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Habitat Utilization by Bottlenose Dolphins (Tursiops truncatus) in Biscayne Bay, Florida

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HABITAT UTILIZATION BY BOTTLENOSE DOLPHINS (*Tursiops truncatus)* IN BISCAYNE BAY, FLORIDA

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Abstract

Bottlenose dolphins (*Tursiops truncatus*) exhibit variable distribution patterns, depending upon their geographic location. Habitat utilization patterns in Biscayne Bay, Florida, were examined using the Biscayne Bay Bottlenose Dolphin Photo-ID database obtained from the National Oceanic and Atmospheric Administration (NOAA) Southeast Fisheries Science Center (SEFSC) Miami Laboratory. Habitat coverages in Biscayne Bay were obtained from the *Atlas of Marine Resources Version 1.3B CD* and the *Biscayne Bay National Park CD*. Dolphin sightings were overlaid on the habitat coverages using GIS Arcview software.

The effects of habitat, season, behavior, zone (sectioned area of Biscayne Bay), and depth on patterns of bottlenose dolphin distribution were examined by analysis of variance to determine the significance of the factors. The total number of dolphins observed during the sightings analyzed was 1,538. The number of dolphins per sighting varied from 1 to 28 dolphins, with a mean of 5.14. The average number of dolphins per survey effort was 10.32. Several significant changes in habitat have occurred between 1991-1992 to 1997. The changes in habitat had some influence on the dolphins' behavior distribution. The highest proportion of all behavior types was found in moderately dense seagrass beds and dredge bottom areas. Habitat quality (habitat types) of Biscayne Bay influenced dolphin sightings, while habitat quantity (habitat area) influenced dolphin numbers. Analysis of variance statistics supported the strong

significant effect of habitat on the variation of sightings and dolphin numbers ($P \leq 0.001$).

No significant difference in sightings was found between seasons or zones throughout the study period. The fall season had the lowest number of dolphins and sightings. The low number of surveys during the fall season does not account for all the influence on the dolphin numbers. Strong significant differences were observed between behaviors ($P < 0.001$). The majority of initial behaviors included traveling, feeding, and socializing. Changes in behaviors were apparent as observations continued. It was determined that the proximity of the research vessel and the duration of observation influenced dolphin behavior. Tail slap and chuffing behavior and boat interaction doubled and quadrupled, respectively during sightings. A strong variation in the number of sightings and number of dolphins occurred between different depths ($P \leq 0.001$). The majority of dolphins were observed in depths of 2.1 - 3 meters. This coincides with the fact that the majority of Biscayne Bay depths are within that range. A time series analysis was performed to determine if there was a cycle present in the pattern of dolphin distribution, and no significant cycle was found. Future analysis of dolphin composition (resident, migratory, nomadic) may yield cyclic patterns.

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Introduction

Atlantic bottlenose dolphins (*Tursiops truncatus*) are found throughout the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea (Leatherwood and Reeves, 1982). They are one of the most extensively studied marine mammals worldwide (Hart, 1997). When geographically distinct bottlenose dolphin populations were compared to each other, variations in their habitat use and behavior were seen (Gulf of Mexico, Atlantic Ocean, Mediterranean Sea, etc.) (Anonymous, 1995). Therefore, each enclosed or semi-enclosed body of water may contain a discrete bottlenose dolphin stock (Anonymous, 1995). This study focused on the waters of Biscayne Bay, located on the southeast coast of Florida.

The coast of Florida provides an excellent example of geographic variability because there is a great diversity of marine and estuarine habitats. These shallow marine habitats are unique because a combination of climatic and physical features, which occur nowhere else (Livingston, 1990). There are both physical, biological, and climatological features distinguishing the north and south as well as the east and west coasts of Florida. Physical and biological features include human development, vegetation, and substrate composition. For example, the natural shoreline of southeastern Florida was once mainly composed of mangroves as opposed to the marshes of north and central east coast of Florida (Livingston, 1990). In recent years, due to increased human population along the coast, the shoreline is now mainly composed of replenished beach habitat or marine facilities.

In general, the shallow marine substrates of South Florida form a mosaic pattern of soft sediments of mud or sand and hard substrates of coral or bedrock, with beds of seagrass scattered throughout. Another feature adding to the diversity of substrates is the fact that coastal marine sediments act as sinks for many materials transported from the land. The composition of these materials includes agricultural, industrial, and urban runoff (Windom et al., 1989).

In order to explain the relationship between dolphins and their habitats, a thorough understanding of the habitat of the particular location is essential. Biscayne Bay, originally a shallow barrier island lagoon, has undergone a considerable number of changes during the last century (Wang and van de Kreeke, 1986; Thompson et al., 1998). These changes included construction of causeways intersecting the bay; the opening of Bakers Haulover Inlet; the opening, widening and deepening of Government Cut; the regulation and elimination of freshwater discharges; numerous dredging projects throughout the bay; and construction of spoil and residential islands (Figure 1) (Wang and van de Kreeke, 1986). The changes in the environment surrounding Biscayne Bay are the main causes for the shifts in the depth, tides, and currents of these waters. These effects include variations in the supply of nutrients, alterations in the natural water flow, and visible declines in marine flora and fauna (Davis and Ogden, 1994). Rapid growth of the human population has and will continue to be one of the main causes of habitat degradation throughout the area (Ault et al., 1998).

As urban development increased, so too did both commercial and recreational water activities. The increased activity led to increased dredging, pollution, and habitat degradation (Thompson et al., 1998). To assess the potential impact of human activities, a study was conducted on the environmental quality of Biscayne Bay (Judge and Curtis, 1979). They found that the environment of Biscayne Bay had been drastically altered. Dredging and filling activities destroyed many areas of seagrass beds and mangrove fringes. One of the major impacts on the southern end of Biscayne Bay has been thermal effluent from the Turkey Point power plant (Thorhaug, 1980). Also artificial canals which discharged storm runoff directly into the bay, increased turbidity and reduced commercial and sport fishing yields (Judge and Curtis, 1979).

Since the late 1970's and early 1980's, large-scale efforts have been implemented to restore damaged marine ecosystems (Thorhaug, 1974; Thorhaug and Austin, 1976). Restoration attempts may be helpful in repairing damaged areas, but still represent changes nonetheless. For example, restoration of the Everglades north of the Florida Keys will result in a substantial change in the timing, volume, and location of freshwater outflows into the coastal marine environment (Harwell et al., 1996)

Natural disturbances also play an important role in the structure and function of marine habitats (Pearson, 1981; Potts, 1983). Tidal forcing, the dominant flow-generating mechanism, renews the water in Biscayne Bay by dispersion and advection (Wang and van de Kreeke, 1986). The Biscayne Bay region is a low energy environment characterized by mild climatic conditions

(Warzeski, 1976). These conditions include climatic factors such as prevailing mild southeasterly and easterly winds, winter cold fronts, and rare major storms. An example of a natural, yet extreme, change occurred in 1992 when hurricane Andrew, a category four hurricane, and several other tropical storms swept across the Biscayne Bay area. The Department of Environmental Resource Management (DERM) in Dade County assessed the damage caused by those storms to coastal and marine habitats. They concluded that a substantial amount of damage had occurred that varied throughout the marine system (Blair et al., 1994). In a previous study of climatic events in Biscayne Bay, wave agitation and storm surge during major storms modified the sediment bodies. Huge amounts of sediment from the bay bottom were carried offshore (Warzeski, 1976).

Biscayne Bay contains a wide range of habitats for over 150 species of fish and macroinvertebrates (Ault et al., 1998). Many qualitative and quantitative studies have been conducted on benthic animal communities in Biscayne Bay, in particular areas affected by human activities (Bader and Roessler, 1972; Roessler et al., 1975; Wanless, 1976; Gassman et al., 1994). Many commercially important fish species are affected by changes in biological and physical parameters such as salinity changes, an increase in turbidity, and over-fishing (Sale, 1991; Polunin & Roberts, 1996). Some examples of over-fished species include mullet (*Mugil* sp.) and the spotted seatrout (*Cynoscion nebulosus*), which are common food sources of bottlenose dolphins (Barros and

Odell, 1990). These particular species spend at least some time in the inshore marine habitats of Biscayne Bay (Livingston, 1990).

Changes in the dolphins' environment are known to cause changes in the dolphins' behavior. In order to categorize dolphin behavior for a particular stock, systematic and quantitative methods are essential to determine the effects of ecological variables on dolphin activity budgets (Mullin, 1988). Although techniques for habitat use and distribution analysis are well established in terrestrial wildlife ecology they were not used extensively in marine systems (White & Garrott, 1990). In the late 1980's, studies became more focused on dolphin ecology (Mullin, 1988).

