Determination of orca vocalization frequency changes in the presence of varying levels of ambient aquatic sound

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I. Abstract

From 1996 to 2001 the southern resident Orca populations of Canada and the United States has suffered from a decline of about 20%. (NMFS, 2005) This study aims to determine if Orca vocalizations, specifically fundamental frequencies, change with varying ambient sound. Audio of Orca calls and ambient sound used in this study is gathered from archived and newly recorded audio recordings. Data Analysis of these underwater sounds has found that fundamental frequencies do not change with changing levels of ambient sound; specifically ambient frequency, ambient peak power, and ambient total power. This finding is significant in its own right, but further behavioral study will help to improve our understanding of why fundamental frequencies do not change with changes in ambient sounds.

II. Introduction

In the Pacific Northwest, killer whales (*Orcinus orca*) have become a major contributor to the regions' tourism, economy, and regional popularity. Orcas have been valued around 1 million dollars per captured whale.(Whale and Dolphin Conservation Society, 2003) This value depicts the enormous economic incentive to both protect and capture these whales. As the image of the iconic Killer Whale continues to prevail and increase in popularity and this population has just been listed as endangered, it has become ever more necessary to assess our impact on these marine mammals. The *National Marine Fisheries Service* has recently completed a study assessing the potential risk for the southern resident Orcas, native to Washington state and British Columbia. This study was sparked by a 20% decline in Orca populations between the years of 1996 to 2001.(NMFS, 2005) The conservation plan takes a comprehensive look at the history of the animals, present status, current protective measures, and concludes by listing potential threats to the southern residents. Within the plan, eight broad categories of necessary actions are listed and include prey availability, pollution/contamination, vessel effects, oil spills, acoustic effects, education, human response, agency coordination, and lastly a lack of research was cited as a threat.(NMFS, 2005) The conservation plan suggests several research topics needed for the creation of a science-based environmental protection policy for the southern resident Orcas. It is the aim of this conservation plan to assist in generating sufficient science to aid in creating effective conservation policies for the Southern Residents.

An important issue noted in the conservation plan and other literature is the need for more acoustic information regarding the disturbances imposed by vessel traffic upon the southern residents. The noise disturbances are mainly derived from cargo ships, passenger vessels, tugs, tankers, and recently, commercial whale watching boats. (NMFS, 2005) Research point B.5 points out that much research needs to be done to understand the southern resident behavior. (NMFS, 2005) Research point B.6.2. further points out that the effects of human generated marine sound from vessel traffic are still largely unknown.(NMFS, 2005) Undertaking research on the acoustic habitat of the southern resident Orcas will allow for determination of whether varying levels of ambient noise specifically, frequencies and power affect the southern residents' vocalizations. The study aims to answer the question of what ambient noise frequency and power levels are and if whales will alter their vocalization depending on these differing levels.

The Orca pod home to the San Juan islands is the J-pod, and the most common call made by the J-pod is the S-1 call.(Foote, 2006) Some other common vocalizations are S4, S7. and S3 calls.(Foote, 2006) For the purpose of maintaining concise and limited vocalization measurements only one syllable of that call will be used. Table one made below established the fundamental frequencies of the calls and the measure standard deviation.(Ford, 1987)

Call Type(ordered by prevalence)	Fundamental Frequency(1st syllable)	Standard Deviation
S1	1020	6.1
S4	159	11.5
S7	1023	4.7
S3	1068	5.3

Table 1: the most common calls of J-pod, fundamental frequencies, and standard deviations in kilohertz

In order to understand how to analyze the acoustic conditions of the southern residents it is necessary to look at how similar threats are being measured and analyzed on both a global and regional level. Past studies on the southern resident Orcas of the Puget Sound have been largely focused on understanding behavioral reactions to boat traffic. A report published by the Canadian department of Fisheries and Oceans, discusses numerous ways in which human presence effects northern resident Orca behavior. Along with taking a very broad look at the types of cetaceans affected by humans; the report also looks a behavioral changes in other than just vocalization, such as changes in movement, eating, and aerial behaviors.(Lien, 2000) The number of whale watching boats within the habitat of the southern residents has increased by about five boats per each pod each whale watching season..(Osborne et al., 1999) Conclusions are made that changes in various types of Orca behavior are occurring and the presence of whale watching boats has been widespread.(Lien, 2000) Relationships between these two findings are still unclear.(Lien, 2000) Previous studies have reported that captive killer whales exhibit changes in vocalization once human contact has been made.(Lien, 2000) The fact that whales do react at all to human contact is crucial in the study being conducted because it allows for the basic assumption that local Orcas are affected by human presence.

