COMMON BOTTLENOSE DOLPHIN (*TURSIOPS TRUNCATUS*) CALVES UTILIZE TRAWLERS IN THE GALVESTON SHIP CHANNEL

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

Common Bottlenose Dolphin Calves Utilize Trawlers in the Galveston Ship Channel

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As the global human footprint increases, animals are forced to adapt biologically and behaviorally. Bottlenose dolphins (*Tursiops truncatus*) show advanced early behavioral plasticity to their environment especially in coastal areas where human activity has steadily increased. Studies of free-ranging common bottlenose dolphins in the Galveston Ship Channel (N29'3, W94'8) have focused primarily on population dynamics leaving many opportunities for behavioral studies that include the assessment of natural and anthropogenic factors that contribute to and affect early developmental adaptations of calves in response to anthropogenic stressors. The objective of this research was to compare historical sighting data to highlight behavioral trends in calf interactions with trawlers and examine the influence of group size on the probability of interaction. Results support the maintained hypothesis that dolphin calves are consistently interacting with trawlers in the Galveston Ship Channel with group size a significant influence. The body of knowledge produced should increase the understanding of how bottlenose dolphin calves adapt to human activity in a congested waterway. Understanding how

anthropogenic influence affects the behavior of this key species will also aid in enhancing coastal management policies and projects geared towards biological and coastal conservation.

DEDICATION

To my family – who never question me when I question everything.

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NOMENCLATURE

CBD	Common Bottlenose Dolphin
GSC	Galveston Ship Channel

CHAPTER I

INTRODUCTION

Wildlife must adapt to changes in their environment. As of 2016, twenty-five percent of mammals are threatened globally (IUCN, 2016) due to natural and anthropogenic habitat degradation. While animal genetic studies show evolutionary-DNA changes are linked to shifts in allele frequencies responsible for adapting, biologically, to environmental changes (Hoffmann & Willi, 2008), an animal's ability to adapt their behaviors to human activity is key for survival. Bottlenose dolphins, *Tursiops sp.*, may be exposed to higher levels of human activities than many other marine species because they typically inhabit and utilize the coasts (Nowacek *et al.*, 2001). Although bottlenose dolphins appear tolerant of human activities (Leartherwood & Reeves, 1982), this species shows distinct adaptations in distribution and habitat use even when in the same general area (de Boer, Simmonds, Reijnders, & Aarts, 2014); indicating that every coastal population can uniquely adapt to similar stressors. Therefore, it is important to study bottlenose dolphins at the population level to assess the positive or negative effects of adaptations to anthropogenic disturbances.

Atlantic Bottlenose dolphins, furthermore referred to as common bottlenose dolphins (CBD), are common in shallow, nutrient-rich estuarine and bay systems along the United States Gulf Coast (Leatherwood & Reeves, 1983). As a large-brained apex predator, *Tursiops sp*. offers critical indications of overall ecosystem health and food resource availability (Wells, 2009). Different from many terrestrial mammals, adaptations to local ecological conditions have the strongest influence on seasonality of reproduction in common bottlenose dolphins (Urian, Duffield, Read, Wells, & Shell, 1996) yet changing environmental conditions have led to increased infant mortality (Hartel, Constantine, & Torres, 2015). Like other large mammals, dolphins experience high calf mortality (Stolen, 2003). On average, 44% of all neonates of this species fail to reach juvenile status (Mann & Watson-Capps, 2005). Many factors contribute to offspring death including predation (Mann & Barnett, 1999; Stanton, Gibson, & Mann, 2011), human interaction such as vessel impacts (Bejder et al., 2006), vessel noise (Buckstaff, 2004) and diminished health from pollution (Wood & Van Vleet, 1996). Even though this species shows advanced behavioral plasticity in response to their environment at critical early life stages (Gibson & Mann, 2008), young dolphins need a lot of education to navigate the complex aspects of living in urbanized environments.

Newborn dolphins grow up in complex fission-fusion societies (Shane, Wells, & Wursig, 1986; Burger, Wursig, Acevedo, & Henningsen, 1994; Mann & Smuts, 1998). Coastal maternal females generally co-exist with other females, with or without calves, in unbounded medium-sized "bands" making up core communities confined to a relatively small range (Wells *et al.*, 1987; Connor *et al.*, 2000;). Social networking has been shown to be very important for young dolphins as early calf-association patterns increase the likelihood of social links when grown (Stanton & Mann, 2012). Bottlenose dolphin calves are unusual among other social mammals in that they have a prolonged nursing period (3-8 years) but precocious motor ability, enabling them to separate from their mothers, with little restriction, and form distinct social bonds at an early age (Mann 1997; Gibson & Mann, 2008). This freedom seems to compliment social interactions where learned adaptions to environmental conditions can be shared among close associates (Stanton, Gibson & Mann, 2001; Gibson & Mann, 2008). Cultural transmission of learned adaptations offers dolphins behavioral flexibility to adapt new foraging techniques (e.g. Connor *et al*., 2000; Mann & Smuts, 1998) when food resources are abundant or scarce. This is evident in Texas where increased seasonal dolphin densities have been attributed to associations with shrimping vessels better known as trawlers (Gruber, 1981).