In spite of numerous studies, many questions regarding bottlenose dolphin ecology are still unanswered. A possible cause in the gap in understanding dolphin ecology is that most ecological studies conducted since the 1970's consisted of areas with homogeneous habitats (Mullin, 1988). The impact of habitat variability on bottlenose dolphins has not been thoroughly investigated. By combining dolphin sightings with known marine habitat coverages in Biscayne Bay, the effect of habitat variation on dolphin behavior was investigated. An analysis of recent data of bottlenose dolphin sightings in Biscayne Bay was conducted. The analysis focused on the adaptability of bottlenose dolphins to variations in the habitats in the Biscayne Bay area over a period of ten years. A time series analysis was also performed to detect the significance of several factors (zones, habitats, behaviors etc.) upon the number of dolphins observed over time. The main objective was to quantify habitat use by the bottlenose dolphins in Biscayne Bay during the time period of 1990-2000.

Methods and Materials

Study Area and Period

Research was conducted in Biscayne Bay, Florida. Originally a shallow estuarine environment, major changes due to urbanization have created more of a low-energy shallow lagoon (Cantillo et al., 2000). Biscayne Bay is approximately 60 km long and 12.9 km at the widest section (Hale, 1993; Cohen, 1998). Map coordinates are centered at 25°33'56"N and 80°13'0"W. Observations occurred throughout the inshore waters. Depths range from 0 m to 6 m (Flamm et al., 2000). For the research project, the bay was divided into three zones, North, Central, and South. The divisions were based on certain major geographic features, mainly bridges and channels (Figure 2).

North Biscayne Bay extends from Haulover Inlet, north of Bal Harbour, south to the Rickenbacker Causeway. The north zone of the Bay is a highly urbanized area, bordered by the barrier islands of Miami Beach and the Miami business district. Major human impacts include the maintenance of the Intercoastal Waterway (ICW); opening of the Haulover inlet; opening, widening and deepening of Government Cut for the Port of Miami traffic; and construction of islands within the bay (Wang and van de Kreeke, 1986).

Central Biscayne Bay stretches from the Rickenbacker Causeway south to Sands Cut. The central bay is geographically located between the cities of

Coconut Grove and Cutler Ridge on the west side and small-scattered barrier islands (Key Biscayne, Sands Key, etc.) and shoals on the east side. Major human impacts include bulkheading, canal discharge and thermal effluents from the Cutler power plant operated by Florida Power and Light (FPL).

South Biscayne Bay extends from Sands Cut south to the northern side of Card Sound Bridge. The south bay is bordered by the Everglades on the west and the northern barrier islands of the Florida Keys to the east and south. Notwithstanding thermal effluents from the Turkey Point power plant, operated by FPL, the south zone is the least affected by human activity of the three zones of Biscayne Bay. Both south and most of the central zone are part of the Biscayne National Park.

Major sources of freshwater in Biscayne Bay include the Biscayne Channel, Little River, Miami River, Coral Gables Waterway, Black Creek Canal, and the discharge of thermal effluents from the Turkey Point and Cutler power plants. Deep natural tidal channels, known as the Safety Valve, transverse horizontally through Central Biscayne Bay located at the southern tip of Key Biscayne (Figure 1). These channels are very important for the exchange of seawater in Central Biscayne Bay. The ICW transects all three zones of Biscayne Bay from north to south. Channels were also carved at the openings of the canals and rivers leading into the Bay.

Dolphin sighting data, examined in this study, extended from July 1990 to May 16, 2001. The years of 1992 and 1993 were not sampled due to lack of project funding and the occurrence of hurricane Andrew and tropical storms during those years.

Dolphin Sightings

Dolphin sighting information was taken from the NOAA Fisheries Biscayne Bay Bottlenose Dolphin Photo-ID database. Dolphin surveys were conducted by NOAA Fisheries SEFSC personnel, from a modified pontoon boat. The shallow draught of the boat enabled researchers to survey all areas frequented by dolphins. A wandering transect throughout the bay was followed. Surveys started approximately 09:00 a.m. and lasted until mid-afternoon. Surveys were generally conducted in calm, clear conditions. Beaufort sea state ranged from one to four. Equipment on board consisted of a Magellan GPS for latitude and longitude, depth recorder with water temperature gauge, and a Nikon F4 camera with a 300mm Nikkor lens. Two sets of datasheets were filled out for each trip. A survey summary sheet was filled out for each survey trip (Figure 3). Information recorded included the best estimate of total number of adults, young of year (YOY), and calves of the day's sightings, and general environmental data. Age analysis was determined by visual observations during the field studies. Young of year was defined as a calf in its first year of life with more than one of the following characteristics: 1) small in size; approximately 50-75% of mother's length, 2) darker coloration than the presumed mother, 3) non-rigid dorsal fin, 4) characteristic "head-out" surfacing pattern, 5) presence of neo-natal vertical stripes, and 7) surfacing in "calf position" (Wells et al., 1996). A dolphin was considered a calf if it was small in size, surfaced in the “calf position,” and did not meet the other four characteristics.

The photo identification sighting summary sheet (Figure 4) was completed for each separate sighting throughout the dolphin survey. Upon an encounter of an individual or group of dolphins, the time sighted, longitude and latitude, and activity were recorded. Photographs were taken of the dorsal fins as each survey trip progressed. The numbers of dolphins present, their age class, their activity during the observations, and additional data were also recorded. Once sufficient photographs of all individual dolphins were obtained, the observers would continue the survey.

Behavior definitions were obtained from Wells et al., 1996 study and slightly modified for this study (Table 1). Several behaviors were grouped together to simplify the number of behavior categories. Boat avoidance, boat interaction, bow riding, and wake jumping behaviors were combined into one category because they each had one common denominator: action caused by presence of boat(s).

<u>Dolphin Database</u>

The information from the two sets of data sheets was then entered into the NOAA Fisheries Biscayne Bay Photo-ID database. A dbase format was used to store the information in three separate dbase tables entitled Survey, Sightings, and Animals using a Microsoft Access program (Microsoft Corporation Redmond, WA). The Sightings dbase was used for statistical analysis. The initial latitude and longitude data were transformed into decimal degrees by using the following formula:

$$\text{LAT} = \frac{(x - 2500)}{60} + 25 \qquad \text{LONG} = -80 - \text{ABS}\left[\frac{(x - 8000)}{60}\right]$$

All fields used for the statistical analysis was transferred from Microsoft Access to Microsoft Excel (Microsoft Corporation, Redmond, WA). The beginning latitude and longitude recorded during the surveys were used to plot the X and Y coordinates for the dolphin sightings onto an ArcView GIS project window (Environmental Systems Research Institute, Inc., Redlands, CA). For the season field, each season contained three months. Spring covered the months of March thru May. Summer covered from June thru August. Fall covered from September to November and winter covered from December thru February.

Habitat Coverages

Habitat coverages from 1991-1992 were taken from the Florida Fish and Wildlife Conservation Commission's *Atlas of Marine Resources Version 1.3B CD* (Flamm et al., 2000). Habitat coverages from 1997 were obtained from the Lewis Environmental Science, Inc.'s *Biscayne National Park CD* (Kruer, 1999). The 1991-92 and 1997 habitat coverages (Figure 5 and 6) consisted of a range of habitats from carbonate mud to moderately dense patches of continuous seagrass beds. The habitat coverage data files were loaded onto a 650MB CD-RW disk. Following the basic ArcView GIS guidelines, the shape files of South Florida's shoreline, bathymetry, and habitat coverage were loaded onto an

ArcView GIS project window (Anonymous, 1996). Color schemes were personalized and compacted. For the purpose of this study, habitat categories were combined and simplified, following the guidelines of individual coverages, (Table 2). After the coverages were in place, the dolphin sighting information was brought into the project window (Figure 7a-c). The habitat data for each sighting were obtained using the dolphin sighting coordinates and habitat coverages. Then the habitat data were incorporated into the dolphin database in Excel (Table 3).

Preliminary Graphing for Statistical Analysis

Each factor (habitat, zone, behavior etc.) was analyzed through preliminary graphing techniques. For example, the number of dolphins and survey sightings within each habitat for each season was tabulated and arranged for ANOVA analyses. Pivot tables were utilized to combine and graph tabulated data from the database. Chart type was chosen based on data type and to achieve clear representation in the graph.

Statistical Analysis

A Model II Two-way ANOVA test was employed after randomization of each factor (Sokal and Rohlf, 1995). Each cell in the data table represented a combination of factors (Sokal & Rohlf, 1995). To determine the significance between combinations of factors, tabular data were sectioned into categories. Each category focused on how the number of sightings of bottlenose dolphins was affected by the combination of two factors (Table 4). The analyses of variance tests were based on time or location as the main factors. When seasonal variation became the main factor, the four constituents of each year were combined into the four respective sections (Table 5). The total number of dolphins per time period was broken down according to the next factor being analyzed in that category. Factors were arranged in database forms under variables 1-3. Variable 1 pertained to the time factor (main factor). Variable 2 pertained to the 2^{nd} factor in the combination (i.e. habitat, zone, tide, etc.). Variable 3 was the total dolphin counts. Analysis of variance without replication was needed since each cell contained a single value (Sokal & Rohlf, 1995). Model II Two-way ANOVA without replication was performed by BIOMstats statistical software for Biologists program, Version 3.30d (Exeter Software, Setauket, NY).

