

Quantifying Vocal Response

in experimental playbacks to Risso's dolphins

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Abstract

In a world of constant technological development and expansion into the marine environment, the marine soundscape is constantly changing. With the addition of anthropogenic sources from naval sonar to seismic survey vessels over the past century, the deficiency of knowledge on the impact of such acoustic disturbance leaves little guidance for effective regulation of anthropogenic marine noise pollution. To help address this, the U.S. Department of Defense's Strategic Environmental Research and Development Program (SERDP) has teamed with multiple academic and scientific institutions to research and catalog the baseline behavioral ecology across a range of odontocete species, which can then serve as a baseline for additional research. This report examines a portion of that project, conducted to assess the response of Risso's dolphin, *Grampus griseus*, to natural stimuli.

During an August 2013 playback study off Southern California, acoustic data were collected via digital acoustic recording tags (DTAGs) to identify the vocal response of three Risso's dolphins, *Grampus griseus*. The playbacks consisted of calls from three cetacean species: *Megaptera novaeangliae*, *Orcinus orca*, and *Grampus griseus*. To determine whether the vocal rate measurements could be reliably quantified, a repeatability experiment was conducted.

Two playback studies (*O. orca* and *G. griseus*) were conducted on one animal, while three playbacks (*O. orca*, *G. griseus*, and *M. novaeangliae*) were presented to two animals. Only one of the tagged animals demonstrated a noteworthy response to the *O. orca* exposure, with more than a 500% increase in vocalizations after the playback. Vocal rate did not vary considerably in the tag with *O. orca* and *G. griseus* playbacks and the other tag resulted in roughly zero vocalizations during pre- and post-playbacks. Based on the small sample size, it appears that *G. griseus* response varies in the presence of a predator – with one tag demonstrating a dramatic increase of vocal rate when exposed to *O. orca* calls. These results are a necessary early step in gathering baseline information on the behavioral ecology of cetaceans susceptible to anthropogenic acoustic impact. A continuation of this project and further research is necessary to fully understand how marine mammals perceive and are impacted by human expansion into the marine soundscape.

Introduction

The Marine Soundscape and Its Impact on Cetaceans

In an ocean where commercial shipping, seismic survey vessels, and military sonar training exercises dominate the soundscape, acoustically sensitive species such as cetaceans are forced to adapt to an array of environments with varying anthropogenic impacts. For instance, the Baltic and North Seas are two of the most heavily used regions in the world (Lucke et al., 2009). Cetaceans (i.e. whales, dolphins, and porpoises) heavily utilize sound as a tool for their natural functions and ecology (Bradley & Stern, 2008).

Unlike the terrestrial world, marine species inhabit a world where sensing and receiving sound is more important than sensing and transmitting information by sight (Tyack, 2009; Johnson et al., 2009). Light does not propagate as well in water as it does in air, but sound propagates much better in the marine environment (Wilcock et al., 2014). This is due to the physical and chemical properties of the ocean and marine mammals, specifically cetaceans, which have adapted to make best utilization of sound to send and receive information about the world around them (Tyack, 2009). It is believed that cetaceans are the most sensitive species to anthropogenic sound due to their highly evolved sensitivity to receiving and transmitting of sound and the impact sound plays in their life history and overall development (Bradley & Stern, 2008).

In the world of marine bioacoustics, sound plays an important role for many charismatic species to survive. Basic ecological functions such as communication, predator detection, and foraging ecology, are often dependent on emitting and receiving sound (Moretti et al., 2014). From the echolocation of odontocete (toothed) whales to the iconic courtship songs of the humpback and North Atlantic right whales, sound produced and utilized by cetaceans plays an extremely important role in their lives and their development. This also increases their sensitivity to

anthropogenic sources of sound that may generate negative auditory, physiological, behavioral or stress effects (Pine et al., 2013; Bradley & Stern, 2008). As mentioned previously, anthropogenic noises come from a range of broad sources, such as commercial vessels, deep-sea mineral or energy exploration, and naval sonar (Weilgart, 2007; Merchant et al., 2014). One common impact of anthropogenic noise on marine mammals is masking, which is when the anthropogenic noise prevents the marine mammal from hearing the natural sounds important to the survival of the species (Merchant et al., 2014). Research shows that such loud and varying noises (e.g. naval sonar) can lead to stress, auditory effects, such as loss of ability to detect and response to natural signals in the environment, temporary threshold shift (TTS), which temporarily raises the animal's hearing threshold, or even worse – permanent threshold shift (PTS), which is the permanent increase in the hearing threshold (Bradley & Stern, 2008). Both TTS and PTS are dependent on the level of sound, duration and species (Lucke et al., 2009).

Physiological effects can lead to tissue damage through blast trauma and decompression-like effects (i.e. “the bends”), and behavioral effects are noted through examples such as stranding after panic or trauma, changes in dive behaviors, and short or long term habitat abandonment (Zimmer & Tyack, 2007). Most publicized are the mass stranding events following naval training exercises, which is connected with both U.S. Navy sonar exercises and other international naval sonar exercises (NRDC online, 2013). In two studies that examined the behavioral responses of cetaceans to mid-frequency active (MFA) sonar, both concluded that when Cuvier's beaked and blue whales were introduced to sonar, their foraging ecology was impacted in some way (either through habitat abandonment or cessation foraging all together) or their behavior was variable (Goldbogen et al., 2013; DeRuiter et al., 2013). Although these two studies demonstrate the variation of behavioral responses between the two species, the results are clear that when subjected to less intense sonar testing events, at least some cetaceans are impacted in some way.

Along with sending acoustic signals to track down a meal (odontocetes only) or find a mate (both odontocetes and mysticetes), hearing or the ability to detect sounds and identify between different frequencies is highly important to the survival of cetaceans (Tyack, 2009). This is especially true in smaller odontocetes, such as beaked whales, pilot whales, and dolphins, which are therefore believed to be subject to harsher impacts of naval sonar (Tyack, 2009; DeRuiter et al., 2013).

