Vessel Noise and Orca Vocalization: Implications for Policy

Alexandra Kougentakis
Beam Reach Marine Science and Sustainability School
Friday Harbor Laboratories, University of Washington
620 University Road
Friday Harbor, WA 98250
E-mail akougent@sas.upenn.edu

Introduction

The Southern Resident killer whales (SKRWs) of the Pacific Northwest have long shared their habitat with humans and marine vessels. The anthropogenic impacts of commercial and private boatcraft are several, including oil spills from petroleum tankers, depletion of salmon prey by fishing ships, and noise disturbance. The latter is one of the least-studied threats and is often underemphasized, in spite of having been identified by the International Whaling Commission Scientific Committee (IWC/SC) Standing Working Group as a "potential population level threat to marine mammals." (IWC/SC 2004). It is this understudied area that is the focus of interest in this paper.

A number of different vessel types traffic through the Juan de Fuca and Haro Straits of northwestern Washington, and the impacts of the noise generated by each are as yet largely not understood. Recent studies have examined the role of whale-watching boats, which have increased in number with the growth in popularity of such ecotourism industries. Vessels have the potential to affect whale communications and behavior, whether through short-term disturbances such as the masking of calls, or through graver effects such as hearing loss. In 2002, a scientific model was proposed to measure noise created by whale-watching boats and effects on orcas. (Erbe, 2002) Software that factored in the propagation of broadband noise, specific physical oceanography properties, and the currently accepted orca audiogram model (Szymanski, 1999) was used to analyze the data collected on SKRW vocalization. Estimates were made for ranges over which boat noise could be audible to orcas, mask their calls, cause behavioral change and cause hearing damage. Each of these zones was distinguished by a successively higher received level (RL) of vessel noise by the orcas.

A National Marine Fisheries Service (NMFS) study regarding the effects of vessel noise on orca behavior used techniques that had been applied to northern resident orcas to investigate their southern counterparts (Bain et al, 2006. Horizontal avoidance of vessels and increased surface active behavior among orcas was noted across different boat types, including those not focused on whale-watching. The boater practice of leap-frogging, in which whale-watching boats enter the path of the whale in order to come within closest possible range while technically following guidelines, was similarly correlated with avoidance behavior in the northern resident population. (Williams et al, 2002)

Currently there is little understanding of the connection between orca vocalization and behavior, but it is unquestionable that communication is a crucial part of life for orcas and the behavioral impact of anthropogenic noise is likely linked to communication disruption. It is difficult to determine with certainty that vessel noise is the actual cause of changes that may be observed in whales vocalization patterns; at best a correlation can be attempted, and even such conjectures are tenuous. The only direct effect communication that was considered by Erbe was that of masking, an effect that is inferred rather than directly observed. Other possible ramifications of vessel noise for vocalization include differences in call duration between periods when vessels are present and periods when they are absent. (Foote et al, 2004) Call frequency is another possible area of impact; a student research study was only able to find a significant difference in the frequency of certain calls, depending on whether or not boats were present, for a single pod (Ayres and Danforth, 2002). No significant correlation was found for data recorded from mixed pods, which led the students to conclude that boat noise was generally not a reliable indicator of changes in call frequency.

The increase in whale-watching on the San Juan Islands in recent decades has been paralleled by protection efforts for SKRWs. The Whale Museum on the island of San Juan has focused on monitoring and advising vessels since the 1980s, using an adaptive management model to determine a set of principles, which has been periodically updated, to guide the behavior of all vessels trafficking through the area. The current edition is "Be Whale Wise," and includes a graphic illustration to indicate the range of distance from orcas at which boats must travel more slowly or stop completely ("Be Whale Wise, Internet). Research and the participation of stakeholders such as the Whale Watch Operators Association Northwest (WWOANW) have contributed to the efforts of the Whale Museum to establish a list of best-practices guidelines for commercial operators. Both private and commercial vessels are monitored by the Soundwatch Program, an educational division of the Museum.

