BEHAVIORAL PATTERNS OF COMMON BOTTLENOSE DOLPHINS IN GALVESTON, TEXAS AND PROTECTION STRATEGY DEVELOPMENT

A Thesis

by

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ABSTRACT

The objective of this study is to establish a protection strategy for common bottlenose dolphins in the Galveston, Texas area based on quantifiable behavioral patterns. This area is subjected to regular vessel traffic entering the commercial ship channels. I used The Galveston-Port Bolivar ferry at the entrance of the ship channels as a platform for assessing variations in dolphin group behavior. Over six months, I conducted 1,412 hours of observation. Resting behavior occurred significantly more frequently than expected in Bolivar; traveling, more frequently in the passage; and foraging more frequently in Galveston ($p < 0.01$). Traveling dominated in open water ($p < 0.01$). Foraging was most prevalent in the morning and resting in the evening ($p < 0.01$). Group size deviated significantly across the assessed factors in a negative binomial hurdle model ($p < 0.01$). Calves were equally common in all three zones ($p > 0.01$), but more common in foraging groups and less common in resting groups ($p < 0.01$). Groups with calves were most frequently found at intermediate distances to shore ($p < 0.01$), and in the morning time ($p < 0.01$). Vessel activity was highest in Galveston and lowest in Bolivar, and decreased from the morning to afternoon to evening ($p < 0.01$)

Next, existing regulation, management, and educational outreach strategies were evaluated to determine their effectiveness, appropriateness, and applicability to marine mammals in Galveston Bay. In many cases, these strategies were insufficient to meet the unique needs of the Galveston area. Federal law enforcement officials are often

overtaxed and unable to enforce existing laws; I advise that the State of Texas pass a state law for marine mammal protection and issue a voluntary dolphin rest zone in Bolivar. Existing management strategies are better suited to large corporations, but participation may be beyond the means of smaller companies. I propose a local "Responsible Marine Business" program be instituted in Galveston to promote conservation on a local scale. Public education is critical to any conservation effort; I recommend a multi-pronged outreach, including public workshops, school programs, and educational signage installation to promote bottlenose dolphin protection and encourage ecotourism.

DEDICATION

For my mom and dad, who encouraged me to follow passion over prosperity.

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NOMENCLATURE

CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
EEZ	Exclusive Economic Zone
EMAS	Eco-Management and Audit Scheme
EMS	Environmental Management System
ESA	Endangered Species Act of 1973
EU	European Union
GoM	Gulf of Mexico
IATCC	Inter-American Tropical Tuna Commission
ICRW	International Convention for the Regulation of Whaling
ISO	International Organization for Standardization
IWC	International Whaling Commission
MMPA	Marine Mammal Protection Act of 1972
MSC	Marine Stewardship Council
NGO	Non-Governmental Organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PBR	Potential Biological Removal
RMB	Responsible Marine Businesses
TPWD	Texas Parks and Wildlife Department

TxDOT	Texas Department of Transportation
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNCLOS	United Nations Convention on the Law of the Sea
USCG	United States Coast Guard
WWF	World Wildlife Fund

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1. INTRODUCTION AND OVERVIEW

1.1 Motivation and Desired Outcomes

The primary goal of this study is to establish a management strategy and public educational outreach plan for common bottlenose dolphins (*Tursiops truncatus*) in the Galveston, Texas area based on quantifiable spatial and temporal behavioral occurrence patterns. The particularly heavy and steady stream of ships including regular ferry traffic in the Galveston and Houston ship channels (Merrick and Harrald 2007) presents a venue for significant interactions between vessels and animals. The Galveston-Port Bolivar ferry runs continuously throughout the year except during severe weather, with between one and five vessels active in the ferry lane at a given time; traffic generally reaches a peak during the summer months (June-August) (Mallini 2001). Common bottlenose dolphins frequent the area surrounding the ferry, which is popular with tourists and locals. Thus, this location provides an opportunity to base recommendation for improving both dolphin management and conservation efforts on their existing habitat use patterns.

Several studies have attempted to quantify the responses of common bottlenose dolphins to vessels (Nowacek et al. 2001, Mattson et al. 2005, Miller et al. 2008), though a comprehensive study of behavioral variation in a heavy traffic area of Galveston has not yet been attempted. Additionally, this location represents a vessel traffic area generally deemed unsafe due to the operating records of shipping corporations entering the port and frequent transport of hazardous cargo (Merrick and Harrald 2007). These factors make this location a particularly extreme case of frequent vessel-animal interaction which necessitates a comprehensive management strategy. To that end, I collected data on Vessel proximity and habitat use by dolphins and to evaluate patterns of vessel traffic in the Galveston ferry lane to infer how changes in management may help to reduce the occurrence rate for disturbance of marine mammals in the area.

The second goal of this study is to determine whether the presence of calves in groups varies by location (near ferry landings or in the traffic lane) or time of day. Evidence suggests that habituation to anthropogenic activity can have adverse effects on cetacean hearing, as well as limit the effectiveness of their evasive responses to vessels (Richardson and Würsig 1997). It is possible that many factors influence the presence of calves in each location (e.g., age and sex composition of groups observed); however, determining where and when mother-calf pairs are commonly observed in this heavy traffic area may have implications for long-term population viability in this and similarly active ports. Thus, the presence of calves in specific areas merits consideration when introducing new traffic lanes or changing existing patterns in ports that have cetacean populations.

This study integrates data on behavioral patterns near the Galveston-Port Bolivar ferry to recommend improvements for industrial management relative to common bottlenose dolphins. While human induced mortality does not presently exceed potential biological removal (PBR) for bottlenose dolphins, the stock is considered depleted (Roman et al. 2013). All marine mammals are protected under the Marine Mammal Protection Act of 1972 (MMPA) (16 U.S.C. § 1361 - 1421h), though enforcement of the

MMPA by the United States Coast Guard (USCG) and National Marine Fisheries Service (NMFS) has proven challenging and is often inconsistent (Roman et al. 2013). By assessing spatial and temporal behavioral trends in Galveston, enforcement of the MMPA can be targeted by the USCG and NMFS to encompass the areas most frequently occupied by the animals. This will allow for more consistent and effective enforcement of the MMPA.

Public education is the final component of this study. Marine mammal regulations and recommendations prohibit the "taking" of all marine mammal species, where taking includes all forms of harassment or disturbance (Benson 2012). Forms of harassment include many activities that may be viewed as innocuous by the general public, including swimming with and feeding wild cetaceans (Spradlin et al. 1999). While dolphin watching is a popular tourist activity, the vessel operation practices employed often include pursuing the animals or approaching them too closely in violation NMFS's recommendations to avoid approaching dolphins within 50 yards (Spradlin et al. 1999).

The lack of consistent enforcement and public awareness demonstrates the need for an educational campaign to promote consciousness of and compliance with regulations pertaining to marine mammals. Violations of the MMPA carry civil penalties of up to $10,000 per violation, and, if convicted of knowingly violating provisions, a fine of up to $20,000 and/or up to one year in prison (16 U.S.C. § 1375). Improving public knowledge of federal statutes and safe dolphin watching practices, coupled with increased enforcement targeted within areas frequented by the animals, will facilitate the ability of the public to enjoy and learn about marine mammals while simultaneously promoting ecosystem stewardship. Coupling educational outreach with encouraging the public to observe the animals in their natural habitat will help to minimize the potential dangers to individual animals and the collective resident common bottlenose dolphin population.

1.2 Objectives

1.2.1 Broad Objective

To establish a management strategy and public educational outreach program for the Galveston-Port Bolivar ferry system to reduce the potential impact of vessel traffic on social groups of common bottlenose dolphins by grounding recommendations for policy, management, and education in the behavioral patterns of the resident population.

1.2.2 Specific Objective

- To quantify variation in social group size and group distance to the shore, to the ferry, and to other vessels
- To assess diel (morning, afternoon, and evening) variation in behavioral patterns as they relate to group size, calf presence, location (Bolivar, Galveston, and passage), and distance to the shore, to the ferry, and to other vessels
- To determine the diel (morning, afternoon, and evening) frequency of calf sightings with regard to social group distance to vessels, to shore, and to the ferry, and the presence of calves in the group

- To develop a public education outreach campaign in which educational resources and public engagement will be employed to improve awareness of and compliance with marine mammal laws
- To develop recommendations to improve marine mammal management in active ports

2. BEHAVIORAL PATTERNS OF COMMON BOTTLENOSE DOLPHINS

2.1 Introduction

2.1.1 Focal Species

Common bottlenose dolphins are globally distributed in tropical and temperate climates, both inshore and in pelagic waters (Jefferson et al. 1994). Following a year-long gestation period, they usually give birth to a single calf in the spring or summer (Boyd et al. 1999, Mann et al. 2000). They can be identified by their stocky, fusiform body shape, with a rounded melon and a shorter beak, and are typically light to very dark gray dorsally and white to pink ventrally (Jefferson et al. 1994, Würsig et al. 2000). Sexual maturity is reached at 10-15 years of age and about 2.6 meters in length for males, and about 10 years of age and 2.4 meters for females; however, a great deal of variation exists and maturity may be reached at a younger age (Boyd et al. 1999, Boness et al. 2002). In the Gulf of Mexico (GoM), individuals are typically 1.9 to 3.8 meters in length at the time they reach maturity, exhibiting slight sexual dimorphism where males are bigger than females (Jefferson et al. 1994). Calves generally reach 1.5 to 1.7 meters within the first year (Leatherwood and Reeves 1989). In captive facilities and in wild populations where long term studies have been completed, common bottlenose dolphins have been documented living up to 50 years of age, though this is atypical (Hohn et al. 1989).

A mature female will give birth to a calf every three years (Boness et al. 2002). In the GoM, peak calving season begins in February and continues through April or

May, which is somewhat earlier than other locations (Urian et al. 1996, Fernandez and Hohn 1998, Boyd et al. 1999). At birth, calves are approximately 1.15 to 1.3 meters in length, and nurse for approximately 18 months (Jefferson et al. 1994, Boyd et al. 1999, Knoff et al. 2008). Within a few months of birth, calves will begin to chase small fish while continuing to nurse (Boness et al. 2002). Though the dietary contribution of milk declines after about one year of age, nursing has been documented in significantly older individuals and in some instances may continue for up to three years (Boness et al. 2002, Knoff et al. 2008).

For a population to be managed effectively as an independent unit, the degree of connectivity between the focal population and other neighboring populations must be established. If management is effective in one area but the population's home range extends beyond the established boundaries of management, conservation efforts may prove ineffective. Genetic analysis is one means through which population connectivity can be established. A variety of distribution patterns and behavioral strategies of common bottlenose dolphins have been documented (Shane et al. 1986). Genetic evidence supports the existence of pelagic (or offshore) and nearshore (or coastal) ecotypes (Hoelzel et al. 1998, Quérouil et al. 2007). Although there are no apparent barriers to population distribution in the Western North Atlantic, there is evidence for genetically distinct populations in specific areas (Rosel et al. 2009). A high level of gene flow is maintained in pelagic populations, mediated by long-distance travel by individuals and apparently large home ranges; in the North Atlantic, the eastern and western pelagic populations are not genetically differentiated (Quérouil et al. 2007). This suggests that management of pelagic populations may prove challenging.

For inshore populations, however, localized management strategies would be useful. Within the Western North Atlantic, the population in the GoM is significantly genetically differentiated from the populations along the eastern seaboard of the United States (Rosel et al. 2009). The common bottlenose population in the GoM constitutes a population which is genetically independent from the worldwide species distribution. Common bottlenose dolphins can be found throughout the GoM in a myriad of different habitats, ranging from inshore bays and estuaries, to coastal waters, to deep waters off the continental slope (Fulling et al. 2003). In the GoM, they are generally observed at depths of less than 1,000 meters (Davis and Fargion 1995). Therefore, the population in the GoM can be analyzed and managed independently of other common bottlenose dolphin populations throughout the world. Though each individual inshore area will have different specific management needs, targeting these populations in the GoM would be effective.

Common bottlenose dolphins spend the majority of their time in shallow water less than 10 meters deep (Würsig and Würsig 1979, Irvine et al. 1981, Mate et al. 1995). A variety of life history patterns ranging from regular annual migration to continuous fidelity within a particular site have been documented in common bottlenose dolphins (Bowen and Siniff 1999). Their complex social behavior varies by subpopulation, although this species exhibits the characteristics of a fission-fusion society (Wells et al. 1999).

Vocal communication behavior serves multiple functions for common bottlenose dolphins, ranging from conspecific recognition, to pod cohesion, to prey manipulation during foraging (Janik and Slater 1998, Janik 2000, Nakahara and Miyazaki 2011). Vocalizations can be categorized into four major classes: tonal signals, single bursts, click bursts, and repeat bursts(Boisseau 2005). There is evidence to indicate that individual common bottlenose dolphins in the GoM employ their own unique signature whistles as specific identification cues within their pods (Sayigh et al. 2007). Vocal behavior in cetaceans also serves as a means of navigating the environment and locating prey through echolocation (Weilgart 2007).

The bottlenose dolphin population in Galveston is relatively small. In one survey, approximately 240 individuals were recorded, though many were not sighted a second time and may have been transient individuals (Fertl 1994). Seasonal fluctuations in common bottlenose dolphin abundance exist: spring and fall surveys showed higher encounter rates than summer and winter surveys (Fertl 1994). Weller (1998) supports the low encounter rate for the winter months, noting that common bottlenose dolphins move toward inshore waters in the summer in the northern GoM, though it is unclear why the encounter rate from Fertl (1994) was low in the summer. There were no significant patterns of preferred associations with other individuals in the Galveston area, suggesting high group fluidity within the region (Bräger et al. 1994).

Several foraging strategies have been noted for dolphins in the northern GoM, including associations with shrimp boats (feeding on the fish disturbed by the shrimp net), herding schools of fish into tight bait balls, crowding fish into shallower water, and foraging independently (Leatherwood 1975). Evidence related to water temperature, dissolved oxygen, salinity, and turbidity suggest that foraging strategies are seasonal in the northern GoM (Miller and Baltz 2010).

For management purposes, assessing the degree of population connectivity is important for determining the scale at which management can be effective. Within the GoM, genetic analyses have revealed fine-scale common bottlenose dolphin population structure. Microsatellite and mitochondrial DNA analyses indicate that the common bottlenose dolphin in the GoM can be treated as genetically independent (Natoli et al. 2004). This suggests that animals in the GoM are not regularly interbreeding with animals from other populations. However, even finer scale genetic differentiation exists within the GoM (Sellas et al. 2005). The level of genetic variation within GoM populations indicates that GoM common bottlenose dolphins are either consistently interbreeding with others within their inshore home range, or interbreeding with others that remain offshore in deeper waters (Sellas et al. 2005). Additionally, patterns of long-term site fidelity in GoM populations along the United States' Gulf Coast has been documented (Miller and Baltz 2010). This suggests that individual inshore populations can be effectively managed independently of each other.

2.1.2 Vessel Interactions

Bottlenose dolphin behavior often changes due to interactions with nearby vessels; exposure to traffic may impact foraging, swimming, respiration, and vocal behavior (Weilgart 2007). Sound exposure, stemming from watercraft and other sources of marine noise, may cause a rise in stress hormones and potentially lead to long-term health problems (Romano et al. 2004). However, common bottlenose dolphins are found in a variety of habitats throughout the world (Jefferson et al. 1994), suggesting that there must exist, to some degree, a tolerance for anthropogenic noise disturbance.

Vessel traffic is a common source of disruption to cetaceans In Hilton Head Island, South Carolina, group activity behavioral changes were documented in 55% of encounters with watercraft, 67% of encounters with jet skis, 100% of encounters with shrimp boats, and 11% of encounters with large ships (Mattson et al. 2005). This finding indicates that the noise of the vessel is not necessarily the sole factor in determining whether the group changes behavior; groups can be disturbed by relatively small, quiet vessels.

In the GoM population resident to Sarasota, Florida common bottlenose dolphins were shown to exhibit longer inter-breath intervals when approached by boats compared to when there were no boats within 100 meters (Nowacek et al. 2001). Additionally, when approached by a vessel, animals swam more closely together (increased group cohesion) and changed direction and swimming speed more frequently than when there were no boats in the vicinity (Nowacek et al. 2001). This population is exposed to traffic regularly, but behavioral disruption was observed. This suggests that while the population may be habituated to a certain degree of noise, vessel traffic still alters behavior.

