OCCURRENCE, DISTRIBUTION, AND MOVEMENT PATTERNS OF OUTER COASTLINE BOTTLENOSE DOLPHINS OFF GALVESTON ISLAND, TEXAS

A Thesis

by

AMY GWEN BEIER

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2001

Major Subject: Wildlife and Fisheries Sciences

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Approved as to style and content by:

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ABSTRACT

Occurrence, Distribution, and Movement Patterns of Outer Coastline Bottlenose Dolphins off Galveston Island, Texas. (August 2001)

Amy Gwen Beier, B.S., Southampton College

Chair of Advisory Committee: Dr. Bernd Würsig

Common bottlenose dolphins (*Tursiops truncatus*) are widely distributed throughout the Gulf of Mexico. Although several dolphin studies have focused on Galveston Bay, Texas, only one has included the adjacent Gulf of Mexico waters. The dolphins of the coastal Gulf of Mexico along Galveston Island were studied from June 1999 to July 2000, and results were compared with those of work dating as far back as 1990. Two techniques were used for observation; shore-based surveys from elevated structures, and boat-based surveys. Dolphins were sighted during all months and times of day, with no apparent peak of occurrence. More groups were sighted, and group size was significantly larger, when shrimp boats were present than when absent. Mean group size was 8.6, which is higher than that found in previous studies inside the bay. A total of 506 individual dolphins were identified, 85% of which were only sighted once. Several individual dolphins were resighted over a period of ten years. Resighted dolphins grouped roughly into four different areas of primary use. Individuals showed greater fidelity to their primary areas than to others, but boundaries were not well defined. The low site fidelity exhibited by dolphins along the outer coast suggests that this is not an area of primary use, but rather an area of overlap of outlying dolphin ranges. The animals may inhabit areas of greater prey distribution in inlet areas, but utilize areas of lower prey abundance for other activities not possible in the bay, such as surfing. While some dolphins appear to show fidelity to the Galveston area, others passed through the study area. These latter dolphins may follow shrimp boats along the coast, easily obtaining prey associated with the boats. The information gathered during this study represents the first detailed description of dolphins of the outer Galveston coast. The population of dolphins is an open one, with some dolphins in the area at all times of year. It is also greatly affected by the shrimp fishery. Due to the high level of human activities, the Galveston area has potential for researchers to use dolphins as long-term indicators of ecosystem change.

DEDICATION

I dedicate this thesis in memory of Uncle Dave. He was always supportive of my education, and he is always in my thoughts.

ACKNOWLEDGEMENTS

First of all, I thank my committee members, Bernd Würsig, Doug Slack, and Don Harper for all of their patience and advice. May I never write a "Germanic" sentence again. Thank you Bernd for the opportunities, beginning back to what seems like an eternity ago, when I was a bright-eyed intern with NO idea of the life I was about to begin. Thank you also for your friendship, support, and a million laughs - here's hoping there are many more to come.

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Thanks to the management and staff of the Galvestonian Condominium, Flagship Hotel, San Luis Resort, Coldwell Banker, and Riviera for allowing me access to the roof-top. I miss the friendly faces and daily updates on the dolphins' whereabouts.

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CHAPTER I
INTRODUCTION

Bottlenose dolphins (*Tursiops* sp.) represent one of the most commonly sighted and studied cetaceans (Shane *et al.* 1986, Connor *et al.* 2000). Their widespread distribution contributes to a high level of interaction with humans, both directly via ecotourism and fisheries, and indirectly by habitat alteration and degradation. This species has both a coastal and offshore form in many areas (Curry 1997, Hoelzel 1998), and the coastal form has been studied more intensively. Of the numerous studies conducted on various wild bottlenose dolphin populations, three stand out due to their long-term data collection and will be reviewed briefly: Sarasota Bay, Florida; Shark Bay, Australia; and the San Diego coast, California (Wells 1986, Scott *et al.* 1990, Wells 1991, Connor *et al.* 1992, Smolker *et al.* 1992, Hanson and Defran 1993, Defran and Weller 1999).

Sarasota Bay

Wells and his colleagues (Scott *et al.* 1990, Wells 1991) have been studying the common bottlenose dolphin (*T. truncatus*) of the Sarasota area for more than 30 years. The dolphins occupying this area are referred to as a "community", composed of approximately 100 individuals that do not often leave the area or associate with dolphins from neighboring areas (Scott *et al.* 1990, Wells 1991, Connor *et al.* 2000). The home range described for the "community", approximately 125 km^2 in size, encompasses a series of small bays and coastal Gulf of Mexico waters out to 1 km from shore. The shallow waters of this area provide extensive sea grass beds, frequented by females with calves, presumably for high prey availability and protection from predators

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This thesis follows the style and format of Marine Mammal Science.

such as sharks. Sharks may be an important influence on these dolphins; studies show 30% of individuals have been seen with scars indicative of shark bites (Reynolds *et al.* 2000). Yearly captures provide sex, age, and genetic information, which allow the description of habitat use by individuals of specific age- and sex-classes, as well as relatedness between individuals. It has been shown that females show great site fidelity to different smaller core areas within the Sarasota study area while adult males travel throughout. Sub-adult males tend to stay along the edges of the southern half of the area. Seasonal shifts in distribution also occur, with dolphins moving to the deeper channels and Gulf of Mexico waters more often in colder months.

Shark Bay

Research began in 1982 on seven individual Indian Ocean bottlenose dolphins, *T. aduncus*, which were "provisioned", or hand-fed by humans close to shore at Monkey Mia Park, Australia (Connor and Smolker 1985). Connor, Smolker, Richards, Mann, and colleagues (Connor *et al.* 1992, Smolker *et al.* 1992, Connor *et al.* 1996, Connor *et al.* 2000) have since conducted numerous behavioral studies within Shark bay. The dolphins in this study area, approximately 250-300 km^2, showed less partitioning of space than those of Sarasota Bay. Close to 400 individuals were identified, with no apparent home range boundaries. Although the researchers do not describe site fidelity or habitat use, they do present data from several individual dolphins that are resighted quite frequently, and therefore some individuals may exhibit a high level of site fidelity. Association patterns are shown to be high for individuals of the same sex, and all-male groups "kidnap" females for mating; this has been the topic of a series of investigations (Connor *et al.* 1992, Connor 1995, Connor and Smolker 1996, Connor *et al.* 1999, Connor 2000).

San Diego

The San Diego coastline provides a distinctly different habitat for common bottlenose dolphins than that of Sarasota and Shark Bay. The coastline is a mix of rocky reef, sandy shore, and estuary mouth (Hanson and Defrán 1993). Kelp beds begin approximately 0.5 km from shore, and the depth gradient is much steeper than in the bays. Boat-based photo-identification studies began in 1981, leading to cliff-based behavioral observational studies (Simonaitis 1991, Hanson and Defran 1993, Tepper 1996). Dolphins utilized the area within 1 km of shore, and mostly within only 0.5 km. Just over 400 individuals have been identified, and they have shown much lower site fidelity than in the other areas studied; many individuals first identified in San Diego were sighted in separate "secondary" study areas, resulting in a range of up to 470 km (Defran *et al.* 1999). Defran *et al.* (1999) speculate that the need to search for patchy prey sources may cause the animals to move up and down the coastline in search of food.

Additional Studies

Many additional studies have been important to the knowledge gained on bottlenose dolphins. Würsig and Würsig (1979) spent 21 months studying the common bottlenose dolphins in Golfo San José, Argentina. They were one of the first teams to implement the use of photographic identification, paving the way for future research (Würsig and Würsig 1977, Würsig and Würsig 1979, Würsig and Jefferson 1990). Several studies have noted a wide variety of prey, and many highly adapted feeding strategies (Gunter 1942, Leatherwood 1975, Würsig and Würsig 1977, Shane 1980, Leatherwood and Reeves 1983a, Shane 1987, Wells *et al.* 1987, Barros and Odell 1990, Würsig and Harris 1990, Ballance 1990,1992, Hanson and Defran 1993, Jefferson *et al.* 1993, Fertl 1994). The study conducted by Lisa Ballance (1992) in the Gulf of California suggests that common bottlenose dolphins there utilize estuary mouths for feeding. Ballance (1990) also supported previous findings that dolphins often feed in the morning and late afternoon hours, when many species of fish are making their daily movements (Saayman *et al.* 1973, Shane *et al.* 1986). There are also striking differences in behavioral modes among populations, pointed out by Shane *et al.* (1986). These differences demonstrate the need for different strategies to feed on different prey items and to survive in different habitat types.

Although the studies mentioned have made vast improvements in the knowledge of bottlenose dolphins, there is still much unknown. More long-term research on dolphins inhabiting a variety of habitat-types (various combinations of depth, steepness of drop-off, level of enclosure, presence of vegetation, presence of structure, and bottom composition) is necessary to investigate all hypotheses of bottlenose dolphin habitat use, social structure, and occurrence patterns. While photo-identification is an important tool used in the majority of the studies mentioned here, behavioral observations (Altmann 1974), stranding data (Barros and Odell 1990), radio and satellite tracking (Mate and Harvey 1983, Würsig *et al.* 1991), and genetics (Duffield and Wells 1987, Curry 1997), are invaluable tools that must be used together to obtain more useful information on dolphins.

Texas Coast

Common bottlenose dolphins are the most common cetacean species found along the Texas coast (Gunter 1942, Schmidly and Shane 1978, Leatherwood and Reeves 1983b). Figure 1 shows the locations of studies conducted on various populations (Shane 1977, Gruber 1981, Shane 1987, Jones 1988, McHugh 1989, Henningsen 1991, Fertl 1994, Bräger *et al.* 1994, Maze 1997); none, however, have lasted longer than 26 months. The Galveston Bay system consists of four major related bays and some smaller connected bays. There are two major areas of freshwater input, various channel systems, and three tidal inlets to the Gulf of Mexico (Figure 2; Wermund *et al.* 1989). The

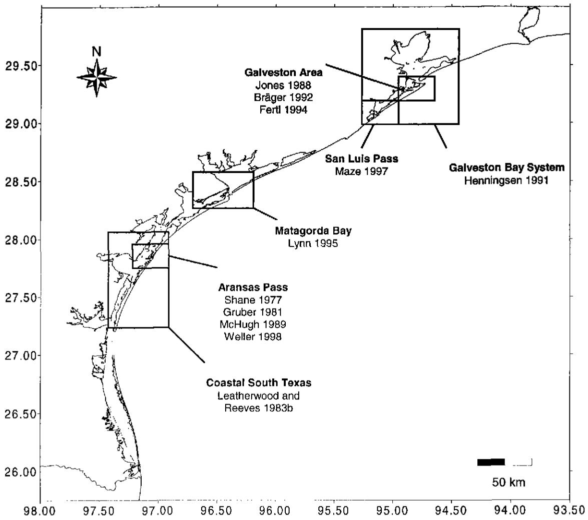

Figure 1. The Texas coast, with sites of previous studies outlined. Boxes do not outline the exact study areas and do not refer to the exact size of study areas.

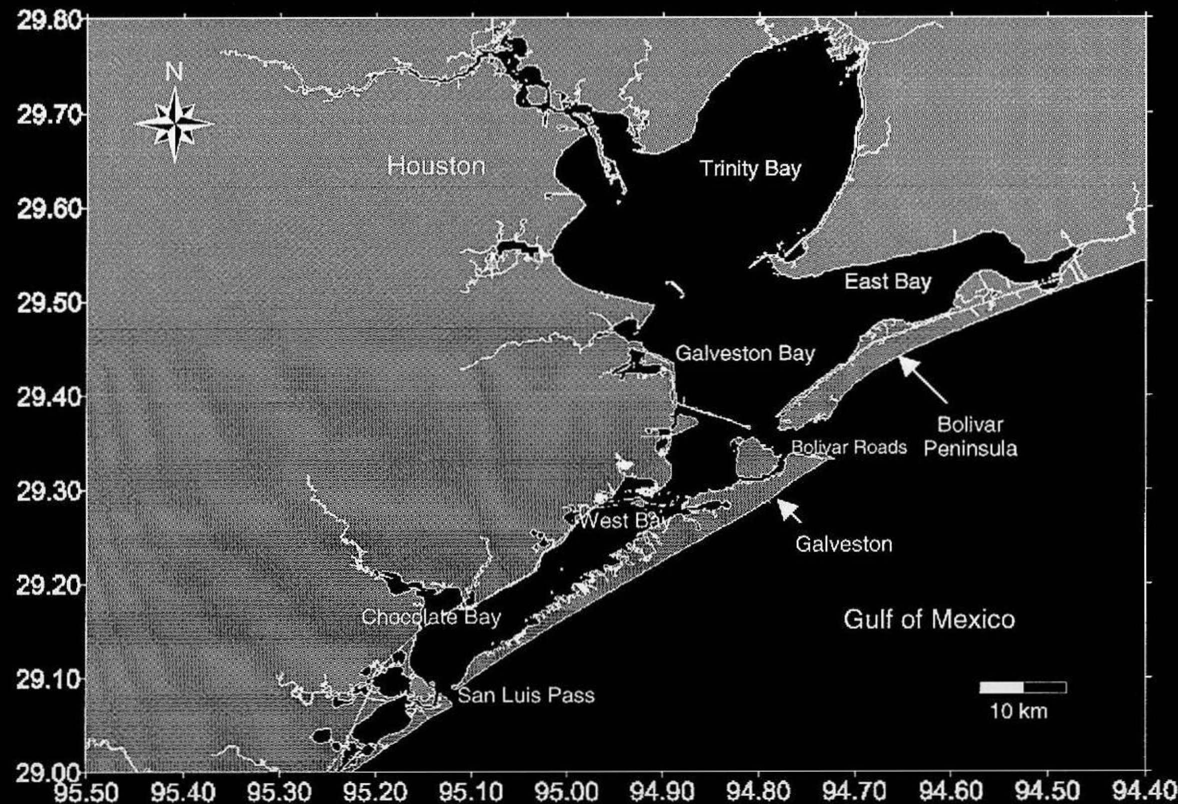

Figure 2. The Galveston Bay system.

bay system is shallow, with a maximum natural depth of approximately 3.6 m, excluding dredged channels of the Houston Ship Channel, Galveston Ship Channel, and Intra-Coastal Waterway. Bottom composition is mostly mud, with oyster reefs throughout, and sparse sea grass beds in the southwestern-most areas (Wermund *et al.* 1989). The port of Houston is listed as the third largest seaport in the lower 48 states, and is responsible for almost half of the U.S. chemical production (Ditton *et al.* 1989).

Bottlenose dolphins are occasionally found in all sections of the Galveston system, but occur most frequently in areas surrounding the bay inlet (Jones 1988). Jones (1988) was first to describe the dolphins in the lower Galveston Bay, Galveston Ship Channel, and Bolivar Roads area by using boat surveys and observing the nearshore Gulf of Mexico along the northeast end of Galveston Island from the beach. Henningsen (1991) used photo-identification to identify 1002 individuals in the entire Galveston area (see Figure 1). Results from Henningsen supported Jones' report of an increase of dolphin density in the area during spring. Bräger (1992) continued photo-identification, examining association patterns between individuals, which were shown to be weak, supporting the documentation of the fission-fusion structure exhibited by bottlenose dolphins in this area (Bräger *et al.* 1994, Maze 1997). Fission-fusion, as related to dolphin social structure, is exhibited when dolphin groups form and break apart often; usually on an hourly to daily basis (Würsig and Würsig 1977, Würsig 1978, Wells 1986, Shane 1987, Wells *et al.* 1987, Ballance 1990, Würsig and Harris 1990, Weller 1991, Smolker *et al.* 1992). The association of dolphins with the shrimp fishery was examined by Fertl (1994). Maze (1997) studied a group of resident dolphins in the San Luis Pass area. Irwin-Smith and Würsig (in prep.) have continued work on the dolphins of the San Luis Pass area.

The studies previously conducted in the Galveston area have greatly increased the knowledge of occurrence and distribution of these populations. All have included only the Galveston Bay system and the San Luis Pass area, with study areas extending partially into the Gulf near the bay inlets (Jones 1988, Fertl 1994, Maze 1997), with the exception of Henningsen (1991). While Henningsen's (1991) study extended into the Gulf of Mexico, there was not an equal effort to survey the Gulf as frequently as some portions of lower Galveston Bay. Henningsen concluded, however, that larger groups were sighted more often in the Gulf of Mexico than in Galveston Bay. Maze (1997) identified 71 individuals in San Luis Pass. Three of these were resighted in Galveston Bay, suggesting the possibility that these "sub areas" do not act as discrete population ranges. The Gulf of Mexico waters are likely an important part of the habitat for the Galveston area dolphins, and should therefore be considered when attempting a complete description of the dolphins of the Galveston area.

Bottom composition of the Gulf of Mexico waters adjacent to Galveston is sand with some silt (Williams 1951, Stetson 1953), with various man-made structures (jetties and fishing piers) along the northeast half of the island. The continental shelf extends past the coast, sloping gradually at approximately 2.25 m per km (Williams 1951).

This study was designed to: 1) determine occurrence patterns and group size of bottlenose dolphins of the Gulf of Mexico along Galveston Island, and 2) gather information on site fidelity, habitat use, and the level of fluidity of individual dolphins in this area. This is the first detailed assessment of the dolphins occupying this area. By extending the study area from past studies, the "overall picture" of dolphin occurrence and habitat preference of the entire Galveston area can be obtained, and thereby contribute to long-term research and management strategies in the Galveston area. Ballance (1990) suggested that differences in site fidelity are possibly related to differences in habitat. By comparing different habitats within this study area and between this and other research sites, these patterns may begin to emerge.

Bottlenose dolphins are top predators of the marine environment. The study of these animals can reveal aspects of their health and survival, which can be a partial indicator of ecosystem health (Irwin-Smith and Würsig in prep.). Galveston Bay experiences high vessel-traffic due to heavy industrialization by the petroleum and chemical companies located along the shore, the ports of Houston and Galveston, and recreational activities (Irwin-Smith and Würsig in prep.). Comparisons of this area to those less affected by humans can provide valuable information on human impact. It is important to gather baseline information on behavior and habitat use patterns so that researchers can better understand the effects of any future anthropogenic factors on the dolphins and other components of the marine ecosystem.

CHAPTER II
OCCURRENCE, DISTRIBUTION, AND GROUP SIZE

Introduction

Common bottlenose dolphins are the most common cetacean species sighted in Texas coastal waters (Gunter 1942, Schmidly and Shane 1978, Leatherwood and Reeves 1983). Many studies have been conducted on various populations in Texas bays (Shane 1977, Gruber 1981, Shane 1987, Jones 1988, McHugh 1989, Henningsen 1991, Bräger *et al.* 1994, Fertl 1994, Maze 1997) (see Figure 1 of chapter I), and some aerial census surveys have been conducted in coastal Gulf of Mexico waters (Leatherwood 1975, Leatherwood and Reeves 1983, Mullin 1988, Mullin *et al.* 1990).

Bottlenose dolphins occur throughout the entire Galveston Bay system, although they have been shown concentrate in specific areas (Jones 1988). Previous research conducted in the Galveston area has primarily included areas of Galveston Bay such as the inlets and ship channels, with study areas extending into nearby Gulf waters, rather than along the entire length of Galveston Island (Jones 1988, Fertl 1994, Maze 1997). While Henningsen's (1991) study did extend into the Gulf of Mexico, the Gulf was not surveyed as frequently as some portions of lower Galveston Bay. The Gulf of Mexico waters are likely an important part of the habitat for these dolphins, and should therefore be considered when attempting a complete description of the dolphins of the Galveston area.

Baseline studies on top predators, such as dolphins, are useful as indicators of ecosystem health (O'Shea *et al.* 1999). Comparisons of the highly industrialized Galveston estuarine system to those less affected by humans can give valuable information on human impact (Irwin-Smith and Würsig in prep.).

Materials and Methods

Study Area

This study covers the waters along the entire length of the island out to three km from shore (Figure 3). The nearshore area is relatively shallow; as the bottom has a very gentle (2.25m/km) (Williams 1951) slope. The greatest depth recorded when a group of dolphins was present was 17 m (excluding depth recorded in the dredged areas of Bolivar Roads at the far northeast end of the island). Bottom composition is mainly sandy bottom with some silt (Williams 1951, Stetson 1953). Various man-made structures (jetties and fishing piers) have been constructed along the northeast half of the island.

Data for this study were collected from June 1999 to July 2000. Two methods of data collection were implemented; shore-based surveys and boat-based surveys. Due to the shallow water and differing amounts of precipitation, salinity fluctuated, ranging between 26 ‰ in July 1999 and 39 ‰ in July 2000. Sea surface temperature ranged from 11.4 ºC in February 2000 to 36.9 ºC in July 2000.

Shore-Based Surveys

Shore-based surveys were conducted from the rooftops of 5 buildings located on or near the Galveston Island shoreline (Figure 3). The observation points were chosen to slightly overlap fields of view. There were no suitable observation points along the southwestern half of the island, therefore, only the northeastern half was covered during shore-based surveys. The heights of the observation points varied from 6 to 54 m (Figure 3). Although Coldwell was substantially shorter (at 6 m) than the other observation points, observers were able to clearly see to the three km boundary, and the area beyond three km from shore was not surveyed from the other buildings. Surveys alternated starting points between the observation points that were furthest northeast or southwest. One to three observers surveyed the area with 10-15x binoculars for a minimum

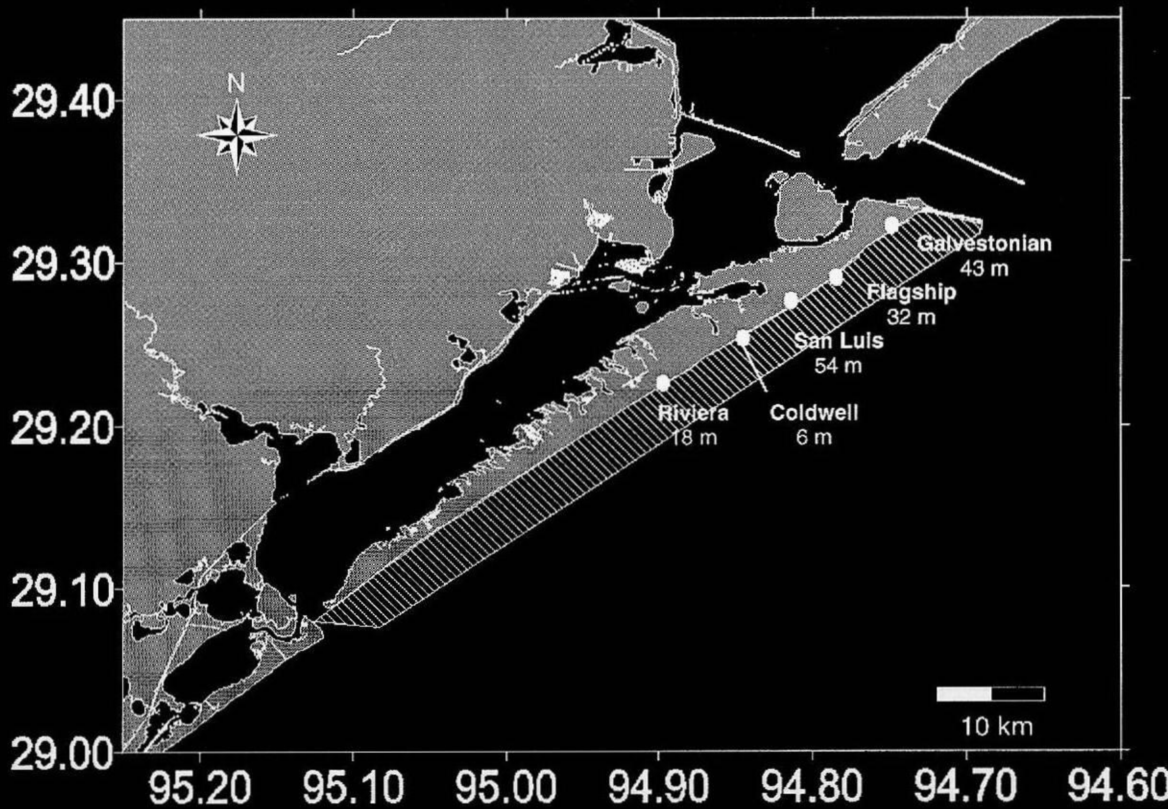

Figure 3. Galveston Island, with observation point locations and heights. Lined area indicates the approximate study area.

of 1 hour without sighting dolphins before moving to the next building (excluding unsuitable weather conditions). Once dolphins were sighted, distances from shore were estimated by comparison to stationary reference points of known distances. A group was defined as any aggregation of dolphins moving in the same general direction and engaged in similar activities (Shane 1990, Weller 1998, Karczmarski *et al.* 1999). The location of the group with respect to the observer was recorded, as well as estimated group size, observation point, date, time, sea state, and tidal state for each sighting. Presence of calves or neonates was also noted. An individual was classified as a calf if it's body length was less than two-thirds of an adult, and was associating closely with another individual. A neonate was classified as being less than half the length of an adult, also associating very tightly with an adult, and sometimes by dark coloration, presence of fetal folds, or uncoordinated surfacing (Fertl 1994). Although calves could often be identified from the shore-based surveys, and their presence was recorded, calf designations from shore were excluded from the analysis to avoid any bias that resulted from an increased ability to distinguish between age classes of groups closer to shore. Observations of each group continued until the group of animals was out of sight. Observers continued to survey by driving to the next observation point until all points had been surveyed, or conditions would not allow additional survey time. Survey times were dependent upon access to the rooftops of the observation points, which was often at the discretion of the personnel of the building.

