Examining Diurnal Patterns in the Vocal Activity of Southern Resident Killer Whales (*Orcinus orca*)

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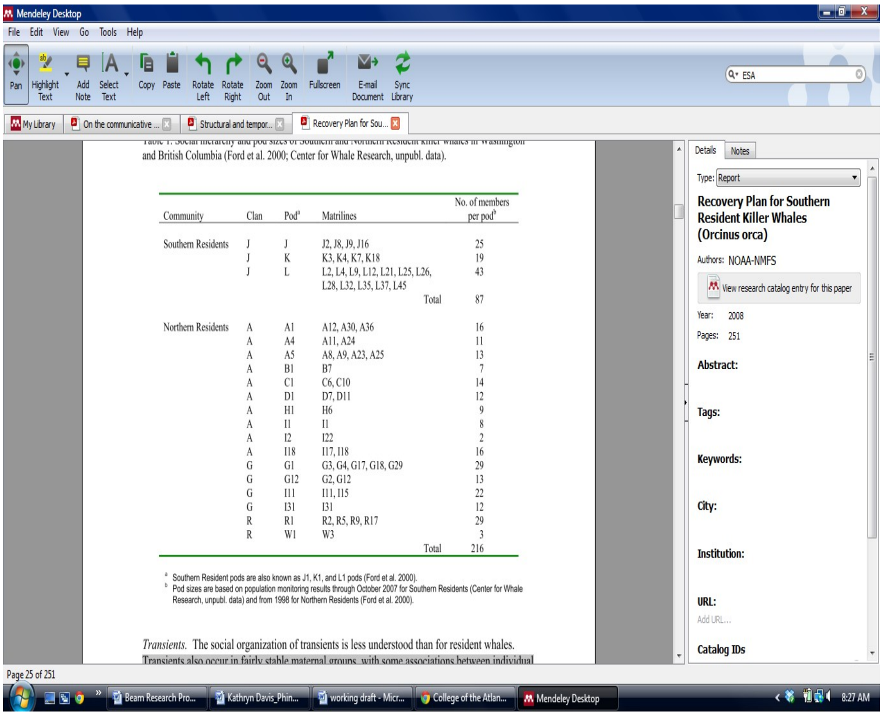
Recent studies have demonstrated that aquatic environments dramatically change the intensity and spectral composition of incident light (Downing 2001). Rapid attenuation of light with depth is common .To compensate for this, numerous marine species have evolved to rely on sound as their primary method of communication. Cetaceans, such as killer whales (*Orcinus orca*) and bottlenose dolphins (*Tursiops truncatus*), use sound to maintain group cohesion during certain behavioural states. Similarly, terrestrial mammals, such as timber wolves (*Canis lupus*), convey information of a behavioural or environmental nature via acoustics. This form of communication is particularly effective when pack members are beyond visual range of one another (Bruce 1967). In Central American frogs, such as *Hyla rufitela*, the male usually produces a loud, conspicuous signal to advertise his presence to other males and to attract females over long distances (Kime, Turner, and Ryan 2000).

Killer whales, similarly to other delphinids, produce many types of vocalizations useful for navigation, communication, and foraging (Thomsen, Franck, and Ford 2000). Regarded as a highly social species, killer whales live in close knit family units that are considered some of the most complex and stable social structures of any animal species. Three different ecotypes exist in the Pacific Northwest; residents, transients (Bigg's killer whales), and offshores. (Thomsen, Franck, and Ford 2000). Residents, composing around 75% of the population (Ford 1990), are found throughout the year but are more common during June-October. Unlike northern residents that occupy the inland waters of Vancouver Island, southern residents reside in the Salish sea; a region that encompasses the water south of Vancouver Island (Bigg et al. 1987).

These whales are not only regionally distinct, but, also demonstrate differing types of calls. The differing call types separate the resident whales into groups called clans. Clans are groups of pods that are united by the calls in their vocal repertoires (Ford 1987). The southern residents have only one clan (J), and this is composed of the three southern resident pods J,K and L. This study will focus on the calls produced by J pod which, as of 2012, was thought to be comprised of 26 members (The Whale Museum, Friday Harbor).



and British Columbia (Ford et al. 2000; Center for Whale Research, unpubl. data).

