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The Acoustics of Introduction: An Analysis of Vocalizations from the Captive Introduction of an Atlantic Bottlenose Dolphin, *Tursiops truncatus*

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The Acoustics of Introduction: An Analysis of Vocalizations from the Captive Introduction of an Atlantic Bottlenose Dolphin, *Tursiops truncatus*

by

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Abstract

Vocalizations from dolphins were recorded using a hydrophone on several different occasions: from seven previously-housed dolphins prior to introduction of a new animal and from all eight dolphins together, both on the day of introduction and post-introduction. The vocalizations were categorized by visual inspection of spectrograms using Raven, then totaled and averaged. Total vocalizations appeared to peak during the physical introduction of a new individual to the previously-housed dolphins; however, the rates of vocalization per animal per hour showed that the post-introduction period had the most acoustic communications between individual dolphins. Whistles, chirps (a subcategory of whistles), and unmodulated burst pulses appear to make up the majority of dolphins' communications during a captive introduction, as an identifier for members of the same tank and as a possible aggressive or agonistic display, respectively. In the future, measurements of dolphins' vocalizations in combination with cortisol tests may serve to increase captive dolphins' overall wellbeing by reducing the stress on introduced animals during the introduction process.

Key Terms: vocalizations, captive introduction, acoustic communication, Atlantic bottlenose dolphin

Dedication

For my parents, Rhonda and Todd Brady, my grandparents, Betty and Ralph Williamson,

and for the dolphins of Vallejo, California

Acknowledgements

I would like to thank my thesis advisor, Stan Kuczaj, for his mentorship during the process of completing this study. My work would not have been possible if I had not come to him out of a sheer passion for dolphins and their behavior; I was met with an amazing mentor and kindred spirit. Thank you for everything.

I would also like to thank Brittany Jones for her tireless work helping me learn to use Raven and differentiate acoustic data during this project. I am truly blessed to have had her support and guidance throughout the lengthy process of data collection and cataloging, along with the rest of the staff at the Marine Mammal Behavior and Cognition Lab, who gave generously of their time and patience to help me in this work.

Finally, I would like to thank the staff at the Honors College, particularly Dr. Dave Davies and Ms. Paula Mathis for putting up with all my questions and queries. I sincerely appreciate your assistance during my time at the Hattiesburg campus.

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List of Abbreviations

MMBCL	Marine Mammal Behavior and Cognition Lab
USM	University of Southern Mississippi
BP	Burst pulse
FM	Frequency modulation
kHz	Kilohertz

Introduction and Literature Review

Dolphins are known for their intelligence and the numerous vocalizations that they use to communicate with one another and the environment. However, the relationship between captive-dolphin introductions and vocalizations is unclear. According to Kuczaj (2013), there is still very little known of the contextual information and signals embedded in dolphin vocalizations. Additionally, little research has been done on introductions, therefore scientists must rely on other sources to infer what the vocalizations they are hearing suggest.

This study involved the viewing and cataloging of prerecorded data along with comparisons of the results to preexisting literature.

Acoustic communication carries multiple functions besides communication; echolocative sounds such as echolocative clicks can allow individual dolphins to visualize their surroundings as well (Douaze, 1993). Additionally, the author suggests that whistles and burst pulses may communicate information about the senders' identity, fertility, feeding behaviors and even emotions (Douaze, 1993). Past research focuses primarily on these three categories, and it is the latter two that were the focus of this study.

Expanding on the idea of interspecies communication, individual dolphins' different sounds may have both a social and a behavioral context (Herzing, 1996). Kuczaj (2013) notes that there is a tendency for humans to anthropomorphize dolphins and their vocalizations.

Herzing (1996) points out that the whistle, when used in a group context, may be an identifier for individuals in a pod. Bruno Díaz López (2011) noted that whistle characteristics can change according to a dolphin's motivational state (e.g., hunger, arousal or aggression). Unfortunately, as previously stated, there is very little information relating to the field of behavioral acoustics in both wild and captive dolphins despite the attention paid to their various vocalizations (Kuczaj, 2013); Díaz López (2011) also points out that the captive/wild dichotomy can make a difference when it comes to dolphins' whistle functions and even the mechanisms they use to produce them.

Visual inspection of spectrograms can lead to misleading conclusions, as humans must make decisions on how to categorize vocalizations (Díaz López, 2011). A lone dolphin would obviously not whistle in a social context, while a larger group or pod size only serves to increase the amount of whistles given off by individuals, supporting the theory that whistles are used as an identification feature or a social response (Díaz López & Shirai, 2009; Kuczaj, 2013). This supports the inference that dolphins will whistle more when put into a group setting through introduction.

Other species, such as the Carolina chickadee, are suggested to use vocalizations to announce identity; as group size increases, vocalization number and information transmitted also increase (Freeberg, 2006). Like chickadees, dolphins can embed various information in their whistles and burst pulsed vocalization (Blomqvist & Amundin, 2004); we can possibly draw parallels between the two species, since both animals can modify their calls depending on group behavior, individual behavior, group size and other motivational factors.

Esch (2006) expanded on the concept of whistles as a stress indicator during introductions, as opposed to a communicative device. Very often, dolphins experience increased levels of stress during capture-release or introduction events, but it is difficult to pinpoint exactly how stress is manifested due to the sheer variety of ways the animals may express stress. If the existing social structure of a captive-dolphin pod is upset to an extreme, their stress response can lead to early mortality (Morgan & Tromborg, 2007; Waples & Gales, 2002).

During focal follows, which were essentially following alongside a dolphin with little to no human interaction, the dolphins' whistles contained significantly less looping (Esch, 2006). In contrast, a capture-release session, in which humans would be involved in catching and reintroducing a wild dolphin to a habitat, caused dolphins to produce whistles with many more loops (Esch, 2006). While we did not look at the physical characteristics of the whistles in this data set, it is just as important to note that location changes and stress can affect vocalizations as well. Sounds from a new animal being introduced can also cause stress for animals in captivity, however; this is seen in chimpanzees, whose screams increase the heart rate of their young (Berntson et al., 1989; Morgan & Tromborg, 2007). Some species will use song or communicative vocalizations as a source of enrichment for both new and current animals; it is sometimes difficult to tell which function the vocalizations will take in an introduction, but the effect of peer vocalizations should not be ignored in this context (Morgan & Tromberg, 2007).