Common bottlenose dolphins exhibit a wide range of responses to vessels, and these responses are not always negative. In some instances, the animals may be attracted to vessels to ride the bow wave of the ship (Fish and Hui 1991). Foraging behind shrimp boats has also been documented, with the animals feeding both on the organisms disturbed by the shrimp boat's nets, and on the bycatch discarded by the shrimper (Leatherwood 1975). Vessel activity may be beneficial to the animals for energetic and foraging purposes, and in certain instances, specific types of vessel activity may be sought out. However, common bottlenose dolphins have been reported as bycatch in trawl nets, potentially as a consequence of vessel associated foraging (Fertl and Leatherwood 1997).

Beneficial foraging habitat may also be found in high traffic areas such as dredged channels. In some areas of the GoM, dolphins have shown a preferential for dredged channels as foraging habitat over natural seagrass beds because fish were larger and less able to hide. (Allen et al. 2001). Habitat preference depends on a myriad of other factors, but availability of desirable prey does appear in some GoM habitats to outweigh the potential negative implications of heavy vessel traffic in the vicinity (Allen et al. 2001). However, the potential limit at which traffic activity may cause animals to leave an otherwise desirable habitat is unknown.

Cetacean watching tourism may prove more detrimental than normal vessel activity. Because common bottlenose dolphins are often found in nearshore waters, they are a popular target for cetacean watching (Weir and Pierce 2013). Tourist vessels commonly target large, active groups, which may disturb or deter the animals from engaging in important foraging or socializing behaviors (Higham and Shelton 2011). In the presence of a cetacean watching vessel, common bottlenose dolphins spend significantly more time travelling and significantly less time resting and foraging

(Arcangeli et al. 2009). The actions of cetacean watching vessels has a significant impact on the behavior of the dolphins observed, and unsurprisingly, vessels permitted for cetacean watching spent significantly more time interacting with animals than other boats (Constantine et al. 2004). Though the animals may habituate to increased or prolonged vessel presence over time, it is unclear how long the habituation process takes and whether there are any detrimental effects associated with habituation (Higham and Shelton 2011).

2.1.3 Activity in Galveston, Texas

The number of vessels at sea, and consequently the vessel traffic in major ports, has risen steadily since the 1950's (Ross 2005). Significant maritime shipping occurs in the GoM both offshore and within the Intracoastal Waterway, and accounts for $129 billion of cargo movement annually (Adams et al. 2004). Several major shipping lanes exist within the GoM, primarily those through the Florida Straits and the ports of Houston and New Orleans (Azzara 2012).

Galveston Bay is the largest estuary in the GoM, and home to three major ports (Houston, Texas City, and Galveston) connected by the Houston Ship Channel, which enters Galveston Bay between the eastern tip of Galveston Island and the western end of the Bolivar Peninsula (Steichen et al. 2012). This entry point is crossed continually throughout the year by the Galveston-Port Bolivar ferry (Mallini 2001). Heavy ship traffic is common in the Galveston area: Approximately 7,000 ships visit the Port of Houston via the Houston Ship Channel annually (Mallini 2001, Merrick and Harrald 2007). The level of traffic to the port is expected to rise following the completion of the

Panama Canal expansion in 2015; container ship traffic alone is expected to increase by 15 percent (Harrison and Trevino 2013).

The Galveston-Port Bolivar ferry crosses the same route year round, 24 hours a day (Mallini 2001), making this area a zone of predictable, regular vessel traffic. Ferry vessels bridge the gap in State Road 87 by traveling 2.7 miles between Galveston and Port Bolivar in approximately 15 minutes per trip (Mallini 2001, Weisbrod and Lawson 2003). One round trip on the ferry vessel typically lasts 45-minutes to an hour. Peak vessel activity occurs during the months of June-August, with less prevalent traffic through the rest of the year (Mallini 2001). In addition to regular transportation, the system acts as a means of evacuation for Port Bolivar residents prior to hurricanes (Mallini 2001, Weisbrod and Lawson 2003). The current ferry fleet consists of six vessels, each 265 feet long and 66 feet wide, capable of holding up to 70 vehicles (Mallini 2001).

2.2 Methodology

2.2.1 Field Observations

All observations were conducted from the second level of the Galveston-Port Bolivar ferry. Observations were conducted from the front of the outdoor viewing deck in order to sight the animals before the ferry passed them. In cases of inclement weather when visibility was still greater than 100 meters, observations were conducted from the forward windows of the second-level cabin, switching sides every two minutes to ensure the most comprehensive data collection possible (Figure 1).

Data were collected in three zones designated with respect to the ferry. In all zones, only dolphin groups within 100 meters of the ferry vessel were included, as this was the maximum distance at which dolphin groups could be accurately counted and behavior characterized when standard vision was unaided. One zone was the Passage channel (P); observations were conducted from on board the Galveston-Port Bolivar ferry while the vessel was underway and more than 100 meters from the center point of the ferry landings (Figure 2). The two other zones were the Galveston (G) and Bolivar (B) ferry docks (Figure 2). The respective docks were characterized as areas within a 100 meter radius of the center of the docking area. The zone identified for each observation was determined by the location of the majority (≥50%) of the individuals in the group being observed. In the event that the group was split evenly at the boundary between two observation zones, the group was recorded in the zone nearest to the ferry where observations occurred.

Figure 1. The Robert H. Dedman, one of the six similar vessels in the Galveston-Port Bolivar ferry fleet. All observations were conducted from the forward-facing second-level outdoor observation deck. In cases of inclement weather that did not inhibit viewing, observations were conducted from the forward cabin viewing windows.

Figure 2. The three zones of observation: Galveston dock (red), in the passage channel (orange), and Bolivar dock (green). (Aerial map from Texas Natural Resources Information System.)

The distances of the center of the dolphin groups from shore, from vessels within 100 meters of the group, and from the ferry were visually estimated for all sighted groups. Evidence suggests that distance estimation, particularly over the water, is rife with human error (Baird and Burkhart 2000). Two steps were taken to minimize the introduction of human error. First, all observers were trained in distances estimation, as experience can improve individuals' distance estimates (Baird and Burkhart 2000). Secondly, distances were estimated as ranges, in accordance with the data evaluating the distance at which dolphins change behavior with vessel approaches (Lemon et al. 2006). All distance estimates were categorized as: Very Close (V, ≤ 10 meters), Close (C, 10-30 meters), Intermediate (I, 30-50 meters), and Far (F, 50-100 meters). A fifth category, Open Water (O, ≥ 100 meters), was used to record the distance to shore only. Due to visual limitations and heavy traffic congestion, groups more than 100 meters away and vessels more than 100 meters from the group were not documented.

Data collection took place from June 1, 2013 through November 30, 2013, weather permitting. During instances of inclement weather which limited visibility to less than 100 meters, observations were not conducted. Observations were divided into three observation blocks: morning (M, 7:00 or sunrise-11:00), afternoon (A, 11:00-15:00), and evening (E, 15:00-sunset or 19:00). The ferry spends an approximately equivalent length of time (15-20 minutes) in each zone per passage (e.g., time spent at the dock in Galveston is equivalent to time in the channel and time at the Bolivar dock), allowing for equal representation of sampling time in each zone while on board the ferry. In the latter portion of the field season when sunrise occurred after 7:00 and sunset occurred before 19:00, observations were initiated or terminated based on the sunrise and set times.

Groups were defined using a 10 meter chain rule per Smolker et al. (1992), wherein all animals within 10 meters of another animal were considered part of the same group. Calves were estimated as those individuals which appeared to be under 1.5 meters in length (Leatherwood and Reeves 1989). The predominant group activity (PAG) (≥ 50% of the group) was recorded on first sighting a group, and every two minutes thereafter if the group remained in sight and within 100 meters (Mann 1999). Groups that were re-sighted following the two minute interval were treated as separate groups, as this re-sight interval provided sufficient time for environmental changes to alter the nature of the group. PAG was characterized as: resting (R), feeding (F), socializing (S), or travelling (T) as described in Ballance (1992).

The following data were recorded in addition to PAG: time of sighting; zone of sighting (P, B, or G); number of individuals within the group; number of those individuals that were estimated to be calves under one year of age (< 1.5 meters); number of vessel(s) within each distance category (V, C, I, or F); ferry proximity to the group (V, C, I, or F); distance of the group from shore (V, C, I, F, or O); and, if the group was photographed by the observer, the corresponding number code for the photos. Shore was considered solid ground that was natural or manually fortified, but excluded piers, docks, and jetties. Vessels that were anchored, docked, or otherwise secured and not operating an engine were not included in the estimates of count and distance to nearby vessels. Vessels outside of the observation zone associated with the observed group were included if they were within 100 meters of the group. Distances to shore, to the ferry, and to other vessels were estimated from the member of the group closest to the vessel, ferry, or the shoreline.

2.2.2 Analysis

All statistical analysis was conducted in R version 3.0.2 for Windows. In order to create a quantifiable measure of vessel traffic, the count of vessels in the vicinity were converted to an ordinal “vessel score.” The categorical distance to the ferry was converted to one of four ordinal “ferry scores” of increasing value with decreasing distance: 1 if the ferry was F, 2 if I, 3 if C, and 4 if V. The total vessel score was then calculated by similarly weighting the count of other vessels within each distance category and summing them using the formula:

$$Vessel\ Score = 4*vessels\ V + 3*vessels\ C + 2*vessels\ I + 1*Vessels\ F + Ferry\ Score$$

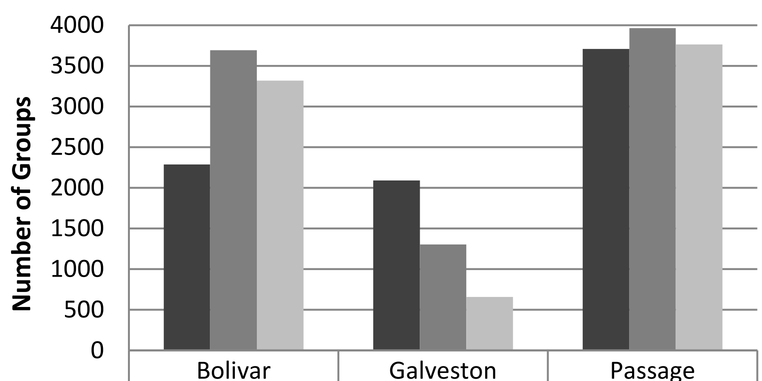
The number of times each behavior was recorded in each zone was calculated. The frequency of behavioral occurrence based on time block, observation zone, distance to shore, and calf presence in the group were analyzed using a series of Pearson’s Chi-squared tests. A truncated negative binomial model was used to quantify variation in dolphin group size based on distance of the groups to the shore, the ferry, and other vessels. Calf presence in groups based on zone of observation, group behavior, and time block, and was assessed using four separate Pearson’s Chi-squared tests.

A two-way analysis of variance was used to determine whether the recorded vessel scores varied based on the time block (morning, afternoon, evening) and zone (Galveston, Bolivar, Passage) of the observation. Three separate one-way analyses of variance were then used to assess differences in vessel scores within each of the three time blocks; if significant, the Tukey Honestly Significant Difference post-hoc test was employed.

2.3 Results

2.3.1 Overview

Between June 1, 2013 and November 30, 2013, 1,412 hours of observation were conducted. During this time I documented, 24,780 observations of dolphin groups; and 89,898 individuals, of which 7,952 were calves. Group size ranged from a single individual to 74 individuals, and the number of calves in the group ranged from zero to 15. The most groups were observed in the afternoon in the passage, and the fewest groups were documented in Galveston in the evening (Figure 3).



	Bolivar	Galveston	Passage
Morning	2286	2090	3706
Afternoon	3692	1305	3961
Evening	3318	658	3764

Figure 3. The number of groups sighted in each zone based on the time block during which they were observed.

2.3.2 Behavioral Variability

Groups were observed foraging in 8,559 instances; resting in 4,679; socializing in 1,965; and traveling in 9,577. Occurrence of each behavioral state varied significantly across each zone ($X^2_{6,24780}$ = 2175.75, $p < 0.01$ (Table 1). Occurrence of resting behavior was significantly higher than expected in Bolivar than the other two zones; there was a significantly lower instance of traveling behavior. Traveling behavior was observed significantly more often than expected in the passage than in Galveston or Bolivar. Social behavior was observed with lower than expected frequency in Galveston, though foraging behavior in this zone was significantly higher than expected.

Significant variation in behavior based on shore proximity was also noted ($X^2_{6,24780}$ = 1711.39, $p < 0.01$): unsurprisingly, based on the high occurrence of traveling behavior in the passage (Table 1), there was a significantly higher than expected occurrence of traveling behavior in the open water (O, > 100 meters) zone (Table 2). Foraging was observed with lower than expected frequency in the open water zone. Resting and socializing behaviors were observed with approximately expected frequencies across all five distances to shore.

There was also a significant difference in behavior based on time block ($X^2_{6,24780}$ = 965.39, $p < 0.01$) (Table 3). Foraging behavior was observed with higher than expected frequency in the morning and lower in the evening, and approximately at the expected level in the afternoon. Resting behavior occurred with lower than expected frequency in the morning and higher in the evening, and again at the expected level in the afternoon. Socializing and traveling behaviors were observed at approximately the expected level across the three time blocks.

Table 1. The observed (O) and expected (E) occurrence of each behavioral state based on the zone.

		Behavior				
		Foraging	**Resting**	**Socializing**	**Traveling**	**Total**
Zone	**Bolivar**	O: 3077 E: 3210.8	O: 2833 E: 1755.3	O: 860 E: 737.2	O: 2526 E: 3592.7	9296
	Galveston	O: 2004 E: 1400.0	O: 454 E: 765.3	O: 104 E: 321.4	O: 1491 E: 1566.4	4053
	Passage	O: 3478 E: 3948.3	O: 1392 E: 2158.4	O: 1001 E: 906.5	O: 5560 E: 295.3	11431
	Total	8559	4679	1965	9577	24780

Table 2. The observed (O) and expected (E) occurrence of each behavioral state based on the proximity to shore.

		Behavior				
		Foraging	**Resting**	**Socializing**	**Traveling**	**Total**
Distance to shore (meters)	**V: < 10**	O: 496 E: 307	O: 148 E: 167.8	O: 32 E: 70.5	O: 213 E: 343.6	889
	C: 10-30	O: 1229 E: 899.4	O: 385 E: 491.7	O: 203 E: 206.5	O: 787 E: 1006.4	2604
	I: 30-50	O: 2345 E: 2112.1	O: 1384 E: 1154.6	O: 468 E: 484.9	O: 1918 E: 2363.3	6115
	F: 50-100	O: 3016 E: 2805.7	O: 1793 E: 1533.8	O: 614 E: 644.1	O: 2700 E: 3139.4	8123
	O: > 100	O: 1473 E: 2434.7	O: 969 E: 1331.0	O: 648 E: 559.0	O: 3959 E: 2724.3	7049
	Total	8559	4679	1965	9577	24780

Table 3 The observed (O) and expected (E) occurrence of each behavioral state based on the time block.

		Behavior				
		Foraging	**Resting**	**Socializing**	**Traveling**	**Total**
Time Block	**Morning**	O: 3804 E: 2791.5	O: 1141 E: 1526.1	O: 457 E: 640.9	O: 2680 E: 3123.5	8082
	Afternoon	O: 2771 E: 3094.1	O: 1673 E: 1691.5	O: 769 E: 710.3	O: 3745 E: 3462.1	8958
	Evening	O: 1984 E: 2673.4	O: 1865 E: 1461.5	O: 739 E: 613.8	O: 3152 E: 2991.4	7740
	Total	8559	4679	1965	9577	24780

2.3.3 Group Size Variability

Variations in group size based on time block, zone, behavior, vessel score, and distance to shore were assessed using regression modeling. Poisson and negative binomial hurdle models were tested to determine the best fitting model and evaluated using AICc. Significant overdispersion was apparent, indicating that a negative binomial hurdle model was a more appropriate analysis. A negative binomial hurdle model was determined to fit the data better than the Poisson model based on the Akaike Information Criterion with correction. This model was used to assess variations in group size based on zone, time block, behavioral state, vessel score, calf presence, and distance to shore ($\Theta = 5.69$, $R^2 = 0.075$, $p < 0.01$). Results of the negative binomial hurdle model are shown in Table 4. The differences in group size were then back-transformed from the logarithmic differences. Vessel score had a significant impact on group size. For every one unit increase in vessel score, the expected group size increased by 0.13 ($p < 0.01$); larger groups were found when vessel scores were higher. Additionally, when one or more members of the group were calves, the expected group size increased by 3.69 compared to the expected value when there were no calves in the group ($p < 0.01$).

