BEHAVIOR OF BOTTLENOSE DOLPHINS (*Tursiops truncatus*) RELATIVE TO BOAT TRAFFIC IN THE GALVESTON SHIP CHANNEL, TEXAS

An Undergraduate Research Scholars Thesis

by

ANNA MARIE PENNACCHI

Submitted to Honors and Undergraduate Research
Texas A&M University
in partial fulfillment of the requirements for the designation as

UNDERGRADUATE RESEARCH SCHOLAR

Approved by
Research Advisor: Dr. Bernd Würsig

May 2013

Major: Biomedical Science

TABLE OF CONTENTS

ABSTRACT

Behavior of Bottlenose Dolphins (*Tursiops truncatus*) Relative to Boat Traffic in the Galveston Ship Channel, Texas. (May 2013)

Anna Marie Pennacchi
Department of Biomedical Science
Texas A&M University

Research Advisor: Dr. Bernd Würsig
Department of Marine Biology
Texas A&M University at Galveston

Heavy boat traffic can negatively affect dolphins by increasing the risk of habitat disruption, emigration, or physical harm by boat propellers. It is important to assess the behaviors of the resident population of bottlenose dolphins (*Tursiops truncatus*) in the Galveston Ship Channel, near the entrance to the second busiest port in the USA, as a 5.2 billion dollar expansion of the Panama Canal is to be completed in 2015 that will bring more and larger ships to Galveston Bay. Hour-long surveys were conducted from a shore-based station along the Galveston Ship Channel in the morning, mid-afternoon, and late-afternoon from August through December 2012. Group size, number of boats, type of boat, and predominant behavior of dolphin groups were recorded during each survey. I predicted a decrease in social behavior and an increase in travelling behavior as boat traffic increased, as noted in previous studies of short-term behavioral shifts of dolphins during periods of heavy boat traffic. Chi squared contingency tests showed that the behaviors of dolphins varied significantly relative to the number of boats, but not the type of boat. However, contrary to predictions, socializing behavior did not change inversely proportionately to boat traffic nor did travelling behavior increase with increasing traffic. Behaviors varied relative to group size, and smaller groups were found in the presence of industrial than non-industrial boats. Behaviors did not change with time of day, although the number of industrial boats increased with time of day. The results suggest that several factors influence behavioral decisions of socially complex dolphins. As smaller group sizes were found in the presence of industrial boats, expansion of the ship channel could potentially disrupt dolphin interactions and habitat use. Further studies are necessary to better understand potential effects of increased ship traffic on the local dolphin population and to establish effective mitigation protocols.

DEDICATION

To my parents, Robert and Denise Pennacchi. Thank you for always believing in me and supporting me unconditionally.

ACKOWLEDGEMENTS

I thank Dr. Bernd Würsig for being such a kind mentor and sharing his profound knowledge and experiences of marine mammals with me. I give special thanks to Dara Orbach for guiding and teaching me throughout this entire project. I would also like to thank Ashley Zander and Sarah Piwetz for their assistance with data collection. In addition, I thank Texas A&M at Galveston and Texas Institute of Oceanography for funding assistance through the TAMUG/TIO Undergraduate Fellowship. I thank the Texas A&M University Honors Program for continuous guidance throughout this project.

LIST OF FIGURES

LIST OF TABLES

TABLE Page

CHAPTER I

INTRODUCTION

A population of common bottlenose dolphins (*Tursiops truncatus*) inhabits the Galveston Ship Channel near Texas A&M University at Galveston, Texas, using the area for traveling, foraging, resting, socializing, and mating. This is surprising, considering the heavy local boat traffic and noise pollution from industrial activity.

Bottlenose dolphins in Galveston Bay have been studied by researchers at Texas A&M University for over two decades (Bräger et al. 1994; Fertl 1994; Maze and Würsig 1999; Candelaria-Ley 2001; Henderson 2004; Irwin and Würsig 2004; Moreno 2005). Most of the research since 1990 has focused on the west end of Galveston Island and studied association patterns (Bräger et al. 1994; Henderson 2004), site-fidelity and occurrence patterns (Maze and Würsig 1999; Irwin and Würsig 2004), and distribution and core feeding densities (Moreno 2005). More than 1,000 dolphins have been identified that use the shallow channels, bays, and estuaries comprising Galveston Bay (Maze and Würsig 1999). The dolphin population in the Galveston Ship Channel was once considered to be an open population with little change in net size (Fertl 1994), although they have since been reclassified as a resident population with strong site-fidelity (Irwin and Würsig 2004). Within the Galveston Ship Channel, Fertl (1994) found that dolphin abundance peaked seasonally in autumn and spring, foraging and socializing were predominant behaviors, and apparent scars were derived from human interactions. Little research in the Galveston Ship Channel has been conducted recently, especially relative to boat interactions.

Bottlenose dolphins may be exposed to higher levels of human activities than many other cetaceans because they typically utilize coastal habitats (Nowacek et al. 2001). Bottlenose dolphins in Texas waters appear to have adapted to human-modified environments, such as ship channels and areas of high human activity, as they live in areas with noise, pollution, and human population centers (Leatherwood and Reeves 1982). Maze and Würsig (1999) hypothesized that dolphins in Galveston Bay utilize the human-modified environment because of the abundant prey in the deep waters of the Galveston and Houston Ship Channels.

Galveston Bay has been subjected to dredging and jetties in the Houston and Galveston Ports, contamination from nearby petrochemical plants, and commercial and recreational fishing. It is difficult to gauge the effects that human activities have on the dolphin population in the ship channel because the dolphins that utilize it exhibit habituation. Habituation is a reduction in response to stimuli over time after an individual learns there are neither beneficial nor adverse consequences (Thorpe 1963). However, methods of determining habituation have recently been questioned (Bejder et al. 2006a). Bejder et al. (2006a) studied Indo-Pacific bottlenose dolphins (*T. aduncus*) in Shark Bay, Australia, at an impact site where dolphins were habitually exposed to boats and a control site where dolphins were not normally exposed to boats. Dolphins in the impact site exhibited moderate behavioral responses to experimental approaches, whereas dolphins in the control site exhibited longer lasting behavioral responses (Bejder et al. 2006a). However, through a study over three consecutive 4.5 year periods in the same area, dolphins in the impact site exhibited a long-term decline in abundance (Bejder et al. 2006b). Caution is warranted when inferring that no significant short-term behavioral responses to boats indicate limited long-term harm to dolphins. Short and long-term assessments of dolphin and boat interactions are necessary for a fuller understanding of potential risks (Janik and Thompson 1996).

Galveston Bay has approximately 90,000 registered recreational boats and is the third largest boating center in the country (Gonzalez 2011; HOGANSAC 2011). The Galveston Ship Channel facilitates several commercial cruises. The Houston Ship Channel, the largest channel in Galveston Bay, is ranked second in national total tonnage and first in foreign total tonnage (USACE 2009). Though the Port of Galveston is ranked fifty-fifth in the national total tonnage, its close proximity to the Houston Ship Channel may enable it to experience many of the same environmental impacts. As the human population along the Galveston Bay grows, which is currently at 4.6 million people and expected to double within coming decades, more pronounced physical and ecological impacts are probable (Gonzalez 2011). Ecological concerns with the massive shipping industry include channel dredging, introduction of exotic organisms, oil spills, erosion of shoreline, water quality, and noise and light pollution (Gonzalez 2011).

An estimated 5.25 billion dollar expansion of the Panama Canal is expected to be completed in 2015 to facilitate travel of post-Panamax ships (explained below) through the Panama Canal (Knight 2008). The Panama Canal links trade between the Atlantic and Pacific Oceans. Though this trade site has been extremely successful since its opening in 1914, its current size cannot effectively facilitate the number and size of ships. During the busy trading season, December through April (Thomas 2013), boats may sit idle for ten days awaiting entrance into the Panama Canal, costing up to $50,000 per day (Knight 2008). Current Panamax ships are at the maximum size possible to use the Panama Canal while post-Panamax ships are supertankers and modern container ships that are too large to travel through the Panama Canal at its present depth and width (Knight 2008). The Panama Canal will be modified through widening and deepening the area, and construction of locks and chambers (USACE 2012). Post-Panamax ships are expected to represent 62% of the worldwide container ship fleet by 2030 (USACE 2012).

Post-Panamax ships are 40% longer and 64% wider (USACE 2012) than current Panamax vessels. A port is considered “Post-Panamax ready” if it has a channel depth of 50 feet and sufficient width for turning (USACE 2012). Major ports on the West Coast of the United States have 50 foot deep harbors that can accommodate the post-Panamax ships while ports along the East and Gulf Coasts of the United States must undergo dredging and expansion projects to stay competitive (Hricko 2012). At a channel depth of 45 feet, Houston would be restricted to facilitating the post-Panamax ships either at high tide or when the ships are not filled to capacity (Knight 2008). Expansion and accommodation projects are currently underway in the Houston and Galveston Bay ports to facilitate transport of more and larger post-Panamax ships (PHA 2012).

