

Identifying Individual Variation in the Vocalizations of the Killer Whale, *Orcinus orca*

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Literature Review

The population of killer whales (*Orcinus orca*) that inhabits the Salish Sea in northwestern Washington and southwestern British Columbia is composed of three pods that make up the southern resident killer whale (SRKW) population (Ford 1987). These three pods are known as J, K, and L pods. The members of each these pods spend at least 50% of their time together and are composed of one to nine matrilineal groups; these matrilineal groups consist of a female, her male offspring, and her young female offspring (Bigg et al. 1990).

The SRKW population is distinguished from the northern resident killer whale population, which inhabits a range extending from Vancouver Island to southeastern Alaska (Bigg et al. 1987), and from the transient population of orcas, which do not frequent any particular area during the summer. Transients, Northern Residents, and Southern Residents do not associate behaviorally, nor do they share any of the same vocalizations (Bigg et al. 1987). Transient orcas also feed on marine mammals, while resident orcas mainly utilize salmon and other fishes for food. It is possible these behavioral, social, and acoustic separations create three reproductively isolated populations of orcas (Bigg et al. 1987).

Orcas produce two major sound types – whistles and pulsed sounds (Ford 1987). Whistles have a continuous waveform of variable structure with little to no harmonics. Pulsed sounds are composed of series of short bursts of sound (Ford 1989). Echolocation clicks, variable calls, and discrete calls are all pulsed sounds (Ford 1987). Echolocation clicks are primarily used

in navigation and in prey location (Au et al. 2004); they are composed of short sound pulses that are generally broadband with repetition rates up to 300 pulses per second (Ford 1989). Variable calls and discrete calls are also pulsed sounds, but their repetition rates extend to more than 4,000 pulses per second; this high repetition rate leads to a smooth waveform appearance in spectrograms without sufficient resolution to identify each individual pulse (Ford 1989). Discrete calls are repeated and have distinct tonal qualities that vary between calls and that may vary between matrilineal groups or pods. Variable calls are not repeated between individuals (Ford 1987).

Each of the three pods in the SRKW population uses several different discrete calls to communicate, which can each be distinguished by a human listener (Ford 1987). The collection of calls a pod uses makes up its call repertoire, and J, K, and L pods each have slightly different repertoires. The call repertoires of these three pods overlap enough that J, K, and L pods are considered to form a clan (known as J clan), or a group of pods related acoustically (Ford 1987). These shared calls and the social associations between the different members, who may gather together to form a “super-pod,” define them as a group known as the southern resident community. They are acoustically separated from the members of the A, G, and R clans, which make up the northern resident community (Ford 1991), and from the transient population.

A vast amount of previous research has been conducted to determine the functions of vocalizations in a variety of cetaceans – Caldwell et al. (1990) determined that bottlenose dolphins (*Tursiops truncatus*) have distinctive signature whistles that may be used in individual recognition and group cohesion. Research on orcas has focused on correlating behavior with certain vocalizations (Morton et al. 1986), but until now, such research has been inconclusive.

Weiß et al. (2006) report that currently, no one has been able to link specific call types with either certain actions or behavioral state.

Ford (1987) compiled a catalog of vocalizations made by individuals in A, G, R, and J-clans and noted that most of the vocalizations produced by these animals were discrete calls. Previous work has determined that there are distinct differences between SRKW pods (J-clan) not only in call repertoire, but also in the characteristics of certain calls (Ford 1987, Reisch et al. 2006, Thomson et al. 2001). Pod-specific variations in the structure of calls may be indicators of social affiliations of the whales, who may use their perceived variations to maintain group cohesion (Thomson et al. 2001). Attempts to detect intra-pod variability in the characteristics of discrete calls of A-pod in the northern resident community has indicated that there is a difference between matrilineal units in the durations of certain syllables, a smaller acoustic unit of a call, of at least six calls (Miller and Bain 2000). Just as the pod-specific calls may be used for social distinction, these matrilineal group-specific variations could possibly help individuals from different matrilineal lines locate one another and maintain group cohesion.

Nousek et al. (2006) found that although they could distinguish between calls of matrilines in their analyses, they could find no distinctive variations between individuals. However, researchers working with other species, such as the southwestern willow flycatcher (*Empidonax trillii extimus*) (Poston et al. 2007) and the Amazonian manatee (*Trichechus inunguis*) (Sousa-Lima et al. 2002) have indicated that there may be enough individual variation in the vocalizations of some animals to make recognition of individuals possible. Aubin et al. (2007) discovered individual variation in kittiwakes (*Rissa tridactyla*) by examining duration, peak frequency, and mean frequencies in the first two harmonics of both the total calls and each syllable of these birds' vocalizations. Vanonni and McElligott (2007) and Reby et al. (2006)

analyzed formants, the resonant peaks in a sounds' spectrum resulting from the properties of the animal's sound resonance chamber of fallow deer (*Dama dama*) and red deer (*Cervus elaphus*), respectively. These investigators discovered that analyses of these peaks can allow identification of individuals based on calls. If there are, in fact, such indicators in the parameters of the vocalizations of other animals, it is reasonable to expect that there may be such variations in the calls of orcas.