An investigation done by Au and Green in the Hawaiian islands is very useful because it specifically looks at the effects of whale watching boats on the migrant humpback whale (*Megaptera novaeangliae*).(Au and Greene, 1999) While this study does not look at the same species, it is still valuable in answering the question of how human generated noise effects marine mammals, specifically the Humpback whale in Hawaii. This research is very useful because it uses a tightly controlled experimental method to determine specific behavioral impacts. Several examples of the tightly controlled experimental method are the use of the Marine Mammal Protection Act regulations, observance of the complete range of both before and during whale watching presence, standardized distance and depth, and cooperation of the whale watching boats. (Au and Greene, 1999) Working to control all of these variables allows for an easier determination of impact. Conclusions were made that humpback whales were affected differently by each type of boat tested, and largely determined by engine size.(Au and

Greene, 1999) The methodology exhibited here is important because it demonstrates how an ideal study on the affects of vessel noise can be conducted to account for the external conditions of an aquatic environment.

In New Zealand a study done by Constantine on the effects of tourism on marine mammals works to assess the status of a wide selection of marine mammals around New Zealand. The aspects of this study which pertain to this project are largely focused around the vessel impact upon two dolphin species. The two species targeted in this portion of the study are the bottlenose and common dolphin. Conclusions were made that tourist boats associated with the dolphins emitted noise in a frequency within the hearing range of the dolphins but, the actual effects on the dolphins is unknown. (Constantine, 1999) Social behaviors are the most likely to change in the presence of whale watching vessels.(Constantine, 1999) Orca vocalizations, specifically calls, are largely used to communicate.(Richardson et al., 1995) Communication is inherently part of social behaviors so, the research conducted on San Juan island will focus on analyzing vocalized communication; a social aspect of behavior.

A study done in Hong Kong, attempted to quantify levels of ambient noise and begin to examine effects on two species of marine mammals.(Wursig and Greene, 2001) Although the location and intensity of ambient noises is drastically different from that of the Southern Residents, it is still crucial to realize the effects of ambient noise on species other than Orcinus Orca. A commonality shared between the this test site in Hong Kong and the test site in the Puget sound is the presence of large 100m plus ocean going oil tankers. (Wursig and Greene, 2001) This study was able to measure the ambient noise as a function of frequency and determine its effects on the Indio-Pacific humpbacked dolphins and finless porpoises. (Wursig and Greene, 2001) Short term presence of high levels of ambient noise is not disruptive to these animals largely because they are continuously exposed to high levels of background noise. (Wursig and Greene, 2001) The conclusion in this study poses an interesting hypothesis that marine mammals are largely unaffected by varying levels of ambient sound.

On the northern coast of Vancouver Island a study was done to look at the effects of 'leapfrogging' on the northern resident Orcas. Leapfrogging is a practice in which whale watching boats will run parallel to the whales at a faster speed and park themselves perpendicular to the whales.(Williams et al., 2002) Analysis was done to look at if increases in boat noise associated with speeding up has the potential to mask killer whale communication. (Williams et al., 2002) Conclusions were made that leapfrogging results in an increase of 14dB in the habitat of the observed specimen at frequencies ranging up to 24 kHz in the habitat of the observed specimen but if masking occurs, it is still unverified.(Williams et al., 2002) This study is important because it allows for the conclusion that whale watching boats practicing 'leapfrogging' do alter the acoustic environment of the Northern Resident killer whales.

The methodological difficulties in correlating boat noise frequencies and power, with whale calls in the same venue necessitates a need to analyze vocalization in reference to ambient noise rather than just specific boat frequencies. In order to answer the question of how human generated marine sound effects the local Orca's necessitates the need to calculate ambient noise and congruent vocalizations. This research project is aiming to answer the alternative hypothesis of whether Orca vocalizations do change with ambient sound or, the respective null hypothesis that vocalizations do not change with varying ambient sound. Answering this question allows for an assessment of wether ambient sound is and has been contributing to the recent losses in Orcas.

III. Procedure

i. Site description

The research being conducted on the Southern Resident Orcas is focused at the Orca Vocalization and Listening (OVAL) base of operations. OVAL is located on the western United States coast in the state of Washington among the San Juan islands close to the border of Canada. More specifically research is based on the western side of San Juan Island between Mitchell bay and False Bay along the Haro Strait in the Puget Sound. On water research is being conducted using the catamaran, *Cat's Cradle*, and a small craft owned by Professor Val Veirs. The OVAL station is equipped with two operational hydrophones and sufficient electronics to record and analyze the audio recordings.

Figure 1: San Juan Island (Google Earth, 2006)

ii. Experimental Methods

This study is reliant on audio recordings from hydrophones to obtain and record underwater sounds. Audio recordings are being taken from the habitat of the J-pod stretching from the mouth of the strait of Juan de Fuca to the northern reaches of the San Juan Islands. Whale activities are highly variable, so the recordings will be made independent of any behavioral analysis.