Echolocation, or the ability to locate objects via sound, is only found in odontocete whales (Voigt-Heuke et al., 2010). Similar to how a dolphin or beaked whale uses echolocation in the water column, naval sonar sends out a “ping” through a sending array. Once the “ping” bounces off the targeting object (i.e. submarine), the sound reverberates back as an echo to the acoustic receiver, which is located separate from where the original sonar sound was produced (Alexander, 2009).

Developing a Baseline Understanding of Cetacean Behavior – The SERDP Project

Little is known about the baseline behavior of cetaceans, specifically odontocetes, in regards to how they respond to anthropogenic noise in the marine environment. To date, regulations aimed at the mitigation of negative impacts of anthropogenic noise are inadequate given this knowledge deficiency. Without understanding how cetaceans respond to natural threats in the environment, regulatory agencies (i.e. NOAA) and sound producing institutions (i.e. U.S. Navy, seismic surveyors, etc.) cannot appropriately assess and make decisions that effectively mitigate the negative impacts of anthropogenic noise in the ocean (Andrew Read, pers comm; Johnson et al., 2009). That being said, there is a huge disconnect between what is known about the natural behaviors of cetaceans and how anthropogenic noise is regulated and monitored.

Funded by the U.S. Department of Defense (DoD) with joint partnership with the Department of Energy (DoE) and the Environmental Protection Agency (EPA), the Strategic

Environmental Research and Development Program (SERDP) is a large institution put in place to gather the most up-to-date technology and science. With this knowledge, the SERDP aims to improve the environmental role of the DoD, as well as to assist the DoD in reducing costs and enhance the effectiveness of each mission (SERDP, 2014). In the context of this Master's Project, the SERDP has supported a portion of the resources required in order to obtain a better understanding of baseline behavioral ecology of small to mid-sized odontocetes. The knowledge to be gained from this experiment, in particular as regards natural predator-response behaviors, can be used to better manage, monitor, and strategically plan for the introduction of anthropogenic noise (e.g., from Naval sonar training exercises) into the marine environment, enhancing the safety of odontocete species. Preliminary knowledge of odontocete behavior is important for the DoD due to the frequency of incidental harassment takes under the Marine Mammal Protection Act (MMPA, 1972) during military training exercises. By identifying and quantifying such natural behaviors, in particular to predator response, this project can provide a basis for assessing behavioral responses to threatening natural and anthropogenic stimuli.

A broader goal of this project is to examine multiple odontocete species of varying social structure (i.e. fission-fusion, tight-knit, or solitary) in order to identify how natural response of small to medium sized odontocetes may react to predators and how that may be attributed to the particular species' social structure. By examining multiple odontocete species with varying sociality, this may reveal varying predator-response behavior that is dependent on their given social structure. This is an important factor in assessing and managing anthropogenic noise impacts since it is well researched that there may be a link between predator-response and response to anthropogenic noise, specifically naval sonar. This is due to overlapping frequencies in both *O. orca* S-call vocalization and certain types of sonar that the U.S. Navy uses in their training exercises (Goldbogen et al., 2013). This principle, the Predator Evasion Hypothesis, postulates that due to the similarities between *O. orca* vocalizations and mid-frequency sonar (MFA), an animal may react to a

predator in the same way it would react to some anthropogenic noise. Obtaining this baseline information can therefore benefit not only the U.S. Department of Defense, but also policy makers, environmental managers, and other sound-producing organizations, and could be used in the future to enhance the strategic planning of naval sonar schedules. In regards to the DoD, this would assist this agency with assuring environmental compliance with the laws enacted and minimizing the negative impact of producing anthropogenic noise in the marine environment (Andrew Read, personal communication, April 2014).

Introduction of this Master's Project – Focusing on Risso's Dolphins

The main objective of this Master's Project is to answer the fundamental question: Do Risso's dolphins, *Grampus griseus*, acoustically respond to predator stimuli (i.e. *Orcinus orca* playbacks)? This builds off the goals of the SERDP by adding a critical component to the results. Identifying and quantifying the vocal rate of Risso's dolphins starts to fill in the knowledge gap of how cetaceans respond to natural acoustic stimuli and whether social structure may be a factor in how odontocete species react to predator stimuli. As described previously, many researchers have acknowledged the Predator Evasion Hypothesis as a driving force in better understanding how cetaceans may respond to anthropogenic noise due to their predator response (Goldbogen et al., 2013). This may be expressed through the "fight or flight" response, where a species may run off and/or decrease vocalizations as the first response to a threat or increase vocalizations as an alarm or broadcasting behavior (Rankin et al., 2013). In response to the fundamental question, this Master's Project hypothesizes that given the predator stimuli via controlled exposure experiments (CEE), or playback experiments, Risso's dolphins will respond to the *O. orca* vocalizations: either through the increase or decrease of social vocalizations (i.e. whistles, social buzzes, and burst pulse calls). For simplicity, social calls were broken down into whistles and non-whistles, where non-whistles consisted of burst-pulses and social buzzes (Corkeron & Van Parijs, 2001). Observing the

predator response of Risso's dolphins will add insight to both the scientific and marine sound-producing community as a preliminary understand of the "anti-predator" response of Risso's dolphins, and possibly species of similar social structure.

Few studies demonstrate the definitive social structure in Risso's dolphin populations. Hartman et al. (2008) noted the secure and long-lasting bonds between individuals of similar age and sex classifications among Risso's dolphins throughout the Azores. They also noted that these bonds may be dependent on the presence of a nursing calf and bonds appeared stronger in adult Risso's dolphins as oppose to subadults. At the end of this study, they suggested that the social structure of Risso's dolphins is unique to other odontocete species and researchers should identify these social groupings as a stratified social organization, as oppose to a matrilineal society or fission-fusion community (Hartman et al., 2008).

Through the extensive research of odontocete social structure, it is generalized that there is a negative dependency between group stability and body size. Smaller odontocetes, like bottlenose dolphins, partake in fission-fusion societies, where individuals weave in and out of subgroups that change in both size and demographics. Research on larger odontocetes, like pilot whales, sperm whales, and killer whales, show the formation of matrilineal societies where the survival of the individual is strongly tied to the connection to the kin-oriented group (Hartman et al. 2013). As mentioned previously, the boarder objective of the SERDP is to catalog such basic behaviors towards natural stimuli across different social structures.