Boat-Based Surveys

Boat-based data were collected from a 5.5 m Boston Whaler equipped with a 50 hp outboard motor and a 5.7 m Carolina Skiff equipped with a 60 hp outboard motor. Surveys began at the northeast end of the island, and ran to the southwest. A track parallel to shore was maintained at a pre-specified distance from shore to maximize coverage, based on weather conditions, until a group was sighted. Each day's survey consisted of two tracks, one closest to the shoreline, and the other further out, again to optimize coverage. These tracks alternated between starting closer to shore and returning further, and starting further from shore and returning closer, and were maintained and tracked using a Garmin GPS 45. When a group was sighted along the track, the boat carefully approached and followed them long enough to attempt to photograph each individual, provided the dolphins did not show signs of disturbance. Disturbance is defined as avoidance of the research vessel or any other agonistic behavior such as tail slapping or forceful exhalations (chuffing) that appears to be a result of the vessel's presence (Weaver 1987, Maze 1997). Photographs were taken with a Nikon F100 camera equipped with a 100-300 mm lens and Kodak Tmax 400 black and white film. Data recorded were the same as those recorded during shore-based surveys, with the addition of water depth and sea surface temperature. Locations recorded were exact coordinates from a GPS.

Photo-identification uses nicks and notches on the trailing edge of a dolphin's dorsal fin to distinguish between individuals (Würsig and Würsig 1977, Würsig and Jefferson 1990). The trailing edge is rather thin, and tears or tatters easily, resulting in a pattern unique to that individual. Developed photos were sorted and examined for quality, judged by criteria of focus and angle. Only acceptable negatives (deemed 'good-quality') were then used for further analysis. Photo-identification analysis followed the methods of Defran *et al.* (1990), with the exception of using Microsoft Office Access for maintenance and analysis of the data set.

Statistical Analysis

All statistical analyses were carried out using STATISTICA software, version 4.1. Each day is considered a sampling unit for these analyses, therefore calculated sample size differs for each test based on the number of categories occurring in each day surveyed. Parametric Analysis of Variance and t-tests or nonparametric Kruskal-Wallis ANOVA and Mann-Whitney U statistical tests were assigned for a comparison of means (Zar 1996). Tests for the assumptions of normality and equal variances were conducted using the Kolomogorov-Smirnov test and Levene's test, respectively (STATISTICA, version 4.1; Zar 1996). Contingency tables were examined using Pearson's chi-square test. A significance level of 5% was used.

Results

Effort

Fifty-four shore-based surveys were conducted from 09 June 1999 to 29 May 2000, resulting in 235 hours of effort. A total of 162 groups of dolphins were encountered during 38 of those surveys (70%). Thirty-seven boat-based surveys were conducted from 24 July 1999 to 14 July 2000. On-effort totaled 261 hours and 149 groups were encountered during 35 of those surveys (95%). Groups occurring in the Galveston and Houston Ship Channels encountered en route to the study site were not included in the further analysis.

Occurrence Patterns

In order to correct for effort, occurrence was calculated as number of groups divided by hours surveyed within each category of variable being tested. While all groups encountered in the study area are described, groups seen in the presence of shrimp boats were removed from statistical analysis to avoid the potential human influence on the dolphins' occurrence patterns. Boat-based data were used for statistical testing in all cases, excluding tests investigating differences of occurrence for location, sea state, tide, and presence of shrimp boats. More detailed data regarding hours surveyed in each category were taken from shore-based surveys, allowing the effort calculation.

Survey days were broken into four seasons, in which summer was classified as June through August, fall as September through November, winter as December through February, and spring as March through May. Although the use of four seasons may not directly correspond with important oceanographic and climatic processes in the Gulf of Mexico which likely affect the occurrence and distribution of the dolphins and/or their prey (Hsu 1999), the correct classification of seasons is unclear and occasionally disputed. Therefore, four seasons were used, and this also allows a better comparison to previous studies. Dolphin groups were encountered across all seasons; 125 in summer, 82 in fall, 58 in winter, and 46 in spring (Figure 4). Figure 5 shows mean occurrence separated by season, Analysis of Variance (ANOVA) shows the differences to be non-significant at $p>0.05$. Distribution of dolphin groups throughout the daytime was investigated by separating daylight hours into three categories; 0600-1000=morning, 1000-1400=mid-day, and 1400-1800=afternoon. A Kruskal-Wallis ANOVA shows these corrected mean values, presented in Figure 6, as being significantly different ($p=0.0086$); posthoc comparison of means using a Newman-Keuls tests shows the groups per hour effort for the morning and mid-day time periods being greater than the afternoon. Further analyses using Kruskal-Wallis ANOVA's were conducted to test for interaction between season and time of day, resulting in a higher corrected mean occurrence value during afternoon of the fall season over the afternoon during the other three seasons ($p=0.0487$); and occurrence during the summer for morning and mid-day was higher than the afternoon ($p=0.0042$).

The location of all group sightings are shown in Figure 7. Figure 8 shows the occurrence of groups at each observation point is not statistically different (Kruskal-Wallis ANOVA, $p>0.05$), and further testing for the interaction between observation point and season, land observation point and time of day resulted in no significant differences.

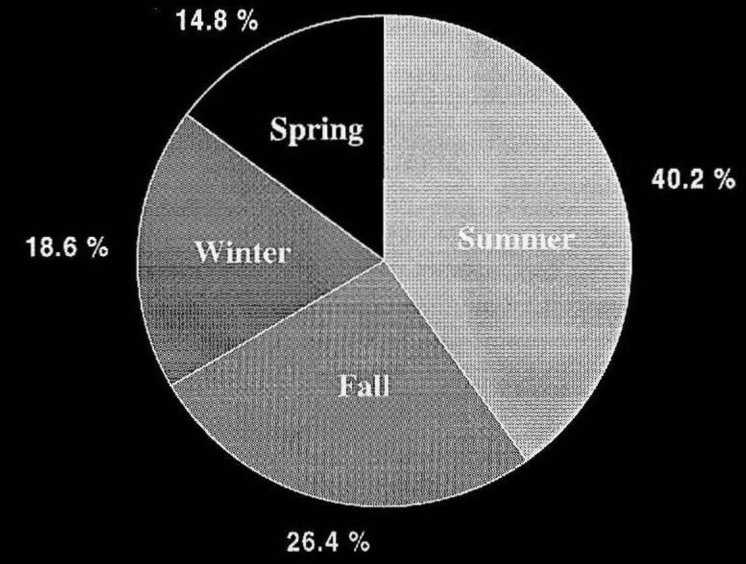

Figure 4. The percentage of groups seen in each season.

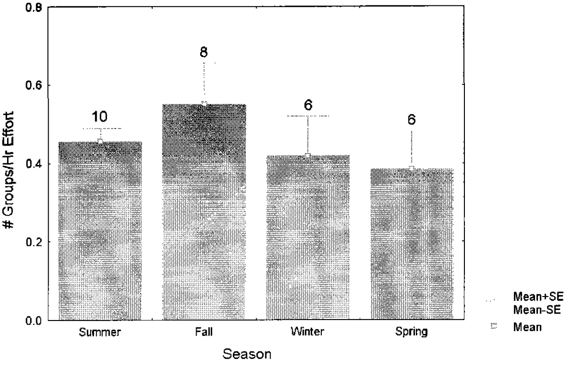

Figure 5. Seasonal occurrence of dolphin groups in the study area. Number of days surveyed within each category is represented above the error bars.

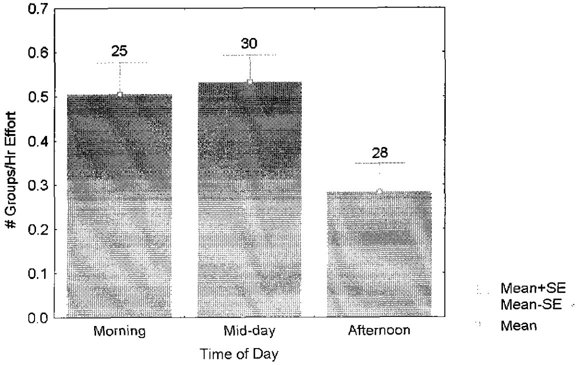

Figure 6. Daytime distribution of occurrence. Data as in Figure 5.

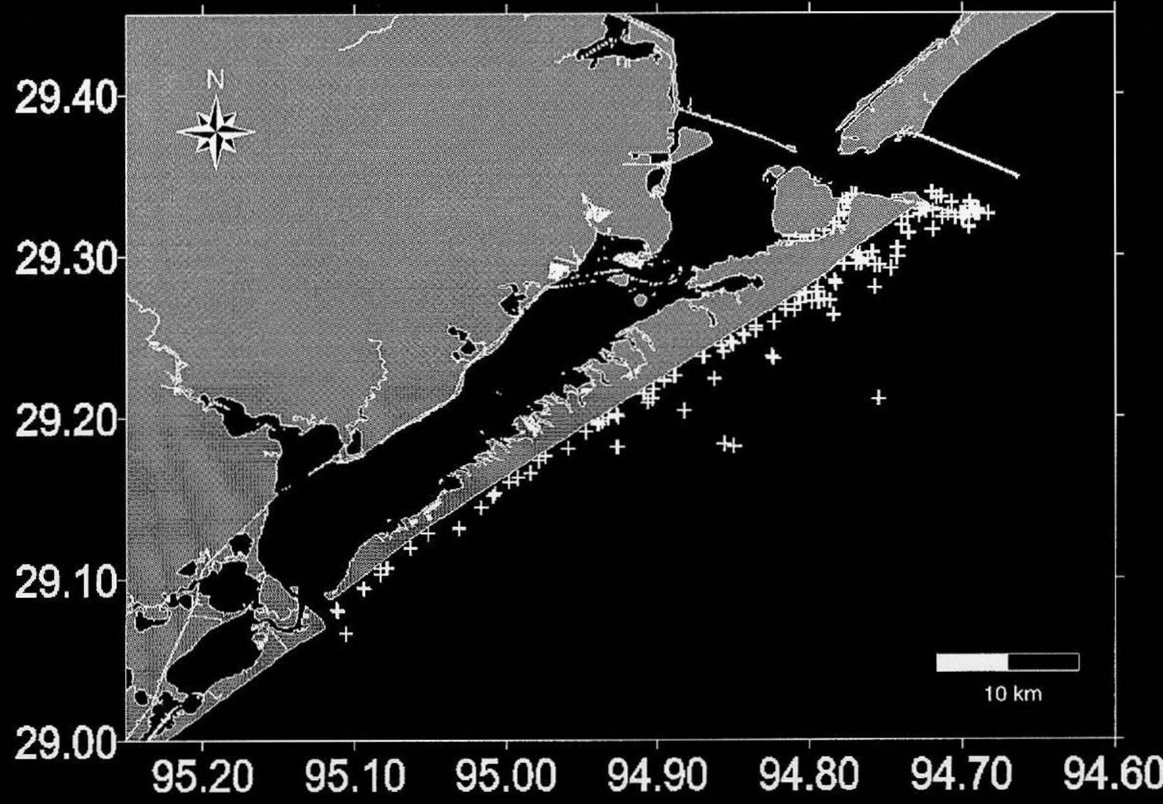

Figure 7. Location of group sightings from boat-based surveys. Crosses represent first sighting of each group.

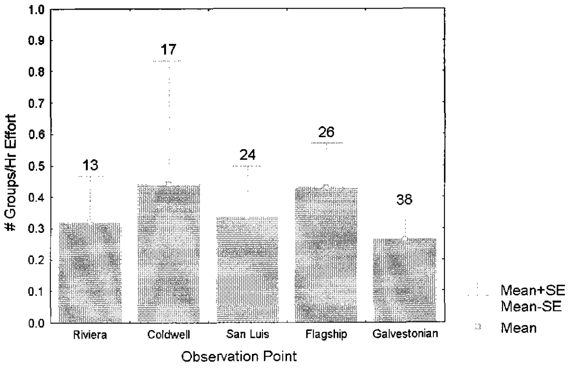

Figure 8. Occurrence compared between locations. Data as in Figure 5.

Occurrence was investigated using the environmental parameters of tidal state, sea state, and depth. All environmental parameters were found to have no effect on dolphin occurrence ($p>0.05$, Kruskal-Wallis ANOVA).

Group Size

Group size estimates were used only for boat-based data, as shore-based group size estimates appeared to be biased toward groups associating with shrimp boats. Since those groups associating with shrimp boats were larger (shown below), group size estimation was likely positively biased and therefore excluded from analysis. The estimated group size of all groups encountered during this study ranged from 1 to 75 individuals (Figure 9), with a mean of 8.6 (SE = 0.79, n=149) and a median of 6.0. Group size was generally small; approximately 46% of all groups included five or fewer individuals, and close to 75% had ten or less. Groups of 25 or more individuals were only sighted in association with shrimp boats. When groups encountered while shrimp boats were in the area were removed, group size ranged from 1 to 24 (Figure 10), with a mean of 6.7 (SE = 0.52, n=115) and a median of 5.0. Estimated group size was averaged for each day within all categories before analysis to reduce bias in results toward a day when more dolphin groups were sighted. Figure 11 shows that mean group size did not change according to changes in season (ANOVA, $p=0.5166$). No differences were found between group sizes during the three time periods, and there was no interaction between time of day and season (Kruskal-Wallis ANOVA, $p>0.05$). Mean group size was also examined for differences among environmental parameters but none of the variation was found significant at the $p<0.05$ level (Kruskal-Wallis ANOVA and ANOVA).

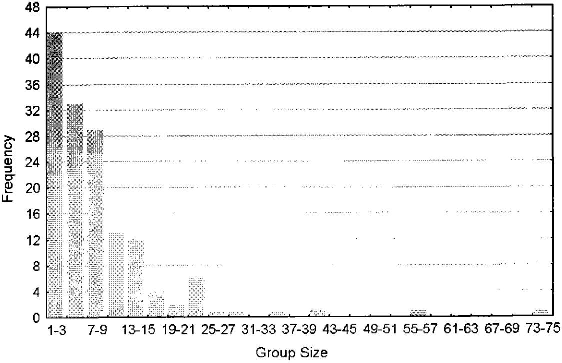

Figure 9. Distribution of group size of all groups sighted during the study.

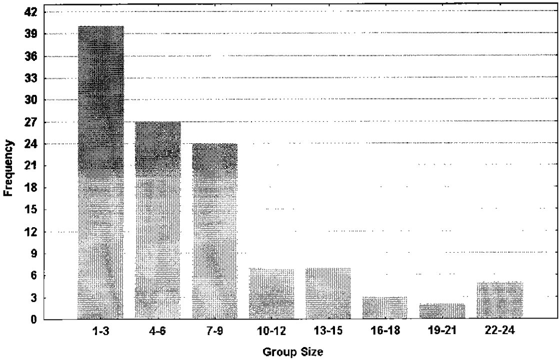

Figure 10. Distribution of group size for groups sighted in the absence of shrimp boats.

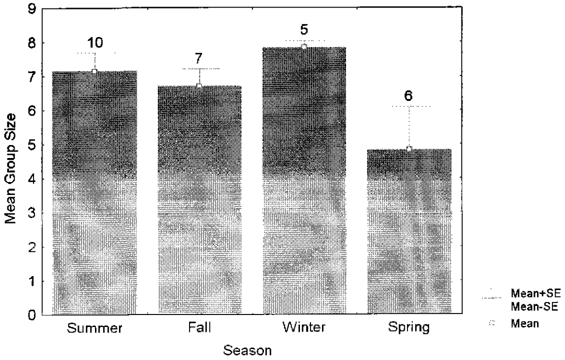

Figure 11. Seasonal distribution of mean group size. Number of days of surveys within each season is represented above the error bars.

Photo-identification

Good-quality photographs were taken of 768 dolphins, and 535 individuals were identified. Of the 535 individuals identified, 29 were only sighted in the channels outside of the study area and were excluded from additional analysis, leaving 506 individual dolphins identified in the Gulf of Mexico waters during the study. Seventy-seven of the identified dolphins, or approximately 15%, were sighted on more than one day. Fifty-seven of the dolphins were seen on two different days (11%), fourteen on three (3%), and only six (1%) on four different survey days. The discovery curve is shown in Figure 12, which shows a high flux of new individuals in most surveys.

Calves and Neonates

Of the 1449 dolphins encountered on the boat-based surveys, 90 individuals were classified as calves and 6 as neonates, 6 and 0.04% of the population, respectively. Calves were observed in 57 of the 149 groups sighted throughout the year (38% of all groups), while neonates were sighted in 5 of the 149 (3%) groups in the months of April, May, and July. Since the number of neonates was so small, they were grouped with the calves for further analysis. Mean group size was found to be larger when calves were present than for those without calves (Mann-Whitney U test, $p<0.0001$).

Influence of Shrimp Boats

Shrimp boats were sighted in the study area on 53.8% of all survey days. Thirty-six percent of all groups (112) observed in this study were feeding in association with shrimp boats. Occurrence, corrected for hours of effort, was significantly greater when shrimp boats were present (Mann-Whitney U, $p<0.0001$, Figure 13), and mean group size was significantly greater when shrimp boats were present (Mann-Whitney U, $p<0.001$, Figure 14). Mean group

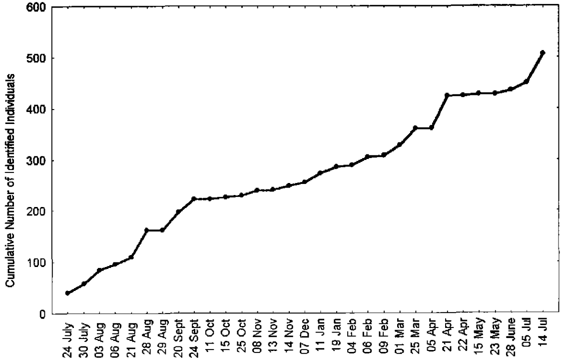

Figure 12. Discovery curve of cumulative number of identified individuals for each survey conducted.

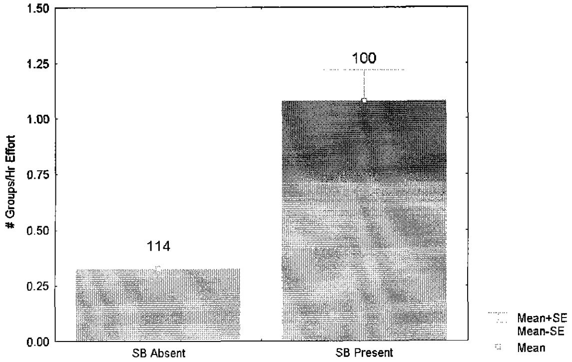

Figure 13. Occurrence of groups and shrimp boat presence. Number of observation points surveyed totaled for all days are represented above error bars.

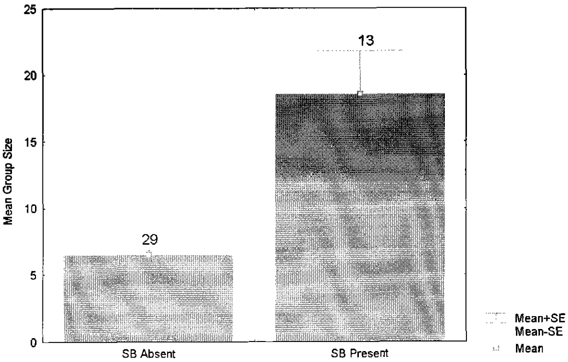

Figure 14. Mean group size and shrimp boat presence. Number of days surveyed within each category is represented above the error bars.

size was 18.5 (SE=5.06, n=13) when shrimpers were present and 6.54 (SE=0.67, n=29) when no shrimp boats were in the area.

Calves or neonates were present in 61% of all groups observed in the presence of shrimp boats (19 of the 31 groups, as observed during boat surveys). Those groups with calves in the presence of shrimp boats comprised approximately 32% of groups seen with calves or neonates during this study, when only 21% of all groups with or without calves were seen in the presence of shrimpers. The frequency of sightings of groups with calves or neonates in association with shrimpers was found to be significantly different than the expected distribution at $p<0.01$ (Pearson's Chi-square).

Discussion

Dolphin groups were encountered across all seasons and during all daytime periods. Although more groups were sighted in the summer, there was no statistically significant peak season of occurrence when examining corrected values. Fewer dolphin groups were seen in the afternoon than any other time of day. These results should be taken with caution, as the summer surveys were longer than those of other seasons, and observer fatigue may have reduced the likelihood of detecting groups. Wind speed often increased in the afternoon, raising the sea state and also possibly contributing to a lower afternoon sighting rate. The lower sighting rate is further supported when examining the interaction of season and time of day, where occurrence in the afternoon during the summer time period was significantly lower than the morning and mid-day time periods. However, within the afternoon, there was a peak occurrence in the fall, which is difficult to interpret. Jones (1988) reported a fall increase in dolphin abundance in the channels and offshore areas, which was also supported by Henningsen (1991) who reported an increase of dolphin abundance during fall for the entire area. Since the increase in occurrence during fall was not evident across all daytime periods, the latter results are not clearly supported.

Dolphins did not show any preference to a particular location in the Gulf, nor did they occur in the Gulf during any particular environmental parameter level measured. Although one might expect dolphins to exhibit preference to areas with more numerous man-made structures, where some species of prey items are more likely to concentrate (Henningsen 1991), only one observation point did not have any man-made structures in the vicinity, making detection of any differences difficult. Groups were sighted outside the three km boundary on several occasions, revealing that they do not demonstrate a restriction in the distance from shore frequented, such as the coastal California common bottlenose dolphins (Hanson and Defran 1993). The gently sloping continental shelf along Galveston offers great contrast to the steep drop along the California coast. The difference is reflected in the prey species and distribution, and therefore the distribution of dolphins.

The mean group size of 8.6 for all groups is higher than those of previous studies in Galveston Bay. Calculated mean group sizes inside the bay system were 3.1 and 4.4 for Jones (1988) and Bräger (1992), respectively. The mean group size of 6.7 for groups without shrimp boats present is still higher, suggesting that there are factors other than the 'prey source' of the shrimpers that are related to group size. The difference in group size is further supported by Henningsen (1991), who also found group sizes to be larger in the Gulf than in the Bay. Larger sizes of offshore groups of dolphins compared to bay groups have been reported in several studies (Norris and Dohl 1980, Wells *et al.* 1980, Mullin 1988), and hypotheses suggest that larger groups in open areas may function to increase protection from predators, and possibly for cooperative foraging of schooling fish (Würsig 1979, Norris and Dohl 1980, Wells *et al.* 1980). However, mean group size for this area is low compared to studies of common bottlenose dolphins of coastal California (Hansen 1990, Defran *et al.* 1999) and Indian Ocean bottlenose dolphins off South Africa (Saayman and Taylor 1973).