The goal of data collection is to gain enough recordings to allow for hypothesis testing. To accurately obtain and measure data containing orca calls it is necessary to rely on a combination of archived data from the *Beam Reach: School of Marine Science and Sustainability*, as well as original recordings made during the course of this study.(BeamReach, 2005) The diverse nature of the data makes it essential to identify and discuss the tools being used to collect the underwater recordings. A key aspect in generating data confidence is to obtain as many samples as possible. In total after listening and analyzing several hundred audio files, a base of 31 audio files are being used to determine frequencies and power of Orca calls and ambient noise levels. The decision to either use or discard a file was based upon call clarity and equipment type.

The unsorted set of audio files came from three sources including ocean based recordings made onboard the Cat's Cradle, OVAL hydrophones, and archived data from *Beam Reach*. The selection of the recordings made during the course of this research was done at the OVAL research station using the pair of hydrophones on the western side of San Juan Island along the Haro strait. These recordings were made on the 2nd and 8th of May, 2006. The rest of the recordings made during this research were conducted aboard the *Cat's Cradle* using a pre-calibrated hydrophone system made by Interocean Systems, inc (http://www.interoceansystems.com). This data was recorded on the 27th and 29th of April, 2006. Archived data was recorded during the beam reach program using a sample of the ten hydrophone setups available to the Beam Reach program. This archived data was collected on the water from the 4th to the 22nd of September 2005. All data included amounted to several hundred audio files with varying levels of sound and calls, respectively.

Data was made into digital WAV files using two different methods; the first method was a simple file transfer from a digital recording devise, called a *Marantz*, to a computer, the second method was to record and transfer directly from the hydrophones located at the OVAL station using a program entitled, *Program for Using Array Data.*(http://www.audiogear.com/Marantz-audio.html) Once the data was on the computer a number of steps were taken to adequately edit and record data. The first step was to use the *Creative Wave Studio* program to edit audio recordings for concise enough recordings to here both a clear call and background noise. Once done the audio files can be looked at using the *Signal Display and Frequency Display Program* program.(Figure 2 &3) This program is integral in assessing frequency and power levels for both the Orca calls and ambient noise present during the recordings.

