Call-Type and Behavioral Event Associations of Southern Resident Killer Whales (*Orcinus orca*) in the Salish Sea

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Introduction

Southern resident killer whales (*Orcinus orca*) are seen in the coastal waters off British Columbia and the Salish Sea. They are among the most studied of marine mammal species because of their consistent residence in these waters from June to October. The southern residents are made up of three pods: J, K and L. Together these pods make up a clan, or a group of pods with similar vocal dialects. They are considered to have a much older maternal connection than other pods of killer whales that inhabit close areas, such as the coastal waters of the northeast coast of the Pacific (Ford 1991, NMFS 2006). Killer whales have a highly developed social structure composed of matrilineal pods, descended from a matriarchal female. The long-term stability of pods allow for detailed study of their vocal behavior over time. Identifying the behavioral contexts during which specific types of vocalizations occur is a crucial step towards understanding vocal communications.

Behavior

There are five broad categories of activities that killer whales display on a regular basis, as described by the National Marine Fishery Service (2004). These are traveling, foraging, resting, play and milling. These behavioral states are usually coordinated by

the entire group; although there are many exceptions to this generalization (Ford et. al. 2000, NMFS 2006). During traveling, killer whales move in a constant direction with varying speeds, usually 5-10 km/hour, attaining speeds up to 40 km/hour. Traveling whales often line up in tight formations and surface and dive in synchrony (NMFS 2006). A considerable amount of time is spent foraging. Cooperative hunting and food sharing are notable actions of foraging whales. Pursuing prey often involves a lot of subtle changes in direction, speed, and dive lengths. Foraging whales may also have sudden bursts of speed, or occasionally works together to corral fish near the shore (but this has not been observed in the Puget Sound) (NMFS 2006). Resting often follows periods of foraging. The matrilines, or pods, gather together in a tight formation, with animals diving and surfacing in unison and at regular intervals; usually 2-3 minutes at the surface followed by a short 2-5 minute dive (Ford et al. 2000, NMFS 2006). Socializing behaviors are seen most frequently by juveniles and may represent a kind of play (NMFS 2006). The three specific categories are 1) object play, such as with kelp or floats, 2) social interactive play, such as touching, breaching, or percussive behaviors, and 3) solitary play (NMFS 2004). Some of these activities may be used as both visual and acoustic communication (Ford et. al. 2000). Play activities typically involve a lot of physical contact, and male members of the pod often display sexual behavior, such as penile erections and nosing of genital areas (NMFS 2006). Milling is defined as repeated, non-linear, non-directional movement, at slow (less than 2 knots) or medium (2-6 knots) speeds (NMFS 2004).

Vocalizations

Killer whales produce three types of sounds in underwater communication; whistles, pulsed calls, and echolocation clicks (NMFS 2006). A great deal of these vocalizations may be utilized as a means of communication between individuals or to the entire pod. While there is no conclusive evidence as to the meaning of specific vocalizations, the social complexity and unity of any one pod or community of killer whales suggests that they must have a communication system that allows them to maintain group cohesion through time and space.

Whistles in killer whales have rarely been studied, and thus their function is still unknown. In a variety of other vocal delphinids, whistles are used as an individual signature (Rehn et al. 2007). Given the social structure of resident killer whales, this is unlikely because group identity is more important than individual identity (Rehn et al. 2007). Also if this were true, we would expect to see a greater variety of stereotyped whistle signatures in order delineate one individual from another (Rehn et al. 2007). Whistles are the dominant sound produced during socializing and also have a high rate of usage during social traveling (when whales from the same or different clans are interacting at close range) (Ford 1989, Thomsen 2002). Sequences of pulsed whistles have often been observed to be used in play-fights among juveniles and subadults (Rehn et al. 2007). It is also possible that the transmission of whistles, in contrast with discrete calls, is not restricted to the dialects of related clans (Riesch et al. 2006).

Echolocation clicks are brief pulses of ultrasonic sound used as a type of sonar for the whales (NMFS 2006). They are heard as single clicks, or many times as click trains, used to assist in prey location and spatial orientation (Barrett-Lennard et al. 1996). There is a fairly large database of information that supports this theory, and thus echolocation

clicks will not be a focus of this study (Ford 1989, Barret-Lennard et al. 1996, NMFS 2006)

Pulsed calls can be discrete, aberrant, or variable. Discrete calls are used by the whole pod and make up the repertoire of their vocalizations (Ford 1991). Pulsed calls have distinct structural characteristics that can be seen in spectrograms. Aberrant calls are based on discrete calls, but are highly distorted in structure (Ford 1989). Variable calls are more complex than discrete calls, cannot be arranged into any discernable structural categories, and are not repetitive (Ford 1989). Ford (1991) classified discrete pulsed calls in an alphanumeric fashion, cataloging calls in an arbitrary fashion by which calls were identified first. They are preceded with the letter S to indicate that the call was consistent with a call given by the southern residents. In total, the southern residents have 44 discrete call types; four of which have variations particular to one or two of the three pods making up the southern resident community.