Although group size varied greatly, it did not show any particular pattern of change according to the variables measured. The lack of pattern suggests that there is no particular time or area that dolphins congregate, and the group size is likely based on other factors. During this study, group size was found to be larger when calves or neonates were present, supporting the results of previous studies (Bearzi *et al.* 1997, Maze 1997). The larger group size is likely a result of the need for added protection of calves, and possibly alloparental care (Wells *et al.* 1987, Mann and Smuts 1998). Shark predation reported in the Galveston area was lower than that of many studies; 5% of dolphins showed signs of shark bite scars compared to 30% in Sarasota Bay, Florida and 36% in Moreton Bay, Australia (Henningsen 1991, Reynolds *et al.* 2000), but there have been reports of populations with virtually no threats by sharks (Connor *et al.* 2000). Use of the percentage of dolphins bearing visible signs of shark attack as a valid indicator of shark predation on dolphins has been questioned, as those exhibiting scars are the animals who survived an attack, and there is no way of knowing how many are attacked and do not survive. However, as a means to compare populations, it has some value if taken as an approximation of predation pressure. Therefore, I surmise that shark predation pressure is present in the Galveston area, although lower than that of some other areas utilized by dolphin populations.

Neonates were sighted in April, May, and July. The primary calving season for the northern Gulf of Mexico ranges from February to May (Odell 1975, Würsig *et al.* 2000). Although the July neonate sightings do not fit into this season, it is not too unusual, as births have been noted to occur during the summer and fall seasons as well (Würsig *et al.* 2000).

This study does not cover the entire home range of the animals. The discovery curve shows no leveling off, as it would in areas with a closed population, once all animals have been encountered and identified. The incline of the curve clearly shows that new individuals were discovered during every survey; it is probable that there are more individuals that utilize the study area that were not yet encountered and photographed. Resighting rates were extremely low, showing little site fidelity. The lack of clear seasonal patterns of occurrence and high fluctuation in group size suggest that this area may either be one that dolphins occasionally pass through, or an overlapping outlying area of several populations' home ranges. Overlapping ranges have been shown of bottlenose dolphins in Sarasota Bay, Florida (Wells *et al.* 1987, Scott, *et al.* 1990). Movement patterns of individual dolphins are examined in Chapter 3, further investigating this possibility.

The presence of shrimp boats in this area is likely of great importance to the bottlenose dolphins of this study. Both Leatherwood (1975) and Fertl (1994) outline the behavior of dolphins feeding in association with shrimp boats, and the possible benefit for the animals. The occurrence of dolphin groups in this study area was clearly greater when shrimp boats were present than when absent, and group size was much higher as well. Although there is potential for a slight bias caused by observers watching shrimp boats more intently, this is likely minimal, as effort was concentrated on covering the entire area. The pattern of higher occurrence with shrimpers suggests that there are large groups that tend to follow shrimpers for the ease of feeding, and this human influence likely has the greatest affect on the occurrence and distribution of the dolphins in this area. The nearshore sandy bottom habitat in the Gulf likely has lower prey availability than the nearby bay system (Moyle and Cech 1988, Henningsen 1991, Ballance 1992) and the shrimp boats may be acting as a "mobile habitat" for these creatures, in which prey is easily found and obtained. The fact that calves and neonates were found in more groups associated with shrimp boats than expected at random may be a cause for concern; if large groups with calves are likely to stay with shrimp boats, they may not be learning alternative foraging strategies. The adaptability displayed by these animals in the past, however, suggests that they could likely adopt new foraging strategies rather quickly.

The information gathered during this study represents the first detailed description of the dolphins in the nearshore Gulf of Mexico waters adjacent to Galveston Island. Although it clearly shows that the population of this study area is an open one that occurs in the area during all times of the year and is greatly affected by the shrimp fishery, more research is necessary. If occurrence patterns were examined further from shore and further along the Gulf coast, greater site fidelity may be evident on a larger scale. To establish whether such a difference scale affects the current analyses, dolphins should be tracked for long periods of time by comparing photographs and radio-tracking individuals (Würsig *et al.* 1991, Mate *et al.* 1995). With a high level of human activities, through industry, fisheries, and recreation, the Galveston area has great potential for studying human impact on marine mammals. Scott *et al.* (1990) detail the importance of long-term research on long-lived creatures, such as dolphins, to truly understand their strategies and social structure. Continuation of the several studies that have been conducted in the Galveston area and along the entire Texas coast will not only be beneficial in itself, but likely lead to a comparison of habitat differences between this area and others of long-term research.

CHAPTER III
MOVEMENT PATTERNS

Introduction

As one of the most commonly sighted cetaceans, bottlenose dolphins (*Tursiops* sp.) have been the subject of extensive research (Wells *et al.* 1980, Shane *et al.* 1986, Wells 1986, Connor *et al.* 2000, Reynolds *et al.* 2000). In Sarasota Bay, Wells and his colleagues (Scott *et al.* 1990, Wells 1991) have classified units of common bottlenose dolphins based on their range patterns (Scott *et al.* 1990, Wells 1991, Connor *et al.* 2000). The patterns have been separated by age- and sex-classes, as well as relatedness between individuals, showing differential use of habitat. This comparison is possible due to yearly captures of the animals.

Research on Indian Ocean bottlenose dolphins in the Shark Bay area has shown less restricted movements compared to those of Sarasota Bay, with close to 400 individuals identified, and no apparent home range boundaries within the area (Connor and Smolker 1985, Connor *et al.* 1996). Researchers describe behaviors of individual dolphins that are resighted quite frequently, and therefore individuals may demonstrate a high site fidelity (Connor *et al.* 1992, Connor *et al.* 2000).

Common bottlenose dolphins that occur in coastal Pacific waters of San Diego, California only utilize the area within 1 km of shore. Just over 400 individuals have been identified, and have shown much lower sight fidelity than in other areas studied; many individuals first identified in San Diego were sighted in separate "secondary" study areas, exhibiting a range of up to 470 km (Defran *et al.* 1999).

The Galveston Bay system is a shallow estuary with three tidal inlets to the Gulf of Mexico (see Figure 2 in chapter I; Wermund *et al.* 1989). The estuary is an area of high industrial activity; there are three dredged channels in the system. Bottom composition is mostly mud, with oyster reefs scattered throughout, and sparse sea grass beds in the southwestern-most areas (Wermund *et al.* 1989). The nearshore Gulf of Mexico waters off Galveston are composed mostly of a sandy bottom with some silt (Williams 1951, Stetson 1953). The coastal waters of the northeast portion of Galveston have various jetties and fishing piers.

Common bottlenose dolphins occur throughout the entire system occasionally, but are found most often in areas surrounding the Galveston Bay inlet (Jones 1988). Over 1000 individuals were identified throughout the entire Galveston area in 1990 (Henningsen 1991). Bräger (1992) found association patterns to be weak, and suggested the dolphins in this area exhibited fission-fusion group structure (Würsig 1978, Wells 1986, Shane 1987, Wells *et al.* 1987, Ballance 1990, Würsig and Harris 1990, Smolker *et al.* 1992, Weller 1991, Bräger *et al.* 1994, Maze 1997). Maze (1997) resighted three of her 71 identified individuals from San Luis Pass in Galveston Bay, suggesting that the "sub areas" previously studied do not act as discrete population ranges. In chapter II, I showed that bottlenose dolphins exhibited a year-round presence in coastal Gulf waters, and had low site fidelity, with periodic influxes of new animals into the area. Individual movement patterns describing the entire area would show to what extent these animals travel and which habitat they are most often encountered.

Estuaries are known be highly productive areas, and the nearshore sandy bottom habitat exhibits relatively low productivity in comparison (Moyle and Cech 1988, Sheridan *et al.* 1989, Ballance 1992). Although various man-made structures such as jetties likely attract some prey items (Henningsen 1991), the Gulf waters probably do not provide prime feeding areas for these dolphins, compared to the bay.

The objective of this study was to examine the habitat use of individual dolphins in the offshore waters immediately adjacent to Galveston Island. By extending the study area from past studies, movements and habitat use and preferences of individual dolphins in the entire Galveston area can be described.

Materials and Methods

Data were collected by the same methods as outlined in boat-based surveys of chapter II. The GPS coordinates of the group location were recorded, as well as estimated group size, date, time, sea state, tidal state, water depth, sea surface temperature, salinity, and calf or neonate presence (see chapter II for definitions). The completed 1990-2000 Gulf of Mexico photo-identification catalog was compared with the catalog of Henningsen (1991), representing the entire Galveston area; the 1995 Galveston catalog, complied by Maze (1997) representing lower Galveston Bay, Galveston Ship Channel, and Bolivar Roads; and the 1998-2000 catalog of identified individuals in San Luis Pass (Irwin-Smith and Würsig in prep.). Data involving location and date of group sighting were located for any matches found between catalogs.

Results

The discovery curve and percentage of identified individuals resighted are discussed in chapter II. Forty-four percent (223) of all groups sighted were first seen feeding in association with shrimp boats (see chapter IV for more information on behavior). Of the 429 individuals sighted only one time, 208 (41% of all groups) were feeding in association with shrimp boats, and seven of the individuals seen twice were feeding in association with shrimp boats both times, then never sighted again.

Only twenty identified individuals were sighted on three or more days during the study. Appendix 1 shows four examples of individual movement patterns of those dolphins. GOM 088 and GOM 102 were sighted only in the Gulf waters near the center of the island. All sightings of those two individuals occurred in August of 1999. GOM 022 stayed on the east end of the island, and was seen in that general location twice in July of 1999 and not again until July of 2000. GOM 090 traversed the entire area.

Comparison of dorsal fin photographs to those in established catalogs from throughout the Galveston area resulted in 67 matches; 17 to the 1990 catalog of the entire Galveston area (Henningsen 1991), 24 to the 1995 Galveston of lower Galveston Bay, the ship channels, and Gulf of Mexico waters near Bolivar Roads, and 18 to the 1998-2000 San Luis Pass/Chocolate Bay catalog (Irwin-Smith and Würsig in prep.). Several of the individuals were found in more than one of the catalogs mentioned above, resulting in an actual total of 52 of the 1999-2000 Gulf of Mexico individuals having been sighted during other studies. Four individuals, GOM 003, GOM 206, GOM 305, and GOM 320, were sighted during 1990, 1995, and 1999-2000. Two individuals, GOM 343 and GOM 107 were sighted during 1990, 1998-2000 in the San Luis Pass study, and again in 1999-2000 in the Gulf of Mexico study.

Movement patterns of individuals sighted relatively often (three or more surveys) throughout the ten-year period were separated based on the differences in areas most often utilized (Figure 15, Appendices 2-7). Appendix 2 shows the individuals that frequented Bolivar Roads and Gulf of Mexico waters adjacent to Bolivar Peninsula. Five individuals that showed high site fidelity to the Galveston Ship Channel, shown in Appendix 3, were also seen in the neighboring Bolivar Roads area, but three individuals were also sighted in the Gulf of Mexico. Another five dolphins appear to stay close to the north and south jetties of the Houston Ship Channel (Appendix 4), but this grouping is very vague, and these individuals were not sighted often. The individuals identified during the San Luis Pass study (Maze 1997, Irwin-Smith and Würsig in prep.) that were matched to individuals of the present study were generally seen from the San Luis Pass area northeast along the island to Jamaica Beach (Appendix 5). However, some of the San Luis Pass individuals were sighted much further down the island, as shown in Appendix 6. Still another individual, GOM 112

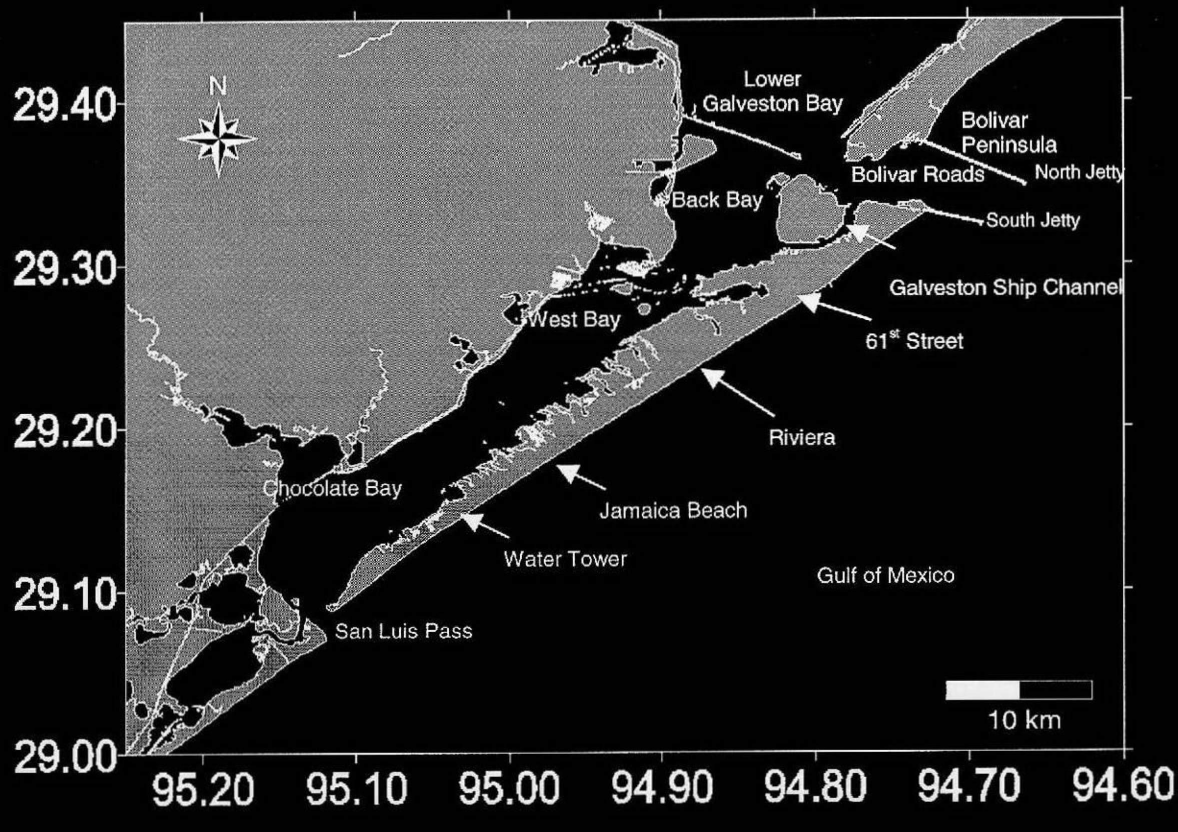

Figure 15. Map of Galveston area, pointing out landmarks and areas discussed.

(Appendix 7) was sighted in several areas, and was followed for more than 30 km for over four hours in the Gulf of Mexico waters, in areas where it was never sighted otherwise. Appendix 8 shows the dates, location, and noted behavioral categories for each sighting of the individuals presented in Appendices 2-7.

Discussion

The coastal Gulf of Mexico waters off Galveston Island are utilized by many dolphins. Only 15% of all identified individuals were resighted on a second survey day. This, paired with the discovery curve, clearly shows that these animals do not stay only in the designated study area, and that we have not identified all animals that utilize this area. Although the movements of those dolphins seen three to four days during the study period do not follow any pattern, some individuals exhibit a potentially interesting pattern. All sightings of GOM 088 and 102 were in a similar area, showing what first appears to be site fidelity. Further examination revealed that all sightings were the same month, August 1999. Another individual, GOM 022 was seen only in one particular area, but the dates show two sightings in July of 1999 and one in July of 2000, with no sightings in other months. Irwin-Smith (pers. comm.) also identified two individuals in Gulf waters near the San Luis Pass study that were seen during the same month, one and two years apart, and never sighted in between. Irwin-Smith also identified nine individuals, sighted several times within a one or two month period, and never resighted. Evidence of seasonal residency in the Gulf of Mexico waters off Sarasota, Florida has been documented by Fazioli and Wells (1999). The resightings of the present study are very interesting, and hint at a possible seasonal fidelity, but this is hard to suggest from a single year study, and highlights the need for further investigation.

The movement patterns of individual dolphins, over a period of ten years, offers more insight into the dynamics of the Galveston area. Matches found may not be an equally representative sample of all individual dolphins. More distinctive fins are more likely to be recognized after years have passed, while the less distinctive animals with fewer notches are more likely to be changed beyond recognition. Therefore it is possible that some individuals present in 1990 were not recognized as the same individual in 2000. There was movement by many individuals between the bay and offshore waters. This movement is different than has been previously observed in Matagorda Bay, however. Lynn (1995) reported that dolphins radio-tracked in Matagorda Bay did not leave the bay waters.

Although sample size is small, those individuals seen multiple times over the years can begin to show patterns. Evidence suggests that individuals show preferences to areas within the Galveston Bay system. The boundaries of areas utilized more often by groups are vague, but do seem to fall into four general groups: Bolivar Roads/Bolivar Peninsula, Galveston Ship Channel, North and South Jetties, and San Luis Pass. These areas of preference must be taken with caution as there is great overlap in most of these regions, especially between those utilizing Bolivar Roads, which confuses the possible pattern. The vagueness could be explained by differences between range patterns and site fidelity of individuals in different age or sex classes, such as those found in Sarasota Bay (Wells 1986, Scott *et al.* 1990, Connor *et al.* 2000). Some of the San Luis Pass animals that ranged far along the island (see Appendix 6) were classified as sub-adults by Irwin-Smith (pers. comm.). Therefore it is possible that some differences in range due to age-class are occurring here as well. Although detailed sex and age-class information would provide great insight into the differences in movement patterns, this information is difficult to obtain in the murky waters of Galveston by means of observation. Further studies involving molecular techniques would prove beneficial.

The coastal Galveston waters do not have a group of individuals that primarily utilize that area, but rather they represent an overlap of outlying ranges of: 1) animals utilizing the channels, jetties, and coastal waters off Bolivar Peninsula spreading out from the estuary entrance; found along the northeast half of the island Gulf waters for the most part, 2) animals using the San Luis Pass/Chocolate Bay area; found along the southwest half of the island Gulf waters for the most part, and 3) animals rarely seen that move into and out of the area, possibly following shrimp boats. The existence of this third grouping is supported by the large number (41%) of those animals never resighted, which were associating with shrimp boats. These individuals may travel distances of up to hundreds of kilometers with the shrimpers, showing fidelity not to a specific area, but to the easily obtained prey resource associated with these trawlers. Offshore shrimpers are known to travel between coastal Gulf of Mexico states during the shrimping season, and it is not unlikely that the dolphins could be traveling those distances. Individual bottlenose dolphins have been sighted over 300 km away from their presumed home range in Argentina, and 470 km from the first sightings of individuals along the coast of California (Würsig and Würsig 1977, Defran *et al.* 1999). Defran *et al.* (1999) show that bottlenose dolphins along the coast of California range long distances, presumably in search of patchy prey items. The shrimp boats could be acting as a food source comparable to that of a prey patch for the Texas coastal dolphins. A comparison of photographs between areas along the Texas coast would provide valuable insight to this hypothesis.

The characterization of some dolphins showing high fidelity to areas within the Galveston Bay system and others passing through, is similar to the dynamic of Aransas Pass, as described by Weller (1998). In this area, 20 identified individuals were sighted in all seasons, but were not present during all surveys. Weller (1998) classified these dolphins that exhibited high site fidelity as “semi-residents”. Over half of the identified individuals, however, were only sighted once, and referred to as “transients”.

Although small sample size precludes the ability to determine the effects of seasonality and behavior on the movements of individual animals, some hints of descriptors can emerge by comparison. For example, individuals in the Bolivar area were seen in all months exhibiting all behaviors, suggesting membership of relatively stable groups occurring there. If an individual utilized the inlet area only for a specific behavior, it would move to other areas more often, therefore showing less fidelity. This stability of groups, or high fidelity, is supported by examination of the habitat; the Bolivar area includes the highly productive estuary mouth, and the jetty structure also likely provides abundant food (Henningsen 1991). The animals which frequent the Galveston Ship Channel (GSC) are found there during all months, exhibiting a wide variety of behaviors. When the GSC individuals were seen offshore, however, their behavioral categories were either socializing, surfing, feeding in association with shrimpers, or travel. These GSC animals also show great site fidelity to the Galveston Ship Channel, but possibly move out of the Gulf either when following a shrimp boat, to socialize with individuals, or for surfing (an activity which cannot occur inside the channel). Dolphins studied in Matagorda Bay were at "the most distant points at which they were ever observed" when with shrimp boats (Gruber 1981). The area of increased fidelity for dolphins that generally remained close to the jetties is more difficult to distinguish, as the potential border of this area is less clear. Groups were seen in all months and all behaviors were observed. Of those individuals that ranged the furthest, many were in association with shrimp boats and therefore may have traveled further, taking advantage of the abundant prey. The individuals of San Luis Pass that ranged further than Jamaica Beach were only seen engaged in play, social, and travel behavior. It is not known whether these movements are related to season or to habitat type.

Bottlenose dolphin behavioral ecology, although quite variable in most cases, can exhibit some patterns when investigating habitat type and foraging strategies. Since these animals have a great ability to adapt to various circumstances, whether utilizing human influence to increase prey acquisition or developing new foraging techniques, it can be expected that occurrence and movement patterns vary considerably. However, prey type and habitat type may offer some striking similarities when related to dolphin behavior.

CHAPTER IV
BEHAVIOR

Introduction

Many studies have been conducted on various populations of common bottlenose dolphins in Texas bays (Shane 1977, Gruber 1981, Shane 1987, Jones 1988, McHugh 1989, Henningsen 1991, Bräger *et al.* 1994, Fertl 1994, Maze 1997). The Galveston Bay system is a shallow estuary with a muddy bottom composition, with oyster reefs throughout, and sparse sea grass (Figure 2 of chapter I; Wermund *et al.* 1989). The Gulf of Mexico waters adjacent to Galveston are composed mostly of a sandy bottom with some silt (Williams 1951, Stetson 1953). The only structures are man-made jetties and piers, which are found along the northeast half of the island.

Bottlenose dolphins are encountered most frequently in the areas of the Bolivar Roads and Galveston Ship Channels, and San Luis Pass (see Figure 15, chapter III), but can be found in all sections of the system (Jones 1988, Henningsen 1991). Previous projects conducted in the Galveston area, with the exception of Henningsen (1991), have only included the Galveston Bay system and the San Luis Pass area, with study areas extending into the Gulf near the inlets, rather than along the entire coastline of Galveston Island (Jones 1988, Bräger 1992, Fertl 1994, Maze 1997, Irwin-Smith and Würsig in prep.). While Henningsen's (1991) study extended into the Gulf of Mexico, there was not an equal effort to survey the Gulf as frequently as some portions of lower Galveston Bay were surveyed. The Gulf of Mexico waters are utilized by the Galveston area dolphins, and should therefore be considered when attempting a complete description of the dolphins of the Galveston area.

Chapters II and III have shown that the dolphins that occupy the study area display very little site fidelity to it. In fact, the nearshore Gulf of Mexico waters likely consist of an overlap of outlying areas of three separate ranges.

The secondary use raises interesting questions about behavior: What are the dolphins doing in the area? The Gulf waters likely provide low prey availability in comparison with the bay system (Moyle and Cech 1988), as well as less protection from predators. The reasons dolphins may opt to utilize this different habitat is explored further in this chapter.

Materials and Methods

Data for this study were collected by the same methods and during the same study period as outlined in chapter II. Both methods of data collection were implemented (shore-based surveys and boat-based surveys). In addition, behavioral data were recorded. One-zero sampling of seven behavioral states were recorded for each group sighting (Altmann 1974). Often more than one category of behavior was exhibited during the sighting duration, and all were recorded once. Behavioral states were modified from Shane (1980) and Fertl (1995) and are defined as:

Travel - moving steadily in one direction

Social - some or all group members in almost constant physical contact with one another, oriented toward one another, and often displaying surface behaviors; no forward movement

Feed - repeated dives in varying directions in one location, often with prey visible at the surface, in a dolphins mouth, or fleeing from a dolphin

FSB - feeding in association with shrimp boats; repeated dives in varying directions around the side or behind the stern of a shrimp boat

Play - surface behaviors or activities of single dolphins, or not involving other members of the group; usually jellyfish tossing or surfing

Mill - moving in various directions in one location but showing no surface behaviors and no apparent physical contact between individuals; usually by staying close to the surface

Unknown - Groups not falling into any of the above categories; usually losing sight of a group after a single surfacing when behavior cannot yet be determined

Statistical Analysis

All statistical analyses were carried out using STATISTICA software, version 4.1. Each day is considered a sampling unit for these analyses, therefore calculated sample size differs for each test based on the number of categories occurring in each day surveyed. Parametric Analysis of Variance and t-tests or nonparametric Kruskal-Wallis ANOVA and Mann-Whitney U statistical tests were assigned for a comparison of means (Zar 1996). Tests for the assumptions of normality and equal variances were conducted using the Kolomogorov-Smirnov test and Levene's test, respectively (STATISTICA, version 4.1; Zar 1996). Contingency tables were examined using Pearson's chi-square test. A significance level of 5% was used.

