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Comparison of Group Size, Abundance Estimates and Movement Patterns of Common Bottlenose Dolphins (Tursiops truncatus) in Mississippi Sound, Mississippi

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COMPARISON OF GROUP SIZE, ABUNDANCE ESTIMATES AND MOVEMENT PATTERNS OF COMMON BOTTLENOSE DOLPHINS (*TURSIOPS TRUNCATUS*) IN MISSISSIPPI SOUND, MISSISSIPPI

Thesis

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To Buster and Molly; my best friends through thick and thin

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Table of Contents

List of Tables

List of Figures

Abstract

Common bottlenose dolphins (*Tursiops truncatus*; dolphins) inhabiting Mississippi Sound (MSS) in the north-central Gulf of Mexico (GMx) are considered a part of a single stock of dolphins that includes Bay Boudreau and Lake Borgne by the National Marine Fisheries Service (NMFS). MSS is bounded by the mainland (north) and several barrier islands (south). Dolphins inhabiting coastal waters directly south of the barrier islands constitute part of the Northern Coastal Stock. Abundance in MSS has been reported to fluctuate seasonally, with higher abundances of dolphins estimated in summer versus winter. Analysis of covariance was used to compare previous abundance estimates. Results indicated significantly more dolphins in the summer and when boats were used as survey platforms. To explore the possibility of finer scale distributions of dolphins within MSS based on movement patterns of individuals, from 2002 to 2005, 78 photo-identification surveys were conducted that sampled four zones in MSS: one Inner-Sound zone near Round Island, two Outer-Sound zones on the northern sides of Horn Island and Petit Bois Island and one Coastal zone outside MSS south of Petit Bois Island. Analysis of variance was used to test for main effects of zone, season (summer and winter) and presence of calves on mean group size. There were no interactions of main effects. Mean group sizes were significantly larger in Outer-Sound zones, in summer and when a calf was present in the group. Limited movement was observed between the Inner-Sound zone and the other zones. Seventy-seven individual dolphins (40%) were sighted both within and outside MSS, therefore spanning two NMFS stock units. Larger summer group sizes at Outer-Sound zones could reflect a seasonal concentration of dolphins, possibly due to zone differences that may increase prey resources or protection. The finding that some individual dolphins routinely use north and south sides of the barrier islands suggested stock boundary modification could be warranted.

CHAPTER 1: INTRODUCTION

Common bottlenose dolphins (*Tursiops truncatus*) (hereafter bottlenose dolphins or dolphins) are found in temperate to tropical waters worldwide, including estuarine, coastal, and offshore environments. Given their close proximity to shore, they are one of the most widely encountered and studied marine mammals in the world (Jefferson *et al.* 2009). Nevertheless, a significant amount of what is "known" about the biology of bottlenose dolphins over their range is inferred from a few spatially discrete areas where small populations of dolphins have been extensively studied. For example, the relatively discrete bottlenose dolphin population in Sarasota Bay, Florida, has been more or less continuously studied since the 1970s (e.g., Irvine *et al*. 1981, Scott *et al.* 1990, Wells 2003, Wells 2014). While these studies have contributed to our understanding of the species, their findings may not accurately represent bottlenose dolphins in areas where information is lacking, even areas in relatively close proximity, such as adjacent bays. Reeves and Leatherwood (1984) and Vollmer and Rosel (2013) suggest that because bottlenose dolphins display a great deal of ecological plasticity and can occupy a diverse set of habitat types with different selective pressures and anthropogenic influences, the biology of the dolphins could differ greatly throughout their range.

In the United States (US), all marine mammals, including bottlenose dolphins, are protected by the Marine Mammal Protection Act (MMPA) of 1972 [16 USC Chapter 31]. Under the MMPA, the National Marine Fisheries Service (NMFS) is required to manage and protect marine mammals in discrete units called stocks. A stock is defined in the MMPA as a group of marine mammals of the same species in a common spatial arrangement that interbreed when mature. In addition to genetics, a number of factors can be used to define marine mammal stocks such as phenotypic data, distribution and movements, and demographics (Dizon *et al.* 1992). For bottlenose dolphins that live in bays, sounds and estuaries (BSEs), the community concept described by Wells *et al.* (1987) is useful for defining stocks, where communities of dolphins are described as ones that display similar patterns of site fidelity, behavior, association patterns and genetic profiles compared to other dolphins in adjacent waters. Under the MMPA a stock is considered strategic when it is or is likely to be listed under the Endangered Species Act or when the known level of direct human-caused mortality or serious injury (e.g., fishery mortality)

exceeds the Potential Biological Removal (PBR). The PBR is defined by the MMPA as the maximum number of animals, not including natural mortality, which may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population (OSP). The PBR for MSS is based on abundance data from a 2012 aerial survey, and is currently 5.6 dolphins (Waring *et al.* 2016).

In the US Gulf of Mexico (GMx) bottlenose dolphins are managed as 36 stocks: one oceanic; one continental shelf; three coastal; and 31 bay, sound or estuarine (BSE) stocks (Phillips and Rosel 2014, Waring *et al.* 2016). Information on exact geographic extent of most dolphin stocks in the GMx is unknown and many stock boundaries are currently geographical rather than ecological boundaries, either based on research strata (e.g., Mullin *et al.* 1990, Blaylock and Hoggard 1994) or configured based on analogy with areas where more dolphin research had been conducted, such as Sarasota Bay, Florida (Irvine *et al.* 1981, Wells 1986, Wells 2003, Wells 2014). However, based on the recommendations of two review panels (Hansen and Hohn 1997, Hubard and Schwartz 2002), current stock structure in the GMx should be maintained unless, through research, substantial evidence warrants revision.

Bottlenose dolphins are found throughout the GMx from shallow BSEs to deep, offshore waters (Waring *et al.* 2016). Many bottlenose dolphin studies have been conducted in various BSEs in the GMx including those in Florida (e.g., Irvine *et al.* 1981, Wells *et al.* 1987, Quintana-Rizzo and Wells 2001, Balmer *et al.* 2008, Conn *et al.* 2011, Tyson *et al.* 2011), Alabama (e.g., Goodwin 1985, Pabody 2008), Mississippi (e.g., Solangi and Dukes 1983, Hubard *et al.* 2004, Mattson *et al.* 2006, Miller *et al.* 2013), Louisiana (Miller and Baltz 2009), and Texas (e.g., Shane 1977, Weller 1998, Maze and Würsig 1999, Henderson and Würsig 2007). The frequency of research has historically been sporadic, and in some cases years or decades elapsed between projects. Lapse in or the complete lack of information on the biology of bottlenose dolphins in some locations of the GMx is problematic when attempting to conserve and manage bottlenose dolphins. Bays, sounds and estuaries in which bottlenose dolphins occur can be very diverse, and conservation measures should probably be tailored to each BSE, including Mississippi Sound.

1.1 Bottlenose dolphins in Mississippi Sound

Mississippi Sound (MSS) (Figure 1a) is located in the north-central GMx. For management purposes, it is a component of the MSS-Lake Borgne-Bay Boudreau Stock of bottlenose dolphins (MSLBBB Stock) (Waring *et al*. 2016). MSS stretches from Half Moon Island, LA to Cedar Point, AL and occupies a surface area of approximately 2100 km^2 (Eleuterius 1978a, b). It is bordered to the north by the mainlands of Louisiana, Mississippi, and Alabama and to the south by six barrier islands: Cat, Ship, Horn, Petit Bois, and Dauphin islands (Eleuterius 1978b). MSS is a relatively open embayment with large passes between the barrier islands to the GMx, including several dredged shipping channels. Average depth at mean low water is 2.98 m and tides are diurnal with an average range of 0.57 m (Eleuterius 1978b). Sea surface temperature can range seasonally from 9˚C to 32˚C and salinity from 0 to 33 psu from winter to summer, respectively (Christmas 1973). The bottom type is soft substrate consisting of mud and/or sand (Moncreiff 2007).

Bottlenose dolphins are the only marine mammal routinely found in MSS and have been studied there since the mid-1970s. In earlier years, bottlenose dolphin research in MSS focused primarily on estimating dolphin abundance using aerial- and boat-based line-transect surveys (Table 1). Other research included movement and behavior studies (Table 1). The more recent boat-based surveys incorporated photographic identification (photo-ID) of individual dolphins, a standard means of identifying individual dolphins using dorsal fins (Würsig and Würsig 1977, Würsig and Jefferson 1990). The trailing edge of bottlenose dolphins' dorsal fins tend to be unique, acquiring various nicks, tears, and notches, along with variable shapes and coloration patterns that tend to be long-lasting, allowing researchers to identify individuals (see Appendix 1 for images of a sighting history for an individual dolphin in MSS). Additionally, during the latter half of the twentieth century, MSS was the site of the largest live capture fishery for bottlenose dolphins in North America (Reeves and Leatherwood 1984). A total of 202 dolphins were removed for public display in aquaria and for US Naval research between 1973 and 1988 (Scott 1990). These removals represented 41% of the total number of animals taken from the wild in the US GMx and over 70% of the animals taken were female (Scott 1990). Therefore, the motivation for most of the early bottlenose dolphin abundance research conducted in MSS in the 1970s and 1980s was driven by concerns related to the live-capture industry.

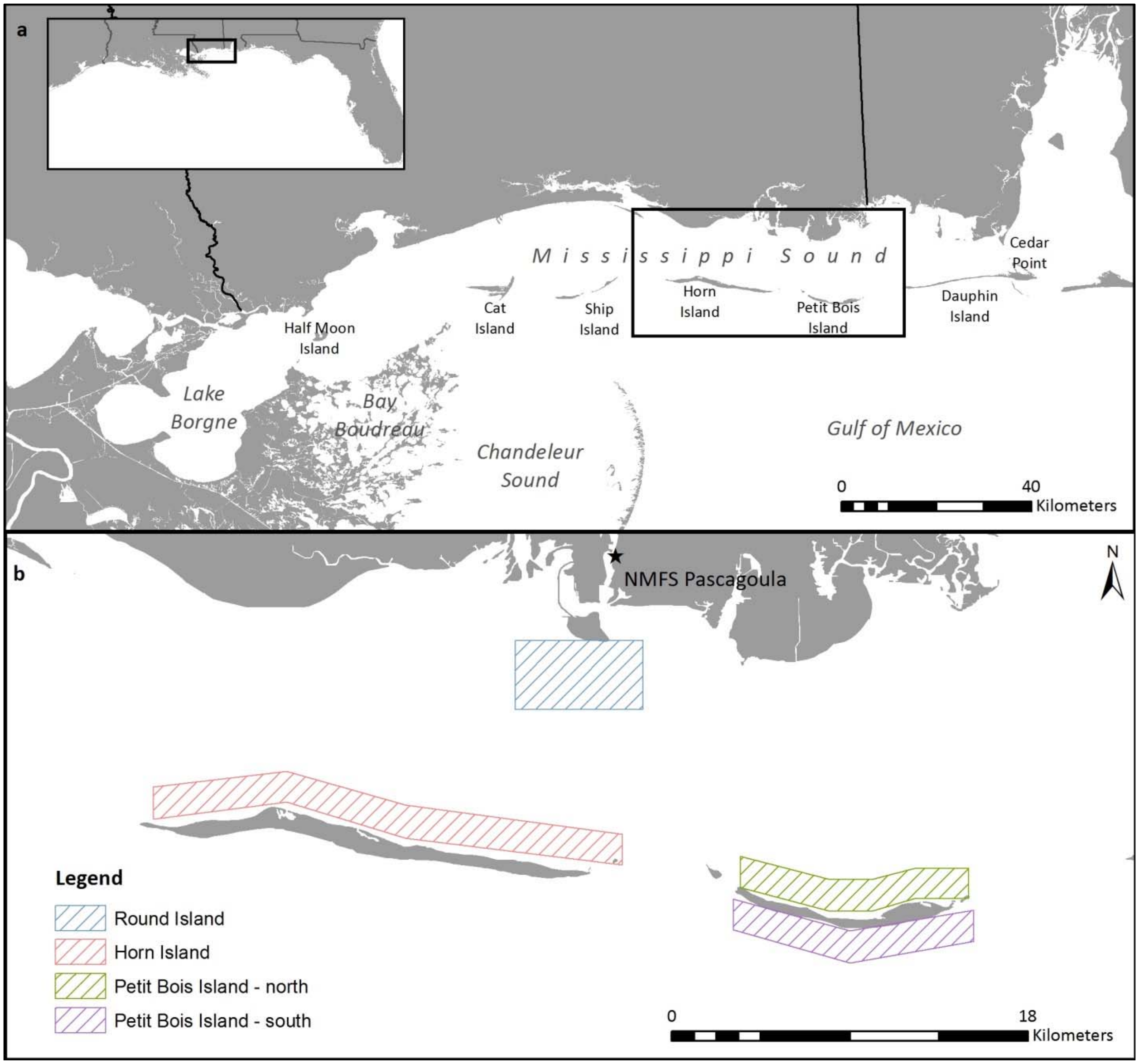


Figure 1. a) Map of the Mississippi Sound, Lake Borgne and Bay Boudreau Bottlenose Dolphin (*Tursiops truncatus*) Stock area with the location of the survey area within Mississippi Sound and an inset showing the location of Mississippi Sound within the northern Gulf of Mexico, and b) four zones within the Mississippi Sound survey area.

1.2 Population abundance

1.2.1 Aerial surveys

Aerial and small boat surveys conducted in MSS yielded a wide range of estimates of density and abundance for bottlenose dolphins. Aerial strip transect surveys were performed during 1974 and 1975 by Leatherwood *et al.* (1978). The main focus was to compare aerial survey techniques for bottlenose dolphins,

Table 1. Summary of previous bottlenose dolphin (*Tursiops truncatus*) research performed in Mississippi Sound by source, range of study (years), and study type.