The adaptive management model is an outgrowth of early efforts, most notably initiated by CS Holling in the 1970s, to develop environmental impact assessment and resource management methods. The process involves bringing together scientists, resource managers, decision-makers and policy advisors. A foundational principle which was emphasized by Holling was the uncertainty involved in the prediction of future behavior of natural systems, given the inherent limitations of models. This should not discourage the pursuit of management altogether, but rather points out that shortcomings must be dealt with through monitoring and continued research. Effective communications between scientists and policy-makers is crucial and is often one of the elements that is most lacking (Morgan, 1998).

On September 11, 2007, ordinance NO. 35 – 2007 was approved by the Council of San Juan County, officially codifying much of what the "Be Whale Wise" guidelines had dictated for voluntary compliance. The decree, which designates a $750 fine for the harassment of killer whales, was submitted for review in June 2007, but the push for binding legislation can be considered to date back to the early monitoring efforts of the Whale Museum. A continuing quandary will be the matter of enforcement; resources for the prosecution of environmental legislation are ever paltry and insufficient. The whale-watching industry had a strong record of positive compliance with the guidelines while they were still voluntary, according to Kari Koski of Soundwatch (Koski, 2007), but private boaters are less predictable. The new law will likely require a significant period in order to properly gauge its real impact.

In 2006 the NMFS proposed a recovery plan for SKRWs. The effects of vessel noise are cited as a threat to orca survival, and the role of such organizations as Soundwatch and the WWOANW in seeking the amelioration of boater behavior is noted as playing an important part in the monitoring and guidance of vessel activity. A further recommendation of NMFS pertains to the importance of evaluating the disturbance to whales caused by the various boatcraft. "Numerous types of vessels have the potential to negatively affect the behavior of killer whales, but little information is available on this issue." ("Proposed Recovery Plan for Southern Resident Killer Whales *(Orcinus orca)*." The potential effects on orca communication are of especially strong concern, given its importance to social organization, foraging, navigation and other essential behaviors.

The impact caused by the noise generated of vessels present in the Puget Sound needs to be more closely investigated. Data that can authoritatively inform policy needs to consider both vessel factors, e.g. size and speed, and biological effects for marine life. Some vessel types are inherently louder than others, leading to higher received levels (RLs) by orcas that can therefore have greater impacts on behavior and communication abilities. The distance of the vessel from an area occupied by orcas is also crucial in affecting how much of the initial source level (SL) will be perceived. Applying the same standards to all boats may undermine the effectiveness of the regulations. Short-term noise effects such as masking and behavioral change can have significant long-term impacts on a small population, in the case of SKRWs currently 89; group survival is contingent upon the welfare of each individual. Further research on the effects of vessel noise can contribute to more effective standards, which could perhaps lead to the amendment of the current legislation.

My paper will seek to build upon previous research as well as to contribute new information to facilitate the creation of reasoned policy that will allow continued use of the Puget Sound by humans, while providing protection for orcas. In particular, I am interested in surveying and characterizing the sound propagation of the vessels that will be encountered during the period of study. The vocalization of orcas during individual sound incidents will be noted and characterized to assess the apparent interference that the vessel noise may have. Source power density spectra for both orca calls and boat noise will be calculated to allow for a direct comparison; as of the time of this study, source power density spectra for orca calls have not been previously studied. Finally, the adequacy of the previously voluntary guidelines that have been designated as law will be assessed with regard to the distances from orcas and the speeds that are recommended for whale-watching boats.

TENTATIVE METHODS

The methods used in this study were developed with the aid of similar work conducted in previous studies (Veirs and Veirs, 2006) as well as through the counseling and support of Val Veirs. The research area will predominantly be in Haro Strait, and will be conducted aboard the *Gato Verde*, a catamaran chartered for 8 weeks of use by the Beam Reach program to enable data collection as well as to teach program participants sailing skills and the philosophy of sustainability.