Problem Statement

Currently, the only system used to identify orcas in the field is one based on visually identifying differences in morphology and pigmentation of each individual, as first described by Bigg et al. (1987). The shape of the dorsal fin, distinctive wounds or scratches, and differences in the pigmentation and shape of the saddle markings are photographed and cataloged for each whale so that humans can identify individuals on the surface of the water. Unfortunately, these distinctions can only be made on the surface, and we can therefore only study their interactions and behaviors to any degree of accuracy on the surface. It is difficult to make underwater observations of these animals, which complicates the study of their complete behavioral repertoire.

Past researchers have searched for behavioral correlates with discrete calls and for grammatical or structural rules to the order of these vocalizations (Dreher 1966, Morton et al. 1986), but the difficulty of identifying the vocalizing individual prevents any headway from being made in this particular area of research. Determining any pattern or social function to call types requires the ability to recognize the vocalizing individual. Since it is extraordinarily difficult to correctly identify a vocalizing orca underwater, it is useful that one be able to identify individuals acoustically if one wishes to understand their vocal relationships and interactions.

In this study, I would like to investigate the possibility of identifying individual variation in the orcas of J-clan. I plan to localize the vocalizations of specific whales using a hydrophone array that will allow me to obtain the direction to a source. I will identify them visually in order to determine which individual is vocalizing so that I can pair the identity of the whale to the recordings of its calls. Matching the calls recorded with the individual will allow me to search for whale-specific variation in these calls.

In my analyses, I would like to examine many of the parameters detailed in Ford (1987); such as total duration for the complete call and for each syllable as well as beginning, end, and peak frequencies for each syllable in several discrete calls. If I can use these parameters to construct a “voiceprint” for each orca from which I have sufficient sample calls, I would like to be able to demonstrate the ability to correctly identify an individual whale simply by analyzing one of its calls.

The ability to construct a voiceprint to acoustically identify individuals in J-clan would provide a passive, non-invasive manner of studying the relationships and vocal behavior of the orcas in this community. It would greatly facilitate acoustic research of these whales by providing vastly more information from each recording than is currently obtained. Such voiceprints would ease behavioral research by de-emphasizing the brief surface actions that make up so little of the behavioral repertoire of killer whales and could allow for easier identification. Instead of focusing on one isolated individual at a time during auditory research, being able to identify whales based on their vocalizations alone would enable researchers to follow the behaviors of multiple whales at a time (Janik et al. 2002). Identifying individual variations in discrete calls can greatly facilitate both behavioral and ecological research.

Experimental Design

I propose to examine several different features of SRKW calls to determine if there is identifiable variation in the vocalizations of each individual. These features will include duration for the entire call and each syllable within the call; and beginning, end, and maximum frequency for each of two formants of each syllable. I will collect recordings while aboard the *Gato Verde* using our hydrophone array. The array is composed of four hydrophones spaced approximately 10 m apart. It will be towed behind the *Gato Verde* about 3.5 m below the surface.

In order to determine any individual variation in orca calls, it will be necessary to match the calls recorded with the hydrophones to the orcas producing the calls. I will localize each of the calls using the hydrophone array and the localization software Ishmael 1.0 (Vents Bioacoustics Program), which will allow me to source sounds to a general bearing and distance. Because this operation can only be performed after the sounds are recorded, it will be necessary to keep track of each orca within range of our hydrophones so I can later determine the position of the individual vocalizing. I will (with help from fellow students and Beam Reach instructor Dr. Shannon Fowler) photograph as many orcas as I can for later identification. I will stand at the port-side stern of the *Gato Verde*, as close to the origin of the array as possible, and take bearings with a protractor facing either the bow or stern of the boat. I will input these bearings along with a photo number into a PDA with a program written by Dr. James Ha.

After a recording session, I can compare the coordinates obtained in Ishmael to the bearings taken with a protractor to match the vocalization to an orca's approximate position. Photo identification will allow me to match calls to specific whales. It is difficult to distinguish finite bearings in animals that are more than 100 meters away using a protractor, and Ishmael is not always accurate because of background noise and asynchronous movements of the whales

and the boat. Because of these constraints, I will only consider data collected from animals spaced 15° or more apart from any other individuals to avoid the risk of confusion.

Once I have obtained calls that I have matched to a particular orca, I will analyze them using Praat 4.6.31 (Institute of Phonetic Sciences). The hydrophone array records sounds in four channels, and Praat can only use one-channel sound files. It will therefore be necessary to use the Beam Reach Sound Analyzer to split each four-channel file into four one-channel files. In order for me to be able to discriminate clearly between the syllables of each call, I will choose the channel of the recording with the highest signal-to-noise ratio discernable to the naked eye. I will measure the duration of each call and of each of its syllables and the beginning, end and maximum frequencies for each of two formants, or resonant bands of one or more harmonics in a sound, of each syllable. I will compare these values between calls of the same type made by the same individual to determine whether or not there are significant differences between calls produced by the same individual. I will also compare the averages of these values between calls of the same type made by different individuals to see if there are individual variations in calls.

If such variation exists in so many parameters for one call type, it is likely that these or more parameters differ enough between individuals to make each whale's calls acoustically distinct from those of others. I would like to determine which parameters of the calls differ most between individuals and whether or not these differences can be easily used to distinguish between individuals. If that is possible, it may be that these parameters could be used to determine the identity of a vocalizing killer whale in the Southern Resident community.

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