Source	**Range of study (years)**	**Study Type**
Boat surveys		
Current study	2002–2005	Group size, movement patterns, photo-ID, trends in abundance
McBride 2013	2006–2010	Behavior patterns, site fidelity, photo-ID
Smith *et al.* 2013	2003–2009	Hurricane impacts on foraging, photo-ID
Miller *et al.* 2013	2007–2008	Line transect, density, abundance and habitat utilization, photo-ID
Miller *et al.* 2010b	2006–2007	Seasonal and diurnal behavior patterns, photo-ID
Miller *et al.* 2010a	2004–2007	Hurricane impacts on reproduction, photo-ID
Mackey 2010	2004–2007	Site fidelity, association patterns, photo-ID
Miller *et al.* 2008	2003–2005	Behavior response to high speed water craft, photo-ID
Hubard *et al.* 2004	1995–1996	Line transect, abundance, photo-ID, site fidelity, ranging patterns
Mullin and Hoggard 1992 a, b	1991–1992	Line transect, density and herd size, photo-ID
Lohoefener *et al.* 1990b	1985–1986	Line transect, abundance
Aerial surveys		
Waring *et al*. 2016	2011–2012	Line transect, density, abundance
Blaylock and Hoggard 1994	1991–1992	Line transect, density, abundance
Scott *et al.* 1989	1984–1985	Line transect, density, abundance
Mullin 1988	1985–1987	Seasonal abundance and ecology
Thompson 1982	1980–1981	Line transect, density, abundance
Leatherwood *et al.* 1978	1974–1975	Strip-sample, abundance
Other		
Balmer *et al*. 2015	2010–2012	Contaminant loads blubber biopsy samples including Mississippi Sound
Van Dolah *et al*. 2015	2010–2012	Gene transciptome in skin biopsy samples in Mississippi Sound
Venn-Watson *et al.* 2015a	2010–2013	Stranded dolphins, unusual mortality events
Venn-Watson *et al.* 2015b	2010–2013	Stranded dolphins, unusual mortality events
Litz *et al.* 2014	1990–2009	Stranded dolphins, unusual mortality events
Carmichael *et al.* 2012	2010–2011	Stranded dolphins, environmental influences
Kucklick *et al.* 2011	2000–2007	Contaminant loads blubber biopsy samples including Mississippi Sound
Mattson *et al.* 2006	1983–2003	Age structure and growth of stranded dolphins
Lohoefener *et al.* 1990a	1982–1985	Mark-recapture abundance, site fidelity
Solangi and Dukes 1983	1982–1983	Live capture, health assessment, freeze brand

but the study also produced population estimates of 1,342 ± 847 in 1974 and 879 ± 368 in 1975. Thompson (1982) surveyed three different BSEs in 1980 and 1981 including MSS, using aerial line-transect sampling methods. The survey area was a central portion of MSS from the western end of Ship Island to the eastern end of Petit Bois Island, between the islands and the mainland of Mississippi. Abundance for MSS was estimated to range from 93 ± 22 dolphins in December 1980 to 140 ± 86 dolphins in September 1980. No significant difference in dolphin

abundance was found among seasons within MSS. While line-transect is considered a rigorous and repeatable survey method, these studies produced negatively biased estimates of density and abundance, due in part to the fact that the strip of transect directly under the aircraft was not observed (Leatherwood *et al.* 1978, Thompson 1982). Scott *et al.* (1989) attempted to correct this bias by utilizing an aircraft with a glass nose from which an observer surveyed the strip directly underneath the aircraft at all times. Dolphin abundance ranged from 136 dolphins in winter to 719 dolphins in summer. Another series of line-transect aerial surveys were performed in fall of 1992 and 1993 by Blaylock and Hoggard (1994) in which the abundance and density of dolphins was reported as 1401 dolphins and 0.2 dolphins km^{-2}, respectively. These surveys encompassed the entire MSLBBB Stock. The most current aerial surveys in MSS were performed by NMFS in 2011 and 2012, in which density and abundance were higher in the spring (0.7 dolphins km^{-2}, 2395 dolphins, CV = 0.42) and summer (0.5 dolphins km^{-2}, 1709 dolphins, CV = 0.59) than fall (0.3 dolphins km^{-2}, 1140 dolphins, CV = 0.41) and winter (0.2 dolphins km^{-2}, 900 dolphins, CV = 0.63). The recent surveys were also corrected for detection probability bias by using a model accounting for environmental variables (e.g., sea state, glare and water color) and two observer teams to develop estimates of visibility bias (Waring *et al.* 2016).

1.2.2 Boat surveys

Lohoefener *et al.* (1990a) tested the ability of boat-based mark-recapture surveys to assess the impacts of the live-capture removal of 30 dolphins from MSS. They concluded that their pre- and post-removal estimates, 2392 and 7052 dolphins, respectively, were probably not accurate estimates as too many mark-recapture assumptions were likely violated. Boat-based line-transect abundance surveys carried out by Lohoefener *et al*. (1990b) in 1985 and 1986 yielded much higher abundance and density estimates of bottlenose dolphins in MSS than the previously discussed aerial strip- or line-transect surveys. Dolphin densities were 1.3 dolphins km^{-2} in summer and 0.3 dolphins km^{-2} in winter, resulting in abundances of 2400 dolphins and 500 dolphins, respectively, and suggested a seasonal shift of bottlenose dolphin abundance occurs in MSS. The two most recent boat-based abundance estimates for MSS did not cover the entire area of MSS or encompass the entire area of the NMFS MSLBBB Stock. In the first of these, Hubard *et al.* (2004) surveyed an area roughly one-third the size of MSS (approximately 446 km^2) in the eastern part of MSS and determined density and abundance fluctuated seasonally.

Higher densities and abundances were observed in summer months in 1995 (1.3 dolphins km^{-2} and 584 dolphins) and 1996 (1.2 dolphins km^{-2} and 555 dolphins) versus winter 1995–1996 months (0.6 dolphins km^{-2} and 268 dolphins). In the second study, Miller *et al.* (2013) covered a larger portion of MSS than the Hubard *et al.* (2004) study and included GMx waters up to 15 km south of the barrier islands that in total was roughly 2104 km^2 in size. Density and abundance estimates were 1.1 dolphins km^{-2} and 2255 dolphins in summer 2007, and 0.67 dolphins km^{-2} and 1413 dolphins in winter 2007-2008 (Miller *et al.* 2013). This seasonal shift in density and abundance, with higher density and abundance of dolphins in summer versus winter months, was consistent with Hubard *et al.* (2004). Miller *et al.* (2013) also observed a higher occurrence of calves in warmer months, particularly spring and summer months. Seasonal boat-based mark-recapture surveys were implemented in MSS as part of the Natural Resource Damage Assessment (NRDA) of the *Deepwater Horizon* oil spill (DWH) from June 2010 to May 2012, and results of that study are currently in review.

1.3 Spatial and temporal occurrence patterns

Previous photo-ID and live-capture research in MSS suggested dolphins display different spatial and temporal occurrence patterns in MSS. During the live capture and release project conducted in the western MSS during the early 1980s, 57 of the animals captured were freeze-branded with a unique number to enable future identification of specific individuals (Solangi and Dukes 1983). Work performed during 1982–1985 by Lohoefener *et al.* (1990a), used re-sighting data from these branded, or marked, dolphins. During the study, four of the more frequently re-sighted dolphins were re-sighted either near barrier islands or near the mainland coast, while a fifth animal ranged throughout MSS (Lohoefener *et al.* 1990a).

The first dedicated photo-ID effort in MSS, performed by Hubard *et al.* (2004), established a working bottlenose dolphin dorsal fin photo-ID catalog. During 1995–1996, some dolphins were sighted with limited ranges, such as barrier islands, channels or mainland coasts. Other dolphins were re-sighted more to the east of the survey area and some more to the west. Some re-sighted individuals were seen in the same seasons both years, while others were seen in multiple seasons, with a gap during winter months. Hubard *et al.* (2004) also noted long-term re-sighting records by some individual dolphins. During the 1995 and 1996 surveys of Hubard *et al.* (2004), several animals seen and photographed during 1991 surveys by Mullin and Hoggard (1992a) were re-

sighted. Also, two dolphins freeze branded during the live capture and release study performed by Solangi and Dukes (1983) in western MSS were re-sighted during the Hubard *et al.* (2004) surveys near Horn Island (eastern MSS). Mackey (2010) examined occurrence patterns of bottlenose dolphins in MSS using photo-ID data. During 2004–2007, Mackey (2010) defined three different residency patterns of dolphins in western MSS (which was limited to a few of the barrier islands and the Gulfport Shipping Channel). Of the 687 dolphins identified during those surveys, 10% were classified as year-round residents, 16% as seasonal residents, and 74% as transients. Mackey (2010) also identified two animals that were freeze-branded during the live capture and release project 20 years earlier (Solangi and Dukes 1983). Both Mackey (2010) and Hubard *et al.* (2004) noted low re-sighting rates of dolphins with a high percentage of dolphins seen on one occasion, making definitive conclusions on bottlenose dolphin spatial and temporal occurrence patterns in MSS difficult. Both studies also suggested dolphins move out of MSS into deeper GMx waters during winter months.

1.4 Intraspecific association patterns

To date, one study on intraspecific association patterns has been performed for bottlenose dolphins in MSS. Mackey (2010) identified social networks and found different levels of intraspecific association present in the western MSS (i.e., waters near Cat, Ship and Horn islands and the Gulfport Shipping Channel). Associations related to residency patterns (i.e., residents, seasonal residents and transients) were examined, and residency classification was not found to influence dolphin associations, meaning a dolphin classified as a resident was just as likely to associate with another resident as a seasonal resident or transient. A highly connected and structured social network was identified at Ship Island and Mackey (2010) postulated this island could be of ecological significance to dolphins. Dolphins in the network were also found to have a strongly connected social network following Hurricane Katrina.

1.5 Behavior and habitat utilization

Miller *et al.* (2010b) studied seasonal and diurnal behavior patterns exhibited by bottlenose dolphins in MSS. Dolphins were found to spend more time socializing in the spring, possibly in relation to a peak in calving, and more time feeding in the fall, possibly to increase fat stores for winter months. Feeding behavior was more prominent in the morning, and social behavior more prominent in the afternoon. Habitat utilization was examined

by Miller *et al.* (2013) by dividing the MSS, its adjacent barrier islands and the GMx into coastal, island and offshore zones where the "coastal" zone extended from the mainland coast to mid-MSS. Density, group size and calf presence were significantly higher in the coastal (near the mainland of Mississippi) zone in the warmer months than the colder months (Miller *et al.* 2013). Density of dolphins increased in the offshore zone during the colder months. The density increase during the warmer months was attributed to the possibility of increased prey abundance and use of the coastal waters as a nursery area. The density increase offshore during the colder months was hypothesized to be due to movement of prey items to deeper, warmer water during that time, though the offshore increase did not entirely account for the decrease observed in the coastal zone.

Seasonal and diurnal behavior of bottlenose dolphins displaying high, intermediate and low site fidelity to the MSS was investigated by McBride (2013). McBride found that dolphins displaying high site fidelity were observed to feed less and travel more in the summer, whereas low site fidelity groups were found to feed more in the summer. It was hypothesized that seasonal residents and transients compose the low site fidelity groups and that these animals may move into the MSS in the warmer months to exploit food resources.

1.6 Environmental and anthropogenic influences

Bottlenose dolphins in the MSS are exposed to a myriad of environmental, biological and anthropogenic influences, including competition for prey resources, biotoxins, vessel traffic, fisheries interactions, contaminants exposure, natural disasters and man-made disasters. Miller *et al.* (2008) examined dolphin behavior in the MSS in response to high-speed personal watercraft. Immediate impacts to bottlenose dolphin behavior were significant and included increased dive duration, group cohesion and breathing synchrony. They suggested that these immediate and short-term behavior changes due to vessel traffic could produce long-term cascading effects, such as decreased foraging and social behavior, which in turn could reduce the health of the dolphin population. Hurricane Katrina impacted bottlenose dolphin reproduction and foraging in MSS. Miller *et al.* (2010a) found that the density of dolphin calves km^{-2} increased in the two years following the hurricane and attributed this to increased reproductive success of females as a result of increased prey from decreased commercial fishing post-Katrina. Smith *et al.* (2013) examined foraging behavior of bottlenose dolphin before and after Hurricane Katrina and reported that foraging behaviors significantly increased for two years following the hurricane. Foraging hot

spots were identified in shallow water near Cat Island before the hurricane and shifted to deeper water after the hurricane.

Anthropogenic contaminant exposure is also a risk in MSS. Kucklick *et al.* (2011) analyzed persistent organic pollutants (POPs) in male bottlenose dolphin blubber obtained from biopsy samples from many locations in the southeastern US Atlantic and GMx, including MSS. Dolphins in MSS, as well as other locations in the southeastern US (e.g., Brunswick, Georgia, and Tampa Bay, Florida), had significantly higher concentrations of Mirex, an organochloride insecticide used for fire ant control until the late 1970s, than samples from dolphins in other locations in the southeastern US (e.g., Apalachicola Bay, St. Joseph Bay and Biscayne Bay, Florida). The MSS dolphins also had significantly higher concentrations of polybrominated diphenyl ethers (PDBEs), a common additive in flame retardants, compared to other BSEs in the GMx, such as Sarasota and St. Joseph bays, Florida. MSS dolphins had the highest concentrations of dichlorodiphenyltrichloroethane (DDT), another organochloride insecticide, of all locations sampled but the differences among locations were non-significant. Balmer *et al.* (2015) also studied POPs in male bottlenose dolphins in St. Joseph Bay, Florida, MSS, Mississippi, and Chandeluer Sound and Barataria Bay in Louisiana. Samples collected from dolphins near the MSS and Chandeleur Sound barrier islands had higher levels of POPs than dolphins from the MSS mainland, as well as those in Barataria Bay, western Chandeleur Sound and St. Joseph Bay. Although the levels were not significantly different, a difference in prey selection between mainland and barrier island animals was hypothesized.

Van Dolah *et al.* (2015) studied seasonal variation in gene expression of bottlenose dolphins using remote biopsy samples collected in MSS, Mississippi and Chandeleur Sound and Barataria Bay, Louisiana, to establish a baseline for assessing health and contaminant exposure. A significant difference was found in gene expression between summer and winter; however variation among locations was non-significant. The microarray used was concluded to be incomplete for assessing contaminant exposure.

<u>1.7 Life history, strandings and unusual mortality</u>

Information on life history parameters of bottlenose dolphins in MSS is limited. A study by Mattson *et al.* (2006) investigated age structure and growth of bottlenose dolphins in MSS from data gathered from deceased

stranded (beached) dolphins during 1983–2003. A growth model fitted to length and age data revealed that asymptotic lengths are approached at about 2.50 m for females and 2.55 m for males around 10 years of age in both cases. A peak in strandings of adults and neonate dolphins was observed in March and April. Dolphin ages ranged from <1 to 27 years for males and 30 years for females. The largest number of dolphins aged (43%, *N* = 48) were <1–5 years old, followed by animals between 6 and 15 years old (36%, *N* = 40) and 16 to 30 years old (21%, *N* = 23).