All three time blocks had significant impacts on group size. Groups were largest in the afternoon block. In the evening, the expected difference in group size was 0.34 lower than the afternoon time block ($p < 0.01$). During the morning time block, the expected group size was 0.80 smaller than the groups found during the afternoon time block. Significant variation was also documented between the Galveston and Bolivar zones. The expected group size in Galveston was 1.45 lower than the expected group size in Bolivar ($p < 0.01$). There was no significant difference in the expected group size between the passage and Galveston zone.

Groups engaged in different behaviors all differed significantly with respect to expected group size. Resting behavior had an expected group size 1.01 lower than the expected value for foraging groups ($p < 0.01$). Socializing groups were larger than foraging groups, with the expected group size 0.61 larger ($p < 0.01$). Traveling groups were the smallest of all the behavioral states, with an expected group size 1.42 lower than the expected group size for foraging groups ($p < 0.01$).

Group size varied based on certain distances to shore; however, the expected group size was not significantly different for groups close to shore and far from shore. The expected group size for groups at the intermediate distance from shore was 0.61 lower than the expected size for groups close to shore ($p < 0.01$). Groups in open water were the smallest, with the expected size for groups in open water 3.06 lower than for groups close to shore ($p < 0.01$). Groups very close to shore were the largest, with the expected group size 0.13 larger than groups close to shore ($p < 0.01$)

Table 4. The results of the negative binomial hurdle model explaining group size based on all other factors analyzed (* = significant).

Variable	Log(Group Size Difference)	Standard Error	*p*-value	Group Size Difference
Intercept	1.48	0.02	$< 2\times10^{-16}$*	N/A
Time Block E	-0.08	0.01	1.19×10^{-10}*	-0.34
Time Block M	-0.20	0.01	$< 2\times10^{-16}$*	-0.80
Zone G	-0.40	0.02	$< 2\times10^{-16}$*	-1.45
Zone P	-0.03	0.02	0.03	-0.13
Behavior R	-0.26	0.02	$< 2\times10^{-16}$*	-1.01
Behavior S	0.13	0.02	6.86×10^{-13}*	0.61
Behavior T	-0.39	0.01	$< 2\times10^{-16}$*	-1.42
Dist. Shore F	-0.07	0.02	0.03	-0.30
Dist. Shore I	-0.15	0.02	8.10×10^{-5}*	-0.61
Dist. Shore O	-1.19	0.02	1.28×10^{-12}*	-3.06
Dist. Shore V	0.03	0.03	1.96×10^{-9}*	0.13
Vessel Score	0.03	0.02	$< 2\times10^{-16}$*	0.13
Calf Present	0.61	0.01	$< 2\times10^{-16}$*	3.69

2.3.4 Calf Presence Variability

Calf presence in groups based on zone, time block, distance to shore, and behavior was assessed using Pearson's Chi-squared tests. There was no significant difference in calf presence in the group based on the zone, ($X^2_{2,24780}$ = 5.97, $p > 0.01$).

Calf presence or absence in the group had a significant impact on the predominant group activity ($X^2_{2,24780}$ = 627.01, $p < 0.01$) (Table 5). Groups where calves were present were observed foraging significantly more often than expected, and were observed resting significantly less frequently than expected. Socializing and traveling behaviors occurred at approximately the expected levels for groups with calves.

There was a significant difference in calf presence based on the distance to shore ($X^2_{2,24780}$ = 150.42, $p < 0.01$) (Table 6). Groups containing calves were found at the intermediate distance to shore significantly more often than expected. Groups with calves were found in open water and very close to shore significantly less often than expected. Groups far from shore and close to shore occurred at approximately the expected frequencies.

There was a significant difference in observation of groups containing calves based on the time block ($X^2_{2,24780}$ = 118.22, $p < 0.01$) (Table 7). Calves were observed in the morning time block significantly less often than expected, and in the afternoon time block significantly more often than expected. Calves were sighted in the evening time block at approximately the expected frequency.

Table 5. The observed (O) and expected (E) occurrence of each behavioral state based on whether one or more calves were present in the group.

		Behavior				
		Foraging	**Resting**	**Socializing**	**Traveling**	**Total**
Calf present?	**Yes**	O: 2943 E: 2176.0	O: 766 E: 1189.6	O: 492 E: 499.6	O: 2099 E: 2434.8	6300
	No	O: 5616 E: 6382.9	O: 3913 E: 3489.4	O: 1473 E: 1465.4	O: 7478 E: 7142.2	18480
	Total	8559	4679	1965	9577	24780

Table 6. The observed (O) and expected (E) occurrence of calves across the five distance to shore ranges.

		Distance to Shore (Meters)					
		Very Close (< 10)	**Close (10-30)**	**Intermed. (30-50)**	**Far (50-100)**	**Open water (>100)**	**Total**
Calves Present	**Yes**	O: 183 E: 226.02	O: 706 E: 662.03	O: 1863 E: 1554.66	O: 202 E: 2065.17	O: 1528 E: 1792.12	6300
	No	O: 706 E: 662.98	O: 1898 E: 1941.97	O: 4252 E: 4560.34	O: 6103 E: 6057.83	O: 5521 E: 5256.88	18480
	Total	889	2604	6115	8123	7049	24780

Table 7. The observed (O) and expected (E) occurrence of calves in groups based on the time block.

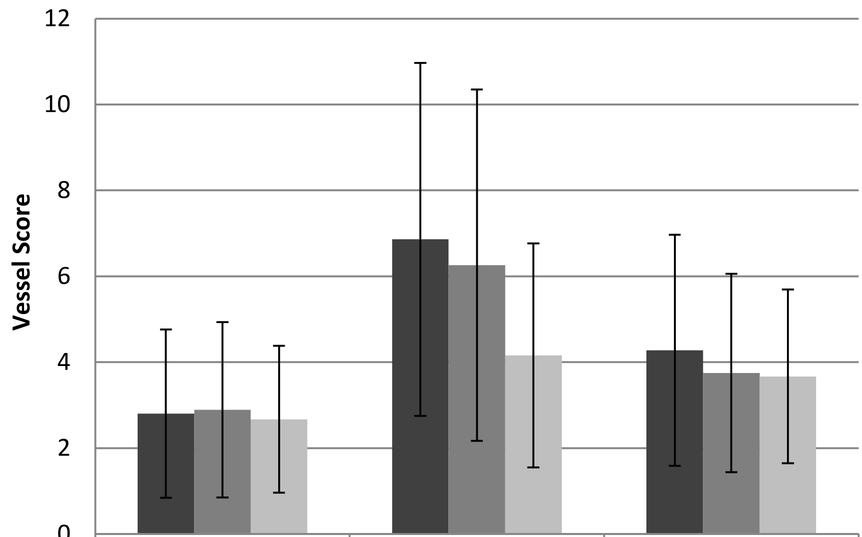
		Time Block			
		Morning	**Afternoon**	**Evening**	**Total**
Calves Present?	**Yes**	O: 1722 E: 2054.75	O: 2549 E: 2277.46	O: 2029 E: 1967.80	6300
	No	O: 6360 E: 6027.25	O: 6409 E: 6680.54	O: 5711 E: 5772.20	18480
	Total	8082	8958	7740	24780

2.3.5 Vessel Activity Variability

In all three time blocks, Galveston had the highest vessel scores, followed by the passage, and then Bolivar (Figure 4). Vessel scores for the zone peaked in the morning in Galveston and the passage, and in the afternoon in the Bolivar zone (Figure 4). There were significant main effects for both zone and time block of the observation (two-way ANOVA; zone $F_{2,24771} = 852.30$, $p < 0.01$; time block $F_{2,24771} = 7.54$, $p < 0.01$). There was a significant interaction effect for vessel score by zone and time block; (two-way ANOVA, $F_{4,24771} = 102.97$, $p < 0.01$). Scores in Galveston were the greatest, lower in the passage, and at the lowest levels in Bolivar. Morning time block scores were the highest in the passage and Galveston and were followed by a decline through the day, whereas scores increased slightly from the morning to afternoon in Bolivar before declining in the evening. Vessel scores were highest in Galveston in the morning and declined throughout the day, while scores in the passage and Bolivar were relatively constant.

Because a significant interaction was detected, follow-up testing was conducted using one-way analyses of variance for each zone and the Tukey Honestly Significant

Difference post-hoc analysis for significant results. Vessel scores in Galveston differed significantly across the time blocks (one-way ANOVA, $F_{2,4050} = 120.2$, $p < 0.01$). Tukey HSD post-hoc analysis showed that vessel scores in all three time blocks differed significantly ($p < 0.01$); vessel scores were highest in the morning, intermediate in the afternoon, and lowest in the evening. Vessel scores differed significantly across time blocks in Bolivar (one-way ANOVA, $F_{2,9293} = 13.31$, $p < 0.01$). Vessel scores in Bolivar in the evening and afternoon differed significantly from each other, with higher scores in the afternoon ($p < 0.01$); however, vessel scores in the evening and morning did not differ significantly from each other, nor did scores from the morning and afternoon. Significant differences in vessel scores were detected in the passage (one-way ANOVA $F_{2,11428} = 73.73$, $p < 0.01$). In the passage, vessel scores in the morning were significantly higher than scores from the evening and the afternoon ($p < 0.01$); scores from the evening and afternoon were not significantly different from each other.



	Bolivar	Galveston	Passage
Morning	2.8	6.86	4.28
Afternoon	2.89	6.26	3.75
Evening	2.67	4.16	3.67

Figure 4. The mean ± standard deviation vessel score based on the time block and zone of the observation.

2.4 Discussion

2.4.1 Behavioral Variations

Significant variations in behavior occurred based on zone of observation, distance to shore, time block and calf presence in the group. Resting behavior occurred at a higher than expected rate in Bolivar, and traveling occurred more frequently in the passage. Foraging behavior occurred more frequently in Galveston than the other two zones. Social behavior occurred at close to the expected levels in the passage and Bolivar, and less frequently than expected in Galveston.

There are a number of considerations that may influence behavioral variations across the study area. I frequently sighted shrimp trawlers in close proximity to the

Galveston dock, but rarely were these vessels fishing beyond the mouth of the Galveston ship channel. The higher than expected occurrence of foraging behavior in Galveston may be associated with the shrimp boat activity present in this area. Shrimp boat trawlers were common in this area, and were often accompanied by a foraging dolphin group. Although shrimp boats occasionally fished in Bolivar and the passage, fishing activity dominated the area just outside the Galveston zone in the mouth of the Galveston ship channel. This suggests that shrimp boat-associated foraging may be an important consideration in Galveston Bay.

Foraging groups were observed much less frequently than expected in open water (> 100 meters from shore). This most likely is related to the higher than expected foraging behavior observed in Galveston, where all groups were within 100 meters of the dock. Though the amount of foraging observed in Bolivar was approximately at the expected level, this still represents over 3,000 groups and likely contributed to the low occurrence of foraging behavior documented in open water. This may indicate a predilection for foraging in shallower waters towards the edges of the dredged channels, as observed in Clearwater, Florida (Allen et al. 2001). However, this may also be related to the often observed shrimp boat associated foraging. Further study is necessary to clarify the foraging preferences of the population in this area so as to minimize impacts to foraging locations.

Foraging and resting behavior occurred with different than expected frequency, with foraging occurring more frequently in the morning and resting occurring in the evening. Social behavior and traveling behavior occurred at the expected rate across all three time blocks. This may again be connected to shrimp boat associated foraging which was generally observed during the morning time block. This may also represent a preference for morning foraging within the bounds of the survey area (Shane et al. 1986). To elucidate the foraging preferences of this population, further research is needed on the foraging habits of the Galveston Bay common bottlenose dolphin population; an expanded survey area is necessary to determine whether there may also be a high-activity foraging location in the afternoon or evening.

2.4.2 Group Size Variations

The size of groups varied significantly across several factors. Vessel score had a significant impact on group size, wherein higher vessel scores were related to larger groups. There is evidence that social groups exhibit greater cohesion when they are near vessels, particularly when calves were present, indicating a group response to stress (Hastie et al. 2003). The larger group sizes near higher levels of traffic may also be a means of managing the stress to the group. Groups were also significantly larger when calves were present, which may be a function of the high level of ship traffic in the survey area. Because the ferry lane is constantly subjected to a high level of vessel activity as a function of its location at the mouth of Galveston Bay, adults with calves may be seeking larger social groups due to the presence of vessels.

Variation was also noted with respect to time block, with groups largest in the afternoon, smaller in the evening, and smallest in the morning. The afternoon represented a “transitional” time block behaviorally, with no behavioral state much more likely to be observed than any other. The large group size documented in the afternoon may be a result of animals moving between locations and behaviors, and coming into contact with other groups during this process. Groups observed during the morning were much smaller than those documented in the other two blocks. Foraging behavior dominated during this time, suggesting that foraging groups may be slightly smaller than groups engaged in other activities. Due to the nature of shrimp boat associated foraging, where too many animals in close proximity to each other and fishing gear may be dangerous, it is plausible that these groups would tend to be smaller. Additionally, on most mornings, a large number of shrimp boats were observed, and foraging in competition with other animals may be less desirable than foraging behind another vessel. Groups in the evening were of an intermediate size, as might be expected when engaged in resting over more strenuous activities such as socializing, traveling, or foraging.

Groups in Galveston, where foraging was observed more often than expected, were the smallest groups of the three zones. It follows that foraging groups, which were present more frequently than expected in Galveston, and foraging behavior which was most prevalent in the morning, would result in smaller groups documented in the Galveston zone. However, foraging groups were not the smallest groups based on behavior, suggesting that other important foraging activity is occurring outside the Galveston area. Groups in the passage and in Bolivar were not significantly differentiated. Because other behaviors predominated in these areas, it is plausible that the expected group size would fluctuate more.

Socializing groups were larger than foraging, resting, or traveling groups and may be attributed to several factors. First, socializing may result when two separate groups of conspecifics come into contact with each other. This behavior serves as a means of establishing relationships. Second, obvious social behavior may occur only when larger groups are present. More subtle social behaviors were difficult to observe from a distance. Traveling groups were the smallest, most likely because traveling is a transitionary activity between more critical functions such as socializing, resting, or foraging. Resting groups were slightly larger than traveling groups, possibly because resting may only occur in certain areas based on the environmental conditions. Foraging groups were the second largest, though this may be due to the high variation in the types of foraging activity documented in the area.

Distance to shore also played an important role in assessing group size, with groups the largest very close to shore. Generally, this is a potentially hazardous area, where a larger group may be necessary to avoid hazards. Groups were also observed foraging very close to shore more frequently than expected and the large group size may be attributed to the behavior of groups approaching the shoreline this closely. The resulting small groups in open water is unsurprising, as traveling activity had the smallest expected group size and predominated in the passage zone. Groups close to shore and far from shore were not significantly different, and groups intermediate from shore were slightly smaller. This suggests that proximity to shore may be more influential than the zone of the observation, wherein groups closer to shore are engaged in more high-energy behaviors such as foraging or socializing, and group size declines as the groups enter open water away from foraging opportunities.

Future research should focus on further categorizing behavioral and positional variables to better assess group size variations. For instance, groups foraging behind shrimp boats may have very different characteristics than groups foraging on schooling fish close to shore. Evaluating these variations in more detail will help improve the determination of critical parts of the Galveston Bay habitat. As areas are deemed important for foraging, resting, socializing, or traveling, appropriate measures can be taken to ensure the continued vitality of the resident common bottlenose dolphin population.