Sound transmission loss was measured in the Spieden channel. Recorded orca calls were played on an underwater speaker that was moved using a dinghy to different distances from the *Gato Verde*. A hydrophone array consisting of 4 hydrophones spaced 10 m apart was deployed off the port bow of the catamaran to measure the sound level received at the boat from each distance. The gain settings were changed between a few of the distances, and the received sound was recorded by computer into one-minute files.

The files were analyzed using Beam Reach Analyzer software. The sensitivity settings were adjusted as was appropriate for each of the changes in gain setting, and the intervals between calls were used to set the background level of noise for each file. A segment of the whale call was chosen, and the reading determined by the program was used as a measure of the received level. These values were graphed on a set of axes along with the log of the corresponding distance to determine the linear relationship. The slope of the calculated trendline was used as the propagation model to determine source sound levels. (See Figure 1)

The measurement of vessel noise was broken into two components: the analysis of the sound generated by individual vessels and the cumulative sound generated in the marine environment by all vessels in the vicinity. To determine the noise levels of individual boats, a single moving boat needed to be within a 400-meter distance from the *Gato Verde*, as determined by a range-finder. This radial distance was chosen as it reflects the outermost extreme at which boat behavior was advised by the SoundWatch guidelines. The hyrophone array was deployed off the port stern of the boat, sound recordings were continuously taken by a computer in 1-minute files. Background noise files were taken for each half hour interval at points during which there were no vessels within 400 m of the *Gato Verde*. The power of the background noise was subtracted from each vessel recording during analysis to accurately calculate source level. Identification of boats will be achieved using binoculars and the "Boat ID Guide" of the Soundwatch Program. Boat speed will be approximated with the help of Todd Shuster, the captain of the *Gato Verde*.

Power density spectra for the calculated real RL of the vessel recording were created using Beam Reach Analyzer software. The calculated RL data was used with the boat's distance and the calculated spreading rate to determine SL, and source power density spectra were created as well. Microsoft Excel was used to determine the peak amplitude and the associated frequency of each source spectrum.

Cumulative vessel noise sound files were taken at 1-hour intervals at which there were no individual boats within 400 m of the *Gato Verde*, but numerous moving boats were present further off. A comprehensive boat count was taken and boat types according to the scheme established by SoundWatch were noted. The distances of all boats within 800 m were noted within ranges. Recorded files were analyzed using Beam Reach Analyzer software to determine RL.

The impact of vessel noise on orca vocalizations was the second crucial objective of this study. It has been shown that orcas increase the amplitude of their calls when vessel noise is present (Holt et al.., 2007). The investigation here was twofold, the first goal to determine whether a call is amplified as a function of vessel noise and how much. The second goal of the was the creation of source power density spectra for localized orca calls. The hydrophone array was deployed during orca events to record vocalizations. The presence of nearby moving boats was noted during each event. Distance was determined for all calls that could be successfully localized using Ishmael 1.0 software (Vents Bioacoustics Program), and SL was calculated using RL data that will be obtained by running recordings through Beam Reach Analyzer software. Analysis of SLs was based on whether the calls occurred in the presence of boats or lack thereof, to compare amplitudes between the two conditions.

The creation of source power density spectra involved the SL from the previous analysis and was used to generate graphs. The SL graphs from the vessel analysis were used to compare vessel sound spectra with those of the orcas for samples when calls were present. Orca call spectra were also compared to determine if there was a difference in SLs depending on the presence or absence of vessels.

The third crucial component of this study was the assessment of the effectiveness of the "Be Whale Wise" guidelines, by considering the range surrounding the orcas that has been specifically cited to regulate boater behavior. The ambiguity of minimum and maximum distances for the "slow zone" in which boats are advised to travel at less than 7 knots yields four points to be considered: 100 m, 91.44 m (100 yards), 400 m, and 365.76 m (400 yards). The SLs of individual boats, calculated from the earlier analysis of RLs and distances, were used to estimate what the RLs would be at the specific R points given above. The boats that had been traveling at speeds below 7 knots were categorized within the group "Compliant with guidelines" and those traveling above 7 knots were classified as "Noncompliant with guidelines."

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