In November and December of 1996, a high number of bottlenose dolphins (*N* = 31) were stranded in MSS and the event was classified as an Unusual Mortality Event (UME). According to the MMPA [16 USC Chapter 31 § 1421h] an UME is "a stranding that is unexpected; involves a significant die-off of any marine mammal population; and demands immediate response." Brevitoxicosis caused by red tide (*Karenia brevis*) was the cause of the 1996 UME (Litz *et al*. 2014). More recently, an increase in the number of stranded marine mammals has been reported in the northern GMx since the winter of 2010. The event is ongoing and was deemed by the NMFS to be an UME on 1 February 2010 (hereafter "ongoing UME"; NOAA Fisheries Office of Protected Resources 2015). Since then, close to 1,300 marine mammals, mostly bottlenose dolphins (87%) have been recovered and most dolphins (94%) were found dead (Venn-Watson *et al*. 2015b). This event includes animals that were recovered during the DWH oil spill. Carmichael *et al.* (2012) explored the possibility of many factors contributing to the ongoing UME. They suggested that an unusually cold winter in 2010 followed by the DWH oil spill later that year could have caused drastic changes to the ecosystem, increasing stress to bottlenose dolphins. The following winter of 2011 had an extremely high snowmelt resulting in increased freshwater input into the ecosystem, and Carmichael *et al.* (2012) thought that increase may have been another potential environmental stressor contributing to the ongoing UME. Venn-Watson *et al.* (2015a) also investigated the ongoing UME of bottlenose dolphins in the northern GMx through June of 2013. For MSS, there were an increased number of dolphins that stranded March–May 2010 through 2011 compared to previous or later years. Also, in 2011 a significantly higher portion of the stranded dolphins were female and perinates (<115cm in length) in MSS and Alabama compared to Louisiana. Venn-Watson *et al*. (2015b) also attributed the high number of stranded dolphins to DWH oil while ruling out other causes such as marine toxins, morbillivirus and poor body condition. Stranded individuals sampled during the ongoing UME

were compared to samples obtained at reference sites and were found to have a higher prevalence of thin adrenal cortices, which can lead to chronic adrenal insufficiency.

1.8 Research Objectives

While the breadth of knowledge on the biology of bottlenose dolphins in MSS is growing, important, basic questions regarding temporal and spatial patterns in group size, movement patterns and abundance remain unanswered. For example, it is not known whether or not individual dolphins in the MSS routinely use the entire sound or occupy smaller ranges. The physical, chemical and geological makeup of the environment throughout MSS could be different (e.g., mainland marsh, barrier islands, dredged shipping channels, etc.) and it is possible that dolphins are more routinely encountered in specific parts of MSS than others. Also, since MSS is a semi-open embayment with multiple passes, dolphins can move between MSS and the GMx. Dolphins found in waters south of the barrier islands just outside MSS are part of the GMx Northern Coastal Stock (Waring *et al.* 2016), so dolphins potentially using both sides of the barrier islands would span two different management units. Dolphins that only range closer to the mainland may also be exposed to different stressors than dolphins at the barrier islands (e.g., contaminant exposure, freshwater input, human interaction). Dolphins routinely using shipping lanes and deeper channels are exposed to increased vessel traffic compared to those that do not. Prey availability and density may be different near the mainland compared to the barrier islands, so dolphins may have different foraging strategies in each. All of these factors may support the concept of one or more stocks within MSS, a BSE that is currently managed as a single stock. MSS was one of the BSEs affected by the DWH oil spill in 2010 (Michel *et al.* 2013) as well as an ongoing UME beginning in February of 2010 (Litz *et al.* 2014, NOAA Fisheries Office of Protected Resources 2015), and the effect these events had on bottlenose dolphins has not yet been fully quantified.

Previous studies reported that some dolphins might move in or out of MSS seasonally, and identified dolphins displayed different ranging patterns (e.g., Lohoefener *et al*. 1990b, Hubard *et al*. 2004). Abundance studies noted increased abundance of dolphins in MSS in warmer months using both aircraft and boats as survey platforms (e.g., Leatherwood *et al.* 1978, Blaylock and Hoggard 1994, Hubard *et al*. 2004, Miller *et al*. 2013). Solangi and Dukes (1983), Lohoefener *et al.* (1990a) and Hubard *et al.* (2004) suggested that some individual dolphins were re-sighted with somewhat discrete ranges in MSS, more specifically, with some individuals sighted

only in “Inner-Sound” (near the mainland coasts) locations and other individuals sighted only in “Outer-Sound” (near the barrier islands) locations. The objectives of the research were to: 1) study how group characteristics of bottlenose dolphins (group size and presence of calves) in MSS differed among zones [Inner-Sound, Outer-Sound, and Coastal (near the barrier islands’ GMx shoreline)] and between seasons (summer versus winter); 2) compare previous estimates of dolphin abundance in MSS; and 3) analyze photo-ID data for spatial and temporal occurrence patterns of individual dolphins among Inner-Sound, Outer-Sound and Coastal zones over the time frame of the research.

CHAPTER 2: MATERIALS AND METHODS

2.1 Survey Area

Four zones were chosen for surveys, one representing the Inner-Sound, two representing the Outer-Sound and, given that the MSS is a semi-open BSE, an adjacent Coastal zone (Figure 1b) with a combined area of approximately 85 km^2. The Inner-Sound zone was designated Round Island (RI) and consisted of waters between Round Island and the Mississippi mainland (19 km^2), from the Pascagoula Shipping Channel in the east to the West River Channel in the west. Outer-Sound zones included Petit Bois Island—north (PBN) (16 km^2) and Horn Island (HI) (33 km^2) and were waters on the north side of each of these barrier islands, from the beach to approximately 1.6 km off the beach. The Coastal zone was Petit Bois Island—south (PBS) (17 km^2) located outside of the MSS in the GMx. Additionally, RI, PBN, and HI were within the boundaries of the Hubard *et al.* (2004) study area.

2.2 Data Collection

Field work was conducted over a four-year period from 16 July 2002 through 12 March 2005. Zones were surveyed following pre-determined track lines entered into a global positioning system (GPS). The number of zones covered during each survey varied and was dependent on factors such as weather and number of dolphin sightings. The survey platforms were small boats (6–7m) powered by outboard motors. Surveys were conducted in Beaufort Sea states ≤3 and usually lasted 4−6 hours, between 0800 and 1600 h. The survey crew consisted of two to four scientists. In a four-person crew, there was a dedicated boat driver, two photographers, and a data recorder. For smaller crews duties were combined. During each survey, crew scanned visually for dolphins, with unaided eye or handheld binoculars, and boat speed was maintained around 2500 rpms (18–22 km/h) until a group of dolphins was encountered. The definition of a dolphin group was adapted from Shane (1990) and defined as one or more animals observed in apparent association in the same area exhibiting similar behavior. If additional dolphins joined the group during a sighting, it was noted, but only initial group sizes were used for analyses. When a group of dolphins was sighted, the survey route was interrupted and the group was approached to collect data. General sighting information (similar to Hubard *et al.* 2004) was recorded on a sighting data sheet (Appendix 2) and included date, time, geographic location, survey platform and survey zone (i.e., RI, HI, PBN or PBS). Dolphin group information consisted of a count of the total number of all dolphins (calves and neonates included), as well

as the numbers of calves and neonates. Dolphins less than two-thirds the length of an adult they consistently swam beside were considered calves (Shane 1990). Dolphins classified as neonates had two or more of the following characteristics: less than half the length of an adult it consistently surfaced alongside, fetal folds, non-rigid dorsal fin, dark body coloration and head-out surfacing pattern (Shane 1990, Urian and Wells 1996). Length estimates were made by eye in the field and agreed upon by the crew. Initial behavior (behavior observed when the group was first encountered and/or approached for data collection) was recorded in a fashion similar to Hubard *et al.* (2004) and included traveling, feeding, socializing and milling (Shane 1990).

After the sighting data sheet was completed, the dolphin group was approached for photo-ID. In 2002, photographs were collected with a 35 mm Canon film camera equipped with a Canon 75−300 mm Ultrasonic Motor (USM) zoom lens and American Standards Association (ASA) 200 slide film. From 2003 on, Canon digital cameras equipped with Canon 100–400 mm USM zoom telephoto, image stabilizing lenses were used. During photo-ID procedures, one or two photographers took pictures of dolphins' dorsal fins. Every attempt was made to photograph all groups encountered and all dolphins within each group. Photo-ID effort was suspended for any of the following reasons: 1) photographers believed the entire group was photographed, 2) dolphins exhibited persistent boat-avoidance behaviors, or 3) time constraints or weather conditions precluded completion. When photo-ID effort was completed, the route was resumed until the next dolphin group was sighted.

Digital photographs of dorsal fins from photo-ID effort were downloaded onto computer hard drives at the conclusion of each survey day. Slide film from the 35mm camera was professionally processed and slides were digitized with a Nikon Super Coolscan 4000 slide scanner and saved onto computer hard drives. Processed images (see Data Analysis – Photograph Identification section) were backed-up on compact discs (CDs) throughout the study period.

2.3 Data Analysis

2.3.1 Group Size

Seasons in the northern GMx are indistinct (Hubard *et al.* 2004, Mackey 2010), so two seasons were defined for analysis purposes based on mean surface temperature (Mackey 2010): Season 1 was "Summer" and

included months from May toOctober and Season 2 "Winter" and included months from November to April. Charts and tables were constructed using descriptive statistics generated using SAS® software, Version 9, Copyright© (2004) SAS Institute Inc and Microsoft® Excel (2010). Statistical analyses were also performed with SAS®. Analysis of variance (ANOVA) was used to test the effects of season, zone and presence of calves on mean group size. For analysis purposes, calves and neonates were collectively referred to as calves. The group size data sets were skewed towards smaller group sizes, failed normality tests and were unbalanced, so a generalized linear mixed model (PROC GLIMMIX) was used for analysis and a Poisson distribution was assigned to the data set. When necessary, adjustments for multiple comparisons were made with a Tukey-Kramer adjustment. Saxton's macro (Saxton 1998) was used to convert mean separation output to letter groupings.

2.3.2 Historical Abundance Data

Historically, MSS is one of the few BSEs in the GMx for which several abundance studies have been performed. Most studies for abundance in MSS observed a seasonal fluctuation in bottlenose dolphin abundance, with a higher abundance of dolphins inhabiting the MSS in warmer months. The more recent studies hypothesized that dolphins move out of MSS in colder months, possibly following schooling fish (Hubard *et al.* 2004, Mackey 2010, Miller *et al.* 2013, McBride 2013). Most historical abundance estimates had summer and winter surveys that fell within the previous definitions of Summer and Winter used for Group Size analyses. Two different types of survey platforms were used: aircraft and small boats. For aerial and boat-based line-transect studies, line-transect density estimation was extrapolated to an area to estimate abundance. Abundance estimates from the Lohoefener *et al*. (1990a) mark-recapture study were not used as authors concluded the estimates were probably not accurate since several mark-recapture assumptions were violated. Density estimates from the Hubard *et al*. (2004) study were extrapolated to the same area (1578 km^2) used for Lohoefener *et al*. (1990b). Analysis of covariance (ANCOVA) was used in a generalized linear model (PROC GLM) to test for effects of season and survey platform on bottlenose dolphin abundance.

2.3.3 Photographic Identification

For each sighting, dorsal fin images were sorted and the best images for each individual dolphin were kept for analysis in a manner similar to that described in Mazzoil *et al.* (2004) and Melancon *et al.* (2011). Image sorting

was typically accomplished using an imaging program with a file browsing utility (e.g., Adobe® Photoshop). The first step in the sorting process was to identify all the images of the same individual dolphin from each sighting. All images of the individual were assigned a temporary, within-sighting, alphabetic identifier (rank). The ranked images were closely compared to each other with the goal of retaining the best right and left images of each individual rank. While it was ideal to capture images of both sides of a dolphin's dorsal fin, factors such as sighting conditions, time constraints, animal behavior and user error could often limit success. When necessary, images were rotated to bring the base of the dorsal fin parallel with the bottom of the frame and cropped so that the frame was filled by the dorsal fin. During the sorting process, other images of interest (e.g., birds, vessels and personnel) were typically saved in "Miscellaneous" folders. Images of water-only or images that were of such poor quality that the subject of the photo could not be ascertained were discarded[1]. The process was repeated for each sighting in a survey. After all individuals were sorted, the survey and sighting numbers were added to the file extension name for each image. Before comparisons to the MSS dorsal fin catalog were made, images were graded for image quality. Only high quality images were retained for analysis. In this study, high quality images had the following characteristics: 1) sharp focus and contrast, 2) good angle (i.e., the dorsal fin was perpendicular to the camera), and 3) the dorsal fin filled most of the frame (Urian *et al*. 1999, Urian *et al.* 2015).

Identifying bottlenose dolphins using the various nick and notch patterns acquired on the trailing edges of their dorsal fins is a well-accepted identification technique (Würsig and Würsig 1977, Würsig and Jefferson 1990, DeFran *et al*. 1999). Typically, new images of individuals are collected and compared to images from previous surveys, generating sighting histories of individual dolphins which allows researchers to track various parameters such as spatial and temporal movement patterns and associations. For this study, sorted dorsal fin images were compared and added to the dorsal fin catalog created by Hubard *et al.* (2004). The catalog and sighting data collected by Hubard *et al.* (2004) were digitized and imported to a custom, Microsoft® Access-based program called FinBase (e.g., Adams *et al.* 2006, Speakman *et al.* 2010, Melancon *et al.* 2011) that served to automate tasks associated with dorsal fin catalog management, such as assignment of fin attributes and matching dorsal fins. User-assigned attributes (Appendix 3) were assigned to each "candidate" fin (i.e., fins from new surveys that may

[1] At least two copies of the RAW images from every survey are kept for archival purposes.

or may not have a match in the catalog) in the order of most obvious to least obvious attribute. After attributes were assigned, the "sort catalog" feature was used, where FinBase sorted the catalog based on similarity of the candidate fin to existing fins in the catalog. When a potential fin "match'' was found, it was incorporated into the catalog under the sighting history for that individual dolphin. Non-matches were entered into the catalog as "new" fins to establish a sighting history for that dolphin. Both matches and new fins were assigned a "tentative" status in the catalog until they were independently viewed and agreed upon by two trained technicians.

