known of the relationship between vocals and social behavior in K and L Pods since they were not in the study area during the study. The small amount of data may have also caused trouble with the Kruskal-Wallis test. The fact that the overall difference was said to be significant but the individual pairs were not is worth noticing. The likely cause is that the sample size is simply too small to say anything definitively.

Despite those difficulties, the geometry of the hydrophone array served to be greatly beneficial. Normally when you are towing an array straight out behind you Ishmael can get a range but it is ambiguous as to which side of the boat the call came from. By having elements on both sides of the boat it eliminated any left-right ambiguity and made localizing calls with animals on both sides of the boat much more certain.

During observations it was noted that the animals generally are silent during resting periods, which coincides with previous thoughts. It was also noted that when the fleet of whale watch boats was present, the whales often did not localize. This could be their way of dealing with a noisy environment much like a person might not try to talk to

someone while standing next to a jet engine for example. In fact there were social travel periods where the animals were silent with boats present. There was also a social interaction where two boats were in very close proximity to the social animals and no calls were localized to that group. This means that the presence of boats might affect vocalizations more than the behavioral state. Because of the possibility that the vocalizations from the social group with no calls could have been affected by the boats I did not use it in my analysis. Because of this future work should be done to examine the effect of vessel presence on whale vocalizations.

Future studies should also be done to examine the relationship between other behavioral states, not just socializing. The behaviors of the animal could give us a clearer picture of what that animal is doing or thinking than vocalizations alone can. However, any future studies involving behaviors and call rate needs to find a way to normalize for the number of whales present. Due to how spread out the animals were when not socializing it was almost impossible to accurately record how many animals the hydrophones might be hearing. This is one reason that the call rate during non-social behavior might be so much higher.

By examining both behavior and vocalizations we can gain a better understanding of the animal as well as what the vocalizations might mean. Regardless of the results found in this study, the results done when looking at a different behavioral category might be different. Although behavioral observations by category might be a small piece of the puzzle, each piece must be understood if we are to fully understand these animals and work to preserve their existence.

Another variable which I was unable to control for was age groups of the animals involved. Little is known about difference in vocalizations between age groups and more work needs to be done with age class separation to better understand that piece of the puzzle. Simply put, studies like this one have many variables which can't be controlled for and it will take the combination of many different studies on each individual piece to understand the bigger picture.

A final thing to be considered is that these behavioral and vocal definitions are things that make sense to us. The same might not be true for the Orcas. There may be no difference in their mind between social travel and regular travel. Also, socializing to them might not require more than one animal. On two occasions a single animal was seen performing object play with kelp or logs. On a third occasion an animal breached and pecked repeatedly in the same general area. This could have only been a communicative measure and nothing to do with behavioral states or it is possible that the benefits from these solo actions are the same as rubbing up against another animal.

Acknowledgements: I would like to greatly thank Jason Wood, Scott Viers, and Val Viers for their guidance and nudging along the way. Without them this project never would have gotten off the ground. I would also like to thank the captains of the *Gato Verde*, Todd Shuster and Mike Kramer, without them the project never would have left the dock. Most of all I would like to thank my fellow students: Ryan Spragg, Lindsay Delp, Laura Howes, and Dominique Walk for all their help with data collection and analysis.

I would further like to thank Kari Koski and the folks at Soundwatch for their help on the water finding the whales. Along the same lines I would like to thank Captain

Ivan from the *Western Prince* and Jim from the *Peregrine* as well as the good people at the Center for Whale Research for all their help as well. Without these helpful individuals my data set would most likely be even smaller.

Finally, thanks must go to my family and friends for all their support during this study. They gave me all the tools and traits that I needed along the way as well as a few kind words during the long hours of data analysis.

Appendix A

Behavioral Data Sheets

Date: _____ Sighting Number: _____

Time Recording Start: _____ Lat: _____

Time Recording Stop: _____ Long: _____

Waypoint: _____ Location: _____

Behavior at beginning of recording: _____

Social Start:							
Social Stop:							

Type of Social Behavior: Social ____ Social Travel ____

Pod: J ____ K ____ L ____

Percussive Events Recorded: Breach ____ Pectoral Slap ____
Tail Slap ____ Other ____

Number of Whales in Social Group: _____

Number of Whales Present overall: _____

File(s) Name: _____

Photos: _____

Video: _____

Conditions: _____

Notes:

Appendix B

Behavioral Definitions

Behavior	Definition
Social	Any tactile interactions between two or more orcas such as rubbing, rolling over, and sexual displays, as well as aerial displays and percussive events over a prolonged period of time while being stationary or nearly stationary.
Social Travel	Swimming at a consistent speed and course with occasional social events while being grouped closely together.
Non-Social	All behaviors which don't fall into the above categories.

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