2.4.3 Calf Presence Variations

A significant difference in behavior based on calf presence was documented, with calves present more often than expected in foraging groups and less than expected in resting groups. The low observation of resting groups in the ferry lane may be due to the high level of vessel activity in the area. In general, calves are relatively weak swimmers until about 10 months post-partum (Noren et al. 2006); because calves were characterized as a year or under for the purposes of this study, it is likely that the majority of the calves observed were not yet adept swimmers. Though calves were observed in the ferry lane, adults caring for calves may have been seeking areas of lower anthropogenic activity for resting. In order to determine when and where resting groups containing calves are present, an expanded survey area including areas of lower vessel activity is necessary.

Calves were present more often than expected in foraging groups, though there was no significant difference in calf presence based on the zone. However, foraging groups were most frequently found in the Galveston zone. This may indicate that calves in foraging groups were not engaged in actively following shrimp boats, where calves may be struck by the nearby vessel or entangled in the nets. Lower activity foraging behavior in other areas is more probable, where groups are hunting schooling fish rather than foraging behind boats. Further research documenting the nature of the foraging activity in addition to whether calves were present in the foraging groups is required to assess foraging activity of groups containing calves.

While there was no significant difference in calf presence based on the zone, there was a significantly higher occurrence of calves in groups intermediate from shore and lower than expected occurrence of calves in open water and very close to shore. This may represent calf groups attempting to avoid the ship channels while maintaining an adequate distance from shore. Ship channels in most areas were far from shore or in open water except in the immediate area surrounding the ferry docks. Weak swimming calves may have been endangered in areas where ships were active, unable to maneuver quickly enough to avoid a strike. Very close proximity to shore may have also presented a danger, with calves potentially injuring themselves on debris or becoming stranded. The lack of a significant effect of zone coupled with these findings indicates that adults may be seeking a safe water depth while still avoiding high vessel activity insofar as possible. The low observation of calves in open water may be correlated with the lack of difference among zones, as the open water distance to shore could only occur in the passage zone.

A significant effect on calf presence was also found for the time block. Fewer calves were sighted in the morning than expected, and more were sighted in the afternoon. Groups were foraging more often than expected in the morning; however, there was no significant difference in calf presence based on zone. This may indicate that, while calves were observed foraging significantly more often than expected in foraging groups, this behavior may have been constrained to later time blocks or different areas when calves were present.

Photographic identification (Würsig and Würsig 1977) of individuals foraging behind shrimp boats, and assessing which calves are frequently associated with which adults may elucidate whether shrimp boat associated foraging is a culturally transmitted activity. This behavior appears to be of particular importance in the Galveston Bay ecosystem, and is most likely learned through observing other foraging animals. Assessing whether the same animals are frequently foraging behind shrimp boats and whether their calves are learning this behavior through observation may help determine the importance of this behavior in the habitat.

Assessing calf presence is critical to understanding important habitat areas of Galveston Bay. Because calves are particularly vulnerable to anthropogenic threats, it is important to assess when and where the groups with calves are resting, socializing, or foraging. Of particular interest is the transmission of shrimp boat associated foraging behavior across generations. Expanding the survey area to include other areas subjected to less anthropogenic pressure may reveal the areas where groups with calves are commonly resting.

2.4.4 Vessel Activity Variations

Significant main effects for time block and zone vessel scores were found, as well as a significant interaction effect. Vessel scores showed a general downward trend over the course of the day in Galveston and the passage, whereas scores in Bolivar were slightly higher in the morning and not significantly different from each other. The significant effect of zone suggests that vessel scores differ across the survey site, subjecting the dolphins to increased anthropogenic pressure in different areas. There is also evidence that vessel scores vary over the course of the day. Combined, these factors indicate that vessel activity is not consistent throughout the survey site over the course of the day.

The high scores documented in Galveston in the morning time block are likely indicative of the shrimping activity occurring in the area, which began to ebb later in the day. Some of the activity in the passage can be attributed to this as well, because shrimping vessels were often observed fishing in the portion of the passage closer to shore in the Galveston ship channel. The overall high vessel activity in Galveston may also be attributed to smaller commercial and recreational vessels traveling through the area. Personal watercrafts were often observed traveling in the Galveston channel, and in nearby portions of the passage.

In the passage, much of the vessel activity consisted of large commercial ships, particularly container ships and oil tankers. The spike of activity in the morning followed by the lower activity in the afternoon and evening may represent the time during which the ships were cleared to enter the port which generally occurred earlier in the day. Ships departing and small commercial and recreational craft also contributed to the passage vessel scores.

Vessel scores in Bolivar were comparatively lower than the scores of the other two zones. Whereas Galveston and the passage have deep, clearly demarcated channels for ships, a comparable channel does not exist within 100 meters of the Bolivar ferry dock. Additionally, the dock is confined by jetties on both sides, rendering it somewhat inaccessible to shrimping vessels which require more space to maneuver. Most charter fishing vessels depart from Galveston and either seek offshore destinations or remain closer to the mouth of the Galveston ship channel. Consequently, vessel traffic in this area was generally limited to small recreational vessels.

Future studies should focus on quantifying not just the number and proximity of vessels, but the size and behavior of the vessel as well. As demonstrated by Mattson et al. (2005), certain vessels such as shrimp boats and jet skis are more likely to influence the behavior of the animals either negatively (through erratic behavior or direct harassment) or positively (providing foraging or bow riding opportunities). While these vessel scores provide some information about the relative anthropogenic pressure placed on the resident bottlenose dolphin populations over space and time, more information is necessary to determine how the animals respond to the presence of vessels based on the behavior and type, rather than only the number and proximity. Evaluating the level of vessel traffic in more general terms, rather than only when dolphins are present, would be beneficial to determining if there are areas that the animals may be avoiding due to the excessive traffic.

2.5 Conclusions

Assessing the habitat use patterns of common bottlenose dolphins in Galveston Bay is critical to ensuring the continued vitality of the population. Though the study area focused primarily on a high traffic zone at the mouth of the Bay, the high level of activity coupled with a large human population provides an opportunity to study how the dolphins interact with anthropogenic pressure. As common bottlenose dolphins are found in many inshore areas in the GoM and around the world, habitat trends such as those found in Galveston Bay may provide valuable information for protecting populations. Several trends and opportunities for future study presented themselves through the results of this study.

The frequent observation of animals foraging behind shrimp boats suggests that this may be an integral part of the population's behavior. Foraging behavior was observed most frequently in the Galveston zone, which was the location where shrimp boats were observed most often. Groups were also smallest in the Galveston zone, which may also be related to the nature of foraging behind these vessels. The close proximity of the boats, the presence of fishing gear in which the animals could become entangled, and the abundance of boats observed in this area all support smaller group size for this behavior. However, foraging groups were not the smallest of all groups observed, and were in fact the second largest. This finding indicates that foraging behavior is occurring in other zones, and groups may be larger in different types of foraging activities occurring in other zones.

Concerns about dolphins "begging" behind boats are reasonable, as this behavior has been shown to harm the animals in other parts of the GoM (Cunningham-Smith et al. 2006), and efforts should be made to determine how this behavior impacts the population. However, in this case, immediately eliminating shrimping or the disposal of bycatch may be more detrimental than allowing it to continue. If shrimp boat associated foraging is in fact an integral part of the behavior of this population, eliminating the opportunity to forage in this manner may result in a potential catastrophe if specific animals are foraging only in this manner. Further study on this behavior is important to determine if this behavior may have potential negative consequences for the health of this population, such as encouraging begging behavior. Included in this study should be an assessment of whether the same animals are frequently observed engaged in this type of foraging behavior. It appears that shrimp boat associated foraging has more benefits than negative consequences; if the behavior were more harmful than beneficial, it would not continue in the population. However, observation of this behavior may lead to means by which shrimping can be made safer for the animals most frequently observed engaging in it.

The presence of calves in groups also appeared to influence the behavior of the animals. When calves were present, groups were significantly larger. The high level of activity of nearby vessels may be important in the size of these groups. Stressful scenarios, such as exposure to vessel traffic, may influence the presence of calves in groups. While there was no significant difference in calf presence based on the zone, significant differences were found based on the time block, with calves present more frequently than expected in the evening and less frequently than expected in the morning. This may be some evidence of groups with calves avoiding the area at times when vessel activity was high. In the morning, vessel scores peaked in Galveston and the passage, and were only slightly lower than the maximum afternoon value in Bolivar. Across all three zones, vessel scores were lowest in the evening. This may indicate that mothers with calves are waiting to enter the area until vessel activity had decreased to a safer level.

Groups with calves were sighted at intermediate distances to shore more frequently than expected. These intermediary distances may represent avoidance of the high traffic middle of the ship channels and areas very close to shore where other hazards exist. Calves were present more frequently than expected in foraging groups; however, foraging occurred most often far from shore. Coupling these findings, it is plausible that groups with calves were foraging in a different manner than groups where calves were not present. Further evaluation is necessary to assess what types of foraging activity calves are engaged in, as well as assessing if there is a cultural transmission aspect of shrimp boat foraging.

Vessel scores showed dramatic variation across the course of the day and between zones. Scores in Galveston were universally higher than the scores in the other two zones throughout all three time blocks, and in fact the maximum score from the passage in the morning only barely exceeded the minimum score from Galveston in the evening. The high scores in Galveston can likely be attributed to the presence of the Galveston ship channel and fishing activity occurring in the area. While the Houston ship channel and part of the Galveston channel exist in the passage zone, the ferry route also covers a large stretch of area in the passage that is not a dredged channel. The greater space available in the passage probably lowered vessel scores, as boats did not need to approach each other as closely as was necessary in Galveston. In Bolivar, vessel scores stayed relatively constant throughout the day. In Galveston, the ferry landing is immediately next to the ship channel; however, a comparable channel did not exist in Bolivar. Instead, there were two jetties that limited access to only the ferry and smaller, primarily personal, vessels which most likely resulted in the lowered vessel scores resulting in this zone.

The vessel scores may be contributing to the behavioral variations found among zones. In Bolivar, resting behavior occurred significantly more often than expected, and this can be attributed to the low vessel scores in the area. The minimal level of traffic may make this zone a desirable area for animals to rest. Traveling occurred more often than expected in the passage, which may have been a result of the intermediate traffic levels. Foraging occurred more often than expected in Galveston, but the passage still dominated foraging activity. The passage zone included a great deal of the Galveston ship channel, and it may be logical to consider the foraging activity in the passage as an extension of the activity in Galveston. If even half of the foraging activity in the passage occurred within the Galveston ship channel, this area – where the vessel scores were highest – becomes the predominant area for foraging behavior. This suggests a high level of importance for shrimp boat associated foraging.

While the vessel scores calculated for this study do provide valuable information, they are limited in that they do not provide an overall assessment of vessel traffic throughout the survey area – only an evaluation of traffic nearby dolphin groups. In order to better determine the impacts of vessel traffic on behavior, the vessel activity throughout the area needs to be quantified separately from the behavior of the animals. Expanding the survey area to include portions of the channel outside the immediate entrance to Galveston Bay will provide more information about the habitat use patterns of this population. Breaking the survey area into more practical zones may also provide more valuable information. Rather than focusing on the zone alone, evaluating the proximity to shore within the zone could elucidate the habitat usage patterns more clearly. For example, the activity very close to shore in Bolivar is probably different than the activity very close to shore in Galveston and the passage. It may also be beneficial to evaluate open water areas independently, with separate areas for open water in the ship channel, and open water beyond the area of high vessel activity.

Finally, determining how different types of vessels influence behavior may provide even more information. Bow riding behavior was often observed in association with large tankers and container ships, whereas foraging was observed behind shrimp boats, and avoidance was observed in the cases of some personal watercraft. In certain cases, behavioral changes may be positive (such seeking out the vessel for foraging), though negative behavioral changes (avoiding a vessel harassing the group) may result in greater stress. Assessing how the type of vessel influences behavior may help improve management of this population and other populations exposed to similar levels of vessel traffic.

The results of this study suggest that a healthy population of common bottlenose dolphins can exist in an active port. The high level of vessel traffic does not appear detrimental to the health of the population, and in fact some important activities such as foraging appear correlated with high traffic. However, the finding that the animals were seeking the Bolivar zone, where vessel activity was lowest, for resting, suggests that there may be some level of stress associated with the presence of vessels. Further research of the relationship with vessel traffic and group size and activity in both Galveston Bay and other active ports in the GoM may prove valuable in protecting these populations.

3. MANAGEMENT AND EDUCATION

3.1 Current Legal Protection

3.1.1 International Agreements

Though a great deal of legislation for the protection of marine mammals exists across many levels of governance, the scope and effectiveness of the regulations varies significantly. Currently, marine mammals are protected under a myriad of international treaties, national laws, state laws, and various management plans. In order to improve management and policy, a thorough exploration of the guidelines, strengths, and weaknesses of the existing policies must first be undertaken.

Marine mammals are protected under several international agreements. The International Whaling Commission (IWC) was created in 1946 by the ratification of the International Convention for the Regulation of Whaling (ICRW), and was originally intended to maintain whale stocks for whaling (Caron 1995). However, in the early 1970's, it became apparent that populations were continuing to decline despite the catch limits set in the ICRW Schedule, and in 1986, a moratorium on commercial whaling was passed (Caron 1995). While the ICRW does permit indigenous subsistence whaling and scientific whaling and, in some cases, sale of scientific whaling byproducts, commercial whaling is prohibited (Punt and Donovan 2007). This moratorium continues to remain in effect.

However, the effectiveness of the IWC is debatable. Several nations have challenged the IWC's ability to impose such a moratorium, and because the IWC lacks any explicit enforcement procedures, these nations are able to proceed with commercial or questionable scientific whaling with relatively little obstruction (Cotterrell and Gray 1998, Punt and Donovan 2007). Member nations of the IWC are able to file an objection within 90 days of a decision, and thereby free themselves from the new restrictions (Cotterrell and Gray 1998). The scientific whaling exemption also opens the doors to questionable research, the products of which may be sold commercially. While the IWC does impose a moratorium, the organization is relatively powerless to enforce its own decisions, even among member nations. Should a nation object to an existing or proposed provision, that nation is free to leave the IWC, thereby opting out of all existing treaty requirements.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was established in 1975 to protect endangered and threatened species from over-exploitation (Smith et al. 2011). Currently, over 175 nations are parties to CITES (Smith et al. 2011). The convention regulates the trade of species listed under three appendixes. Appendix I species are directly threatened with extinction, and only in "exceptional circumstances" may they be traded (CITES art. II). Appendix II species are those which may become threatened with extinction unless trade is regulated, and other species which may require regulation to be properly managed (CITES art. II). Species listed under Appendix III are regulated by signatories, and require cooperation from other nations for proper regulation (CITES art. II). Species listed under Appendix I may not be traded commercially; Appendix II species may be traded, but the trade must be non-detrimental to the species' survival (Raymakers 2006).

When export of an Appendix I species is necessary, an export permit is required (CITES art. III). In order to obtain an export permit, a nation must first establish that: a proper Scientific Authority is satisfied that export will not be detrimental to the survival of the species; a management authority establishes that the organism was not obtained illegally; organisms will be transported properly; and an import permit has been obtained by the destination (CITES art. III). To obtain an import permit, the State must establish that: import will not be detrimental to the species; the recipient of the imported organism is able to properly care for it; and that the specimen is not intended for primarily commercial purposes (CITES art. III).

Trade in Appendix II species requires similar permits. The terms of the export permit are the same, though the importing nation does not need to obtain an import permit (CITES art. IV). Export of Appendix III species follows similar guidelines, though the exporting nation does not need to satisfy that the export will not be detrimental to the species' survival, and an import permit for the destination is not required (CITES art. V).

Certain exemptions to the permitting process are allowed under CITES art. VII. Personal specimens do not require permits for trade provided that they were not obtained illegally or outside the individual's nation. Captive-raised animals or plants protected under Article I will be treated as Article II species for trade purposes. Exemptions are also allowed for scientific purposes, when the trade is a loan, donation, or exchange among reputable scientific organizations.

Currently, all cetaceans are protected under CITES Appendix II, with the exception of 23 species that are protected under Appendix I. Common bottlenose dolphins (*Tursiops truncatus*) are protected under Appendix II. However, common bottlenose dolphins from the Black Sea are presently under a zero annual export quota (CITES App. II).