Photo-ID data were used to generate a discovery curve combining all four survey zones. Discovery curves are typically used to assess the total number of distinctive dolphins in a survey area (Wilson *et al.* 1999). A discovery curve that levels off could indicate most of the dolphins have been encountered and the area is adequately surveyed. A discovery curve that continues to climb could indicate not all animals were encountered or the area was not adequately surveyed.

To track movements of individual dolphins among zones, individuals with ≥2 sightings were grouped into categories according to how many zones in which they were sighted and if they were sighted only in MSS, in both MSS and the Coastal zone, or Coastal zone only. To maintain consistency with the previous photo-ID study (Hubard *et al*. 2004), dolphins with ≥4 sightings were plotted with ArcMap® 10.2 (ESRI 2014) to examine spatial occurrence patterns. Since the abundance has been reported to fluctuate seasonally, these dolphins were also examined for temporal occurrence patterns, more specifically, seasonal variation in sightings histories. Finally, since the dorsal fin catalog began in 1995, sighting histories of individuals could include sightings made outside of the time frame of this project. Sightings histories of individual dolphins seen during, prior to, and after this project were also examined for evidence of long term occurrence in MSS.

CHAPTER 3: RESULTS

3.1 Group Size

A total of 78 surveys were completed during the study. More surveys were completed in the summer (*N* = 53) than winter (*N* = 25). Over the course of the survey, 223 dolphin groups (Summer *N* = 144, Winter *N* = 78) were encountered and a total of 2087 individual dolphins (Summer *N* = 1618, Winter *N* = 469) were observed (Tables 2 and 3). Group size counts were recorded for 222 of the groups encountered. The highest mean group size was observed at the PBN zone in the Summer season (*M* = 17.6, *SE* = 3.39) and group size ranged from 1 to 55 dolphins (Table 3). The lowest mean group size was observed at the RI zone in the Winter season (*M* = 2.4, *SE* = 0.40) where group size ranged from 1 to 5 dolphins per group (Table 2). Group size counts were skewed towards smaller group sizes, where 50% of the groups contained 1–5 individuals, and 80% of the groups contained 15 or less individuals (Figure 2). All observations of >20 individuals in a group (*N* = 36) were seen at the Outer-Sound and Coastal zones (HI, PBN and PBS). All observations of >30 individuals in a group (*N* = 7) were seen in the Summer season. Calves were present in all zones and in both seasons. Groups with calves present constituted 38% (*N* = 85) of total dolphin groups. Most of the groups with calves had one calf (Figure 3a-d). The RI zone had an equal number of groups with one or two calves (*N* = 6, 10%), and one group with three calves (1%) (Figure 3a). All of the observations of four calves in a given group were at the HI (*N* = 2, 3%), PBN (*N* = 2, 4%) and PBS zones (*N* = 2, 5%) (Figure 3b-d). There were three groups (4%) that had more than four calves (*N* = 5, 7 and 12 calves) and all were located at the HI zone (Figure 3d).

Table 2. Number of surveys performed, groups encountered, and best estimate of individual bottlenose dolphins (*Tursiops truncatus*) within groups encountered in each zone in Mississippi Sound in Winter from 2002 to 2005.

Winter					
Zone	**No. Surveys**	**No. Groups**	**No. Dolphins**	**Mean Group Size (SE)**	**Group Size Range**
Round Island	6	15	36	2.4 (0.40)	1–5
Horn Island	8	29	183	6.3 (1.33)	1–28
Petit Bois Island – north	7	27	188	6.9 (1.50)	1–35
Petit Bois Island – south	4	7	62	8.9 (4.06)	1–30
Total	25	78	469	6.0 (0.82)	1–35

Table 3. Number of surveys performed, groups encountered, and best estimate of individual bottlenose dolphins (*Tursiops truncatus*) within groups encountered in each zone in Mississippi Sound in Summer from 2002 to 2005.

Summer					
Zone	**No. Surveys**	**No. Groups**	**No. Dolphins**	**Mean Group Size (SE)**	**Group Size Range**
Round Island	21	47	290	6.2 (0.61)	1–18
Horn Island	13	43	567	13.2 (1.53)	1–36
Petit Bois Island – north	10	23	405	17.6 (3.39)	1–55
Petit Bois Island – south	9	31	356	11.5 (1.74)	1–38
Total	53	144	1618	11.2 (0.88)	1–55

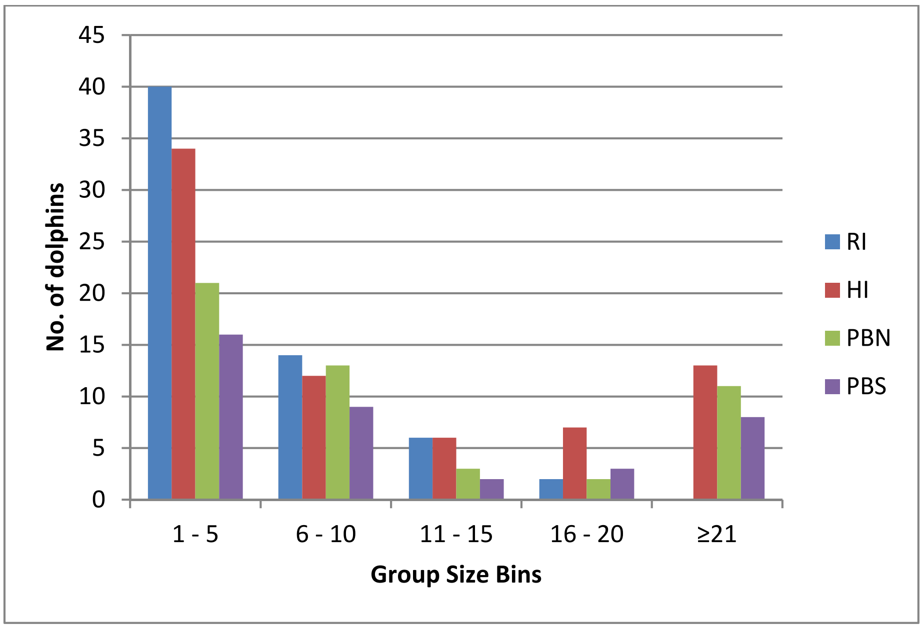


Figure 2. Group size bins for bottlenose dolphin (*Tursiops truncatus*) groups encountered (N = 222) in Mississippi Sounds from 2002 to 2005 in each zone: Round Island (RI), Horn Island (HI), Petit Bois—north (PBN) and Petit Bois—south (PBS).

Analysis of variance revealed significant of effects of zone, season and presence of calves on bottlenose dolphin group size (Figure 4a-c, Table 4). The main effect of zone yielded an F ratio of $F(3, 31) = 3.74$, $p = 0.0210$. Saxton's macro (Saxton 1998) separated the zones into three groupings, with significantly larger group sizes observed at the HI (M = 10.4, SE = 1.13) and PBN (M = 11.9, SE = 1.90) zones than at the RI zone (M = 5.3, SD = 0.51) (Figure 4a). The PBS zone (M = 11.0, SD = 1.59) was not significantly different than HI, PBN or RI. The main effect of season yielded an F ratio of $F(1, 31) = 18.22$, $p = 0.0002$, indicating that mean group sizes observed in Summer (M = 11.2, SE = 0.88) were significantly larger than in Winter (M = 6.0, SE = 0.82) (Figure 4b). Lastly, the

main effect of calf-presence in a group had a significant effect on group size [$F(1, 31) = 57.64$, $p < 0.0001$], where groups with at least one calf present ($M = 15.7$, $SE = 1.16$) had significantly larger mean group size than groups with no calves ($M = 5.5$, $SE = 0.58$) (Figure 4c). Two- and three-way interaction effects of presence*zone [$F(3, 31) = 1.55$, $p = 0.2222$], presence*season [$F(1, 31) = 3.27$, $p = 0.0803$], zone*season [$F(3, 31) = 0.33$, $p = 0.8057$] and presence*zone*season [$F(3, 31) = 1.49$, $p = 0.2375$] were non-significant.

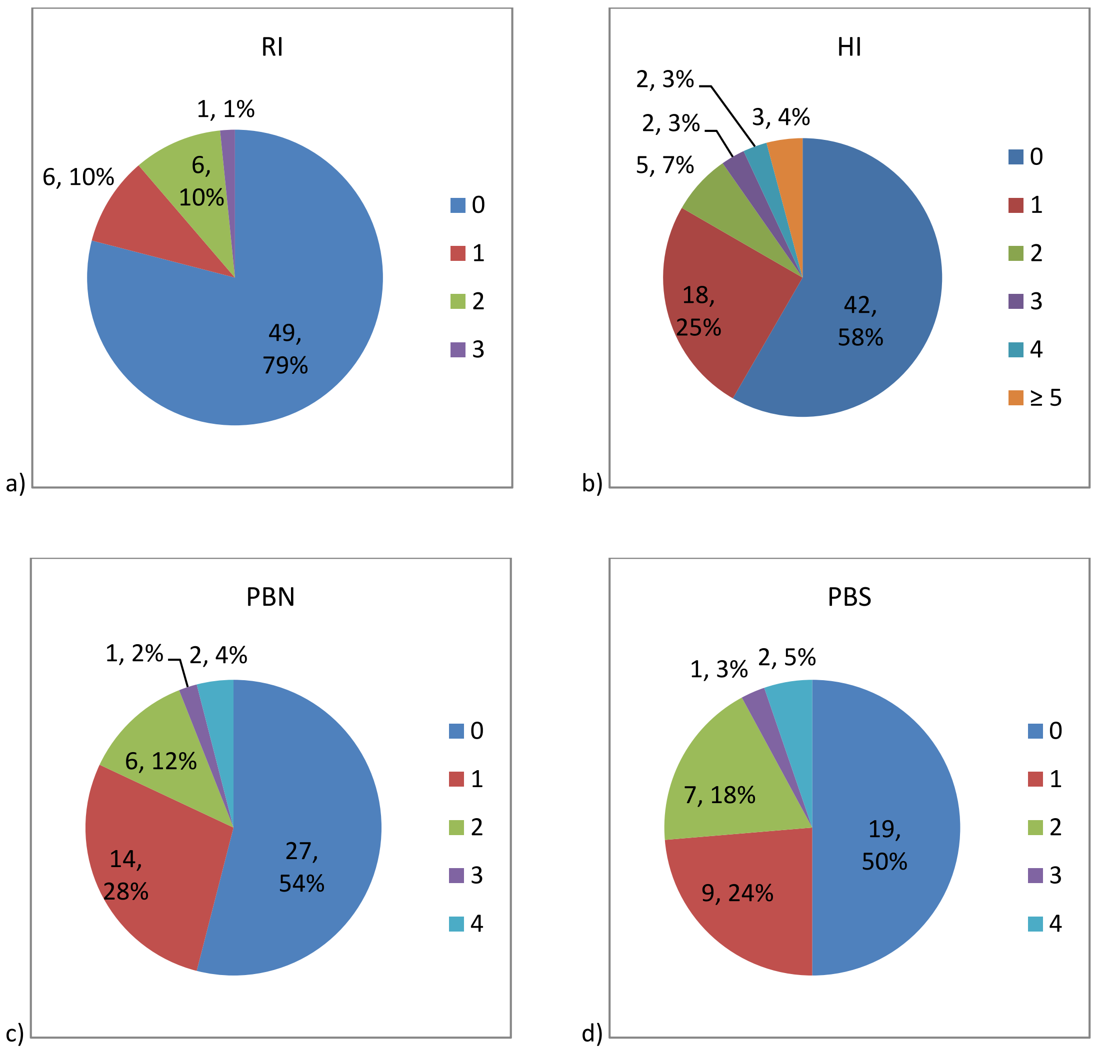


Figure 3. Percentages of bottlenose dolphin (*Tursiops truncatus*) groups with calves in the four zones in Mississippi Sound from 2002 to 2005: a) Round Island (RI) (N= 62); b) Horn Island (HI) (N = 72); c) Petit Bois—north (PBN) (N = 50); d) and Petit Bois—south (PBS) (N = 38).

Table 4. Summary of Type III fixed effects of analysis of variance performed on bottlenose dolphin (*Tursiops truncatus*) mean group size.

Effect	Num DF	Den DF	F-value	Pr > F
Present	1	31	57.64	<0.0001
Zone	3	31	3.74	0.0210
Season	1	31	18.22	0.0002
present*zone	3	31	1.55	0.2222
present*season	1	31	3.27	0.0803
season*zone	3	31	0.33	0.8057
present*zone*season	3	31	1.49	0.2375

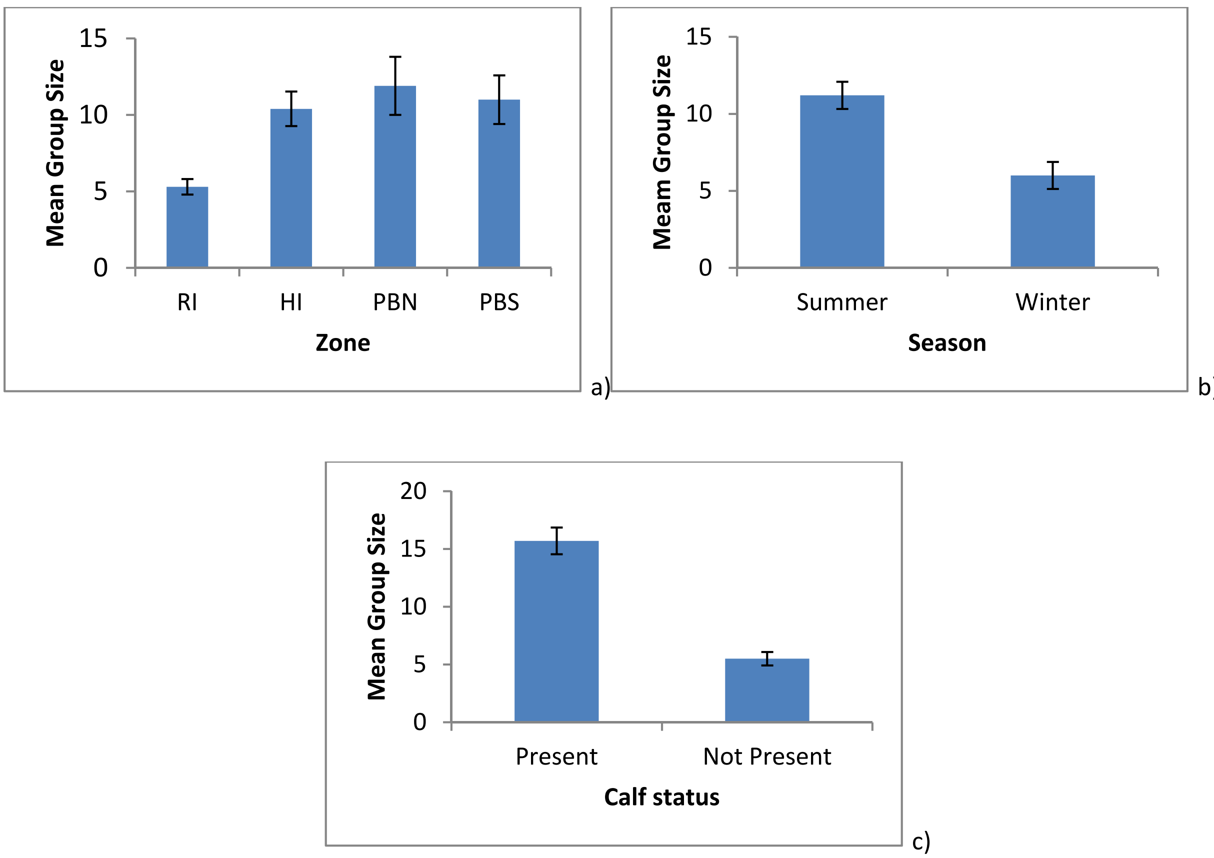


Figure 4. Mean and standard error of bottlenose dolphin (*Tursiops truncatus*) group size a) in four zones [Round Island (RI), Horn Island (HI), Petit Bois—north (PBN), and Petit Bois—south (PBS)]; b) in Summer and Winter (Summer was defined as May to October and Winter as November to April); and c) with calves present (N = 85) and not present (N = 137) in Mississippi Sound from 2002 to 2005.