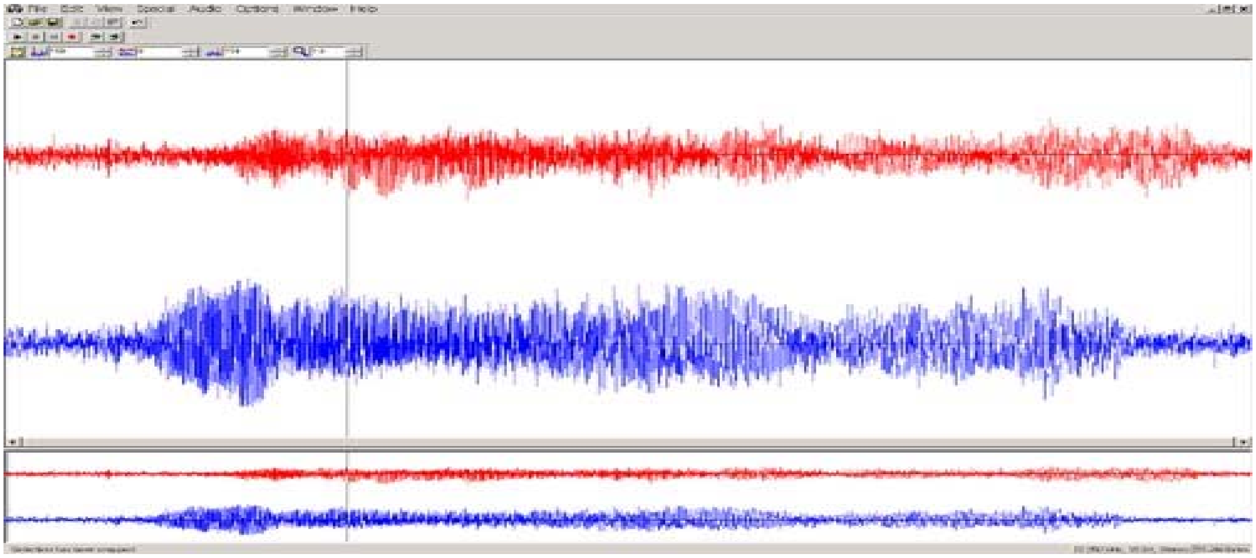


Figure 2: Creative Wave Studio, sample of edited sound file, screenshot

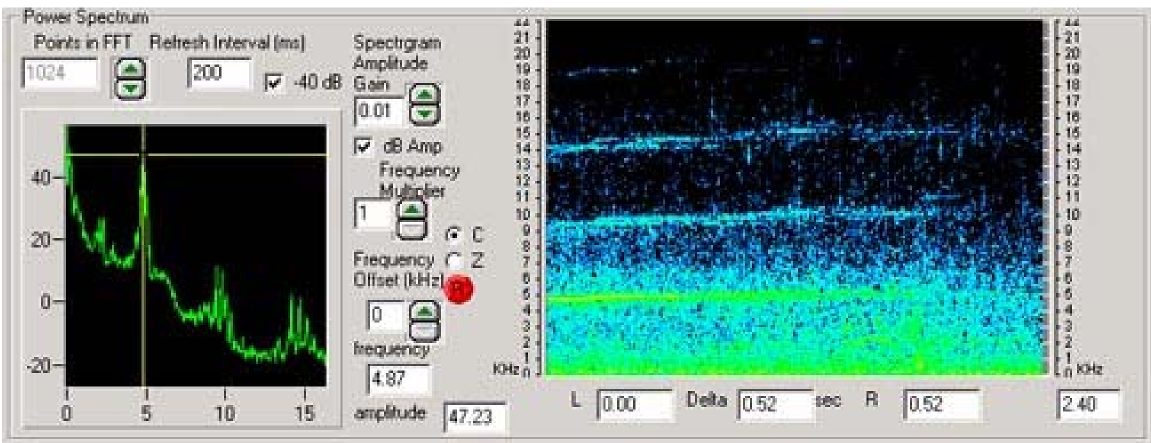


Figure 3: Signal Display and Frequency Display Program, 1st syllable of S1 call, screenshot

A recent advancement in the program allows for greater ease in analysis because it saves a file of every point on the average power spectrum for regions selected by cursors. This function of the program combined with manual visual peak identification using the cursors, was crucial in the identification of each frequency level available to assess the mean interval of each call as well as ambient noise. Using this program, 3-4 frequency levels, depending on clarity, were identified and recorded for each call. The recording of ambient noise levels was accomplished by identifying a point in the same audio recording void of any noticeable Orca call. The program's automated peak measurement system was used in the range of the strongest and most probable background noise. Manual identification was also used to identify areas where the most prevalent peaks were most likely to occur. In terms of ambient noise, a prevalent peak was determined as being clearly defined and not overly sharp. The system built into the *Signal Display and Frequency Display Program* helped to distinguish between peaks by calculating the second derivative and power for each peak. These methods allowed for an accurate measurement of both ambient noise levels, in terms of power and frequency, and the mean frequency interval levels for each Orca call. This data was entered into Microsoft Excel and SPSS for statistical interpretation.

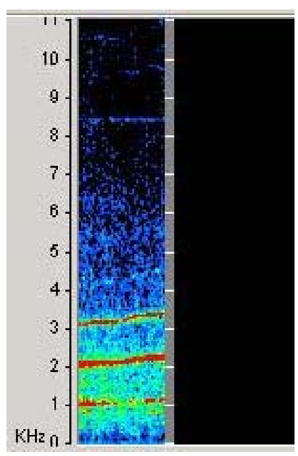


Figure 4: S1 call frequency levels, screenshot

iii. Data Analysis

The main goal of this study is to assess the impact of varying levels of ambient noise on Orca behavior, specifically vocalization. Statistically, the goal of this study is to either accept or reject the null hypothesis of no change in the frequency structure of vocalizations. Several steps are needed to accurately test this hypothesis with reasonable confidence. The first step is to decide whether the data is normally distributed, than run a regression to look for correlations between the two variables, and finally a nonparametric t-test will be conducted to compare absolute difference between the two means. Along with these steps, statistics will be collected for mean, standard deviation, kurtosis and skew; thus allowing for statistical tests to be shaped according the specific parameters of the data. Accomplishing these three steps allows for the null hypothesis to be either accepted or rejected with relative confidence.

Step one is to check the data for a normal distribution of data. Normally distributed data is important because for many statistical tests normal distributions are assumed. This normality check is done by creating a histogram of the data and then analyzing the data distribution for a normal distribution. It is extremely important in this study to check for normal distribution because an abnormal distribution can help to discriminate between differing call types and equipment problems. Histograms were made in SPSS for the fundamental frequency with and without outliers, ambient frequency, and lastly for ambient total power. Outliers have been manually removed because the data distribution can easily be distorted by human and instrumental error. Calls well outside the standard deviation were removed because they likely represented a different type of call other than the S1,S3, S7, or S4 call. This histogram for mean interval allowed for the removal of six outliers too large and one outlier too small.(Figure 5.) Ambient frequency was normally distributed so the data was untouched. Total ambient power was skewed to the right because of one very large outlier, which was removed. Now that the data has been checked and manipulated into normalcy it is possible to run several regressions against differing data sets. (Figure 9,10)

Regression is used to find relationships between two variables, independent and dependent variables. In this study several measurements of ambient sound are being used for the independent variable because they do not depend on the dependent variable of vocalization frequency. Regressions were run on ambient frequency vs. ambient peak power, ambient frequency vs. ambient total power, mean interval vs. ambient peak power, mean interval vs. ambient total power, mean interval vs. ambient frequency. A line of best fit and r-square value is found on each of these regressions. Each regression contained a line of best fit and a coefficient of determination for use in assessing the quality of correlation. An r-square value closer to one implies greater correlation between the two variables, while an r-square value closer to zero suggests less or no correlation in the variables.