The analysis of changes in vocal rate through pre- and post-playback studies is the first step in understanding baseline behavior ecology in odontocete cetaceans. By using vocal rate as a method for measuring such behavioral change across species – both those involved and not involved in the controlled exposure experiments - this will shed light on the unknown baseline ecology of Risso's dolphin.

Materials and Methods

In order to collect acoustic data from Risso's dolphins, DTAGs (Johnson & Tyack, 2003) were used in the field portion of this project. A DTAG, or digital acoustic recording tag, is an important, non-invasive tool ideally designed for studies on wild marine mammal acoustics and movements (Johnson & Tyack, 2003). The DTAG is attached to the wild animal via a 7m carbon fiber pole to the back of the mammal, where the tag is placed near the dorsal fin by four silicon suction cups. The DTAG is excellent for short-term experiments, as it can stay attached to the wild animal up to 24 hours and can record highly detailed information about the acoustic environment, vocalizations from focal and surrounding animals, and movement behavior of the focal animal (Johnson & Tyack, 2003). The data are collected through an embedded hydrophone that records uninterrupted acoustic data, and sensors measure the orientation of the focal animal (i.e. acceleration, heading, depth, roll, and pitch) (Johnson & Tyack, 2003).

For obvious reasons, the DTAG is a go-to tool for marine mammal researchers and scientists. Since many deep diving odontocetes (e.g., sperm whale, beaked whales) are only observable for roughly five percent of the time (only when near the water's surface) there is a large proportion of information that is lost beneath the surface of the water and visual observation can only fill in a small portion of information about such marine mammals (Johnson & Tyack, 2003). The importance of the DTAG in filling in knowledge pertaining to the time spent under the water is vast and can provide the answers to some questions related to, but not limited to, marine mammal acoustics, movement, dive behavior, foraging ecology, and life history – just to name a few (DeRuiter et al., 2013; Goldbogen et al., 2013; Johnson et al., 2009). In an ocean that, in many areas, is growing increasingly loud, DTAGs provide such necessary information of how wild cetaceans respond to sound (either natural or anthropogenic) and open the gateway to better understand

how these animals are impacted by such acoustic stimuli through either changed in acoustic and/or movement behavior (Johnson & Tyack, 2003).

In August 2013, 8 Risso's dolphins were fitted with DTAGS. Their movements and acoustic behavior was recorded for up to roughly 4 hours at a time. Of the 8 individuals, 3 were non-invasively subjected to 2-3 playbacks. One individual of the 8 tagged was part of a group that contained a neonate, which made this tagged animal the control group for this study and no playbacks were conducted with this animal, according to the experimental protocol.

Data collection

Data collection took place along the Southern California coast, south of the Channel Islands National Park, during 11 August 2013 and 24 August 2013 (**Figure 1**). Digital acoustic recording tags (DTAGs) were attached to 8 individual Risso's dolphins, *Grampus griseus*, for a span of roughly 20 minutes to 4 hours 30 minutes at a time. For this study, the DTAG recorded vocalizations during the time it was first deployed on to each individual to the time it was removed. The DTAG recorded vocalizations of the tagged, or focal, individual along with vocalizations from nearby individuals. Three of the 8 tagged dolphins underwent a controlled exposure experiment (CEE) and were subjected to playback recordings of 3 acoustic stimuli: *Megaptera novaeangliae*, *Orcinus orca*, and *Grampus griseus*. *O. Orca* and *G. griseus* recordings were presented to focal animal gg13_228b before the DTAG popped off gg13_228b 2 hours prior to the first playback. CEEs were completed for both gg13_228b and gg13_231c with recordings of *M. novaeangliae*, *O. orca*, and *G. griseus*. Out of the 8 individuals tagged, gg13_230a consisted of a group that contained a mother-calf pair.



Source: Google Maps. 2014.

Figure 1. Study area for Duke SERDP predator response behavioral response study (BRS) in SOCAL.

Data analysis

From the field to the lab

Acoustic data were kept in flash memory on the DTAG and downloaded to a computer through an infrared port. Audio files were saved as .WAV files that could be processed post hoc through audio analyzing software. For this experiment, wave files were broken up into smaller, more manageable files using the simple audio software, Audacity. Once the data were transformed into shorter clips, it was uploaded in XBAT, which is an extensible sound analysis program and MATLAB platform for analysis. XBAT was created at the Cornell Lab of Ornithology to support research for the Cornell Bioacoustics Research Program (BRP) (XBAT, 2014). This program imports the audio data into a spectrogram, producing a visual representation of sound that graphs frequency by time, so data can be logged, detected, and examined with various research goals in mind. All files for analysis in this study were assessed in XBAT.

Repeatability Test

The purpose of the repeatability test was to identify whether or not the observer could provide consistent results when observing and analyzing the recordings of *G. griseus* behavioral change (i.e. vocalization response). For the repeatability test, 10 clips, each 30-seconds in length, were chosen randomly from the gg13_228b tag and analyzed for vocal rate. The number of social vocalizations (i.e. whistles and burst-pulse) per each 30-second clip described vocal rate. Each trial of this test consisted of quantifying the vocal rate for each of the same ten clips once per trial. Clips were chosen randomly but represented pre- and post-playbacks, as well as varying vocal rates (low, medium, and high) where low vocal rate ranged from roughly 0-5 vocalizations per 30-second clip, medium 6-15 vocalizations per 30-second clip, high above 16 vocalizations per 30-second clip. For each trial, social whistles and non-whistle (i.e. burst-pulse and social buzz) vocalizations were logged and quantified in XBAT. The presence and absence of echolocation clicks and buzzes was also noted. Six trials were run, however, this study solely considered the last three trials.