Community	Clan	Pod[a]	Matrilines	No. of members per pod[b]
Southern Residents	J	J	J2, J8, J9, J16	25
	J	K	K3, K4, K7, K18	19
	J	L	L2, L4, L9, L12, L21, L25, L26, L28, L32, L35, L37, L45	43
			Total	87
Northern Residents	A	A1	A12, A30, A36	16
	A	A4	A11, A24	11
	A	A5	A8, A9, A23, A25	13
	A	B1	B7	7
	A	C1	C6, C10	14
	A	D1	D7, D11	12
	A	H1	H6	9
	A	I1	I1	8
	A	I2	I22	2
	A	I18	I17, I18	16
	G	G1	G3, G4, G17, G18, G29	29
	G	G12	G2, G12	13
	G	I11	I11, I15	22
	G	I31	I31	12
	R	R1	R2, R5, R9, R17	29
	R	W1	W3	3
			Total	216

[a] Southern Resident pods are also known as J1, K1, and L1 pods (Ford et al. 2000).
[b] Pod sizes are based on population monitoring results through October 2007 for Southern Residents (Center for Whale Research, unpubl. data) and from 1998 for Northern Residents (Ford et al. 2000).

Transients. The social organization of transients is less understood than for resident whales.

Figure 1: Social hierarchy and pod sizes of Southern and Northern Resident Killer Whales in Washington and British Columbia (Thomsen, Franck, and Ford 2000; Centre for Whale Research, unpubl. Data).

Resident killer whales have a diverse repertoire, and have a hearing range from 1 to 100 kHz (Szymanski et al. 1999). Three different types of vocalizations have been identified for the southern residents; echolocation clicks, tonal whistles, and pulsed calls (Ford 1989). Vocalizations can vary in multiple parameters, such as call rate, frequency, amplitude, or duration, and these parameters can change for many reasons (Wieland, Jones, and Renn 2009). Ford (1989) proposed that pulsed calls be classified as either discrete, variable, or aberrant. Discrete calls are stereotyped, repetitive and conform to a fundamental structure. Not only are discrete calls distinctive in structure, they appear to be population specific (Ford 1987, 1989). In both northern and southern resident communities, discrete calls are most frequent during vocal exchanges, and thus serve to signify group affiliation (Ford 1991). Focusing on the southern residents specifically, approximately 25 discrete calls have been recorded (Ford 1987). The predominant call types for southern residents are S1 in J pod, S16 in K pod, and S2iii and S19 in L pod during directional travel (Foote and Nystuen 2008). It has been suggested that S1 could be a contact call, but, this is not an established phenomenon nor is it supported by available data. A contact call is primarily used to establish the location of other pod members during certain behavioural states (Ford and Fisher 1983). Foraging, for example, generally involves moderately sized subgroups travelling quickly, spread out in flank formation with an average distance of about 400m between groups (Hoelzel 1993). In the terrestrial world, contact calls are widespread among primates, other social mammals and birds (Rendall, Cheney, and Seyfarth 2000). For example, in Chacma baboons (*Papio cynocephalus ursinus*) loud calls are given periodically by separated individuals whilst participating in activities with a high risk of separation such as foraging (Rendall, Cheney, and Seyfarth 2000). Given S1 is thought to be a contact call produced when group members are beyond visual range, one could hypothesize that it will be produced more frequently at night, in the absence of light, relative to other calls.

Until relatively recently, it was assumed that cetaceans had excellent hearing and echolocation, despite having poor vision. This assumption was made on the basis that sight would play a minimal role in the ocean environment. Although developed auditory capabilities are key to survival, other forms of communication, for example vision, should not be overlooked. In Southern Resident habitat, human divers reported an underwater visual range of 3-15 metres (Peninngton 2012).Throughout the last thirty years, behavioural investigations of visual capabilities, through captive research, suggests that the visual system of most cetaceans is highly-developed, and thus well adapted to both aquatic and aerial media(Basin and Mammal 1995). Through captive experiments, White et al. (1971) estimated that the underwater visual acuity of the killer whale to be at least 5.5 min of arc within a stimulus range of 10-20ft (3-6m). In the wild, closely related killer whales have been observed travelling within 1-10 metres of each other, and 10-100 metres for matriline members (NOAA-NMFS 2004). This would suggest that they often travel beyond visual sight of one another, and thus need to communicate in order to preserve group cohesion. At night, and times of the day where light penetration is at its lowest, distances at which killer whales can effectively see will be compromised. It is hypothesized that during such times the whales will increase their ‘contact call’ relative to all other calls.