Results

The most common behaviors observed were travel and play, which were seen in approximately 37% and 36% of all groups, respectively. These two behaviors were followed by socializing and feeding, each comprising 24% of all groups sighted. Feeding in association with shrimp boats was seen in 19% and milling in 5% of groups. Percentages do not add up to 100%, as many groups exhibited more than one behavioral category. FSB groups were removed from the data set for further analysis to remove the potential human influence. Behavioral data used for statistical testing were those observed from boat surveys unless otherwise noted. Behavior was compared across the four seasons (summer = June - August, fall = September - November, winter = December - February, and spring = March - May) (Figure 16). Behaviors during spring are slightly more evenly distributed than in the other seasons, and there is a peak of travel in the summer and play in the fall. The proportion of feeding

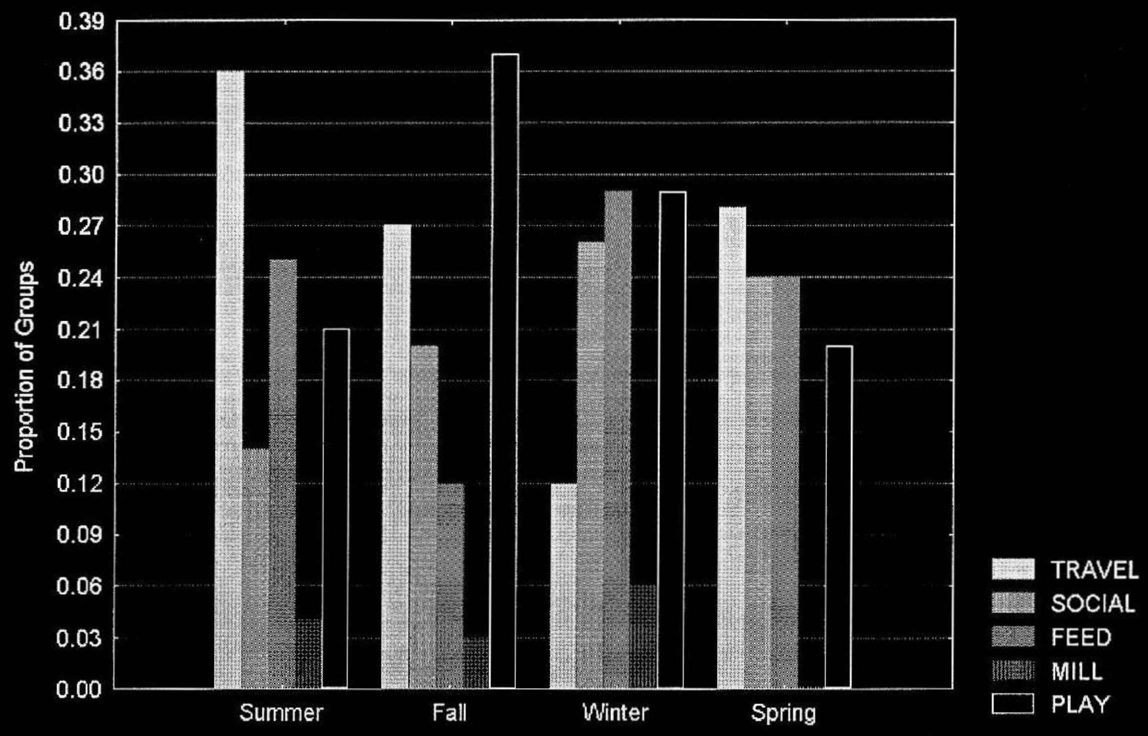

Figure 16. Proportion of behavioral categories by season.

was lower in the fall than in all other seasons. The occurrence of behaviors was not significantly different by season (Pearson's chi-square, p = 0.3170). Distribution of behavioral categories observed throughout the daytime was investigated by separating the daylight hours into three categories; 0600-1000=morning, 1000-1400=mid-day, and 1400-1800=afternoon, and this distribution was also not significantly different than expected (Figure 17, Pearson's chi-square, p = 0.5870). Location was investigated as a potential influence on behavior, in which the data from the shore-based surveys were used for comparison. There are potential trends of more traveling and socializing at the Galvestonian and more playing at the Flagship and San Luis observation points, but this was not found significantly different than expected at random (Figure 18, Pearson's Chi-square, p = 0.4905).

Mean group size tended to be largest during social and play behaviors, and smallest during mill. A significant difference was not found for mean group size compared by different behaviors (Figure 19, ANOVA, p = 0.0736). A trend of feeding in deeper water is evident, but the difference is also non-significant (Figure 20, ANOVA, p=0.0736). Occurrence of behaviors compared across tidal state was not significantly different (Pearson's Chi-square, p = 0.7783). The frequency of calves and neonates present in groups separated by behavior had no significant difference (Figure 21, Pearson's Chi-square, p = 0.1949). However, it is shown that more calves or neonates were present during play behavior and less during traveling, feeding, and milling.

Discussion

Although the behavioral sampling method did not allow for a time budget, comparison to budgets in the literature is still valuable, as the more time spent engaged in a particular activity, the more likely that activity is to be observed. It is fairly common that travel is one of the most common behaviors seen, but play

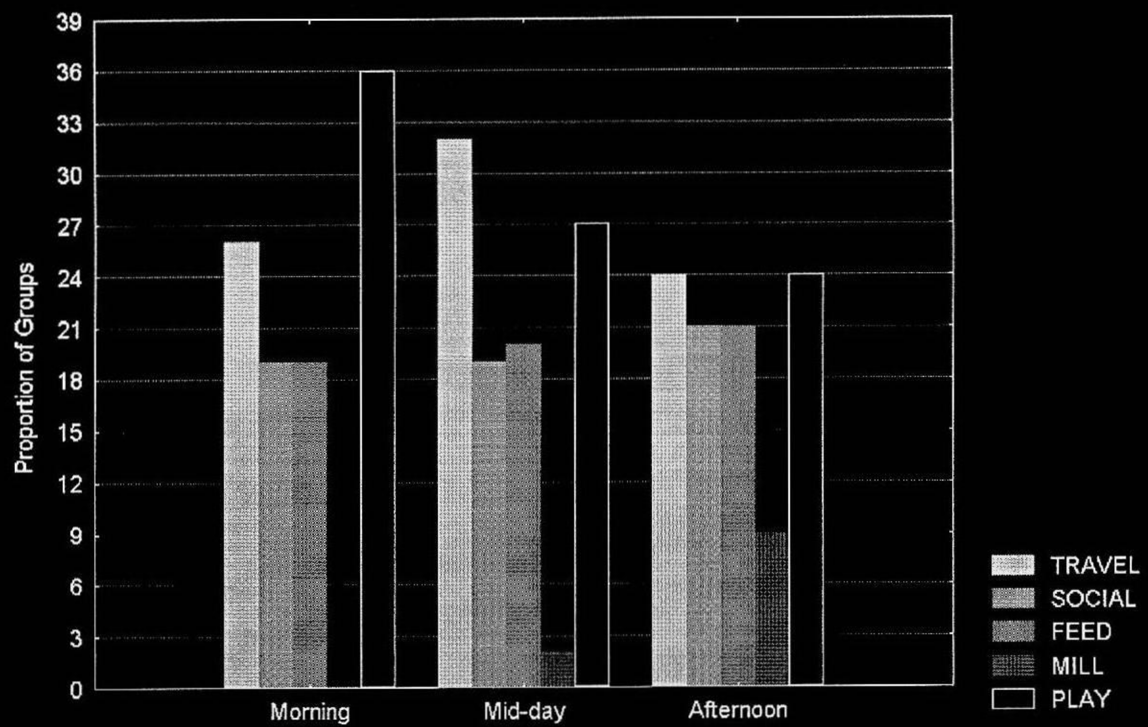

Figure 17. Proportion of behavioral categories by daytime period.

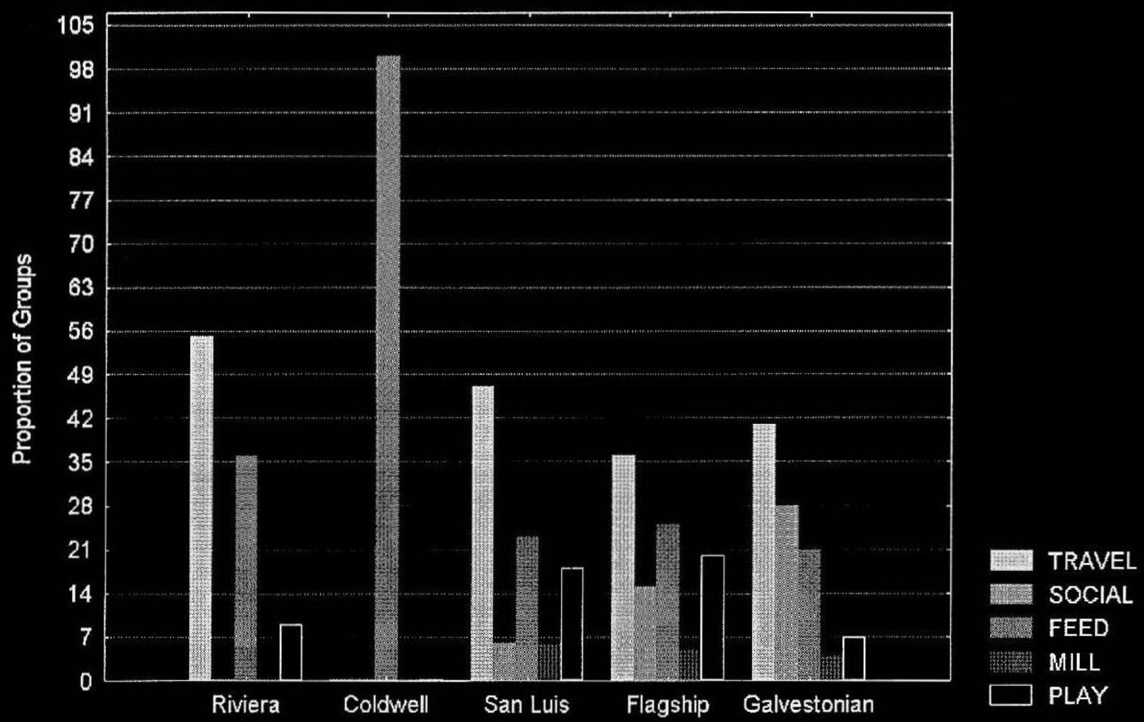

Figure 18. Proportion of behavioral categories by location.

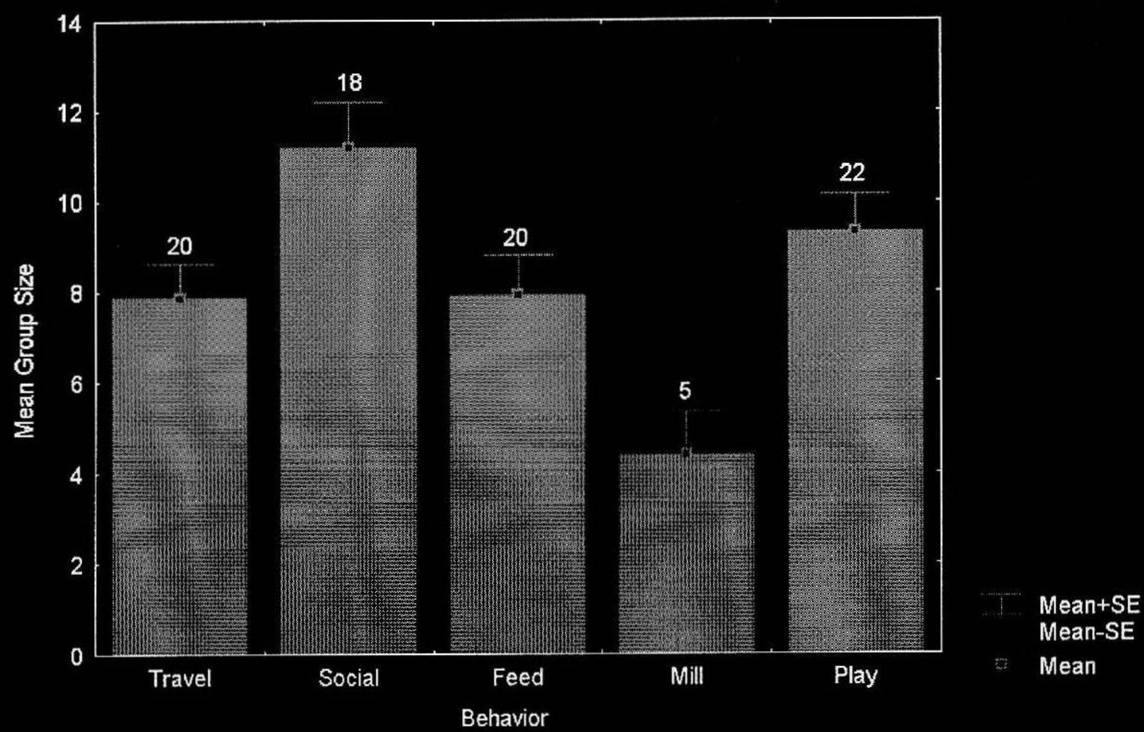

Figure 19. Mean group size and behavior. Number of days each behavioral category was observed is represented above the error bars.

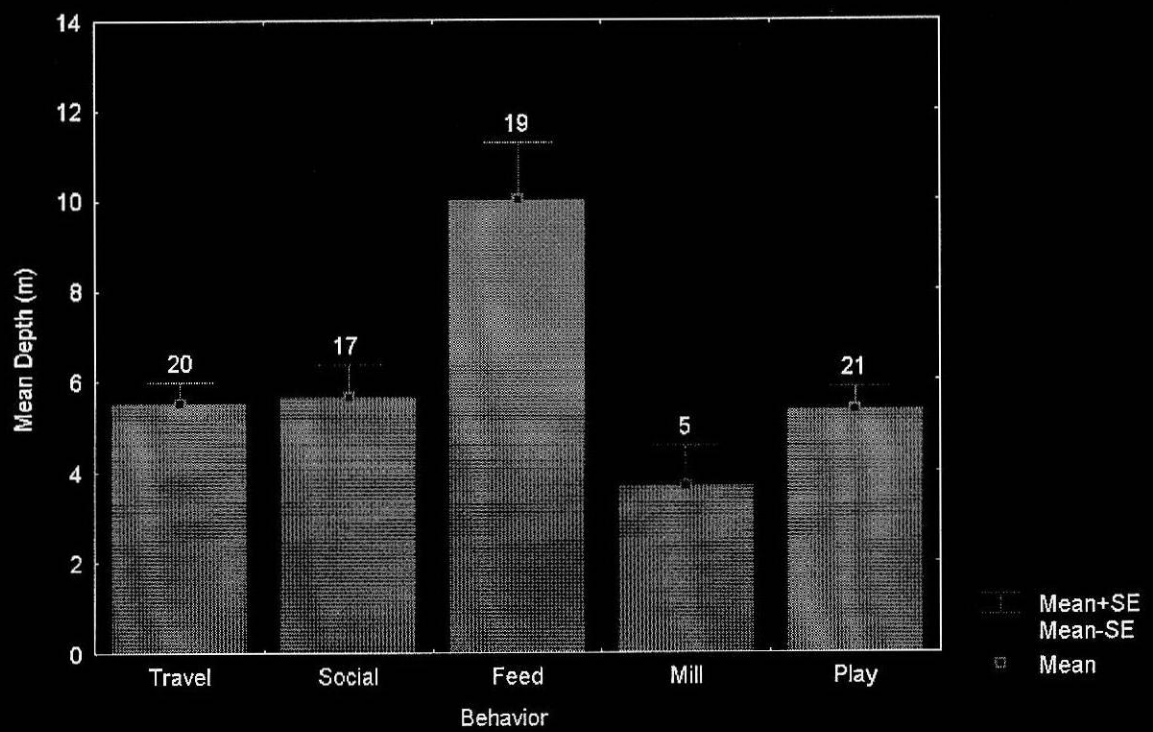

Figure 20. Mean depth and behavior. Data as in Figure 18.

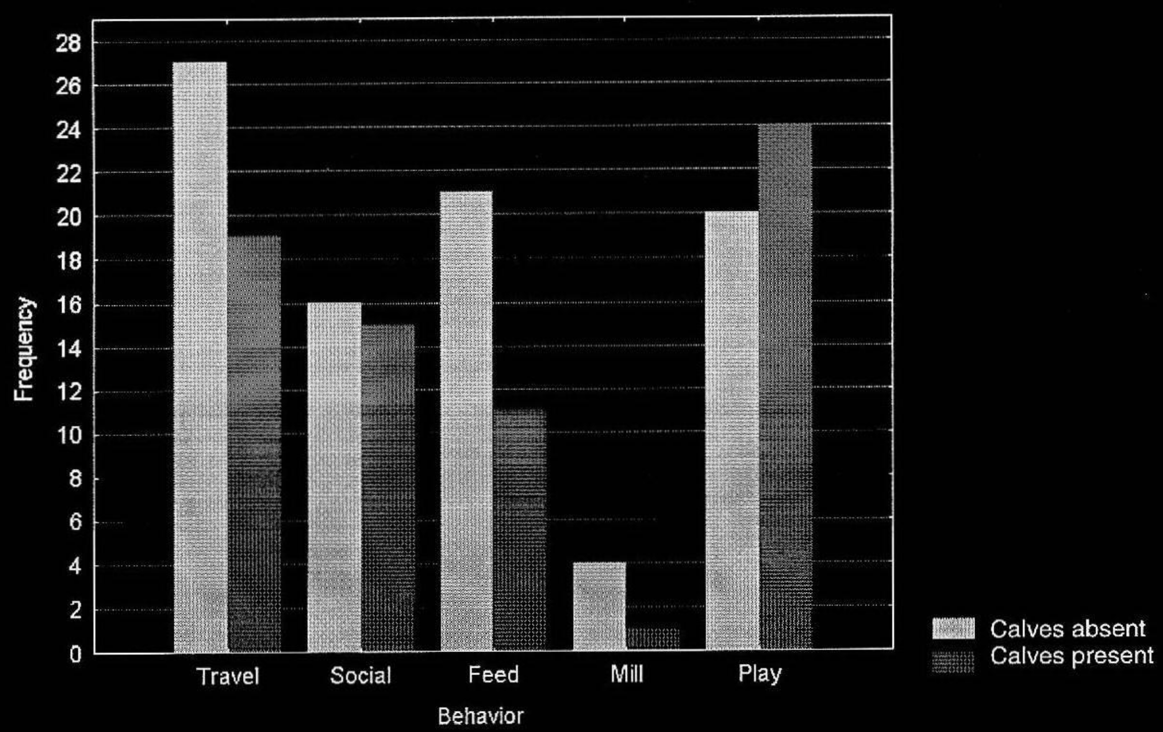

Figure 21. Frequency of behaviors compared to calf and neonate presence.

has seldom been included as a top-ranking behavioral category (Scott *et al.* 1990, Shane 1990, Hanson and Defran 1993, Reynolds *et al.* 2000). The difference in study area is a fundamental one; most studies conducted on bottlenose dolphins have been in easily accessible bay systems, where surfing, the predominant play behavior observed in this study area (49% of play behavior was surfing), is impossible due to the lack of surf. The data discussed in chapter III indicate that many individual dolphins from the study area potentially reside, at least some of the time, in the bay system, and move to the nearshore Gulf waters for reasons unknown. Could these different habitats be utilized for different behaviors? Estuarine habitat is generally a much more reliable source of certain prey-types than the neighboring sandy bottom Gulf of Mexico waters (Moyle and Cech 1988). It is possible that the animals move between these areas for different reasons. The idea of habitat utilization is one that needs to be explored further, with studies of longer duration and focused hypotheses of habitat preference.

Although the sample size was too small for statistical significance, some trends of the proportions of behaviors observed in each season are apparent. The proportion of feeding in the fall was lower than that in all other seasons, which may be related to the fall spawning of striped mullet, *Mugil cephalus* (Hoese and Moore 1998). During the fall season the mullet are plentiful in the coastal Gulf waters and dolphins may need to spend less time foraging, and have more time for other activities, such as play, which peaked in the fall. The seasonal feeding proportions, however, are not supported by previous research in other Texas studies; Shane (1977) and Gruber (1981) found an increase of feeding in fall and winter seasons.

The additional parameters that were examined as possible contributors to behavioral patterns hinted at some trends, but were possibly swayed by unequal sampling effort, therefore resulting in no significant differences. This suggests that further study is necessary, in which data can be collected over a longer time period, likely resulting in a better representation of behavior across all environmental parameter values.

CHAPTER V
CONCLUSIONS

Dolphins were present in the study area throughout all daytime periods and during all seasons. No pattern of occurrence was evident during this study, however, increasing sample size would increase the power of detecting such differences. Mean group size was greater than that in some studies, especially those occurring in bay systems. The differences in group size between bay and open water areas support the findings of several previous studies (Norris and Dohl 1980, Wells *et al.* 1980, Mullin 1988). Larger groups in open areas may function to increase protection from predators, and possibly for cooperative foraging of schooling fish (Norris and Dohl 1980, Wells *et al.* 1980). Group size within this study was larger when calves or neonates were present, also supporting the results of previous studies (Bearzi *et al.* 1997, Maze 1997, Weller 1998). This larger size is likely a result of the need for added protection of calves, and possibly alloparental care (Wells *et al.* 1987, Mann and Smuts 1998). Apparent shark predation in the Galveston area is lower than that of other areas (Henningsen 1991, Reynolds *et al.* 2000, Connor *et al.* 2000), but may still play a role in the determination of group size.

The nearshore Gulf of Mexico waters off Galveston Island are utilized by many dolphins. Only a fraction (15%) of all identified individuals were resighted on a second survey day. The discovery curve and low resighting rate indicates that these animals do not remain only in the designated study area, and that we have not identified all animals that utilize this area. Although sample size is small, movement patterns of dolphins, seen multiple times over a period of ten years, offers insight into group dynamics. It is clear that individuals show preferences to areas within the Galveston Bay system. The boundaries of areas utilized more often by groups are vague, but fall into four general groups:

Bolivar Roads/Bolivar Peninsula, Galveston Ship Channel, North and South Jetties, and San Luis Pass. Although there is great overlap in most of these areas, obscuring potential patterns, differences of range patterns and site fidelity of individuals in different age or sex classes possibly explain this ambiguity (Wells 1986, Scott *et al.* 1990, Connor *et al.* 2000). Some of the San Luis Pass animals that ranged furthest northeast along the island (see Appendix 6) were classified as sub-adults by Irwin-Smith (pers. comm.), which supports the possible age class differences. The Gulf of Mexico waters adjacent to Galveston appear to be an area of overlap of outlying ranges of: 1) animals utilizing the lower Galveston Bay region, including the channels, jetties, and coastal waters off Bolivar Peninsula, which occasionally extend along the northeast half of the island in coastal Gulf waters, 2) animals using the San Luis Pass/Chocolate Bay area, spreading out along the southwest half of the island Gulf waters, and 3) rarely seen animals that move into and out of the area. It is possible that a portion of this third grouping of dolphins are following shrimp boats. Almost half of the individuals identified, but never resighted, were associating with shrimp boats, supporting the characterization of this grouping. Shrimp boats could be acting, for Texas coastal dolphins, as a food source comparable to that of a prey patch, as described by Defran *et al.* (1999) for common bottlenose dolphins off the coast of California. Defran *et al.* (1999) suggest the function of long range movements of these dolphin are to search for patchy prey items. Harzen (1998) suggested a similar hypothesis for the Sado estuary area of Portugal. A comparison of photographs between areas along the Texas coast would provide valuable insight to this hypothesis.