Discrete calls are most often used during times of group dispersion, and comprise 95.2% of all calls during foraging, and 94% of all calls during traveling in the northern residents (Ford 1989). This indicates that discrete calls are used as a way to maintain contact between pod members and/or maintain spatial organization (Ford 1989, Riesch et al. 2006). However, this does not explain the large repertoire of calls when only one or two discrete calls could serve this function. Ford (1989) proposed that:

"repertoires of multiple discrete calls have evolved in killer whales to increase the reliability and efficiency of intrapod communication and to maintain the integrity of the pod. Dialects in the repertoires enhance the effectiveness of this acoustic signaling system, although they may not have evolved specifically to serve such a function."

Discrete calls could also serve other functions, such as reflecting emotional states, behavioral activities or specific features within the environment.

Problem Statement

Most previous studies associating wild killer whale behavior with vocalizations have looked at a group of animals and summarized their behaviors with the calls coming from the group; localization of any one animal was not attempted. The objective of my study is to identify the vocalizations coming from a specific killer whale and relate that directly to the behavior that particular animal is expressing at the same time. This kind of detailed analysis could be very useful in recognizing the patterns that indicate the function or meaning of discrete calls or whistles. The three southern resident pods each have their own dialect shared within the pod and many calls overlap between the pods. These repertoires have remained relatively stable in excess of 25 years (Ford 1991). There is some inherent change that comes with the death and birth of individuals as the community changes, or with changes in their environment. These factors, over an extended period of time, could stimulate the loss or gain of new calls in the pod's repertoire; nevertheless these changes are consistent with the whole pod (Ford 1991). Because the southern residents share a similar dialect, it can be assumed that the calls have similar meanings, even between pods. A greater understanding of the communication system of killer whales could give us a better understanding of their customs, health and mental states as individuals or in the whole community. This information would be critical to the protection of the species.

Methods

The study area is the waters surrounding the San Juan Islands, WA, USA. The observational platform will be a 42-foot catamaran, the *Gato Verde,* with a quiet, hybrid, diesel engine. A hydrophone array will be connected to two solid state recorders and towed behind our research vessel, at known distances from the aft stern. The four hydrophones are LAB-core hydrophones, with peak sensitivity at ~5,000Hz and decreases 30dB at ~200Hz and ~10,500Hz. The solid state recorders used will be Sound Devices 702; sensitivity flat from 10 - 40Hz (+0.1 to -0.5dB). The sampling rate will be set to 44,100 samples/sec and the gain setting to 37dB. An 8 lb weight will be attached to the end of the hydrophone array by a bungee cord, and supported by a rope, to sink the array to a depth of 3-5 m. This will deploy the hydrophones below the turbulence of the upper layer of water and keep all four hydrophones parallel to the surface. At the start of each recording session, time and file name will be logged. During the recording period, surface behaviors will be monitored and distinct behavioral events recorded. These behavioral events are defined in Jacobsen (1986) and Osborne (1986). For each behavioral event, the number of times the event occurred, real time (hour: minutes: seconds), estimated bearing and distance, and number of individuals in the group will also be recorded. The bearing will be estimated with the aid of a protractor with the 0 degree reference point fixed at the head of the boat; regardless of the actual bearing of the boat. The distance will be visually estimated with the aid of a Newcon Optik rangefinder (LRM 2000 PRO).

After collecting data, individual behavioral events will be reviewed for analysis. Any call within two minutes (one minute before and one minute after) will be determined to be associated with the behavior. No other previous research has looked at behavioral

events, only behavioral states. Therefore this time interval is appropriate because it allows for some reaction time of the animal on either side of the event, and is short enough to distinguish between events.

The files will be split into 1 min, 16 bit files in order to make them easier to analyze. Each call identified in the 1-min interval will be localized using the Ishmael 1.0 program (David Mellenger). The sound files will be analyzed using the time difference between when a call reached each hydrophone to determine the origin of the call. I will use the hyperbolic localization option in the Ishmael program, because it creates six hyperbolae by pairing each of the hydrophones to each other to create the most accurate point of origin of the call by finding the intersection of the hyperbolae.

The localization point of a call given by Ishmael, will be matched to the distance and bearing of individual whales while they are displaying surface behavior. The distances can be calculated using the Pythagorean Theorem with the coordinates of the call given by Ishmael. The source points given by Ishmael will be incorporated into the analyses if the bearings and distances estimated on the boat are within 15 degrees and 100 meters. This was chosen due to the large sources of error on both types of measurements, and there is no precedence found in previous studies to distinguish between individuals. The bearing was eyeballed with the use of the protractor on the boat, and thus is subject to a large magnitude of human error. The rangefinder has an error range of plus or minus one meter. However, if it doesn't hit a large enough target, then the distance will be estimated by sight only and this could produce a large range of human error as well. Acoustic localization error increases with the distance of the source from the hydrophone array (Janik 2000). Ishmael's program also produces cross-

correlation graphs that can be used as a qualitative representation of its own level of error and this will also be taken into account.

The calls will be visually and acoustically compared to Ford's call (1987) catalogue of southern resident calls to determine call type. All data will then be assembled into an Excel version (Microsoft) spreadsheet. This organizes all observed behaviors with associated calls in that minute, along with the time, bearing, and distance.

The call-type data for each type of behavior will be summarized by taking a simple summation of the number of times each call type was represented within the one minute time interval of the observed behavioral event and divided by the total number of recorded calls. These proportions will be compared using a two-tailed t-test to determine if there are any calls used at statistically significant higher rates during each behavioral event.

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