OCCURRENCE PATTERNS AND BEHAVIOR OF BOTTLENOSE DOLPHINS (*TURSIOPS TRUNCATUS*) IN THE GALVESTON SHIP CHANNEL, TEXAS

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Abstract.—Surveys for bottlenose dolphins (*Tursiops truncatus*) were conducted in the Galveston Ship Channel between January 1990 and December 1992. Dolphins occurred year-round with seasonal peaks in spring and autumn. Many of the dolphins were well-marked and some appear to have scars resulting from human interactions. Dolphins observed in the Galveston Ship Channel appear to be part of an open population with no pronounced changes in the population size. Fifty-six individuals (23% of the individuals identified) were observed in all three years. Thirteen (23%) of the 56 dolphins were photographed as early as 1986/1987 in this same area, nine of these were determined to be females. Seventy-five percent of the 240 identified dolphins were sighted more than once during 1990-1992. Group sizes were small ($\bar{x}=3.2\pm$S.D.2.02 for groups without mother/calf pairs; $\bar{x}=2.9\pm$S.D.2.10 for groups with mother/calf pairs), and solitary dolphins were frequent (23% of groups with no mother/calf pairs were single individuals). The smallest groups, both with and without mother/calf pairs were observed in association with shrimp boats ($\bar{x}=2.7\pm$S.D.1.80 and $\bar{x}=2.7\pm$S.D.1.78, respectively), while the largest were socializing ($\bar{x}=3.7\pm$S.D.1.81 and $\bar{x}=4.2\pm$S.D.2.06, respectively).

The last 50 years has been characterized by a marked increase in studies conducted on the ecology of bottlenose dolphins (*Tursiops truncatus*) from coastal waters of the southeastern United States; particularly for dolphins in Florida and Texas. Gunter (1942, 1944, 1951, 1954) and Baughman (1946) provided the first opportunistic reports of Texas bottlenose dolphins. Bottlenose dolphin densities in Texas have since been reported by Shane and Schmidly (1978), Barham et al. (1980), Shane (1980), Gruber (1981), Leatherwood & Reeves (1983), Jones (1988), McHugh (1989), and Mullin et al. (1990). Detailed ecological studies have been conducted by Shane (1980), Gruber (1981), McHugh (1989), Henningsen (1991), and Bräger (1993). Most research had been limited to the Corpus Christi area; however, in the late 1980's through the early 1990's, studies were conducted in Galveston Bay (Jones 1988; Henningsen 1991; Bräger 1993, Bräger et al. 1994).

Bottlenose dolphins appear tolerant of human activities throughout their range (Leatherwood & Reeves 1982). Texas bottlenose dolphins occur in shallow and turbid waters which are often noisy, polluted, and near human population centers. The fact that bottlenose dolphins persist