3.2 Differences in Abundance

Analysis of covariance revealed non-significant three-way interactions of season*platform*year [$F(1)$ = 0.18, p = 0.6828] and non-significant two-way interactions of platform*season [$F(1)$ = 2.08, p = 0.1831], platform*year [$F(1)$ = 0.94, p = 0.3588], season*year [$F(1)$ = 0.03, p = 0.8571]. There were significant main effects

Table 5. Summary of analysis of covariance results performed on bottlenose dolphin (*Tursiops truncatus*) abundance estimates.

Source	DF	F-value	Pr > F
Year	1	6.77	0.0231
Season	1	24.33	0.0003
Platform	1	9.95	0.0083
year*platform	1	0.94	0.3588
year*season	1	0.03	0.8571
platform*season	1	2.08	0.1831
year*platform*season	1	0.18	0.6828

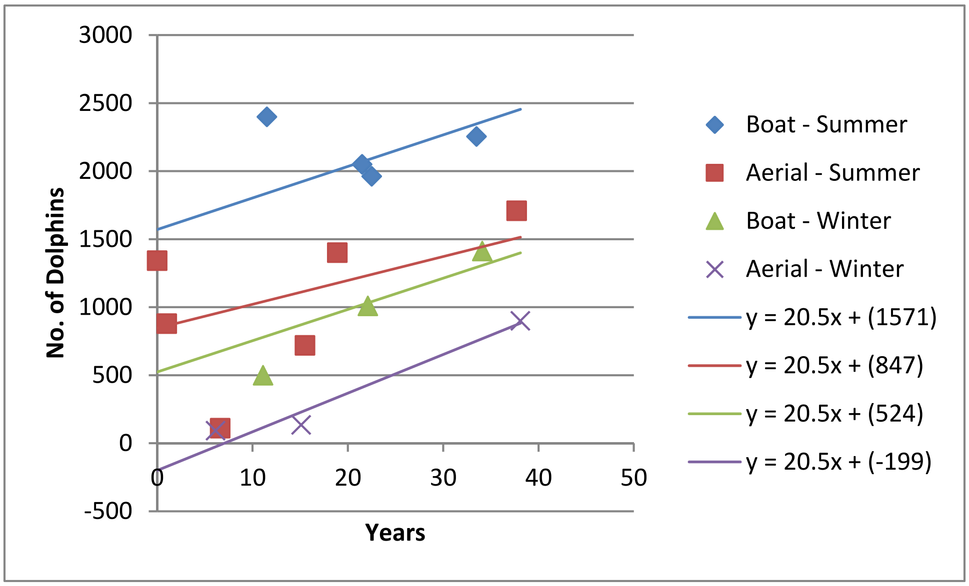


Figure 5. Increase over time of common bottlenose dolphins (*Tursiops truncatus*) abundance in Mississippi Sound. Linear increase was 20.5 dolphins per year. The difference in the intercepts for seasons was 1046 dolphins and platform (aerial or boat) was 724 dolphins. Summer was defined as May to October and Winter as November to April. Year zero was equal to 1974.

of platform [$F(1) = 9.95$, p = 0.0083], season [$F(1) = 24.33$, p = 0.0003] and year [F(1) = 6.77, p = 0.0231] on dolphin abundance (Table 5). A linear regression was calculated to predict abundance of dolphins based on season, survey platform and year. A significant regression equation was found ($F(3, 12) = 13.68$, $p = 0.0003$) with an R-square of 0.77. The regression (Figure 5) had a single, increasing slope of 20.54 dolphins per year. Year 0 was equal to 1974. The regression also had four intercepts, one for each season-platform combination (Figure 5). Each intercept predicted an abundance of dolphins for that season-platform combination for Year 0 of the analysis. For example the regression predicts that a boat survey conducted in Year 0 would have been expected to find an abundance of 524 dolphins in Winter and 1571 dolphins in Summer. According to the regression, the number of dolphins

appears to have increased over time in MSS (Figure 5). Surveys conducted from boats yielded higher abundance estimates than surveys conducted from aircraft by a difference in intercept of 724 dolphins. Surveys conducted in the Summer yielded higher abundance estimates than those conducted in Winter by a difference in intercept of 1046 dolphins.

3.3 Photographic Identification

During 2002–2005, over 13,000 digital photographs were gathered from 223 dolphin groups. From these photographs, 488 individual dolphins were identified and catalogued. The frequency of individual dolphins re-sighted throughout the project by zone reflected the same general trend: most animals were seen once, followed by a steep drop off in multiple re-sightings (Figure 6), and therefore all zones will be summarized together. A majority of dolphins (64%, N = 310) of the dolphins were

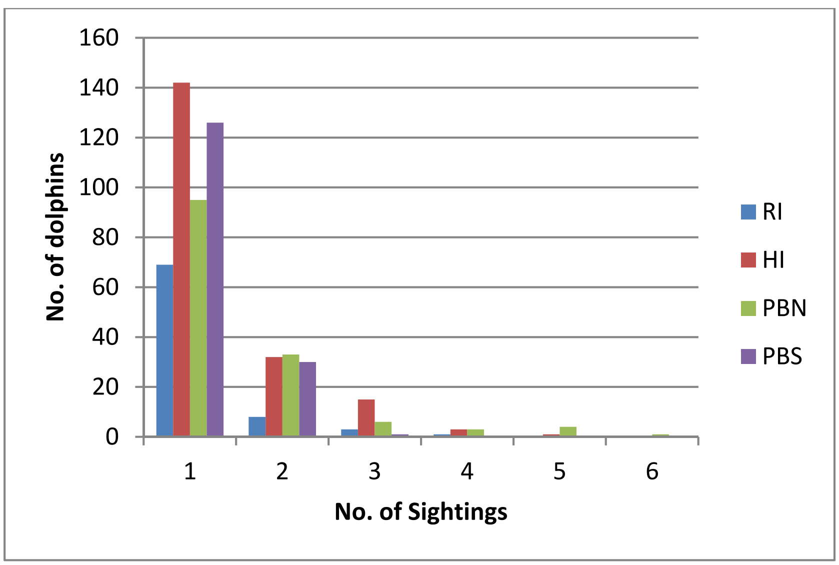


Figure 6. Frequency of individual bottlenose dolphins (*Tursiops truncatus*) sighted during photographic identification surveys in Mississippi Sound from 2002 to 2005 in four zones.

sighted one time. The remaining dolphins (36%, *N* = 178) were sighted multiple times: 105 dolphins were sighted two times (21%), 39 dolphins were sighted three times (8%), 19 dolphins were sighted four times (4%), nine dolphins were sighted five times (2%) and six dolphins were sighted six times (1%) (Figure 6). New dolphins were encountered on every survey, and added to the dorsal fin catalog during the course of the study. The number of newly observed individuals continued to increase through the end of the study (Figure 7).

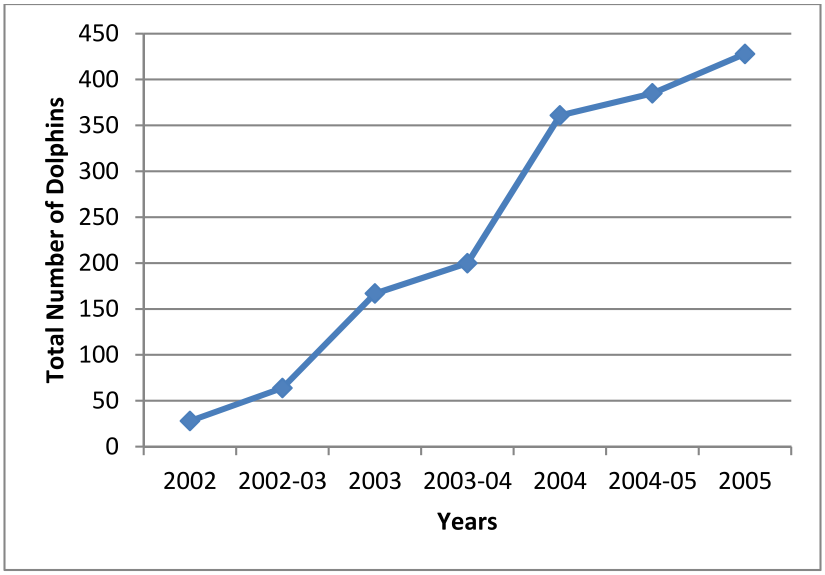
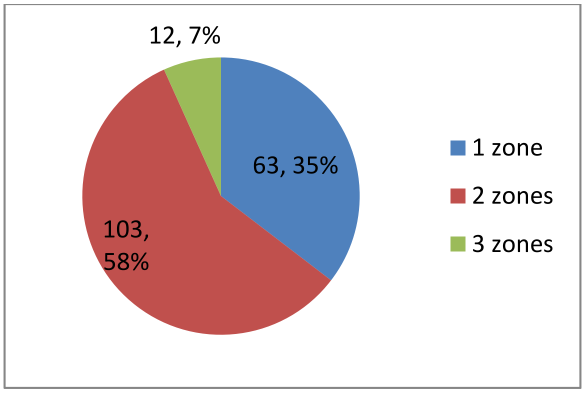


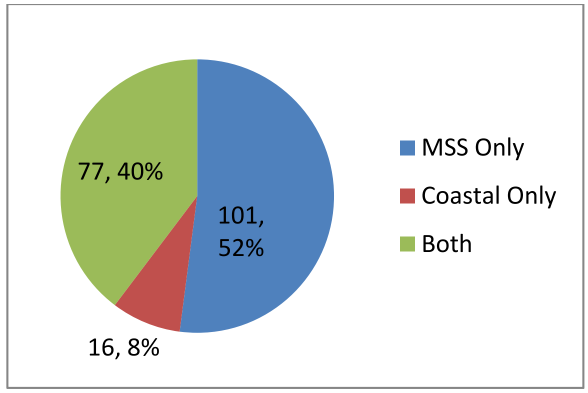
Figure 7. Discovery curve of new marked individual (*N*= 488) bottlenose dolphins (*Tursiops truncatus*) added to the dorsal fin catalog from Mississippi Sound from 2002 to 2005.

Of the dolphins photographed two or more times (*N* = 178), 35% of these individuals were seen exclusively in one zone, 58% were seen in two zones, 7% were seen in three zones, and none were seen in four zones (Appendix 2, Figure 8a). Ten individuals were seen at the Outer-Sound zone HI and the Inner-Sound zone RI. One individual was seen in the Inner-Sound, one Outer-Sound and the Coastal zones. Fifteen individuals were seen at the two Outer-Sound zones, HI and PBN. Also, 52% (*N* = 101) of the individuals seen more than once were only seen within MSS (Appendix 2, Figure 8b). Seventy-seven (40%) were seen between MSS and the Coastal zone (PBS), and 16 (8%) were seen only in the Coastal zone (Appendix 2, Figure 8b).

Dolphins with four or more sightings (*N* = 32) generally appeared to fit into two broad patterns of seasonal occurrence: 1) dolphins sighted in multiple summer and winter seasons and 2) dolphins sighted in multiple summers but only one winter season (Table 6). Dolphin 3005 (*N* = 4 sightings) appeared to be a seasonal visitor, and was sighted in Summers of 2002, 2003, 2004 and 2005. Four dolphins had ≥4 sightings, but were only seen in two seasons (Dolphin 2167: Winter 2003–04 and Summer 2004; Dolphin 3037: Winter 2003–04 and Summer 2004; Dolphin 6093: Summer 2002 and Winter 2004–05; Dolphin 12054: Winter 2003–04 and Summer 2004), which made interpreting seasonal occurrence difficult. Dolphins sighted in multiple summer and winter seasons (*N* = 12) included both consecutive and non-consecutive seasonal sightings. For example, Dolphin 6102



a)



b)

Figure 8. Proportion of individual bottlenose dolphins (*Tursiops truncatus*) with ≥2 sightings (*N* = 178) in a) one, two and three survey zones; and b) in Mississippi Sound (MSS) only, the Coastal zone [Petit Bois—south (PBS)] only, or both MSS and Coastal zones in Mississippi Sound from 2002 to 2005. The proportion is expressed as a value (number of individual dolphins) and a percentage of the total. No dolphins were seen in four zones.

was sighted in five consecutive seasons from Summer 2003–2005. Dolphins 2023, 2025 and 8046 were all sighted in four consecutive seasons from Winter 2002–03 to Summer 2004. Dolphins 2019, 3021, 6107 and 7113 were also sighted in four consecutive seasons, but from Summer 2003 to Winter 2004–05. Dolphin 2130 was sighted in Summer 2002, then again in Summer 2003 through Winter 2004–2005. The remainder of the dolphins (*N* = 15) were seen in multiple summer seasons but only one winter season. For instance Dolphin 6063 was sighted Summer 2002, Winter 2002–03, Summer 2003, Summer 2004 and Summer 2005. Several dolphins (2091, 3004, 7108, 7117, 8052 and 8069) were seen in three consecutive seasons from Summer 2003–2004 (Table 6).

