**Occurrence of movement instigation ‘signals’ in *Orcinus orca.***

Nora Carlson

Beam Reach Marine Science and Sustainability School

Friday Harbor, WA

Nora.0.Carlson@gmail.com

*Orcinus orca* is the largest whale in the *Delphinidae* family. Orcas are classified into three distinct ecotypes in the northeastern Pacific Ocean: Transients, Offshore and Residents. Each ecotype is distinct in its behavior, morphology, ecology, and vocalization repertoire. Significant genetic differences among the ecotypes indicate that they do not interbreed (NMFS 2008, Ford 1991).

Offshores are the least well studied due to the scarcity of sightings. What is known is that they tend to be smaller than either Transients or Residents, they eat mostly fish, and they have the largest geographic range. As is true with all of the ecotypes, Offshores do not intermingle with either of the other types (NMFS 2008, Ford 1991).

Transients travel in groups of generally fewer than 10 individuals. They eat primarily marine mammals and have straighter dorsal fin tips (NMFS 2008, Ford 1991).

Residents can be distinguished from Transients and Offshores by a slightly more curved dorsal fin tip, their occurrence in stable groups and a fish focused diet. Residents have a very complex social structure consisting of four levels characterized by their interrelatedness. The smallest, the matrilineal group, consists of a female and her offspring for up to four generations. Pods, the most commonly occurring group consists of closely related matrilines which spend the majority of their time together (NMFS 2008, Ford 1991). The next largest groupings are designated as clans, one or more pods who share similar dialects and ancestry. The largest groupings are communities which include clans and pods that regularly associate with each other regardless of matrilineal relatedness (NMFS 2008, Ford 1987, 1991).

On the west cost of the US and Canada there are 4 different communities: Southern Residents, Northern Residents, Southern Alaska Residents and Western Alaska Residents (NMFS 2008, Ford 1991, 1987). The Southern Residents will be the focus of this study.

Orcas have a complex social structure which is theorized to be the reason for the complexity of their vocalizations which seem to send information among orcas in a form of communication. There are three categories of vocalizations: clicks, whistles, and pulsed calls (Ford 1991,1987).

Clicks are very short bursts of sound that often are produced in a series called a click train (Ford 1989). These click trains are used mostly for navigation and foraging, but since they also occur during social interaction, and information from clicks is shared, it is thought that they may serve a communicative function as well (Barrett-Lennard et al. 1996, NMFS 2008).

Pulsed calls are defined as a string of pulses so close together that they sound like a single tone. They last from 50 milliseconds - 10 seconds long and have an average frequency ranging from 1-6kHz (Ford 1987, NMFS 2008). These calls are broken into three categories: discrete, variable, and aberrant (Ford 1987, 1989).

Discrete calls are characterized by being highly structured and having repeated occurrences. It is thought that their function is to help maintain group identity and contact. Aberrant calls are variations of discrete calls. Variable calls are characterized as random unrepeated calls varying in length and duration (Ford 1987, 1989, 1991).

Whistles are continual tonal calls with harmonics that last about .06 - 18.3 seconds. They have a high average dominant frequency of 8.3kHz. In most whistles, there are harmonics around a fundamental frequency (Thompson et al. 2001). Whistles, like discrete calls, have discrete and variable call types (Reisch et al. 2006). They are used a bit differently by the Southern and Northern Residents. Among the Northern Residents whistles are used primarily during social-traveling and socializing indicating that they serve a communicative function during close-range interactions (Thompson et al. 2002). Among the Southern Residents, whistles are most commonly used both during foraging and socializing (NMFS 2008, Ford 1987, 1989), and in situations when the individuals of the pod are more than 10m away from each other (Barry 2006).

Orcas’ complex social structure is mirrored in the existence of dialects that differ among clans, pods and matrilines. Dialects are characterized by differences in vocal repertoires and acoustics (Ford 1991).