Large delphinid species, like CBD, have few natural predators (Heithaus, 2001) but are often threatened by human activity, especially marine vessel traffic where injury or death can occur from collisions in heavy traffic areas (Fertl, 1994) such as the Galveston Ship Channel (GSC) located in Galveston Bay along the Texas Gulf Coast. Studies in the last 20 years provide convincing evidence that Galveston Bay (Fig.1) maintains resident populations of CBD in distinct subareas whose ranges overlap (Leatherwood & Reeves, 1983; Burger, Wursig, Acevedo, & Henningsen, 1994; Maze & Wursig, 1999; Irwin and Wursig, 2004; Fazioli et al., 2016). While ecologically diverse, Galveston Bay is one of the top 10 most polluted waterways in the U.S. -- primarily attributed to industrialization contributing to increased vessel traffic and rapid population growth (Smith, 1972; Galveston Bay Foundation, 2016). Although studies in the Galveston Bay area support a connection between dolphins and human vessel interactions (Piwetz & Wursig, 2015; Fazioli et al., 2016), the possible link between early calf adaptation to commercial trawlers in the Galveston Ship Channel remains unexplored.

The primary focus of this study was to investigate interactions of dolphin calves with trawlers which frequent the GSC. This study examined whether bottlenose dolphin calves were interacting with trawlers and if so, whether any variables (group size, season, time of day, year) influence that interaction. Given that bottlenose dolphins adapt to ecosystem changes such as anthropogenic stressors, the maintained hypothesis is trawler interaction is a behavior learned during early calf growth periods and is significantly influenced by the size of the group. The relationship between habitat and trawler interactions offers key information on their behavioral plasticity which allows this well-studied species to adapt to urban industrialized ecosystems.

CHAPTER II

METHODS

Study Area

The study included only those sightings in the Galveston Ship Channel (including Texas A&M at Galveston's small boat basin; Figure 1). The Galveston Ship Channel is narrow (370m to 950m wide) with year-round commercial and recreational vessel traffic.

Figure 1. Study Area. The Galveston Ship Channel and small boat basin of Texas A&M Galveston Campus.

Land Surveys. — Land-based observations were conducted at the small boat basin of the Texas A&M University, Galveston Campus (Fig.1). The viewable area was approximately 500m x900m and monitored by observers and theodolite tracking.

Boat Surveys. — A variety of small Texas A&M University at Galveston boats were used to conduct surveys, including a Boston whaler and flat bottom Bateau, ranging between the hours of 6am and 8pm. Boat trips typically consisted of operating from west to east, down the center of the GSC, and not exceeding 30km/hr. When a group of dolphins was located, speed was reduced upon approach, and approaching groups head on was avoided. Each group was followed until all individuals were photographed, for a maximum duration of 20 mins.

Data Collection. — Land- and boat-based data collection included the number of individuals present in each group by age class (Adult, Calf, Young of the Year; Maximum, Minimum, and Best estimates for each class), predominant group behavior and vessel presence.

Determination of Group Size and Age Class

Four group codes (group is used in this context as the assemblage of dolphins seen at each sighting) were created post hoc based on the number of individuals recorded and observed during in situ sampling in the Galveston Ship Channel (Table 1). The age class of the dolphins during sightings was determined by one of more of the following criteria: **Calf**: an individual, one-third or less the length of an adult, that swam beside or slighting behind and adult (Shane, 1990) and **Non-calf**: an individual approximately two meters or more(?) long and/or swam independently (Shane, 1990).

Table 1. Group Codes based on the number of individuals observed during sampling in the Galveston Ship Channel (2010-2016).

Group Code	Number of Individual Dolphins
1	1-2
2	3-5
3	6-9
4	≥10

Behavioral Data

Dolphin behavior was collected ad libitum by the Texas A&M University Galveston Campus Marine Mammal Behavioral Ecology Group once research vessel approached dolphins and determined as resting, foraging, feeding, traveling, socializing, leap/tail slap, with the research vessel or other. Interaction with trawlers was collected, and defined as traveling or repeated dives in varying directions around the side or behind the stern (the trawl cod end) of the vessel.

Statistical Analysis

Data were digitized into excel and processed through Stata IC. Behavioral trends were tabulated to examine the proportion of behaviors observed overall throughout the study. Behaviors were also tabulated and delineated by group size. A third analysis was conducted to distinguish trawler interactions by group size for all age classes and repeated for only sightings where calves were observed interacting with trawlers. Logistic regression models were employed to estimate (i) the probability of observing dolphin activity other than resting and (ii) the probability of dolphin and trawler interaction given trawlers were present. The dependent variable in model (i) is called dolphin (calf) activity and is defined to equal 1 if dolphins were engaged in any activity other than resting, and zero otherwise.[1] The logistic regression was used to analyze the probability of dolphin behavioral activity and how this probability was influenced by trawlers being present, group size, time of day, season and recreational vessel (which includes dolphin tour boats) presence.