When testing the significance in a Model II ANOVA the subgroup sum of squares (SS_{AxB}) is the same as the total sum of squares (SS_{total}). If there was no interaction between factors then the fixed level (MS_A) was tested over the

<u>Two-way ANOVA analysis formulas</u>

$$\text{Grand mean } (Y) = [1 / (ab)] * \sum^{a}\sum^{b} Y$$

$$SS_A = b \sum^{a} (Y_A - Y)^2 \quad \text{and} \quad SS_B = a \sum^{b} (Y_B - Y)^2$$

$$SS_{error} = \sum^{a}\sum^{b} (Y - Y_A - Y_B + Y)^2$$

$$MS_A = SS_A / SS_{error} \quad \text{and} \quad MS_B = SS_B / SS_{error}$$

$$F_s = MS_A / MS_{error} \quad \text{or} \quad F_s = MS_B / MS_{error}$$

remainder mean square (MS_{error}). Since interaction was present, Model II ANOVA can be entirely tested and the F_s value comes from the division of the

MS of variable of A or B from the Error Variable (Sokal & Rohlf, 1995). Critical F was obtained from the statistical table (Rohlf and Sokal, 1995).

Time Series Analysis

An event-based time series was used for the final analysis. Before the analysis could begin, several criteria were addressed. First, the time-series variable needed to be an approximately continuous variable. Second, points on the time-series variable needed to have an approximate normal distribution. Non-normal distribution shapes require special handling (Warner, 1998). Third, if observations were event-based, cycle length needed to be expressed in terms of number of events per cycle (VanLear, 1991). Fourth, the number of observations should be reasonably large (Warner, 1998).

The times-series analysis began with an examination of the time-series. Sample frequency (Δt) of the event-based time series analysis was based on survey dates. The duration of the time series extended from the summer of 1994 to the spring of 2000. Data from 1990 and 1991 were not included because of the gap in surveys between 1991 and 1994 and the time series needed to be continuous for this analysis. Factors such as variance of counts and appearance of trend and cycles were deduced. Next, the histogram for normal distribution was examined. Kolmogorov – Smirnov statistics from the BIOMstats program were used to test the fit of the histogram to a normal distribution curve. The Box-Cox transformation was necessary to fit data to a normal distribution. I used the following square root transformation:

$$\sqrt{(Y+1/2)}$$

The addition of 0.5 to all variants compensated for the presence of several zero values. Mean, minimum, maximum, and skewness are several of the factors that were also examined. These factors helped determine sufficient variance. Heterogeneity of variance across time was examined as well. The basic assumption was that the data set had independence of variance (Kenny & Judd, 1996). Any significant outliers were eliminated. Regression statistics were run through a BIOMstats program to remove trend and obtain residuals.

A lagged autocorrelation function was used to determine stationarity. The null hypothesis for this test is that the time series consists of white noise (observations are uncorrelated with each other) (Warner, 1998). A lagged correlation (lag) is defined as $(t_2 - t_1)$ (Chatfield, 1991). The Box-Ljung Q statistic was used to determine the significance of the set of lagged correlations. If the lags are different from zero, then they are significant and a trend is present.

$$Q = N \overset{m}{\underset{k=1}{}} r^2$$

(N is the number of observations in the time-series
m is the number of lagged r's included in the sum
k equals the lags (Chatfield, 1991))

Finally, both periodogram analysis and spectral analysis were performed. Periodogram analysis was used to identify any significant periodic components.

$$X_t = \mu + \Sigma(A_i c_{it} + B_i s_{it}), \qquad \text{for } i = 1,2,3,\ldots,N/2$$

(X_t is the values of the X time series; t is the time; c_{it} is the cosine function of frequency ω_i evaluated; and s_{it} is the sine function of frequency ω_i evaluated (Warner, 1998).

The Fisher test was used to test the statistical significance ($\alpha = 0.5$) of the peaks from the periodogram. The critical value depends on *N*, the length of the time series, and upon α, the risk of Type I error. It is a conservative test, in the sense that it assesses how large the largest of such components has to be before it is unlikely that such a large peak could arise by chance from white noise data (Warner, 1998). Finally, I performed a spectral analysis using the Tukey weights window.

$$\text{Tukey weights (edf)} = 2.67N/M$$

(M = width of window; N = number of cases)

The widths (M) are used to balance the resolution against the variance. If the width is too small, important features will be smoothed out. If the width is too large the spectrum will show erratic variation (Chatfield, 1996).

$$\text{Lower Bound Confidence Interval} = \text{edf} * s(fi) / X^2_{.995}$$

$$\text{Upper Bound Confidence Interval} = \text{edf} * s(fi) / X^2_{.005}$$

When the spectrum is drawn a peak indicates an important contribution to the variation of the frequency in the applied interval (Chatfield, 1996). A significance test is applied to the peak to see if it fits within the confidence interval of the spectral value (Warner, 1998). The peak is significant if it lies beyond the confidence interval. The spectral analysis was used to determine if any significant cycle was present in the number of dolphins in Biscayne Bay between 1994 and 2000.

Results

The number of bottlenose dolphin sightings used for analysis was 299 out of 310. Eleven were excluded from analysis because they were out of the study area. The total number of dolphins observed during the sightings analyzed was 1,538. Group size varied from 1 to 28 dolphins, with a mean of 5.14. There were 149 surveys performed during the survey period. The average number of dolphins per survey effort was 10.32. The proportions of survey effort per season were similar, ranging from 21% - 29% (Figure 8). Accordingly, the proportions of dolphin numbers per season were similar, ranging from 20% - 29% (Figure 9). In comparison, the spring season had a low proportion of surveys and a high proportion of dolphins. The opposite is true for the summer, with a high proportion of surveys and a low proportion of dolphins. When comparing the survey effort to dolphin numbers the proportions were approximately equal.

Habitats

Some habitat coverages in Biscayne Bay underwent significant changes from 1991-92 to 1997 (Figure 5 and 6). Habitat changes were characterized as major when a turnover of one or more dominant habitat types occurred in any given area. Although occurring infrequently (32.7%), the major habitat change in Biscayne Bay was the fluctuation of seagrass beds. Habitat changes were characterized as minor when less than 50% turnover rate occurred in any given area. These minor changes, spreading or shrinking of seagrass beds; increase in dredged bottom channels; or small amounts of habitat turnover, occurred frequently (57.7%) throughout Biscayne Bay.

The total study area encompassed 631.22 km^2. Moderately dense seagrass beds (324.85 km^2; 51.5%) and hard bottom with seagrass beds (180.08 km^2; 28.5%) covered the majority of the study area (Figure 10). The proportion of dolphins to habitat type varied significantly (Figure 11). The majority of dolphins seen were in the moderately dense seagrass beds (40.8%) (Figure 12). A large proportion of dolphins (32.6%) was seen in the unknown habitat areas, while 15.8% of the dolphin numbers occurred in dredged bottom areas. All other habitat types formed the remaining 10.8% of dolphin sightings.

Further analysis focused on the possible influence of habitat areas on the dolphin numbers. The number of dolphins was normalized by habitat area to determine if the size of habitat areas influenced the number of dolphins per habitat (Figure 13). The highest numbers of dolphins per km^2 were seen in unknown, dredged bottom, and carbonate sand habitats. After comparing the proportions of dolphin numbers to the proportions of normalized dolphin numbers, it was found that habitat area did have some influence on the number of dolphins. The normalized dolphin numbers were used accordingly for later analysis.

Bottlenose dolphin habitat preferences between the seasons were examined next to determine if any significant pattern was present throughout the seasonal cycle (Figure 14). Dolphins were seen in almost all habitats during all seasons, with two major exceptions. In the carbonate sand habitat, dolphins were only sighted once (group size: 18) during the spring season. In the soft bottom with seagrass beds, dolphins were sighted only once in each of the spring (group size: 9), summer (group size: 2), and winter seasons (group size: 1). Each season was compared with identical seasons throughout the years to determine if any significant pattern was present within each of the four seasons (Figures 15a-d). Excluding the dolphin numbers in unknown habitats, moderately dense seagrass beds and dredged bottom habitats had the highest number of dolphins in almost all seasons per year than any other habitat. An exception was in the fall of 1997, when there was a higher number of dolphins in hard bottom with seagrass areas than any other habitat.

A statistical analysis of variance was performed on the number of dolphin sightings for each season versus habitats (Table 6). Twenty-four data records were used for the test. There was no significant difference of sightings between the seasons ($F = 2.9548$, $df = 3$, $0.10 > P > 0.05$). In contrast, the number of sightings between habitats differed significantly ($F = 182.8277$, $df = 5$, $P < 0.001$). Dolphin counts were used in the analysis of variance to see if they were also impacted by seasons versus habitats (Table 7). Twenty-four data records were used for the test. In accordance with the number of sightings, dolphin numbers did not differ significantly between the seasons ($F = 2.4025$, $df = 3$, $0.25 > P > 0.10$). A strong significant variation of dolphin numbers also occurred between the habitats ($F = 113.7633$, $df = 5$, $P < 0.001$). Overall, there was no seasonal influence on the bottlenose dolphin numbers or number of dolphin sightings. However, variation in habitats did influence the number of dolphins and the number of dolphin sightings. Since, there appeared to be some influence from the habitats, further analysis was performed to determine if the influence came from the variations in habitat type or habitat area. The number of dolphin sightings and total dolphin counts, normalized by habitat, were used in the following analyses (Tables 8-9). Twenty-four data records were used for each test. The number of sightings (normalized by habitat area) did not differ significantly between the seasons ($F = 1.5857$, $df = 3$, $0.25 > P > 0.10$). They did however differ between the habitat types ($F = 4.7263$, $df = 5$, $0.025 > P > 0.01$). The dolphin numbers (normalized by habitat) did not differ significantly between the seasons ($F = 1.9606$, $df = 3$, $0.25 > P > 0.10$), nor did they differ between the habitat types ($F = 1.1662$, $df = 5$, $0.50 > P > 0.25$). Overall, the sightings were influenced by habitat type, while dolphin numbers were influenced by habitat area.