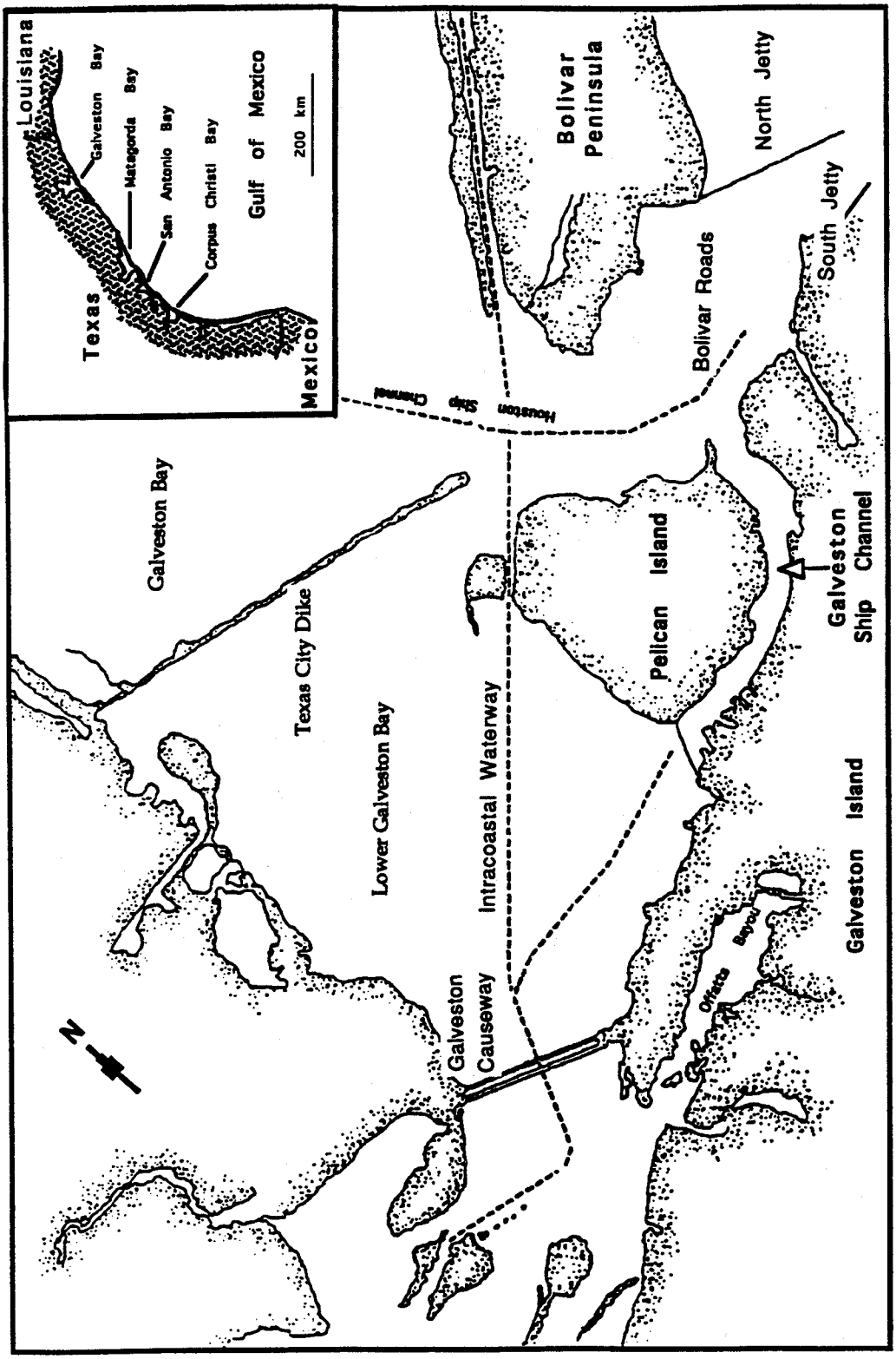

Figure 1. Map of Bolivar Roads and Lower Galveston Bay. Broken lines represent dredged areas for large vessel traffic. Inset map is of Texas coast.

in heavily trafficked ship channels and in areas of great human activity attests to their adaptability to human modified environments (Leatherwood & Reeves 1982).

The primary focus of this study was to investigate residence patterns and behaviors of dolphins which frequent the Galveston Ship Channel. It describes seasonal and inter-annual residence patterns, frequency of sightings, group sizes, and behaviors of identified dolphins.

Methods

Study Site.—The Galveston Bay complex is connected to the open waters of the Gulf of Mexico by two natural passes, Bolivar Roads and San Luis Pass. Bolivar Roads is an extensively modified area, with several dredged navigation channels, located in lower Galveston Bay between the northeast end of Galveston Island and southwestern tip of Bolivar Peninsula (Fig. 1).

The Galveston Ship Channel is one of the major channels in Bolivar Roads which facilitates commerce in the Galveston/Houston area. It is a 6.8 km long channel that is 342 m at the widest point, with a U-shaped bottom reaching a maximum depth of 12 m (T. Renny, U.S. Army Corp of Engineers, pers. comm.).

Survey Procedure.—The channel was surveyed by piloting a 5 m Boston Whaler at a slow speed in a meandering course always starting at the western end of the channel. Data were collected by two to four observers. Photographs of all individuals in each group encountered were taken and the group's behavior was recorded. Additional information noted included date, sighting conditions (weather and sea state), location, time of each group observation, group size and composition, and familiar animals.

Definition of Group.—A group of dolphins was one or more individuals engaged in the same activity within five dolphin body lengths of each other. Additionally, for shrimp boat associations, all dolphins following within 10 m behind or to the side of the stern of one shrimp boat were considered to be a group.

Recognition of Individual Dolphins.—The most commonly applied method for recognition of individual bottlenose dolphins is photo-identification by natural marks on the dorsal fin (Würsig &

Würsig 1977; Würsig & Jefferson 1990). Black and white photographs (Kodak T-MAX 400) and color slides (Kodachrome 200 and 64) were taken with 35 mm Nikon FM and Nikon 2000 cameras, equipped with 70-210 mm zoom lenses and motor drives. Photographs were printed from high quality negatives or slides. Dorsal fin photographs were catalogued by fin shapes and number and location of fin notches.

Definition of Age/Sex Classes.—The sex of dolphins was determined by one or more of the following criteria:
Female: observation of a calf consistently accompanying an adult; long genital slit and the presence of mammary slits [Though the presence of mammary slits should not be not used alone to determine sex of an animal since males sometimes develop skin folds that resemble mammary slits (Jefferson et al. 1994)];
Male: observation of an erect penis; a sexually dimorphic distance between the genital slit and anus.

A calf was considered to be an individual, two-thirds or less the length of an adult, that swam beside and slightly behind an adult (Shane 1990a). A mother was identified when it was an adult along with a calf, or observed as part of a group with a calf on several days. Repeated observations helped determine individuals as a mother (Shane 1990a). Juveniles were approximately two meters long and swam independently (Shane 1990a).