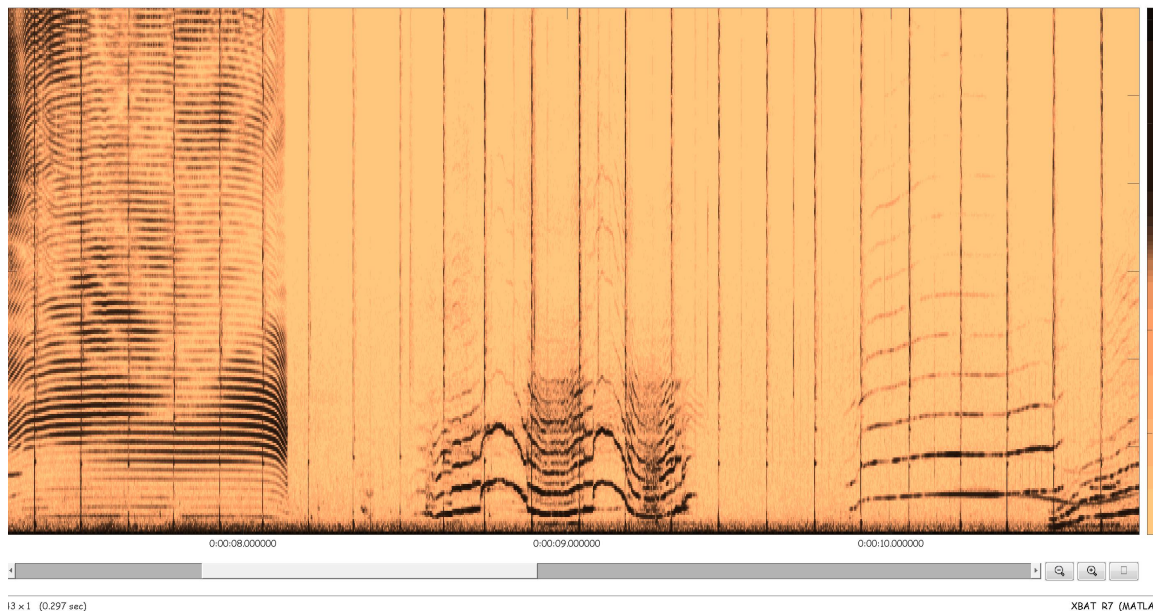


Figure 2. Spectrogram with four distinct social whistles identified in Clip 7 of the repeatability test.

Comparison of the vocal rate of Controlled Exposure Experiments

Vocalization rates from pre- and post-playback studies were observed and quantified within each of the three playback experiment tags. Acoustic analysis was conducted in XBAT, where each tag was analyzed at least two times. If variability between the first and second trial was high, a third trial was conducted. Based on these two or three trials, the trials were averaged to obtain a vocal rate for each of the 30-second bins (see Appendix). The five minutes leading up to each playback and the five minutes directly after each playback was examined. The five minutes pre- and post-playback (10 minutes in total) were divided into 30-second bins for simplicity, where 10 30-second clips for pre-playback data and 10 30-second clips for post-playback data were assessed. Tag gg13_227b was exposed to *O. Orca* and *G. griseus* recordings, while gg13_228b and gg13_231c were exposed to playbacks of *M. novaeangliae*, *O. orca*, and *G. griseus*.

Due to excessive flow noise on tag gg13_228b, further acoustic analysis was conducted. This analysis consisted of employing a whitening filter (order = 1, r = 1) to filter out the low frequency flow noise. The data from this tag was also examined under multiple FFT size conditions (FFT size = 512, 1024, 1048).

Results

Repeatability Test

In order to confirm whether or not the observer could produce consistent results when analyzing the same audio files, a repeatability test was conducted. As the level of variation between each of the three trials for each clip increases, the value of vocal rate decreases (i.e. the closer the variance is to zero, the better the metric is). In this case, the more vocalizations, or larger vocal rate for each clip, the higher the variance as well as variance a percent of average, and standard deviation increased. The exception to this observed pattern is Clip #7, which has a standard

deviation almost equivalent to its vocal rate average (average: 2.7, standard deviation: 2.3), and Clip #3, which contained a large vocal rate (71.3) and relatively small standard deviation in comparison (3.2) (**Table 1**). Three out of the ten 30-second clips did not vary from trial to trial, however one of the three clips consisted of zero vocalization. Five of the ten clips exhibited modest variances (lower than 25% variance of average), while four clips consisted of vocal rates that differed relatively drastically from trial to trial. Clip #7, #9, and #10 differed the most between trials.

Table 1. Repeatability Test with average vocal rate, variance, variance as a percent of average, and standard deviation for each of the ten 30-second clips examined.

Clip Number	Average	Variance	Var as % of Average	Standard Deviation
1	2.0	0.0	0.0%	0.0
2	33.7	22.3	66.3%	4.7
3	71.3	10.3	14.5%	3.2
4	3.7	0.3	9.1%	0.6
5	5.0	0.0	0.0%	0.0
6	0.0	0.0	0.0%	0.0
7	2.7	5.3	200.0%	2.3
8	79.0	28.0	35.4%	5.3
9	44.3	49.3	111.3%	7.0
10	61.7	70.3	114.1%	8.4

Clips #1, #4, #5, and #6 were the most consistent across all three trials with a standard deviation below 1.0 and variation below 0.3. Clips with vocal rates larger than 5 vocalizations per 30-second clip were the most stable through the repeatability test.

Table 2 and **Figure 3** below present the absolute figures for the number of vocalizations for each thirty-second clip. Of the four clips which presented a variance percent well above the 25% threshold (#2, #7, #9 and #10) one can see from the table and chart that in three of the four instances (clips 2, 7 and 10), the variance is driven primarily by one “outlier” trial, where the counts for two trials are quite close, or the same, and a third trial introduces the variance.