The reduced site fidelity of dolphins in the Galveston area compared to those residing in Sarasota Bay, may be related to the reliability of available prey. Sarasota Bay has extensive sea grass beds, which provide a relatively reliable source of prey to the dolphins (Scott *et al.* 1990, Wells 1991). The Sarasota dolphins may not need to travel further than that system in search of food, resulting in a high site fidelity and low association with dolphins of neighboring areas. Although a productive area, abundance of some prey species in the Galveston area fluctuates seasonally, with movements of estuarine fish in and out of the bay for spawning (Sheridan 1983, Sheridan *et al.* 1989). The prey is possibly not predictable or plentiful enough for the large number of dolphins utilizing the area, resulting in the remainder of animals ranging further from the bay, but returning periodically. This is supported by the identified individual GOM 022 of this study, sighted in July of 1999 and then again in July of 2000. Irwin-Smith (pers. comm.) and Fazioli and Wells (1999) also have evidence of such a seasonal fidelity.

A comparison of sighting dates and behaviors observed of individuals seen during the ten-year period suggests those dolphins showing "preference" to specific areas are possibly residents in various areas of Galveston Bay. Those dolphins were sighted during many months of the year rather than only during some seasons. As animals were seen repeatedly exhibiting a variety of behavioral categories in that area, they are likely more stable in their occurrence there. Bottlenose dolphins of Aransas Pass, Texas were shown to have a similar dynamic (Weller 1998). Weller (1998) suggested most individuals utilizing the area were transients, with approximately 20 "semi-residential" individuals exhibiting a higher site fidelity. This is in contrast to the findings of Lynn (1995), who did not record any movement of radio-tagged dolphins outside of Matagorda Bay. It is possible that a similar pattern to those described above does exist in Matagorda Bay, however. The tracking effort of the ten dolphins lasted for just over two months (Lynn 1995). The animals tracked could therefore be residents, or similar to those individuals showing a seasonal fidelity to the Galveston area, leaving the bay at a later time.

Groups were seen in all months and all behaviors were observed. Of those individuals that ranged the furthest, many were in association with shrimp boats and therefore may have traveled further, taking advantage of the easily obtained prey. Other individuals sighted far from their "preferred" areas were seen engaged in play, social, and travel behaviors. It is clear that many individual dolphins from the study area are likely individuals that reside, at least some of the time, in the bay system, and move to the outside Gulf waters for reasons unknown. Animals may move between these different habitats for different uses.

Shrimp boats are an important factor in the lives of bottlenose dolphins of the Galveston area, and probably the Texas coast. Occurrence of dolphin groups in the nearshore Gulf waters was clearly greater when shrimp boats were present than when absent, and group size was also much higher. The greater number of groups containing calves and neonates found associating with shrimpers may be a cause for concern; if large groups with calves are likely to stay with shrimp boats, they may not be learning alternative foraging strategies. The adaptability displayed by these animals in the past, however, suggests that they could likely adopt new foraging strategies rather quickly.

The data presented represent the first detailed description of the dolphins of the coastal Galveston waters. Using a comparison of photographs, it is apparent that the Galveston Bay system is home to a large population of dolphins. The dynamic is much different than has been previously shown in other areas. While some fidelity to areas within the system is apparent, there is great movement and interaction between individuals, as shown by the weak associations found by Bräger (1994). This low association level may be due not only to the greater number of affiliates in this large population, but also to differences in habitat. The habitat differences among the Galveston area, and between Galveston and other areas studied, contribute to a variety of feeding strategies and varying levels of predation pressure. Galveston may represent a combination of habitat use patterns, as suggested for the dolphins in Sado estuary, Portugal (Harzen 1998). The estuary can provide a stable food source for many dolphins, but may not be enough for the number of dolphins frequenting the area. Therefore, the other inhabitants of the area are temporary, moving with various prey sources, including shrimp boats.

Although the information shows that the population occurring in the Gulf waters is an open one that is greatly affected by the shrimp fishery, more research is necessary. This study has raised several hypotheses related to emergent patterns of individual and group movement and range patterns. It is unknown whether the movements of the Galveston population of dolphins are related to season, habitat type, or are human-influenced. The information gathered during this study provides the background necessary to spark further hypothesis-driven studies.

With a high level of human activities, through industry, fisheries, and recreation, the Galveston area has great potential for studying the impact of humans on marine mammals (O'Shea *et al.* 1999, Irwin-Smith and Würsig in prep.). Scott *et al.* (1990) detail the importance of long-term research on long-lived creatures, such as dolphins, to truly understand their strategies and social structure. Continuation of the studies that have been conducted in the Galveston area and along the Texas coast will be beneficial, and possibly lead to a comparison of habitat differences between this area and others of long-term research.

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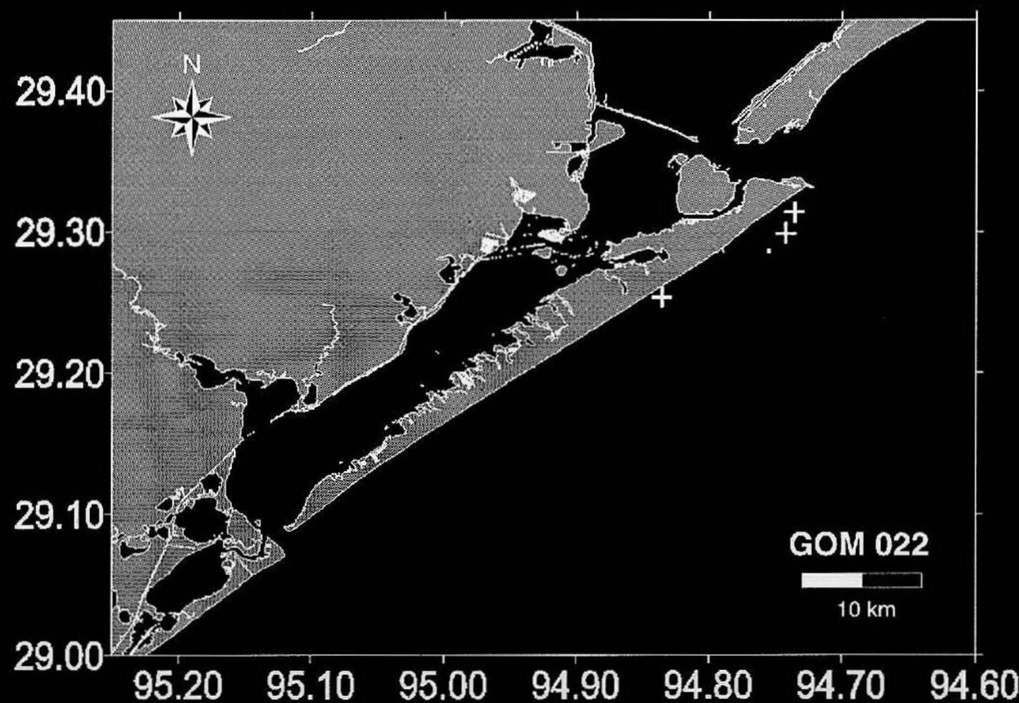
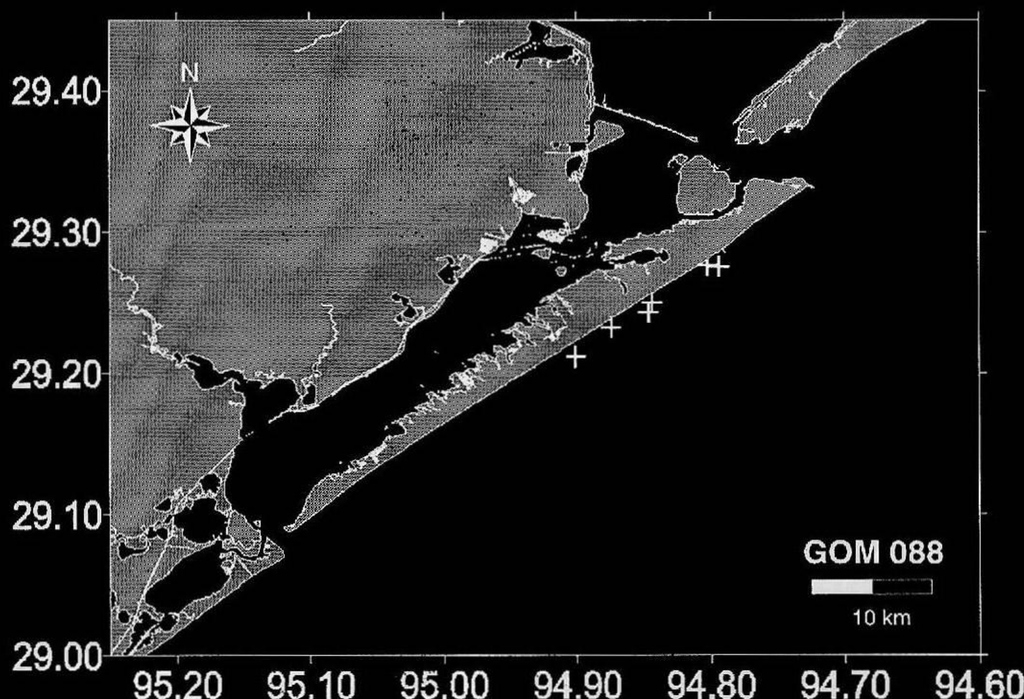
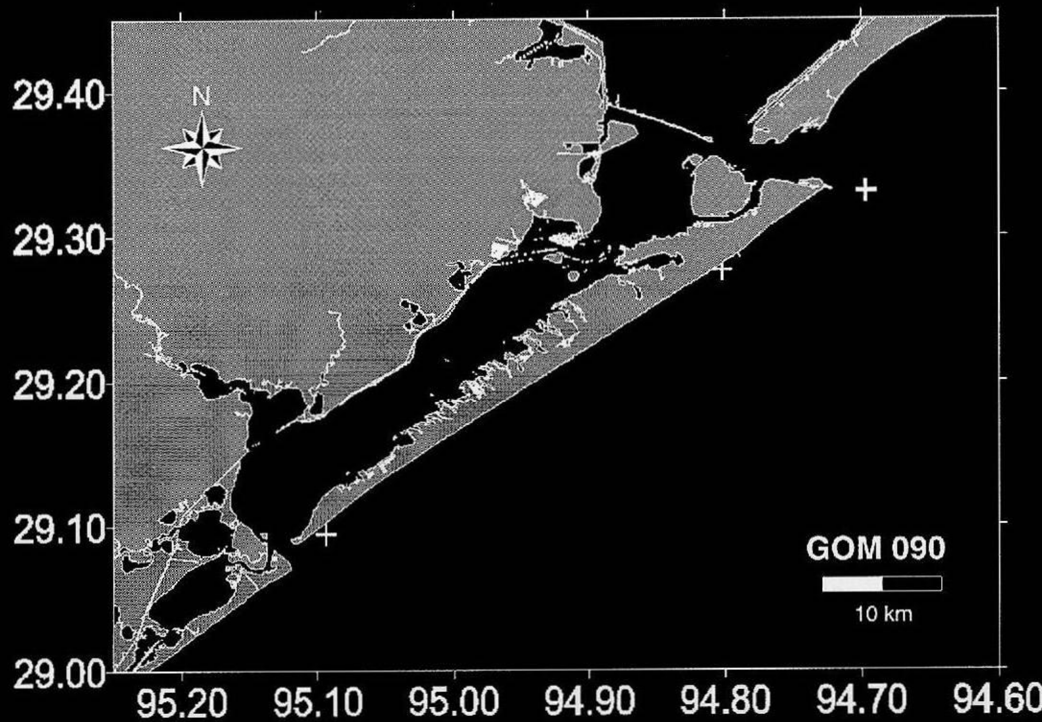
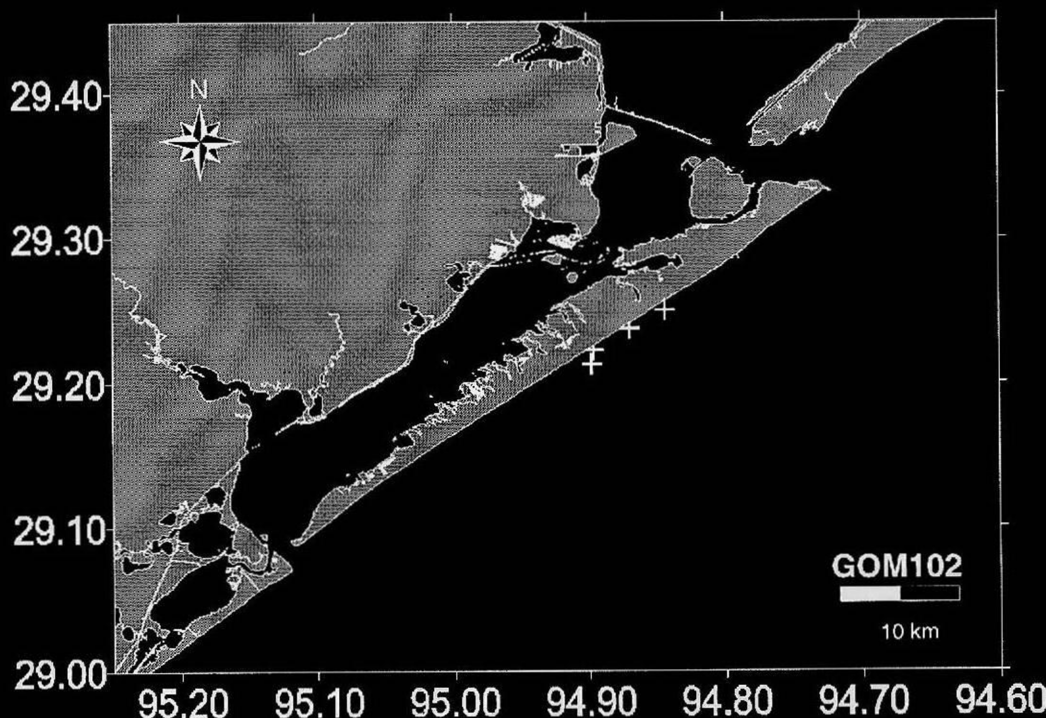
APPENDIX 1

Movement maps of individuals seen on three or four days. Crosses represent each sighting, some locations are within the same day.



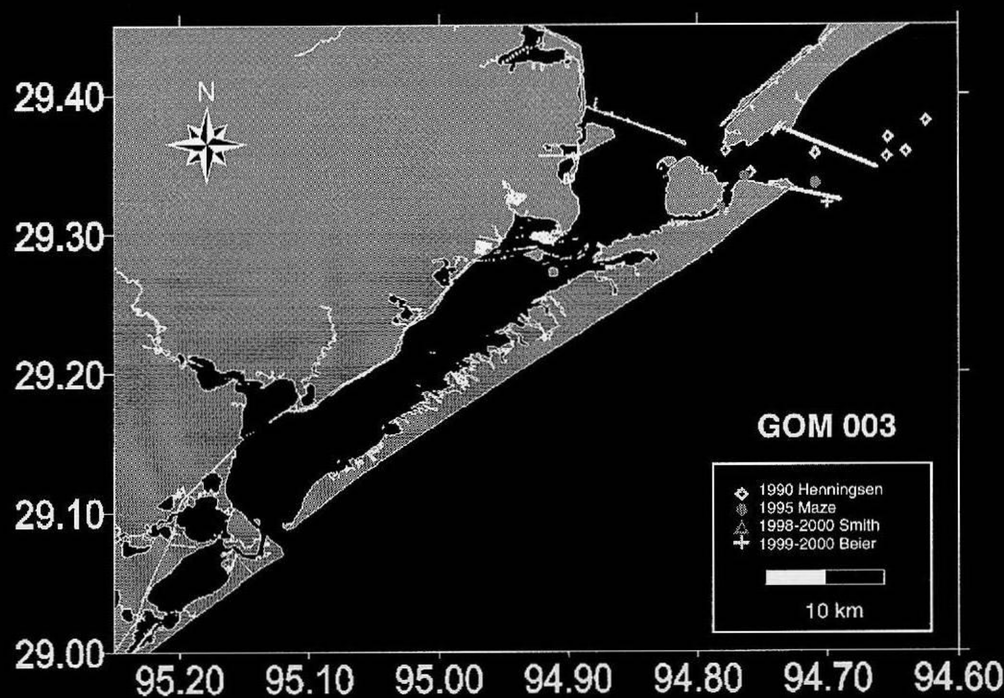


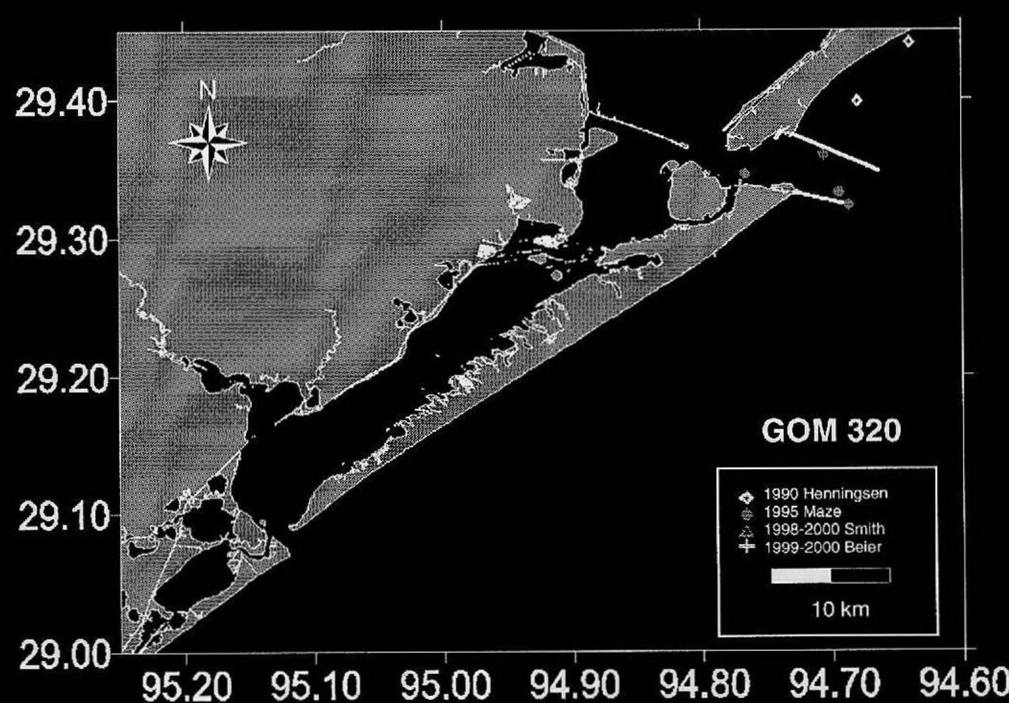

29.40
29.30
29.20
29.10
29.00
95.20
95.10
95.00
94.90
94.80
94.70
94.60
N
GOM 090
10 km

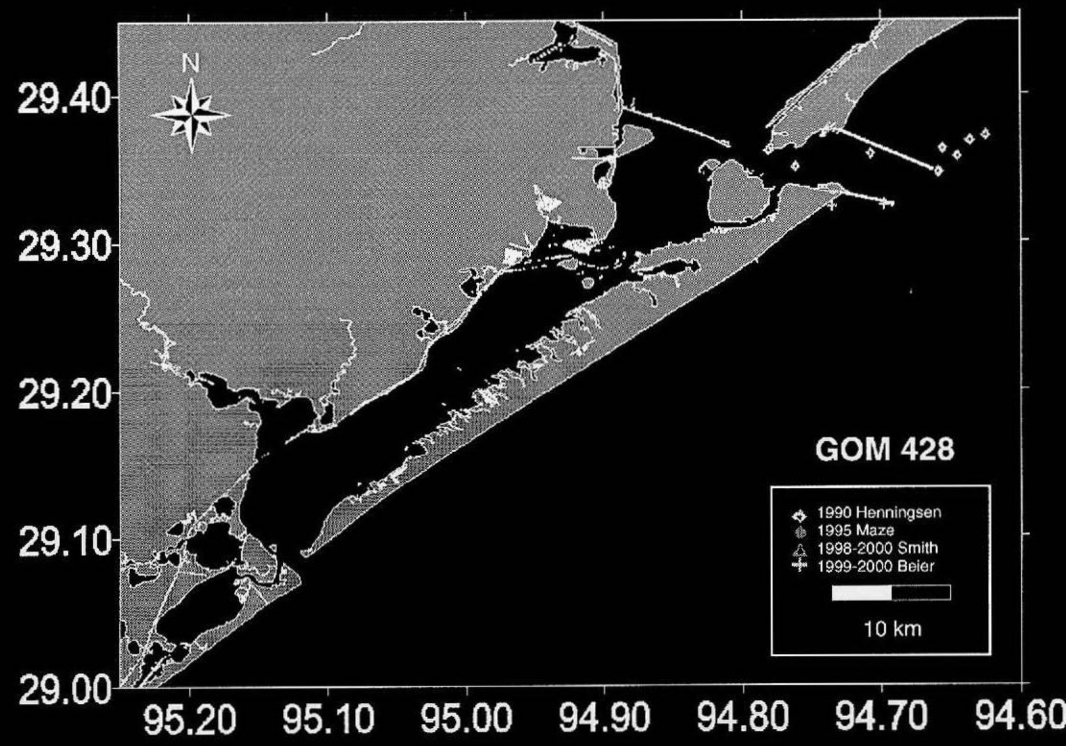

29.40
29.30
29.20
29.10
29.00
95.20
95.10
95.00
94.90
94.80
94.70
94.60
N
GOM102
10 km

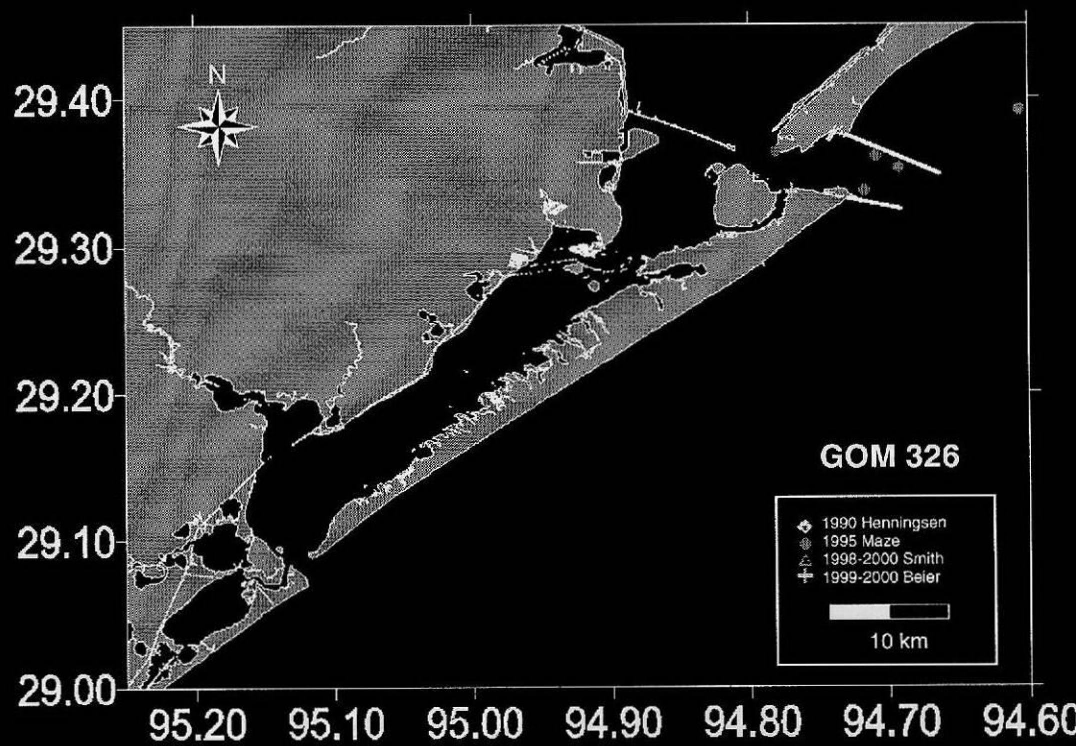
APPENDIX 2

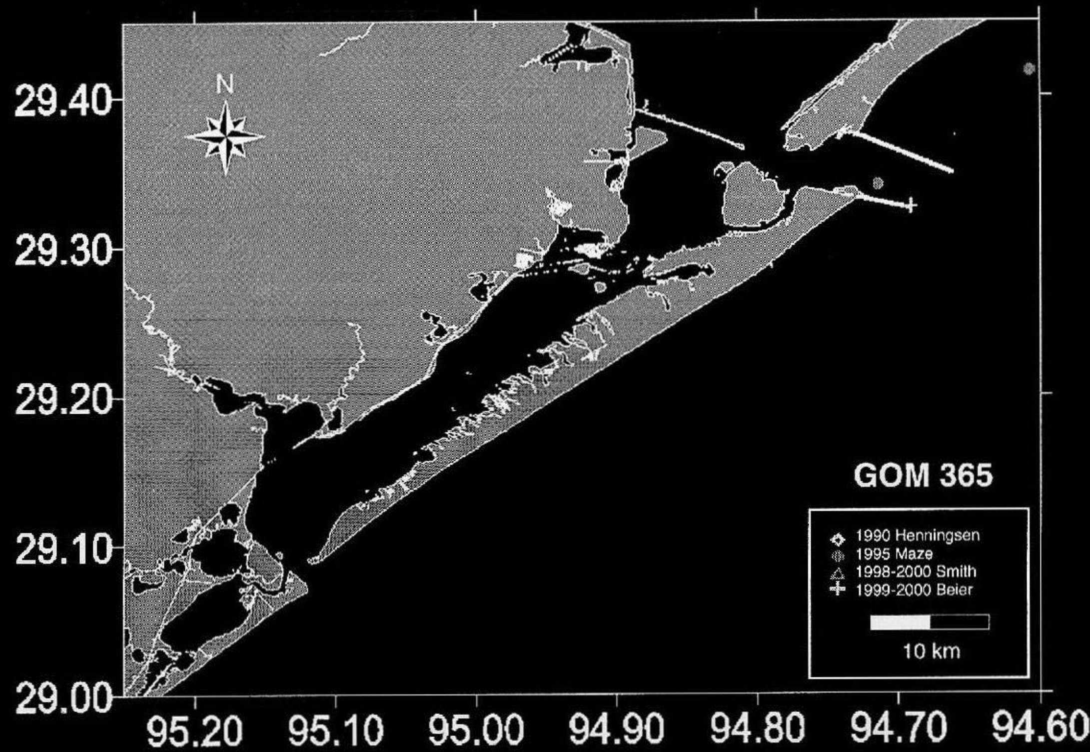
Movement pattern maps of individuals seen mostly in the Bolivar Peninsula and Houston Ship Channel areas.