The dependent variable in model (ii) was created to equal one if dolphins (calves) were observed to interact with trawlers and zero otherwise. Again, the logistic regression models estimated how bottlenose dolphin interaction with trawlers (trawler interaction; calf & non-calf) was affected by group size with additional control variables including time of day, season and year.

[1] To understand and highlight the nature of potential risks associated with interacting with trawlers, the number of fishers or vessel related calf deaths from 2010-2015 in the Galveston Bay area, including the study area, was also investigated

CHAPTER III

RESULTS

Summary Statistics

The number of dolphins per sighting ranged from 1-25 individuals (adjusted for 'best estimates' in the field) in each group with a total of 546 groups recorded from April 2010-November 2016. The total number of groups that included calves (unadjusted for calf uniqueness) was best estimated at 105 with total calves ('best estimates') ranging from 1-3 individuals per sighted group.

Dolphin Behaviors

Dolphins in the Galveston Ship Channel were most frequently observed foraging (26.2%), resting (20.5%) or traveling (19%). Feeding (4.8%), socializing (12.3%), object play (0.9%), Leap/Tail Slapping (1.5%) and w/Research vessel (5.3%) and other behavior (9.5%) were observed less often. Dolphins also spent 9.5% of observed behaviors engaged in "other" activities than the above categories where behavior was unknown or unobservable. The spectrum of observed behaviors between 2010-2016 is listed in Figure 2.

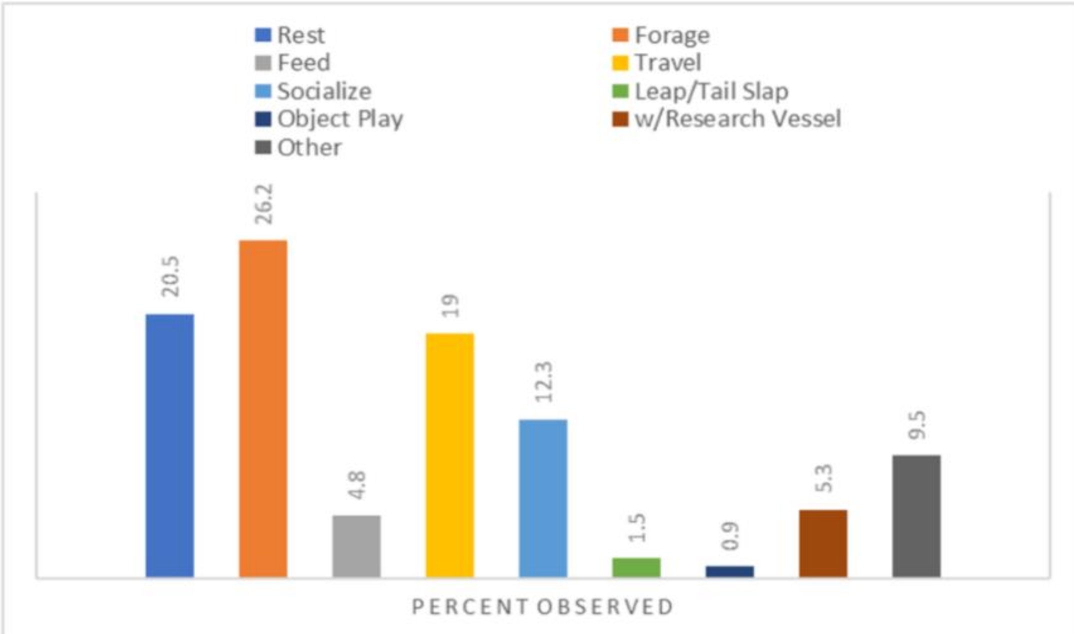

Figure 2. Behavioral observations of common bottlenose dolphins in the Galveston Ship Channel. Foraging was the most dominant behavior (26.2%) during 546 sightings from 2010-2016.

Group Size and Behaviors

Analysis of frequency of group size categories during the sampling period (Fig. 3) indicated the highest proportion of dolphins were observed in Group category 2 (n=222) or 3-5 individuals. Group 1, made up of 1-2 individuals, was the second most documented group size (n=172). The largest two groups were observed less frequently. Group 3 (6-9 individuals) was recorded 115 times during the 2010-2016 sampling period and Group 4 with 10 or more individuals, was the least observed (n=37). Behaviors by group size category are listed in Figure 4. Resting, foraging and traveling were the most dominant behaviors observed in all size categories except Group 4 (Group 1: resting = 25.58, foraging =19.19, traveling =23.26; Group 2: resting =21.17, foraging = 22.52. traveling = 20.27; Group 3: resting = 10.43, foraging = 46.96, traveling = 11.3; Group 4: resting = 24.32, foraging = 16.22, traveling = 16.22). Group 4 consisted of 10 or more individual dolphins and displayed socializing behaviors predominantly (24.32) over all other behaviors. Less dominant behaviors for all groups included feeding and swimming/traveling with the research vessel. Object Play, Leaps & tail slaps and behaviors documented as “other” were not observed in at least 1 group.