In order to gain further confidence in the results of this study a t-test is necessary to assess the difference between the means of the two samples. The data series being analyzed do not share common variance or even sample number size, so it is necessary to perform a nonparametric test. The Kruskal-Wallis test is special because it normalized the data using ranks, thus allowing for more accurate assessment of variation between means. With regards to the sample size these tests will provide for the most confidence in assessing the hypothesis.

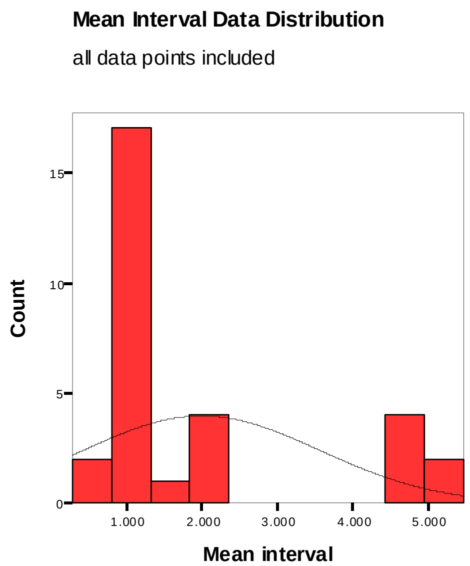
III. Results

The data in this project is being analyzed in four separate series including mean frequency interval, ambient frequency, ambient total power, and ambient peak power. Mean interval is the calculated fundamental frequency for each call; for hypothesis testing it is being used as the dependent variable. Fundamental frequency is a measurement of the differences between each of the frequency levels for calls with harmonic structure. The calls being used are mostly S1 but it is not entirely possible to eliminate the other S4, S7, and S3 calls. Ambient frequency is representative of the most defined peak in the power spectrum, outside the Orca call. Ambient peak power (APP) is a measurement of the power underneath the recorded peak frequency. Ambient total power (ATP) is a quantification of the total power under the entire series of background noise peaks. Running descriptive statistics allows us to see how the data is arranged. In order to compensate for the differences in audio gain and recording conditions; both nonparametric statistical tests and ratios are being used to look at the data with equivalent audio ranges.

	N	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Std. Error
Amb Freq.	31	.240	1.171	.71319	.044481	.247662	-.154	.421	-.894	.821
ATP	24	8103.850	991020.180	429078.75333	68652.794018	336328.629519	.414	.472	-1.416	.918
APP	23	25.490	486.390	124.12348	28.873302	138.471494	1.724	.481	1.700	.935
Mean interval	30	.280	5.470	1.99253	.286018	1.566586	1.309	.427	.177	.833
Valid N (listwise)	22									

Table 2: Descriptive statistics for each series of data

Table two, listed above, gives the preliminary descriptive statistics about the raw data before any outliers or data transformations have been made. These statistics are beneficial for determining if the data will need to undergo any sort of transformation or if significant outlier exist. By looking at the range of data and the standard deviation it is evident that outliers must exist for both the mean interval and APP; therefore they can be manually removed.



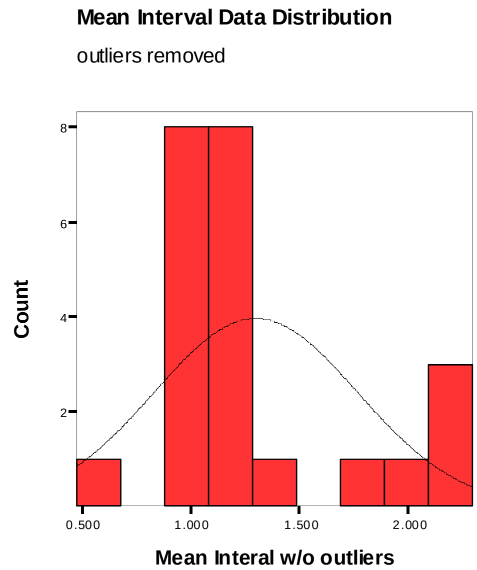


Figure 5: Histograms of the fundamental frequency(mean interval) before and after outlier removal

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Std. Error
Mean interval	30	.280	5.470	1.99253	.286018	1.566586	1.309	.427	.177	.833
Mean Interal w/o outliers	23	.475	2.297	1.29961	.097717	.468634	1.020	.481	.369	.935
Valid N (listwise)	23									

Table 3: Descriptive statistics of fundamental frequency(mean interval) before and after outlier removal

After the removal of the outliers several things occur, most obvious is the change in histogram to have even greater normality. Also the difference becomes apparent in the decrease in range, decrease in SD/SE, and a reduction in skewness.(Table 3.) Other data distributions can be seen below in figures 6, 7, and 8.