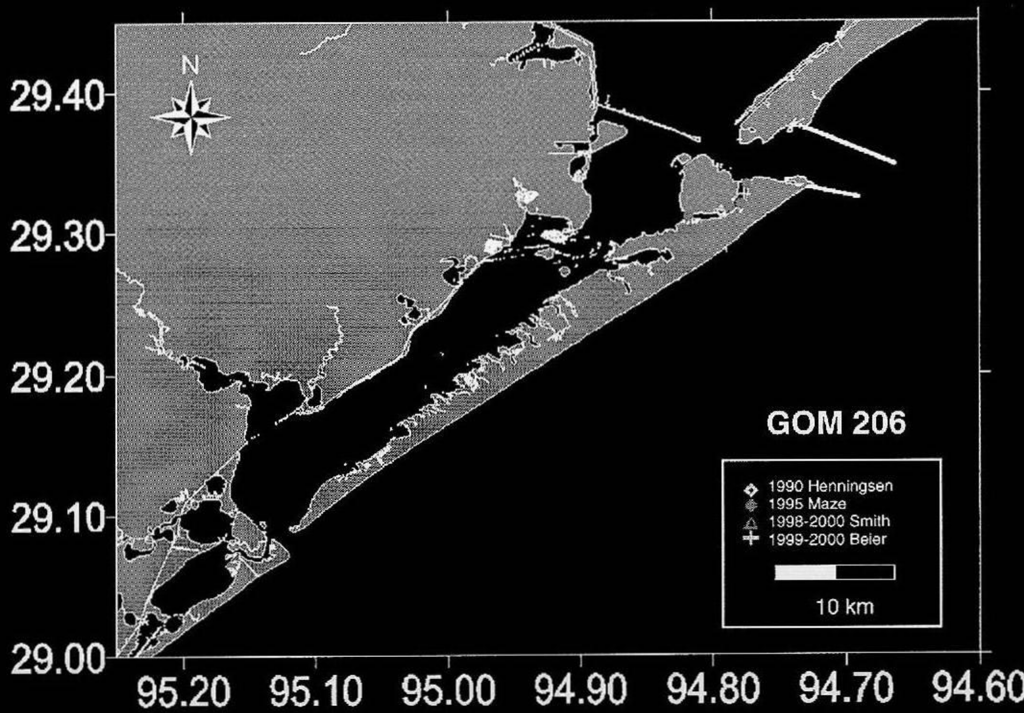

N
29.40
29.30
29.20
29.10
29.00
GOM 428
1990 Henningsen
1995 Maze
1998-2000 Smith
1999-2000 Beier
10 km
95.20
95.10
95.00
94.90
94.80
94.70
94.60

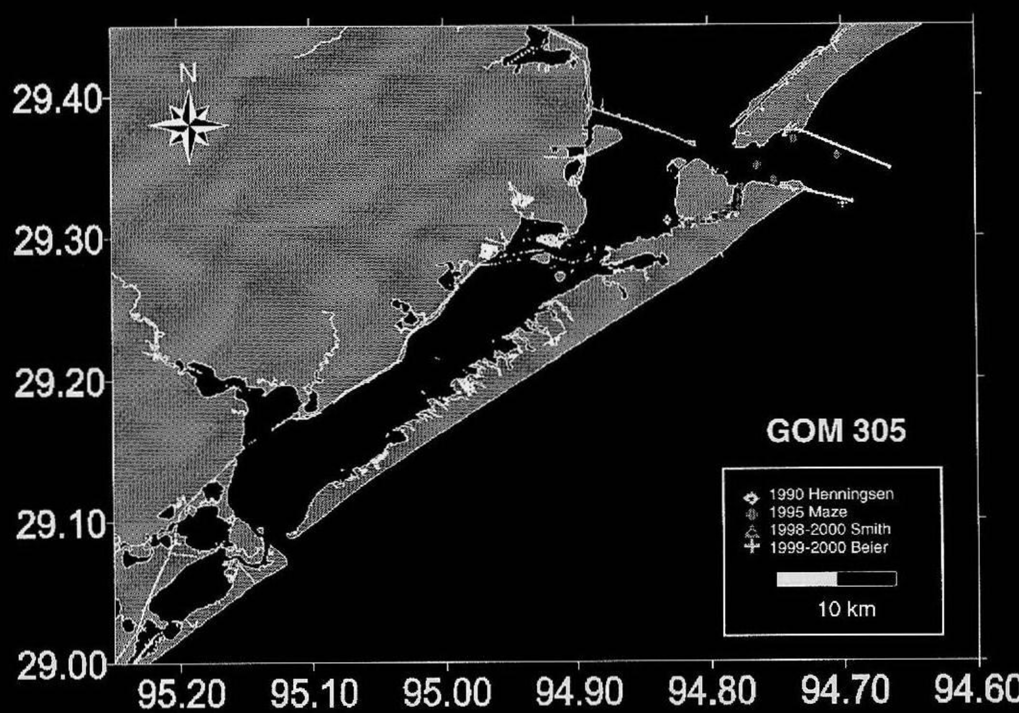

N
29.40
29.30
29.20
29.10
29.00
GOM 326
1990 Henningsen
1995 Maze
1998-2000 Smith
1999-2000 Beier
10 km
95.20
95.10
95.00
94.90
94.80
94.70
94.60

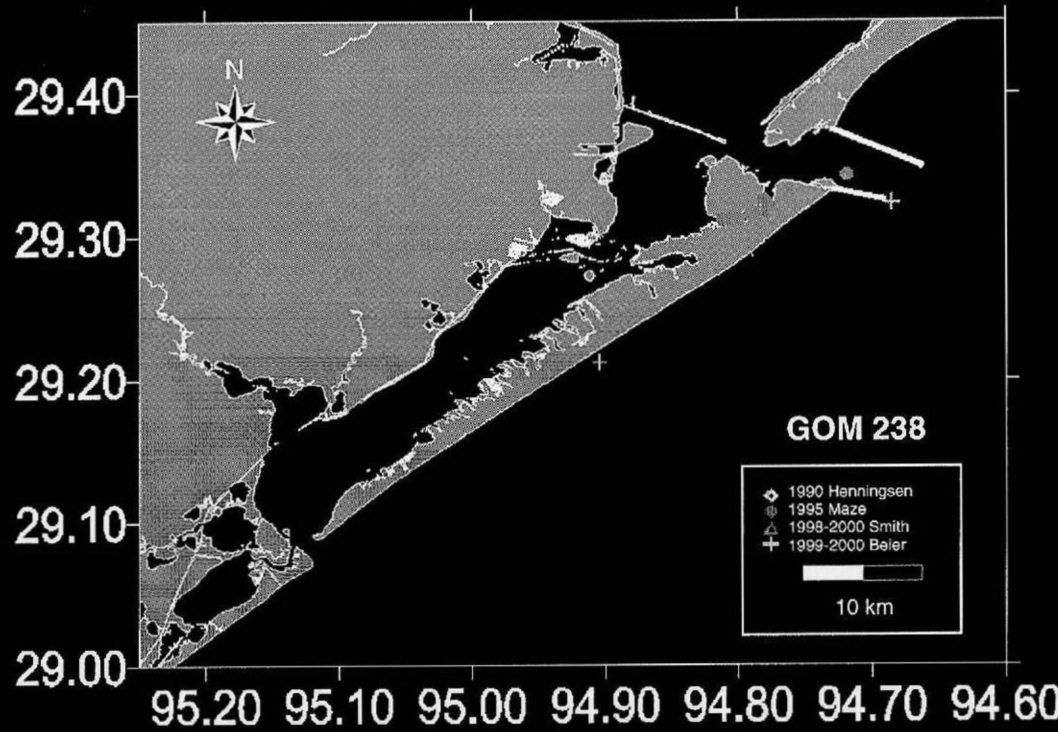

N
GOM 365
1990 Henningsen
1995 Maze
1998-2000 Smith
1999-2000 Beier
10 km
29.40
29.30
29.20
29.10
29.00
95.20
95.10
95.00
94.90
94.80
94.70
94.60

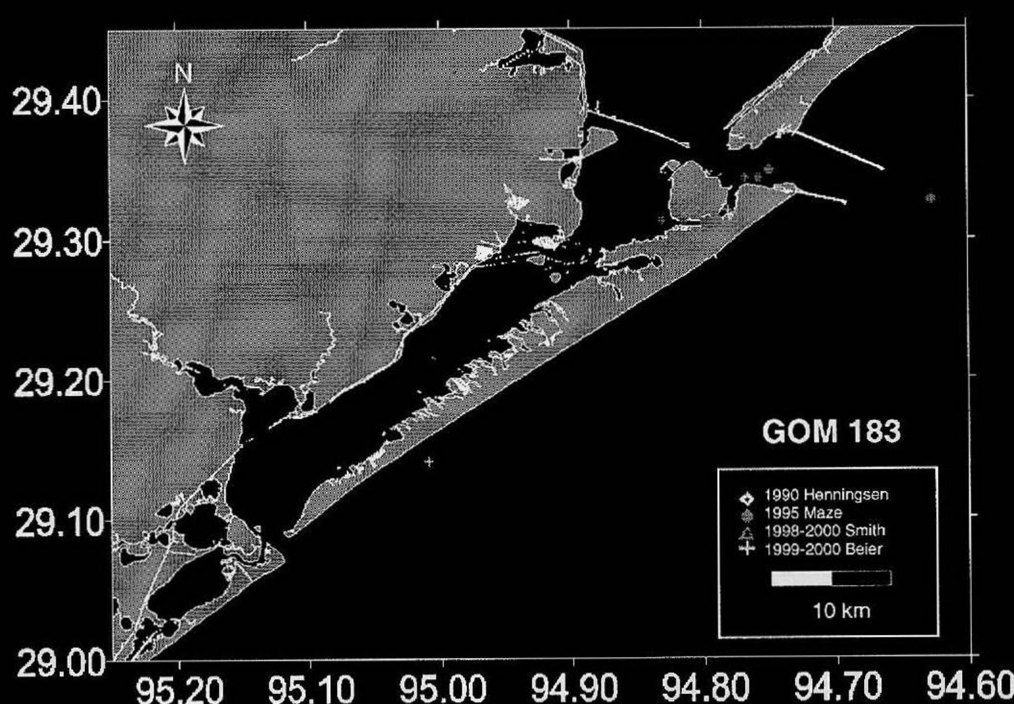
APPENDIX 3

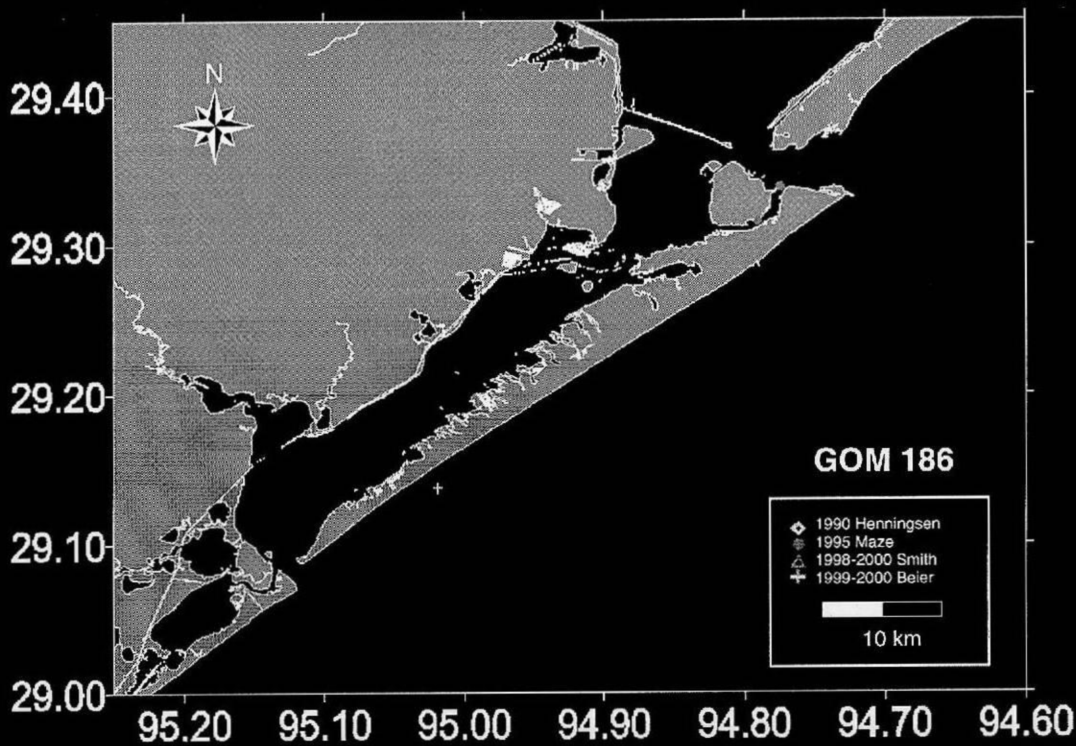
Movement pattern maps of individuals primarily seen in the Galveston Ship Channel.





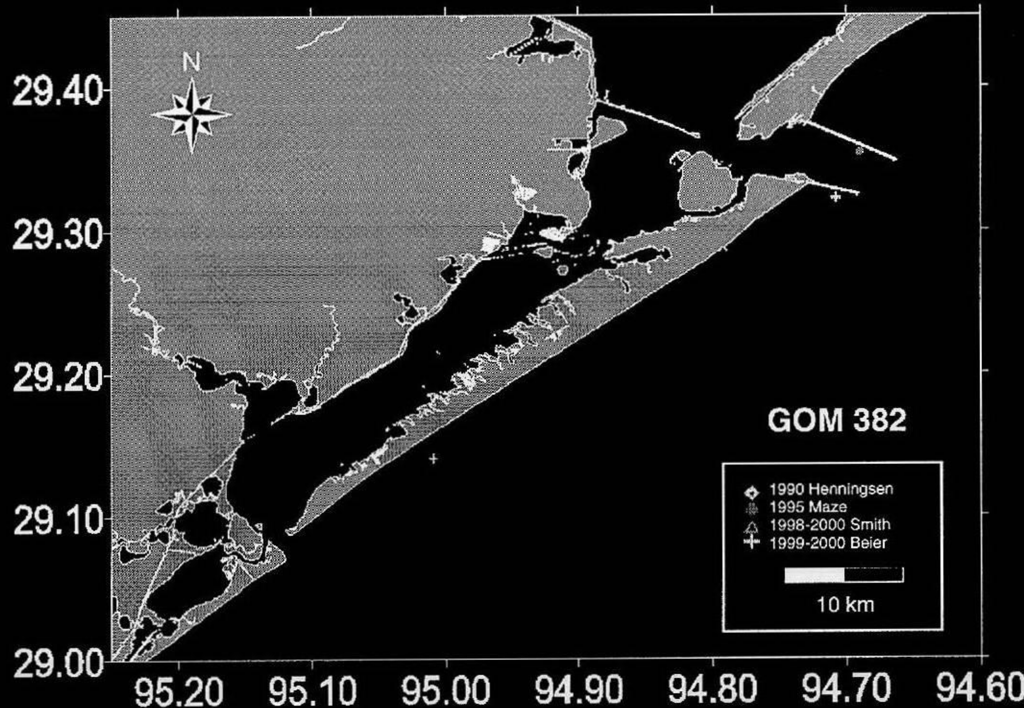

29.40
29.30
29.20
29.10
29.00
95.20 95.10 95.00 94.90 94.80 94.70 94.60
N
GOM 238
1990 Henningsen
1995 Maze
1998-2000 Smith
1999-2000 Beier
10 km

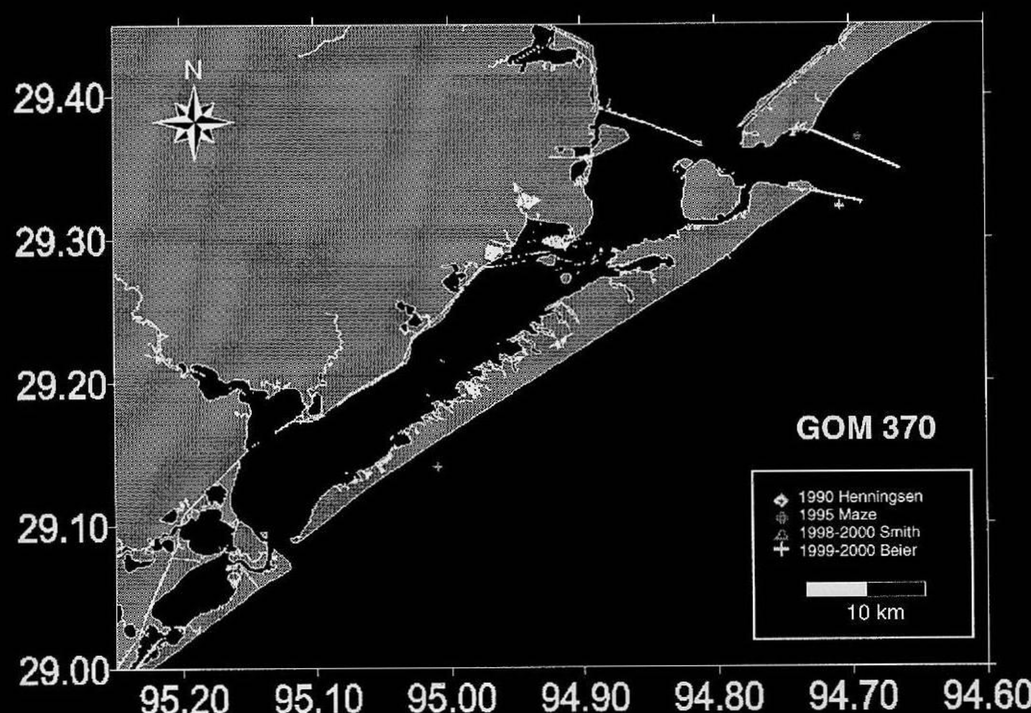

29.40
29.30
29.20
29.10
29.00
95.20 95.10 95.00 94.90 94.80 94.70 94.60
N
GOM 183
1990 Henningsen
1995 Maze
1998-2000 Smith
1999-2000 Beier
10 km

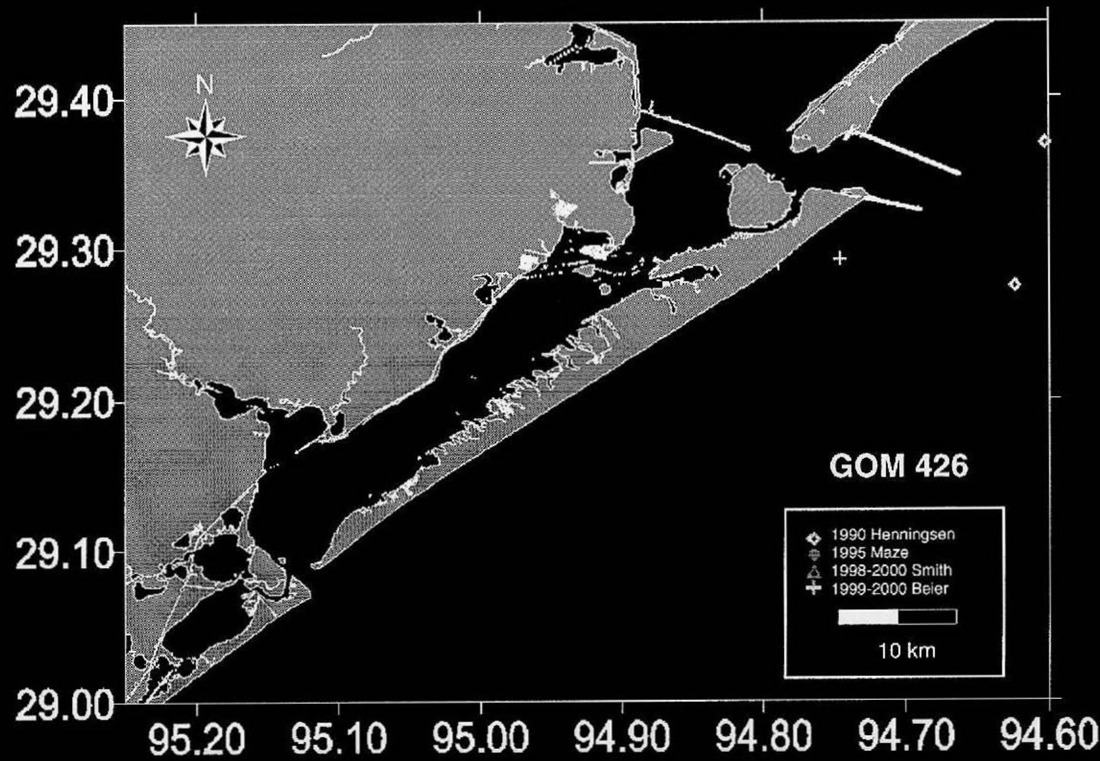

N
29.40
29.30
29.20
29.10
29.00
95.20
95.10
95.00
94.90
94.80
94.70
94.60
GOM 186
1990 Henningsen
1995 Maze
1998-2000 Smith
1999-2000 Beier
10 km