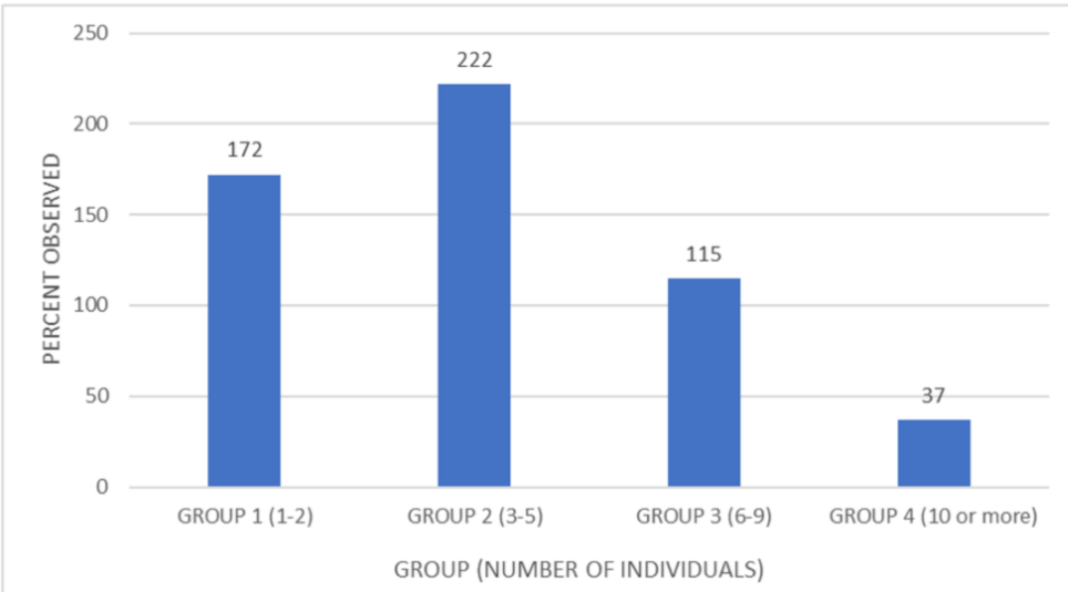

Figure 3. Frequency of defined group sizes. Dolphins were most observed in groups of 3-5 individuals during the 2010-2016 sampling period.

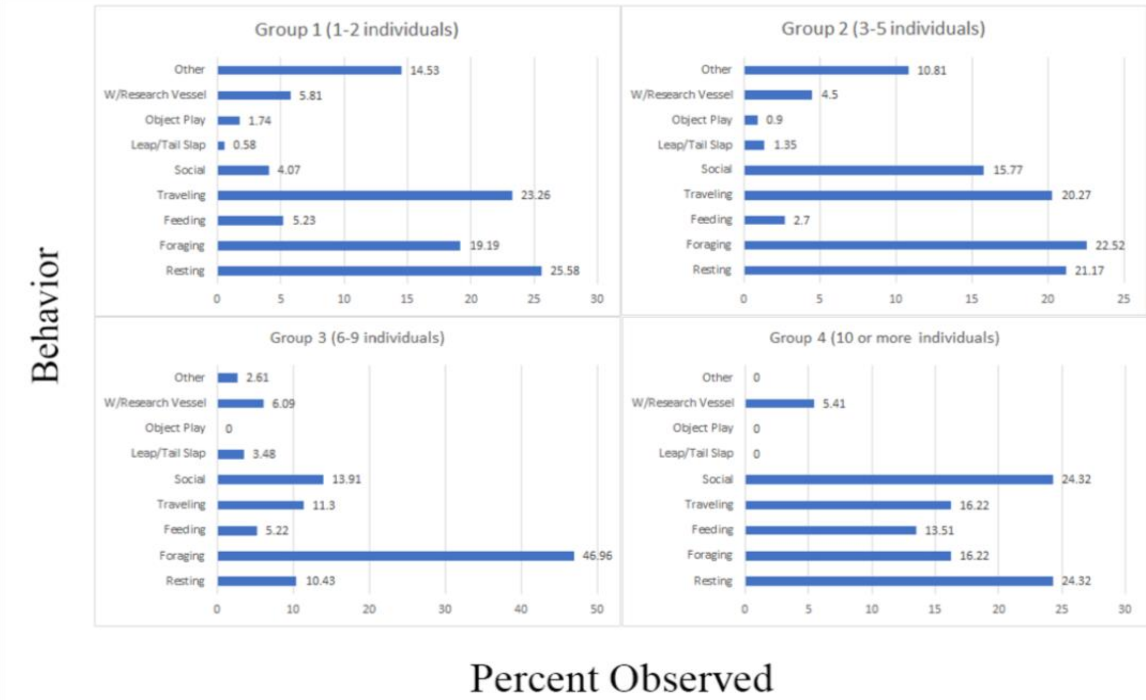

Figure 4. Behaviors observed by defined group size. Observations of behaviors by group size during sampling in the Galveston Ship Channel indicate this site is mainly used for foraging by all groups.