Issues of national sovereignty and jurisdiction over the seas led to the creation of the United Nations Convention on the Law of the Sea (UNCLOS III) in 1982 (von Zharen 1999). Because many marine organisms range well beyond the borders of a single nation, UNCLOS III is designed to promote proactive management of marine resources and encourages cooperative management between nations (Camhi et al. 2009). Provisions within UNCLOS III mandate that nations engage in practices so as to conserve the resources of the open sea, which are considered a global common fishing ground (Davies et al. 2007).

Under UNCLOS III, nations are allowed to claim rights to fisheries within 200 miles of the shore as exclusive economic zones (EEZ) (von Zharen 1999). While the United States has not ratified UNCLOS III, Presidential Proclamation 5030 established a 200 mile Exclusive Economic Zones (EEZ); the Proclamation was later codified as the Magnuson-Stevens Fishery Conservation and Management Act (FCMA) (16 U.S.C.A. §§ 1801-1882). The Act was first amended in 1996 by the Sustainable Fisheries Act, which incorporated ecosystem-level management and clarified existing provisions (Fluharty 2000). The Magnuson–Stevens Fishery Conservation and Management

Reauthorization Act of 2006 mandated catch limits and improved accountability of fisheries (Schrope 2010).

This act is significant particularly for the management of inshore common bottlenose dolphins and other resident marine mammal populations, establishing them as under United States jurisdiction and consequently facilitating their management. Catch limits established also promote marine conservation, which aids in conservation of important cetacean prey species.

3.1.2 United States Federal Laws

Within United States waters defined by the Exclusive Economic Zone (EEZ), several laws protect marine mammals. The most overarching domestic law for the protection of marine mammals in the United States is the Marine Mammal Protection Act of 1972 (16 U.S.C. § 1361 - 1421h). The Act focuses on four major provisions: bridging science and management; re-branding marine mammals as wild animals rather than simply a resource; creating transparency in conservation and management procedures; and uniting scientists and politicians in an effort to create the most effective management policy (Ray and Potter 2011).

The creation of the MMPA represented the first step for integrating science and policy to create the most effective possible management strategy, and intended to maintain marine mammal populations at the optimum sustainable level in order to allow them to fulfill their role as some of the ocean's most important predators (Roman et al. 2013). This represented the beginning of a trend toward ecosystem-based management, focusing on understanding the relationships among all members of the ecosystem –

including humans – and managing them as a collective unit instead of disjointed stocks (Ray and Potter 2011).

Although marine mammals are not generally seen in the United States as a consumable resource, the management of the populations functions similarly to fisheries management. As an apex predator in many ecosystems, maintaining sustainable populations is crucial for ensuring the continued stability of the community. Section 2 of the MMPA establishes the requirement to maintain stocks at a level where they are a "significant functioning level of the ecosystem," including the necessary habitat maintenance to ensure the survival of the species of concern. Section 3 defines depleted stocks as any stock below the optimum sustainable level. This provision is critical as it dictates that requirement of continual research in order to ensure that the population is growing or maintaining at least the optimum sustainable population size. A moratorium on the take and import of marine mammals or marine mammal products is established under 16 U.S.C. § 1371. Under this moratorium, all marine mammals are protected by law from intentional take, and accidental take through commercial fishing must be minimized. Exemptions are allowed for indigenous subsistence fishing, necessary national defense measures, permitted research, and scenarios of self-defense or defense of others.

Harassment of marine mammals is expressly prohibited under the MMPA, and includes any behavior which may potentially alter the behavior of individual marine mammals or marine mammal groups. Harassment is defined as: "...any act of pursuit, torment, or annoyance which (i) has the potential to injure a marine mammal or marine mammal stock in the wild or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering." (16 U.S.C. § 1361(A)). Section B prohibits any actions that would injure wild marine mammals or marine mammal stocks (16 U.S.C. § 1361(B)(i)) or any act which might potentially disturb marine mammals or marine mammal stocks (16 U.S.C. § 1361(B)(i)).

In the event that scientific research requires an action which would otherwise be characterized as harassment, a permit must be obtained prior to beginning work. The permitting process of the MMPA (16 U.S.C. § 1374) recognizes the importance of marine mammal research, and establishes a process by which scientists can conduct projects which would otherwise be in violation of the Act. The Secretary of the department under which the National Oceanic and Atmospheric Administration (NOAA) is currently operating, the Secretary of Commerce, is responsible for overseeing permitting of all cetaceans and pinnipeds except for walruses; all other marine mammals are overseen by the Secretary of the Interior (16 U.S.C. 1362 §3).

Though these regulations are restrictive, certain exemptions are allowed through the issuance of permits. The provisions for permits are covered under 16 U.S.C. § 1374. Section 104(b) covers permitting procedures. All permits must specify the number and species of animals which are to be taken or imported, the location and manner in which the animals are to be taken or imported, the time period during which the permit is valid, and any other conditions issued at the discretion of the Secretary. Under section 104(e), the Secretary may revoke or modify complete or partial permits issued in order to make the permit consistent with changes to the Act after the date the permit was issued or if the holder of the permit is found to be in violation of the permit (another part of this section addresses polar bears). The permit holder must be notified prior to revocation or modification, and is entitled to a hearing and judicial review of the proposed changes (16 U.S.C. 1374 § 104(e)(1-2)). The permit must be in possession of the permit holder at the time of the authorized take or import, the transit period, and any time when the animal taken or imported is in the permit holder's possession (16 U.S.C. 1374 §104(f)).

The MMPA carries steep penalties for violations (16 U.S.C. §1375). Any violation of the Act is subject to a civil penalty of up to $10,000. Knowing violation of the Act or violation of the terms of a permit is subject to a fine up to $20,000, and/or up to one year in prison.

The Endangered Species Act of 1973 (16 U.S.C. § 1531 – 1544) was designed to protect species of fish, wildlife, and plants that "have been so depleted in numbers that they are in danger of or threatened with extinction" (16. U.S.C. § 1531(a)(2)). Species protected are determined under section 4, based on the "best scientific and commercial data available." Several international agreements are used as a basis for coverage under the ESA including: the Migratory Bird Treaty Act of 1918 (MBTA) (first between the U.S. and Great Britain, acting on Canada's behalf; followed similar conventions to include Mexico, Japan, and the Soviet Union – and its successor state Russia – into the MBTA); the Convention on Nature protection and Wildlife Preservation in the Western Hemisphere; the International Convention for the Northwest Atlantic Fisheries; the International Convention for the High Seas Fisheries of the North Pacific Ocean; and the

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Sec. 2(a)(4)(A-G)) (discussed previously). Marine mammals are covered specifically under CITES, (Sec. 2(a)(4)(F)). Factors considered for an endangered or threatened species include: potential or current habitat damage; overutilization; predation and disease; inadequate regulation; and other natural and anthropogenic threats.

The MMPA and the ESA have several similarities. For example, as with the MMPA, the ESA emphasizes the importance of making regulations based on "the best scientific and commercial data available … after conducting a review of the status of the species and after taking into account those efforts, if any, being made by any State or foreign nation, or any political subdivision of a State or foreign nation, to protect such species..." (Sec. 4 (2)(b)).While marine mammals are covered under both the ESA and the MMPA, section 17 of the ESA explicitly states that: "Except as otherwise provided in this Act, no provision of this Act shall take precedence over any more restrictive conflicting provision of the Marine Mammal Protection Act of 1972." The MMPA also provides special consideration for marine mammals covered under the ESA, mandating non-lethal deterrent methods when necessary and modeling recovery plans on the ESA (16 U.S.C. § 1533(f)). Marine mammal observers are also given priority placement on fishing vessels in the fisheries with the highest occurrence of mortality of species covered under the ESA (16 U.S.C. § 1387 118(d)(4)(A)).

Under the ESA, any person under the jurisdiction of the United States is prohibited from importing listed species; taking endangered species; possessing, selling, or carrying by any means a listed species; selling any species internationally; or violating any regulation pertaining to any listed species (Sec. 9(a)(1)). Some exceptions are permitted under section 10, which details the permitting process requisite to scientific research on species covered by the ESA. Permits are issued by the Secretary and must specify the potential impact of the take; what steps the permit holder will take to minimize impact; what alternative actions were considered and why they were not used; and any other measures deemed necessary at the Secretary's discretion (Sec. 10(2)(A)). After a public comment period, if the Secretary finds that the take is incidental, will be minimized insofar as possible by the permit holder, the plan is adequately funded, and the take will not impact the likelihood of the species' survival, the Secretary will issue a permit (Sec. 10(2)(B)). As with the MMPA, exemptions are allowed for indigenous subsistence hunting (Sec. 10(2)(C)(2)(e).

Civil penalties are assessed for violations of the ESA. Knowing violation of any provision of the Act, engaging in business with an importer or exporter who violates the Act, or violating the terms of a permit is subject to a penalty of $12,000 or $25,000 per violation based on the provision violated, and may be subject to criminal penalties and up to six months in prison (Sec 11(a-b)). For cetaceans, enforcement of the MMPA and ESA are under the jurisdiction of the USCG (Sec. 11(e)). As federal law enforcement officers are often tasked with other more pressing responsibilities such as homeland security issues, this can sometimes make enforcement of the ESA and MMPA problematic. Rather than overarching federal laws which require specialized and often overtaxed officials to enforce, state laws may be more efficient in protecting cetaceans effectively.

3.1.3 State Laws

A handful of U.S. states have promulgated statutes to protect cetaceans in their waters. For example, Massachusetts has instituted a 500 yard no-approach law for whale watching, and imposes an anti-harassment law (with similar provisions to the MMPA) directed specifically at North Atlantic Right Whales which applies to vessels and aircraft (Spalding and Blumenfeld 1997). This law is more stringent than the federal regulations, and is intended to provide additional protection for the endangered species found in Massachusetts waters (Spalding and Blumenfeld 1997). California also has state laws to supplement MMPA and ESA regulations, and prohibits the taking and harassment of whales in California waters (Spalding and Blumenfeld 1997).

Hawaii, Maryland, New Jersey, and South Carolina have state laws similar to the MMPA. In Hawaii and Maryland, species protected under the ESA are protected from harassment and take (Spalding and Blumenfeld 1997). New Jersey includes laws to give special protection to Sperm, Blue, Fin, Sei, Humpback, and Right whales, while South Carolina provides protection for Atlantic Right, Blue, Bowhead, Finback, Humpback, Sei, and Sperm whales (Spalding and Blumenfeld 1997).

As noted, many of these state laws closely mirror provisions already found in the MMPA and/or the ESA. Some states have laws that are stricter than federal law. For example, the ESA prohibits the taking, possession, sale, and transport of species determined by the federal government to be in danger of extinction. Section 379.411 of the Florida statutes holds that it is unlawful for a person to intentionally kill or wound any species of fish or wildlife listed as endangered, threated, or of special concern as determined by the state of Florida. Whereas enforcement of federal laws requires a federal law enforcement entity, state laws may be enforced by state officers. This may facilitate more frequent and consistent enforcement of regulations designed to protect marine mammals. The additional protection provided by these state laws also allows each state to enforce stricter regulations, thereby providing better protection for endangered species.

3.2 Management Strategies

Voluntary management strategies have proven a useful way of promoting environmental stewardship. While many strategies focus on the general environment or the marine environment, cetaceans benefit indirectly from the results of these plans. Existing management strategies range in scope and effectiveness; assessing current strategies for ecosystem management, both directly applicable to marine mammals and more indirectly through environmental conservation is critical to improving marine mammal management. While some strategies do not include marine mammal-specific considerations at all, the principles established demonstrate important ecological management strategies. Several of these strategies may prove useful for marine mammal protection if adapted to meet these needs.

Several large-scale marine resource management strategies currently exist. The Ocean Charter, produced in 1998 by the Cousteau Society in conjunction with the United Nations Educational, Scientific, and Cultural Organization (UNESCO), is predicated on the preservation and further understanding of the marine ecosystem (von Zharen 1998). The Ocean Charter promotes responsible stewardship of marine resources. However, there are no provisions for quantifiable goals rooted in scientific standards. Despite the nobility of these goals, specific objectives and management recommendations are not provided, rendering it a positive sentiment but a relatively insignificant management strategy.

The Earth Summit in 1992 highlighted the need for international environmental management standards (von Zharen 1999). The International Organization for Standardization (ISO), an international non-governmental organization (NGO), is responsible for environmental management guidelines through the ISO 14000 series, particularly ISO 14001, the implementation standard, which focuses on integrating all levels of organizational activities to improve ecosystem stewardship (von Zharen 1998, 1999). To obtain certification, an organization must demonstrate environmental policy commitments clearly communicated to the public and those within the organization (von Zharen 1998).

ISO 14001 is intended to serve as a framework for continually improving the environmental management of organizations which aim to be more responsible stewards, and have made active steps towards this goal through their environmental management system (EMS) (Rondinelli and Vastag 2000). The organization must also develop a plan for implementation prior to certification (Morrow and Rondinelli 2002). A company's EMS can be certified either through self-documentation declaring that ISO 14001 standards have been met, or officially certified through an external, third-party auditor (Rondinelli and Vastag 2000).

While ISO 14001 is a positive step in that it provides businesses and organizations with tools for responsibly conducting themselves to avoid harming the environment, it is intentionally broad and overarching in order to meet the needs of a variety of businesses and organizations globally. This leaves the responsibility of developing specific management plans based on the requirements of ISO 14001 but tailored to the individual organization. Critics have contended that ISO 14001 is simply a corporate label used for enhancing public opinion, as there is no legal obligation for an organization to abide by the tenets of their own EMS (Rondinelli and Vastag 2000). A more specific strategy for cetacean management, targeted primarily to companies who directly or indirectly impact the marine realm, is needed in order to ensure continued population resiliency.

ISO 14001:2015 is currently under revision; these changes are intended to address many of the existing criticisms of the management strategy. The proposed changes place particular emphasis on the development of an implementation strategy for the organization's EMS and heightened institutional transparency (Petursson 2013). The International Organization for Standardization aims to improve inter-organizational consistency in language and strategy, increasing the accountability of certified companies (Briggs 2012). The ISO 14001:2015 revisions also include more provisions requiring communication outside of the company in order to hold the certification holders accountable for their EMS (Briggs 2012).

The eco-management and audit scheme (EMAS) developed by the European Union (EU) is similar to ISO 14001, but requires performance based indicators (as opposed to existing ISO 14001 standards which require management indicators); transparency (periodic reporting of performance); and continual improvement of performance and not just continual improvement of the management system. The standards set by EMAS are more rigorous than those set by ISO 14001 in that it requires recertification at least every three years and more information must be distributed to the public, holding the company accountable for their own internal plans (Morrow and Rondinelli 2002). As with ISO 14001, EMAS requires a thorough environmental review, a declaration of the company's environmental policy, and an environmental management system (Strachan 1999). Unique to EMAS is that a public statement on the environmental audit is published each year and must be validated by an independent reviewer (Strachan 1999). This system makes the company accountable to consumers.

The World Wildlife Fund (WWF) and Unilever PLC/NV joined forces to create the Marine Stewardship Council (MSC), based on the WWF's successful Forest Stewardship Council (FSC) but focused on the specific needs of the marine environment (von Zharen 1999). The MSC independently certifies firms to accredit fisheries as environmentally sustainable (von Zharen 1998). Certification may be issued to a fishers' organization or industry organization stakeholder (Gulbrandsen 2009). A proper assessment involves a panel consisting of experts in fisheries stock assessment, ecosystem management, and fishery management who assess data from the fishery and confers with industry stakeholders (Gulbrandsen 2009). This facilitates responsible marine resource management while simultaneously engaging the consumer in choosing sustainable seafood.

Once again, however, the MSC applies broad standards in order to meet the needs of numerous fisheries, stopping short of providing an active management plan. As of 2008, only about 7% of fisheries were certified or in the process of becoming certified by the MSC, and about 60% of MSC certified fish caught were from the Alaskan Pollock fishery (Gulbrandsen 2009). Unfortunately, the process of certification is voluntary, costly, and time-consuming (Gulbrandsen 2005). Undertaking such a process requires resources that may be beyond the means of interested parties, and may dissuade organizations from attempting to obtain certification.