Individual dolphins with ≥4 sightings displayed different zone movement patterns as well, and two broad patterns emerged, reflecting the same results as dolphins sighted ≥2 times (Figure 8a-b): 1) individuals sighted in multiple zones, both within MSS and between MSS and the Coastal zone (*N* = 21); and 2) individuals sighted in one zone (*N* = 11) (Table 7, Appendix 2). Four individuals were sighted within MSS, Dolphins 12031 and 2130 at zones HI and PBN and Dolphins 6091 and 8049 at zones HI and RI. The majority of individuals sighted in multiple zones (*N* = 15) were between MSS and the Coastal zone. Dolphins 2109, 2167, 3004, 3037, 6107 and 8070 were sighted at HI and PBS. Dolphins 1061, 2091, 3021, 3023, 6063, 7106, 7113, 7117 and 12054 were sighted at HI, PBN and PBS. Two individuals (3005 and 6093) were sighted at PBN and PBS. The remaining individuals were sighted within one zone. Five dolphins (6102, 7108, 7146, 8052 and 12039) were sighted only at the HI zone. Five individuals

Table 6. Bottlenose dolphins (*Tursiops truncatus*) with ≥4 sightings in Mississippi Sound from 2002 to 2005 and seasons and years in which they were sighted. Summer was defined as May to October and Winter as November to April.

Catalog ID	Summer (2002)	Winter (2002–03)	Summer (2003)	Winter (2003–04)	Summer (2004)	Winter (2004–05)	Summer (2005)
1016				■	■	■	■
2023		■	■	■	■		
2025		■	■	■	■		
2091			■	■	■		
2130	■		■	■	■	■	
2167				■	■		
3004			■	■	■		
3005	■		■		■		■
3021			■	■	■	■	
3023			■	■	■		■
3037				■	■		
6032	■	■	■		■		
6063	■	■	■		■		■
6091	■			■	■		
6093	■					■	
6102			■	■	■	■	■
6107			■	■	■	■	
7106	■				■	■	
7108			■	■	■		
7110			■	■	■		■
7113			■	■	■	■	
7117			■	■	■		
7146			■		■	■	■
8046		■	■	■	■		
8049	■			■	■		■
8052			■	■	■		
8069			■	■	■		
8070				■	■	■	
12031		■	■		■		
12039				■	■	■	
12054				■	■		

Table 7. Bottlenose dolphins (*Tursiops truncatus*) with ≥4 sightings and zones in which they were sighted in Mississippi Sound from 2002 to 2005. Dolphins with ≥3 sightings are denoted "*". Green cells signify dolphins sighted in both MSS and the Coastal zone. Blue cells signify dolphins sighted only within MSS.

Catalog ID	**Round Island (RI)**	**Horn Island (HI)**	**Petit Bois Island – north (PBN)**	**Petit Bois Island – south (PBS)**	**Total No. of Zones Sighted**
1016					3
2019					2
2023					1
2025					1
2127*					1
2091					3
2130					2
2167					2
3004					2
3005					2
3021					3
3023					3
3037					2
6032					1
6063					3
6091					2
6093					2
6102					1
6107					2
6117*					1
7058*					1
7103*					3
7106					3
7108					1
7110					2
7113					3
7117					3
7146					1
8046					1
8049					2
8052					1
8069					1
8070					2
12031					2
12039					1
12054					3

(2023, 2025, 6032, 8046 and 8069) were sighted only at the PBN zone. There were no individual dolphins with ≥4 sightings that were sighted only at zones RI or PBS, however, a reduced threshold of dolphins with ≥3 sightings yielded 3 individuals (2127, 6117 and 7058) seen only within the RI zone.

Dolphin dorsal fins were also compared to the established photo-ID catalog from Hubard *et al*. (2004), which included several projects from 1995 to 2006, to look for evidence of long term occurrence and movement patterns. Of the dolphins sighted ≥4 times, ten dolphins were found with sighting histories prior to 2002 or post-2005 (Figure 9a-c). Four major patterns were evident: 1) dolphins using the eastern portion of MSS; 2) dolphins that ranged throughout MSS; 3) dolphins sighted in the Inner-Sound zone; and 4) dolphins sighted in the Outer-Sound and Coastal zones. Dolphins 2023, 2025, 2091 and 8046 were sighted in the eastern portion of MSS (Figure 9a). Dolphins 2023, 2025 and 8046 were seen exclusively within MSS, and ranged from the eastern tip of Petit Bois Island to the eastern tip of Horn Island, and between the barrier islands and the mainland coast. Dolphin 2091 was the only one of these four that was sighted south of the Petit Bois and Horn islands, and it also did not range northward beyond the middle of MSS. Two dolphins ranged throughout the survey area (Figure 9a). Dolphin 3005 was sighted both north and south of Petit Bois Island in the east, as well as in the western portion of the MSS survey area closer to the Mississippi mainland (Figure 9b). Dolphin 6032 had an eastern distribution from the southwestern tip of Dauphin Island to the northeastern tip of Horn Island, and also was sighted close to the Mississippi mainland north of Petit Bois Island (Figure 9b). The remaining dolphins had strictly Inner-Sound or Outer-Sound and Coastal sightings (Figure 9c). Dolphins 2019, 3004 and 6063 were sighted exclusively at Petit Bois and Horn Islands. Dolphin 7058 was sighted strictly in the Inner-Sound, RI zone.

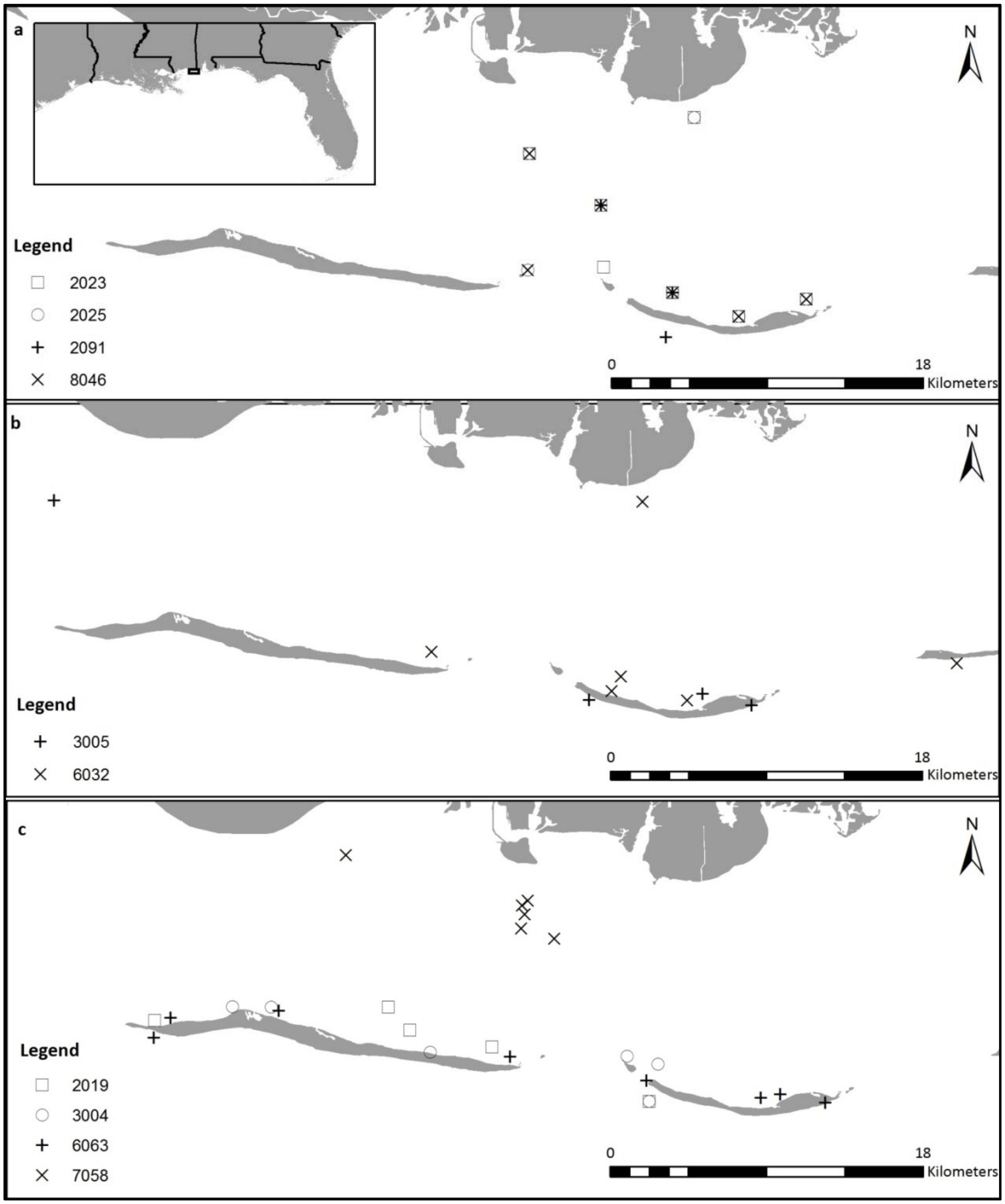


Figure 9. Bottlenose dolphin (*Tursiops truncatus*) with ≥4 sightings in Mississippi Sound (MSS) from 1995 to 2006 that were distributed a) in eastern MSS ; b) throughout MSS; and c) either barrier island or inshore MSS

CHAPTER 4: DISCUSSION

4.1 Group Size

Most GMx bottlenose dolphin studies have reported mean group sizes as a basic population parameter (Table 8). For comparison to the current study dolphin groups were placed into BSE, coastal and oceanic bins according to NMFS stock designations and seasons. Three of the zones were within a BSE stock (RI, HI, PBN), while the fourth was a coastal stock (PBS). Within their assigned stock, HI and PBN appeared to have higher summer group sizes (M = 13.2, 17.6 respectively) than those from other summer studies in the GMx where mean group size of dolphins ranged in Florida BSEs from 3.8–5.8 (Mullin *et al.* 1990), in Mississippi BSEs from 5.7–9.1 (Miller *et al*. 2013, Mackey 2010, Hubard *et al*. 2004, Mullin and Hoggard 1992a,b, Thompson 1982, Mullin *et al*. 1990) and in Texas BSEs from 3.8–5.8 (Thompson 1982, Mullin *et al.* 1990). For the Coastal zone, PBS appeared to have a much higher mean group size than the other coastal waters around the GMx, including those off of Florida, Louisiana, and Texas where group size ranged from 3.8–7.5 dolphins (Mullin *et al*. 1990).

In addition to the current study, three other studies in MSS have examined dolphin group size in relation to season and presence of calves with similar results (Hubard *et al.* 2004, Mackey 2010, Miller *et al*. 2013), and all found a seasonal difference between summer and winter group size, with higher group sizes observed in summer months. All four studies also found groups with calves to be significantly larger than groups without calves. This finding is not uncommon, as most studies that reported group size in relation to calf presence, such as those in Florida (Wells *et al.* 1987, Kent *et al.* 2008), Alabama (Pabody 2008) and Texas (Fertl 1994, Maze-Foley and Würsig 2002), reported the same trend.

This study was the only one to report a significant difference in group size by zone within the MSS. Hubard (1998) compared mean group size among channels, open water, barrier islands and mainland but did not find significant differences, although she did note that bottlenose dolphin sightings appeared to be concentrated at the barrier islands with a high prevalence of calves. Miller *et al*. (2013) found a significant difference in dolphin density between coastal (near the Mississippi mainland), barrier island and offshore zones, but did not examine differences in relation to group size.

All four zones had larger group sizes in the summer than winter. The Outer-Sound zones were significantly larger than the Inner-Sound zone. The Coastal zone appeared to have similar group sizes to the Outer-Sound zone, and they were not significantly different. A low number of surveys were performed in the Coastal zone compared to the others. Increased effort may help elucidate the relationship of group sizes between other zones with the Coastal zone. Differences in group size could be related to variability in zone size, food resources and predation pressure (Shane *et al.* 1986, Wells 1986, Weller 1998, Connor *et al.* 2000, Hubard *et al.* 2004, Kent *et al.* 2008, Mackey 2010), and these factors may vary by zone in MSS.

The Inner-Sound is near the mainland coast which can vary from estuarine marshes to manmade beaches. Several freshwater inputs (e.g., Pearl, Wolf and Pascagoula rivers) are located along the mainland coast which could drastically influence the salinity. Carmichael *et al.* (2012) hypothesized that increased fresh water input may have had severe deleterious effects on dolphins in MSS in 2010 and 2011, contributing to the ongoing UME. According to the US Census Bureau (2010), close to 380,000 people inhabit the coastal counties adjacent to MSS. The adjacent human population to the Inner-Sound zone may increase chances of fisheries interactions, boat strikes and pollution run-off.

The Outer-Sound and Coastal zones are located on the north and south sides of Horn and Petit Bois islands, respectively. These islands are located from 8–12 km from the mainland, can only be accessed by boat and, apart from a National Park Service ranger station on Horn Island, are uninhabited. The islands also represent a barrier between the more protected waters of the MSS and the open waters of the GMx. Deeper passes and/or dredged channels are located at the ends of the barrier islands. The combination of the barrier islands and deep channels could provide a bottleneck through which organisms must enter and leave the estuary, concentrating prey species for dolphins. Moncreiff (2007) also pointed out the importance of the barrier islands and associated seagrass beds as important nursery areas for fish and crustaceans, as well as providing the base of the food web for important game fish and sharks. Since dolphins are comparable apex predators, the seagrass beds may also provide prey resources for dolphins. Horn and Petit Bois islands are part of the Gulf Islands National Seashore, and

Table 8. Mean group sizes of common bottlenose dolphin (*Tursiops truncatus*) groups from various studies in bay, sound or estuarine, coastal and oceanic environments in the US Gulf of Mexico. Mean group sizes reported for each study were assigned to Summer (May to October) or Winter (November to April) to facilitate comparison to the current study.