As an indicator for stress, the whistle may not be reliable; as previously stated by Herzing (1996), whistles are mainly hypothesized to be an identifier for individual dolphins. Looping of whistles is another characteristic that is affected by a variety of factors, similar to stress. Esch (2006) states this, and that the increased looping is out of "a motivation to communicate" rather than increased stress levels. There is no strong correlation between this type of vocalization and stress levels, but it does provide a point for further research (Esch, 2006). Waples and Gales (2002) found that *Tursiops* normally display stress responses through loss of appetite as well as increased cortisol levels, factors that, when used in conjunction with vocalization levels, could allow park employees to monitor the stress levels of animals both during and after physical introductions. This provides evidence for the hypothesis that the studied dolphins might whistle more in the context of an introduction; if a stress response is being induced, increased rate of vocalization might also follow suit.

In contrast, the clicks used in echolocation are also used at high intensities in burst pulses, but burst pulses also have a social element seen in numerous cetaceans (Blomqvist & Amundin, 2004). Díaz López and Shirai (2009) note that the burst pulse is a much less studied acoustic category, mainly because they require large amounts of data and work in order to achieve an appreciable sample size. A burst pulse is a wide, broadband, intense series of clicks, usually at a high frequency (Blomqvist & Amundin, 2004). Normally, in a social context, these vocalizations are used in displays or aggression towards other individuals, not feeding, as seen in the adult Hector's dolphin (Dawson, 1991). Blomqvist and Amundin (2004) observed this vocalization during a typical introduction, both when adult *Tursiops truncatus* were allowed to see one another through a net barrier and when the barrier was suddenly removed. The researchers found that, in agonistic displays, the dolphins would often pair high-frequency burst-pulsed vocalizations with an aggressive S-shaped body posture or a behavior such as a jaw clap (Blomqvist & Amundin, 2004). Also, Blomqvist and Amundin (2004) hypothesized that the barrier may have had a positive influence on the dolphins' aggression; that is to say, the dolphins on one side may have sensed less of an immediate danger associated with displaying agonistic behavior while the net was in place. We can infer that the dolphins might use more aggressive vocalizations, such as burst pulses, with more frequency during the acoustic introduction; during the physical introduction, the dolphins might decrease the frequency with which they produce burst-pulsed vocalizations.

Also in the context of introductions, Douaze (1993) noted that captive bottlenose dolphins who were newly placed into a tank whistle continuously, though no reasoning was given for this behavior. From this data, we might possibly assume that the whistles come from a need to identify oneself to whatever peers are available in the tank at the time. Based on this, it can be inferred that individual dolphins will whistle more frequently during a physical introduction.

There is another side to this debate. Some scientists believe that acoustic vocalizations are not necessarily a communicative gesture. Kuczaj (2013) states that wild bottlenose dolphins might not even intend to give other animals information at all; the issue of contextual messages in dolphin vocalizations is a hotly contested one. While acoustic data may not convey all of the signals researchers are proposing, pairing an acoustic signal (such as a click train or a whistle) with a tactile one (such as fin rubbing) may give the vocalization a social context, whether to the rubbed dolphin or others in the vicinity that are not participating in the interaction (Evans-Wilent & Dudzinski, 2013). Despite the contact, there was always a possibility that vocalizations were not intended in the social context; the dolphins could have been clicking to ascertain their surroundings (Evans-Wilent & Dudzinski, 2013). Based on this information, there is still much to be studied regarding behavioral acoustics, and it is difficult to assign a context to the dolphins' vocalizations in this study and at this time.

Methodology

The seven original dolphins in this experiment were kept in the Six Flags Discovery Kingdom facilities, located in Vallejo, California. The dolphins resided in a gated enclosure that allowed individual animals to see one another, but not make physical contact until the gate was opened. Prior to introduction, a hydrophone from the Marine Mammal Behavior and Cognition Lab was placed in the pool on various dates and used to record the animals' vocalizations. A total of 2.069 hours of data were recorded for the original seven animals. This process was repeated for the introduced dolphin (known henceforth as Deke) while he was physically but not acoustically isolated from the other animals, for a total of 1.036 hours of acoustic data. This is labeled as the acoustic portion of the introduction.

On the day of introduction, the gate was opened to the pool and he was allowed to make contact with the seven other animals. 2.041 hours, spanning two days of recordings, were used in this analysis. This set of recordings is labeled as the physical introduction since they involved all the animals being either in sight or contact with one another.

For the post-introduction data, the hydrophone was reintroduced into the pool and the dolphins' vocalizations were recorded for an additional 1.036 hours, during the week following the introduction.

All data was recorded onto microcassettes and sent back to the MMBCL at the University of Southern Mississippi. The acoustic data was converted to a digital format, and Raven was configured to show accurate spectrograms of each clip. Figure 1 shows the specific parameters that were used with the data set.

These parameters offered a consistent view of the data set across all the different time periods. The Hann function ensured that the spectrogram would have a very low rate of aliasing, or in other words, the amount of visual static on the recordings would be reduced. A window size of 908 samples was also chosen in order to get the best, most uniform view across multiple clips.

After the spectrograms were visible, the MMBCL's definitions of different vocalizations were used to analyze them. Figure 2 shows these definitions, along with short descriptions of each type of vocalization.

A whistle was defined as a narrowband, frequency-modulated sound, generally linear in appearance. Whistles are usually between 4 to 18 kHz and last anywhere between 0.5 to 8 seconds; chirps, a subset of whistles, last 0.3 seconds or less. Burst pulses are wide-band areas on the spectrogram caused by high-intensity clicking. A burst pulse with frequency modulation would appear patterned across the x-axis, while a burst pulse with no frequency modulation would appear blurred in comparison. A whistle-squawk was described as a whistle combined with either a frequency-modulated or unmodulated burst pulse. Sounds that did not fall into any of these categories were counted as 'other' and not included in this data set.