Behavioral Data.—Dolphin behavior was collected in an *ad libitum* manner (Altmann 1974), two to three minutes into the observation period, and then upon a change in group behavior. Observed behavior was classified into four major categories (traveling, milling, socializing, feeding) according to the definitions provided by Shane (1990a). In addition to these four categories, a sub-behavior of feeding was added: **Feeding in association with shrimp boats (FSB)**: repeated dives in varying directions around the side or behind the stern (the trawl cod end was approximately 20 m behind the stern) of a shrimp boat.

Seasonal Occurrence.—Seasons were defined as those by Shane (1977), Gruber (1981), Jones (1988): summer (June, July, August), fall (September, October, November), winter (December, January, February), and spring (March, April, May).

Seasonal patterns of occurrence was determined for the 56 individuals observed during all three years by pooling sightings by seasons.

Analysis by season was done to help correct for uneven survey effort within smaller time frames.

Inter-annual Sightings.—As examination of sighting patterns was conducted for identified dolphins to determine if any individuals exhibited inter-annual trends of residency. Each identified dolphin was placed in one of three categories of annual sighting (i.e. a dolphin was seen either during one, two, or all three years). A portion of the incomplete photo catalog of Michael Hunt of University of Houston-Clearlake, who previously photographed bottlenose dolphins in the study area, was reviewed to determine if any of the dolphins identified during the course of this study were observed as early as 1986/1987 in the area.

Data Set Partitioning.—For analysis of group size and behavior patterns, I used only data collected during April 1991 through March 1992, which not only reflected confidence in that data set, but also provided me with the most accurate description of group composition and behavior.

Mother/calf group data were analyzed in several ways to answer different questions. Calves were included as members of groups to determine if mother/calf pairs occurred in larger groups than other individuals. Calves were excluded from calculations for mean group sizes, to compare group sizes of non-calf individuals relative to behavioral state, and because a mother/calf pair were considered to be a behavioral unit.

Results

Survey Effort.—A total of 272 surveys, with approximately 880 hours spent in direct observation of dolphins, was conducted in the Galveston Ship Channel between January 1990 and December 1992. Dolphin groups were encountered on 90% (n=245) of these surveys.

Identified Dolphins.—Two hundred and forty individual dolphins were identified from natural dorsal fin markings. Twenty-seven were determined to be females and two were males. Several animals had wounds that were probably either the result of shark bites or boat propeller collisions and other human interactions.

Rate of Discovery.—The rate of discovery curve can provide information regarding immigration into a study area. The rate at which

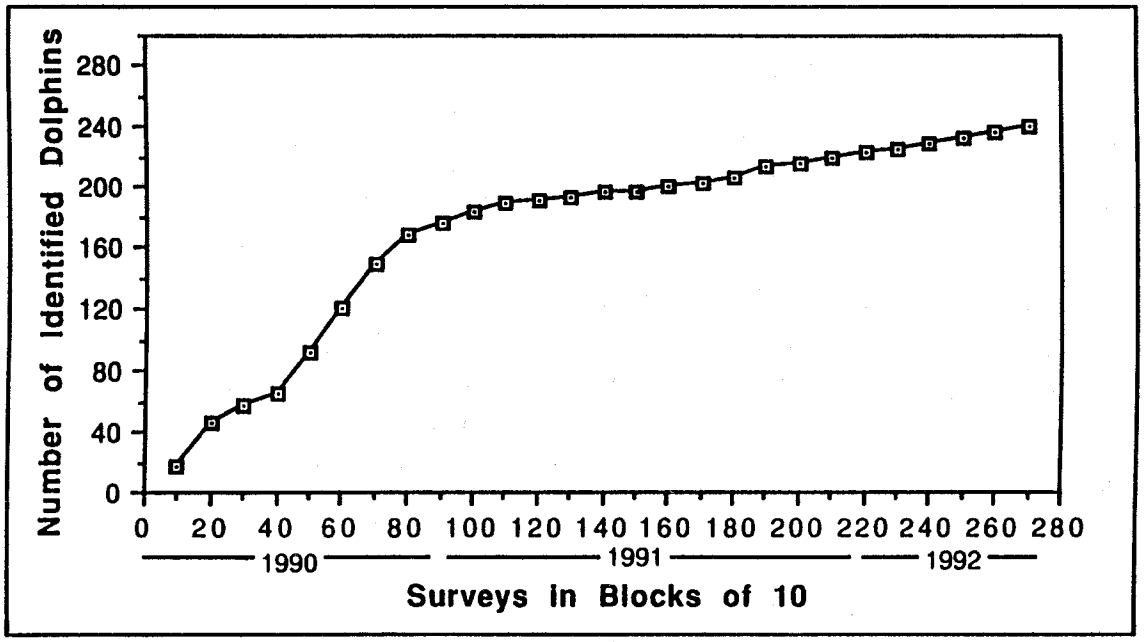

Figure 2. Cumulative rate at which individual dolphins were photo-identified in the Galveston Ship Channel. The data is presented in blocks of 10 surveys and the corresponding year is provided.

new dolphins were identified decreased at about ten months into the study (Fig. 2). Within ten months, or 80 surveys, 71% of the total number of dolphins using the study area had been photographed. The slight increase in the curve after 10 months demonstrates that new dolphins were continually being identified in the Galveston Ship Channel.