In the 1970's, several important mechanisms for protecting dolphins from fishing activities were enacted, perhaps inspired by the passing of the MMPA. The tuna fishery in the eastern tropical Pacific Ocean operated for many years by encircling dolphin groups in purse seine nets in order to catch the tuna associating with the dolphins, a process which resulted in many dolphins deaths (Hall 1998, Körber 1998, Teisl et al. 2002). Prior to enactment of certain laws, estimates indicate that upwards of 100,000 dolphins were killed annually by United States tuna vessels alone (Hall 1998, Teisl et al. 2002).

Following the promulgation of the MMPA in 1972, fisheries which impact marine mammals either directly (e.g., whaling) or indirectly (e.g., bycatch) were forced to change practices. In 1974, the NMFS initiated an onboard vessel observer program (Hall 1998, Körber 1998). In 2011, for example, the observer programs included over 1,000 observers and 79,570 sea days in 47 fisheries nationwide (NOAA 2011). The member nations of the Inter-American Tropical Tuna Commission (IATTC), originally intended to research population biology of tuna species, implemented a program in 1976 with the goals of maintaining sustainable dolphin stocks and avoiding unnecessary dolphin deaths (Hall 1998). IATTC researchers began observations on U.S. vessels in 1979 (Hall 1998). The U.S. Dolphin Protection Consumer Information Act was passed in 1990, and establishes regulations for labeling tuna products as “dolphin safe” (Gulbrandsen 2005). There is evidence to suggest that “eco-labeling” practices, such as the dolphin safe label, may significantly alter consumer behavior, thereby further improving conservation efforts (Teisl et al. 2002).

Observing wild whales is a popular tourist attraction in many areas throughout the United States and the world. However, whale watching vessels in U.S. waters are still expected to abide by ESA and MMPA regulations, and NMFS guidelines encourage all operators to remain at least 100 feet away from all cetaceans (Spalding and Blumenfeld 1997). However, despite these well-intentioned guidelines, enforcement on a large scale presents many challenges, and violations are likely to remain undocumented. The NOAA Fisheries Office of Protected Resources (2012) issues a code of conduct, suggesting a minimum viewing distance of 50 yards from all dolphins, and avoiding circling or trapping animals between vessels. When approached by any marine mammal or sea turtle, vessels should put engines in neutral, and time spent viewing the animals should be limited to half an hour.

Dolphin SMART is a program initiated by NMFS and several NGOs aimed at teaching cetacean tour operators how to responsibly operate so as to minimize disturbance to wild populations (Goss 2013). The guidelines include: remaining 50 yards from all dolphins; moving away if the animals show signs of disturbance; putting engines into neutral when near dolphins; avoiding touching, feeding, or swimming with wild dolphins; and teaching others how to behave responsibly around dolphins (NOAA Fisheries 2012) . Independent evaluators are employed to assess tours and ensure that operators are abiding by the guidelines (Goss 2013). Unfortunately, however, Dolphin SMART programs currently only exist in Florida, Hawaii, and Alabama (NOAA Fisheries 2012).

3.3 Public Education

As Lunney et al. (2008) state: "Wildlife management is, in our view, as much about education, and managing people's attitudes, as it is about the science of the populations of animals." In a study in Scotland, Howard and Parsons (2006) demonstrated that the public is in general concerned about cetacean populations but uninformed about the most serious threats. For example, 25% of individuals surveyed were not aware as to how military activities may impact cetaceans, and 20% were not aware of the impacts of oil exploration; and 60% of participants did not know whether or not Scottish laws provided sufficient protection for marine mammals (Howard and Parsons 2006).

A similar lack of marine mammal knowledge was found by Parsons et al. (2010) among American college students. Of the 230 George Mason University students surveyed, less than 5% were able to correctly identify the North Pacific right whale as the most threatened, only one third could correctly identify the United States' whaling policy, and nearly one quarter had never heard of the IWC (Parsons et al. 2010). While this study was restricted to student participants, it is plausible (and perhaps likely) that the lack of awareness exhibited here among relatively educated individuals is characteristic of the general American public.

Clearly, further educational efforts available to the general public are necessary. One means of improving public awareness is through programs providing educational (targeted to students) and interpretive (targeted to all visitors) services (Lück 2003). This can be accomplished through a range of methods, from videos to displays to personal interaction with staff members (Lück 2003). Orams (1997) showed that engaging tourists in an education program, when coupled with an Australian dolphin interaction program, increased the visitors' enjoyment of the experience and knowledge of cetaceans, and most participants intended to tell their friends about dolphins. Tourists who participated in the education and interaction programs together were significantly more likely to seek additional information about dolphins than those who participated in the interaction program without the accompanying education (Orams 1997). In wild dolphin swim programs in New Zealand, Lück (2003) found that all three programs surveyed lacked an educational component, but that visitors typically desired one. This indicates that tourists, particularly participants in ecotourism programs who likely already have positive attitudes towards the environment, desire an education about cetaceans, and public outreach can provide information which will improve conservation and protection efforts.

Ecotourism programs that expose visitors to marine mammals are popular in many areas, but the behavior of the tourists is not always desirable or appropriate. Orams and Hill (1998) documented the behavior of visitors to an Australian wild dolphin hand-feeding program. Inappropriate behavior included attempting to touch or swim with the animals or behaving erratically while engaged in contact. Following the initiation of a public education program where visitors were specifically told what behaviors were inappropriate and why, there was a significant reduction in problematic tourist behavior (Orams and Hill 1998). While a wild dolphin feeding program would not be desirable (nor legal) in most areas, these results demonstrate that tourists do have in interest in ensuring that they do not harm the animals. This suggests that introducing a public education program may be an effective way of reducing undesirable behavior around wild populations.

Educational programs targeting children may be effective ways of improving awareness of marine conservation issues. Van Bressem et al. (2006) implemented a marine education program in several schools ranging from kindergartens to high schools in Lima, Peru. These programs included video, booklets, workshops, art, and visits to a local museum. The information present in the museum was correctly recalled by over 87% of the students surveyed following the programs, and nearly 90% of students thought that protecting marine animals was important (Van Bressem et al. 2006). Perhaps most significantly, however, of the 55 students surveyed, 54 of them wished to visit the museum again and to receive further environmental education (Van Bressem et al. 2006). Effective youth outreach programs may serve to stimulate interest in the aquatic world among students, which may in turn aid the effectiveness of conservation efforts.

Community level workshops can also assist in marine mammal conservation efforts. Minton et al. (2012) held workshops in Sarawak, Malaysia, home to populations of Irrawaddy dolphins and finless porpoises. Six hour-long community workshops on cetacean biology and conservation were held between March 2009 and July 2010, and welcomed between 100 and 200 participants of all ages (Minton et al. 2012). Even two years after the workshop, participants had a significantly better understanding of basic cetacean biology, conservation issues, and how to respond to an entangled or dead animal than those who did not attend a workshop (Minton et al. 2012). These results demonstrate that even relatively limited outreach efforts, when designed to provide information about the most salient issues, may dramatically improve public knowledge of cetacean biology and conservation.

Providing voluntary recommendations for interacting with cetaceans may also be an effective means for educating and improving the behavior of the public. A voluntary rest period, established by the New Zealand Department of Conservation, was in effect from 11:30-13:30 daily from December 1 to March 31 for dusky dolphins in Kaikoura (Duprey et al. 2008). While traffic during this period was not completely eliminated, Duprey et al. (2008) found a significant decrease in the number of visiting vessels during the rest period. However, while the voluntary recommendations did improve the behavior of boaters, without effective enforcement of mandatory regulations, negative behavior cannot be completely eliminated (Duprey et al. 2008).

"Whale watching" – observing cetaceans in their natural habitat – is a popular tourist attraction in many locations around the world. Many tour managers, however, incorrectly assume that tourists are most satisfied with their trip when the boat is physically close to the whales (Orams 2000). To the contrary, Orams (2000) found that proximity to the whales was not a major factor involved in the enjoyment of the trip. Tourists were most satisfied when a large number of animals were sighted, and when the behavior observed was interesting. This suggests that whale watching is just as enjoyable for tourists when a safe distance to the animals is maintained. In fact, approaching animals too closely may reduce the tourists' enjoyment, as it may cause the animals to leave the location or change behavior as a result of the whale watching vessel's proximity.

3.4 Future Directions in Management, Policy, and Education

3.4.1 Policy Recommendations

The existing federal laws provide ample protection for marine mammals to protect them from harassment. However, observations during data collection suggest that enforcement of these laws is an issue. Those responsible for MMPA and ESA enforcement are the NOAA Office of Law Enforcement in partnership with the USCG, at least in the case of common bottlenose dolphins (NOAA Fisheries Office of Law Enforcement). Ensuring compliance with these laws requires some degree of enforcement, but devoting a significant amount of time to looking for violators is impractical at best, and at worst may put the security of the port at risk. Targeting enforcement to the areas where the largest groups of dolphins are present during peak vessel traffic time can help make the most efficient use of the time and resources available for law enforcement.

Working with the law enforcement officers, who are likely already familiar with the dates and times when recreational activity is at its peak, to help them target areas where large groups are frequently resting, socializing, and foraging, can help to enforce the law while not detracting from the other more duties. However, rather than issuing citations, the officers should focus on warning boaters that their behavior is not legal, and providing educational materials with information about safe cetacean watching to improve compliance.

Enforcement of existing regulations should be targeted to specific areas to make most efficient use of the resources available. For instance, groups were largest and most numerous in the afternoon. Focusing boater observation and intervention efforts to the afternoon time block may serve to decrease negative behavior of boaters, while providing the greatest possible benefit to the largest number of animals. Vessel scores were highest in Galveston throughout the day. Therefore, if officers are available, targeting the Galveston zone and portion of the Galveston ship channel in the passage may be more practical, particularly as the USCG station in Galveston is located immediately next to the Galveston ferry landing. Using the information contained herein about group sizes and activity can help law enforcement officers make the most efficient use of their limited time.

While federal laws provide significant protection for marine mammals and severe penalties for violations, in many cases these laws are difficult to enforce. Assessing a $10,000 fine for a minor violation such as chasing a dolphin is excessive; however, without enforcement, one cannot expect the behavior to cease. Several states have implemented state laws to supplement federal laws, and this would be an appropriate course of action for the state of Texas. A state law would alleviate the burden of enforcement from federal agents and allow local law enforcement, when practicable, to enforce violations and protect cetaceans from problematic harassment occurrences. Local enforcement could include, for example, the Galveston Police Marine Division including its Marine Patrol Unit which currently makes "courtesy marine patrols."

The goal of this state legislation should not be handing out tickets and collecting fines, but rather educating the public and affirming that the state of Texas takes conservation seriously. Issuing smaller fines assessed by the state (such as a $100 citation for chasing animals) can help firmly establish that the cetacean populations are under the protection of the state. For the first three months after passing the law, enforcement officers should issue warnings rather than tickets. This will inform the public about the new legislation, educate boaters about safe cetacean watching, and provide an opportunity for tourists and residents to change their behavior prior to the issuing of fines. Once the initial "warning" period has passed, officers should begin issuing citations for harassment.

Under existing Texas regulations (Texas Parks and Wildlife Code, Title 4, Chapter 31, Subchapter D § 31.099), boaters must not operate in a circular path around vessels engaged in fishing. However, there are no expectations as to a distance that should be maintained by other vessels, other than ensuring sufficient distance so as to not entangle the other boats in the fishing gear. During data collection, dolphins were observed foraging in association with shrimp vessels 1,836 times. To protect foraging dolphins from a vessel strike injury, the state of Texas should enact measures that would prohibit operators of other vessels from approaching within 50 meters of a boat engaged in shrimping. When this distance is impossible to achieve due to the nature of the passage or other vessels in the area, operators should slow to headway only speed so as to minimize or prevent potential injury to animals which may be engaged in foraging around the shrimp boat.

Working with the State of Texas to pass a state law for marine mammal protection is an arduous process that will likely require several years. However, such a law may prove beneficial for alleviating the burden of MMPA enforcement from federal officials. In Galveston, the other responsibilities of NOAA/NMFS, and USCG law enforcement officers are extensive. Enacting measures that would allow enforcement on the state and local level, such as the Galveston Marine Patrol, would aid in ensuring the health and safety of Galveston Bay's marine mammal population. No matter which level of enforcement, federal or state, the focus of enforcement efforts should be to protect the population of cetaceans local to Galveston Bay. In many cases, boaters are unaware that their behavior is harmful for the animals and do they realize that they are violating federal and in some instances state laws. Enforcing violations should be done in a manner so as to educate violators about why the activities in which they are engaging are illegal, and the potential impacts that harassing cetaceans may have on individuals and the population. Providing education for law enforcement officers is a crucial step to achieving this goal.

Establishing a rest period for bottlenose dolphins in Galveston similar to the rest period established for dusky dolphins in New Zealand may also curb problematic boater behavior while also increasing boater safety (Duprey et al. 2008). Because major shipping lanes are positioned near the Galveston dock through part of the passage, the most practical location to establish a rest area would be the area surrounding the Bolivar ferry landing. While ferries would still be entering the area regularly, the ferry vessels move in predictable patterns and are likely less disruptive than the recreational vessels that regularly enter the area. Such measures would also be beneficial for boater safety, as in several instances recreational vessels passed in close proximity to the ferry; on one occasion, a vessel lost power directly in front of the ferry landing, resulting in a near-collision and a ferry delay. This area is popular for recreational fishing, but under a rest period would still be accessible for fishing from the Bolivar ferry landing jetty. A voluntary rest period would not completely eliminate recreational traffic in the area, but because such provisions have been effective in reducing traffic and improving boater behavior previously (Duprey et al. 2008), establishing a rest period in Bolivar would likely prove beneficial for both the animals and the boaters.

3.4.2 Management Recommendations

While the Ocean Charter, ISO 14001, EMAS, and MSC all represent positive steps toward responsible marine stewardship, a more comprehensive management plan is needed, particularly with respect to marine impacts. In general, these existing strategies suffer from the same affliction: in attempting to create a highly comprehensive management plan, each falls short of giving specific directives for improving conservation efforts. Of the existing strategies, EMAS does perhaps the most thorough job of holding organizations accountable for their actions. ISO 14001 guidelines are not as stringent, and do not provide the same level of public accountability through transparency as EMAS.

A new management strategy can draw on the strength of these existing management schemes while attempting to overcome its shortcomings. This new strategy should be targeted to local businesses on Galveston Island and run through the city of Galveston. Obtaining a "buy in" from the city and the businesses is a complicated process which is beyond the scope of this research. To convince the city of Galveston to participate in such a program, there must be some type of benefit to the city. As demonstrated by Pindyck (2000), a cost-benefit analysis is generally requisite to environmental policy adoption; although a cost-benefit analysis is beyond the scope of this research, there is support for the adoption of environmental policies, as such policies have proven to provide tangible benefits for the city. For example, there is evidence to indicate that reduction of emissions significantly reduces public health costs (Rabl and Spadaro 2000). In a case study in Santiago, Sao Paulo, and Mexico City, Bell et al. (2006) demonstrated that over the course of a year, pollutant reduction would have saved the three cities a combined total of about $567 million. While long-range transport of pollutants is a factor in monitoring air quality, local-level transport is also a significant factor in air quality monitoring (Isakov and Özkaynak 2008). This suggests that a Galveston-scale approach to environmental management would be an effective way to reduce public health costs, therein directly benefiting the city.

The businesses stand to benefit financially from participating in this green initiative, and therefore such a program is viable. In 1999, pollution abatement operating costs for businesses in the southeast section of United States" totaled upwards of $1 billion, including $374.2 million for air pollutants and $409.8 million for water (US Census Bureau 2002). Reducing pollution emission through relatively small initial investments is a viable option for businesses seeking to reduce their costs, and public reputability may reduce labor costs (Ambec and Lanoie 2008). Particularly for companies whose work carries certain risk management problems (for example, chemical companies and oil and gas), environmental initiatives can positively benefit public perception and stakeholder relationships (Ambec and Lanoie 2008). Waste reduction plans implemented by 3M in the 1970's saved the company a total of over $500 million over 15 years (Hart and Ahuja 1996). For most companies, the return on investment for pollution reduction programs is one to two years (Hart and Ahuja 1996)

Rather than focusing specifically on marine mammals, a new management plan should be implemented to focus on the most crucial needs of the marine environment, the impacts of which will undoubtedly apply to the health of marine mammal populations as well. In order for a management scheme to be effective, quantifiable and objectively-measurable goals must be established. In the case of the eastern tropical Pacific tuna fishery, the goals were clear: to minimize unnecessary take of dolphins. The program coupled this goal with research and on board observers to assess the effectiveness of the program. Instead of focusing on lowering negative impacts to a certain level with no continual improvement from that level, an effective management strategy should focus on a proportional decline. Larger businesses will most likely have larger impacts than smaller businesses, but will also have the means to reduce their impacts more dramatically. By setting a low percentage rather than baseline level, businesses can focus on taking small steps each year to minimize their impacts on the ocean.