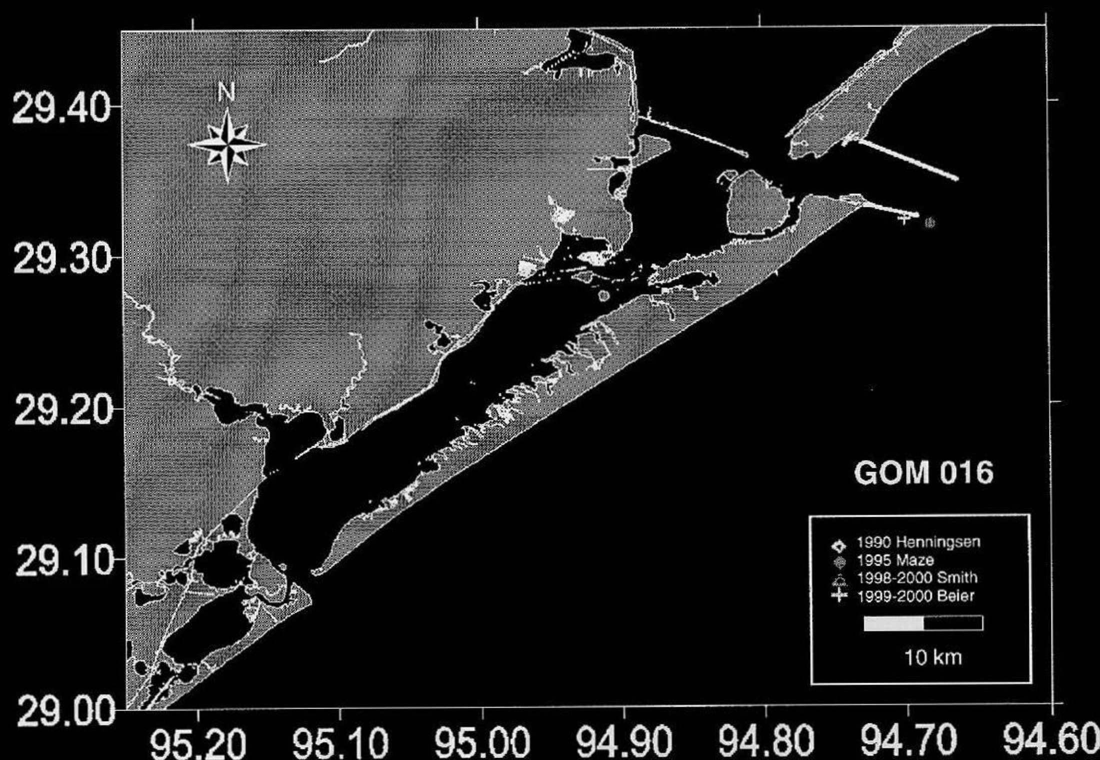
APPENDIX 4

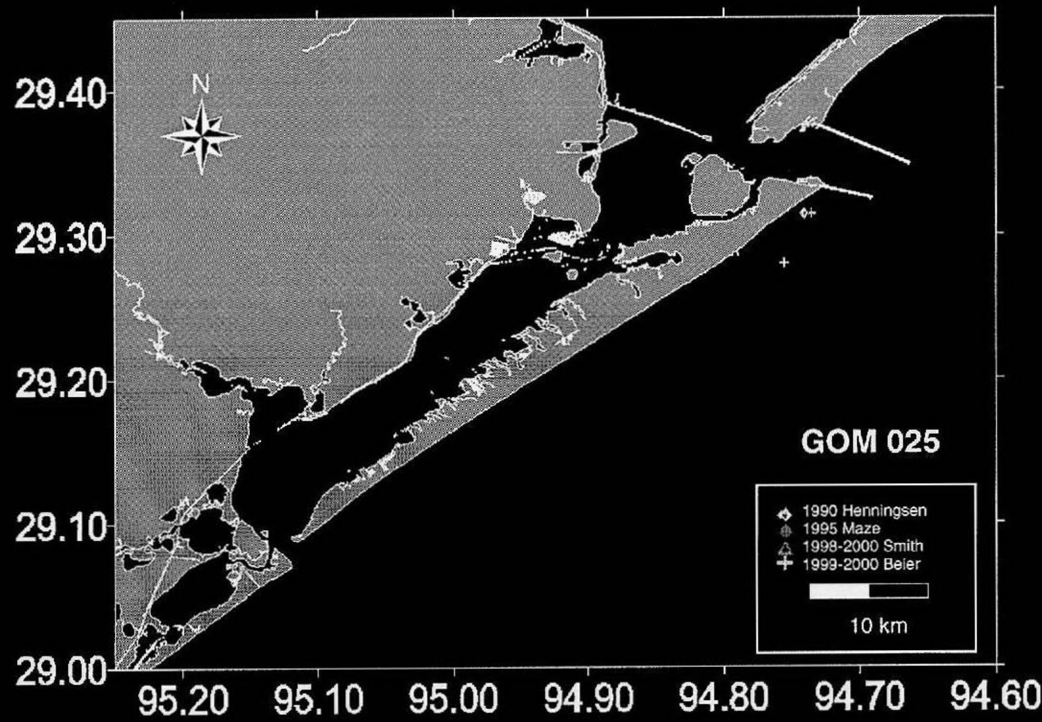
Movement pattern maps of individuals seen primarily near the North and South Jetties.





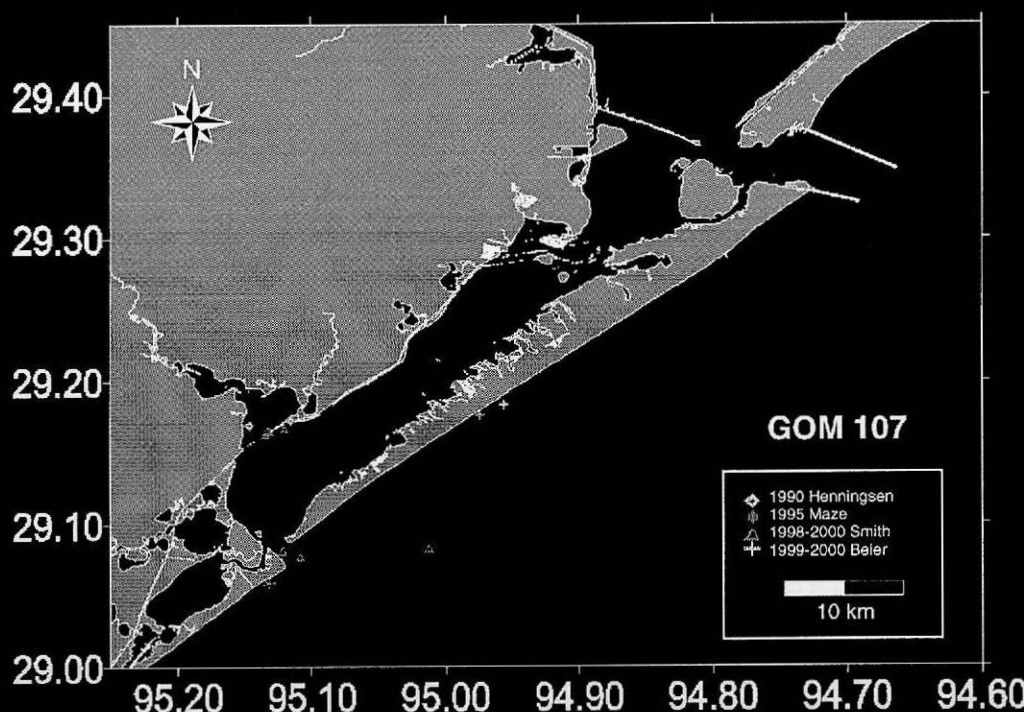

N
29.40
29.30
29.20
29.10
29.00
95.20
95.10
95.00
94.90
94.80
94.70
94.60
GOM 426
1990 Henningsen
1995 Maze
1998-2000 Smith
1999-2000 Beier
10 km

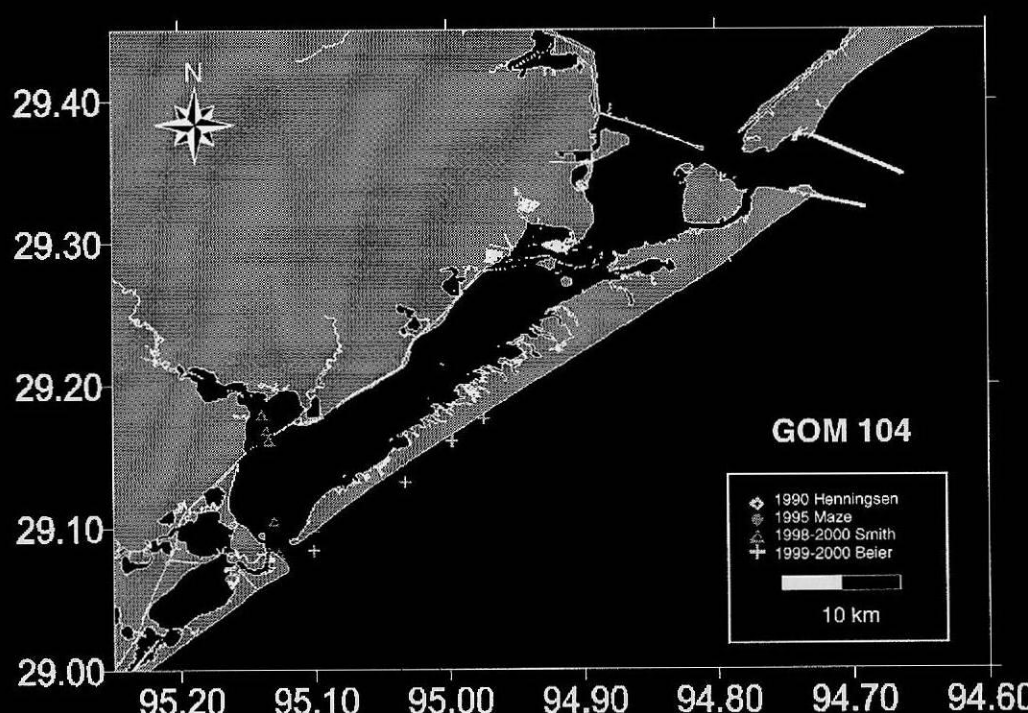

N
29.40
29.30
29.20
29.10
29.00
95.20
95.10
95.00
94.90
94.80
94.70
94.60
GOM 016
1990 Henningsen
1995 Maze
1998-2000 Smith
1999-2000 Beier
10 km

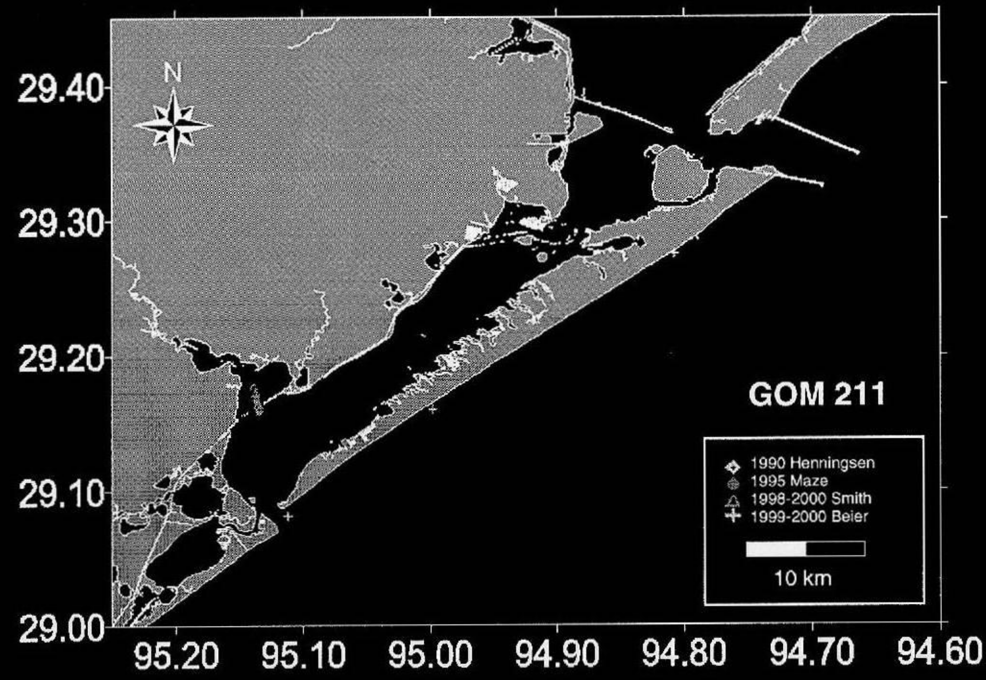

29.40
29.30
29.20
29.10
29.00
95.20
95.10
95.00
94.90
94.80
94.70
94.60
N
GOM 025
1990 Henningsen
1995 Maze
1998-2000 Smith
1999-2000 Beier
10 km

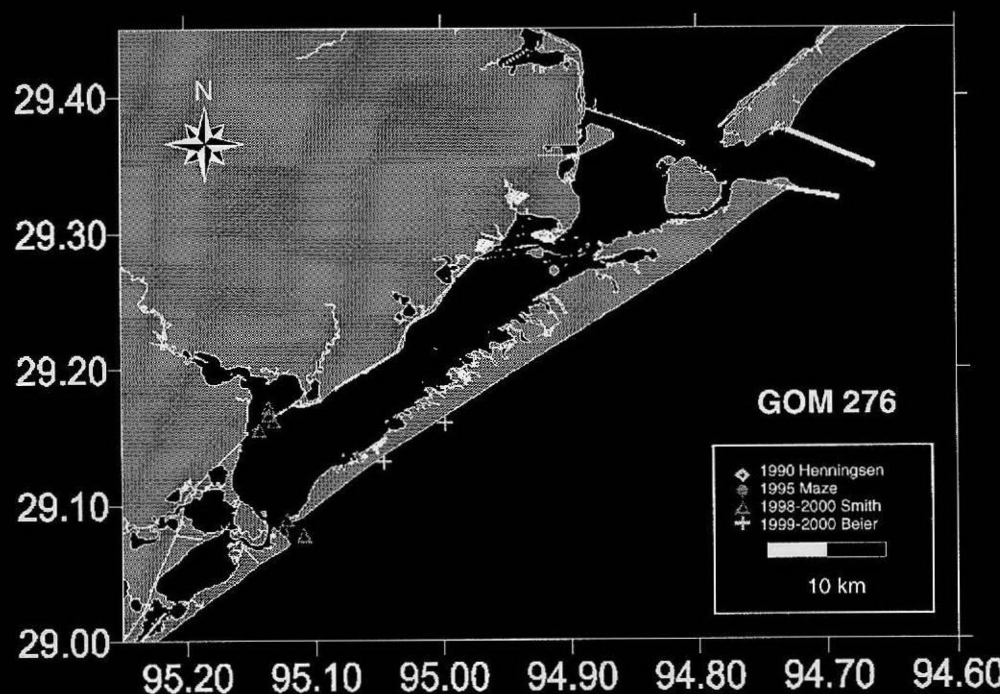
APPENDIX 5

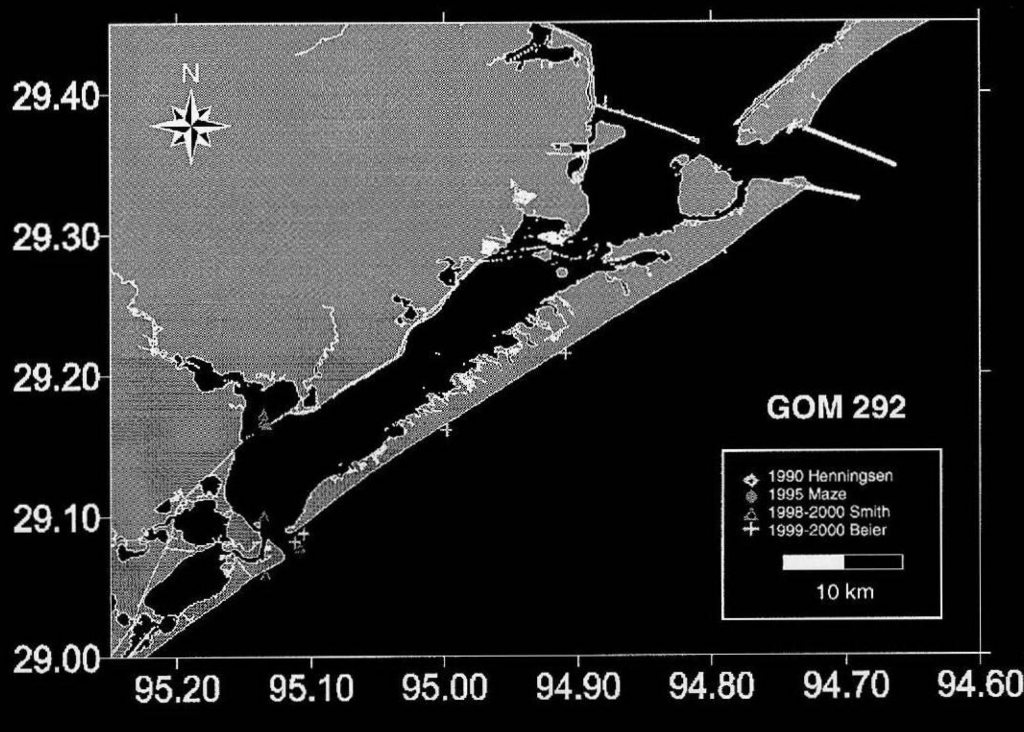
Movement pattern maps of individuals designated as San Luis Pass "residents" that do not travel far into the Gulf along Galveston Island.

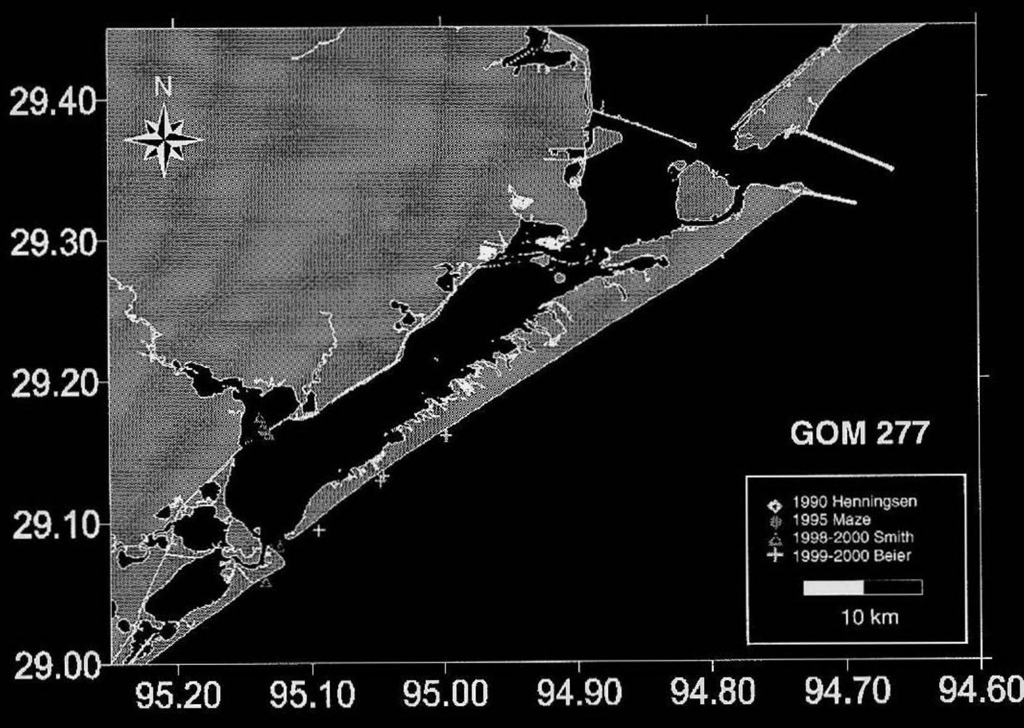





29.40
29.30
29.20
29.10
29.00
95.20
95.10
95.00
94.90
94.80
94.70
94.60
N
GOM 211
1990 Henningsen
1995 Maze
1998-2000 Smith
1999-2000 Beier
10 km

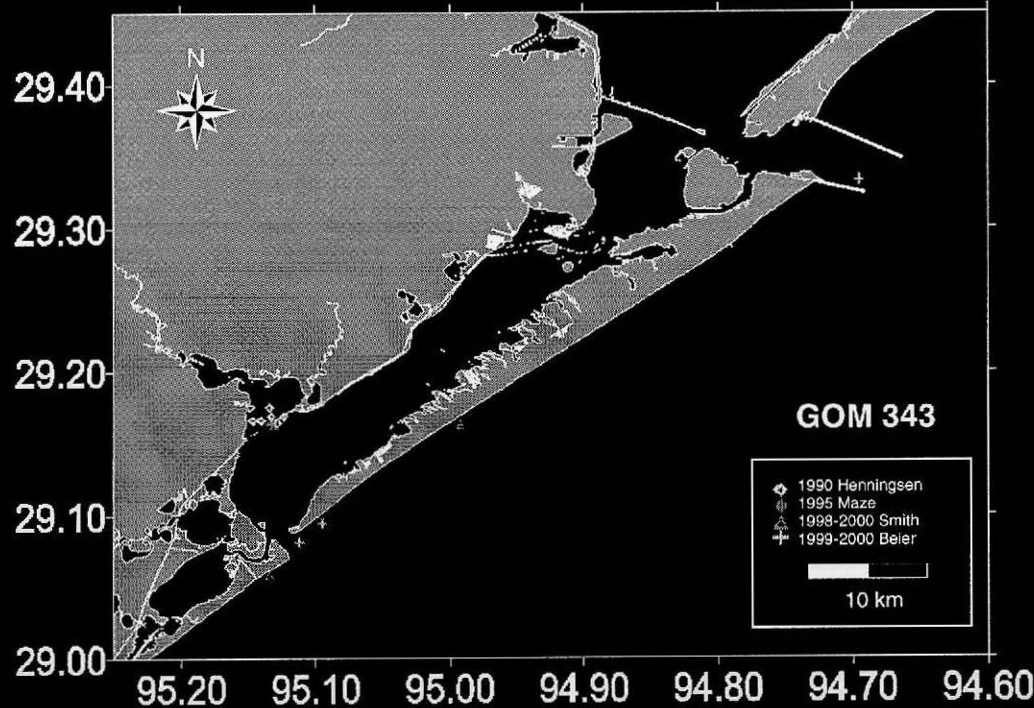

29.40
29.30
29.20
29.10
29.00
95.20
95.10
95.00
94.90
94.80
94.70
94.60
N
GOM 276
1990 Henningsen
1995 Maze
1998-2000 Smith
1999-2000 Beier
10 km

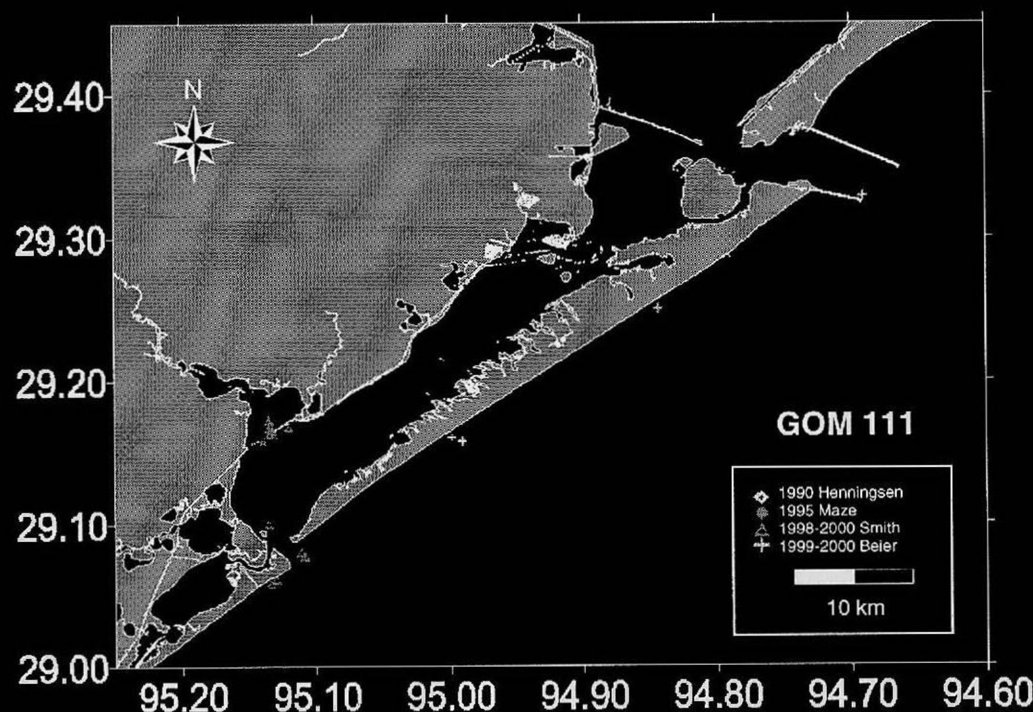

N
GOM 292
1990 Henningsen
1995 Maze
1998-2000 Smith
1999-2000 Beier
10 km
29.40
29.30
29.20
29.10
29.00
95.20
95.10
95.00
94.90
94.80
94.70
94.60

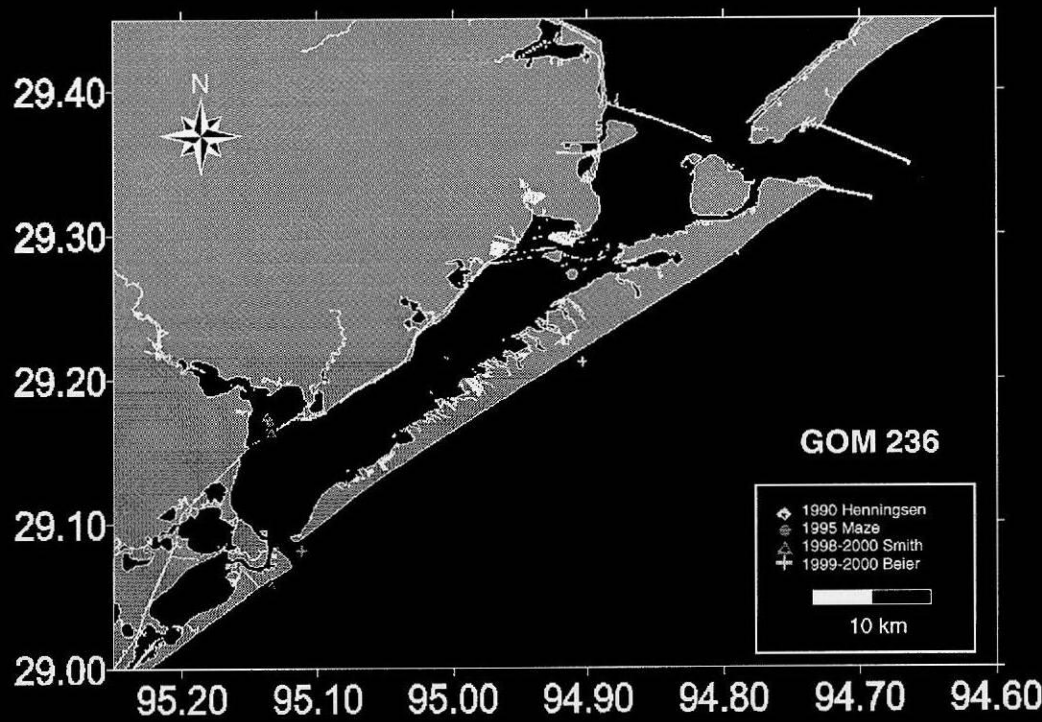

N
GOM 277
1990 Henningsen
1995 Maze
1998-2000 Smith
1999-2000 Beier
10 km
29.40
29.30
29.20
29.10
29.00
95.20
95.10
95.00
94.90
94.80
94.70
94.60

APPENDIX 6

Movement pattern maps of individuals designated as San Luis Pass "residents" that traveled further than Jamaica Beach along Galveston Island in the Gulf.