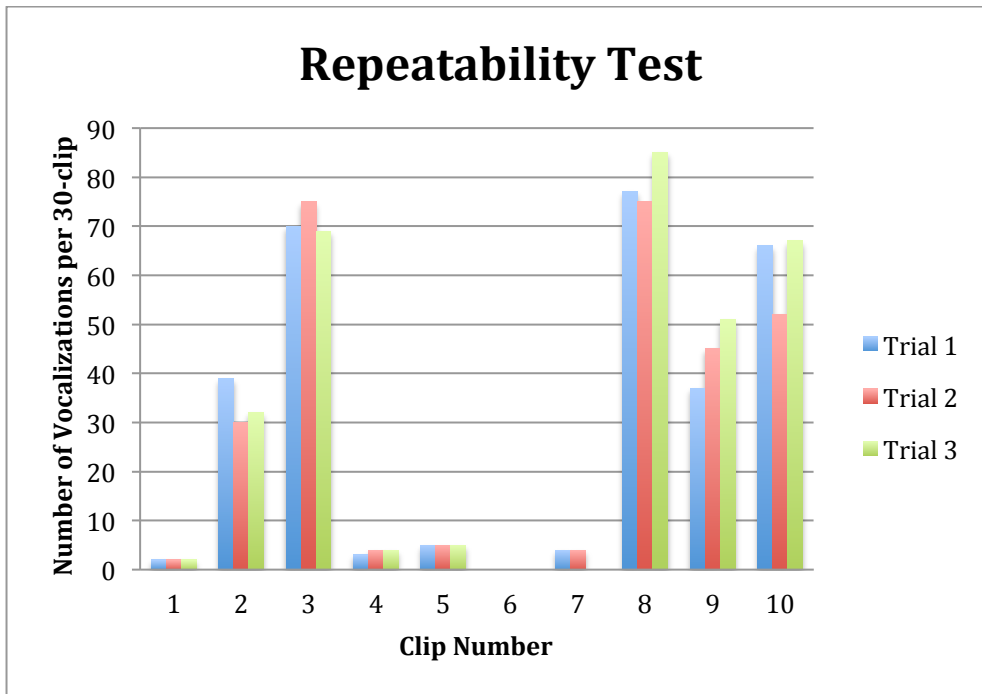


Figure 3. Vocal Rate for each of the three trials per ten 30-second clips.

Table 2. Vocal rate quantified for each of the ten 30-second clips for each of the three trials conducted.

Clip Number	Trial 1	Trial 2	Trial 3
1	2	2	2
2	39	30	32
3	70	75	69
4	3	4	4
5	5	5	5
6	0	0	0
7	4	4	0
8	77	75	85
9	37	45	51
10	66	52	67

Vocal rate pre- and post-acoustic playbacks

Table 3. Average vocal rate and variance data summarized by playback and tag across all trials conducted.

Tag	Playback	Average Vocal Rate (Pre-playback)	Average Vocal Rate (Post-playback)	Standard Deviation (Pre-playback)	Standard Deviation (Post-playback)
227b	Grampus	1.80	1.37	1.68	2.85
	Orca	2.21	1.74	3.27	1.93
228b	Grampus	0.00	0.00	0.00	0.00
	Orca	0.00	0.40	0.00	1.26
	Mega	0.00	0.00	0.00	0.00
231c	Grampus	0.37	2.30	0.71	2.26
	Orca	1.65	12.23	1.81	8.97
	Mega	7.47	12.07	3.43	7.25

Observational data notes that focal animal gg13_227b was in an environment with multiple groups. Post *O. orca* playback, gg13_227b and other individuals in the same group increased swimming speed and surface behavior such as charging and porpoising into a more cohesive group (SERDP log, 2013). Shortly after this playback and surface active behaviors, the DTAG on gg13_227b popped off and the focal animal continued to swim away from the research vessels along with the group it was in (A. Read, pers comm). Despite observed reaction, there was little change in the average vocal rate 5-minutes before and 5-minutes after both the *Grampus griseus* and *Orcinus orca* playbacks (**Table 3**). That being said, most vocal rates for the *G. griseus* playback remained between 0.0 and 2.3 vocalizations per 30-second bin during the 5-minutes leading up to and after the playback. The exception to this is 30-seconds after the *G. griseus* playback, where vocal rate increased to 9.3. Despite the behavioral response made through movement and group cohesion observed visually, vocal rate is fairly consistent throughout the 5-minutes before and after the *O. orca* playback, with the highest vocal rate (3 minutes before playback stimuli presented) was 11.0 (**Figure 6**).

Focal animal gg13_228b was observed around lots of other *G. griseus* that were spread apart from each other in smaller subgroups. Following the *O. orca* playback, two subgroups joined together and moved away as one (SERDP log, 2013). The acoustic results show no vocal rate for all three of the playbacks presented to the focal animal gg13_228b or nearby individuals (**Figure 6**). There was an increase in vocal rate from zero to four subsequently after the *O. orca* playback, but this vocal rate varied throughout the three trials conducted during the analysis. Interference may be an issue for this tag, as flow noise from the hydrophone may have masked subtle and quiet vocalizations throughout the 5-minutes before and after for each of the three playbacks. Additional steps were added to the methods to confirm whether or not the first two trials examined were an accurate representation of the data. The outcome of these extra steps produced the same results as the previous trials. The data remains that the vocal rate for the *G. griseus* and *M. novaeangliae* is zero pre- and post-playbacks. An average vocal rate after the *O. orca* playback was 0.4.