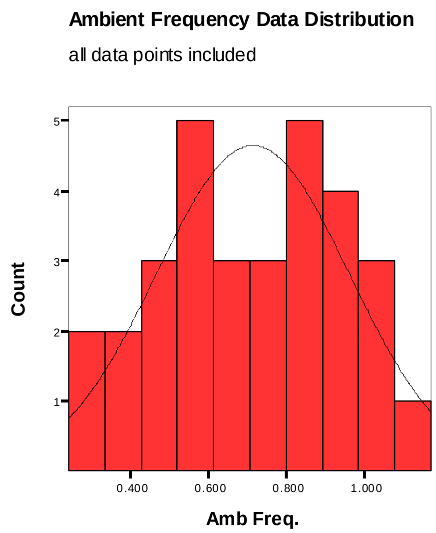


Figure 6: Data distribution histogram of ambient frequency

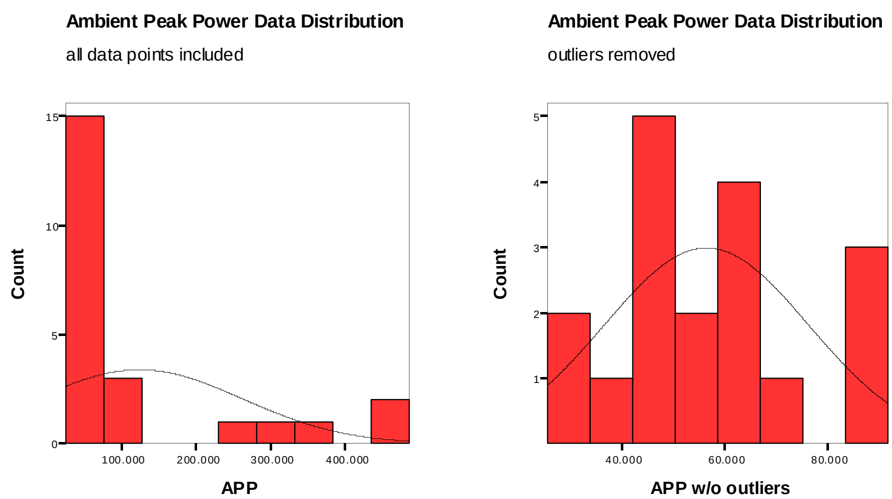


Figure 7: Data distribution histogram of APP before and after outlier removal

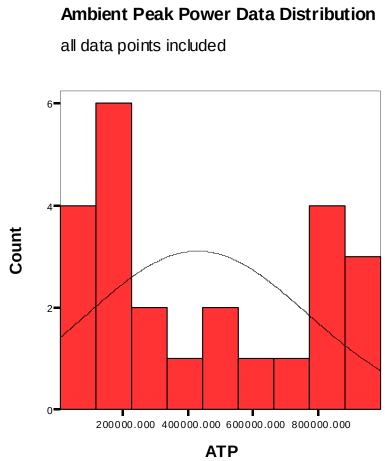


Figure 8: Data distribution histogram of ambient total power

The histograms demonstrate the varying levels of normality in the distribution of the data. For the mean interval histogram 7 outliers were removed 6 high and 1 low. Post removal the data exhibits a much more normal distribution. The APP histrogram necessitated the removal of 5 outliers to increase the normalcy of the data. Each of the other data sets displayed much less skew and did not require any sort of statistical transformation. For correlation analysis the normalized data will be used, to gain confidence in either accepting or rejecting the null hypothesis.

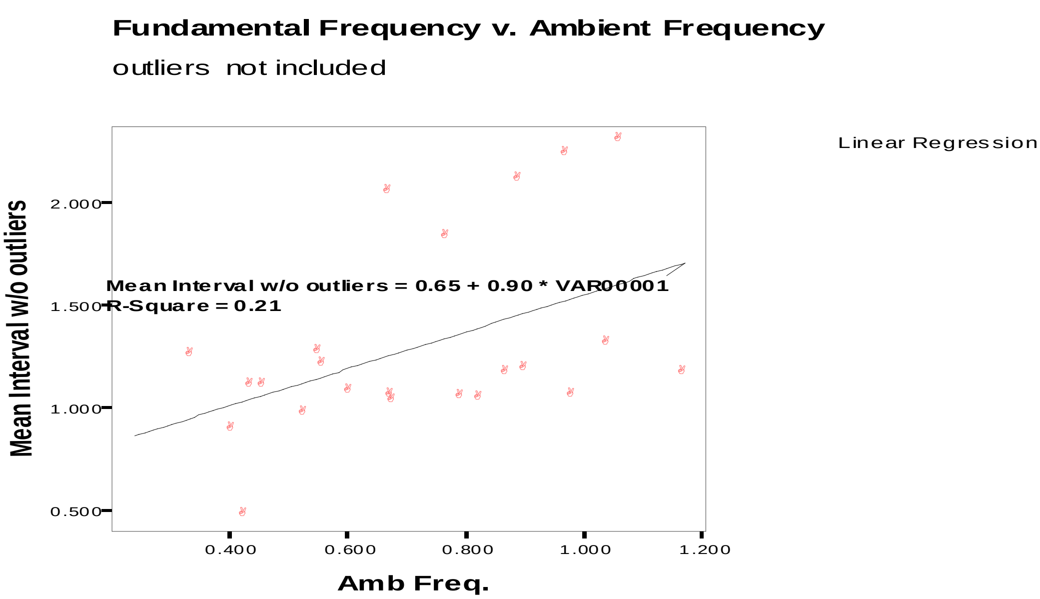


Figure 9. Scatter plot analyzing correlation between Ambient frequency and Fundamental Frequency, r-square of .21