After cataloging all the vocalizations, the values were totaled in Excel. Vocalizations were then compared across time periods and categories.

Results

Table 1 gives the number of individuals present during each period of the introduction as a reference point. As seen in Table 2 and Figure 3, during the pre-introduction recording, the dolphins are much more vocal; when Deke is put into isolation on one side of the gate, the number of whistles increases, but the total vocalizations are not nearly as numerous as they were during the pre-introduction. Thus, the vocalizations seem to taper off during the acoustic introduction of Deke to the other dolphins. They can hear him and see him, but the gate prevents them from having contact with him. Whistle-squawks also increase (see Figure 6), but both categories of burst pulses show a significant decrease during the acoustic introduction (in Figures 7 and 8).

During physical introduction, Deke was allowed to come into contact with the other individuals, for a total of eight dolphins in contact with one another. Here there is a significant increase in total vocalizations – from 463 to 2,252 in the time that they were allowed to come into contact with one another, according to Table 2 and Figure 3. For all categories of vocalization, a sharp increase in frequency was seen; consult Figures 3 through 8 for detailed graphs of each category over all periods of introduction.

During the post period, the dolphins were allowed to become acclimated to one another for several days before the hydrophone was reintroduced. The number of vocalizations is still fairly large, at 1189, but the individual sounds in each category are less frequent as a whole, which can be seen on their individual graphs.

Whistles and chirps seemed to follow a similar pattern, with chirps showing the most increase during the physical introduction and whistles tapering off (from 24.25 per dolphin per hour to 20.33 per dolphin per hour) during physical introduction. Burst pulses disrupted the pattern the most out of all categories; the burst pulses with frequency modulation decreased from pre-introduction to the physical introduction, while the burst pulses without frequency modulation sharply increased from the physical introduction to post-introduction recordings: from 60.45 vocalizations per dolphin per hour to 79.51 per dolphin per hour. Overall, each vocalization tended to follow the trends previously stated; the total rate of vocalizations dropped off during the acoustic introduction but peaked during physical introduction. In this case, however, the post-introduction recordings seem to show the most vocalizations per animal.

Discussion

Overall, the results of this data appear to support the lines of questioning mentioned in the introduction. Whistles, chirps (which are a subset of whistles) and burst pulses with no frequency modulation appear to be the most commonly used by dolphins during physical introduction of a new animal; when the dolphins were allowed to see Deke, but not interact with him, there was a definite drop-off in vocalizations before the gate was open and they were allowed to come into contact with Deke. The question now, and a possible practical application of the data, is whether or not vocalizations can be used as an indicator for bottlenose dolphin stress responses.

Díaz López (2009) found that dolphins whistled more frequently when engaged in social activities with other individuals, second only to feeding. Dawson (1991) states that the purpose of the burst pulse is closer to an aggressive response than a whistle, possibly due to its intensity.

As previously stated by Esch, whistles do not appear to be a reliable indicator of stress in *Tursiops truncatus*; burst pulses, however, with their related aggressive behaviors, may be a slightly better marker for park officials and marine biologists to use in monitoring stress (Esch, 2006). The results raise the question of how stress could practically be measured during captive introductions while still incorporating the use of acoustics.

In Waples and Gales' (2002) research, the upset in social structure caused a stress response to be given off by the dolphins; this ended in their mortality. For future studies, revisiting the eight dolphin subjects of this experiment at Vallejo, maybe as part of a related study, but from a more stress-related position, might be a possibility. A possible application of this research for captive-dolphin programs might be the pairing of whistles and burst pulses with blood tests for the stress hormone cortisol, as well as individual monitoring of the subject animals, due to the complex, multilayered way in which dolphins and other marine mammals make their stress known (Esch, 2006).

As stated by Díaz López and Shirai (2009) and reproduced in this data, the dolphins appeared to whistle more when introduced to one another in the same tank, possibly in a social context. However, the different vocalizations that actually showed up in this data set are extraordinarily diverse and are not limited to the categories set by the MMBCL, and even within the same category, the quality of each vocalization differed from one individual to the next.

In a later paper by Díaz López (2009), the issue of categorization and sample size was brought up. While the whistle and the burst pulse may be the most common vocalizations, the sheer amount of raw data and effort required to get a reasonable sample size can be off-putting (Díaz López & Shirai, 2009). More importantly, the human element can cause problems. Similar to human languages, dolphin vocalizations have their own context that will either require additional technology to translate or remain unknown – or they may not even contain a social context at all (Kuczaj, 2013). Categorizing these vocalizations requires humans to decide on specific parameters, but differences between individual research groups and even humans' subjective qualifications of each sound can cause disagreement (Díaz López & Shirai, 2009; Kuczaj, 2013). As a result, there is a definite call for standardization among the biological community: what constitutes a whistle? What constitutes a whistle-squawk, a chirp, a burst pulse; what can scientists do to solve these problems? Díaz López and Shirai (2009) proposed that biologists first use the actual structures of the acoustic data in order to create a more standard definition overall. Kuczaj (2013) also noted that it is critical to continue investigating the drives and motivations of dolphin behavior, vocalizations included, before we try to make any definite conclusions on the function and role of dolphin vocalizations.

In conclusion, there is still much to be learned about the vocalizations of dolphins. While *Tursiops truncatus* has been a subject of interest for its wide range of acoustic communications, exactly what is embedded in those sounds still remains unclear to scientists, especially in the context of a captive introduction. By synthesizing the information currently available on dolphin vocalizations, standardizing their definitions and incorporating low-impact physiological tests as well as behavioral observations, scientists can eventually reduce the stress to introduced marine mammals overall.