Behaviors

The proportions of initial behavior and behavior during observations were examined (Table 10). The majority of initial behaviors were traveling (39.6%), feeding (31.8%), and social activity (17.0%) (Figure 16). All other initial behaviors comprised the remaining 11.6%. The majority of behaviors during observations were boat interactions (37.0%), feeding (18.9%), and traveling (18.6%) (Figure 17). All other behaviors during observations represented the remaining 14.6%.

Major changes in behavior, presumably due to the presence of the observation vessel, were documented (Figure 18) by changes in the proportions of behavior in initial observation compared to proportions of behavior during observation. Traveling and feeding dropped by 21% and 12.9%, respectively and social activity decreased by 6.1%. Boat interaction had the highest increase of 35.5%. Tail slap and chuffing and leaping were the only other behaviors that increased, by 4.8% and 1.4% respectively. Figure 19 shows the overall changes between initial behaviors and behaviors during observations. Sightings where none of the initial behaviors were identical to behaviors during observation are considered under the category of "a complete change in behavior." Sightings with one or more identical initial behaviors versus behaviors during observations are considered under "partial change in behavior." The rest of the sightings were considered under "no change in behavior." For all sightings, 59.2% displayed a partial change in behavior. Only 24.4% showed a complete change in behavior and 16.4% showed no change in behavior.

Initial behavior and behavior during observation were compared by season. Of the initial behaviors during the spring season, 47.1% were traveling, 20.3% were feeding, and 24.6% were social activity (Figure 20a). No tail slapping or chuffing activity was seen as an initial behavior during the spring season. The remaining behaviors covered 8.0% of the total number of dolphins. During the summer season, initial dolphin behaviors consisted of traveling (33.4%) and feeding (25.6%), with 17.3% comprising social activity (Figure 20b). The remaining 23.7% of initial behaviors made up the other categories. In the fall season, initial behavior consisted of traveling (30.6%), feeding (29.2%), and social activity (31.0%) (Figure 20c). There was no initial behavior of boat interaction during the fall season. Resting, leaping, and tail slap and chuffing comprised 9.2% of initial behaviors in the fall season. In the winter season, traveling represented 41.8% of the observed initial behavior, while feeding and social behavior contributed 29.0% and 22.7%, respectively (Figure 20d). The remaining behaviors covered 6.5% of the total number of dolphins. Overall, traveling activity decreased from the spring to the fall season, while feeding and leaping increased. Social activity fluctuated between the seasons. Resting activity increased in the summer season and decreased in the winter season.

As the observations continued during a sighting, a shift in behavior patterns was observed. During the spring season, boat interaction ranked as the highest continuing behavior (28.6%) (Figure 21a). Social activity, traveling and feeding behaviors consisted of 20.3%, 16.3%, and 14.4%, respectively. Tail slap and chuffing activity, as a continuing behavior, increased to 12.3%, as compared to the 0.0% as an initial behavior in the spring. For the summer season, boat interactions represented 32.8% of the behaviors recorded during observations (Figure 21b). Traveling and feeding ranked at 19.3% and 11.3%, respectively. Resting activity was highest during the summer season (6.9%). During the fall season, boat interactions during observations remained high (39.9%) (Figure 21c). The continuing behaviors of traveling and feeding were similar in proportions (16.7% and 15.7%) in the fall season. All other behaviors ranked below 11.0% in the fall season. Finally, boat interactions represented 34.6% of the continuing observation in the winter season (Figure 21d). Traveling, feeding and social activity were similar at 18.3%, 17.4%, and 16.4%, respectively. Overall, boat interaction and leaping activities increased from the spring to the fall, while tail slap and chuffing behavior decreased. Resting activity increased during the summer and then decreased during the winter. The remainder of the behaviors during observations varied irregularly throughout the seasons.

An analysis of variance was performed on sightings for initial behaviors versus seasons (Table 11). Thirty-two data records were used for the test. No significant difference in the number of sightings occurred between the seasons ($F = 1.8887$, $df = 3$, $0.25 > P > 0.10$). In contrast, the number of sightings per behavior varied significantly ($F = 43.7477$, $df = 7$, $P < 0.001$). Dolphin counts were used in the analysis of variance to compare initial behaviors to seasons (Table 12). Thirty-two data records were used for the test. Dolphin numbers did not differ significantly between the seasons ($F = 1.2955$, $df = 3$, $0.50 > P > 0.25$). However, a significant variation in the number of dolphins per behavior was present ($F = 23.6373$, $df = 7$, $P < 0.001$). Overall, the behaviors based on number of sightings and number of dolphins varied significantly. There was no influence by the seasons on the number of sightings or the number of dolphins.

The next analysis focused on the behaviors within the habitats. Even though there was only one sighting (18 dolphins) in the carbonate sand habitat, numerous behaviors were seen. The initial behaviors observed in this habitat were traveling and social activity, while the behaviors during observation were traveling, social activity, boat interaction, tail slap and chuffing activity. Certain habitats had the majority of certain occurrences of behavior. The highest occurrences of traveling (72.5%), social activity (59.5%), resting (74.4%), and boat interactions (89.5%) were seen in the moderately dense seagrass beds. Feeding proportions were highest in dredge bottom (44.4%) and moderately dense seagrass areas (49.4%). Leaping and tail slap/chuffing behaviors were more often seen in dredge bottom areas at 48.8% and 100.0%, respectively. When looking at behavior percentages per individual habitat, traveling, feeding, and social activity had the highest proportions of initial behaviors for the majority of habitats.

Major behavioral changes were seen during observation from the research vessel and these were ranked by habitat type. In soft bottom with seagrass areas, there was a complete decrease in traveling, with partial decreases in feeding and social activity as the observations progressed (Figure 22a). Boat interaction increased from 0.0% (initial) to 47.8%. In hard bottom with seagrass areas, the proportions of traveling, feeding, social activity, and leaping decreased (Figure 22b). Resting, tail slap and chuffing behaviors increased from 2.2% to 4.1% and 0.0% to 9.2%, respectively. The proportions of boat interaction increased from 1.5% to 35.7% as observations progressed. Traveling, feeding, social activity, and resting behavior decreased during observations in the moderately dense seagrass habitat (Figure 22c). In the same habitat, the proportions of leaping and tail slap/chuffing behavior increased from 1.1% to 8.4% and 2.8% and 4.6%, respectively. Boat interaction increased from 3.7% to 34.2% during observations. In the dense seagrass habitat, the proportions of feeding, traveling, social activity, and leaping decreased during observations (Figure 22d). Tail slap and chuffing activity increased during observations from 0.0% to 5.1%. Boat interaction had a major increase from 0.0% to 42.4%. In the dredged bottom habitat, the proportions of traveling, feeding, social activity, resting, and leaping decreased as observations progressed (Figure 22e). Tail slap/chuffing activity increased from 2.1% to 6.1%. Boat interaction had a substantial increase from 0.5% to 36.0%.

Analysis of variance was performed on sightings for initial behaviors versus habitats (Table 13). Forty-eight data records were used for the test. No significant difference in the number of sightings occurred between the habitats ($F = 2.1005$, $df = 5$, $0.10 > P > 0.05$). No significant difference in the number of sightings was seen between the behaviors ($F = 1.4787$, $df = 7$, $0.25 > P > 0.10$). Dolphin counts were used in the analysis of variance to compare initial behaviors versus habitats (Table 14). Forty-eight data records were used for the test. In contrast, the number of dolphins varied significantly between the habitats ($F = 4.7249$, $df = 5$, $0.005 > P > 0.001$) due to differences in group size. A significant variation in dolphin numbers occurred between the behaviors ($F = 2.4582$, $df = 7$, $0.05 > P > 0.025$) again due to variation in group size. Overall, the number of sightings was similar in all habitats and behaviors. However, the dolphin numbers were varied between the habitats and behaviors. Since there appeared to be some influence from the habitats, further analysis was performed to determine if the influence came from the variations in habitat type or habitat area. The dolphin counts, normalized by habitat area, were used in the following analysis (Table 15). Forty-eight data records were used for the test. There was no significant difference between the behaviors ($F = 2.1576$, $df = 7$, $0.10 > P > 0.05$). Likewise, there was no significant difference between the habitat types ($F = 1.7379$, $df = 5$, $0.25 > P > 0.10$).