Because light doesn’t travel very far in water but sound does, it is theorized that marine animals must rely on sound to keep in contact with each other (Myberg 1980 in Miller et al. 2004). Vocalizations are very important when studying marine mammal behavior because observing their behavior can be extremely difficult. As one of the only ways scientists are able to research free-ranging orcas, decoding the information in sounds is very important to understanding both their communication and behavior. Understanding how they communicate and what drives their behavior will help scientists better understand the impacts of human presence in their habitat and thus their ability to not only thrive but to survive.

Both Bigg et al. (1987) and Ford (1987, 1991) thought that discrete pulsed calls were significant because of their frequent occurrences and their importance in creating the differences among dialects. Recently Reich et al. (2006) documented discrete whistle types. Both Thomson et al. (2001) and Reisch et al. (2006) found that orca whistles are much more complex than previously suspected, and, among Northern Residents, most commonly occur during socializing behavior leading them to believe that, like discrete pulsed-calls, they are important to communication. Barry (2006) theorized that because Southern Residents have the highest whistle rate during rest and when the whales are at distances of greater than 10m, whistles may have a communicative function primarily between members of the same pod as whistles don’t travel as far as pulsed calls and clicks.

Miller (2004) found that orcas exhibit call-typing behavior, in which after one whale calls, another will often respond with the same or very similar call. He also found that of the one or two most frequent calls produced, those calls occur in series a significant percent of the time. Weiland (2007) found something similar: that the most frequent call had patterns of repetition. She also discovered that, although they are much more repetitive than human language, orca calls are not random.

Like Weiland (2007) and Miller (2004), Morton (1986) studied sequence patterns in vocalizations of captive Northern Residents as well as the correlation of sounds and behavior. She concluded that when the frequency of calls was measured during different behavior states, there were correlations between behaviors and calls. She also suggests that there is a high degree of order in ‘sound sequencing’ and found that a sound that she called ‘F1’ was frequently repeated at both the start and stop of ‘conversations’.

Although the aforementioned scientists have found many interesting call pattern occurrences, no further study on the existence of movement instigation calls in free-ranging orcas has been pursued. This, as well as the question of whether or not other repetitive call patterns or call sequence patterns exist in relation to other orca behavior, warrants further study.

Knowledge of behavior triggering patterns in vocalizations may allow biologists to better understand behavioral trends and patterns as well as group cohesion and decision-making. This knowledge would allow biologists and conservationists to understand the patterns in orca behavior and how these behaviors may be changed by outside influence. It would further their ability to study short and long term behavioral shifts due to factors such as food quantity, disruptions in their movements and activities as well as to understand if masking calls could result in pod dispersal and the unintentional separation of individuals from the pod.

It is common in some terrestrial animals and birds for an individual to signal for group movement or change of foraging area (Radford 2004, Boinski 1993, 1996, Bradbury 1998). Whoodhoopoes, white-faced capuchin monkeys and squirrel monkeys have been found to have certain calls that instigate troop movement and direction change. (Radford 2005, Boinski 1993, 1996, Boinski & Campbell 1995). Boinski & Campbell (1993, 1995) found that white-faced capuchins’ trills occurring during movement served to maintain contact, directionality and trajectory. They found that trills were the only call that triggered group movement and orientation demonstrated by white-faced capuchins who were visually separated from their group and who would periodically orient themselves to the others but only in response to a trill (Boinski 1993, Boinski & Campbell 1995).

The Pacific Ocean is, in some ways, not that different from the forests in which woodhoopoers, squirrel monkeys and white-faced capuchins live. In these kinds of habitats visibility is low when individuals spread out during travel and foraging ,making vocalization vital to group cohesion, movement, direction and identity (Radford 2004, Boinski 1993, 1996).

In light of these similarities in habitat which could lead to similarities in group movement initiation, I have decided to focus my study on the following questions: Does a higher frequency of call occurrence happen at the beginning of pod movement and direction change? Does this phenomenon occur during other behavior, such as foraging, resting, milling, traveling or socializing?

To investigate these questions I will test the following hypotheses: 1. Prior to pod speed and direction change, calls occur at a higher rate than occurs during the time from the previous speed or direction change to the beginning of the ‘signal’. 2. Behavior states like foraging, resting, and traveling are preceded by a change in call rate.