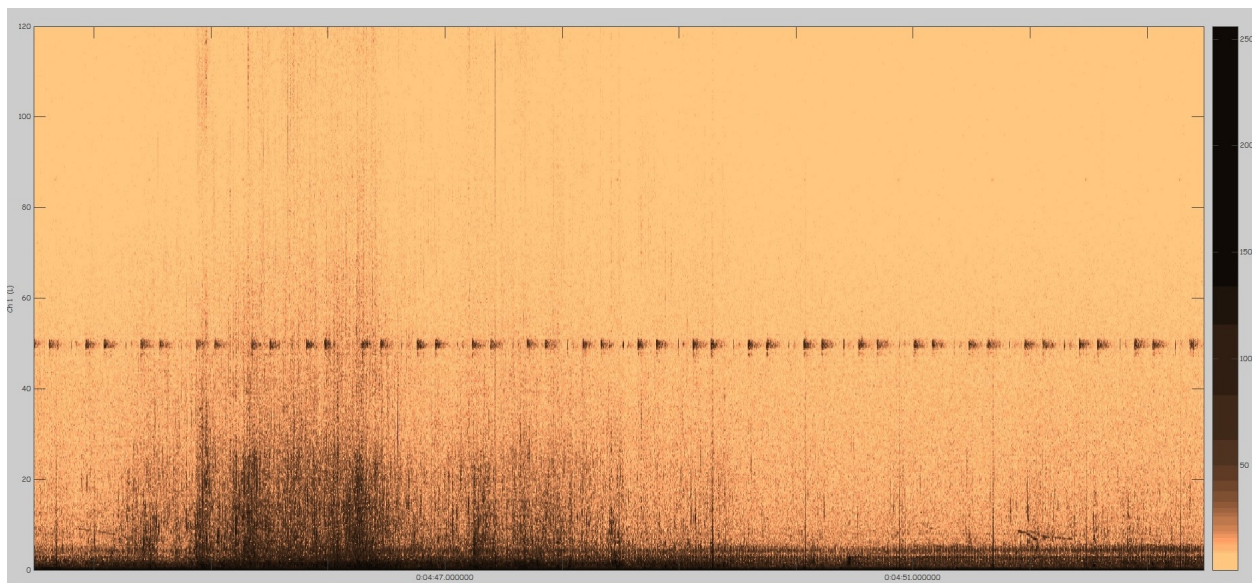


Figure 4. 30-second bin leading up to *O. orca* playback with low vocal rate for gg13_231c.

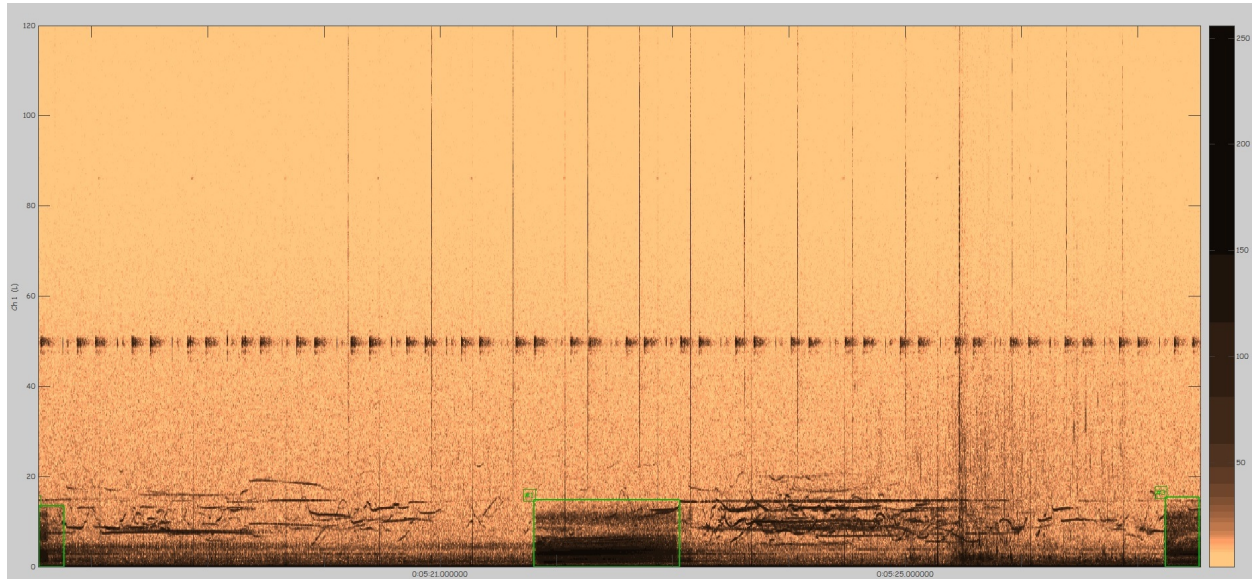


Figure 5. Spectrogram after start of *O. orca* playback for focal animal gg13_231c. Playbacks are in green boxes, while chorus of social whistles is between each playback.

Visual observation from ship noted that researchers witnessed focal animal gg13_231c and a large group of both *Delphinus* and *Grampus*. After the *O. orca* playback, animals relocated and increased swimming speed, heading south of the sound source and researchers. The animals slowed speed momentarily roughly 20 minutes after the *O. orca* playback. No notable behavior was observed from ship for the *M. novaeangliae* or the *G. griseus* playbacks (SERDP log, 2013). Change in vocal rate from previous or prior *G. griseus* playback was not major (**Figure 6**). However, there was a subtle increase in the vocal rate from 30-seconds before and 30-seconds after the *M. novaeangliae* playback, where average vocal rate increased from 14.3 to 24.0. The most impressive change in vocal rate was demonstrated post-playback, after the *O. orca* recording was presented. During the 30-seconds leading up to the *O. orca* playback and 30-seconds after the exposure, the vocal rate increased from 2.7 to 30.7, with vocalizations from possibly the focal animal and nearby individual Risso's dolphins that overlap each other, as well as others underneath the *O. orca* recording (**Figure 4; Figure 5**).