Biscayne Bay Zones

Since there were no surveys conducted in North Biscayne Bay and South Biscayne Bay until 1994, the time period for the statistical analysis on zones began in the summer of 1994. Most of the bottlenose dolphins were seen in Central Biscayne Bay (45.4%) (Figure 23). Fewer dolphins were seen in North Biscayne Bay and South Biscayne Bay with proportions of 26.1% and 28.5%, respectively.

The dolphin proportions within the three zones were examined seasonally. In the spring season, dolphin numbers in North Biscayne Bay increased from spring of ‘95 to the spring of ‘97, declined the following year, and proceeded to increase again (Figure 24a). The opposite pattern in dolphin numbers was seen in Central Biscayne Bay, with three years of decline, a year of increase, and then three more years of decline. Dolphin numbers in South Biscayne Bay paralleled North Biscayne Bay after the spring of 1995, but were not proportional. For the summer season, the dolphin numbers between North Biscayne Bay and Central Biscayne Bay displayed an inverse relationship, though not proportional to one another (Figure 24b). The dolphin proportions in South Biscayne Bay decreased from the summer of ’95 to the summer of ’98. Again in the fall season, the dolphin proportions between North Biscayne Bay and Central Biscayne Bay displayed an inverse relationship, though not proportional to one another. For three consecutive years (1996 – 1998), dolphin numbers increased in South Biscayne Bay during the fall season (Figure 24c). A large increase in dolphin numbers was seen in Central Biscayne Bay from 1994/95 to 1996/97 during the winter season (Figure 24d). As related in the other three seasons, the dolphin numbers throughout the years between North Biscayne Bay and Central Biscayne Bay corresponded negatively, but not proportionally.

Analysis of variance was performed on sightings (Table 16) for zones versus seasons. Twelve data records were used for the test. No significant difference in the number of sightings occurred between the seasons ($F = 0.7629$, $df = 3$, $0.75 > P > 0.50$). There was no significant difference in the number of sightings between zones ($F = 2.4664$, $df = 2$, $0.25 > P > 0.10$). Dolphin numbers were used in the analysis of variance to compare zones versus seasons (Table 17). Twelve data records were used for the test. Dolphin counts did not differ significantly between the seasons ($F = 2.0385$, $df = 3$, $0.50 > P > 0.25$). Also, no significant difference in dolphin numbers occurred between the zones ($F = 4.5057$, $df = 2$, $0.25 > P > 0.10$). Overall, seasons and zones did not significantly influence the number of sightings and the number of dolphins observed in the three zones.

An analysis was then conducted on the influence of habitat within each zone on the proportions of dolphins seen in each zone. In North Biscayne Bay, dredged bottom areas had the highest proportion of dolphin numbers at 61.2% (Figure 25a). The remainder of the dolphin numbers in North Biscayne Bay was in moderately dense seagrass, carbonate sand, and soft bottom with seagrass areas. The largest portion of the dolphin numbers in Central Biscayne Bay was in the deep natural basins categorized under unknown habitat type (Figure 25b).

The rest of the dolphin numbers in Central Biscayne Bay were in moderately dense seagrass, hard bottom with seagrass, dense seagrass, and dredged bottom areas. Of these, moderately dense seagrass habitat had the highest proportion of the number of dolphins (36%). The highest proportion of dolphin numbers in South Biscayne Bay was in the moderately dense seagrass habitat type (77%) (Figure 25c). Small percentages of dolphin numbers also occurred in dense seagrass and hard bottom with seagrass areas. The most common habitat in which dolphins were found in all three zones was moderately dense seagrass beds.

Analysis of variance was performed on sightings (Table 18) for zones versus habitats. Eighteen data records were used for the test. No significant difference of sightings was seen between the zones ($F = 0.0129$, $df = 2$, $P > 0.75$), nor was there significant difference between the habitats ($F = 2.3498$, $df = 5$, $0.25 > P > 0.10$). Dolphin counts were used in the analysis of variance to compare zones versus habitats (Table 19). Eighteen data records were used for the test. Dolphin numbers did not differ significantly between the zones ($F = 0.0536$, $df = 2$, $P > 0.75$), nor was there significant difference in the number of dolphins between the habitats ($F = 2.3179$, $df = 5$, $0.10 > P > 0.05$). Overall, there was no influence upon the number of sightings and number of dolphins due to the variation in habitats within the zones.

A comparison of zones and behaviors was then performed. The three main behaviors in all three zones were traveling, feeding, and social activity (Figure 26). In North Biscayne Bay, the majority of behaviors seen were feeding

(36.8%), traveling (31.3%), and social activity (21.1%). Leaping, tail slap, and chuffing activities were more often seen in North Biscayne Bay out of all three zones. The majority of behaviors in Central Biscayne Bay were traveling (43.9%), feeding (31.3%), and social activity (16.3%). Traveling, feeding, resting, and boat interaction were more often seen in Central Biscayne Bay out of all three zones. The majority of behaviors in South Biscayne Bay were traveling (46.7%), social activity (30.3%), and feeding (16.8%). Social activity was more often seen in South Biscayne Bay out of all three zones.

Analysis of variance was performed on sightings (Table 20) for behaviors versus zones. Twenty-four data records were used for the test. A strong significant difference in the number of sightings occurred between the behaviors ($F = 21.6751$, $df = 7$, $P < 0.001$). There was no significant difference in the number of sightings between the zones ($F = 1.2003$, $df = 2$, $0.50 < P < 0.25$). Dolphin counts were used in the analysis of variance to compare behaviors versus zones (Table 21). Twenty-four data records were used for the test. The number of dolphins differed significantly between the behaviors ($F = 15.4643$, $df = 7$, $P < 0.001$). There was no significant difference in the number of dolphins between the zones ($F = 1.4433$, $df = 2$, $0.50 > P > 0.25$). Overall, number of sightings and number of dolphins varied in the behaviors between the zones. There were no significant variations in the number of sightings or the number of dolphins between the zones.

Depths

The effect of depth on the proportions of dolphins was examined. The majority of dolphins (49%) were seen in the depth range of 2.1 – 3 m (Figure 27). The proportion of dolphins in the depth ranges of 1.1 – 2 m and 3.1 - 4 m contained 24% and 22%, respectively. A small minority (5%) of dolphins was found in depths below one meter and above four meters.

Next, the dolphin proportions in the depth ranges were analyzed by season (Figure 28). For all four seasons the depth range of 2.1 – 3 m had the highest occurrences (33.3% – 57.6%) of dolphins. During the spring and winter seasons, dolphin occurrences were greater in the 1.1 – 2 m range than the 3.1 – 4 m range. On the other hand, dolphin occurrences were greater in the 3.1 – 4 m range than the 1.1 – 2 m range for the summer and fall seasons. Dolphin percentages were within 2% of each other for three depth ranges (1.1 – 4 m) only during the summer season.

Analysis of variance was performed on sightings (Table 22) between depths and seasons. Twenty data records were used for the test. No significant difference in the number of sightings was determined between the seasons ($F = 0.9600$, $df = 3$, $0.50 > P > 0.25$) for each depth. In contrast, a significant variation in the number of sightings occurred between depths ($F = 19.6685$, $df = 4$, $P < 0.001$) for each season. The second test was performed on dolphin counts between depths and seasons (Table 23). Twenty data records were used for the test. The number of dolphins did not differ significantly between the seasons ($F = 1.1394$, $df = 3$, $0.50 > P > 0.25$) for each depth. A significant variation in the number of dolphins also occurred between the depths ($F = 13.7240$, $df = 4$, $P < 0.001$) for each season. Overall, the number of sightings and the number of dolphins were influenced by the variation in depths, but there was no influence from the seasons.

The analysis of habitats versus depths showed that the highest bottlenose dolphin proportions (61.4% - 24.5%) in the known habitats were found in the moderately dense seagrass habitat for the first four depth ranges (1 – 4 m) (Figure 29). However, in depths greater than 4.1 m, a greater number of dolphins (82.3%) were found in dredged bottom areas. The proportions of dolphins in depth ranges of 1 m and 1.1 – 2.0 m were 12.7% and 15.2%, respectively, in hard bottom with seagrass areas. Meanwhile, 23.3% and 10.8% of the dolphins were recorded in dredged bottom areas for the depth ranges of 2.1 – 3.0 m and 3.1 – 4.0 m, respectively. Dolphins were only seen in carbonate sand habitats in the depth range of 2.1 – 3.0 m. In the soft bottom with seagrass habitat, dolphins were in the depth ranges of 1 m and 2.1 – 3.0 m. As for the dense seagrass habitat, dolphins were present only at the 1.1 - 3.0 m depth range.