Previous construction and maintenance of the Houston Ship Channel has caused widespread fluctuations in water circulation and salinity levels throughout Galveston Bay (Gonzalez 2011). The increase in dredging associated with post-Panamax construction is predicted to have economic and environmental effects on Galveston Bay, including raising water salinity and increasing air pollution, which could have negative effects on the shrimp industry (Kompanik et al. 2012). The Galveston Ship Channel is one of several channels that facilitate commerce in the Houston/Galveston area (Lester and Gonzalez 2008), making it an important area to assess the condition of wildlife before, during, and after construction. Section 404 of the Federal Clean Water Act requires that any destruction of wetlands must be compensated with mitigation including greater restoration, enhancement, or construction of wetlands diminished by permitted land disturbances (Clean Water Act of 1972). The number of permits approved by the Federal Clean Water Act in Galveston Bay has risen since the early 1990s (Gonzalez 2008). From 1992–2003, the number of permits approved (3,067) was approximately 75% of the number of permits approved in the 50 prior years (Lester and Gonzalez 2006).

Although mitigation procedures are regulated by law, dredging still has persistent effects on estuarine environments. For example, approximately 35 sea turtles are killed annually by dredging in the Galveston Ship Channel (Gonzalez 2011). Dredging and heavier boat traffic could also potentially affect dolphins by increasing the risk of habitat disruption, emigration, or physical harm by boat propellers (reviewed in Nowacek et al. 2001). For example, Fertl (1994) found 10 common bottlenose dolphins with obvious propeller cuts and two other dolphins with other human-caused markings in Galveston Bay. Such injuries have a higher probability of occurring in areas with heavy boat traffic, such as the Galveston Ship Channel. Boats have been found to affect bottlenose dolphin dive times (Sini et al. 2005), surfacing patterns (Janik and Thompson 1996), echolocation (Richardson and Würsig 1997), and habitat-use (Wells 1993) in several locations. Nowacek et al. (2001) found that bottlenose dolphins increased their inter-breath intervals (IBI), decreased inter-animal spacing, changed heading, and increased swimming speed in response to approaching vessels.

Dolphins have been observed changing their behavioral states in response to vessel approaches and numbers. In the Mississippi Sound, common bottlenose dolphins significantly decreased foraging behavior and increased travelling behavior within one minute after the appearance of personal watercraft (Miller et al. 2008). Indo-Pacific bottlenose dolphins in Port Stephens, Australia, decreased foraging and socializing behaviors in the presence of dolphin-watching boats, particularly as the number of boats increased (Steckenreuter et al. 2012). Similarly, common bottlenose dolphins in the Bay of Islands, New Zealand, decreased resting behavior in the presence of dolphin-watching tour boats proportionally to boat number (Constantine et al. 2004). Common bottlenose dolphins in Oahu, Hawaii, alter their behavior to wave-ride large ships as a playful behavior and to reduce energetic costs of rapid swimming (Williams et al. 1992).

Dolphins have also been observed changing their habitat use patterns in response to vessel traffic. A long-term study in Shark Bay, Australia, observed a decrease in relative abundance of Indo-Pacific bottlenose dolphins relative to increased tourism and dolphin-watching boats (Bejder et al. 2006b). In Milford Sound, New Zealand, common bottlenose dolphins that use the fjord were spotted significantly less often and closer to the entrance of the fjord during periods of heavy boat traffic, indicating avoidance and potential long-term effects on demography (Lusseau 2005).

Bottlenose dolphins have been observed in many places to increase their foraging and socializing behaviors in the presence of fishing boats and shrimp trawlers (Shane 1990). Dolphins may alter their direction of travel and behavioral state in proximity to fishing boats and shrimp trawlers to feed on the stirred up by-catch (Leatherwood 1975). Although dolphins typically forage in the morning, travel at midday, and socialize in the late-afternoon in Galveston Bay (Henderson 2004), local anthropogenic disturbances such as recreational boating, commercial boating, and shrimp trawling are not consistent throughout the day (Moreno 2005). Dolphins may adjust their temporal and spatial patterns to the schedules of shrimp trawlers (Shane et al. 1986). Shipping and industrial noise affected dolphins in Galveston Bay (Candelaria-Ley 2001). Dolphins exhibited significantly lower whistle frequencies and louder whistles in noisier areas, such as the Galveston Ship Channel, compared to quieter areas of Galveston Bay (Candelaria-Ley 2001). Due to the high volume of recreational, commercial, and industrial boats in the Galveston Ship Channel, it is crucial to assess daily patterns of dolphins, boats, and boat types. A formal study of how boats affect dolphin behaviors in the Galveston Ship Channel has not been conducted, but is especially important at a time when boat traffic and the size of boats are expected to grow. An increased understanding of what behavioral changes, if any, various types of boats elicit from the local bottlenose dolphin population is necessary prior to expansion of the Galveston Ship Channel. Mitigation protocols could be implemented once a base-line level of behavioral responses to vessel traffic has been established.

Objectives

The purpose of this study is to monitor changes in the behavioral response of common bottlenose dolphins in the Galveston Ship Channel to interactions with boats. The specific objectives are to:

1. Examine changes in dolphin presence, behavior, and group size relative to boat traffic.
2. Evaluate changes in dolphin behavior relative to group size and time of day.

Predictions

I predicted a decrease in social behavior and an increase in travelling behavior as boat traffic increased, as noted in previous studies of short-term behavioral shifts of dolphins during periods of heavy boat traffic (Wells 1993; Lusseau 2003). I predicted an increase in social behavior with larger group sizes and time of day.

Hypotheses

H_O1: Dolphins do not exhibit any change in presence or behavior relative to boat traffic.

H_O2: Dolphins exhibit no change in behavior relative to group size and time of day.

CHAPTER II

METHODS

Study Area

Texas A&M University at Galveston (29°18’45” N, 94°49’00” W) is located along the west end of the Galveston Ship Channel on Pelican Island, a small island linked by a causeway to Galveston Island, Texas (Figure 1). The campus provides easy accessibility and a clear view of the Galveston Ship Channel. The Galveston Ship Channel separates Pelican Island from Galveston Island and receives boat traffic from Galveston Bay. All boats traveling to the Houston Ship Channel must pass through Galveston Bay, but the Galveston Ship Channel is adjacent to the major Houston Ship Channel, and does not have the large traffic and larger vessels of the latter (Figure 2). The Galveston Ship Channel has a minimum depth of 14 m and is approximately 430 m wide at the study site (Gonzalez 2011). The study area was approximately 0.7 km^2. Shore-based observations were conducted from an observation pier adjacent to the Texas A&M University at Galveston boat basin (Figure 3). The pier is approximately 5 m wide and extends into the channel, providing an unobstructed view of the dolphins and both recreational and industrial boats passing by. Unlike a traveling research vessel, the stationary study site provided the advantage of eliminating interference with dolphin behavior as a confounding factor (Nowacek et al. 2001; Constantine et al. 2004).

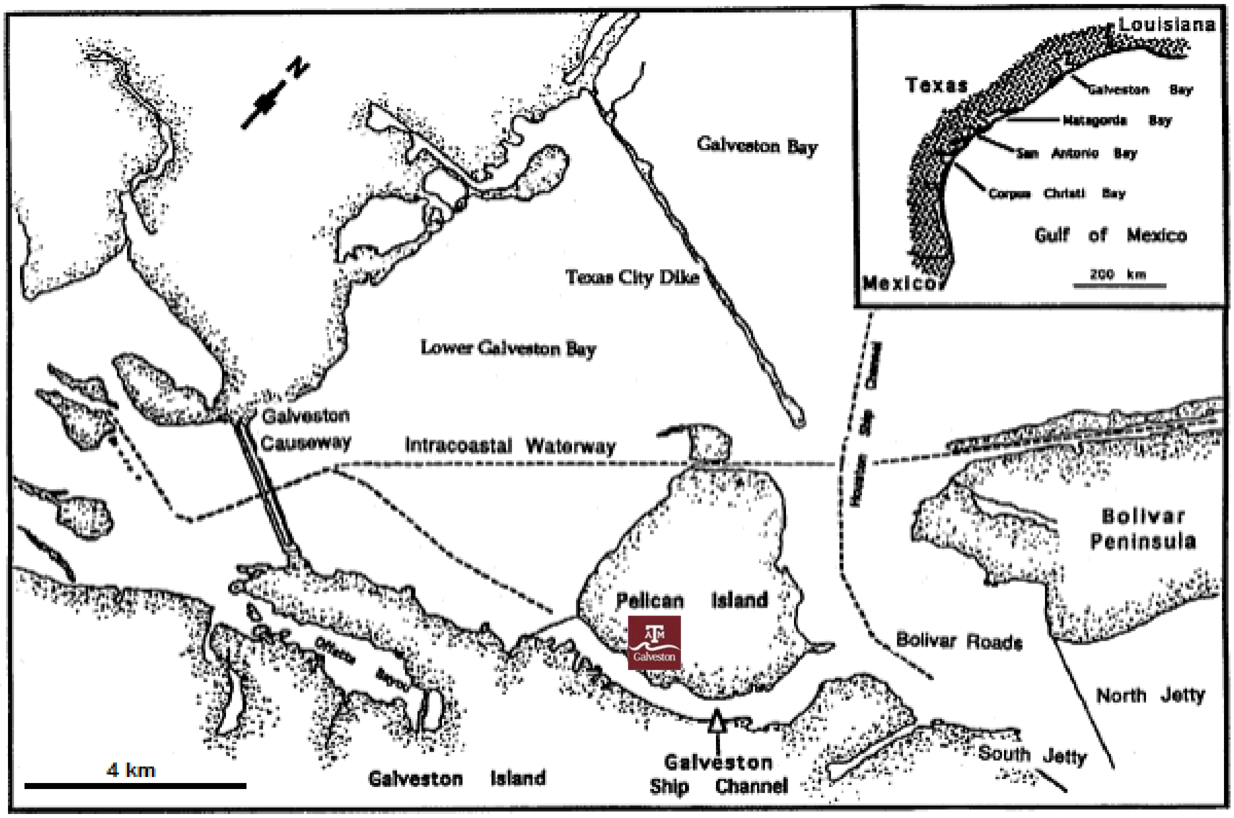

Figure 1. Map of the coastal areas within Galveston Bay (Fertl 1994). The Galveston Ship Channel is identified by an arrow and is located between Pelican Island and Galveston Island. The location of Texas A&M University at Galveston is denoted by the university's logo. The much larger Houston Ship Channel runs essentially north-south, and is shown here as between Pelican Island and the Bolivar Peninsula.