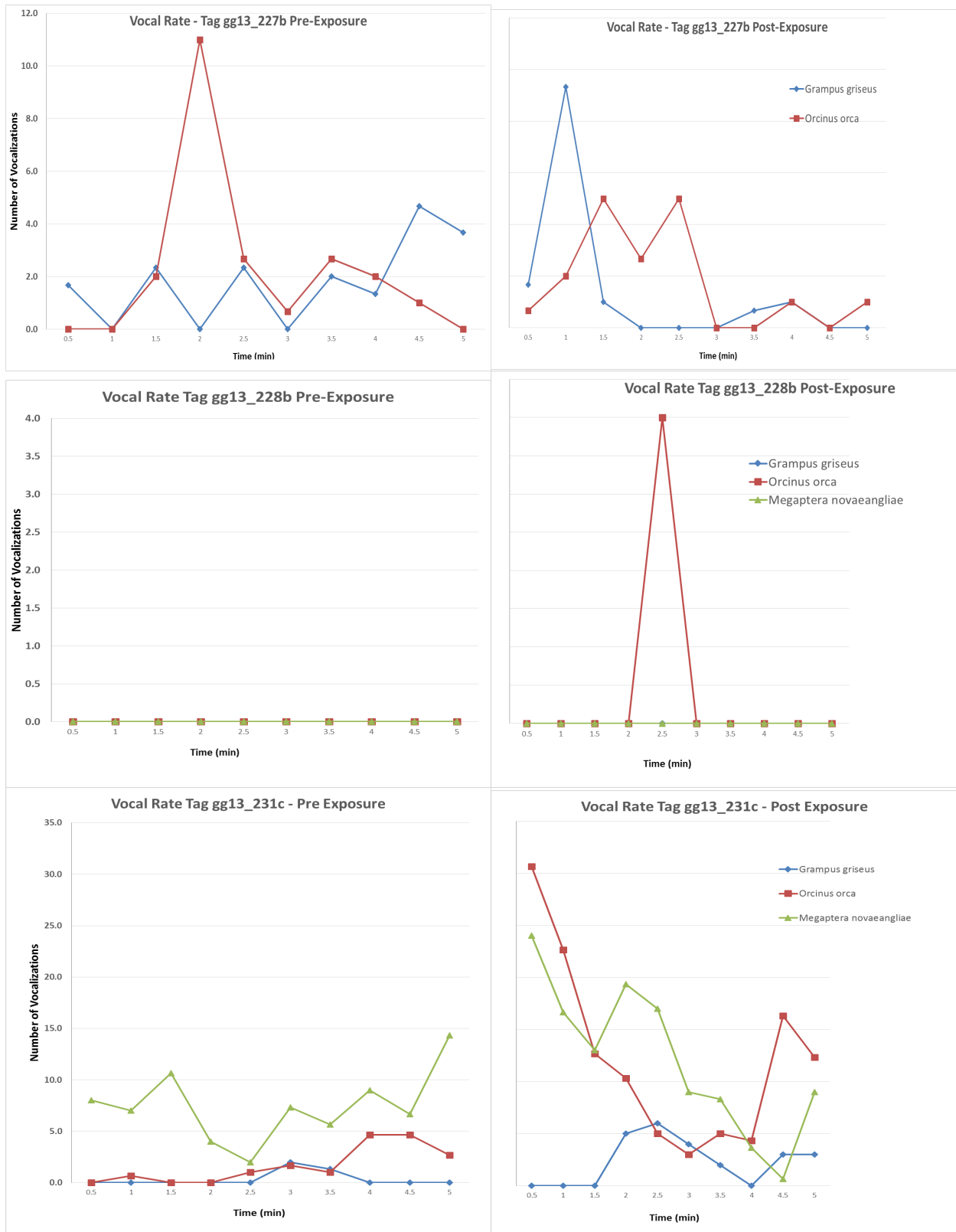


Figure 6. Vocal rate before and after each playback for tags gg13_227b, gg13_228b, and gg13_231c.

Discussion

The central question this project aimed to answer is: *Do Risso's dolphins respond to predator playbacks, as measured by increased or decreased vocal rate?* The hypothesis behind this question is that there would be a response to *O. orca* playbacks. The results presented in this paper provide mixed support for this hypothesis. The impressive increase in response to the *O. orca* playback recorded on the tag of focal animal gg13_231c demonstrates that vocal rate did change post-playback. In turn, the data from tags gg13_227b and gg13_228b do not appear to support this hypothesis. Further, the results from tag gg13_227b appear to disprove this hypothesis. In considering the results, more examination of tag gg13_228b should be considered, as further analysis of the sound and visual quality of the spectrogram may provide more insight into the vocal rate throughout the tag.

These findings are important as they provide an initial look at how Risso's dolphins respond to natural stimuli. Based on the incredible increase of vocal rate of gg13_231c, this data demonstrates how these animals may react to predators, possibly by employing an audible alarm call system. Alarm or distress calls that broadcast the presence of predators are most commonly observed in terrestrial animals, but this may be a preliminary look into alarm calls in the world of cetaceans (Rankin et al., 2013). Understanding these reactions and cataloguing the basic behavior of how cetaceans respond to natural stimuli in the wild is important not only for our understanding of their biology, but also to guide efforts to develop proper regulation and mitigation plans to address anthropogenic acoustic impacts in the marine soundscape. Given the preliminary nature of the results from this paper, they cannot yet be considered directly in policy decisions, but they do introduce early insight into marine mammal response. Zimmer and Tyack introduced the link between predator evasion response and sonar response in marine mammals (Zimmer & Tyack, 2007). If cetaceans do respond to sonar (i.e. Mid-Frequency Active sonar), the analysis discussed in

this paper can provide a foundation on which to base efforts to protect against the risks of sonar (Zimmer & Tyack, 2007; Goldbogen et al., 2013). Risso's dolphins possess a unique social structure that resembles that of other tight-knit groups (Hartman et al., 2008). Further examination of the baseline behavioral ecology of similar cetacean and odontocete species will provide necessary information that can be used in future conservation and preservation purposes.

In the repeatability test, the data examined proved to be highly variable and hard to consistently quantify vocal rate. This can be a consequence of not only acoustician error, which is always a factor despite a range of experience, but also the broad array of social whistles and buzzes that make standardizing such calls difficult to evaluate consistently. Odontocetes are known for the range of types of their social calls. Risso's dolphins are most definitely not an exception to this, with many different patterns, upsweeps, and buzz formations in their acoustic repertoire. For these reasons, vocal rate was deemed appropriate for this project and used as a metric in quantifying behavioral change before and after the playbacks. Further research should examine the many types and patterns observed in Risso's dolphin vocalizations, as this might be another gateway into gaining more knowledge about this elusive species.

Collecting and analyzing acoustic data can provide extremely powerful information that is not only intrinsically valuable by leading towards a better understanding of cetacean function but by enhancing our understanding of the human-influences on cetacean ecology as well. With any kinds of research, there are pros and cons to the methods and analysis of the project. The obvious "pro" to analyzing acoustic data is that it opens up a world that was once a mystery. In the context of this project, this is an introduction to the world of baseline behavioral ecology that can be catalogued and added to through further research and investigation. That being said, analyzing large audio files (many hours in length) can be daunting to even the best acoustic analysis programs, like XBAT. Also, as observed in **Figure 5**, overlapping calls and choruses of sound can make it difficult for the acoustician to consistently log appropriate vocalizations. Variation, as

previously mentioned, was an apparent issue in this study and more work should be done to either better understand the source of this inconsistency or assess how this impacts the overall analysis of the data. The margin of error can most likely be attributed to the variation in the data itself, as well as the error rate of the observer.