Methods

In order to gather data which will allow me to investigate whether pod movement and behavior are instigated by a vocal signal—a vocal signal being a call rate change—I will undertake two types of data gathering: acoustic recording and behavioral observation.

To obtain this data I will study the orcas from a 42’ electric motor powered catamaran named *Gato Verde* used as a mobile research platform for orca observation. We will primarily be in the northern inland waters near or among the San Juans, as the Southern Resident Killer Whales consisting of J, K and L pods, who are the focus of this study, tend to spend most of their time there during the late spring and summer. During the times that we are observing the orcas, the *Gato Verde* will keep at least 100m from the orcas when traveling parallel to them and 400m from the path of the whales at all times as the Whale Watch Guidelines mandate.

**Acoustic Study**

To obtain my acoustic data I will use a Lab Core 4 hydrophone array, with a frequency response curve with peak sensitivity at 5kHz plugged into two Sound Device 702 solid state audio recorders.

The hydrophones are approximately 10 meters apart beginning with hydrophone number one at approximately 10 meters from the stern port engine; the hydrophones will be deployed horizontally behind the *Gato Verde*. The hydrophones will be positioned 7.5 meters under the surface of the water by a weight and will be spaced beginning approximately 7.5 meters from the first hydrophone. The hydrophones are each approximately 10 meters apart (1-2 is 9.93m, 2-3 is 9.78m, 3-4 is 9.96 m). This will keep the hydrophones from getting caught by other ships that may come too close to the stern of the boat.

The sound Device’s gains will be set at 37 dB and the sampling rate will be 44.1 kHz. When the orcas are present, the hydrophones will be turned on and recording begun in real time with a start time recorded for the beginning of every new file, so the acoustic and behavioral data can be compared accurately. While recording, I will mark whether or not calling has occurred for every minuet of recording allowing me to quickly find calls when analyzing the recordings.

**Behavioral Study**

For my behavioral study I will be looking at two sets of behavioral data: speed and direction change and behavior.

The first data set will be a change in speed (the five speeds being motionless, slow 1-2 knots, medium 3-5 knots, fast 6-10 knots and proposing) or direction (directions being N, W, S, E as well as the directions in between. When 70% or more of the pod has changed speed or direction, I will mark the time.

I will also be gathering behavioral data. I have identified five behaviors states that I will be recording. The five behaviors are traveling (directional movement of any formation and orientation), foraging (flank or non-linear formation movement at all speeds and orientation with lunge and chase events), resting (non-linear formation tight to touching orientation with no percussive events and slow directional movement), socializing (non-linear formation with non-directional movement with little to no progress forward and play activity [physical interaction, surface activity and displays]), and milling (non-linear formation with non-directional slow or medium movement) (NOAA 2004). A change in behavior will not be recorded unless approximately 70% of the pod exhibits the new behavior state.

These two behavioral date sets will be recorded on two separate sheets in order to keep them clearly separate. Each data sheet will include the acoustic file number so the audio and behavioral data can be matched in real time.

For each research encounter with the orcas, I will record the number of individual whales present in order to have all of the information to get a call rate/individual/second. I will use continuous sampling to collect the behavior data on a data collection sheet.

**Analysis**

I will be examining the behavioral and acoustic data together to determine whether or not there is a significant correlation between a change in speed and direction and the call rate, and behavior state change and the call rate 10 minuets before the speed and direction or behavior state change. I chose 10 minuets because in Boinski’s (1993) study of movement instigation calls in white-faced capuchin monkeys, she found that movement instigation calls most frequently occurred within 10 minuets of group movement.

The call rate of every data set will be found by calculating the number of calls per individual per second.

I will compare the behavioral data (independent variable) with call rate data (dependent variable) using the ANOVA test. I will be running two separate ANOVA tests. One will test if there is a significant difference between the call rate during the 10 minuets before speed and direction change and the call rate during the total time from the previous speed or direction change and the 10 minuets before the new change. The other will be testing if there is a difference in the call rates during the 10 minutes before behavior state change and the call rates of from the change prior to the current change and the 10 minuets before the current behavior state change.

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