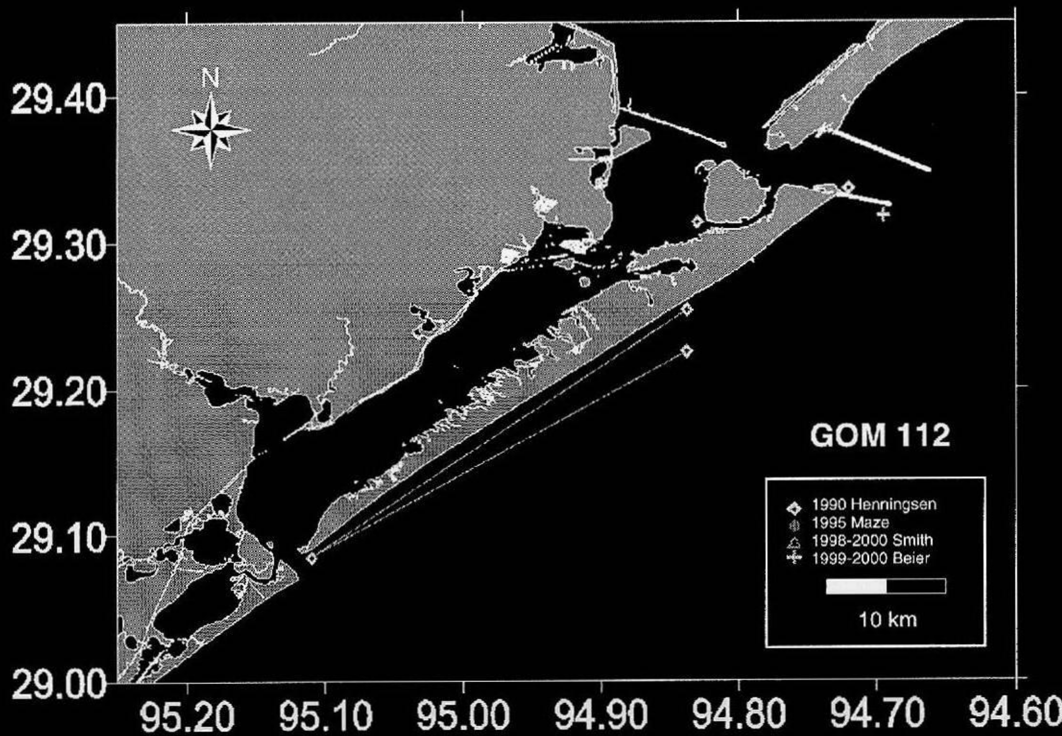





N
29.40
29.30
29.20
29.10
29.00
95.20
95.10
95.00
94.90
94.80
94.70
94.60
GOM 236
1990 Henningsen
1995 Maze
1998-2000 Smith
1999-2000 Beier
10 km

APPENDIX 7

Movement pattern map of an individual that was followed for almost four hours.



APPENDIX 8

Table listing date, location, and behavior observed by all groups seen in more than one study.

GOM ID Number	Match Study and ID Number	Date	Group Number	Nearest Landmark*	Behavior
GOM 003		07/24/99	1	SJ	Travel, Social, Feed
	GAL 042	02/19/95	2	GSC	FSB
		08/10/95	4	HSC	Unknown
		08/15/99	6	HSC	Travel
	Hen 005	05/09/90	4	BOL	FSB, Social
		07/03/90	3	HSC	Travel, Social
		07/22/90	2	NJ	FSB
		07/27/90	4	BOL	FSB
		08/02/90	5	NJ	FSB, Travel, Play
		08/05/90	2	BOL	FSB
		08/07/90	3	HSC	Travel
		09/18/90	4	HSC	Travel, Feed
GOM 016		07/24/99	1	SJ	Travel, Social, Feed
	GAL 521	09/13/95	5	SJ	Travel, Social, Feed
GOM 035		07/24/99	3	GV	Travel, Mill, FSB
		07/14/00	5	FG	FSB
	Hen 053	05/05/90	3	GV	Feed
GOM 067		08/28/99	2	SJ	Feed, Play, Social
	GAL 431	08/17/95	6	BOL	Feed
GOM 070		07/30/99	6	69th	Feed, Play, Social
	Hen 061	05/09/90	4	BOL	FSB, Social
		09/29/90	2	HSC	Travel, Play
GOM 104		08/03/99	3	JB	Travel
		10/15/99	2	WT	Play, Travel
		11/08/99	2	JB	Play, Social
		11/14/99	4	SLP	Play, Social
	SLP 006	06/23/98	1	CB	Social, Travel, Feed
		07/09/98	2	CB	Feed, Social
		07/21/98	1	SLP	Feed, Social
		11/27/98	3	SLP	Travel, Social Play
		11/28/98	2	SLP	Social, Play
		01/31/99	3	SLP	Travel, Play, Social
		08/26/99	2	SLP	Feed, Social, Play
		08/12/00	2	SLP	Feed
		09/02/00	2	CB	Feed
GOM 106		08/03/99	3	JB	Travel
		08/03/99	4	JB	Travel

APPENDIX 8, cont.

		11/14/99	4	SLP	Play, Social
		12/07/99	3	SLP	Play
	SLP 032	04/16/98	1	SLP	Feed, Travel, Play
		11/28/98	2	SLP	Social, Play
		08/26/99	1	CB	Social, Feed, Travel
		06/25/00	2	CB	Social
		09/02/00	1	CB	Social, Feed, Play
		09/02/00	3	CB	Social, Play, Feed
GOM 107		08/03/99	3	JB	Travel
		08/03/99	4	JB	Travel
	SLP 018	07/21/98	1	CB	Feed, Social
		11/27/98	3	SLP	Travel, Social, Feed
		01/31/99	3	WT	Travel, Social, Play
		07/29/99	2	CB	Social, Travel
		08/26/99	2	SLP	Feed, Social, Travel
	Hen 620	08/31/90	1	CB	Play, Feed
		09/07/90	1	CB	Travel, Play, Feed, Social
GOM 111		08/06/99	2	69th	Play, Social
		09/20/99	3	JB	Travel, Play, Social
		11/08/99	2	JB	Play, Social
		12/07/99	2	SJ	Feed, Social
	SLP 085	06/23/98	1	CB	Social, Travel, Feed
		07/02/98	2	CB	FSB, Travel, Play
		11/27/98	3	SLP	Travel, Social, Feed
		01/31/99	3	SLP	Travel, Play, Social
		07/29/99	6	CB	Social, Travel, Play
		09/16/99	1	CB	Feed
GOM 112		08/21/99	5	SJ	Feed
	Hen 544	08/05/90	10	HSC	Social, Travel, Play
		08/09/90	10	**	Travel, Social
		09/09/90	3	BB	Feed
GOM 145		02/09/00	5	SJ	Feed
	GAL 430	05/10/95	5	BOL	Travel
GOM 183		08/28/99	9	WT	FSB, Social, Play
		09/10/99	1	GSC	Social, Play, Travel
	GAL 061	03/11/95	4	BB	Travel, Feed
		04/19/95	2	GSC	Social
		05/10/95	4	BOL	FSB
		06/01/95	5	GSC	Feed, Travel
		06/14/95	8	GSC	Social, Travel
		06/21/95	2	GSC	FSB, Travel
		07/01/95	4	HSC	
		08/10/95	4	HSC	Unknown

APPENDIX 8, cont.

		08/25/95	2	HSC	Social, Play
		09/01/95	1	GSC	FSB
		09/06/96	3	HSC	Travel, Feed, Social
GOM 186		11/14/99	2	SJ	Play
		11/14/99	3	JB	Social, Travel, Play
	GAL 334	07/01/95	1	GSC	FSB
		07/01/95	3	GSC	FSB, Social, Play
GOM 200		09/10//99	1	GSC	Social, Play, Travel
		09/10/99	2	GSC	Travel, Feed
	GAL 265	06/14/95	8	GSC	Social, Travel
GOM 206		09/10/99	1	GSC	Social, Play, Travel
	GAL 412	08/25/95	6	GSC	Feed, Social
		09/13/95	2	GSC	Play
		09/13/95	3	GSC	Feed, Social, FSB
		09/27/95	1	GSC	Feed, Social
	Hen 698	09/15/90	1	GSC	FSB, Social
GOM 211		09/20/99	2	SLH	Social, Play, Travel
		11/08/99	2	JB	Play, Social
		12/07/99	3	SLP	Play
	SLP 086	06/23/98	1	CB	Social, Travel, Feed
		07/02/98	2	CB	FSB, Travel, Play
		07/21/98	1	CB	Feed, Social
		11/27/98	3	SLP	Travel, Social, Feed
		11/28/98	2	SLP	Social, Play
		05/20/99	1	CB	FSB, Travel, Social
		07/29/99	6	CB	Social, Play, Travel
GOM 221		09/20/99	4	SLP	Social
		12/07/99	3	SLP	Play
		01/19/00	4	JB	Play, Mill
	SLP 002	04/23/98	1	SLP	Travel
		07/21/98	1	CB	Feed, Social
		11/27/98	3	SLP	Travel, Feed, Social
		07/29/99	6	CB	Social, Travel, Play
		08/12/00	3	CB	Social, Feed, Play
GOM 223		09/21/99	4	SLP	Social
		10/15/99	2	WT	Play, Travel
		11/18/99	2	JB	Play, Social
		11/14/99	4	SLP	Social, Play
	SLP 165	06/23/98	1	CB	Social, Travel, Feed
		07/21/98	1	CB	Feed, Social
		11/28/98	2	SLP	Social, Play
		01/31/99	3	WT	Travel, Social, Play
		09/16/99	1	CB	Feed
GOM 224		09/20/99	4	SLP	Social

APPENDIX 8, cont.

		10/15/99	2	WT	Play, Travel
		11/08/99	2	JB	Play, Social
	SLP 195	03/17/98	1	SLP	Feed, Travel, Social
		06/23/98	1	CB	Social, Travel, Feed
		07/02/98	2	CB	FSB, Travel, Play
		04/07/99	1	SLP	Feed, Travel, Social
		07/22/99	1	CB	FSB, Social, Play
		06/25/00	2	SB	Social
GOM 225		09/20/99	4	SLP	Social
	SLP 034	11/28/98	2	SLP	Social, Play
		07/29/99	6	CB	Social, Travel, Play
		08/26/99	2	SLP	Feed, Social, Travel
		09/16/99	1	CB	Feed
GOM 236		09/20/99	6	RV	Travel, Social
		12/07/99	3	SLP	Play
	SLP 012	06/23/98	3	CB	Social, Play
		07/21/98	1	CB	Feed, Social
		11/27/98	3	SLP	Travel Social, Feed
		04/27/99	1	SLP	Feed. Travel, Social
GOM 238		09/20/99	6	RV	Travel, Social
		02/09/00	5	SJ	Feed
	GAL 114	04/29/95	2	GSC	FSB
		05/05/95	5	GSC	Feed, Social
		05/26/95	3	HSC	Social
		05/26/95	4	GSC	Social, Travel
		06/10/95	6	GSC	Travel
		06/26/95	1	GSC	FSB
		06/26/95	2	GSC	FSB
		08/05/95	1	GSC	FSB, Social
		08/10/95	5	GSC	Play
		08/15/95	1	GSC	FSB
		08/25/95	6	GSC	Feed, Social
		09/13/95	2	GSC	Play
		09/20/95	1	GSC	Travel, Social, FSB
		10/15/95	1	GSC	Social, Feed
GOM 262		09/24/99	3	69th	Feed, Travel
	Hen 900	10/14/90	4	69th	FSB
GOM 276		10/15/99	2	WT	Play, Travel
		11/08/99	2	JB	Play, Social
	SLP 051	07/02/98	1	CB	FSB, Social, Travel
		07/09/98	1	CB	FSB, Social
		01/31/99	1	WT	Travel, Play, Social
GOM 277		10/15/99	2	WT	Play, Travel
		10/25/99	7	WT	Play, Social

APPENDIX 8, cont.

		11/08/99	2	JB	Play, Social
		11/14/99	4	SLP	Play, Social
	SLP 004	07/02/98	2	CB	FSB, Travel, Play
		11/27/98	3	SLP	Travel, Social, Feed
		04/27/99	1	SLP	Feed, Travel, Social
GOM 288		11/08/99	1	SJ	Play
	GAL 467	08/25/95	2	HSC	Social, Play
GOM 292		11/08/99	2	JB	Play, Social
		11/08/99	3	RV	Play, Mill
		11/14/99	4	SLP	Play, Social
		12/07/99	3	SLP	Play
	SLP 061	07/21/98	1	CB	Feed, Social
		04/27/99	1	SLP	Feed, Travel, Social
		09/16/99	1	CB	Feed
		09/02/00	3	CB	Social, Play, Feed
GOM 293		11/08/99	2	JB	Play, Social
		11/14/99	4	SLP	Social, Play
	SLP 017	06/23/98	3	CB	Social, Play
		07/21/98	1	CB	Feed, Social
		04/27/99	1	SLP	Feed, Travel, Social
GOM 296		11/08/99	2	JB	Play, Social
		11/14/99	4	SLP	Social, Play
	SLP 007	07/21/98	1	CB	Feed, Social
		08/26/99	4	CB	Play
		06/25/00	2	CB	Social
GOM 297		11/08/99	2	JB	Play, Social
	SLP 218	07/22/99	1	CB	FSB, Social, Play
		08/26/99	4	CB	Play
GOM 305		11/10/99	1	GSC	Feed
		11/13/99	1	SJ	Travel, Play
		11/14/99	1	GSC	FSB
		06/30/00	3	GSC	Feed, Social
	GAL 034	01/28/95	1	GSC	Travel
		03/24/95	2	NJ	Feed, Travel
		06/01/95	2		
		06/21/95	3	HSC	Travel, Play
		07/09/95	1	GSC	FSB
		08/05/95	1	GSC	FSB, Social
		08/10/95	5	GSC	Play
		08/25/95	6	GSC	Feed, Social
		09/01/95	4	GSC	
		09/20/95	1	GSC	FSB, Travel, Social
		10/15/95	7	HSC	Feed
		11/15/95	2	HSC	Feed, Play

APPENDIX 8, cont.

		12/10/95	3	GSC	Travel, Feed
	Hen 657	10/14/90	1	BB	FSB
		09/28/90	1	GSC	FSB
GOM 307		11/10/99	3	HSC	Play
		01/11/00	1	SJ	Feed
		06/30/00	2	GSC	FSB
	GAL 147	05/10/95	6	BOL	FSB
		06/14/95	5	61st	Travel, Feed, Social
		06/21/95	4	BOL	Feed, Travel, Social, Play
		07/01/95	3	GSC	FSB, Social, Travel
		09/06/95	3	HSC	Social, Travel, Feed
		09/13/95	3	GSC	Feed, Social, FSB
		09/27/95	3	HSC	Unknown
	Hen 002	05/05/90	1	HSC	Feed, Social, Travel
		05/22/90	5	HSC	Feed, Social
		06/12/90	1	HSC	Feed
		07/06/90	1	GSC	FSB, Social
		07/10/90	1	GSC	FSB
		07/26/90	5	GSC	FSB, Travel
		08/02/90	2	HSC	Travel, Play
		08/09/90	3	BOL	Travel
		08/21/90	8	GSC	Travel
		08/24/90	1	GSC	FSB
		08/31/90	7	GSC	FSB
		09/16/90	3	GSC	Travel, FSB
		09/18/90	1	GSC	FSB, Social
		09/28/90	2	GSC	FSB
		09/29/90	3	GSC	FSB
		09/30/90	9	GSC	Rest, Feed, Social
		10/04/90	2	GSC	FSB
		10/07/90	1	GSC	Travel
		10/09/90	1	GSC	FSB
		10/29/90	2	GSC	Unknown
		10/30/90	2	GSC	FSB
		10/31/90	5	GSC	Unknown
GOM 313		11/10/99	3	HSC	Play
	GAL 117	05/05/95	2	GB	FSB, Travel
GOM 320		11/10/99	3	HSC	Play
	GAL 214	06/14/95	1	HSC	Travel, Social
		08/25/95	2	HSC	Social, Play
		09/01/95	9	HSC	Travel
		12/10/95	6	HSC	Feed, Travel, Play

APPENDIX 8, cont.

	Hen 270	06/19/90	3	BOL	Feed, Social
		09/18/90	9	BOL	FSB
GOM 326		11/10/99	3	HSC	Play
	GAL 079	04/14/95	3	BOL	Social, FSB, Travel, Feed
		09/01/95	9	HSC	Travel
		09/01/95	10	HSC	Travel
		09/06/95	2	HSC	Feed, Social
		09/06/95	3	HSC	Travel, Feed, Social
GOM 343		11/14/99	4	SLP	Play, Social
		12/07/99	3	SLP	Play
		01/19/00	1	SJ	Play, Social
		05/21/90	1	CB	Feed, Travel
		06/04/90	1	CB	Feed, Travel
		06/16/90	1	WB	Feed, Travel
		08/31/90	1	CB	Feed, Play
		09/07/90	1	CB	Travel, Feed, Play, Social
		09/17/90	1	CB	Feed, Play
		10/02/90	1	CB	Travel, Social
	SLP 020	06/23/98	1	CB	Social, Travel, Feed
		11/27/98	3	SLP	Travel, Social, Feed
		01/31/99	3	SLP	Travel, Social, Play
		05/20/99	1	CB	FSB, Travel, Social
GOM 350		11/14/99	4	SLP	Social, Play
		12/07/99	3	SLP	Play
	SLP 005	07/21/98	1	CB	Feed, Social
		11/28/98	2	SLP	Social, Play
		06/25/00	2	CB	Social
GOM 365		01/11/00	5	SJ	Feed, Social
	GAL 256	06/14/95	6	HSC	Unknown
		06/21/95	4	BOL	Feed, Social, Travel, Play
GOM 366		01/11/00	1	SJ	Feed
	GAL 177	06/01/95	7	GSC	FSB
		07/01/95	7	GSC	Feed, Social
		07/15/95	2	HSC	FSB, Play
GOM 370		01/11/00	2	SJ	FSB, Travel, Mill
	GAL 432	12/10/95	5	HSC	Travel
GOM 382		01/11/00	5	SJ	FSB, Play, Travel, Mill
	GAL 662	12/10/95	5	HSC	Travel
GOM 426		02/06/00	8	GV	FSB, Play, Social
	Hen 856	10/13/90	8	SJ	Travel

APPENDIX 8, cont.

		10/29/90	1	BOL	FSB, Social
GOM 428		02/09/90	3	SJ	Social
		04/05/00	3	SJ	Social, Play, Travel
	Hen 004	05/13/90	2	BOL	FSB, Travel, Social
		05/22/90	5	HSC	Feed, Social
		07/02/90	3	HSC	Travel, Social
		07/22/90	2	NJ	FSB
		07/27/90	4	BOL	FSB
		08/02/90	5	BOL	FSB, Travel, Play
		08/05/90	2	BOL	FSB
		08/07/90	3	HSC	Travel
		09/18/90	4	HSC	Travel, Feed
GOM 461		03/25/00	4	JB	FSB
	Hen 075	05/13/90	2	BOL	FSB, Travel, Social
GOM 483		03/25/00	4	JB	FSB
	Hen 063	05/05/90	3	BOL	FSB
GOM 545		04/21/00	1	FG	FSB, Social, Play
	Hen 885	10/14/90	2	69th	FSB
GOM 607		06/28/00	2	GV	Play
	GAL 304	06/21/95	4	BOL	Feed, Social, Travel, Play
GOM 614		07/24/99	1	SJ	Travel, Social, Feed
		07/30/99	6	69^{th}	Feed, Social, Play
	GAL 018	06/14/95	5	61^{st}	Travel, Feed, Social
GOM 616		07/14/00	2	ST	FSB, Travel
	GAL 308	06/21/95	4	BOL	Feed, Social, Travel, Play
GOM 626		07/14/00	6		Travel
	GAL 321	06/21/95	6	HSC	Mill, Social
GOM 315		11/10/99	3	GSC	Play
	GAL 029	10/25/95	8	GB	Social, travel
		01/10/95	6	HSC	Play
GOM 638		07/14/00	9	FG	FSB
	Hen 800	10/11/90	3	BOL	FSB

* Abbreviations are as follows: Bolivar Peninsula (BOL), Back Bay (BB), Chocolate Bay (CB), Flagship (FG), Galveston Bay (GB), Galveston Ship Channel (GSC), Galvestonian (GV), Houston Ship Channel (HSC), Jamaica Beach (JB), North Jetty (NJ), Riviera (RV), San Luis Hotel (SLH), San Luis Pass (SLP), South Jetty (SJ), Water Tower (WT), 61^{st} Street (61^{st}), and 69^{th} Street (69^{th}).

**Group was followed, starting at 69^{th} street to San Luis Pass, and back to 61^{st} Street.

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