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Figures

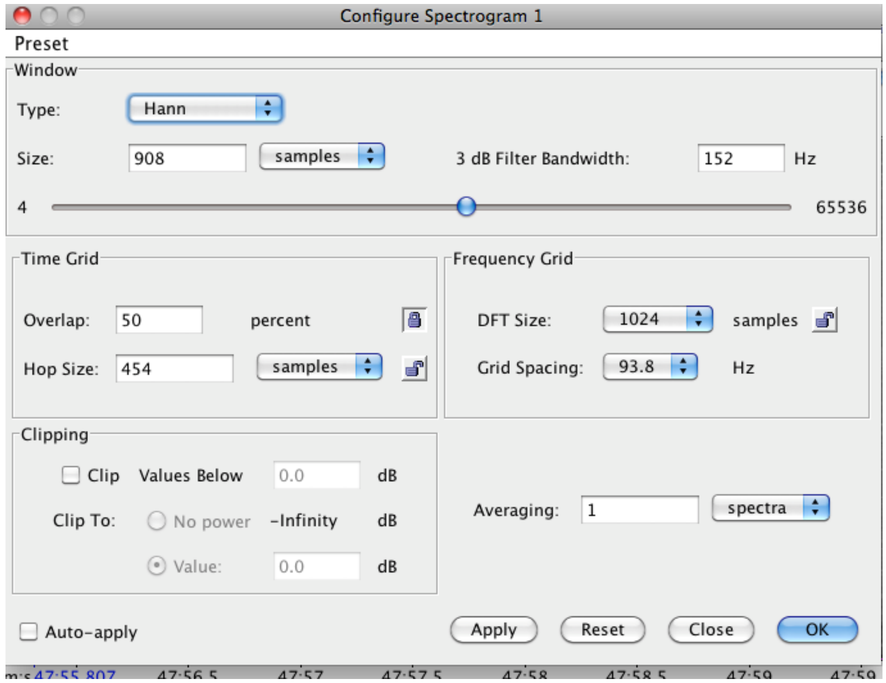

Figure 1. Raven parameters used in the study. This figure shows the window settings used for the spectrograms of the data.

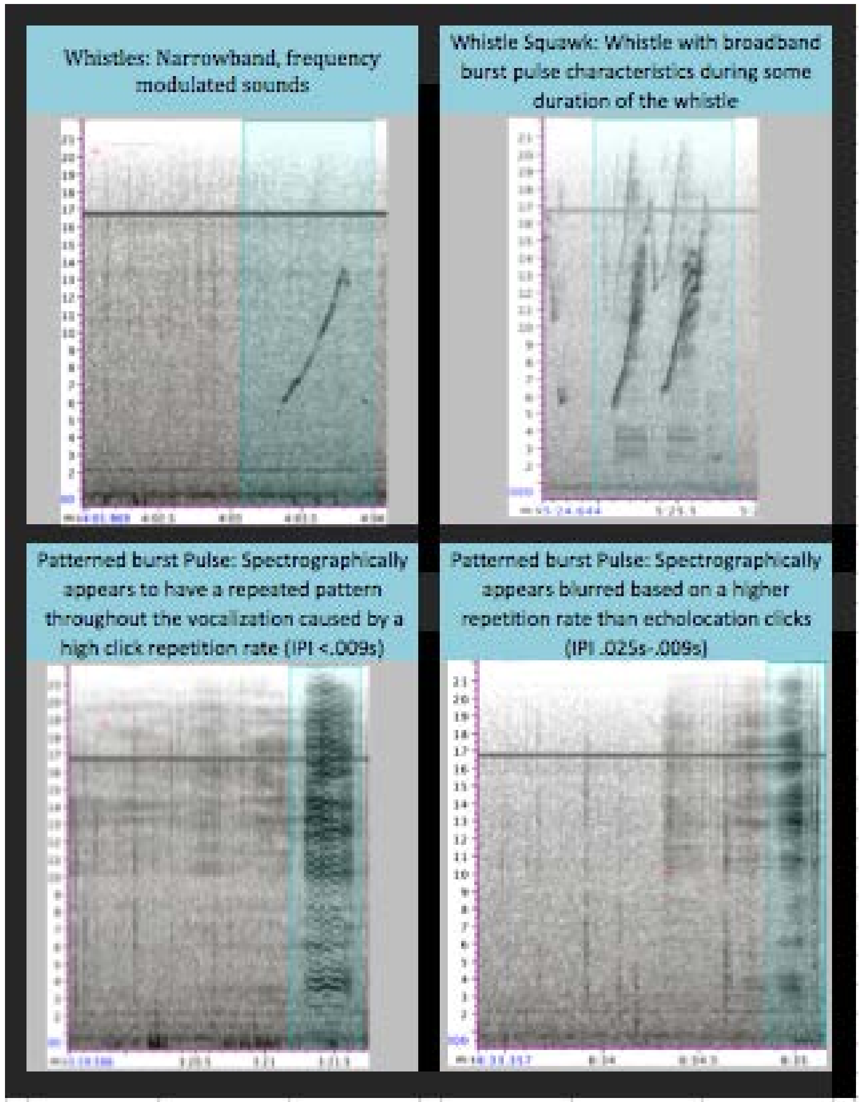

Figure 2. Four definitions of vocalizations. This figure illustrates the definitions created by the MMBCL to describe each type of sound displayed in the spectrograms.