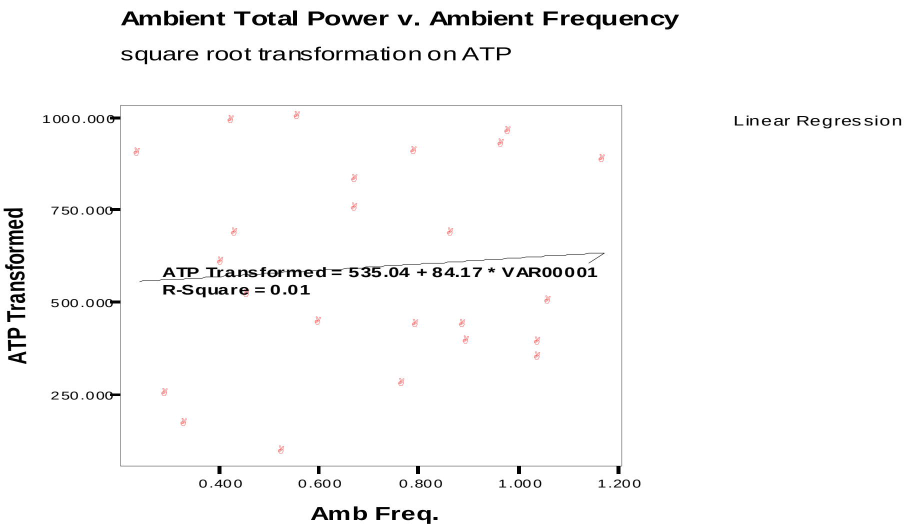


Figure 10. Scatter plot analyzing correlation between Ambient frequency and ATP, r-square of .01

Figure 9 and 10 show the lack of correlation between each set of variables. The graphs and r-square values of these regressions show that little of the variation in the dependent variable is explained by the independent variable. The low r-square levels in Table 4 demonstrate the percentage of variation explained by the independent variable.

Independent Variable	Dependent Variable	R-squared	Percent Explained Variation
Ambient Frequency	MI w/o outliers	.21	21%
Ambient Frequency	APP w/o outliers	.03	3%
Ambient Frequency	ATP transformed	.01	1%
ATP Transformed	MI w/o outliers	.04	4%
APP w/o outliers	MI w/o outliers	.22	22%

Table 4: Regression results for correlation, no correlation

Here it is possible to see that there is no correlation between any of the regressions.(Table 4.) This means that variations in fundamental frequency can not be explained by ambient frequency, ambient total power, or ambient peak power. It is also possible to say that variations in ambient frequencies cannot be explained by ambient peak power or ambient total power. In pursuit of further confidence beyond that of a regression, a t-test will be run on this data.

Test Statistics(a,b)

	APP w/o outliers	Amb Freq.	ATP Transformed
Chi-Square	.889	1.750	.041
df	1	1	1
Asymp. Sig.	.346	.186	.840

a Kruskal Wallis Test
b Grouping Variable: Mean Interval w/o outliers

Table 5: Results of nonparametric kruskal-wallis Test

The above graphs make it apparent that there is little correlation between either of the independent variables and the fundamental frequency.(Table 4.) For maximum confidence in this data it is necessary to take the analysis one step further to include a t-test. Kruskal-wallis tests look primarily for significant difference between data series.(Wheater, 2000) Specifically, this research is going to use a kruskal-wallis test because it allows for compensation for unmatched quantities of tests and unpaired samples. (Wheater, 2000) To accept the alternative hypothesis it required to have a chi-square value over 3.841 with only one degree of freedom for 95% confidence. Therefore after analyzing variances between each of these ambient data series we are able to accept the null hypothesis of no significant change. The fact that none of the chi-square values are close to the listed value gives great power to state that the null hypothesis can be accepted.

One issue with the variability in data sources is the lack of knowledge about ambient conditions or set gain levels. In order to better cope with this unknown several things are being done. One, is that the statistical test disregarded the varying weights of the ambient sound values by ordering the values not, weighing them purely on number.

Another step taken is that a comparison between the fundamental frequency range and the ambient frequency range is being taken to determine the ratio of ambient power and fundamental frequency. The ratio will be able to help in determining how much of the total power level is made up of the fundamental frequency.