Groups with Calves

Common bottlenose dolphin calves were observed most often in groups consisting of 6-9 individuals (Group 3: n=34, 37.78%) during sampling in the Galveston Ship Channel (Fig. 5). Group 2, or 3-5 individuals, was observed and recorded slightly less with 36.67% (n=33). The largest and smallest group sizes, Group 4 (22.21%, n=20) and Group 1 (3.33%, n=3), were observed with calves the least during *in situ* observations.

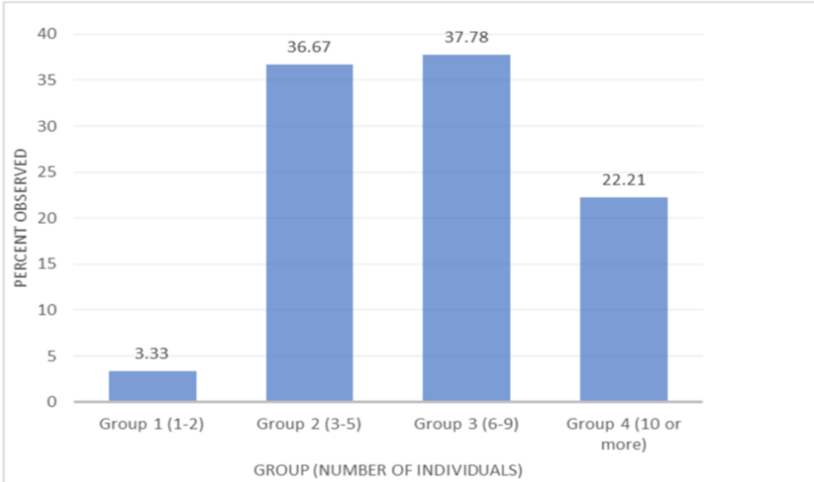

Figure 5. Percent observation of defined group sizes that include calves. Calves were observed primarily in groups with 3-9 individuals during sampling period 2010-2016.

Determinants of Dolphin Activity

Determinants of dolphin behavioral activity was examined for all dolphins as well as for a subsample when a calf was present. Results for the entire CBD sample, separated by age class, are reported in Table 2. Columns (1) and (2), for each age class, report logistic regression coefficients and standard errors, respectively and column (3) reports marginal contribution of these factors to the probability of dolphin activity.

Results from the entire sample suggests trawlers (P=0.034; Table 2) and recreational vessels (P=0.006) significantly increase the probability of observing dolphins executing behaviors other than resting in response to these variables. Specifically, the probability of activity increases by approximately 14% when trawlers are present relative to when they are absent. Recreational vessels increase this probability by 28%. These results support findings of Piwetz & Wursig (2015) that provided evidence that dolphins increase swim speed and change direction when vessels are present. Group size did affect activity of those that included all age classes but was not significant (P=0.231). In addition, results suggest that time of day and seasons are important determinants of dolphin activity possibly suggesting behavioral adaptations to changes in their environment.

Similar patterns were observed for the subsample that included on those groups where a calf was present (Table 2). The probability of observing calves in any activity other than resting was significantly affected by group size (P=0.000). Specifically, an increase of one individual dolphin to groups where calves were present increased the probability of activity by 1.4%. Given that these results suggest trawlers and group size, when measured independently, increase the probability of dolphin behavioral activity, it is important to understand how the two variables are linked. That is to say - how does group size affect the probability of trawler interactions in cases where calves are present and when they are not? This question is examined in the sections that follow.

Table 2. Determinates of dolphin activity by age class. Dolphin activity was analyzed using marginal analysis to determine variables that affect the probability of observing dolphins performing behaviors other than resting and activity measured during season relative to winter (season 1). Most variables showed considerable influence on observing non-resting behaviors for all age classes. These results support evidence that the Galveston Ship Channel is used primarily as a foraging site.

	Dolphin Activity (all ages) Log likelihood = -295.41602			**Dolphin Activity (calf)** Log likelihood = -191.41221		
Variable	**Coef.**	**Std. Err.**	**dy/dx**	**Coef.**	**Std. Err.**	**dy/dx**
Trawler Present	.7913331**	.372417	.135971**	.6696738**	.3215318	.0622416**
Group Size	.0389432	.032511	.0066914	.1488002***	.0329135	.01383***
Morning	.6715911***	.2423299	.1153963**	.7210574**	.3180995	.0670173**
Recreational vessel	1.626497**	.6592805	.2794734**	0	omitted	0
Spring	-.9504301**	.4691621	-.1173652**	1.268715**	.6011245	.1023659**
Summer	-1.428009***	.4524738	-.2076522***	.9346802	.5787357	.0646699*
Fall	-1.091921**	.435004	-.141892***	.8916529	.5700355	.0604697*
_cons	.0244004	.7880917		-4.163696***	.6031679	

Notes: * p<0.1; ** p<0.05; *** p<0.01

Trawler Interactions

When sightings with trawlers present (n=81: Figure 6) were analyzed among all age classes, dolphins were observed to interact 90% of the time (n=73). Figure 6 indicates trawler interactions by group size categories including all age classes. The most observed group size that interacted with trawlers during the sampling period was Group 3, or 6-9 individuals (35.62%). Group 2 which consisted of 3-5 dolphins was observed 32.88% interacting when trawlers were present. Group 1 (1-2 individuals) and Group 4 (10 or more) were observed interacting 16.44% and 15.07% respectively. Furthermore, the results from logistic regression presented in Table 3 for all age classes, indicated that the group size was not a significant factor (P = 0.336) in determining dolphin-trawler interaction probabilities when calves were absent from the group.