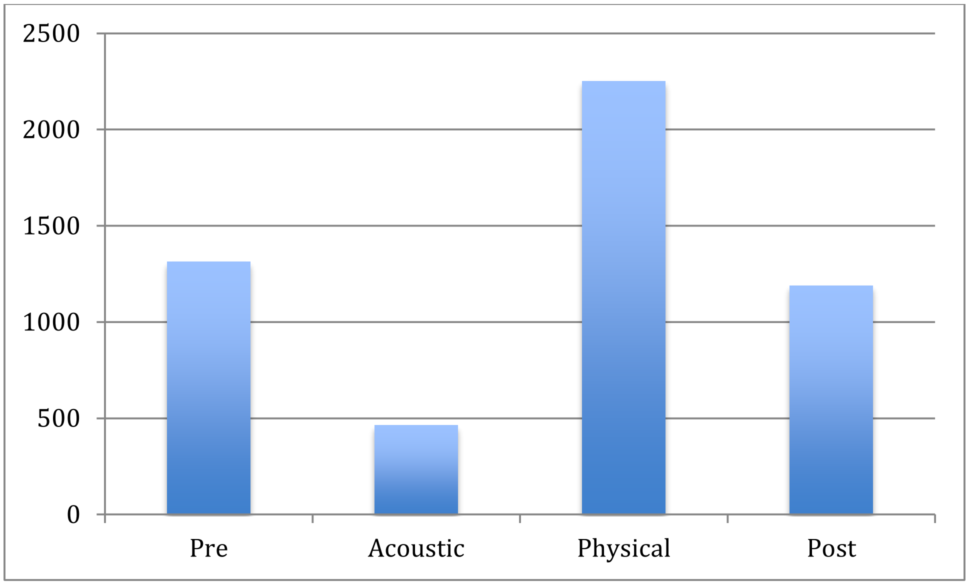

Figure 3. Total number of vocalizations per introduction period. In this graph and the categorical graphs following, the X-axis gives the period of introduction, while the Y-axis gives the number of vocalizations. See Table 2 on page for reference.

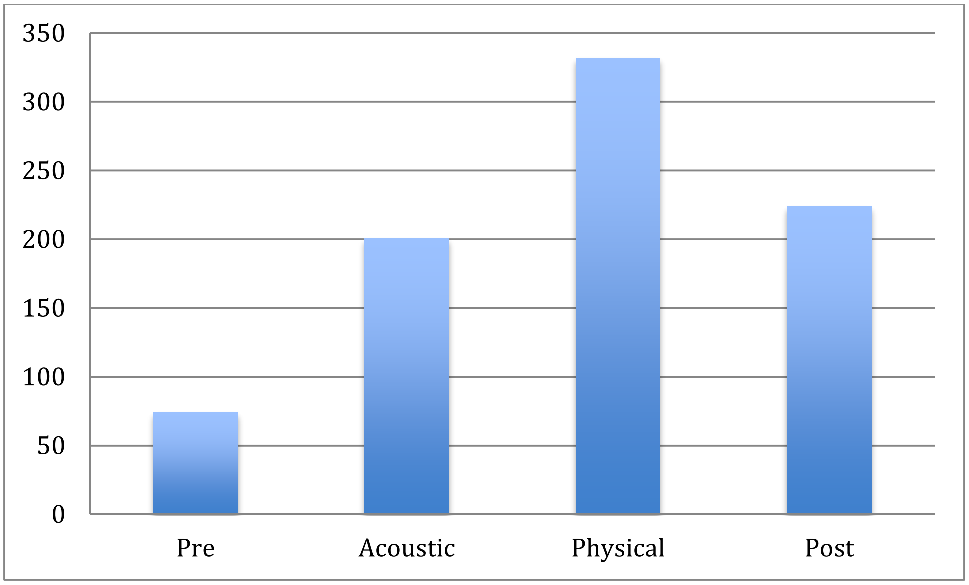

Figure 4. Total number of whistles per introduction period.

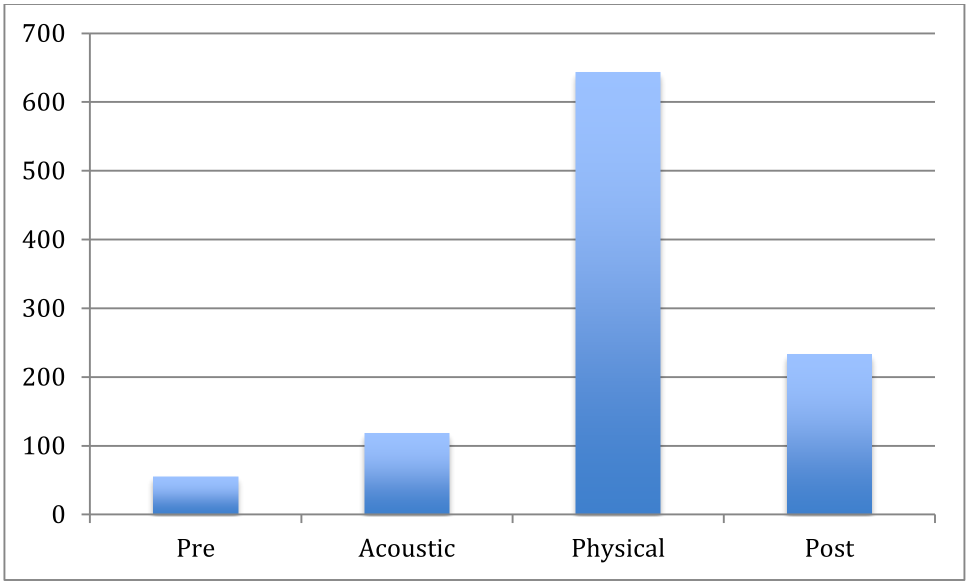

Figure 5. Total number of chirps per introduction period.