Due to the small sample size of the research animals (n=3) and small sample size of the total playbacks (n=8), it would be ideal with more support and funding to conduct more field research and tag more animals to produce additional playback studies. In planning any future extension of this project, time should be devoted early on to the acoustician's training in cetacean acoustics and additional time allotted for data analysis.

In considering this project as a whole, there is an apparent variability of the results. By focusing on one tag or another, there is evidence both for and against the validity of the underlying hypothesis that there would be an identifiable response to *O. orca* playbacks. Similar to a previous study with pilot whales in Cape Hatteras, NC, the results for tagged focal animal gg13_231c indicate a strong reaction to *O. orca* playbacks (Read, 2013). External factors outside the realm of the research project, like the life history and previous experiences of focal and individual animals in the group may be something to consider when reviewing these results. Rankin et al. (2013) noted that multiple elements and factors impact vocal behavior, thus it can be assumed that these external influences (natural and anthropogenic) increase the variability of a data set (Rankin et al., 2013). Clearly more studies are warranted.

Conclusion

In spite of the challenges inherent in marine bioacoustics research, the promise and potential is clear. The knowledge gained through such research will help expand the understanding

of the marine environment around us, the creatures that live within it, and the manner in which we must behave to be responsible stewards of the seas. The Risso's dolphin project provides an important insight into the potential application of baseline behavioral ecology. Comprehending the basic vocal responses of different cetacean species across different social structures can help scientific researchers, policy makers, and anthropogenic sound producers alike make the best decisions in regards to mitigating harmful anthropogenic impacts and regulating sound production in the ocean.

The data collected and analyzed for this project provide a preliminary glimpse at the natural vocal behaviors of odontocetes in response to the presence of predators. Further application of this research can be used to acquire a baseline across multiple cetacean species and/or cetacean social structures. The baseline vocal ecology and "anti-predator" responses observed through future studies across multiple species and social structures will help catalog the behavioral norms. From this, the "anti-predator" response can be taken into account in diverse ways, such as when planning strategically for military training exercises that use sonar and for anticipating which species will be most vulnerable to military sonar.

It is strongly believed that due to the similarity of overlapping frequencies shared between marine mammal-eating killer whales (*Orcinus orca*) and mid-frequency active (MFA) sonar, acquiring such information on predator response in different cetaceans can provide important clues as to how these species will react to sonar (Zimmer & Tyack, 2007). This, in conjunction with a catalog of baseline vocal behaviors, could be used to better inform policy makers and federal agencies in their efforts to anticipate the impact of marine use and regulation policies.

Regulating and mitigating the impacts of anthropogenic noise in the marine environment is incredibly difficult. Little is known about the impact and response that anthropogenic noise may induce in cetaceans, especially across different species, social structures, and age classes (Weilgart,

2007). In the absence of clear data on the extent of this impact, regulations put in place to control or reduce anthropogenic noise in the ocean and coastal waters may be ineffective and may use inappropriate noise thresholds (Alexander, 2009). This Master's Project provides an introduction to the methods and research necessary for obtaining powerful data that can be used to inform and improve future policy decisions. To realize this potential, future studies should focus on the species that are taken most often each year through military actions, such as naval sonar training exercises. By doing so, regulations designed to control harmful impacts of anthropogenic sound can be developed specifically for and across species, region, and anthropogenic sound source.

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For my parents.

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Appendix

I. Vocal Rate Details for Tag gg13_227b

Tag	Playback	Bin Number	<i>Grampus griseus</i>	<i>Orcinus orca</i>
gg13_227b	Pre	0.5	1.7	0.0
		1	0.0	0.0
		1.5	2.3	2.0
		2	0.0	11.0
		2.5	2.3	2.7
		3	0.0	0.7
		3.5	2.0	2.7
		4	1.3	2.0
		4.5	4.7	1.0
		5	3.7	0.0
	Post	0.5	1.7	0.7
		1	9.3	2.0
		1.5	1.0	5.0
		2	0.0	2.7
		2.5	0.0	5.0
		3	0.0	0.0
		3.5	0.7	0.0
		4	1.0	1.0
		4.5	0.0	0.0
		5	0.0	1.0

II. Vocal Rate Details for Tag gg13_228b

Tag	Playback	Bin Number	<i>Grampus griseus</i>	<i>Orcinus orca</i>	<i>Megaptera novaeangliae</i>
gg13_228b	Pre	0.5	0.0	0.0	0.0
		1	0.0	0.0	0.0
		1.5	0.0	0.0	0.0
		2	0.0	0.0	0.0
		2.5	0.0	0.0	0.0
		3	0.0	0.0	0.0
		3.5	0.0	0.0	0.0
		4	0.0	0.0	0.0
		4.5	0.0	0.0	0.0
		5	0.0	0.0	0.0
	Post	0.5	0.0	0.0	0.0
		1	0.0	0.0	0.0
		1.5	0.0	0.0	0.0
		2	0.0	0.0	0.0
		2.5	0.0	4.0	0.0
		3	0.0	0.0	0.0
		3.5	0.0	0.0	0.0
		4	0.0	0.0	0.0
		4.5	0.0	0.0	0.0
		5	0.0	0.0	0.0

III. Vocal Rate Details for Tag gg13_231c

Tag	Playback	Bin Number	Grampus griseus	Orcinus orca	Megaptera novaeangliae
gg13_231c	Pre	0.5	0.0	0.0	8.0
		1	0.0	0.7	7.0
		1.5	0.0	0.0	10.7
		2	0.0	0.0	4.0
		2.5	0.0	1.0	2.0
		3	2.0	1.7	7.3
		3.5	1.3	1.0	5.7
		4	0.0	4.7	9.0
		4.5	0.0	4.7	6.7
		5	0.0	2.7	14.3
	Post	0.5	0.0	30.7	24.0
		1	0.0	22.7	16.7
		1.5	0.0	12.7	13.0
		2	5.0	10.3	19.3
		2.5	6.0	5.0	17.0
		3	4.0	3.0	9.0
		3.5	2.0	5.0	8.3
		4	0.0	4.3	3.7
		4.5	3.0	16.3	0.7
		5	3.0	12.3	9.0