S1 Call Rate in Relation to Visibility Profiles of the Salish Sea

Rachel Bramble

Beam Reach Marine Science and Sustainability School

Friday Harbor Labs, University of Washington

620 University Road, Washington 98250

Introduction

Social interaction in mammalian species plays an important role in the survival and function of cohesive family groups. For example, individual timber wolves (*Canis lupus*) have distinct howls which, along with olfactory senses, are effectively used to communicate when members are separated at great distances (Falls, 1967). Similarly, African elephants use very low frequency vocalizations to stay in contact with one another, their calls spanning over vast areas of land (Poole et al. 2012). This kind of social interaction ensures group cohesion and can not only be found in terrestrial mammals, but also in marine mammals. Bottlenose dolphins produce signature whistles that enable individual recognition and are mainly used when individuals are at distant proximities (Sayigh et al. 2007).

Killer whales (*Orcinus orca*), the largest member of the *Delphinidae* family, are considered one of the most social mammals of the sea, using their vast repertoire of calls, whistles, and clicks to communicate during a number of different social behaviors (Wieland 2007). The southern resident killer whales of the Pacific Ocean are among the most extensively studied killer whales in the world. Their vocalizations have been intensely studied over the past few decades (Ford 1987), revealing the extent to which killer whales communicate with one another. Vocal communication is thought to be imperative for maintaining social cohesion and organizing activity within a pod of killer whales (Weiss et al. 2007).

The southern resident killer whales consist of three different pods, J, K and L, who share a common dialect and have a habitat ranging from as far south as central California, up to northern British Columbia. During the summer and fall months, the southern residents are usually found residing in the inland waters off the coast of northern Washington and southern British Columbia (Hanson et al. 2010). Each pod is made up of various small family groups,

often referred to as 'subpods' (Connor et al. 1998). Each subpod consists of up to four generations of immediately related individuals. The family structure of killer whales is matrilineal, meaning that offspring continue to travel with their mother throughout the duration of their lives. This matrilineal social structure of killer whales is considered to be among the most stable social structures of any mammalian species, and results in tight group cohesion (Weiß et al. 2006). Calls used in vocal interaction that are shared among the members of a matriline are called discrete calls. Because killer whales live together in groups consisting of a number of different matrilines, all closely related, they share an abundance of calls that make up their own dialect. The discrete calls that make up the dialect of a pod are thought to be important in the social cohesion of each pod (Weiß et al. 2006).

Of the three resident pods, the vocalizations of J Pod reveal a particularly interesting and common call, S1, which is easily identifiable and is theorized to be used as a contact call. It is thought that pods rely upon contact calls to maintain group cohesion, especially when traveling (Ford and Fisher, 1983). Assuming killer whales use S1 as a contact call implies that killer whales may rely on vocal communication to remain in a cohesive group when they are out of visual range. Therefore, it can be hypothesized that the S1 call rate increases, relative to all other calls, in areas of the water with less visibility.

Visual range can be affected by a number of different factors that influence light attenuation, such as water depth, what kinds of materials are suspended in the water, and the quantity of those materials (Gallegos 2000). Such factors can be as simple as the lack of light due to nightfall, or can be more complex. Phytoplankton, for example, contribute to both the absorption and scattering of light in water (Gallegos 2000). Particle content and salinity changes from estuarine areas of the water like the Fraser River runoff can also affect visibility

(Sutherland et al. 2011). As there are many variables that affect visibility in water, visibility in turn affects the form and function of eyesight in many of the creatures that live in the water, including killer whales.

Odontocete eyesight is specifically adapted for an aquatic environment. The structure of an odontocete eye is similar to that of a human, with subtle differences that allow them to see effectively both in and out of the water, such as the difference in shape of the lens. Odontocete lens structure is almost spherical, creating a pressure on the iris which causes a large bulge on the cornea. The curvature of the lens is steeper in odontocetes than it is in humans, as it has been determined that all of the refraction is carried out by the lens, and none by the cornea. (Dral, 1975).