ATP	APP	Fund Freq. PP	ATP / FFPP	APP / FFPP
148,760.89	42.30	18.930307	7858.345164	2.23426804
185,016.61	25.49	29.958538	6175.755521	0.85071318
263,876.06	25.95	22.14543	11915.59895	1.17181536
185,796.41	46.16	51.051642	3639.381724	0.90423235

Tale 6: Ratios between ATP: Fundamental Frequency power peak (FFPP), and APP: FFPPb

Table 6 indicates that the fundamental frequency did not make up a significant or consistent portion of the ambient sound total power. Another conclusion is that fundamental frequency was found to have both more and less power than the total power associated with the peak in ambient peak power. This last conclusion is important because it looks at the data within the same recording, thus controlling for gain and conditions. Implications of the myriad data collected and analyzed in this study will be further scrutinized in the following section for the determination of significance.

IV. Discussion

The Orca conservation plan written by the *National Marine Fisheries Services* identifies human generated marine noise as a potential risk to the southern resident Orcas' behavior. After recording and analyzing a select quantity of orca vocalizations and ambient noise levels, it is with confidence that this study can accept the null hypothesis and state that Orca vocalizations do not exhibit a significant difference in the presence of varying levels and types of ambient sound. Specifically, ambient sound is in reference to only power and frequency. Understanding this conclusion allows for future assessment of the actual risks the Orcas are exposed to, and what implications these risks have upon future conservation efforts.

This project aids in assessing Orca behavior in contact with varying levels of ambient noise levels. *Orcinus orcas* not altering fundamental frequencies can be explained in through several different approaches. One take on this behavioral finding suggests that the whales are not at all affected by the ambient noise. Another possible reason for no significant difference is that it is not within the ability of the whales to adjust their fundamental frequency to the changing ambient sounds. This implies that it is not possible for southern resident whales to adapt with their changing ambient acoustic environment. For social reasons it is important for Orcas to be able to maintain adequate communication in their perpetually changing acoustic environment. The true effects of this failure to change fundamental frequency are largely unknown but, it is possible to state with confidence that Orcinus Orca does vary its fundamental frequency depending on changes in ambient noise levels.

Speculation for why frequency might or might not change in the presence of ambient sound is difficult but studies have been done which determine why frequency change naturally occurs. Ambient noise has been associated with a reduction in the range of an underwater signal.(Foote, 2005) One reason why the southern residents haven't altered their fundamental frequency might be because having such tightly knit pods does not necessitate the need for communication changes, even if signal range has decreased. Bottlenose dolphin species are reported to adjust their communication structure based on random drift and community interaction, rather than ecological differences.(Foote, 2005) If translated to the southern residents this would mean that their changing environment would not affect communication as much as influxes of new vocalization patterns from other social groups. Whatever the true biological meaning behind the lack of fundamental frequency change; only further research will reveal and explain this vocal behavior.

Association of causality with the results of this study is limited due to the experimental design and limited findings. If more time were available to study the effects of this failure to adjust fundamental frequency, it would be interesting to make a correlation with the decline in whale population and changing levels of ambient noise. It is interesting ecologically as to why, if effected and unable to adapt, these animals would continue to live in less than ideal habitats and not relocate their niche or adapt their behavior. Is it a necessity to live around the south end of Vancouver Island or is it simply outside the ability of killer whales to adapt as quickly as the perpetually changing ambient sound conditions? No matter what the answer is to these questions, it will facilitate in answering the questions of why the local orca population is declining and how they are being effected by human generated marine sound.

In order to expand and improve this study it is essential to alter both the data collection and the range of data types. Ideally this would help to remove some of the inherent biases associated with any research. Expanding the accepted call types would be useful to help identify if other call types do in fact experience fundamental frequency changes and if varying levels of ambient noise result in preferential selection of calls. More replication would be helpful in securing even greater confidence in support of the null hypothesis. It is even possible that with a large enough data set, the accepted hypothesis might actually change to the alternative. A positive note is that this project can be positively associated with the study done in Hong Kong which, found that two separate species of dolphin were not affected by varying levels of ambient noise. (Wursig and Greene, 2001)

V. Conclusion

The purpose of this study is to determine if Orca fundamental frequencies change significantly because of varying levels of ambient background noise. It is concluded that no, orca vocalizations did not change significantly when in the presence of varying ambient background noise. Through the use of original recordings and archived audio files, it is found that fundamental frequencies of the first syllable of a southern resident's most common calls is not dependent upon ambient noise. Such a distinct lack of correlation apparent in the results suggests that Orcas are either unaffected by varying levels of ambient noise or simply unable to adjust to changes in ambient noise. Data found in this study will be useful in future behavioral studies to help in identifying reasons for this observed whale behavior.

VII. Bibliography

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"Is it a basic necessity for Orcinus orca to live around the south end of Vancouver Island or is it outside their ability to adapt with the perpetually changing ambient sound conditions of their habitat?"