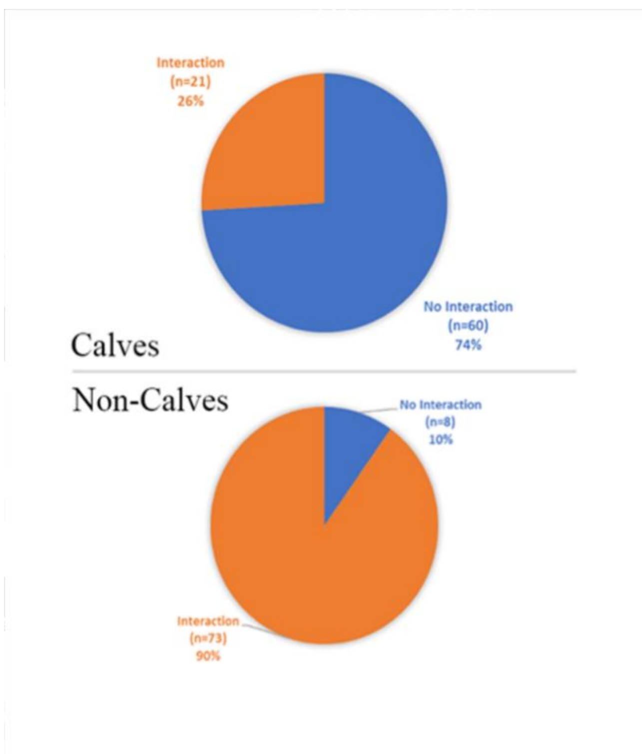

Figure 6. Trawler Interaction by calves and non-calves. Red denotes *interaction* and blue denotes *no interaction*.

Table 3. Probability of Trawler Interaction Relative to Influencing Factors. Group Size is a significant influential factor for trawler interaction when calves are present and not significant for non-calf groups.

Trawler Interaction by Age Class	Influencing Factor	Coef.	Std. Err.	Z	P>|z|	95% Confidence Interval	
Calf (n=65) Log likelihood= -32.367189	Group Size	0.2318351	0.1101532	2.10	0.035*	0.0159388	0.4477314
	Morning	-0.0376235	0.8539548	-0.04	0.965	-1.711351	1.636104
Non-Calf (n=38) Log likelihood= -16.238253	Group Size	0.1913763	0.1719355	1.11	0.266	-0.1456111	0.5283638
	Morning	-0.8438663	1.238774	-0.68	0.496	-3.271818	1.584086

Notes: * p>0.05 **significant influence**; Variables that were not significant (time of day, season, year, recreational vessel presence) were not displayed in the table. Samples from sightings during 2010-2016.

Calf Interactions with Trawlers

Calves in the GSC were observed interacting with trawlers 26% (n=21; Figure 6). Group 3, or 6-9 dolphins, was observed 47.61% (n=10). Group 4, or ten or more animals, was the next highest with 33.33% (n=7). Group 2 (19.05%) was observed 4 times during the sampling period. When a calf was in a group of 1-2 individuals there was no observed vessel interaction (Fig.7).

The results from the logistic regression for the subsample of Calves (see Table 3) indicate that the likelihood of trawler interaction, when calves were present, increased in larger groups and the effect was estimated to be statistically significant (P=0.035). Time of day, as reported in Table 3, did not show statistical significance on interaction probabilities in each of the samples analyzed. In addition, season and year were analyzed but no considerable influence was found for either calves or non-calves; these coefficients are not reported in Table 3.