Habitat	Location	Mean Group Size		Source
		Summer	Winter	
Bay, sound or estuarine	*Florida*			
	Southern, inshore	5.8	4.7	Mullin *et al.* 1990
	Central, inshore	-	5.1	Mullin *et al.* 1990
	Northern, inshore	3.8	2.5	Mullin *et al.* 1990
	St. Joseph and Apalachicola Bays	12.2	5.2	Thompson 1982
	Alabama			
	Wolf Bay	2.6	5.4	Pabody 2008
	Mississippi			
	Mississippi Sound (Round Island)	6.2	2.4	Current study
	Mississippi Sound (Horn Island)	13.2	6.3	Current study
	Mississippi Sound (Petit Bois Island - north)	17.6	6.9	Current study
	Mississippi Sound	8.4	5.7	Miller *et al.* 2013
	Mississippi Sound	11.1	5.4	Mackey 2010
	Mississippi Sound	6.0, 9.1[a]	5.2	Hubard *et al*. 2004
	Mississippi Sound	5.7	3.5	Mullin and Hoggard 1992b
	Mississippi Sound	5.7	3.1	Mullin and Hoggard 1992a
	Mississippi Sound	9.1	3.1	Thompson 1982
	North Central Gulf, inshore	5.8	-	Mullin *et al.* 1990
	Louisiana			
	Louisiana, inshore	5.8	7.2	Mullin *et al.* 1990
	Texas			
	Northern, inshore	5.8	2.5	Mullin *et al.* 1990
	Aransas, Copano, and San Antonio Bays	3.8	5.4	Thompson 1982
	Southern, inshore	5.1	8.1	Mullin *et al.* 1990
Coastal	Southern Florida	3.8	4.6	Mullin *et al.* 1990
	Central Florida	-	4.5	Mullin *et al.* 1990
	Northern Florida	6.1	5.7	Mullin *et al.* 1990
	Petit Bois Island – south	11.5	8.9	Current study
	North Central Gulf	7.4	-	Mullin *et al.* 1990
	Louisiana	5.8	5.7	Mullin *et al.* 1990
	Northern Texas	4.1	7.5	Mullin *et al.* 1990
	Southern Texas	5.4	9.2	Mullin *et al.* 1990
Oceanic	Gulf of Mexico, US	20.6	-	Maze-Foley and Mullin 2006
	Gulf of Mexico, US, outer continental shelf and slope	18.2	9.0	Mullin *et al.* 2004

[a] Summer 1995, Summer 1996

are therefore federally protected. While recreational fishing is allowed, no commercial fishing is allowed within the park boundaries (36 CFR Chapter 1 § 2.3). Decreased commercial fishing in the National Seashore may mean that more prey resources are available for dolphins to exploit. Also, personal water craft are required to observe a

flat wake speed near shore, extending anywhere from 200 yards to ½ mile (~180–800m) (depending on the island) within park boundaries (36 CFR Chapter 1 § 3.9). Therefore there is possibly a reduced amount of fast vessel traffic compared to the rest of MSS. Miller *et al.* (2008) reported changes in dolphin behavior when in close proximity to personal water craft.

Sharks present the greatest predation risk for bottlenose dolphins, especially calves, in shallow estuaries (Wells *et al.* 1987, Connor *et al.* 2000). In Sarasota Bay, dolphin groups with calves were more likely found in shallow water with seagrass beds, possibly in an effort to avoid sharks (Wells *et al.* 1987). MSS is hypothesized to be an important nursery ground for several shark species (Hoffmayer and Parson 2003). Shark bites have been observed on dolphins in MSS previously (Mackey 2010). Shallow seagrass beds of the barrier islands may provide similar protection for bottlenose dolphins in MSS.

4.2 Differences in Abundance

Regression analysis indicated an increasing trend in dolphin abundance in MSS, for both the Summer and Winter populations. This regression is probably confounded by survey frequency and survey methodologies. Gerrodette (1987) pointed out that when using linear regression the chances of a Type I Error are high (detecting a trend when one does not exist) unless abundance estimates are frequent and very precise. While MSS probably had the most abundance surveys performed in the GMx, they were probably not sufficient in frequency to detect a true trend. The range in years used for the regression was from 1974 to 2012, with gaps in surveys between 1 and 11 years. According to Wilson *et al.* (1999), for animals with a low theoretical maximum rate of population growth (R_{max} = 4%) like bottlenose dolphins (Wade and Angliss 1997), it takes longer to detect a change in trend and the precision of the estimates then has a larger effect on the ability to detect the trend. So, for MSS more frequent surveys with the same sampling method and survey design are necessary to accurately detect trends for bottlenose dolphin abundance.

Aside from the most current aerial surveys, none of the aerial line-transect surveys were corrected for perception and availability bias (Marsh and Sinclair 1989). There was also a lack in continuity in survey area sizes; some surveyed the entire MSLBBB Stock while some surveyed a portion of the MSS and extrapolated that density

estimate to the entire MSS or stock area. Since the early studies, methodologies have improved to be less negatively biased.

In addition, the live capture fishery was active from 1974 to 1988 (Scott *et al.* 1990), so dolphins were being removed from the population at the same time as the early surveys, where the trend still appears to be increasing. The difference between the first estimates given by Leatherwood *et al.* (1978) (1342 dolphins in 1974 and 879 dolphins in 1975) was considerably higher than the next estimate given by Thompson (1982) (111 dolphins in 1980). The difference was not equivalent to the number of dolphins removed from the MSS, and no mass stranding or unusual mortality event was reported during that timeframe.

A yearly increase of 20.5 dolphins per year was calculated in the regression analysis. This is not out of the realm of possibility for MSS, assuming the population is well below carrying capacity. If the intercept predicted by the regression for a boat survey (524 dolphins) conducted in the Winter of Year 0 (1974) reflected the abundance of the Winter population in MSS then, using the theoretical maximum growth rate of 4% (R_{max}) (Wade and Angliss 1997) for small cetaceans would equate to an expected annual increase of 21 dolphins, a value close to the 20.5 dolphins per year predicted by the regression. Given the current Winter abundance estimate of 900 dolphins (Waring *et al.* 2016) and R_{max}, the current Winter dolphin population in MSS could potentially grow by 36 dolphins per year.

The historical abundance results also pointed to a significant difference between Summer and Winter dolphin abundance in MSS. Lohoefener *et al.* (1990b), Hubard *et al.* (2004) and Miller *et al*. (2013) all hypothesized that dolphins leave MSS in the colder months in pursuit of food. It was thought that dolphins may be following certain species of schooling fish, such as mullet (*Mugil cephalus*) and Gulf menhaden (*Brevoortia patronas*), which migrate into deeper waters in the Winter as part of their life history cycle (Pattillo *et al*. 1997). While this is plausible, dolphins are present in MSS year round, so an alternative is instead of dolphins leaving MSS in the colder months, other dolphins move into MSS in the warmer months. The reason for the influx could be related to food resources. According to stomach content analysis from stranded dolphins, bottlenose dolphins in MSS had a more diverse diet compared to stranded dolphins from other locations in the GMx (Barros and Odell 1990). Stomach

contents were composed of roughly equal proportions of finfish, crustaceans and squid, whereas in Florida finfish dominated stomach contents. They also noted a high proportion of small-sized fish. The most common fish found were Atlantic croaker (*Micropogonias undulatus*), sand seatrout (*Cynoscion arenarenis*) and silver perch (*Bairdiella chrysoura*). Leatherwood *et al*. (1978) noted that in addition to barrier islands, shrimp trawlers and menhaden purse seine boats also served to concentrate dolphins and they were most likely feeding in association with these fisheries. Burrage (2004) reported ratios of up to 7.7:1 kg of bycatch (largely finfish) to target species in control trawl nets in MSS. The largest proportions of finfish were comprised of Gulf menhaden, Atlantic butterfish (*Peprilus triacanthus*), Atlantic croaker and sand seatrout. Given that a high number of smaller sized fish were noted by Barros and Odell (1990) and the fact these species compose typical bycatch in fisheries, it is possible dolphins in MSS are taking advantage of discarded bycatch as an easy prey resource. The menhaden fishery is the largest fishery by volume in MSS (SEDAR 2013, Nance 1993). The menhaden and shrimp fisheries are most active in the warmer months (late April–November), which coincides with the increase in abundance of dolphins in MSS. Since dolphins are present in the MSS year round, it seems plausible that the summer increase in abundance observed is from seasonal visitors, most likely from the Northern Coastal Stock, moving in to exploit abundant food resources and fisheries bycatch. More research is needed to further elucidate the Summer population stock composition, and to what extent they could be adversely affected by several factors such as increased human interaction and mortality from moving into closer proximity to shoreline activities such as boating, fishing and pollutants.

Survey platform was also found to have a significant effect on dolphin abundance. Hubard (1998) suggested that the high speed of aircraft combined with turbidity in nearshore water probably affects the detectability of dolphin groups. Balmer (2007) also suggested that aerial surveys may not be the optimal survey strategy for bottlenose dolphins in St. Joseph Bay in Florida. In terms of repeatability and in order to detect long term trends, boat-based line-transect or capture-recapture surveys may be more optimal than aerial surveys in BSE environments.

4.3 Photographic Identification

The number of individual dolphins identified during the course of this study (*N* = 488) was similar to other studies in MSS, even though the time frames of the studies were different. Hubard *et al.* (2004) and Mackey (2010) identified 515 dolphins during 88 surveys and 678 dolphins during 129 surveys, respectively. McBride (2013) identified 862 dolphins but did not report number of surveys. All the surveys had a relatively high percentage of dolphins seen once (~65%), with the exception of McBride (42%), suggesting either a high prevalence of seasonal or one-time visitors to the MSS or that MSS has not been adequately surveyed to capture all the dolphins utilizing the BSE. The discovery curve of new individuals supported this, as it continued to climb throughout the course of the survey. This was not unexpected as the zones surveyed were very small compared to the size of MSS. Mackey (2010) plotted discovery curves for suspected visitors (i.e., seasonal residents and transients) and individuals seen year round over multiple years (i.e., year-round residents). The curves for the seasonal visitors and year-round residents did in fact level off, whereas as the curve for one-time visitors did not. Hubard *et al*. (2004) reported a discovery curve which continued to climb, again indicating either a high number of one-time visitors or inadequate survey area size relative to the range of the dolphins. While this may be the case, neither survey area covered the entire MSS, so animals may have been one-time visitors to the survey areas, but not necessarily to MSS. Where the visiting dolphins come from and to which stock they belong is unknown.

Detection of movement between the Inner-Sound (RI), Outer-Sound (HI and PBN) and Coastal (PBS) zones was limited in this study. Few dolphins were seen between the Inner-Sound and other zones, suggesting that movement between the mainland coast and barrier islands is infrequent. The majority of dolphins seen more than once used at least two zones, but a modest amount (35%) were only seen within one zone, which may suggest those zones represent some portion of their home range, or the area where the dolphin forages, finds mates and rears young (Burt 1943). A larger percentage (40%) used two zones, and these zones were typically adjacent; either Outer-Sound or Outer-Sound and Coastal zones. Mazzoil *et al.* (2008) also observed limited movement patterns between segments of Indian River Lagoon (IRL), a BSE on the Atlantic coast of Florida. A similar percentage of dolphins only used one segment (32%) and dolphins seen in 2−3 segments were typically adjacent segments (~75%). However, Mazzoil *et al.* (2008) surveyed the entire IRL BSE Stock, whereas this study surveyed

discrete zones that did not cover the entire MSLBBB Stock. Since only discrete zones were surveyed, it is difficult to make definitive conclusions about individual dolphin movement patterns throughout the MSLBBB Stock.

The most important finding related to management was movement of dolphins between the Outer-Sound zones (HI and PBN) and the Coastal zone (PBS) at a modest level (40%). The Outer-Sound zones are considered part of the NMFS MSLBBB Stock, whereas the Coastal zone is part of the GMx Northern Coastal Stock (Waring *et al.* 2016). Routine use of two different managements units by several individuals who could be year-round or repeated seasonal visitors may warrant a stock boundary revision. The south side of the barrier islands may need to be included in the MSLBBB Stock, since many dolphins appear to use both sides of the islands. Continued photo-ID surveys and comparison to other catalogs within the MSLBBB Stock may help to support these findings. Also, telemetry data from satellite tagged dolphins would provide further insight to spatial use of the MSLBBB and Northern Coastal stocks by dolphins.

Findings from this project support the Hubard *et al.* (2004) study on seasonal occurrence and movement patterns in MSS. Individual dolphins with higher sighting frequencies were sighted at the barrier islands (in this study referred to as Outer-Sound and Coastal zones). Hubard *et al.* (2004) also observed individuals re-sighted frequently in shipping channels and near the mainland coast (i.e., Inner-Sound zone). The current study did not survey shipping channels. Few animals were re-sighted in the Inner-sound zone (i.e., mainland coast), but that could be due to survey design. The Inner-Sound zone was relatively small, whereas Hubard *et al.* (2004) covered the entire mainland coast, roughly parallel to the west end of Horn Island to the east end of Petit Bois Island. Further evidence of long-term occurrence in MSS was also observed. Individual animals were re-sighted in the same zones across as many as 12 years. Several animals were sighted across multiple seasons within the timeframe, or were seen in multiple summers. Since some dolphins were seen in multiple consecutive seasons, it is likely that those dolphins reside in the MSS year-round. Only one animal was categorized as a truly seasonal visitor. It is difficult to draw conclusions on long term occurrence patterns in MSS due to the infrequency of surveys and the small sizes of the survey zones relative to the expanse of MSS.

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APPENDIX 1: EXAMPLE DORSAL FIN IMAGES

Appendix 1. Example dorsal fin images of individual dolphin number 6063 in Mississippi Sound Photographic Identification Catalog, Pascagoula, Mississippi. Images of 6063 are in chronological order by month and year in which the image was captured: a) August 2002, b) March 2003, c) July 2003, d) July 2004, e) July 2005, f) October 2006, g) July 2010, h) May 2011.

a)

b)

c)

d)

Appendix 1. Continued


e)


f)


g)


h)

APPENDIX 2: BOTTLENOSE DOLPHIN SIGHTING FORM

Appendix 2. Example sighting form used during bottlenose dolphin surveys is Mississippi Sound.