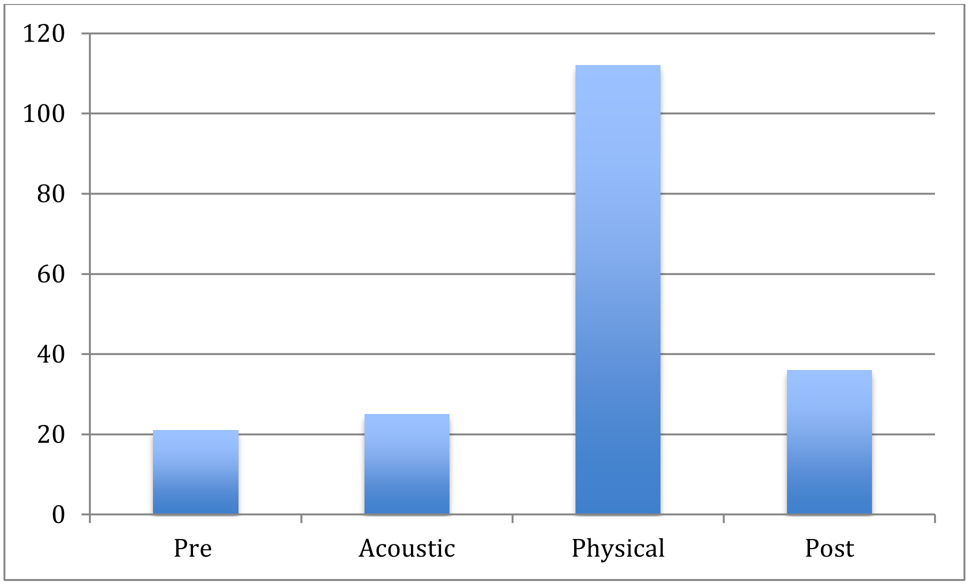

Figure 6. Total number of whistle-squawks per introduction period.

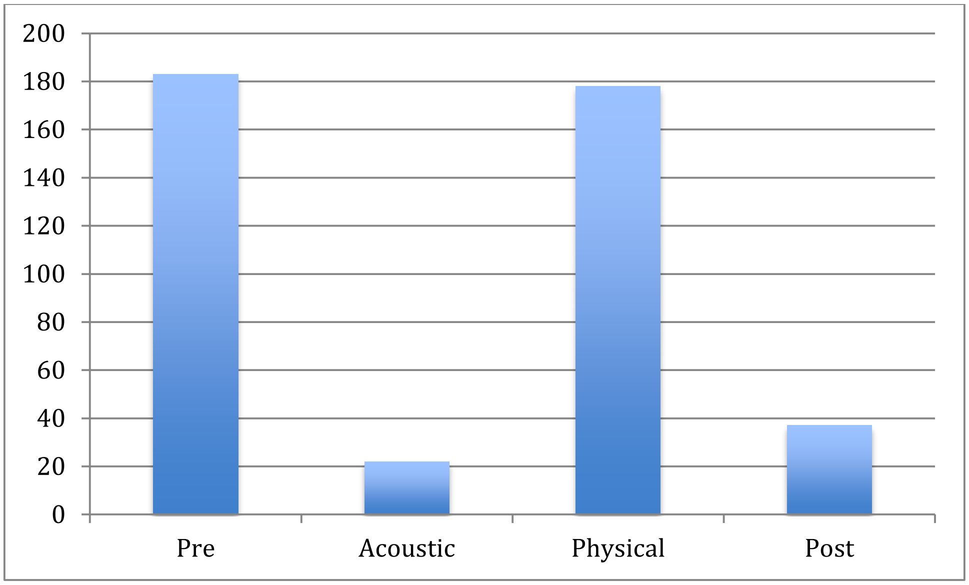

Figure 7. Total number of frequency-modulated burst pulses per introduction period.

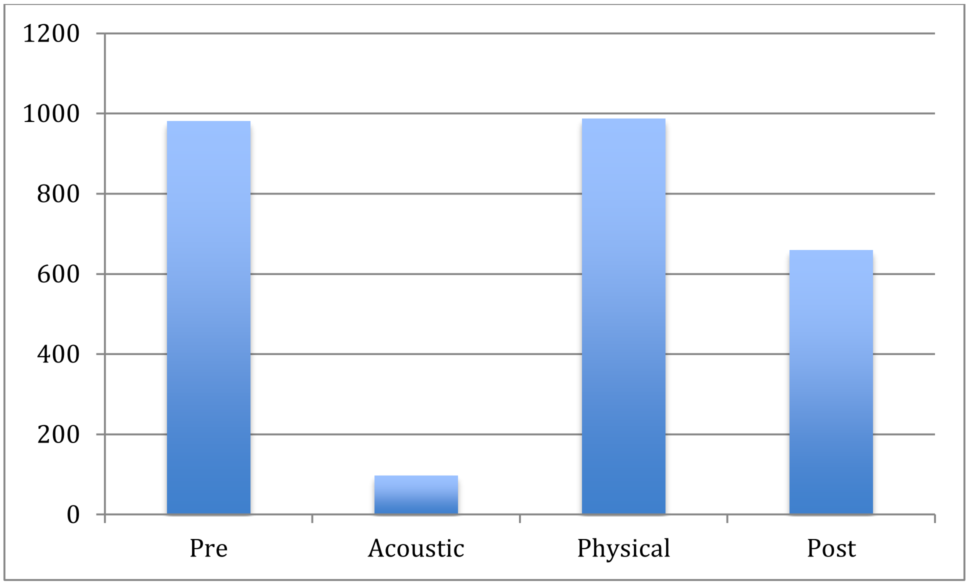

Figure 8. Total number of burst pulses with no frequency modulation per introduction period.

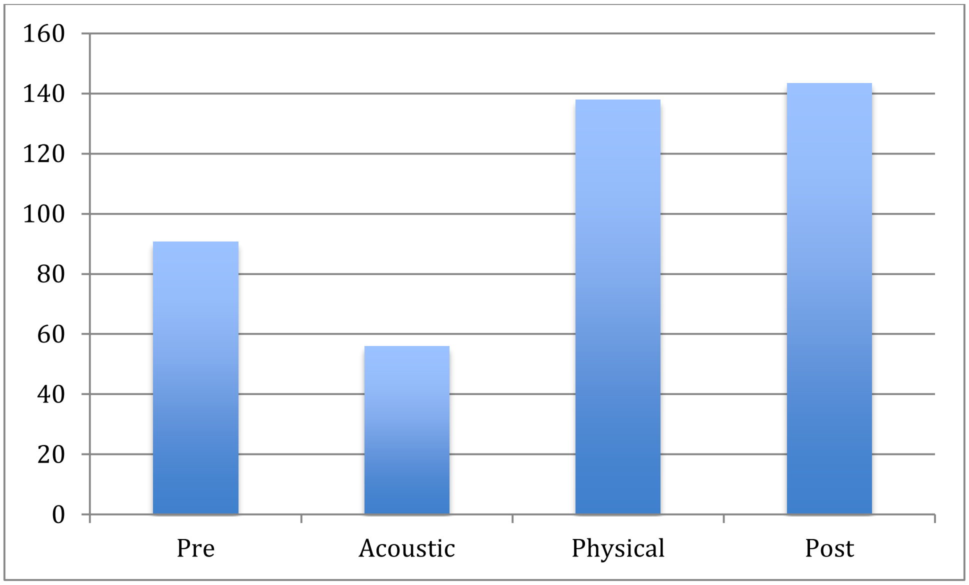

Figure 9. Rate of vocalizations per dolphin per hour, per introduction period. In this graph and the categorical graphs following, the X-axis gives the period of introduction, while the Y-axis gives the number of vocalizations. See Table 3 on page for reference.