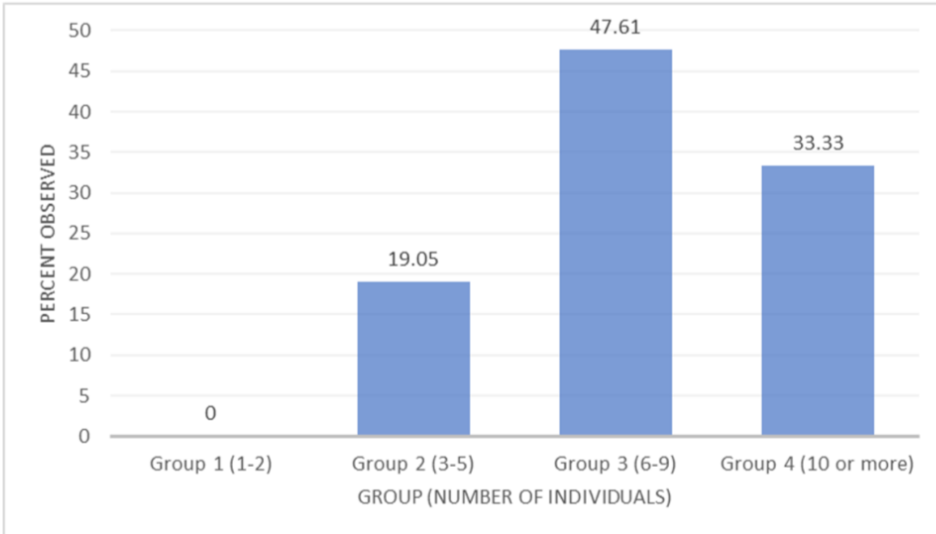

Figure 7. Trawler interaction involving calves by group size category. Calves were most often observed interacting with trawlers when a group consisted of 6-9 dolphins.

Risk Analysis for Trawler Interaction

Analyses of dolphin (calf; non-calf) mortality due to fishing or vessel related injuries was conducted utilizing Texas data downloaded from the National Oceanic and Atmospheric Administration (NOAA) Marine Mammal Stranding Response National database on September 17, 2015. The data was filtered to only include retrieved specimens from those areas in Galveston Bay where dolphins in this study most likely inhabit – including all of Galveston Bay, Harris County, Jefferson County and San Louis Pass area. This analysis allowed for an understanding of the potential risks associated with dolphins adapting behaviors to human vessel traffic. Bodies recovered, in both age classes from vessel or fishing related injuries between 2010-2014 accounted for only 3% (calf = 3.33%; non-calf = 3.29%; Figure 8) of the deaths. Results indicate that dolphins who are adapting their foraging behaviors to trawlers should not be considered a negative influence on common bottlenose dolphins in the GSC.

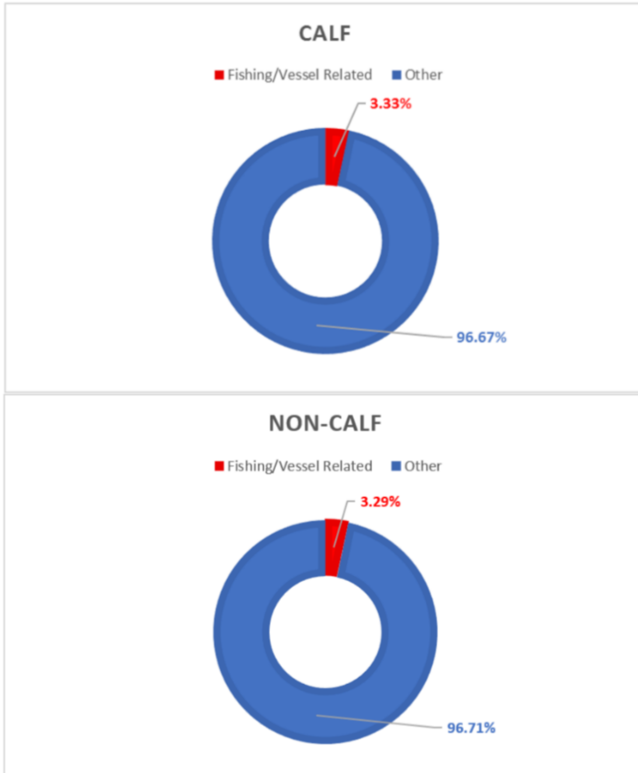

Figure 8. Percent of common bottlenose dolphin mortality due to fishing or vessel related injuries for calves and non-calves. Only 3% of both age classes were recovered due to fishing or vessel related injuries from 2010-2014. (source: NOAA, 2015)

CHAPTER IV

CONCLUSION

The goal of this research was to retroactively assess data for indications that common bottlenose dolphins in the Galveston Ship Channel are learning to adapt to human vessel traffic, specifically trawlers during critical early life stages. Results support the maintained hypothesis that calves frequenting the Galveston Bay area and utilize congested shipping lanes are interacting with trawlers. Logistic regression models provided evidence that, although dolphin calves are interacting with trawlers, the more individuals in the calf-group plays a significant part in determining whether observations of interaction will occur. This determinant loses its influence as calves grow older and become more independent.

Some error in the findings should be considered due to the nature of observing dolphins in the wild from observation vessels and land surveys. Due to these limitations, error, for this study, was minimized by selecting an easily observable behavior (interacting with a trawler or not) and age class (calf vs non-calf delineation *in* situ). But more detailed studies focusing on common bottlenose dolphin calf interactions with human vessels is recommended to state with some degree of statistical confidence that individual calves are adapting their behavior to anthropogenic stimuli.