Herein, the proposed program will be referred to as: “Responsible Marine Businesses” (RMB). Similar to the voluntary EMAS and ISO 14001, running the voluntary RMB program through the city of Galveston will lend the program legitimacy. Businesses are significantly more likely to adopt green initiatives when influenced by entities such as a local government, again supporting the conclusion that a government-run program is most likely to be successful (Clemens and Douglas 2006). Companies who want their environmental commitments recognized should be asked to publicize their goals and report their successes to the public including their adherence to their management plans. Additionally, voluntary certification and re-certification could be required on an established basis similar to ISO 14001 and EMAS (three or five years in order to minimize costs to businesses), and companies should publish an annual report detailing their progress in the past year.

A wide-reaching plan of action for implementation is outside the scope of this research; however, cities across the U.S. have taken the “greening of their city” seriously, particularly now that there is stimulus money tied to such agenda items as energy efficiency and green jobs. For example, Denver became the first U.S. city to achieve registration to the ISO 14001 standard across multiple departments (Westervelt

2009). The standard was used to gauge progress on the Mayor's sustainability plan which required green fleets and renewable energy program which, in turn could be influential in securing additional federal and state funding for the city (Westervelt 2009). Savings based only on the vehicle maintenance department's choice to change from solvent to aqueous washers save the city $3,200 per year; other cities such as San Jose, Dallas, San Diego, and Scottsdale aim to follow Denver's example (Westervelt 2009).

The RMB program should focus on reduction of three major oceanic problems that every business, regardless of their nature, can directly address through responsible practices. The first goal should be reduction of carbon dioxide emissions of manufacturing and transportation. High carbon dioxide levels contribute to ocean acidification which can contribute to a variety of problems ranging from fish development to coral calcification rates (Bignami et al. 2013, Kuffner et al. 2013). The biological impacts on the marine world as a result of carbon dioxide emissions affect the bottom of the food chain, with wide-ranging results on economically important species as well as marine mammals. As a result, companies seeking RMB certification should aim to reduce carbon dioxide emissions by small, achievable increments – perhaps 5 to 10% – from the previous year. While this may not be a significant reduction *per se*, many businesses committing to small reductions in emissions can potentially have dramatic benefits for the local ecosystem. The means by which the business seeks to reduce emissions will depend on the specific nature of their activity, and can change each year based on the company's objectives, but the year's focus reduction method should be specifically stated and made available to the public. Success of the management plan should also be made available to the public.

The second goal of the RMB program should be reducing garbage output of the business, with particular attention to plastics. Cetaceans, marine turtles, and seabirds have been documented ingesting plastic and other kinds of debris, becoming entangled, or experiencing contamination from polychlorinated biphenyls (Tarpley and Marwitz 1993, Derraik 2002). Similar to the carbon dioxide emissions goal, companies should focus on a small proportional annual reduction in their use or production of plastic products. Focusing on reduction of marine debris will vary among businesses. Eliminating plastic products, engaging in recycling programs, changing to biodegradable materials, or discouraging the use of disposable plastic products are some methods by which a company may reduce its marine debris. Again, the means by which the company seeks to reduce its plastic use and its success rate should be publicized, and an annual report made available to any interested party.

Finally, the RMB program should focus on reducing ocean noise. In many systems, marine mammals are apex predators that provide top-down control for the food web (Block et al. 2011). Cetaceans in particular are affected by activities such as shipping and drilling. Behavioral responses include altered surfacing and vocal behavior, and continued close proximity exposure may lead to hearing loss (Nowacek et al. 2007, Finneran and Schlundt 2010). Again, a small proportional reduction in ocean noise for a RMB business should be sought. The management strategy for reducing ocean noise will vary according to the individual company. Documentation of the plan for each year and the success of the chosen option should be provided to the public.

As demonstrated by Teisl et al. (2002), eco-labeling can be an effective way to improve business while holding companies accountable for how their practices impact the environment. Incorporating an eco-labeling component into the RMB program, one that draws attention to the organization's green strategy, may help draw consumers toward purchasing products and engaging in services from these local, environmentally responsible businesses. Businesses may also benefit from their improved environmental image associated with the RMB program.

In an eco-conscious society, consumers are often cognizant of how their purchasing and other decisions impact the environment. An easily recognizable label issued by the city of Galveston that represents compliance with the RMB program would ultimately benefit the business. This label would be issued only to companies who are in compliance with the RMB program, and would be revoked in the event that the standards are not met. Displaying this label on packaging, company vehicles, and websites will notify consumers that this is a local business committed to marine conservation. Such a label would lend legitimacy to the company's environmental commitment, inspiring consumer rapport and, theoretically, increased financial gains for the company.

The cost associated with the design and implementation of an RMB-type program could be significant, but the economic benefits derived from greening fleets to increased energy efficiency can also be dramatic. Such a greening program would demonstrate that the city of Galveston is committed to marine conservation through recognizing environmentally conscious local businesses. If successful and beneficial, similar programs can be established in other areas.

3.4.3 Education Recommendations

Although law and management are important components of cetacean protection, arguably the best way to protect a local cetacean population is through a well-educated community that potentially interacts with these cetaceans. In other areas, public viewing platforms have been used successfully for marine mammal education. The Whale Trail (2011) in Washington state, for example, provides locations where orca whales and other marine mammals can be viewed from shore. In the North Sea, the organization ORCA works with public transportation to deliver cetacean outreach programs to local schoolchildren (Cohen and McNaught 2012). A program similar to ORCA's educational outreach efforts and the Whale Trail in Washington would be well suited as templates for outreach efforts in the Galveston area.

Galveston provides a unique opportunity to reach out to the public to encourage protection of a local marine mammal population. As Minton et al. (2012) demonstrated, as little as an hour of education can significantly improve knowledge of cetacean biology and how to behave when encountering animals. The most effective outreach program must target multiple age groups in a variety of programs. Outreach efforts should target the general community through educational workshops; visitors to area attractions via educational displays; and schoolchildren through classroom educational visitation and field trips. Documenting the success of the workshops in a manner similar to Minton et al. (2012) may encourage other universities to engage in similar programs. This could be accomplished through surveys at the workshop and follow-up surveys, and comparing the knowledge of participants to non-participants.

Free community workshops open to all interested adult visitors could be hosted. These workshops could be run by volunteer TAMUG faculty (as part of their "service" requirement, if applicable) and graduate students in partnership with local businesses in order to provide a venue. Working with local businesses to provide promotional materials such as flyers and posters would make such workshops free or nearly of cost for facilitators and participants. Assisting with these workshops would provide Texas A&M Galveston students with a volunteer opportunity relevant to their future career, e.g., a noteworthy inclusion on a resume, and would serve to bring customers into local businesses.

These workshops should focus on providing an overview of dolphin biology and behavior, and emphasize the most pressing conservation concerns. Workshops should address basic dolphin biology including common questions such as whether dolphins are fish or mammals, and what kinds of dolphins inhabit Galveston Bay. These workshops will also provide an opportunity to educate the public about when and where they can watch dolphins in a manner that is safe for the animals and the observers. Participants should be encouraged to view animals from shore-based observation stations such as Seawolf Park, the Galveston-Port Bolivar ferry, and the Port Bolivar ferry landing jetty. Maps showing the viewing areas would be provided as well as viewing times (based on this research).

Another major focus of these workshops should be what constitutes "harassment" of a marine mammal, and what types of behaviors violate federal laws. Teaching participants about dolphin behavior will encourage them to enjoy cetaceans safely so as not to disrupt them during observations. Many local residents are boaters, and providing information about NOAA safe marine mammal watching practices (NOAA Fisheries Office of Protected Resources 2012) may help in reducing harassment. Finally, workshops can inform participants about how they can protect the ocean through reducing carbon dioxide emissions and cutting down on waste products. This outreach effort would provide valuable information to the public, an opportunity for the TAMUG community to engage local residents, and an opportunity for local businesses to attract customers while supporting conservation efforts.

These educational efforts may also provide an opportunity for others with a vested interest in conservation and tourism to engage in public outreach. Including both local and federal law enforcement officers, zoo and aquarium staff and volunteers, the Texas Marine Mammal Stranding Network (TMMSN), the Galveston Chamber of Commerce, and others could help promote eco-tourism in Galveston on a larger scale. Safety enforcement officers such as Galveston's Marine Patrol could help educate participants about enjoying cetacean viewing safety, from shore or other public viewing platforms. A broad "buy-in" from community stakeholders demonstrates that Galveston takes seriously the importance of environmental conservation and protecting cetaceans in Galveston waters.

The Dolphin SMART program is a valuable resource for cetacean watching tours (NOAA Fisheries 2012). Cetacean watching businesses currently operate in Galveston. Encouraging these operators to seek Dolphin SMART certification not only would be beneficial for the animals in the Bay, it would be of benefit to visitors seeking to learn about the animals rather than just observe them. There are currently no Dolphin SMART certified tours in the state of Texas. During public outreach, participants could be encouraged to choose cetacean tours that have committed themselves to responsible practices; this may also provide an opportunity to raise funds for the local cetacean tours to defray the costs of certification if they are interested in demonstrating their commitment to cetacean conservation. The operators would also be encouraged to become part of the RMB program.

Educating children is another area of focus. Van Bressem et al. (2006) demonstrated that students are interested in learning about the marine environment especially outside the classroom. Reaching out to local primary schools would allow TAMUG's undergraduate and graduate students to engage with the community while building their own professional resumes. Outreach efforts, coordinated by volunteer graduate students and faculty and supported by undergraduates, could be conducted through TAMUG for interested public schools in Galveston County once a year. These outreach efforts should begin in the classroom, showing students pictures and videos to provide elementary students with a basic overview of marine mammal biology and behavior. Coordination with the local stranding network in these educational endeavors would stress the importance of proper response when encountering a stranded or entangled animal.

After learning about marine mammals in the classroom, students would have an opportunity to observe marine mammals in their natural habitat. Because the data presented here provide information as to when the largest groups of dolphins are most active, targeting field trips to shore based areas during these times will ensure students are likely to see animals and will enjoy the viewing experience. This field trip will give students an opportunity to experience science in the real world, sparking interest in conservation and potentially careers in biological science. While on the trip, students can also be informed about how to observe marine mammals safely in their natural habitat, from a location on shore or from other public areas like the Galveston-Port Bolivar ferry. Students would be encouraged to share information and material about marine mammal conservation with their families at home. These field trips can be targeted to the afternoon when dolphin groups were largest and in Bolivar where animals were frequently observed resting close to shore. Using the temporal and spatial information from this research may ensure a more successful observation experience which, in turn, can help make the field-trip experience more engaging for students in Galveston primary schools.

Another outreach endeavor is signage. There is evidence to suggest that the use of educational displays in conservation has a high potential for changing tourist behavior resulting from a lack of knowledge, and signs were examined by more than two-thirds of site visitors (Manning 2003). In Acadia National Park, educational signs significantly increased the proportion of visitors who complied with park regulations (Park et al. 2008). Signage regarding avoiding feeding wild animals has also proven effective in reinforcing the problems it may cause, as well as influencing visitor's decisions not to feed the wildlife (Mallick and Driessen 2003). As such, informational displays may aid in local conservation efforts.

Galveston is a popular tourist destination, and the waterfront areas provide ample opportunities to view dolphins from docks, ferries, and jetties. Installing signage in these locations can help spark interest in the wildlife native to Galveston, while encouraging compliance with laws and regulations. Currently, there is one poster outside the Galveston ferry office, and a small poster inside some of the ferry vessel cabins, provided by the TMMSN. While the poster provides some valuable information regarding very basic cetacean anatomy and stranding response, it is small, colorless, and not prominently displayed. Because the animals are so easily viewed from the ferry and the ferry is a much safer alternative for viewing the animals than aboard a boat, working with TxDOT and TMMSN to produce more prominent signage may draw more tourists to view the dolphins from the ferry. More obvious, colorful signs with additional information about behavior, biology, times when animals are most active and in which areas, and marine mammal laws can serve to increase eco-tourism while promoting safe cetacean watching from the ferry or shore based platforms. Larger posters could be mounted inside the ferry cabins, providing maps of the most frequent sighting areas and links to the TMMSN's cetacean identification and stranding response smartphone applications. Potential funding for this effort could come from TxDOT or granting agencies such as Texas Sea Grant's outreach and education program.

Seawolf Park on Pelican Island is another location where animals were frequently sighted close to shore. The park currently provides tours of decommissioned warships, and is also a popular location for fishing and picnicking. If Seawolf Park's staff is open to adding an environmental education component, TAMUG student volunteers could act as interpreters during the tourist season. This location would also be ideal for distributing pamphlets about dolphin biology, behavior, and laws for observing animals safely. Providing signs and displays may also increase tourist traffic to the park. Additionally, offering information about protecting the oceans may spark interest in conservation.

While laws provide protection for marine mammals, educating the public is critical to ensuring compliance with laws. Conversations aboard the Galveston-Port Bolivar ferry indicated that many people were not aware that there is a common bottlenose dolphin population in Galveston Bay, but on seeing the animals, were interested in learning more. The proximity of the animals to a popular tourist destination offers an opportunity for TAMUG students, faculty, and staff to engage the local community to spark interest in conserving the marine environment. By targeting local residents through workshops, students through educational outreach programs, and tourists by providing information at popular destinations, Galveston may also experience an economic boost sparked by interest in these animals. Coupling educational efforts with awareness of laws and improved enforcement can allow the public to appreciate these animals in their natural habitat while protecting them from anthropogenic threats.

4. GENERAL CONCLUSIONS

"In the end we will conserve only what we love. We will love only what we understand. We will understand only what we are taught." –Baba Dioum, Environmentalist

Cetaceans are charismatic animals, and watching them in their natural habitat is an activity already enjoyed and appreciated by many. Recognizing the importance of protection through laws, effective management, and outreach education is the best means to protect the cetacean population in Galveston Bay, while also using bottlenose dolphins as ambassadors for the environment. Teaching tourists and residents about the importance of conservation provides a unique opportunity to use a thriving resident population as a means of creating an environmentally conscious community, motivated by protecting resident cetaceans.

The implementation of the recommendations contained herein, however, will undoubtedly be a time consuming, expensive process, and one which must be carefully executed to avoid doing more harm than good. For example, encouraging tourists and the community to enjoy the resident common bottlenose dolphin population too quickly, before being properly educated about how to safely observe the animals, could have the potentially disastrous consequence of major population disruption. In order to avoid these undesirable effects insofar as possible, implementation of the recommendations must include: education of local law enforcement officers; development and implementation of a specific management plan for the City of Galveston; establishment of a coordinated educational outreach plan; and state-level promulgation of marine conservation law.

The cetacean population in Galveston is deserving of further research: Behavioral variations beyond those contained in this study are likely to emerge with further observation. Evaluating the impacts of anthropogenic activity on this population and in similar high activity areas may improve conservation and management efforts. Common bottlenose dolphins are highly charismatic animals, and are appreciated by many people, even those whose main focus is not on the marine environment. Encouraging the community of Galveston and other areas where inshore populations of dolphins are present could serve to instill a passion for marine conservation. Using these animals as ambassadors for the marine environment, if done in such a way so as to promote observation of these animals safely and respectfully, would provide benefits not only for these populations, but the marine ecosystem itself.