Analysis of variance was performed on the number of sightings for depth versus habitat (Table 24). Thirty data records were used for the test. There was a strong significant influence of habitat on the number of sightings ($F = 5.0239$, $df = 5$, $0.005 < P < 0.001$), and a significant variation in the number of sightings was determined between depth ranges ($F = 2.9288$, $df = 4$, $0.05 < P < 0.025$). The next test was performed on the dolphin counts between depths and habitats

(Table 25). Thirty data records were used for the test. There was a strong significant difference in the number of dolphins between the habitats (F = 5.0371, df = 5, 0.005 < P < 0.001) and in the number of dolphins between the depth ranges (F = 3.0425, df = 4, 0.05 < P < 0.025). Overall, there was a strong influence due to the variation in habitats and depths on the number of dolphins and number of sightings. Since there appeared to be some influence from the habitats, further analysis was performed to determine if the influence came from the variations in habitat type or habitat area. Dolphin sightings, normalized by habitat area, were used in the following analysis (Table 26). Thirty data records were used for the test. Again, the variation in depths had a significant influence on the dolphin sightings (F = 4.8841, df = 4, 0.01 > P > 0.005). The habitat types had a significant influence on the dolphin sightings as well (F = 3.2012, df = 5, 0.05 > P > 0.025). The dolphin counts, normalized by habitat area, were used next (Table 27). Thirty data records were used for the test. The variation in depths had a significant influence on the dolphin numbers (F = 4.5279, df = 4, 0.01 > P > 0.005). However, there was no significant difference between the habitat types (F = 1.2367, df = 5, 0.50 > P > 0.25). Overall, habitat area had a significant influence on the dolphin numbers, while habitat type had a significant influence on the dolphin sightings.

When initial behaviors were analyzed by depth, traveling behavior was the top activity (34.2% – 46.8%) in all depth ranges (Figure 30). Feeding was the second highest activity (26.1% - 36.2%) in the majority of the depth ranges. The exception was in the depth range of 1.1 – 2.0 m where social activity ranked the second highest at 27.4%. The remainder of the behaviors comprised 0.0% - 8.0% of the dolphin behaviors within each of the depth ranges.

Analysis of variance was performed on sightings (Table 28) for initial behaviors versus depths. Forty data records were used for the test. There was a strong significant difference in the number of sightings between the behaviors ($F = 5.7023$, $df = 7$, $P < 0.001$) for each depth range. The number of sightings between each depth range was significantly different ($F = 4.3934$, $df = 4$, $0.01 > P > 0.005$) for each behavior. Another test was performed on the dolphin counts for initial behaviors versus depths (Table 29). Forty data records were used for the test. The number of dolphins had a strong significant difference between the initial behaviors ($F = 5.1966$, $df = 7$, $P > 0.001$) for each depth range. A strong significant variation of dolphin numbers occurred between the depth ranges ($F = 5.1128$, $df = 4$, $P > 0.001$) for each initial behavior. Overall, the number of sightings and number of dolphins varied in the initial behaviors between the depth ranges. Also, the variation in the depths influenced both the number of sightings and the number of dolphins.

Finally, the variation of dolphin numbers in each zone per depth was analyzed. Central Biscayne Bay had the highest proportions of dolphins in 1 m depth (54.5%), 2.1 – 3.0 m (42.5%), and 3.1 – 4.0 m (79.8%) (Figure 31). South Biscayne Bay had the highest proportions of dolphins (54.0%) in 1.1 – 2.0 m. North Biscayne Bay had the highest proportion of dolphins in 4.1 + m (82.4%).

Analysis of variance was performed on sightings (Table 30) for depths versus zones. Fifteen data records were used for the test. The number of sightings was significantly different between depth ranges (F = 8.6270, df = 4, 0.01 > P > 0.005) for each zone. They were not significantly different between zones (F = 0.9881, df = 2, 0.50 > P > 0.25) for each depth range. Another test was performed on the dolphin counts for depths versus zones (Table 31). Fifteen data records were used for the test. The numbers of dolphins between the depth ranges were significantly different (F = 6.7676, df = 4, 0.025 > P > 0.01) for each zone. In contrast, there was no significant difference in the number of dolphins between the zones (F = 1.1644, df = 2, 0.50 > P > 0.25) for each depth range. Overall, there was a strong influence from the variation of depths upon the number of sightings and dolphin numbers within each zone.

Times Series Analysis

The survey dates (Δt) and number of dolphins sighted per day (x) were used to construct the Preliminary Results graph (Figure 32). The number of records used (N) was 171. Several conclusions may be drawn from a visual examination of the graph. First, the number of dolphins sighted varied from a minimum of 0 to maximum of 45. Second, there appears to be a very slight increasing trend in the number of dolphins sighted as the project progressed through the years from the summer of 1994 to the spring of 2000. The increasing trend may be based on an increase in surveys over time or on an increase in dolphins per survey. To determine if either suggestion was the case, the number of dolphins per survey effort was analyzed over a yearly basis (Table 32). Only the years from 1995 to 1999 were analyzed because only these years had surveys conducted throughout the complete year. The variation in survey effort between 1995 and 1999 was high (s^2 = 45.20, s = 6.72). There was a sharp increase in dolphin numbers per survey effort in 1996, then a gradual decrease, until another sharp increase in 1999. These sharp increases, with the high increase in variance in survey effort early on, may have caused the false reading of an increasing trend in dolphin numbers. Finally, there appears to be a hint of a two-year cycle, but the spacing and height of the peaks in the cycle are not perfectly regular.

The steps outlined in the methods section produced the following results: First, the data series from the summer of 1994 to the spring of 2000 comprises one continuous variable. Second, the histogram of the preliminary results for the time series analysis (Figure 33) shows a distribution skewed to the right, which indicates a Poisson distribution. Square-root transformation was applied to the data to remedy the skewed distribution of the time-series variables and fit the data to a normal distribution (Sokal & Rohlf, 1995). Third, the cycle length is expressed by surveys over time, which is considered an event-based time series. Fourth, the number of surveys is large (171).

Sufficient variance in the time-series variables was determined from the preliminary results. The standard deviation of the number of dolphins per survey was 8.28. Also, based on a histogram after square-root transformation, an outlier was identified and rejected. The number of records (N) was reduced to 170 for further analysis.

A regression analysis was performed upon the X_t time series to remove any trend (Table 33). All further analyses were based upon the residuals from the trend removal results. Next, the test of Lagged Autocorrelation was conducted (Table 34). At 24 lags, evidence pointed to data being “white noise” (observations were uncorrelated with each other), meaning no evidence of a trend was present. The lagged autocorrelations oscillated, which may have been evidence of a cyclic pattern. The Box-Ljung Q test, a significance test, was used to determine if the lagged autocorrelations were different from zero. If they are different from zero then the Lagged Autocorrelation test needs to be redone using different lags. Since there was no significance in the lagged autocorrelations, there was no trend present. A periodogram was performed (Table 35). The Fisher test, a significance test, was used to determine if the peaks from the periodogram were significant (Figure 34). There was no significance in the peaks, confirming there was no cyclic component. Finally, a spectral analysis (Table 36) was conducted using a Tukey weight window with a width of 13. At the 97.5% confidence interval (4.13 - 20.57) around the spectral value, the mean (3.82) is lower than the Lower Bound confidence interval (CI). Since the mean was not within the confidence interval boundaries, the largest peak was determined statistically significant at period 5.667 years. This means there is a possible cycle present at 5.667 years interval. When the peak was further tested at the 99.5% confidence intervals (3.65-12.79), it was no longer significant. The second highest peak was tested for significance, with 99.5% CI (3.42-11.98). The peak was not significant, so no cycle was present at that period. At the 99.5% confidence intervals there were no cycles present.

Discussion

Possible Sources of Bias

The first potential source of bias is the general survey route. Some sections of the bay may have been left out of the survey route due to inaccessibility, depth, or low bridges. This may have led to lower numbers of dolphin sightings per survey than actually present. To compensate for depth limitation, the type of research vessel used enabled the observers to travel in the minimum depth range in which bottlenose dolphins had previously been observed.

Another potential source of bias is the continuous presence of the boat during the sighting period. The comparison of the initial and continuous behaviors for each sighting documented the effect of the research vessel on the behavior of the dolphins. The boat may also have unintentionally herded the dolphins into another habitat. To avoid this potential bias, analysis of spatial distribution was based on the initial location of the dolphin sightings.

The next possible source of bias was the irregularity of sightings through time. Surveys were not conducted in an interval/ratio level of measurement because the period between survey dates varied over time. Fortunately, the use of parametric statistics with data not having true interval/ratio levels of measurement has become common practice (Warner, 1998). The data obtained were instead categorized for an event-based analysis. This allowed the analysis of the length of cycles to be based on the number of events.

The square root transformation of the data for the time series analysis may also be a potential source of bias. Caution should be taken when choosing the correct transformation to fit the data to normal distribution patterns. There are some problems in practice where transformations of the data do not achieve all the requirements needed to continue with analysis (Chatfield, 1996). Square-root transformation was used because it is typically used for count data. Second, logarithmic transformation (another type of transformation) of dependent variables is indicated when percent changes in the dependent variable vary directly with changes in the independent variable (Sokal and Rohlf, 1995). Upon analysis of the data's basic statistics, there was no indication the dependent variable (dolphin numbers) varied directly with the changes in the independent variable (time).