By a method known as retinal topography mapping Mass and Supin (1997) were able to show that unlike the retina of terrestrial mammals, which contains a single area of high ganglion cell density, the retina of whales contains two; one in the temporal part and the other in the nasal part of the retina. These two areas are likely involved in vision both inside and outside of a water medium. Underwater, cetaceans, regardless of their suborder, rely on both areas of the retina. This provides a wide field of monocular vision. Out of the water, however, it is suspected that only one area of the retina is utilized (a M. Mass 2002). Bottlenose dolphins have demonstrated that they are capable of visually recognizing an array of arbitrarily shaped figures, in two and three dimensions underwater (Herman et al. 1989). From these studies, one could infer that the ability to see underwater is essential for predator avoidance, successful capture of prey, as well as social interactions and orientation. Antarctic Type B Killer Whales, that show preference for Weddell seals, have been recorded spy hopping around ice floes looking for seals resting on the ice (Pitman; American Cetacean Society 2011). By using sight, they are able to discriminate between the different seal species. Other forms of communication in the marine environment include tactile communication, and producing chemical signals. These however, unlike sound, sight, and echolocation, are not effective over large distances.

Methods

To investigate the call density among J pod, specifically whether the discrete call S1 is more common during the night, southern resident killer whales will be observed and recorded in the Salish Sea for a study period lasting three weeks from 30th April to 24th May 2012. All observations and acoustic recordings will be made from a 42ft hybrid electric-biodiesel catamaran called the Gato Verde. This vessel has the potential to operate on a battery pack, if needed, allowing for at least three hours of ‘silent’ travel. This will be beneficial when studying the whales because it will not only reduce the vessel’s presence, but, will enable sounds to be more easily detected by any hydrophones used. A four hydrophone array (Labcore 40’s Array with peak sensitivity at 5 kHz) will be deployed from the stern when a J pod interaction is anticipated. The Gato will then tow the hydrophone array, at a steady speed, for the duration of the interaction. For this study, data will only be collected for periods when members of J pod are present; photographic identification will enable discrimination between pods. The recording device will automatically assign a file name, and record the date and time. Having made the recording, sub samples will be imported into Audacity 2.0.0, and be examined for S1 calls. Discrete calls are easily differentiated by the human ear and also provide a unique spectrographic structure. With every ten minutes of recording, one minute will be sampled and analyzed. Many studies have used frequency contours to describe vocalizations. Ford et al. (1999) found that humans perceive the acoustics of killer whale calls differently from person to person when classifying them. Therefore, to remove observer bias in this study, two people will count S1 calls, and the average score will be used. S1 calls will be determined using visual parameters outlined in the call catalogue (Ford 1987).