Figure 2. Map of Houston/Galveston Complex. Pelican Island and the Galveston Ship Channel, the study site, are indicated at the entrance to Galveston Bay. The Houston Ship Channel extends northwest from Galveston Bay (Integration and Application Network 2010).

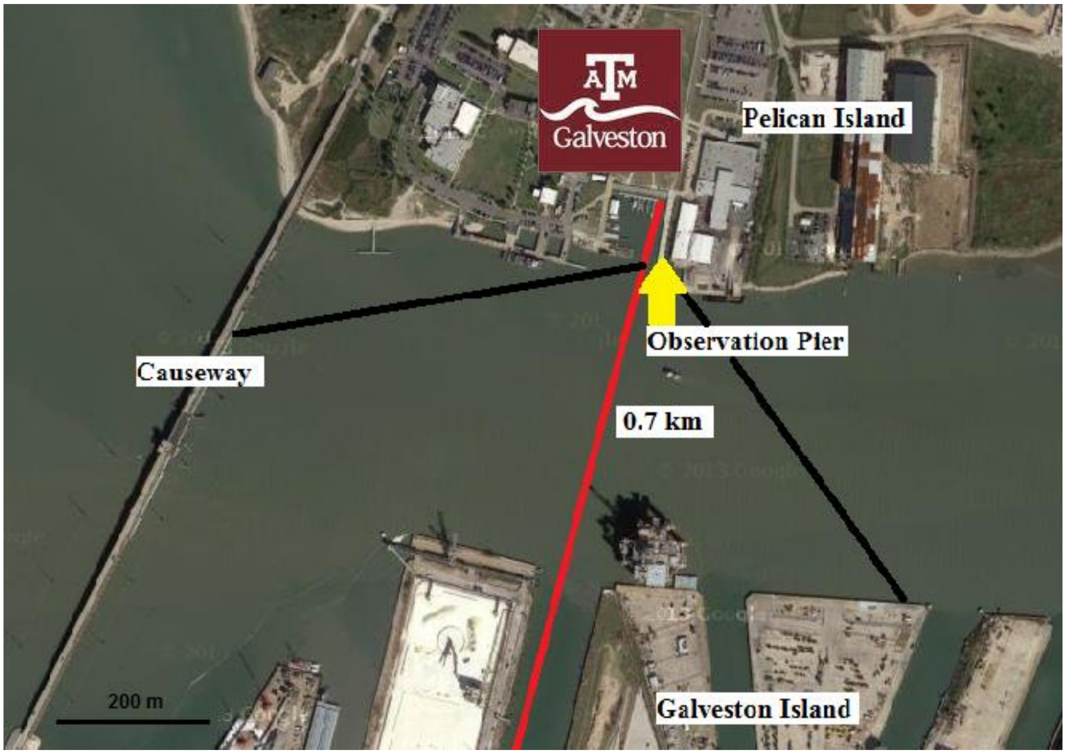

Figure 3. A map of the study area in the Galveston Ship Channel. Texas A&M University at Galveston is denoted by the university's logo. The yellow arrow identifies the observation pier where I observed dolphins and boats during hour long focal follows. The black lines indicate my line of vision, approximately 0.5 km^2 in area (Google Maps 2010).

Data Collection

One hour-long surveys were conducted from the observation pier at Texas A&M University at Galveston (Figure 3) up to three times daily between 8:00-9:00 (morning), 12:45-14:45 (midday), and 16:00-18:00 (afternoon) from August through December 2012. Dolphin group sizes, number of boats, type of boats, and predominant behavior of dolphin groups were recorded during each survey. Data were collected when dolphins and boats entered my line of vision and I followed them until either they left my line of vision or the one hour observation period ended. I defined a group of dolphins as one or more individuals engaged in the same behaviors within approximately 100 m of each other. If more than one dolphin group was in my line of vision during a survey, I followed each group and recorded the predominant behavior of the groups and group sizes separately. Throughout each survey, I constantly scanned the area for dolphins. If dolphin groups separated or fused, I recorded the change in group size and behavior and used the new group size in my statistical analysis. The predominant group behaviors were categorized as traveling, socializing, foraging, resting, or unknown (Table 1). Only one behavior was assigned to each group, and it was the behavior observed most consistently by most members of the group for the majority of the survey. Boats were categorized as either industrial or nonindustrial. Industrial boats included container ships, barges, and tugboats. Nonindustrial boats included research vessels, commercial boats, and recreational boats, such as sailboats, speed boats, fishing boats, trawlers, yachts, and kayaks. Sometimes no dolphins were present during surveys and at other times no boats were present during surveys.

Table 1. Descriptions of the predominant dolphin behaviors. The five behavioral categories recorded in the Galveston Ship Channel included traveling, socializing, foraging, resting and unknown.

Traveling (T)	individuals swimming together at moderate to fast pace in one general direction
Socializing (S)	group touching, splashing, mating or leaping out of water
Foraging (F)	searching for or ingesting prey, indicated by long dives and sometimes flukes out of water
Resting (R)	individuals swimming together slowly with slow surfacing, typically in one general direction
Unknown (U)	unable to clearly identify behavioral state

Table adapted from Pearson 2008

Data Analysis

Statistical analyses were performed in Microsoft Excel 2010. Chi square contingency tests were used to assess changes in behavior of dolphin groups relative to group size, time of day, and number of boats. Contingency tests were also used to determine the relationships between boat type and dolphin behavior, time of day, and number of boats. Only traveling, socializing, and foraging behaviors were included in the statistical analysis, as unknown and resting behaviors were infrequent (<5% of observations). When multiple groups within one hour-long survey were observed performing different predominant group behaviors, the behavior of the group with the largest group size was included in the chi-square contingency test. The number of boats was grouped into 0-1, 2-4, and 5+ and dolphin group sizes were grouped into 0, 1-4, and 5+ because these divisions led to relatively even splits of the data in the contingency tests.

CHAPTER III

RESULTS

Ninety-four hour-long surveys were conducted over 48 survey days, of which 36 surveys were in the morning (34% of groups, n=27), 27 surveys at midday (25% of groups, n=20), and 31 in the afternoon (41% of groups, n=33; Figure 4). Dolphins were sighted on 98% of the survey days. Of the 80 groups recorded, I observed 555 dolphins. Dolphin group sizes ranged from 1 to 32 individuals, with a mean of 6.9 (S.D.= ± 5.4). Foraging was the most common behavior observed in the groups (63% of follows, n= 50), followed by socializing (26% of follows, n=21), and traveling (11%, of follows n=9; Figure 5). Boats were present 86% of the time when dolphins were present.

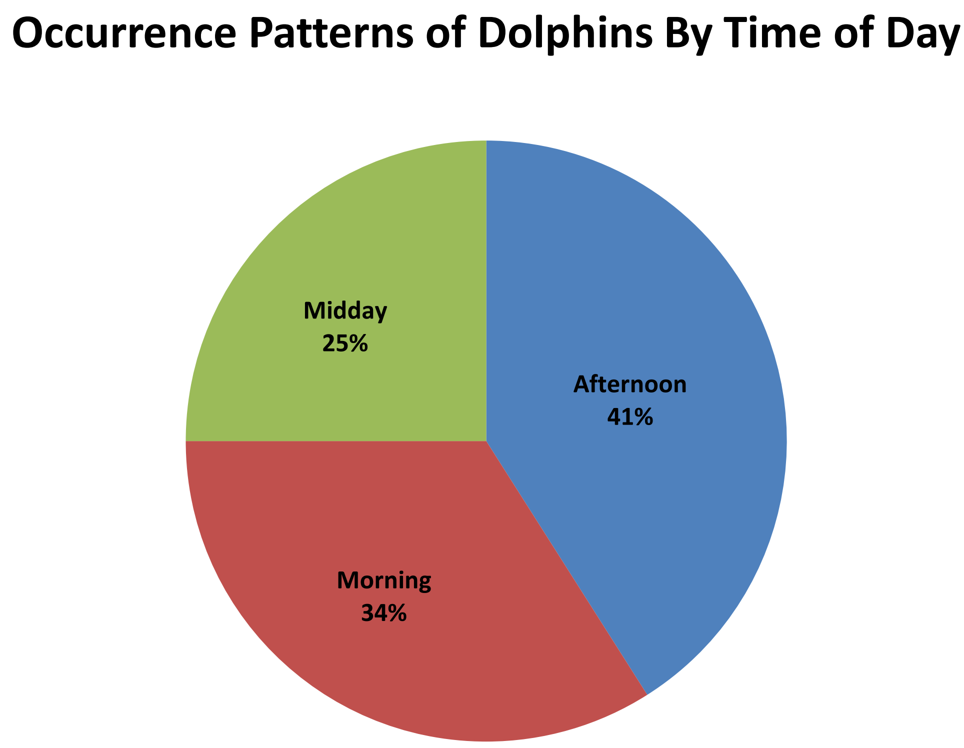

Figure 4. Daily occurrence patterns of dolphins. Blue= percent dolphin groups seen in the afternoon (16:00-18:00). Red= percent dolphin groups seen in the morning (8:00-9:00). Green= percent dolphin groups seen at midday (12:45-14:45).