For many years, it was unclear how the lens of the odontocete eye was able to change shape drastically enough to account for both air and water visualization, as a change in lens shape seemed to be the only sound theory about how this unique vision worked. In sea otters, it was found that the eye has an accommodation range and its curvature is altered to be visually accurate in water and in air (Murphy et al. 1990). Recently, however, the most likely theory combines several different factors that influence how odontocetes are able to see both in and out of the water. Odontocetes can focus images on their retina at different angles in different media (Dral, 1975) and they have two areas of high density ganglion cells on which the images are focused (Mass and Supin 1997). They also have "giant" axons making up a great portion of the optic nerve, of which there are no comparisons to terrestrial mammals (Mazzatenta et al. 2001).

Both high density areas of ganglion cells are used by odontocetes in underwater visualization, where only one group is used when seeing in air, similar to terrestrial mammal

visualization (Mass, 1997). In addition, it was found that both odontocetes and mysticetes have a

lower density of optic nerves and fibers that attribute to underwater viewing (Mazzatenta et al.

2001). The strength and accuracy of odontocete vision underwater is thought to be emmetropic

(accurately focused) when their vision is directed with one eye at a subject, however above

water, odontocete vision is only emmetropic within the naso-ventral view, a view in which

odontocetes see by focusing their vision forward. The idea of the naso-ventral view comes from

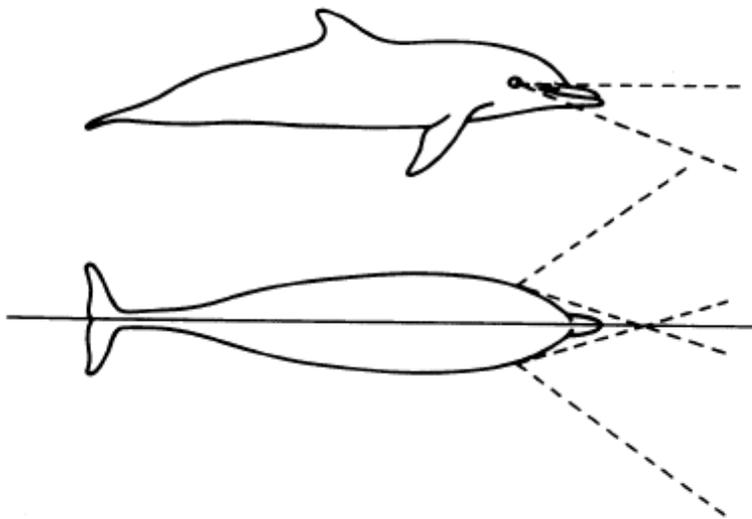age-old observations of behaviors such as spyhopping.

Figure 1: The naso-ventral
view where vision is emmetropic in air (Dral,
1975).

Odontocetes are adept at seeing well in their aquatic world, and are even thought to have

accurate vision out of the water if objects are seen through the naso-ventral view (Dral, 1975).

However, they are just as affected by light attenuation as any other mammal, both aquatic and

terrestrial, and things such as nightfall, chlorophyll from phytoplankton, and particles in the

water may play a part in reducing their ability to see in the water. From what is known about the

theory that the S1 call of southern resident killer whales in J Pod is a contact call, and that killer whales use vocal communication to maintain social cohesion, it is safe to assume that, in areas of the water with limited visibility, the rate of the S1 call increases in comparison to all other calls.

Methods

An original visibility profile of certain areas in the northeastern waters of the Pacific Ocean will be created using transmissometer and fluorometer data from CTD casts, secchi disk deployments, YSI measurements of water quality, and plankton tows. The YSI data will be analyzed in conjunction with the CTD data to visualize relationships between transmissometer data, and salinity and temperature, for when the CTD is no longer on the research vessel, the Gato Verde. The areas in which the profiles will be made are salmon bank, offshore of salmon bank to the south, north of San Juan Island near Boundary Pass and Swanson Channel, the west side of San Juan Island, and the south side of Lopez Island. These areas are frequently occupied by southern resident killer whales belonging to J Pod (Hauser, 2007), and will include data about Fraser River particles, phytoplankton and chlorophyll abundance, and depth, collected from CTD deployments.

Data recorded from the hydrophone array deployed from the Gato Verde and the stationary hydrophone located at Lime Kiln will be observed in Audacity to determine the call rate of S1 in comparison to all other calls from J Pod. The call rate is to be calculated from one minute segments of ten minute recordings taken in areas where the visibility profiles have been created. The number of S1 calls heard in that given minute will be divided by the total number of calls during the one minute time span. The number of whales in the given areas will not be taken

into account. Both new and archive data are to be analyzed for the calls and the visibility profiles.