Inter-annual Sightings.—One hundred and two (42%) of the 240 identified dolphins were sighted only during one year, 82 (34%) during two years, and 56 (23%) in each of the three years. A minimum of thirteen dolphins (23%) of the 56 sighted in 1990-1992 were photographed as early as 1986/1987 in this area, and nine of these were females. Seven of these females were accompanied by a calf at some time during April 1991 - March 1992; one was classified as a juvenile, while the remaining animal was an adult female. The only other animals for which sex was determined, were accompanied by calves during April 1991 - March 1992.

Seasonal Occurrence.—The average number of identifiable individuals sighted per hour peaked in the late spring and early fall of each of the three years (Fig. 3).

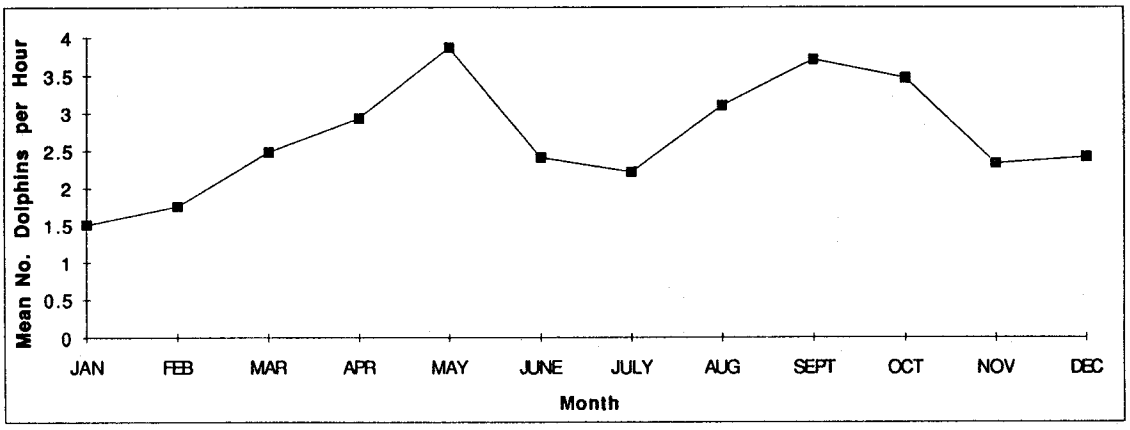

Figure 3. Mean number of recognizable dolphins sighted per hour per month in the Galveston Ship Channel during 1990-1992.