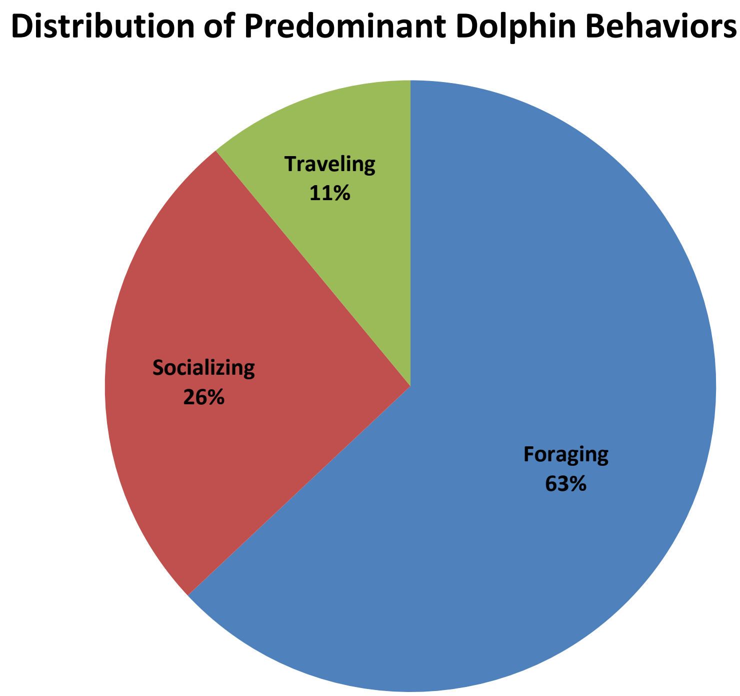

Figure 5. Distribution of predominant group behaviors observed during hour-long surveys. Each color represents a different predominant group behavior. Blue= foraging behavior (n=50), red= socializing behavior (n=21), and green= traveling behavior (n=9).

Of the 700 boats sighted, 83% were nonindustrial (n=581) and 17% were industrial (n=119; Figure 6). The nonindustrial boats were 82% powerboats (n=572) and 1% sailboats (n= 9), but were pooled together to have a large enough sample size for analysis. The average number of boats present during each survey was 3.8 boats (S.D. =± 4.7). Forty-three percent of boats were seen midday (n=300), 32% in the afternoon (n= 221), and 26% in the morning (n=179). The smallest number of dolphin groups was sighted midday when the largest number of boats was observed.

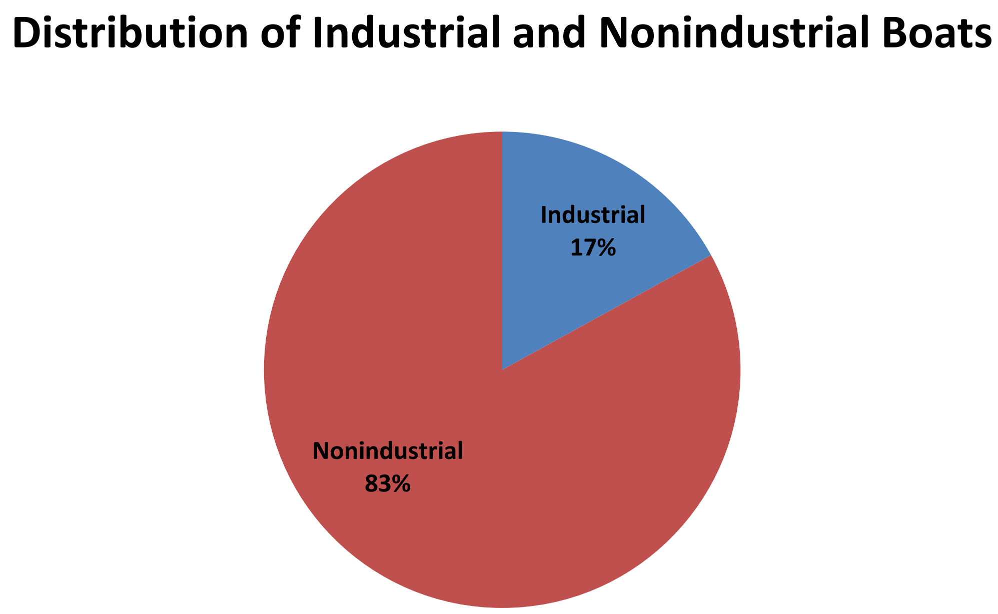

Figure 6. Two boat types present when dolphins were in the Galveston Ship Channel. Each color represents a different boat type. Red= nonindustrial boats including sailboats, speed boats, fishing boats, trawlers, yachts, and kayaks. Blue= industrial boats including container ships, barges, and tugboats.

Chi-square contingency tests indicated that dolphin behaviors varied significantly relative to the number of boats (χ^2= 9.72, d.f.= 4 at p= 0.05). As the number of boats increased, there was a relative decrease in the number of dolphin groups exhibiting traveling behaviors (Figure 7). There was a relative decrease in the number of dolphin groups exhibiting foraging behavior as the number of boats increased (Figure 7). Socializing behavior was highest with an intermediate number of boats, and was lowest with a small number of boats (Figure 7).

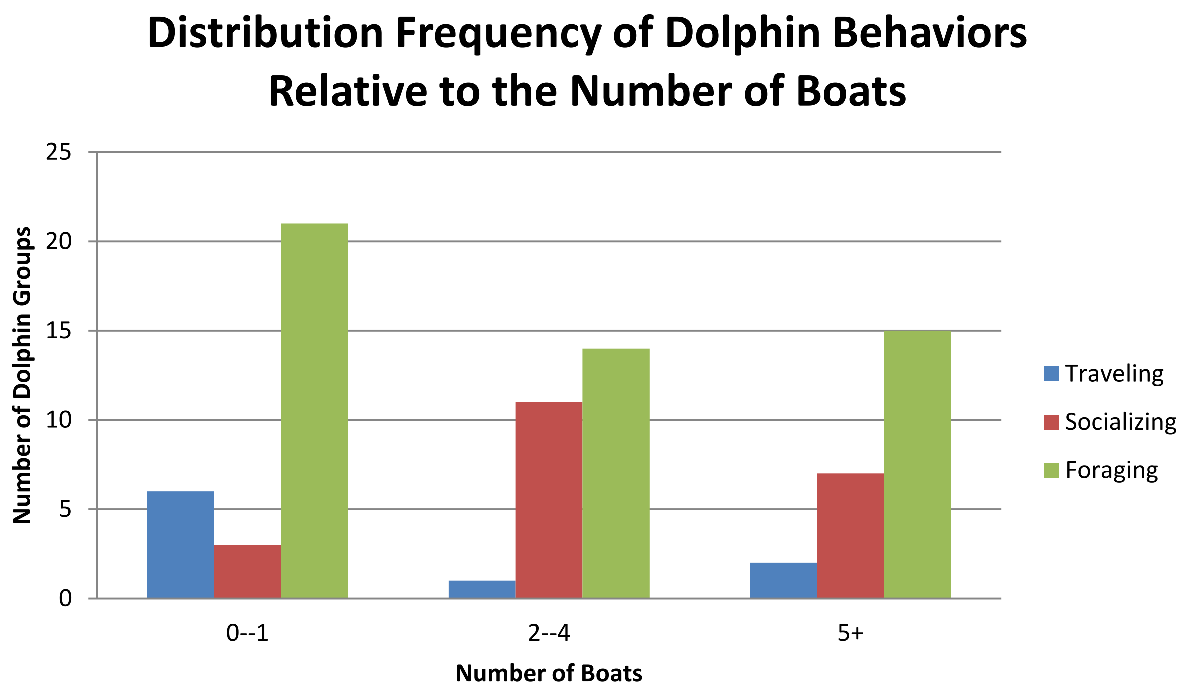

Figure 7. Distribution frequency of dolphin behaviors (blue= traveling, red= socializing, and green= foraging) are compared to the number of boats (0-1, 2-4, and 5+).

Dolphin behaviors did not change significantly relative to industrial or non-industrial types of boats (χ^2= 2.60, d.f.= 1 at p= 0.05). Traveling and socializing behaviors were grouped together as non-foraging behavior because the sample size of traveling and socializing behavior when industrial boats were present was too small (n=4 and n=21) to perform a chi-square test when they were not grouped together.