In addition to the daylight factors that affect visibility, the absence of light due to nightfall will be analyzed based on the data collected and interpreted from a concurrent project. The relationship between visibility factors and the interpretation of visibility profiles will be determined from the following additive equation:

$$Sd - Cp + Sa + Cd - T$$

Where Sd=secchi disk reading, Cp=chlorophyll from the presence of phytoplankton, Sa=salinity, Cd=conductivity, and T=transmissometer reading. As the number increases, visibility in the water decreases. In the final stages of the research, a graph indicating the relationship between visibility and S1 call rate will be plotted.

Works Cited

Connor, R C, J Mann, P L Tyack, and H Whitehead. "Social evolution in toothed whales." *Trends in ecology & evolution* 13, no. 6 (June 6, 1998): 228-32.

Dral, A. G. D. "Vision in Cetacea." *The Journal of Zoo Animal Medicine* 6, no. 1 (March, 1975): 17-21

Falls, J. Bruce & John B. Theberge. "Howling as a means of communication in timber wolves". *Oxford Journals* 7, no. 2 (May 1967): 331-338.

Ford, John K.B. and Fisher, Dean H. "Group specific dialects of killer whales (*Orcinus orca*) in British Columbia". *Westview Press, Inc*. (1983): 129-161.

Ford, John K. B. "A catalogue of underwater calls produced by killer whales (Orcinus orca) in British Columbia". *Canadian Data Report of Fisheries and Aquatic Sciences* no. 633 (1987): 1-165.

Gallegos, Charles L. "Factors Contributing to Water-Column Light Attenuation." SAV Technical Synthesis II: 35-55. 2000.

Hanson, M Bradley et al. "Species and stock identification of prey consumed by endangered southern resident killer whales in their summer range." *Endangered Species Research* 11 (2010): 69-82.

Hauser, D. D.W. et al. "Summer distribution patterns of southern resident killer whales *Orcinus orca*: core areas and spatial segregation of social groups." *Marine Ecology Progress Series* 351 (December 6, 2007): 301-310.

Mass, Alla M, & Alexander Ya Supin. "Ocular anatomy , retinal ganglion cell distribution , and visual resolution in the gray whale , Eschrichtius gibbosus." *Aquatic Mammals* 23, no. 1 (1980): 17-28.

Mazzatenta, Andrea, M Caleo, N E Baldaccini, & L Maffei. "A comparative morphometric analysis of the optic nerve in two cetacean species, the striped dolphin (Stenella coeruleoalba) and fin whale (Balaenoptera physalus)." *Visual neuroscience* 18, no. 2 (2001): 319-25.

Murphy, C. J., et al. Refractive state, ocular anatomy, and accommodative range of the sea otter (*Enhydra lutris*)." *Pergamon Press* 30, no. 1 (1990): 23-32.

Poole, J. H., K. Payne, W. R. Langbauer, & C. J. Moss. "The social contexts of some very low frequency calls of African elephants." *Springer* 22, no.6 (1988): 385-392.

Sayigh, L. S., H. C. Esch, R. S. Wells, and V. M. Janik. "Facts about signature whistles of bottlenose dolphins, Tursiops truncatus." *Animal Behaviour* 74, no. 6 (December, 2007): 1631-1642.

Sutherland, D.A., P. MacCready, N. S. Banas, & L. F. Smedstad. "A Model Study of the Salish Sea Estuarine Circulation." *Journal of Physical Oceanography* 41, no. 6 (June, 2011): 1125-1143.

Weiß, B. M., F. Ladich, P. Spong, & H. Symonds. "Vocal behavior of resident killer whale matrilines with newborn calves: The role of family signatures." *The Journal of the Acoustical Society of America* 119, no. 1 (2006): 627.

Weiss, B. M., H. Symonds, P. Spong, & F. Ladich. "Intra- and intergroup vocal behavior in resident killer whales, Orcinus orca." *The Journal of the Acoustical Society of America* 122, no. 6 (December, 2007): 3710-6.

Wieland, Monika. "Repertoire Usage of the Southern Resident Community of Killer Whales (Orcinus orca)". Reed College. 2007.