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APPENDIX A: BEHAVIORAL ANALYSIS

Zone:

```
>rfd <- read.csv("RivardFerryData.csv")
> table(rfd$Zone,rfd$Behavior)

     F    R    S    T
  B 3077 2833  860 2526
  G 2004  454  104 1491
  P 3478 1392 1001 5560
> source("contingencyTableUtilities.R")
> ppt(table(rfd$Zone,rfd$Behavior),"Zone","Behavior")
                               Behavior
             F           R           S           T                     Total
        ---------------------------------------------------------------
       B |       3077 |      2833 |           860 |      2526 |      9296
Zone    |  3210.834 |  1755.286 |  737.1525 |  3592.728 |
        |  5.578461 |  661.6972 |  20.47269 |  316.7254 |
        ---------------------------------------------------------------
       G |       2004 |           454 |         104 |       1491 |      4053
        |  1399.904 |  765.2941 |  321.3941 |  1566.408 |
        |  260.6833 |  126.6232 |  147.0475 |   3.63016 |
        ---------------------------------------------------------------
       P |       3478 |        1392 |         1001 |        5560 |     11431
        |  3948.262 |   2158.42 |  906.4534 |  4417.865 |
        |  56.01103 |  272.1434 |  9.861579 |  295.2723 |
        ---------------------------------------------------------------
    Total |     8559 |     4679 |        1965 |         9577 |     24780
> chisq.test(table(rfd$Zone,rfd$Behavior))

        Pearson's Chi-squared test

data:  table(rfd$Zone, rfd$Behavior)
X-squared = 2175.746, df = 6, p-value < 2.2e-16
```

Distance to Shore:

```
> table(rfd$DistShore,rfd$Behavior)

     F    R    S    T
  C 1229  385  203  787
```

```
 F 3016 1793  614 2700
 I 2345 1384  468 1918
 O 1473  969  648 3959
 V  496  148   32  213
> source("contingencyTableUtilities.R")
> ppt(table(rfd$DistShore,rfd$Behavior),"Distance To Shore","Behavior")
                                   Behavior
                    F          R           S          T         Total
                 -----------------------------------------------------------------------
      Dist     C |      1229 |         385 |        203 |         787 |       2604
      Shore      |  899.4203 |    491.6915 |   206.4915 |    1006.397 |
                 |  120.7697 |    23.15086 | 0.05903753 |    47.82893 |
                 -----------------------------------------------------------------------
               F |      3016 |        1793 |        614 |        2700 |       8123
                 |   2805.68 |    1533.798 |   644.1362 |    3139.385 |
                 |  15.76601 |    43.80343 |   1.409935 |    61.49597 |
                 -----------------------------------------------------------------------
               I |      2345 |        1384 |        468 |        1918 |       6115
                 |  2112.118 |    1154.644 |   484.9062 |    2363.332 |
                 |  25.67755 |    45.55866 |   0.589431 |    83.91551 |
                 -----------------------------------------------------------------------
               O |      1473 |         969 |        648 |        3959 |       7049
                 |  2434.721 |    1331.004 |   558.9703 |    2724.305 |
                 |  379.8824 |    98.45702 |   14.18015 |    559.5821 |
                 -----------------------------------------------------------------------
               V |       496 |         148 |         32 |         213 |        889
                 |  307.0602 |    167.8624 |   70.49576 |    343.5816 |
                 |  116.2582 |    2.350235 |   21.02146 |    49.62886 |
                 -----------------------------------------------------------------------
           Total |      8559 |        4679 |       1965 |        9577 |      24780
> chisq.test(table(rfd$DistShore,rfd$Behavior))

      Pearson's Chi-squared test

data:  table(rfd$DistShore, rfd$Behavior)
X-squared = 1711.385, df = 12, p-value < 2.2e-16
```

Time Block:

```
> table(rfd$TimeBlock,rfd$Behavior)

      F    R    S    T
  A 2771 1673  769 3745
```

```
  E 1984 1865  739 3152
  M 3804 1141  457 2680
> source("contingencyTableUtilities.R")
> ppt(table(rfd$TimeBlock,rfd$Behavior),"Time Block","Behavior")
                              Behavior
              F           R           S           T         Total
          -------------------------------------------------------------------
Time    A |      2771 |        1673 |          769 |        3745 |      8958
Block     |  3094.089 |   1691.464 |   710.3499 |   3462.097 |
          |  33.73737 |  0.2015564 |   4.842454 |   23.11722 |
          -------------------------------------------------------------------
        E |      1984 |        1865 |          739 |        3152 |      7740
          |  2673.392 |   1461.479 |   613.7651 |   2991.363 |
          |  177.7748 |   111.4137 |   25.55338 |   8.626229 |
          -------------------------------------------------------------------
        M |      3804 |        1141 |          457 |        2680 |      8082
          |  2791.519 |   1526.056 |    640.885 |    3123.54 |
          |  367.2259 |    97.1579 |   52.76093 |   62.98222 |
          -------------------------------------------------------------------
    Total |      8559 |      4679 |        1965 |        9577 |     24780
> chisq.test(table(rfd$TimeBlock,rfd$Behavior))

        Pearson's Chi-squared test

data:  table(rfd$TimeBlock, rfd$Behavior)
X-squared = 965.3936, df = 6, p-value < 2.2e-16
```

APPENDIX B: GROUP SIZE ANALYSIS

```
>rfd <- read.csv("RivardFerryData.csv")
> gs.hurdle<-
hurdle(GroupSize~TimeBlock+Zone+Behavior+DistShore+VesScore|1,data=rfd.nb,dist
="negbin")
> AICc(gs.hurdle.p,gs.hurdle)
         df     AICc
gs.hurdle.p 14 107689.7
gs.hurdle   15 101401.5
> summary(gs.hurdle)
Call:
hurdle(formula = GroupSize ~ TimeBlock + Zone + Behavior + DistShore +
   VesScore | 1, data = rfd.nb, dist = "negbin")
Pearson residuals:
   Min      1Q  Median      3Q     Max
-1.5645 -0.6403 -0.2789  0.3280 25.4874
Count model coefficients (truncated negbin with log link):

            Estimate Std. Error z value Pr(>|z|)
(Intercept)  1.481094   0.022526  65.750  < 2e-16 ***
TimeBlockE  -0.079426   0.012333  -6.440 1.19e-10 ***
TimeBlockM  -0.195437   0.012730 -15.352  < 2e-16 ***
ZoneG       -0.396132   0.017928 -22.096  < 2e-16 ***
ZoneP       -0.031824   0.014838  -2.145   0.0320 *
BehaviorR   -0.259278   0.015219 -17.037  < 2e-16 ***
BehaviorS    0.132159   0.018401   7.182 6.86e-13 ***
BehaviorT   -0.392573   0.012524 -31.346  < 2e-16 ***
DistShoreF  -0.039784   0.018665  -2.131   0.0331 *
DistShoreI  -0.074237   0.018836  -3.941 8.10e-05 ***
DistShoreO  -0.151113   0.021293  -7.097 1.28e-12 ***
DistShoreV  -0.192628   0.032099  -6.001 1.96e-09 ***
VesScore     0.029119   0.002107  13.819  < 2e-16 ***
Log(theta)   1.343422   0.024077  55.796  < 2e-16 ***
Zero hurdle model coefficients (binomial with logit link):
           Estimate Std. Error z value Pr(>|z|)
(Intercept)    10.12       1.00   10.12   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Theta: count = 3.8321
Number of iterations in BFGS optimization: 22
Log-likelihood: -5.069e+04 on 15 Df
```

APPENDIX C: CALF PRESENCE ANALYSIS

```
> # PAG by YN calf
> table(rfd$Yncalf,rfd$Behavior)

     F    R    S    T
  0 5616 3913 1473 7478
  1 2943  766  492 2099
> source("contingencyTableUtilities.R")
> ppt(table(rfd$Yncalf,rfd$Behavior),"Calves Present?","Behavior")
                                   Behavior
                 F            R            S            T         Total
              ---------------------------------------------------------------------------
Calves?    0 |       5616 |       3913 |       1473 |       7478 |       18480
             |   6382.983 |   3489.424 |   1465.424 |   7142.169 |
             |   92.16114 |   51.41733 | 0.03916948 |   15.79102 |
              ---------------------------------------------------------------------------
           1 |       2943 |        766 |        492 |       2099 |        6300
             |   2176.017 |   1189.576 |   499.5763 |   2434.831 |
             |   270.3393 |   150.8242 |  0.1148971 |   46.32032 |
              ---------------------------------------------------------------------------
         Total |       8559 |       4679 |       1965 |       9577 |       24780
> chisq.test(table(rfd$Yncalf,rfd$Behavior))

        Pearson's Chi-squared test

data:  table(rfd$Yncalf, rfd$Behavior)
X-squared = 627.0074, df = 3, p-value < 2.2e-16

>
> # Dist. Shore by YN Calf
> table(rfd$Yncalf,rfd$DistShore)

     C    F    I    O    V
  0 1898 6103 4252 5521  706
  1  706 2020 1863 1528  183
> source("contingencyTableUtilities.R")
> ppt(table(rfd$Yncalf,rfd$DistShore),"Calves Present?","DistShore")
```

```
                          DistShore
         C        F        I        O        V      Total
         ------------------------------------------------------------
Calves?  0 |    1898 |    6103 |    4252 |    5521 |     706 |   18480
           | 1941.966 | 6057.831 | 4560.339 | 5256.881 | 662.9831 |
           | 0.9953923 | 0.3368009 | 20.84778 | 13.26997 | 2.791109 |
         ------------------------------------------------------------
         1 |     706 |    2020 |    1863 |    1528 |     183 |    6300
           | 662.0339 | 2065.169 | 1554.661 | 1792.119 | 226.0169 |
           | 2.919817 | 0.9879494 | 61.15348 | 38.92525 | 8.187253 |
         ------------------------------------------------------------
     Total |    2604 |    8123 |    6115 |    7049 |     889 |   24780
> chisq.test(table(rfd$Yncalf,rfd$DistShore))

        Pearson's Chi-squared test

data:  table(rfd$Yncalf, rfd$DistShore)
X-squared = 150.4148, df = 4, p-value < 2.2e-16

>
> # Zone by YN Calf
> table(rfd$Yncalf,rfd$Zone)

     B    G    P
  0 6915 3084 8481
  1 2381  969 2950
> source("contingencyTableUtilities.R")
> ppt(table(rfd$Yncalf,rfd$Zone),"Calves Present?","Zone")
                       Zone
         B        G        P      Total
         ----------------------------------------
Calves ?  0 |    6915 |    3084 |    8481 |   18480
            |  6932.61 | 3022.576 | 8524.814 |
            | 0.04473323 | 1.248231 | 0.2251812 |
         ----------------------------------------
          1 |    2381 |     969 |    2950 |    6300
            |  2363.39 | 1030.424 | 2906.186 |
            | 0.1312175 | 3.661479 | 0.6605316 |
         ----------------------------------------
      Total |    9296 |    4053 |   11431 |   24780
> chisq.test(table(rfd$Yncalf,rfd$Zone))

        Pearson's Chi-squared test
```

```
data:  table(rfd$Yncalf, rfd$Zone)
X-squared = 5.9714, df = 2, p-value = 0.0505

>
> # Time by YN Calf
> table(rfd$Yncalf,rfd$TimeBlock)

      A    E    M
  0 6409 5711 6360
  1 2549 2029 1722
> source("contingencyTableUtilities.R")
> ppt(table(rfd$Yncalf,rfd$TimeBlock),"Calves Present?","Time Block")
                             Time Block
                    A           E           M        Total
                 ---------------------------------------------------
Calves ?      0 |      6409 |      5711 |      6360 |      18480
                |  6680.542 |  5772.203 |  6027.254 |
                |  11.03732 | 0.6489471 |  18.36985 |
                 ---------------------------------------------------
              1 |      2549 |      2029 |      1722 |       6300
                |  2277.458 |  1967.797 |  2054.746 |
                |  32.37613 |  1.903578 |  53.88489 |
                 ---------------------------------------------------
          Total |      8958 |      7740 |      8082 |      24780
> chisq.test(table(rfd$Yncalf,rfd$TimeBlock))

        Pearson's Chi-squared test

data:  table(rfd$Yncalf, rfd$TimeBlock)
X-squared = 118.2207, df = 2, p-value < 2.2e-16
```

APPENDIX D: VESSEL SCORE ANALYSIS

```
>rfd <- read.csv("RivardFerryData.csv")
> library(nlme)
> source("tukeyToGraph.R")  #  For graphs
> source("profilePlot.R")
>
> vs.gls<-gls(VesScore~Zone*TimeBlock,data=rfd)
> anova(vs.gls,type="marginal")
Denom. DF: 24771
               numDF  F-value p-value
(Intercept)        1 4806.641  <.0001
Zone               2  852.302  <.0001
TimeBlock          2    7.543   5e-04
Zone:TimeBlock     4  102.965  <.0001
>
> table(rfd$Zone,rfd$TimeBlock)

       A    E    M
  B 3692 3318 2286
  G 1305  658 2090
  P 3961 3764 3706
> qqnorm(resid(vs.gls))
>
> rfd$Zone.TimeBlock<-paste(rfd$Zone,rfd$TimeBlock)

Analysis of Variance Table

Response: z
             Df Sum Sq Mean Sq F value    Pr(>F)
f             8   9024 1127.96  321.15 < 2.2e-16 ***
Residuals 24771  87002    3.51
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
>
>
> par(mfrow=c(2,3))
> rfd$score.supp<-as.factor(paste(rfd$Zone,rfd$TimeBlock))
> for (l in levels(rfd$score.supp)) {
+ qqnorm.with.sim.bounds(resid(vs.gls)[rfd$score.supp==l],sw=T,main=l)
+ }
```

```
> # Post-hoc analysis
> # Galveston
> rfd.aov.G<-aov(VesScore~TimeBlock,data=rfd[rfd$Zone=="G",])
> anova(rfd.aov.G)
Analysis of Variance Table

Response: VesScore
            Df Sum Sq Mean Sq F value    Pr(>F)
TimeBlock    2   3657 1828.41  120.17 < 2.2e-16 ***
Residuals 4050  61622   15.22
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> (tuk.G<-TukeyHSD(rfd.aov.G,conf.level=0.99))
  Tukey multiple comparisons of means
    99% family-wise confidence level

Fit: aov(formula = VesScore ~ TimeBlock, data = rfd[rfd$Zone == "G", ])

$TimeBlock
         diff        lwr       upr    p adj
E-A -2.099442 -2.6431219 -1.555762 0.00e+00
M-A  0.603100  0.2019168  1.004283 3.58e-05
M-E  2.702542  2.1942382  3.210846 0.00e+00

> # Bolivar
> rfd.aov.B<-aov(VesScore~TimeBlock,data=rfd[rfd$Zone=="B",])
> anova(rfd.aov.B)
Analysis of Variance Table

Response: VesScore
            Df Sum Sq Mean Sq F value    Pr(>F)
TimeBlock    2     97  48.438  13.306 1.696e-06 ***
Residuals 9293  33830   3.640
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> (tuk.B<-TukeyHSD(rfd.aov.B,conf.level=0.99))
  Tukey multiple comparisons of means
    99% family-wise confidence level

Fit: aov(formula = VesScore ~ TimeBlock, data = rfd[rfd$Zone == "B", ])

$TimeBlock
           diff          lwr         upr     p adj
E-A -0.23466587 -0.367675124 -0.10165661 0.0000008
```

```
M-A -0.09173674 -0.239716014  0.05624254 0.1674283
M-E  0.14292913 -0.008205736  0.29406399 0.0161609

> # Passage
> rfd.aov.P<-aov(VesScore~TimeBlock,data=rfd[rfd$Zone=="P",])
> anova(rfd.aov.P)
Analysis of Variance Table

Response: VesScore
             Df Sum Sq Mean Sq F value    Pr(>F)
TimeBlock     2    821  410.43  73.733 < 2.2e-16 ***
Residuals 11428  63613    5.57
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> (tuk.P<-TukeyHSD(rfd.aov.P,conf.level=0.99))
  Tukey multiple comparisons of means
    99% family-wise confidence level

Fit: aov(formula = VesScore ~ TimeBlock, data = rfd[rfd$Zone == "P", ])

$TimeBlock
           diff        lwr        upr     p adj
E-A -0.07807761 -0.2345767 0.07842146 0.3134463
M-A  0.53033707  0.3732113 0.68746282 0.0000000
M-E  0.60841468  0.4493138 0.76751554 0.0000000
```