Behaviors varied significantly relative to the group size (χ^2= 9.51, d.f.= 4 at p= 0.05). Foraging behavior decreased as group size increased, whereas socializing behavior increased with increasing group size (Figure 8). Traveling behavior was slightly higher with smaller group sizes and lowest with intermediate-sized groups (Figure 8).

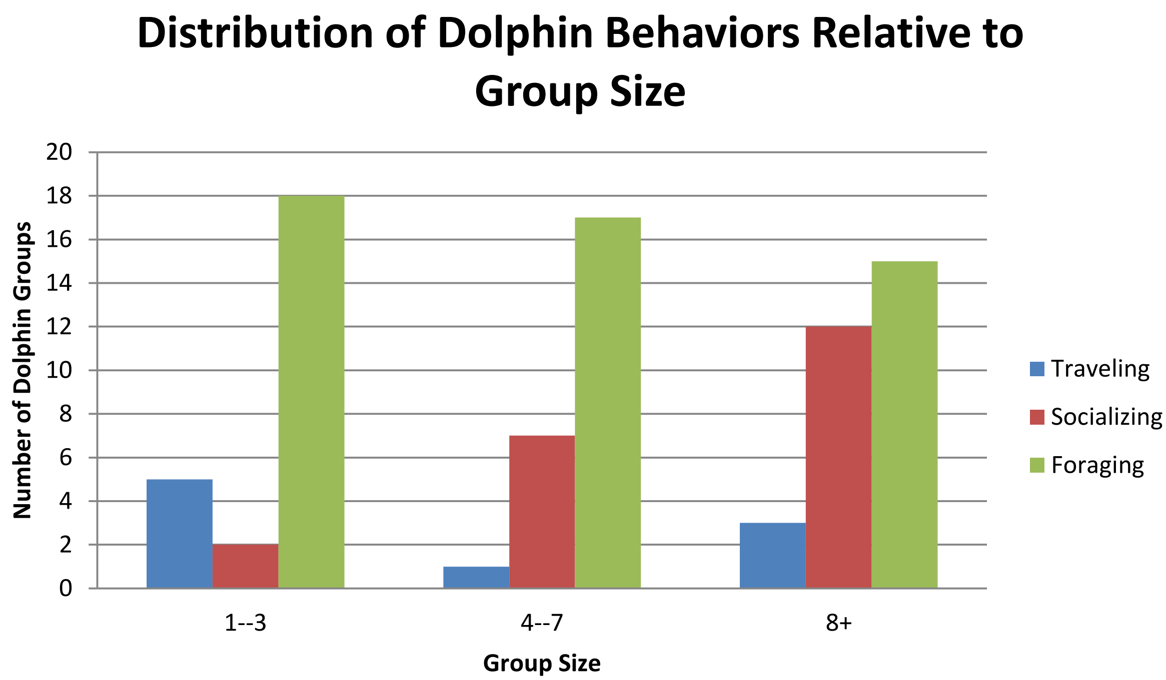

Figure 8. Distribution frequency of dolphin behavior (blue= traveling, red= socializing, and green= foraging) are compared to dolphin group size (1-3, 4-7, and 8+).

Behaviors did not change significantly with time of day (χ^2= 9.02, d.f.= 4 at p= 0.05). In the morning, dolphins showed the least amount of traveling behavior with the least number of boats present. Traveling behavior increased throughout the day, socializing was low midday, and foraging peaked in the afternoon (Figure 9).

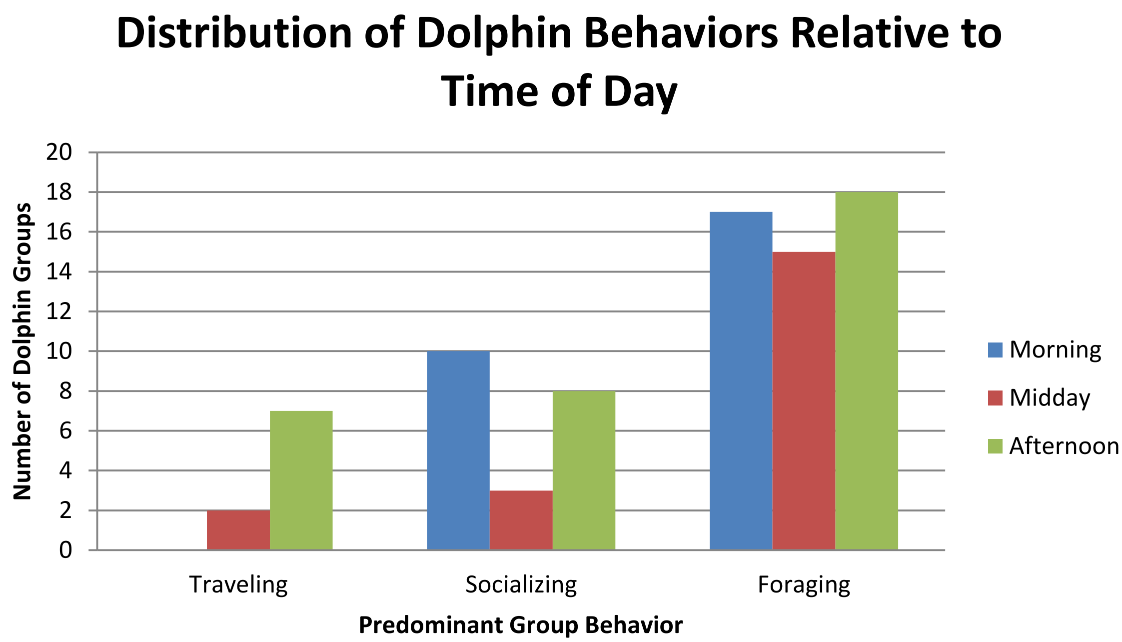

Figure 9. Distribution frequency of dolphin behaviors (traveling, socializing, and foraging) relative to the time of day (blue= morning (8:00-9:00), red= midday (12:45-14:45), and green= afternoon (16:00-18:00)).

The type of boat varied significantly with the time of day (χ^2= 14.11, d.f.= 2 at p= 0.001). The number of industrial boats increased with time of day (Figure 10). The number of nonindustrial boats was lowest in the morning, peaked midday, and decreased in the afternoon (Figure 10).

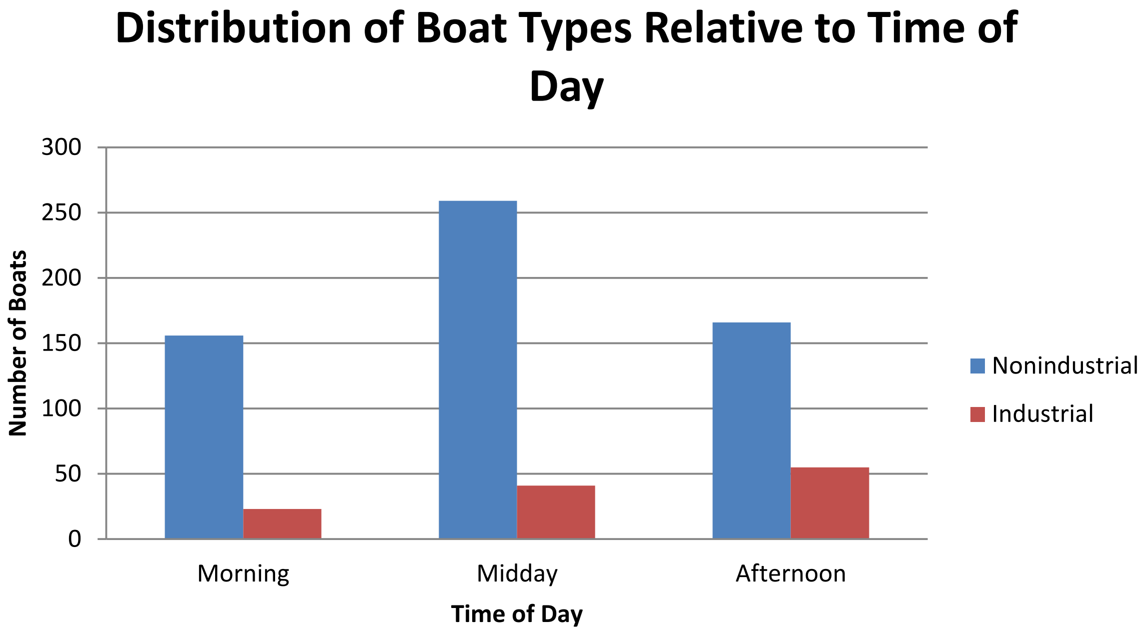

Figure 10. Distribution frequency of boat type. Blue= nonindustrial boats including sailboats, speed boats, fishing boats, trawlers, yachts, and kayaks. Red= industrial boats including container ships, barges, and tugboats. The three times of day are morning (8:00-9:00), midday (12:45-13:45), and afternoon (16:00-18:00).

The size of dolphin groups varied significantly relative to boat type (χ^2= 11.14, d.f.= 2 at p= 0.01). Smaller groups were found in the presence of industrial boats compared to non-industrial boats (Figure 11). The highest number of nonindustrial and industrial boats was observed when no dolphins were present (Figure 11).