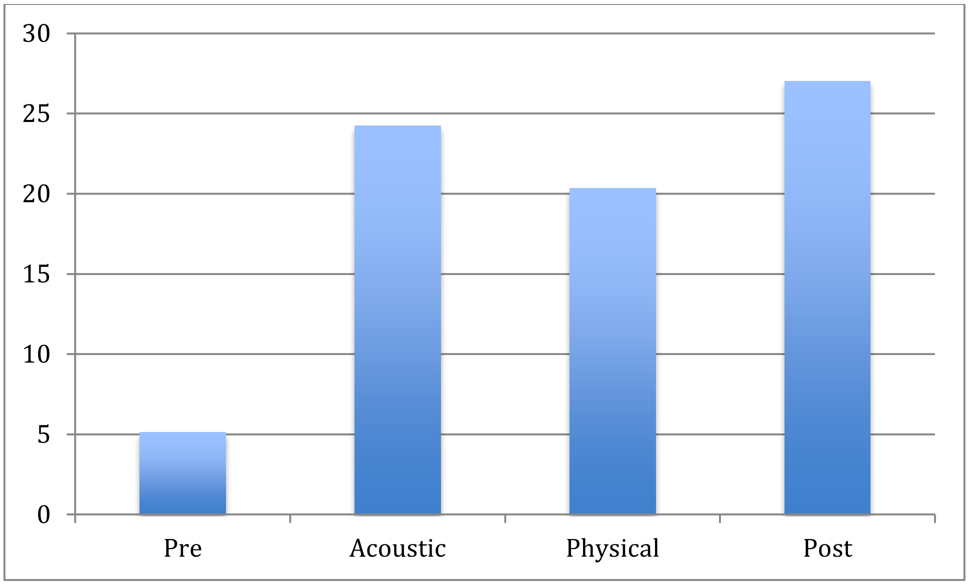

Figure 10. Rate of whistles per dolphin per hour, per introduction period.

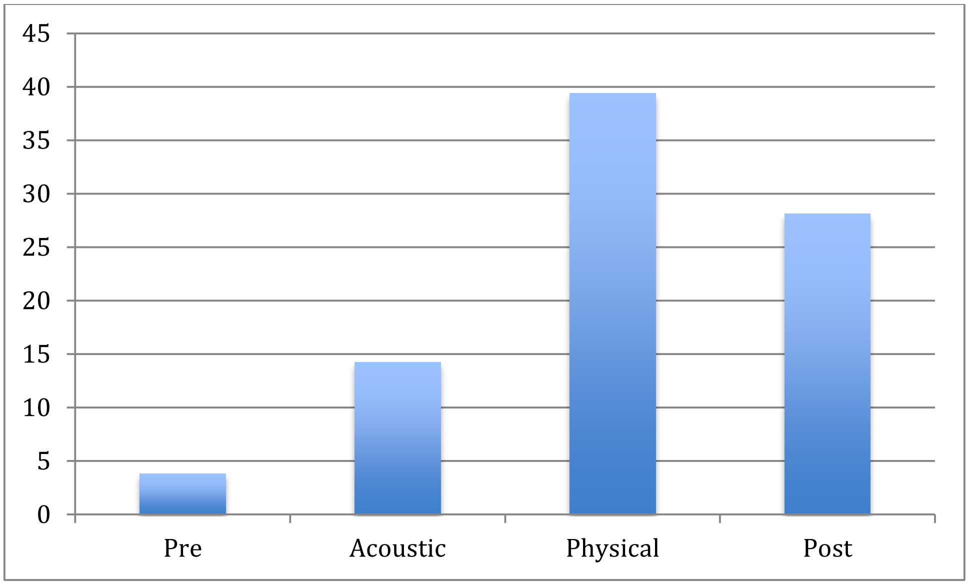

Figure 11. Rate of chirps per dolphin per hour, per introduction period.

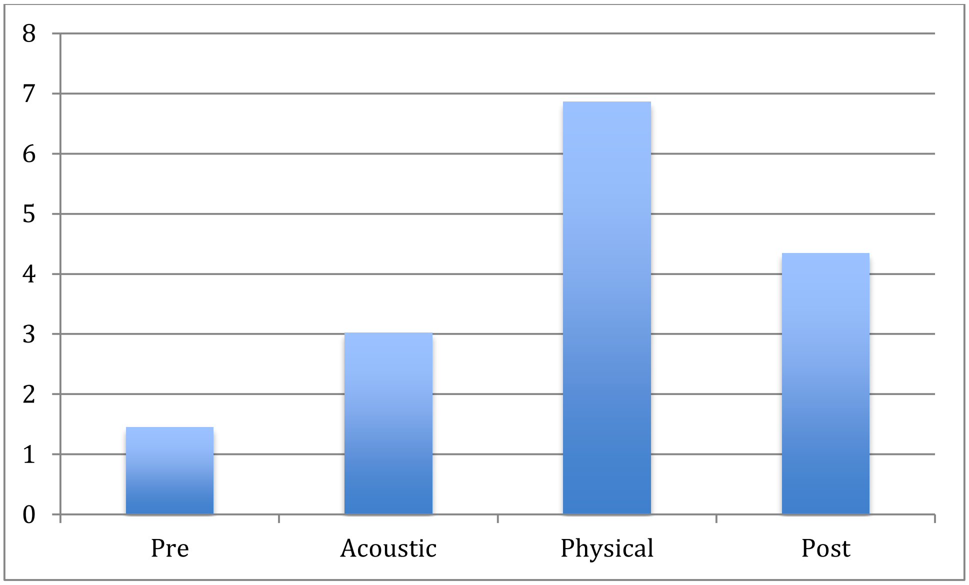

Figure 12. Rate of whistle-squawks per dolphin per hour, per introduction period.