In the United States, all marine mammals are protected from harmful human interaction by federal law as mandated under the Marine Mammal Protection Act (1972). Due to little oversight and a lack of funding, studies geared towards assessing these protective measures were not conducted. So, in 1994, Congress directed the National Marine Fisheries Service, part of NOAA, to regularly prepare reports that assess marine mammal stocks including major threats from humans. But, as these studies are primarily enforced through aerial surveys, state and local management lacks the ability to prevent and address issues with species, like common bottlenose dolphins who inhabit estuaries and bays, where aerial studies are not conducive or provide less accurate data (Caruba, 2016).

Dolphins, with slow maturation and long lives (Connor *et al.*, 2000), are prime candidates for conservation and biological studies. Although management strategies aimed at increasing reproductive rates are likely to be more feasible or more effective, research focusing on dolphin survival through behavioral adaptations to human activity should be considered of utmost importance as survival has the greatest influence on population growth (Brault and Caswell 1993; Saether and Bakke 2000; Crone 2001; Oli and Dobson 2003; van de Kerk et al. 2013). While actions aimed at reversing or preventing population declines often address both survival and reproduction, optimizing population recovery by targeting those variables that influence behavioral survival, especially in calves, should be the long-term strategy.

To identify such management strategies, future studies must account for factors that influence positive and negative adaptations – factors like human vessel traffic which has been found to influence dolphin reproduction (Lusseau et al. 2006). It has also been shown that boat presence causes short-term behavioral reactions (Lusseau 2005; Bejder et al. 2006) which can lead to long-term declines in relative dolphin abundance in areas where vessel traffic becomes too oversaturated (Bejder et al. 2006). As findings of this study support the delineation of the Galveston Ship Channel as an important foraging site for resident common bottlenose dolphins, the shipping lane continues to become more congested with trawlers (Figure 9), recreational and other commercial vessels. Understanding how marine environmental conditions affect behavior in these marine mammals, at early ages, will aid in enhancing coastal management policies and future projects geared towards biological and coastal conservation.

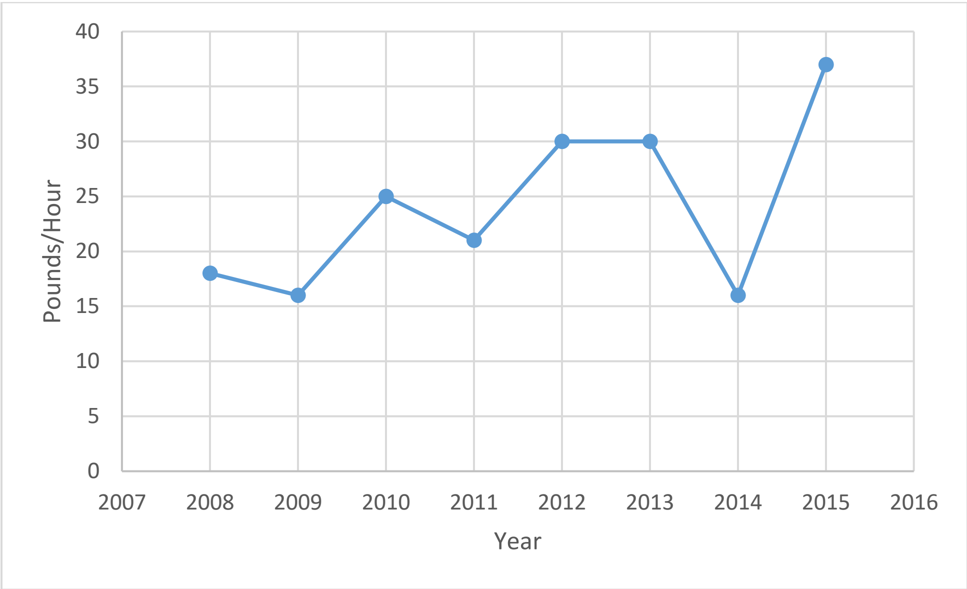

Figure 9. Commercial trawler activity in Galveston Bay (2007-2016). Although a stark decline in pounds/hour was documented from 2013-2014, trawler activity continues to increase in study area. (NOAA, 2015)

As suggested by this study, certain behaviors are formed during critical early life stages that allow dolphins to better adapt to natural and anthropogenic changes in their environment. Hence, studies that focus on dolphin calves, during these crucial growth periods, will provide important insights allowing for a better understanding of how behavioral changes characterize socially complex marine mammals, such as dolphins, which could further help create policies related to marine mammal survival. Although management policies focusing on animal/human interaction is key to enhancing species survival, generating public attention to issues involving those species' decline has been shown to be effective.

The aesthetic value of a species is the primary driver behind public attention and conservation (Kansky & Knight, 2014). Although gender plays a role in the level of emotional response, humans tend to act more empathetically to young, cute or injured animals than to even their own species (Luke, Levin, & Arluke, 1997; Angantyr, Eklund, & Hansen, 2011; Lehmann, Huis, & Vingerhoets, 2013). As large scale die offs of bottlenose dolphins continue along coastlines in the U.S. and globally (Wells *et al.*, 2004), and given that humans are more empathetic to young animals, efforts targeting dolphin calves should be expected to have enhanced public support. Moving forward, researchers must be concerned with conservation in conjunction with all other behavioral and population studies.

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