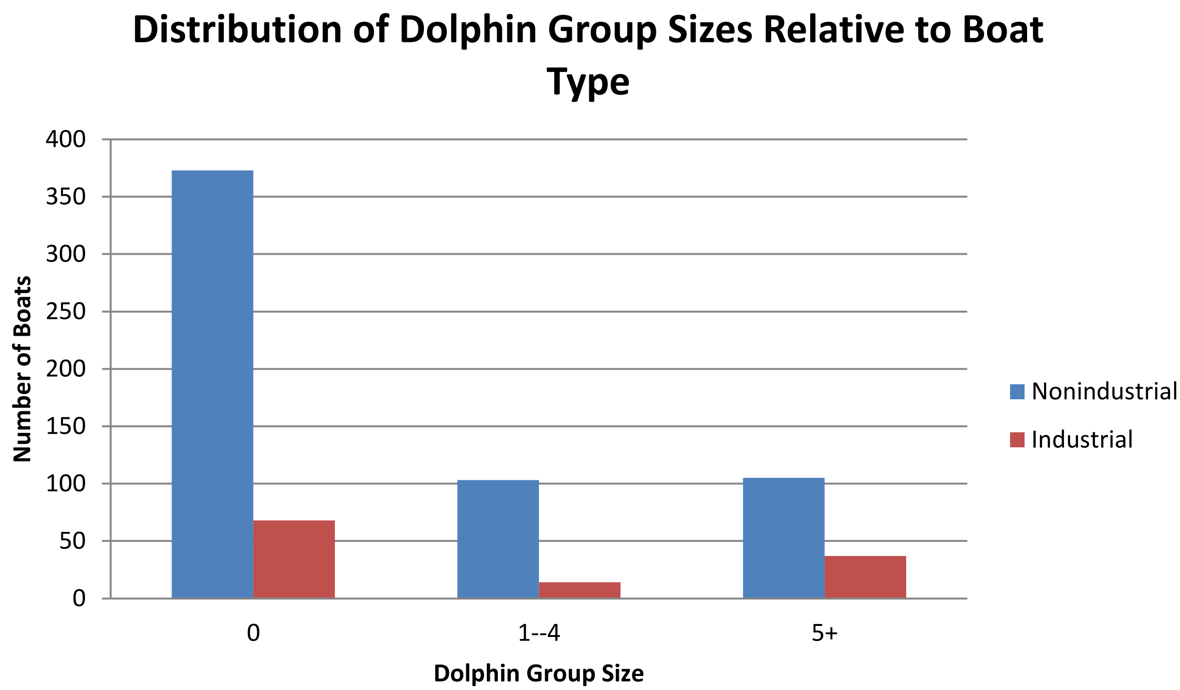

Figure 11. Distribution frequency of dolphin group size (0, 1-4, and 5+) relative to boat type (blue= nonindustrial boats including sailboats, speed boats, fishing boats, trawlers, yachts, and kayaks and red= industrial boats including container ships, barges, and tugboats).

CHAPTER IV

DISCUSSION

The high rate of common bottlenose dolphin sightings from a stationary position during the study period (98% of days) indicates that the Galveston Ship Channel is a frequently used habitat by dolphins and supports the need to understand their behavioral responses to boats as increased boat traffic will result from expansion of the Panama Canal. My study did not assess if the same dolphins were re-sighted over the study period. Such information could be useful to assess site fidelity and determine if there is individual variation in response to boats.

Dolphin behaviors varied significantly relative to the number of boats. As the number of boats increased, traveling behavior decreased. This result was contrary to my prediction and previous findings that traveling behaviors increase when boats approach (Wells 1993; Lusseau 2003). The observed trend was congruent with a study in Jervis Bay, Australia. Lemon et al. (2006) found that Indo-pacific bottlenose dolphin behaviors changed from traveling to milling in the presence of dolphin-watching tour boats. Milling was defined as dolphins moving in various directions with no observable surface behaviors (Lemon et al. 2006). A switch from resting to milling behavior upon approach of dolphin-watching tour boats has also been reported for bottlenose dolphins in the Bay of Islands, New Zealand (Constantine et al. 2004).

No significant changes in dolphin behaviors occurred relative to the type of boats in the Galveston Ship Channel. I did not include tour boats in my study, which typically follow dolphin groups, as no tour boats passed through the study area. Although Lemon et al. (2006) and Constantine et al. (2004) found that dolphins changed their behavior in response to dolphin-watching tour boats, they note that tour boats must be considered independently from other types of boats, as they directly target dolphins by moving with them.

It is important to study how noise affects the behaviors of marine mammals so that these anthropogenic factors can be limited if they are creating a disturbance. Areas with heavy boat traffic that contribute to sound pollution can have negative effects on dolphin behavior and residency. Specifically, anthropogenic noises may interfere with short-term and long-term behavior, reduce echolocation abilities, and cause hearing impairment (Richardson and Würsig 1997). A positive correlation was found between increased ambient sea noise and the seasonal displacement of common bottlenose dolphins from noisy areas in the waters off the Cres–Lošinj archipelago, Croatia, during heavy periods of boating (Rako et al. 2013). A study in Saguenay-St. Lawrence Marine Park, Canada, found that loud noises from container ships and inflatable boats in a heavily-trafficked area could potentially interfere with beluga (*Delphinapterus leucas*) behavior and fitness, but that inflatable boats had a significantly larger interference with beluga vocalizations than the larger ships (Mcquinn et al. 2011). In Aberdeen harbor, Scotland, bottlenose dolphins exhibited generally positive reactions, such as bow-riding and foraging, in the presence of large boats, and negative responses, such as increased dive-time and traveling away from boats, in the presence of small boats (Sini et al. 2005). The results from these studies suggest that smaller nonindustrial boats have a more negative effect on marine mammal behavior than larger industrial boats. In the Galveston Ship Channel, industrial ships comprised only 17% of the boats recorded, whereas 83% of boats were nonindustrial. As boat traffic increases in the next few years, boat type should be considered when enforcing any regulations if needed, especially in regulating the number of recreational boats permitted to facilitate the Galveston Ship Channel.

Another aspect to consider when assessing the health of the dolphins in the Galveston Ship Channel is the number of stranding events and the probable cause of each stranding. Common bottlenose dolphins comprised 80% of strandings along the Texas Coast from 1980 through 2004 and the Galveston Ship Channel was one of the top three locations for highest density of strandings (Mullins 2008). Mullins (2008) describes several causes for stranding events, including anthropogenic factors such as: human-induced noises, injury from human interactions, and behavior alterations in the presence of boats (Constantine 2004).

Foraging behavior was observed most often when few boats were present, suggesting a decrease in net foraging and lowered activity budgets in the presence of many boats. Any decreases in critical behavior should be monitored closely to determine potential short-or long-term consequences. Dolphin residency in Galveston Bay could be attributed to physical and biological factors in the environment, such as the abundance of prey (Bräger et al. 1994). Fishing boats, shrimp trawlers, and cetaceans may be attracted to areas of high prey concentration for the increased likelihood of capturing food (Fertl and Leatherwood 1997). Dolphin presence and foraging behavior were higher in the Galveston Ship Channel than other areas of Galveston Bay, and appeared to reflect prey availability (Moreno 2005). However, it is difficult to quantify underwater behaviors and gather data on precise prey abundance (Moreno 2005). The Galveston Ship Channel comprises less than 1% of the entire Galveston Bay (HOGANSAC 2011), suggesting food availability may be more important to dolphins in habitat-use decisions than other physical environment factors, such as isolation from industrial development.

Bottlenose dolphins have a highly developed cognitive system with advanced visual and acoustic senses (Ridgway 1990). These qualities enhance their ability to make decisions based on past successes and failures (Moreno 2005). For example, Leatherwood (1975) describes how dolphins have learned to exploit byproducts of human activity for food. Henningsen and Würsig (1991) hypothesized that the dolphins might tolerate disturbance and noise pollution from the Galveston and Houston Ship Channels to obtain prey easily (Maze and Würsig 1999). Bottlenose dolphins have flexible feeding tactics that facilitate the exploitation of food resources in conditions of changing availability and location (Shane et al. 1986). Fish comprise the majority of the diet of bottlenose dolphin along the Northern Gulf Coast, followed by cephalopods and crustaceans (Barros and Odell 1990). Six common fish species found in the stomachs of bottlenose dolphins along the Northern Gulf Coast (Atlantic croaker (*Micropogonias undulatas*), sand seatrout (*Cynoscion arenarius*), silver perch (*Bairdiella chrysoura*), spot (*Leiostomus xanthurus*), striped mullet (*Mugil cephalus*) and white mullet (*Mugil curema*); Gunter 1942; Barros and Odell 1990) were the most abundant commercial by-catch species caught in the Galveston area, and were in significantly higher abundance in warmer seasons (Henderson 2005). Dolphin sightings have significantly increased in warmer months, which supports the hypothesis that the dolphins are influenced by abundance of prey in the Galveston Bay (Fertl 1994).

My finding that foraging behavior decreased relative to increasing boat traffic is consistent with Steckenreuter et al.'s (2012) observed trend. Indo-Pacific bottlenose dolphins in Port Stevens, Australia, spent 66.5% less time feeding in the presence of dolphin-watching tour boats and changed their direction away from boats (Steckenreuter et al. 2012). In the Galveston Ship Channel, several boat tours that advertise dolphin-watching have been observed to alter their direction to approach dolphin groups and/or follow them (personal observations). The short-term disruption of critical behaviors (foraging, resting, and socializing) can lead to a long-term overall reduction in critical behavior, which is potentially harmful to dolphin fitness (Lusseau and Higham 2004; Steckenreuter et al. 2012).