The presence of any trend in a time series analysis is also a possible source of bias. The presence of any linear or curvilinear trend component in the data will influence the partitioning of variance in the periodogram (Warner, 1998). Based on the preliminary result graph, there was a slight increasing trend present. After further analysis the trend was determined to be a false reading. A linear regression test was performed, which confirmed the elimination of any trends.

The final source of potential bias was the type of time series analyses used. In a periodogram analysis, the sampling errors associated with estimates of Sums of Squares are quite large (Warner, 1998). Spectral analysis techniques were utilized to minimize the problem of sampling error. Both analyses were used to verify results.

Seasons, Surveys, and Zones

From the statistical analysis of dolphin numbers and sightings versus seasons, seasons were not an influential factor. A similar study conducted in Florida Bay (south of Biscayne Bay) also found no significant difference in the number of dolphin sightings per season (McClellan et al., 2000). There are however several hypothetical reasons why so few dolphins were seen during the fall season or so many during the spring season. First, the prey of the bottlenose dolphin may occur in a seasonal cycle, being lower in the fall. This would have caused dolphins to leave the area in search of food. Second, an influx of more people in the area could have lead to the dolphin’s habitat displacement. For example, an increase in human activity in the Bay may lead to the displacement of dolphins seeking less congested areas. Third, there may be a decrease in the migratory dolphin population in the fall season. Fourth, survey effort may have had some influence on the number of dolphins sighted. The fall season had the lowest survey effort and the lowest number of dolphins. Even when looking at certain years, lower numbers of surveys resulted in lower numbers of dolphins. There appears to be some other factor(s) influencing the dolphin numbers along with survey effort. Survey effort per season compared to the dolphin numbers per season was similar in proportions. However, the spring had the highest survey effort to dolphin number ratio, while the summer had the lowest ratio. The relevance of the other three scenarios is unclear at this time. Future studies, with an approximately equal number of surveys throughout the seasons may shed some light on the importance of the other three scenarios and further support the fourth scenario.

There was no significant difference between the number of dolphins or the number of sightings in each zone. Even though dolphin sightings were scattered throughout the Bay, distribution patterns within each zone did vary. In North Biscayne Bay, the majority of sightings were in or along the dredged bottom areas. In Central Biscayne Bay, the majority were located off the west coast of Key Biscayne. In South Biscayne Bay a large number of sightings were recorded in the Card Sound Bay area and in a channel located in the middle of the southern zone. Previous studies have documented bottlenose dolphins exhibiting variable distribution patterns (Verway, 1975; Leatherwood, 1979; Wells et al., 1987; Corkeron, 1989; Mullin et al., 1990; Wilson et al., 1997). For example, one study in Sarasota Bay (west coast of Florida) showed that dolphins used certain regions of the bay, more than others (Wells et al., 1980). They were more often seen in passes and the Gulf of Mexico during certain seasons (Wells et al., 1980). There also has been documentation on other cetaceans and their varying distribution patterns. Hector's dolphins (*Cephalorhynchus hectori*) concentrated near river mouths or prominent headlands off the west coast of New Zealand (Bräger and Schneider, 1998). Numerous studies on odontocetes have shown preferences for narrow channels with strong currents (Leatherwood and Reeves, 1983; Lockyer and Morris, 1986; Leatherwood et al., 1988; Felleman et al., 1991). There are several factors that account for these distribution patterns. They include, but are not limited to, habitat type, depth, and human presence. For example, North Biscayne Bay has been the most affected by urban development (Anonymous, 2000). It has the least amount of open area and the majority of boating activity throughout the Bay occurs in the Port of Miami area. It would be beneficial for dolphins to stay in the deep areas (dredged bottom) to maintain minimum contact with boats and have optimum area for maneuvering. Central Biscayne Bay has the best access to offshore waters (Anonymous, 2000). It encompasses a broader area, has deep natural channels and urban development is located on the western edge of the zone. These characteristics allow dolphins to spread out more, increasing the ability to avoid or maneuver around boats, and gain a larger area to pursue prey. South Biscayne Bay has sustained the least amount of impact from urban development, but has limited access to offshore waters. It also encompasses a large area and only has urban development on the western edge of the zone. Again, this allows dolphins to spread out, increasing the ability to avoid or maneuver around boats and gain a larger area to pursue prey.

Habitat Changes

Several studies have reported that the distribution of inshore dolphins is susceptible to the effects of human activities in the coastal zone and general degradation of inshore habitats (Klinowska, 1991; Thompson, 1992; Cockcroft and Krohn, 1994; Reeves and Leatherwood, 1994). Throughout the last several decades, human impacts (coastal development, dredging, thermal and agricultural effluents) on the waters of Biscayne Bay have increased substantially. In order to examine the effect of changes in habitat on dolphin distribution, both the quality and quantity of the habitat must be considered (Karczmarski et al., 2000). Habitat quality (ecological status of environment, abundance of resources, and degree of disturbance) determines the adaptedness of the species and the probability of continuous survival. Habitat quantity scales the total population size and may influence aspects of the species distribution (Gilpin and Soulé, 1986).

In terms of habitat quality, Biscayne Bay has been dramatically modified in morphological aspects, sedimentary environments, and sedimentary dynamics (Wanless, 1976). Proposed hydrologic projects are expected to make substantial changes in timing, volume, and location of freshwater outflows (Harwell et al., 1996). These changes in turn will affect the salinity and turbidity of Biscayne Bay. Significant changes in salinity and turbidity may affect the quality of habitat, which in turn affects the distribution of prey, and eventually the distribution of dolphins. When looking at habitat quality (habitat type), the variation in habitat type is small (7 types). There is even less variation when the types of seagrass beds are lumped together in one category. This leaves only 3 main types: carbonate sand, seagrass beds, and dredged bottom. Even so, through statistical analysis the number of sightings was influenced by the variation in habitat type. Excluding the dolphin numbers in unknown habitats, moderately dense seagrass beds and dredged bottom habitats had the highest number of dolphins in almost all seasons per year than any other habitat.

When looking at the habitat quantity (habitat area), the majority of Biscayne Bay is covered by moderately dense seagrass beds (324.85 km^2) and hard bottom with seagrass beds (180.08 km^2). The rest of the habitats cover small areas scattered throughout the bay. Through statistical analysis habitat area was seen to have some influence on the dolphin numbers.

It is unwise to predict the distribution patterns of bottlenose dolphins using findings in similar habitats, but in different locales (Wilson et al., 1997). This is due to the variation of dolphin distribution caused by the variation in geography and environmental parameters. In the Biscayne Bay study area, dolphin sightings varied between the habitats. To go a step further, the frequency of sightings within a habitat was dependent upon the proportion of each habitat in the area. For example, 76.1% of the dolphins sighted in moderately dense seagrass beds in South Biscayne Bay coincide with the high proportion of the habitat in South Biscayne Bay.

Habitats vs. Behaviors

Habitat use patterns of bottlenose dolphins are believed to be a function of habitat heterogeneity and indicate importance in the daily activities of dolphins (MacArthur and Pianka, 1966; Rosenzweig, 1981; Samuel et al., 1985; Brown, 1988; Karczmarski et al., 2000). Certain habitats may be more important to bottlenose dolphins for certain behaviors (Lear & Bryden, 1980; Shane et al., 1986; Ballance, 1992; Hanson and Defran, 1993; Waples et al., 1995; Grigg and Markowitz, 1997). Seagrass beds exhibit high biomass and productivity, which is why they are important nursery beds for juvenile reef and seagrass fish

(Sedberry and Carter, 1993). This in turn provides a rich source of food (fish) for dolphins. Dredged bottom areas are thought to provide access to areas that might otherwise be inaccessible. For example, a dredged channel may connect several areas of deep water, which were inaccessible before due to sand bars separating them.

Through statistical analysis, the habitat areas had a significant influence on dolphin numbers based on behaviors. Hart's (1997) study also noticed behavior varied significantly with habitat type. In Biscayne Bay the proportions of behaviors varied throughout the habitats. The highest proportion of all behavior types was seen in moderately dense seagrass beds and dredged bottom areas. Traveling, feeding, and socializing were the most frequent behaviors that occurred in all habitats. Resting occurred more often in dredged bottom and moderately dense seagrass beds than any other habitats. Leaping was only seen in dredged bottom and moderately dense seagrass beds. Behaviors within dense seagrass beds and soft bottom/seagrass beds consisted of only traveling, feeding, and socializing.

Seasonal Behaviors

As an initial behavior, dolphins were most often seen traveling (39.6%), feeding (31.8%), and socializing (17.0%). A dolphin study off Sanibel Island, FL recorded similar proportions of 46% traveling, 38% feeding, and 17% socializing (Shane, 1990b). In a study near Chandeleur Sound, LA 39% of the dolphins were resting and milling, 24% traveling, 25% feeding, and 12% socializing

(Mullin, 1988). These statistics show how variations in geography vary the behavioral patterns of dolphins as well.