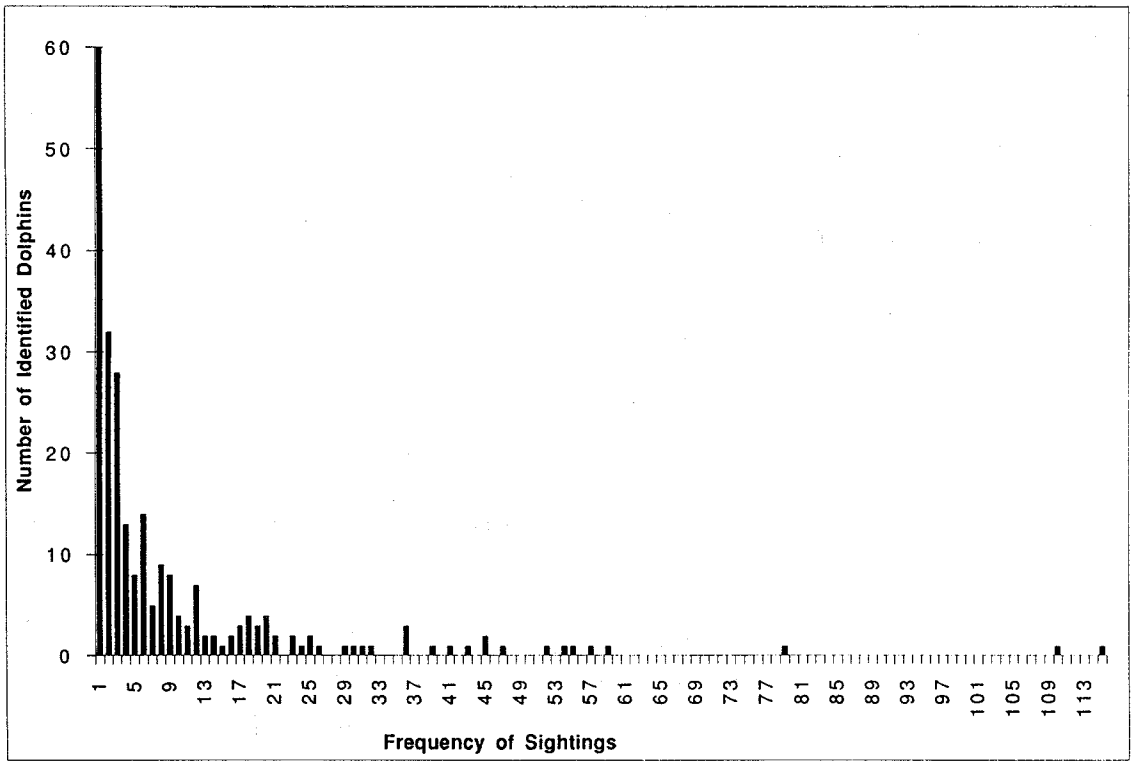

Figure 4. Frequency of sightings of identified dolphins for 1990-1992. For example, one dolphin was sighted on 115 separate days.

Forty-six percent (n=26) of the 56 dolphins sighted during all three years were sighted in multiple winters; 55% (n=31) in multiple springs; 46% (n=26) in multiple summers; 79% (n=44) in multiple falls.

Frequency of Resightings.—Number of sightings for the 240 identified dolphins ranged from one to 115 (Fig. 4). Seventy-five percent (n=180) of all dolphins were sighted more than once. The maximum number of sightings was for dolphin AAB, a juvenile female. Sixty-

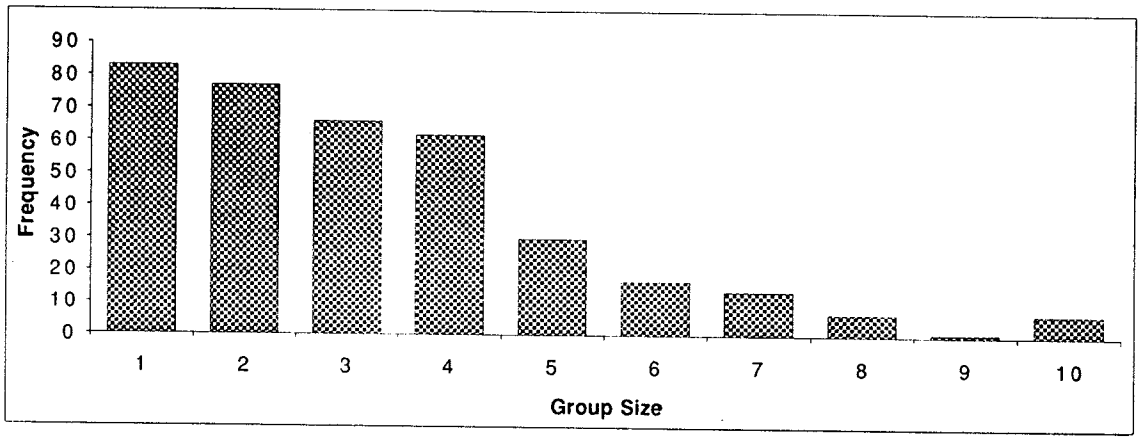

Figure 5. Frequency of group sizes for non-mother/calf groups in the Galveston Ship Channel.

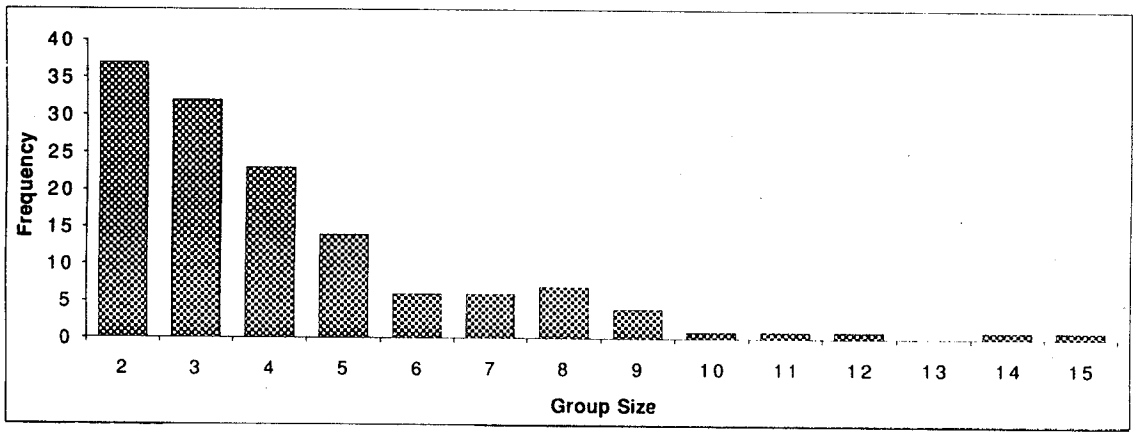

Figure 6. Frequency of group sized for mother/calf groups in the Galveston Ship Channel.

seven percent ($n=160$) of the dolphins were seen during April 1991 through March 1992; 47% ($n=113$) were sighted on more than one day. The highest number of sightings for any dolphin during this time period was 67 (again, dolphin AAB).