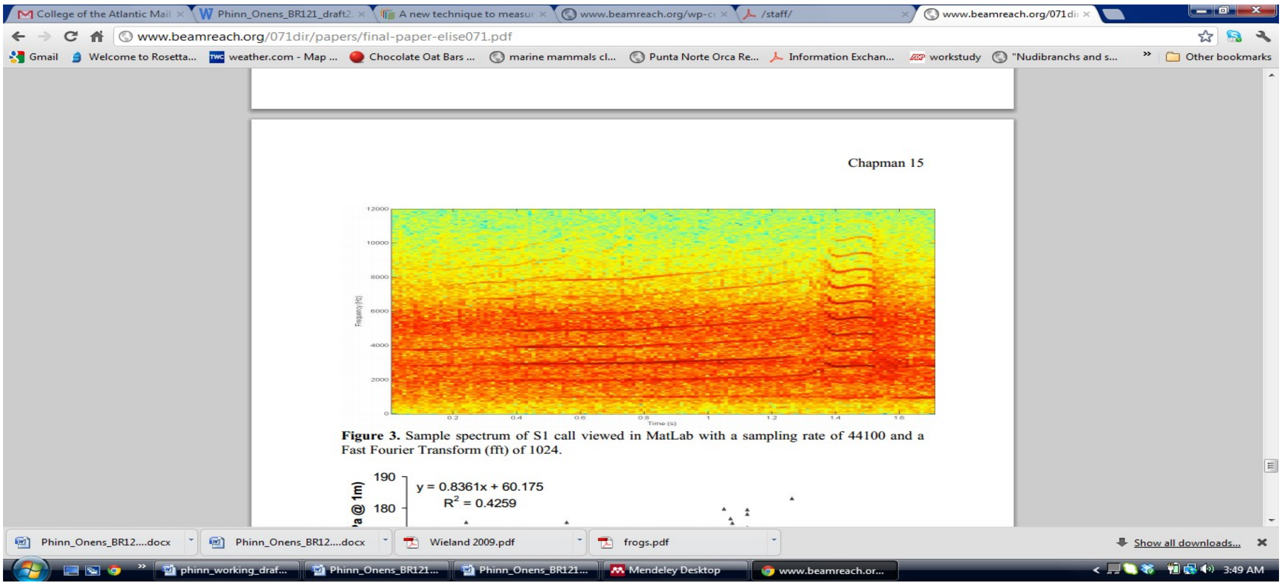


Figure 2: An example of a S1 call, produced by a member of J pod (Chapman, E. 2007)

In addition, total number of other calls will be recorded allowing ‘call density’ to be calculated. For the purposes of this study, ‘call density’ will be defined as the number of S1 calls per interaction, per group. The call density of S1 can be calculated by the equation;

# of S1 per minute

# of other calls per minute

In order to test the hypothesis, day time call density will be compared to night time call density. Night time data will be collected from the Gato, if safe to do so. Sailing at night can prove challenging due to a variety of different variables including lack of light, tides, and location of whales to name just a few. All these factors need to align before data collection can be conducted at night. During the three weeks out on the research vessel there should be at least one window of opportunity to sail at night. When sampling at night, the methods will remain the same as daytime protocol, apart from heightened safety measures. Anchorages will be chosen with respect to killer whale migratory corridors. This will allow for opportunistic data collection. Archival night data, collected in August 2010, will be used to supplement any data collected. August 2010 was a strong month for night calls, in part, due to observer effort during that time period; samples were recorded throughout the night, and analyzed by volunteers. In order to fully explore the hypothesis time of sun set, in particular how it varies through the season, will be taken into consideration. At this latitude, daytime will lengthen until 21st June 2012, and then shorten until 21st December 2012. For this reason, samples will be collected during midnight $\pm$ 2 hours (10pm-2am). This corresponds with a time of known darkness. Night recordings will also be made from both Lime Kiln and OrcaSound hydrophones, during the study period, in order to develop a greater sample size.

In order to ensure consistency between night and daytime data, daytime recordings will be made between noon $\pm$ 2 hours (10am-2pm). This will incorporate a period of known day light, and coincide with the predicted time of sailing. Recordings made outside of these time bands will be discarded. Because J pods S1 is theorized to be a contact call, additional data such as group size and group spread will be recorded per interaction. Group size will be determined by using high-quality photographs to distinguish individuals in the encounter based on the pattern of nicks, lesions, scars and variation in dorsal fin shape as suggested by Wilson et al. (1999). Calculating group spread will prove more challenging. One focal group will be monitored throughout the duration of the encounter. If multiple groups are present, the focal group will be determined based on the number of individuals. When group members are within 20ft of one another, the maximum distance at which killer whales are thought to see, the group will be categorized as “in association”. If any individual travels beyond 20ft of the main group, for a period lasting 5 minutes or longer, the whale will be considered “not in association”. The distance of 20ft will be estimated by one individual throughout the entirety of the study period. This distance would be equivalent to roughly half the length of the Gato Verde, a 42ft catamaran. Acknowledging that this measurement is a raw estimate, emerging results should not be viewed as conclusive. After each encounter, the proportion of time the focal group spent in association with each other will be calculated. Proportion of time spent in association will be plotted against S1 call density per interaction.

Following an interaction with J pod, visibility of the water will be determined by using a Secchi disk. The Secchi disk will be attached to a marked line and deployed over the stern of the research vessel on the most shaded side. Weights will be used to ensure the descent is vertical. The depth at which the disk disappears will be recorded. To minimize error, two people will be responsible for lowering the instrument into the water to a depth where it can no longer be seen. This experiment will also be conducted in bad weather, such as fog, given it may further reduce visibility in water. In addition to collecting daytime readings, the Secchi disk will be utilized at night with light sources attached. Daytime visibility will be plotted against call density for that particular site. Regarding night time calls, average visibility will be plotted against averaged call density of archived data.

In addition to examining the diurnal patterns in vocal behaviour, the absence of light due to phytoplankton density, concentration of water particles, and depth will be taken into consideration from a concurrent project. This will broaden the scope of the research, and strengthen any conclusions drawn.

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