Contrary to my prediction, socializing behavior did not decrease with increasing vessel numbers. Decreases in socializing behavior in the presence of boats have been reported in several other studies (Wells 1993; Lusseau 2003; Constantine 2004; Steckenreuter et al. 2012). While socializing behaviors changed with vessel traffic in my study, they did not change directionally. One hypothesis why no directional changes in social behavior were observed could be due to the narrow width of the Galveston Ship Channel. The confined space of the Galveston Ship Channel might limit the amount of socializing as these behaviors can take up much space, such as bow-riding and mating. Socializing behavior may be more of a function of group size than the number of boats.

Behaviors varied significantly relative to the group size, with socializing behaviors increasing and foraging behavior decreasing with increasing group size. My results were congruent with those of Fertl (1994), who found that the largest groups were associated with social behavior and the smallest with foraging in the Galveston Ship Channel. Deeper waters with patchy food distributions and increased predation pressure are associated with large, cooperative groups in pelagic dolphins compared to smaller coastal groups (Bertram 1978; Wells et al. 1980; Norris and Dohl 1980). However, exceptions of large group size in coastal bottlenose dolphins have been observed as well (Würsig 1978). Coastal and confined water systems, such as ship channels, typically provide a predictable and consistent food source, which may indicate why smaller groups have been observed foraging in the Galveston Ship Channel (Fertl 1994).

Smaller groups were found in the presence of industrial boats compared to non-industrial boats. This could be a result of increased group cohesion. Bottlenose dolphins have been recorded to increase group cohesion, possibly for enhanced cooperation, in the presence of boats (Bejder et al. 1999; Nowacek et al. 2001; Bejder et al. 2006a). Because bottlenose dolphins in the Galveston Ship Channel were found to decrease social behavior directly proportional to group size, smaller groups could suggest an increase in other behavior, such as foraging in the presence of industrial boats.

Behaviors did not significantly change with the time of day, although there were observed trends. I found a possible tendency that traveling behavior increased throughout the day, socializing was low midday, and foraging peaked in the afternoon. Henderson (2004) found that dolphins in Galveston Bay consistently foraged in the morning, traveled at midday, and socialized in the late afternoon. Seasonality may account for the differences in daily patterns between the two studies because Henderson's study was conducted throughout the year, whereas my study was only in the fall. Predictable daily behavior patterns have been observed in other species of dolphins. In New Zealand, dusky dolphins (*Lagenorhynchus obscurus*) exhibit off-shore feeding behaviors at night followed by socializing and acrobatic leaps in the morning in shallow coastal waters (Markowitz 2004). Hawaiian spinner dolphins (*Stenella longirostris*) exhibit a similar predictable behavior, moving off-shore to feed on the deep scattering layer (DSL) at night, remain active in the morning, and rest in the afternoon (Würsig et al. 1994).

Knowledge of a dolphin population's daily patterns can be useful for suggesting regulations when human activities begin to disturb baseline dolphin behaviors. For example, the presence of more trawlers in the morning than any other time (personal observations), and Henderson's

(2004) finding that dolphin foraging was the most common behavior in the morning, could suggest a relationship between the trawlers and dolphins, although explicit hypothesis-testing of this interaction is necessary. The stationary nature of my study site may have hindered my ability to assess dolphin-trawler interactions, as trawlers rarely passed by. Further assessment of daily patterns in the Galveston Ship Channel should incorporate boat-based observations to determine if foraging behavior increases in the morning relative to trawlers.

Although dolphin behaviors did not change with the time of day, boat type varied. The number of industrial boats increased as the day progressed, whereas nonindustrial boats were present in highest numbers in the early afternoon. These data suggest that the highest boat traffic occurs in the afternoon in the Galveston Ship Channel, and represent an important consideration for amendments to future boat regulations. Although foraging behavior was not highest in the morning at my study site, it is unknown if most dolphins are foraging significantly more in the morning further down the ship channel, as Henderson found (2004).

As boat traffic will undoubtedly increase with the expansion of the Galveston Ship Channel to accommodate post-Panamax vessels, I recommend low-intensity monitoring of the dolphins in Galveston Bay and the Galveston Ship Channel, with special attention to behavioral responses to ships. I also advise incorporating supplemental data. For example, future studies of boat influences on dolphin behavior in the Galveston Ship Channel could record the dolphin behavioral states before and after vessels approaches (i.e. Lusseau 2003), directional changes (Lemon et al 2006; Steckenreuter 2012), and changes in surfacing and diving behaviors (Janik and Thompson 1996). I suggest that future studies of bottlenose dolphin behaviors in the Galveston Ship Channel collect data across seasons to increase understanding of how the dolphins utilize the ship channels. Dolphins are known to be present in the Galveston Ship Channel year-round, with greater abundance in the shallow bays during warmer seasons and in deeper channels and the Gulf of Mexico during cooler seasons (Maze and Würsig 1999; Irwin and Würsig 2004).

Future studies that will reassess the idea of an open population consisting of resident and transient dolphins in the Galveston Ship Channel will be able to determine dolphin site-fidelity before, during, and after the expansion of the Panama Canal is completed. Though the dolphins in Galveston appear relatively unperturbed by boat traffic in the past and present, I cannot assume that this will be the case in the future, especially with the upcoming changes. While monitoring short-term behaviors is time and cost efficient, long-term studies should be implemented in Galveston Bay.

LITERATURE CITED

Barros, N.B. and Odell, D.K. (1990). Distribution and herd structure of bottlenose dolphins in the eastern tropical Pacific Ocean. In S. Leatherwood and R.R. Reeves (Eds.), *The bottlenose dolphin* (pp. 309-328). San Diego, CA: Academic Press.

Bejder, L., Dawson, S.M. and Harraway, J.A. (1999). Responses by Hector's dolphins to boats and swimmers in Porpoise Bay, New Zealand. *Marine Mammal Science*, 15(3), 738-750.

Bejder, L., Samuels, A., Whitehead, H., and Gales, N. (2006a). Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. *Animal Behaviour*, *72*(5), 1149-1158.

Bejder L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R.C., Heithaus, M., Watson-Capps, J., Flaherty, C., and Kruetzen, M. (2006b). Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology*, 20(6), 1791–1798.

Bertram, B.C.R. (1978). Living in groups: predators and prey. In J.R. Krebs and N.B. Davies (Eds.), *Behavioural Ecology: an evolutionary approach* (pp. 64-96). Oxford: Blackwell Scientific.

Bräger, S., Würsig, B., Acevedo, A. and Henningsen, T. (1994). Association patterns of bottlenose dolphins (*Tursiops truncatus*) in Galveston Bay, Texas. *Journal of Mammalogy*, 75(2), 431-437.

Candelaria-Ley, R.I. (2001). Frequency and amplitude shifts in the whistle vocalizations of bottlenose dolphins in response to anthropogenic noise. (M.S. Thesis). Texas A&M University, College Station, Texas.

Clean Water Act of 1972, 33 U.S.C. § 1251 et seq. (2002). Retrieved from http://epw.senate.gov/water.pdf

Constantine R., Brunton D.H. and Dennis T. (2004). Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. *Biological Conservation*, 117, 299–307.

Fertl, D.C. (1994). Occurrence patterns and behavior of bottlenose dolphins (*Tursiops truncatus*) in the Galveston Ship Channel, Texas. *The Texas Journal of Science*, 46(4), 299-317.

Fertl, D. and Leatherwood, S. (1997). Cetacean interactions with trawls: a preliminary review. *Journal of Northwest Atlantic Fishery Science*, 22, 219-248.

Google Maps. (2010). [Trinity College, Hartford, Connecticut] [Street map]. Retrieved from https://maps.google.com/

Gonzalez, L. A. (2011). Chapter 4 The Human Role, Present. *The State of the Bay: A Characterization of the Galveston Bay Ecosystem, Third Edition*. L. J. Lester and L. A. Gonzalez (Eds). Texas Commission on Environmental Quality, Galveston Bay Estuary Program, Houston, Texas, 37 pp.

Gunter, G. (1942). Contributions to the natural history of the bottlenose dolphin, *Tursiops truncatus* (Montagu), on the Texas coast, with particular reference to food habits. *Journal of Mammalogy*, 23, 267-276.

Henderson, E.E. (2004). *Behavior, association patterns and habitat use of a small community of bottlenose dolphins in San Luis Pass, Texas*. (M.S. Thesis). Texas A&M University, College Station, Texas.

Henningsen, T. and Würsig, B. (1991). Bottle-nosed dolphins in Galveston Bay, Texas: Numbers and activities. In: *Proceedings of the Fifth Annual Conference of the European Cetacean Society. Sandefjord, Norway*. pp. 36–38.

HOGANSAC. (2011). Sharing our bay. *Houston-Galveston Navigation Safety Advisory Committee*. Retrieved from www.galvestonpilots.com/HOGANSACSharingourbay.pdf

Hricko, A. (2012). Progress and Pollution: Port Cities Prepare for the Panama Canal Expansion. *Environmental Health Perspectives*, 120(12), a470–a473.

Integration and Application Network. (2010). *Illustration of Galveston Bay in Texas, USA*. Retrieved from http://ian.umces.edu/imagelibrary/displayimage-5882.html

Irwin, L.J. and Würsig, B. (2004). A small resident community of bottlenose dolphins, *Tursiops truncatus*, in Texas: monitoring recommendations. *Gulf of Mexico Science*, 22(1), 13-21.