Group Size.—The 497 groups observed between April 1991 and March 1992 contained between one and 15 individuals. Twenty-seven percent of these groups ($n=133$) included at least one calf.

Groups without mother/calf pairs ranged in size from one to ten individuals (Fig. 5), with an overall mean of $\bar{x}=3.2\pm$S.D.2.02 ($n=364$). Twenty-three percent of these had only one individual present, while 79% had <5 individuals.

Groups with mother/calf pairs (including calves in the calculation) ranged in size from two to 15 individuals (Fig. 6). Seventy-three

percent of these groups had only one mother/calf pair; 27% had two or more mother/calf pairs. Twenty-seven percent of these groups consisted only of the mother with her calf, while 73% had at least one individual accompanying a mother/calf pair. The overall mean size of groups with mother/calf pairs (excluding calves from the calculation) was $\bar{x}=2.9\pm$S.D.2.10 ($n=133$).

Group Size vs. Behavior.—The largest groups, both with and without mother/calf pairs, consisted of socializing dolphins ($\bar{x}=3.7\pm$S.D.1.81 and $\bar{x}=4.2\pm$S.D.2.06, respectively), while the smallest were those feeding behind shrimp boats ($\bar{x}=2.7\pm$S.D.1.80 and $\bar{x}=2.7\pm$S.D.1.78, respectively). Mean group size was significantly different among the five behavior categories for non-mother/calf groups, but not for groups that included mother/calf pairs (Kruskal-Wallis Rank Test: $H=34.964$, $df=4$, $p=0.001$; $H=5.294$, $df=4$, $p=0.26$, respectively).

Discussion

Survey Effort.—Dolphins were sighted during 90% of survey days. The findings indicate that dolphins utilize the Galveston Channel year-round, on almost all days.

Identified Dolphins - Causes of Natural Marks.—Many of the dolphins in this study had distinctive markings. Distinctive marks can be caused by natural pigmentation, scars from interactions with conspecifics, shark attacks, and marks due to human interactions. The latter two sources often cause particularly large marks (Würsig & Jefferson 1990).

Five individuals had visible crescent-shaped scars behind their dorsal fin. Wounds of this type were described by Wood et al. (1970) as shark bites. While the frequency of shark attacks on Galveston dolphins is unknown, the frequency of non-fatal attacks appears to be low. This is due to the fact that only 2% of the individuals identified during this study exhibited shark bites. Henningsen (1991) found that 5% of dolphins observed in the waters of Galveston Bay and the surrounding Gulf waters had scars on their backs that were most likely related to shark attacks. As noted by Ross (1977), it is possible that a lack of bite-scarred animals reflects a low escape rate. Shane et al. (1986) reported that dolphin remains were found most often in tiger, dusky (*Carcharhinus obscurus*), and bull sharks. Sharks from the family Carcharhinidae, such as tigers (*Galeocerdo cuvieri*) and bulls (*Carcharhinus leucas*), are common in the inshore waters of the Gulf of Mexico (Hoese & Moore 1977).

Collisions with boat propellers can cause injury or death of dolphins; this is probably more likely in areas where there are large concentrations of boats, such as the Galveston Ship Channel. Ten of the dolphins identified had obvious propeller cuts (clean v-shaped marks): four on their backs, five along the front edge of the dorsal fin, and one in its caudal peduncle. Others had grotesquely bent or cut dorsal fins, or had white scarring on the top that indicated the possibility of a serious cut. Collisions with boat propellers have been implicated in several cases of dolphin mortality in Texas waters (Shane 1977; Haubold et al. 1994; Reynolds 1985). Reynolds (1985) recommended that such situations be further studied to determine whether action should be taken to reduce dolphin mortality from propellers.

Two individuals exhibited marks from human interactions other than boat collisions: one had an apparent rope mark (a long indentation, with a roundish edge to it) that seemed to extend around the girth of the dolphin, while another one had a fluke that appeared to have been cut (probably by a knife due to its location and the straight-edge of the cut), or may have been a result of entanglement with fishing twine [as described for an adult spinner dolphin, *Stenella longirostris* by Green et al. (1991)].

