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

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*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 indicates 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 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 communication (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 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. Similarly 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 some kinds of 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 that were visually separated from their group 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: Do repetitive call patterns, call sequences or a higher frequency of call occurrence happen at the beginning of pod movement? Does this phenomenon occur during other behavior, such as foraging, resting, milling, traveling and socializing?

 To investigate these questions I will test the following hypotheses: 1. Pod movement among orcas begins with a repetition sequence – a repetition sequence being one call repeated (S1, S1, S1). 2. Pod movement among orcas begins with a call sequence— a call sequence being a series of calls (S1, S2, S3), which may differ among behaviors but stays consistent for a particular behavior. 3. Prior to pod movement calls occur at a higher rate than occurs during behavior states. 4. Behavior states, like foraging, resting and traveling, are preceded and followed by a ‘signal’.

Methods

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

When obtaining this data I will be aboard a 42’ electric motor powered catamaran named *Gato Verde* usedto seek and track whales for 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 (AR and Cecil).

The hydrophones are approximately 10 m 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 \_\_\_\_\_m under the surface of the water by a weight at approximately \_\_\_\_m from the first hydrophone. This will keep the hydrophones from getting caught by other ships that may come too close to the stern of the boat.

ARJ and Cecil ‘s gains will be set at \_\_\_\_\_\_\_\_ 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 a call has occurred for every 3 minuets of recording allowing me to quickly find calls when analyzing the recordings.

**Behavioral Study**

For my behavioral study I have identified five behaviors states that I will be recording. The five behaviors are traveling (directional movement of any orientation), foraging (flank or non-linear orientation movement at all speeds and spread distance with lunge and chase events), resting (non-linear orientation tight to touching dispersal with no percussive events and slow directional movement), socializing (non-linear orientation with non-directional movement with little to no progress forward and play activity [physical interaction, surface activity and displays]), and milling (non-linear orientation with non-directional slow or medium movement) (NOAA 2004).

 In addition to behavior states I will also record sudden directional or speed changes as well as formation (how the whales are spatially oriented in relation to each other), orientation (the distance the whales are from one another within the group), speed, and directionality.

 A change in behavior will not be recorded unless approximately 70% of the pod exhibits the new behavior state.

 I will use continuous sampling to collect the behavior data on a data collection sheet (Table 1).

**Analysis**

I will be examining the behavioral and acoustic data together to determine whether or not there is a significant correlation between behavior state change and the call rate and type approximately 10 minuets before behavior state changes. 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.

I plan to use a chi^2 tests to look for call sequences. This will tell me whether or not call sequences exist among orca vocalizations. I will compare the behavioral data (independent variable) with call rate and call sequence data (dependent variable) using an ANOVA test. This will tell me whether or not there is a significant correlation between the behavior state changes and the rate or sequences of calls within 10 minuets prior to the change.

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