Sighting Form

Date: ____ / ____ / ______   Sighting: __________

Survey#: __________   Effort: ☐ ON ☐ OFF

Platform: __________   Time: ________ to ________

Crew:

Number: __________
Photographer: __________
Recorder: __________

Crew #1: __________   *Crew #4:* __________
Crew #2: __________   *Crew #5:* __________
Crew #3: __________

Sighting Location:

Location: ____________________________________

Boat WPT/Distance: ____________ / ____________
Latitude/Longitude: ____________ / ____________
Start WPT: ____________
End WPT/Distance: ____________ / ____________
Latitude/Longitude: ____________ / ____________

Sighting Conditions:

Animal(s) Heading: __________

Precipitation: ☐ None ☐ Rain ☐ Tstorm ☐ Snow
Cloud Cover: ☐ Clear ☐ PtCldy ☐ Overcast
Visibility: ☐ Clear ☐ Haze ☐ Fog
Sightability: ☐ Exc ☐ Good ☐ Fair ☐ Poor
Shrimp Boats: ☐ None ☐ Pr/NA ☐ Pr/A
Swell: ☐ 0-2ft ☐ 2-4ft ☐ 4-6ft ☐ >6ft

BSS: __________   *Salinity (‰):* __________
H_2O Temp(^oC): __________   *Depth (m):* __________

Field Estimates:

	Min	*Max*	*Best*
Total Dolphins:	______	______	______
Total Calves:	______	______	______
Total Neonates:	______	______	______

**NC:* ______

**number of dolphins previously sighted during survey*

Behaviors:

ST: ☐ Init ☐ Obs
FT: ☐ Init ☐ Obs
pFD: ☐ Init ☐ Obs
FD: ☐ Init ☐ Obs
SO: ☐ Init ☐ Obs
Oth: ☐ Init ☐ Obs

**describe other behaviors in sighting notes*

Observations:

Xenos: ☐ Single ☐ Multiple ☐ Not Obs
Shark Bites: ☐ Single ☐ Multiple ☐ Not Obs
Sucker Fish: ☐ Single ☐ Multiple ☐ Not Obs
SDO: ☐ Single ☐ Multiple ☐ Not Obs
Cohesiveness: ☐ <10 ☐ 11-50 ☐ 51-100

Oil in water: yes no CBD (if yes, describe)
Oil on shore : yes no CBD no view of shore

Photo/Video:

Camera: __________
Folder: __________
Start Frm: ______ *End Frm:* ______
Num Pics: __________
Camcorder: __________
Tape: __________
Start Ctr: ______ *End Ctr:* ______

Sighting Notes:

____
____
____
____

Mom/Calf Pairs

Mom Frm:________ **Mom Frm:**________ **Mom Frm:**________ **Mom Frm:**________ **Mom Frm:**________
Calf Frm:________ **Calf Frm:**________ **Calf Frm:**________ **Calf Frm:**________ **Calf Frm:**________

APPENDIX 3: DORSAL FIN ATTRIBUTE TABLE

Appendix 3. List of attributes assigned to dorsal fins using FinBase version 2.0. Adapted from Melancon *et al.* (2011).

Attribute	**Description**
Chopped fin	Missing ≥1/3 upper portion of dorsal fin
Apex	Mark in tip of dorsal fin
Lead	Mark in leading edge of dorsal fin
Peduncle scar/notch	Scar or mark on peduncle (tail stock)
Scar posterior to fin	Scar or mark just posterior to dorsal fin
Scar anterior to dorsal fin	Scar or mark just anterior to dorsal fin
Scar on head	NA
Upper fin notch	Mark is in upper third of dorsal fin
Middle fin notch	Mark is in middle third of dorsal fin
Lower fin notch	Mark is in lower third of dorsal fin
Bend	Dorsal fin with obvious bend to the right or left
Lasagna	Dorsal fin with a scalloped trailing edge (typically seen in young calves)
Fin shape	Fin with distinctive shape (e.g., very triangular)
Fin scar	NA
Skin disorder	Splotches of white or pink on the dorsal fin or body
Rake	Temporary mark; evenly spaced parallel scratches caused by teeth of conspecifics
Other	Other distinctive markings not listed
Marginally distinct	Fin that has only one or two very small marks; does NOT include poor quality images of usually distinct individuals
Non-distinct	No marks; does not permit matches across sightings

APPENDIX 4: INDIVIDUAL BOTTLENOSE DOLPHIN SIGHTINGS BY ZONE

Appendix 4. Catalog identification number (Catalog ID) and total number of individual bottlenose dolphin (*Tursiops truncatus*) sightings in each of the survey zones of Horn Island (HI), Petit Bois—north (PBN), Petit Bois—south (PBS) and Round Island (RI). Other refers to individual sightings that occurred outside of a designated survey zones.

Catalog ID	HI	PBN	PBS	RI	Other	Total No. of Sightings
1002				1		1
1003			2			2
1005		2				2
1016		1				1
1018		1				1
1037		1				1
1049			1			1
1052		2				2
1055	1	1	1			3
1056			2			2
1057			1			1
1058	2					2
1059	1					1
1060	1					1
1061	1	2	2			5
1062				2		2
1063	1			1		2
1064				1		1
1065			2			2
1066	1	1				2
1067				1		1
1068		2				2
1069		1				1
1072	1			1		2
1075			1			1
1076			1			1
1077	1		1			2
1078			1			1
1079	1					1
1083			1			1
2014		2	1			3
2016				1		1
2019	3		1			4
2020	3					3
2023		5				5
2025		5				5
2029		1				1
2032				1	1	2
2040		1	1			2

Appendix 4. Continued

Catalog ID	HI	PBN	PBS	RI	Other	Total No. of Sightings
2041		1	1			2
2043		2				2
2044				2		2
2049	1			1	1	3
2050	1					1
2052					1	1
2053	1		1			2
2062				1		1
2071		2				2
2074			1			1
2081		1				1
2083				1		1
2084		3				3
2091	1	2	1			4
2095		1				1
2096			1			1
2098	1					1
2103	1					1
2110	1					1
2111				4		4
2112			2			2
2116		2	1			3
2119			1			1
2124	1	1				2
2125			1			1
2127				3		3
2128		1	1			2
2129		2	1			3
2130	1	5				6
2131	3					3
2132			1			1
2133		2	1			3
2134		1				1
2136		2				2
2137		1				1
2138		1				1
2139	1					1
2141		1				1
2142				2		2
2143		1				1
2144		4				4
2146			1			1
2147				2		2
2149		1	1			2
2151		1				1

Appendix 4. Continued

Catalog ID	HI	PBN	PBS	RI	Other	Total No. of Sightings
2152				1		1
2153	2					2
2155	1					1
2156					1	1
2157	1					1
2158		1				1
2159		1	1			2
2160				1		1
2161			1			1
2162		1	2			3
2163			1			1
2164		1				1
2165				1		1
2166	1					1
2167	3		1			4
2168			1			1
2169				1		1
2171	1					1
2172	1					1
2174				1		1
2175				1		1
2176		1				1
2177		1				1
2178			2			2
2179		1				1
2180		1	1			2
2181			1			1
2182				1		1
2183					1	1
2184			1			1
2185			1			1
2186	1					1
2187		1	1			2
2188			1			1
2189	1					1
2190			1			1
2191			1			1
2192	1					1
2193				1		1
2194		2	1			3
2195				1		1
2196			1			1
2197				1		1
2198	1					1
2204	2					2

Appendix 4. Continued

Catalog ID	HI	PBN	PBS	RI	Other	Total No. of Sightings
2206			1			1
2212				1		1
2213			2			2
2239	1					1
2241	1					1
2243			1			1
3004	3		1			4
3005		2	2			4
3007	1					1
3011			1			1
3020			1			1
3021	3	1	1			5
3023	1	3	1			5
3024	3					3
3025			1			1
3026	3					3
3027					1	1
3028		2	1			3
3029		2	1			3
3030	1					1
3031				1		1
3032	3					3
3035	1					1
3036		1				1
3037	2		2			4
3038	1					1
3039	1	1				2
5000				1		1
5001	1					1
5002		1				1
5003			2			2
5004	1					1
5005			1			1
5006		1				1
5007	1					1
5008	1					1
5009			1			1
5010			1			1
5016			1			1
5017			1			1
6002		1				1
6024	1					1
6029				2	1	3
6032		5				5
6048		1				1

Catalog ID	HI	PBN	PBS	RI	Other	Total No. of Sightings
6056	1					1
6060				1		1
6063	1	4	1			6
6076			1			1
6077			1			1
6085		1				1
6088		1	1			2
6089			2			2
6091	3			1		4
6093		2	2			4
6094	1	1				2
6096				1		1
6097				1		1
6098			1			1
6099			1			1
6100	1	1				2
6101	2	1				3
6102	5				1	6
6103			2			2
6104	1					1
6105		2				2
6106	2					2
6107	3		2			5
6108	1					1
6109				1		1
6110	1					1
6111		2	1			3
6112		1	1			2
6113	1					1
6114				1		1
6115		1				1
6116		1				1
6117				3		3
6118	1					1
6119				1		1
6120					1	1
6121			1			1
6122	2					2
6123		1				1
6124				1		1
6125			1			1
6126				2		2
6127	1					1
6128	2					2
6129			1			1

Appendix 4. Continued

Catalog ID	HI	PBN	PBS	RI	Other	Total No. of Sightings
6130				1		1
6132	1					1
6133		1				1
6134	1					1
6135	1					1
6136	1					1
6137				1		1
6138	1					1
6139	1					1
6140	1					1
6141	2	1				3
6142			1			1
6143		1				1
6144	1					1
6145	1					1
6146			1			1
6148			1			1
6149		1				1
6150			1			1
6151	1		1			2
6152	2					2
6153			1			1
6154	1					1
6155	1					1
6156				1		1
6157	1					1
6158			1			1
6159	1					1
6160			1			1
6161				1		1
6162		1				1
6163	1					1
6164		2				2
6165	1					1
6166	2	1				3
6167			1			1
6169		2	1			3
6179				1		1
6184			1			1
6193			1			1
6198	1					1
6199	1					1
6200	1					1
7000			2			2
7003	1					1

Appendix 4. Continued

Catalog ID	HI	PBN	PBS	RI	Other	Total No. of Sightings
7010		1	2			3
7011		1				1
7017			1			1
7018		1				1
7024	1	1				2
7028				1		1
7047	1					1
7048				1	1	2
7049					1	1
7050					1	1
7058				3		3
7075			1			1
7083			1			1
7092		1	1			2
7093		1				1
7095				2		2
7097			1			1
7098				1		1
7100		1	1			2
7101		2				2
7103	1		1	1		3
7105		3				3
7106	1	1	2			4
7107		1	2			3
7108	6					6
7109		1				1
7110		3	3			6
7111			2			2
7113	3	1	1			5
7114					1	1
7115		1				1
7116	1	1				2
7117	1	1	2			4
7118		2				2
7119				1		1
7120	1					1
7122	1					1
7123	1					1
7124				2		2
7125	1					1
7126		2				2
7127				1		1
7128					1	1
7129	1					1
7130	2					2

Appendix 4. Continued

Catalog ID	HI	PBN	PBS	RI	Other	Total No. of Sightings
7132	1					1
7134		1	1			2
7137		2	1			3
7139		1				1
7140		1				1
7141		1	1			2
7143	1					1
7144				1		1
7145				1		1
7146	4					4
7147	2					2
7148			1			1
7149	2					2
7150				1		1
7152	1					1
7153				1		1
7154	1	1				2
7155	1		1			2
7156			1			1
7157	2					2
7158	1			1		2
7160			1			1
7161			2			2
7163			1			1
7164		2				2
7165	1		1			2
7166				1		1
7167			1			1
7168				1		1
7169	1		1			2
7170	1					1
7171		1				1
7173	1					1
7174	1					1
7175	1					1
7176			1			1
7177			2			2
7178	2					2
7179		1				1
7181		1				1
7182			1			1
7183		1				1
7184	1					1
7185	1					1
7187			1			1

Appendix 4. Continued

Catalog ID	HI	PBN	PBS	RI	Other	Total No. of Sightings
7188		1	1			2
7189	1					1
7191				1		1
7192			2			2
7194	2					2
7195	1					1
7197		1				1
7200				1		1
7201		2	1			3
7202			1			1
7204		2				2
7207				1		1
7222	1					1
7227			1			1
7228			1			1
7237	1					1
7238	1					1
7255			1			1
7256			1			1
8004	2					2
8018		3				3
8019	2					2
8022				1		1
8031			1			1
8033	1					1
8035		2				2
8037	1					1
8040		1				1
8046		6				6
8047				1		1
8049	4			1		5
8050	1	1				2
8051		1	1			2
8052	3				1	4
8053	2					2
8054	2		1			3
8055			1			1
8056		3				3
8057		2				2
8058		1				1
8059	2					2
8060	1					1
8061	1		2			3
8062		1				1
8063		2				2

Appendix 4. Continued

Catalog ID	HI	PBN	PBS	RI	Other	Total No. of Sightings
8065	2					2
8066	1					1
8067	3					3
8068	1					1
8069		4				4
8070	2		2			4
8071	1			1		2
8072	2					2
8073		1	2			3
8074			1			1
8075	1					1
8076	1					1
8077				1		1
8078	2					2
8080	1					1
8082	1					1
8083	1					1
8084	1					1
8085	2		1			3
8086	1					1
8087	1					1
8088	1			1		2
8089				1		1
8097			2			2
8100			1			1
8102			2			2
8106	1					1
12021			1			1
12022				1		1
12023		2				2
12024	1					1
12025				1		1
12026	1	1				2
12028					1	1
12029		2				2
12030	1					1
12031	3	1				4
12032	2			1		3
12035	1					1
12036	2					2
12037		1	1			2
12038			1			1
12039	4					4
12040				1		1
12041	1					1

Appendix 4. Continued

Catalog ID	HI	PBN	PBS	RI	Other	Total No. of Sightings
12042		1				1
12043		1				1
12044	1					1
12045		1				1
12050	2					2
12051	1					1
12052	1					1
12053	2					2
12054	1	1	2			4
12055	2					2
12056				1		1
12057				1		1
12058			1			1
12059			1			1
12060				1		1
12061	1					1
12062	1					1
12063				1		1
12064		1	1			2
12065		1				1
12066		1				1
12067	1					1
12073	1					1
12074			1			1
12095			1			1
12097	1					1
12101			1			1
20000	1					1
20001	1					1
20002	1					1
20003				1		1
20004			1			1
20005	1					1
20006	1					1
20007		1				1
20013	1					1
20014		1				1
20015	1					1
20016	1					1
20017	1					1
20018				1		1
20032			1			1
20033		1				1
20043			1			1

VITA

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