Wound healing was observed in two animals during this study. Both animals - "Scarback" and "Gougeback", had deep propeller cuts. "Gougeback's" deep propeller cut may be classified a major wound [Lockyer and Morris (1990) classified body marks and scars into four different categories: superficial scratches; minor wounds and deeper scratches; deeper wounds; and major wounds], because it appeared to have penetrated the skin, blubber, and muscle, with a significant loss of tissue, and will probably leave a permanent indentation. "Gougeback's" wound healed by having the skin fold inwards, and within five months of the sighting, this wound became less visible. "Scarback" had propeller cuts similar to those seen on the back of manatees (Moore, 1956). These scars also healed in less than six months to the point that they were barely visible.

Very few individuals in the study area were observed to have the barnacle *Xenobalanus* on their dorsal fins or flukes. This lack of barnacles, which are common in dolphins south of this study area, greatly aided re-identification of individuals due to the fact that their fin notches were not covered. Only one individual was observed to exhibit a heavy barnacle encrustation on the dorsal fin and flukes.

Rate of Discovery.—Discovery of previously unidentified dolphins reached an asymptote after 10 months of survey effort. However, a continued but slight increase in the number of newly identified dolphins indicated that new individuals continued to visit this area. Other studies of bottlenose dolphins reveal discovery rates that also leveled off within the study period (Wells 1986; Ballance 1990; Shane 1987). Caution should be exercised in interpretation of the leveling trend (Shane 1987; Weller 1991) as long-term studies have revealed pulsed-recruitment of new individuals into the study area (Würsig 1978). Over the three years, however, I recorded no new pulse of previously unidentified individuals, suggesting that Galveston Ship Channel dolphins represent an open population with little net change in population size.

Other studies of Texas bottlenose dolphins also have shown an interplay of movement patterns: some individuals have restricted movements, while others move long distances at least at times (Shane 1980; Gruber 1981; Jones 1986, 1991). During this study, "new" individuals probably also immigrated from other parts of Galveston Bay, Texas inlets, or from the Gulf of Mexico. However, the low sighting rate of new dolphins over time indicates that the dolphins of Galveston Bay are quite different from the Pacific bottlenose dolphin population along southern California. Weller (1991) found that his discovery curve was relatively steep, and attributed this to extensive alongshore coastal movements by the dolphins in response to patchily distributed prey. It would be reasonable to assume that restricted areas, such as channels, that might concentrate food sources, would have a relatively higher resight rate than open habitat, which may require dolphins to make longer movements in response to prey distribution. Shane (1990b) observed that dolphins concentrated their activities in closed channels, and suggested that these areas provide more concentrated food sources. Additionally, Ballance (1992) found that estuary mouths attract feeding dolphins.

Inter-annual Sightings.—Twenty-three percent of the 240 photo-identified individuals were observed repeatedly during each of the three years of this study. Twenty-three percent of these repeatedly sighted individuals used the study area as early as 1986/1987. These 19 animals are probably only a minimum estimate of the number of dolphins exhibiting long-term site fidelity, because weather and operational constraints did not allow for equal effort on a year-round basis for prior studies.

Bottlenose dolphins in different areas display temporally variable occurrence (Wells 1986, Shane 1990a). Some animals are observed infrequently, while others are seen regularly. Dolphins sighted infrequently may be sighted again as a long-term study continues. Site fidelity is believed to be a common feature of coastal bottlenose dolphins (reviews by Leatherwood & Reeves, 1982; Shane et al. 1986). Würsig & Harris (1990) reported the resighting of members of a community in Argentina studied 8-12 years before, while some of the members of the Sarasota, Florida community have been known to inhabit that particular area for more than 21 years (Wells 1992). Recognizable individuals have frequented Shark Bay, Australia for over 20 years (Connor & Smolker 1985).

Seasonal Occurrence.—Observed increases were noted in the number of identified dolphins in spring and during late summer through fall. Similar findings for this area were reported by Hunt & Weeks (1990) & Jones (1988). Henningsen (1991) observed a similar increase in this area in autumn, but his study did not fully cover the spring months.

This study confirms the patterns observed in previous Texas studies (Shane 1980; Gruber 1981; McHugh 1989), that contrary to Gunter (1942), there is evidence for seasonal changes in dolphin abundance in Texas waters. Dolphin abundance in Port Aransas was twice as high in winter as in summer (Shane 1980; McHugh 1989), with similar trends for Matagorda Bay dolphins (Gruber, 1981). Jones (1988) attributed seasonal differences to the possibility of partial north-south migrations along the Texas shoreline. Researchers have attributed seasonal dolphin densities to associations with shrimp-fishing activities (Gruber 1981; Anonymous 1985); however, it is difficult to determine whether fish movements or shrimper operations were primarily responsible (Gruber 1981). Possible shifts in habitat use require further study of actual spatial and temporal distribution of prey. Seasonal movements by dolphins have been correlated with seasonal abundance of sharks in some areas such as Sarasota Bay, Florida (Wells et al., 1980) and Corpus Christi, Texas: (McHugh, 1989), but have not yet been studied for this area.