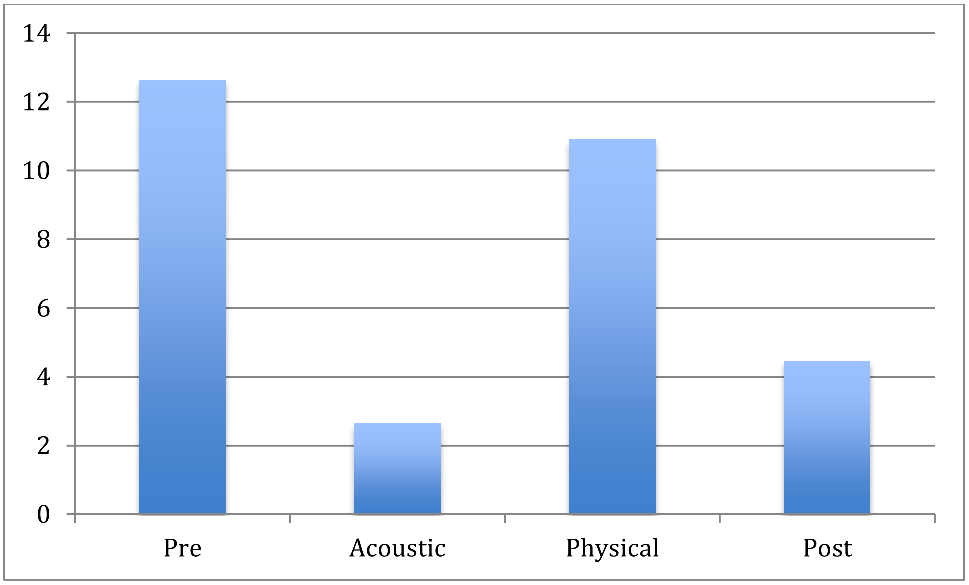

Figure 13. Rate of frequency-modulated burst pulses per dolphin per hour, per time period.

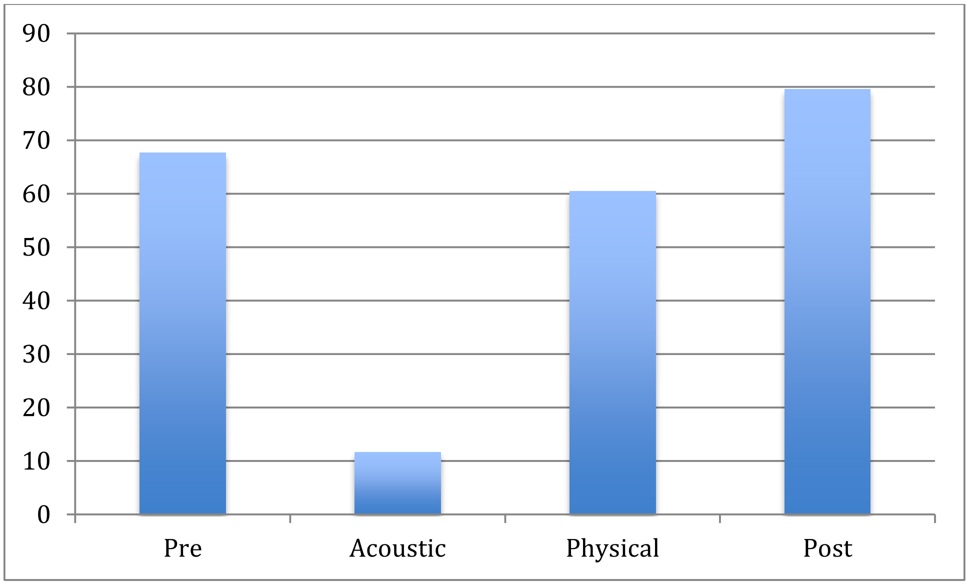

Figure 14. Rate of burst pulses without frequency modulation per dolphin per hour, per time period.

Tables

Period	Number of Individuals Present
Pre	7
Acoustic	8
Physical	8
Post	8

Table 1. Number of individual dolphins present at each time period. This table is a reference point for the number of animals present during each phase of the introduction.

Period	Total Time (hr:min:sec)	Total Time (hr)	Whistles	Chirps	Whistle-Squawks	BP w/ FM	BP w/o FM	Total Vocalizations
Pre	2:04:08	2.069	74	55	21	183	980	1313
Acoustic	1:02:08	1.036	201	118	25	22	97	463
Physical	2:02:29	2.041	332	643	112	178	987	2252
Post	1:02:08	1.036	224	233	36	37	659	1189

Table 2. Total vocalizations for each time period. This table shows the raw data for the amounts of vocalizations per introduction period.

Period	Total Time (hr:min:sec)	Total Time (hr)	Whistles	Chirps	Whistle-Squawks	BP w/ FM	BP w/o FM	Total Vocalizations per hr per dolphin
Pre	2:04:08	2.069	5.109	3.798	1.450	12.64	67.67	90.68
Acoustic	1:02:08	1.036	24.25	14.24	3.016	2.654	11.70	55.86
Physical	2:02:29	2.041	20.33	39.38	6.859	10.90	60.45	137.9
Post	1:02:08	1.036	27.03	28.11	4.344	4.464	79.51	143.5

Table 3. Rates of vocalization per hour per dolphin for each time period. This table shows each individual's average number of vocalizations of a given type per hour.