Janik, V.M. and Thompson, P.M. (1996). Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. *Marine Mammal Science*, 12(4), 597-602.

Knight, K. (2008). The Implications of Panama Canal Expansion to U.S. Ports and Coastal Navigation Economic Analysis. *U.S. Army Corps of Engineers, IWR White Paper*. Retrieved from http://www.iwr.usace.army.mil.lib-ezproxy.tamu.edu:2048/docs/iwrreports/WhitePaperPanamaCanal.pdf

Kompanik, E., Stachowski, S., and Rosen, Z. (2012). We need to respond now to Panama Canal upgrade. *Houston Chronicle*. Retrieved from http://www.chron.com/opinion/outlook/article/We-need-to-respond-now-to-Panama-Canal-upgrade-3813829.php

Leatherwood, S. (1975). Some observations of feeding behavior of bottlenosed dolphins (*Tursiops truncatus*) in the northern Gulf of Mexico and (*Tursiops cf. T. gilli*) off southern California, Baja California, and Nayarit, Mexico. *Marine Fisheries Review*, 37, 10-16.

Leatherwood, S. and Reeves, R.R. (1982). Bottlenose dolphins and other toothed cetaceans. In J.A. Chapman and G.A. Feldhamer (Eds.), *Wild mammals of North America* (pp. 369–414). Baltimore, MD: John Hopkins University Press.

Lemon, M., Lynch, T.P., Cato, D.H. and Harcourt, R.G. (2006). Response of travelling bottlenose dolphins (*Tursiops aduncus*) to experimental approaches by a powerboat in Jervis Bay, New South Wales, Australia. *Biological Conservation*, 127(4), 363-372.

Lester, L.J. and L. A. Gonzalez. (2006). Galveston Bay Status and Trends Final Report. *Galveston Bay Status and Trends*. Texas Commission on Environmental Quality, Galveston Bay Estuary Program, Houston, Texas.

Lester, L.J. and L. A. Gonzalez. (2008). Galveston Bay Status and Trends Final Report. *Galveston Bay Status and Trends*. Texas Commission on Environmental Quality, Galveston Bay Estuary Program, Houston, Texas.

Lusseau, D. (2003). Effects of tour boats on the behavior of bottlenose dolphins: using Markov Chains to model Anthropogenic Impacts. *Conservation Biology*, 17(6), 1785–1793.

Lusseau, D. (2005). The residency pattern of bottlenose dolphins (*Tursiops spp*.) in Fiordland, New Zealand, is related to boat traffic. *Marine Ecology Progress Series*, 295, 265–272.

Lusseau, D. and Higham, J.E.S. (2004). Managing the impacts of dolphin-based tourism through the definition of critical habitats: the case of bottlenose dolphins (*Tursiops spp*.) in Doubtful Sound, New Zealand. *Tourism Management*, 25(6), 657-667.

Markowitz, T. M. (2004). *Social organization of the New Zealand dusky dolphin.* (Doctoral dissertation). Texas A&M University, College Station, Texas.

Maze, K.S. and Würsig, B. (1999). Bottlenose dolphins of San Luis Pass, Texas: Occurrence patterns, site-fidelity, and habitat use. *Aquatic Mammals*, 25(2), 91-103.

Mcquinn, I.H., Lesage, V., Carrier, D., Larrivée, G., Samson, Y., Chartrand, S., Michaud, R., and Theriault, J. (2011). A threatened beluga (*Delphinapterus leucas*) population in the traffic lane: vessel-generated noise characteristics of the Saguenay-St. Lawrence Marine Park, Canada. *The Journal of the Acoustical Society of America*, 130(6), 3661-3673.

Miller, L.J., Solangy, M. and Kuczaj, S.A. (2008). Immediate response of Atlantic bottlenose dolphins to high-speed personal watercraft in the Mississippi Sound. *Journal of Marine Biological Association of the United Kingdom*, 88(6), 1139-1143.

Moreno, M.P.T. (2005). *Environmental predictors of bottlenose dolphin distribution and core feeding densities in Galveston Bay, Texas*. (Doctoral dissertation). Texas A&M University, College Station, Texas.

Mullins, R.L. (2008). *Characterizing Marine Mammal Stranding Events along the Texas Coast*. (M.S. Thesis). Texas A&M University, College Station, Texas.

Norris, K.S. and Dohl T.P. (1980). The structure and function of cetacean schools. In L.M. Herman (Ed.), *Cetacean behavior: Mechanisms and function* (pp. 211-261). Wiley-Interscience, New York, NY.

Nowacek, S.M., Wells, R.S. and Solow, A.R. (2001). Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. *Marine Mammal Science*, 17(4), 673-688.

PHA. (2012). Overview. *Port of Houston Authority*. Retrieved from: http://www.portofhouston.com/about-us/overview/

Pearson, H.C. (2008). Fission-fusion sociality in dusky dolphins (*Lagenorhynchus obscurus*), with comparisons to other dolphins and great apes. (Ph.D. Thesis), Texas A&M University, College Station, Texas, United States.

Rako, N., et al. (2013). Leisure boating noise as a trigger for the displacement of the bottlenose dolphins of the Cres–Lošinj archipelago (northern Adriatic Sea, Croatia). *Marine Pollution Bulletin.*

Richardson, W.J. and Würsig, B. (1997). Influences of man-made noise and other human actions on cetacean behavior. *Marine and Freshwater Behaviour and Physiology*, 29(1-4), 183-209.

Ridgway, S.H. (1990). Distribution and herd structure of bottlenose dolphins in the eastern tropical Pacific Ocean. In S. Leatherwood and R.R. Reeves (Eds.), *The bottlenose dolphin* (pp. 69-97). San Diego, CA: Academic Press.

Shane, S.H., Wells, R.S. and Würsig, B. (1986). Ecology, behavior and social organization of the bottlenose dolphin: a review. *Marine Mammal Science*, 2(1), 34-63.

Shane, S.H. (1990). Behavior and Ecology of the bottlenose dolphin at Sanibel Island, Florida. In S. Leatherwood and R.R. Reeves (Eds.), *The bottlenose dolphin* (pp. 245-265). San Diego, CA: Academic Press.

Sini, M.I., Canning, S.J., Stockin, K.A. and Pierce, G.J. (2005). Bottlenose dolphins around Aberdeen harbour, north-east Scotland: a short study of habitat utilization and the potential effects of boat traffic. *Journal of the Marine Biological Association of the United Kingdom*, 85(6), 1547-1554.

Steckenreuter, A., Möller, L. and Harcourt, R. (2012). How does Australia's largest dolphin-watching industry affect the behavior of a small and resident population of Indo-Pacific bottlenose dolphins? *Journal of Environmental Management*, 97, 14-21.

Thomas, E. (2013). Boat Tours of the Panama Canal. *USA Today: Travel Tips*. Retrieved from http://traveltips.usatoday.com/boat-tours-panama-canal-16796.html#http%3A//traveltips.usatoday.com?&_suid=13642624165050053906412982 45341

Thorpe,W.H. (1963). *Learning and Instinct in Animals*. Methuen: London. S. de la Torre, C.T. Snowdon and M. Bejarano (2000). Effects of human activities on wild pygmy marmosets in Ecuadorian Amazonia. *Biological Conservation*, 94, 153-163.

USACE. (2009). U.S. waterway data: principal ports of the United States. *U.S. Army Corps of Engineers, Waterborne Commerce Statistics Center*. Retrieved from http://www.iwr.usace.army.mil/ndc/data/datappor.htm.

USACE. (2012). U.S. Port and Inland Waterways Modernization: Preparing for Post-Panamax Vessels. *U.S. Army Corps of Engineers, Institute for Water Resources*. Retrieved from http://www.iwr.usace.army.mil/index.php?option=com_content&view=article&catid=44:project-stories&id=820:ports-and-waterways-expansion-study&Itemid=4

Wells, R.S., Irvine, A.B., and Scott, M.D. (1980). The social ecology of inshore odontocetes. In L.M. Herman, (Ed.), *Cetacean behavior: Mechanisms and function* (pp. 263-317). Wiley-Interscience, New York, NY.

Wells R.S. (1993). The marine mammals of Sarasota Bay. In P. Roat, C. Ciciccolella, H. Smith, D. Tomasko (Eds.), *1992 Framework for Action*. (pp. 9.1-9.23). Sarasota National Estuary Program: Sarasota Bay, FL.

Williams, T.M., Friedl, W.A., Fong, M. L., Yamada, R. M., Sedivy, P., and Haun, J. E. (1992). Travel at low energetic cost by swimming and wave-riding bottlenose dolphins. *Nature*, 355(6363), 821-823.

Würsig, B. (1978). Occurrence and group organization of Atlantic bottlenose porpoises (*Tursiops truncatus*) in an Argentine bay. *Biological Bulletin*, 154(2), 348-359.

Würsig, B., Wells, R.S., Norris, K.S. and Würsig, M. (1994). A spinner dolphin’s day. In: K.S. Norris, B. Würsig, R.S. Wells, and M. Würsig, (Eds.), *The Hawaiian Spinner Dolphin* (pp. 65-102). Berkeley, CA: University of California Press.