Frequency of Resightings.—A very high percentage (75%) of the 240 identified dolphins was resighted during the course of this study. Henningsen (1991) resighted only 14% of dolphins photo-identified in the Galveston area. His study area was mainly offshore in the Gulf and many of his animals may have been transient or ranging over a larger

area. This current study was also conducted over a longer period of time than Henningsen's (1991).

The dolphins identified during this study may comprise a subset of a population or community that resides in Galveston Bay. The home range of the identified dolphins is not known. Dolphins sighted infrequently might represent another community or population, of which individuals occasionally move into Galveston Bay. Such an explanation has been suggested for the varying residence patterns of bottlenose dolphins in different locations (Shane et al. 1986; Wells et al. 1987) and short-finned pilot whales (*Globicephala macrorhynchus*) off Tenerife, Canary Islands (Heimlich-Boran 1993).

Group Size.—Commonly reported bottlenose dolphin group sizes are between two to 15 individuals; however, ranges between one and 100 individuals have been documented (review by Shane et al. 1986). Group size ranged from one to 15 dolphins in the Galveston Ship Channel. The small group sizes in this area are quite similar to observations made previously by Jones (1988) and Bräger et al. (1994). Twenty-three percent of the sightings of non-mother/calf pairs in my study were solitary dolphins, 27% of groups with mother/calf pairs were the mother and calf alone. While the sighting percentage of lone dolphins in the Galveston Channel is not high, it is greater than that previously reported for this species (10% for Matagorda Bay, TX by Gruber 1981; less than 15% near Sarasota, FL by Irvine et al. 1981; 12-18% for Sanibel Island, FL by Shane 1990a).

Habitat structure, in terms of complexity and water depth, is generally a major force that shapes bottlenose dolphin groupings (Leatherwood & Reeves 1982; Shane et al. 1986). Groups tend to be smaller in marshlands and estuaries, where acoustic contact and coordinated activities would be difficult. Open or deep-water areas typically have larger group sizes than shallow waters (Shane et al. 1986) or constricted areas such as channels or passes (Gruber 1981). The small group sizes observed during this study are comparable to those reported in closed coastal studies from various areas of Texas, such as Aransas Pass (Shane 1977), and Matagorda Bay (Gruber 1981), as well as for Sarasota, Florida (Wells et al. 1980). Off the coast of Texas and Florida, the continental shelf is wide and extends far, and the deeper waters of the Gulf of Mexico are further offshore. Larger group sizes have been described for bottlenose dolphins in exposed coastal areas (where the continental shelf is narrow, and deep waters are close to shore) such as

Argentina (Würsig 1978); California (Weller 1991); Kino Bay, Gulf of California (Ballance 1990); and Mississippi Sound (Leatherwood & Platter 1975). Henningsen (1991) did not find a difference between group sizes in Galveston Bay and surrounding Gulf waters. Gruber (1981) observed that open water groups tend to be larger than those in constricted areas such as channels or passes.

The evolutionary advantages of group living include increased vigilance and protection against predators; passive or active transfer of information on the presence of patchily distributed resources; increased ability to capture or subdue prey, and increased ability to gain access to and defend resources (Bertram 1978; Clark and Mangel 1986). Predation pressure and patterns of food distribution are considered to be two of the most important ecological factors shaping average group size (Pulliam & Caraco, 1984). Group size related to physiography has been linked to availability of resources and predation pressure (Norris & Dohl 1980; Wells et al. 1980; Weller 1991). Inshore waters often provide predictable and confined food resources, particularly in the case of this study area where bait shrimping occurs year-round and fish tend to school around docks and non-working oil rig platforms. Therefore, it would appear that the restricted habitat and predictable food sources have resulted in smaller group sizes in this study area than in some of the other more open ocean or deeper water studies.

Group Size vs. Behavior.—Bottlenose dolphin group size is often a reflection of activity patterns (Shane et al. 1986). The mean group sizes for all groups in this study were largest during socializing and smallest for feeding with shrimp boats. Groups foraging away from shrimp boats were slightly larger than those feeding near shrimp boats. Dolphins integrating their sensory capabilities increase the probability of locating patchily distributed food sources, in the form schooling fish (Norris & Dohl 1980; Würsig 1986). Because shrimp boats represent a predictable food source, and are probably easy for dolphins to find by listening for the motors, this may explain the smaller group size.

Findings from this study support similar observations of dolphin group sizes relative to behavioral states in Galveston (Bräger 1992), Port Aransas (Shane 1977), and Sanibel Island (Shane 1990a). Average group size of dolphins with shrimp boats was within the range found by Gruber (1981) for dolphins associated with bay shrimpers.

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