Analysis of the behaviors indicated that behavior was dependent on several environmental factors, including boat proximity, habitat, and season. When comparing behaviors to seasons, feeding activity increased during the fall and winter seasons, while traveling decreased. Social activity increased in the spring and fall, but decreased in the summer and winter. In a similar study near Galveston, Texas, seasonal behavior patterns of bottlenose dolphins were observed. Feeding increased towards the fall, while traveling and social activity decreased (Bräger, 1993). A study in the Indian River Lagoon system (Florida) also found that activity was significantly dependent on seasons, with feeding activity being higher in the fall (Hart, 1997). Several reasons why seasons affect dolphin behavior include the seasonal cycle of prey, seasonal cycle of human activity, and their seasonal cycle.

Boat Interactions

The proportions of boat interactions increased substantially as the transition from behavior at initial observation to behavior during observation occurred. The main reason for this behavior change was the close proximity of the research vessel and the duration of the observation. A recent study in Sarasota Bay, Florida was conducted to observe short-term effects of boat traffic on bottlenose dolphins. Significant changes in behaviors, in particular an increase in boat interaction, were observed as well (Nowacek et al., 2001). The majority of boat interaction occurred in moderately dense seagrass beds and dredged bottom areas. This coincided with the high percentage of dolphins in each of the habitats.

Depths

The majority of dolphins were seen in depths of 2.1-3 meters, which coincides with a large portion of Biscayne Bay having that depth. Previous studies conducted in the Florida Keys nearshore and offshore waters have also found significantly higher counts in shallow nearshore depths (McClellan et al., 2000; Hansen, 1986). Future analysis on the proportions of depth area to dolphin numbers throughout Biscayne Bay will beneficial to determine if depth area has any influence on the dolphin numbers.

Time Series Analysis

After the analysis was complete, a cycle was present at 5.667 years for the 97.5% confidence interval (CI), but no cycle was present at the 99.5% CI. Two possible reasons are the frequency of dolphin surveys and the composition of the bottlenose dolphin groups. The fluctuation in the number of surveys per year may have inhibited the detection of any cycle present, at higher confidence intervals, by changing the frequency of dolphin numbers. Also, high numbers of surveys are needed to accurately determine cycles. For this study, there may not have been enough surveys conducted to find the cycle. Finally, the composition (resident, migratory, or nomadic) of the Biscayne Bay bottlenose dolphins has not been determined at this time. If the composition of the groups were mixed, then the detection of the seasonal cycle by the resident dolphins may have been inhibited by the seasonal cycle of the migratory dolphins.

Future Studies

Future studies are essential in order to broaden our understanding of Biscayne Bay dolphin population. One study should focus on the food resources of Biscayne Bay. Food resources are a primary factor in determining dolphin movements and site fidelity (Wells et al., 1980; Shane et al., 1986). For example, in a similar study of bottlenose dolphin habitat use off the coast of Texas, striped mullet (*Mugil cephalus*) (known as a primary food item of *Tursiops truncatus*) were often found in groups on shallow banks of bays and estuaries during flood tide. They would also gather into larger schools in deeper water as tide begins to ebb. Dolphins were seen the majority of time in the same areas of the mullet (Würsig and Würsig, 1979).

Another study should examine the factors affecting fish distribution. Factors affecting fish distribution may directly or indirectly affect the dolphin distribution. For example, fish movements may be influenced by tides or seasons, which in turn influence dolphins feeding activities (Grigg and Markowitz, 1997). Correlations of dolphins and their prey have been reported for near-shore dolphins (Würsig and Würsig, 1979) and hump-backed dolphins (*Sousa teuszii*) (Saayman and Tayler, 1973). Understanding how animals are using these areas will require examining the behavior of the animals in this area (Grigg and Markowitz, 1997). For example, the presence of estuaries, mangroves, or physical barriers (mud banks) can provide higher prey density and opportunities for corralling prey (Shane, 1990a). Gathering fish distribution data and analyzing these with respect to dolphin movements is essential to understanding dolphin feeding behavior. Future analysis of fish distributions in Biscayne Bay may broaden our understanding of dolphin distributions and provide further motivation for marine conservation of both fish and dolphin species.

The categorization of the Biscayne Bay bottlenose dolphin population should be examined. Dolphin populations have been categorized as migratory, residential, or nomadic (Tanaka, 1987; Wells et al., 1987; Kenney, 1990). Currently, the distinction between locally resident bottlenose dolphins and migratory bottlenose dolphins is not clear (Anonymous, 1999). In fact, groups within Biscayne Bay may contain representatives of both resident and migratory dolphins. Thus, a decrease in the resident population will not be adequately represented in this analysis. Future analysis of the distinction between the resident and migratory dolphins will further clarify this relationship.

The significance of group size is also important. Group size is often associated with a particular location (Shane et al, 1986; Grigg and Markowitz, 1997). Habitat structure, activity patterns, and food patchiness are prime factors influencing bottlenose dolphin group size (Shane et al., 1986; Corkeron, 1990). The frequency distributions of groups of bottlenose dolphins generally varied in size between 100-500 individuals, off the coast of South Africa (Saayman and Tayler, 1973). The study of group size in Biscayne Bay as a future analysis would be beneficial to determine the impact habitat, season, and depth have on group size.

An analysis of key habitats will be beneficial in future analysis of home ranges. Home range is defined by regular usage by an individual or group in the course of performing normal daily activities. They usually encompass minimum amounts of preferred habitats. Smaller more dispersed key habitats generally lead to larger home ranges (Mitchell, 1975; Rice, 1977; Leatherwood and Reeves, 1982; Karczmarski et al., 2000). Off the coast of New Zealand, some dolphins were seen traveling between 'nodal home ranges'. Their behavior concentrated around a series of geographically separated nodes (Muller et al., 1998). Various dolphins use ranges differently. Some are seasonal, while others are year round (Shane et al., 1986). Adequate identification of key habitats within a population's home range and core areas where biologically and socially important behaviors concentrate are important in understanding the species ecology (Karczmarski et al., 2000).

Dolphin abundance analysis would also be beneficial. From 1973 to 1975 there were fewer dolphins (50) in Biscayne Bay than adjacent waters of Everglades National Park (1137) (Odell, 1976). Aerial surveys were conducted to document the distribution and abundance of bottlenose dolphins in the coastal waters of South Florida. Odell suggested the difference in number of dolphins sighted in Biscayne Bay as opposed to Everglades National Park were due to percentage of open water, absolute or seasonal abundance of prey, or pollution (Odell, 1976). Analyzing several of the factors mentioned above will eventually lead to the overall understanding of their impact on dolphin abundance.

Conclusions

1) Dolphin numbers did not vary significantly between seasons. The proportions of survey effort to dolphin numbers were similar. The fall season had the lowest number of dolphins and survey effort, but there appears to be some other factor(s) influencing dolphin numbers along with survey effort. Three possibilities include, seasonal cycle of prey, seasonal cycle of human activity in the Bay, or seasonal cycle of migratory dolphin population.

2) Behavior was dependent upon several environmental factors, including boat proximity, habitat type, and season. The majority of initial behaviors were feeding and traveling. The majority of continuous behavior was boat interaction.

3) As the boat observations continued for each sighting, noticeable changes in behavior were observed. The close proximity of the research vessel and the duration of observation affected the dolphins' behavior. Tail slap/chuffing and boat interaction doubled and quadrupled in occurrence, respectively.

4) Habitat changes have occurred throughout the Biscayne Bay area between 1991-1992 and 1997. The changes in habitat were categorized into three types: major change (turnover of one or more dominant habitat types in a given area), minor change (less than 50% turnover rate in a given area), and no change (no turnover rate in a given area). The majority of changes were slight fluctuations of

habitats throughout the study area (57.7%). However, there were several major habitat changes (e.g. fluctuations of seagrass beds) (32.7%) as well. Analysis shows the fluctuations have had some impact on dolphin occurrences. For example, the habitat quality (habitat type) of Biscayne Bay influences the dolphin sightings, while habitat quantity (habitat area) influences the dolphin numbers.

5) Habitat areas had a significant influence on dolphin numbers based on behaviors. Moderately dense seagrass beds and dredged bottom areas had the highest proportion of all behavior types. Traveling, feeding, and socializing were the most frequent behaviors that occurred in all habitats.

6) There was no significant difference between zones. Central Biscayne Bay did have the majority of sightings. Some possible reasons include the broad expanse of the zone, best access to offshore waters, and urbanization limited to western edge of zone. Overall, the dolphin sightings were scattered throughout the three zones, but there were high concentrations based on each individual zone. In the North Biscayne Bay there were high concentrations in or along the dredged bottom areas. In Central Biscayne Bay, a large portion of sightings was located off the west coast of Key Biscayne (natural deep channels). In South Biscayne Bay, a large portion of sightings was recorded in the Card Sound Bay area and in channels in the middle of the zone.

7) The majority of dolphins were observed in 2.1-3 meter depths. Traveling was the highest behavior in all depths. Habitat type, based on depth, had a significant influence on dolphin sightings. Habitat area, based on depth, had a significant influence on dolphin numbers. Future analysis on the proportions of depth area to dolphin numbers will be beneficial to determine if depth area has any influence on dolphin numbers.

8) No significant cycle was found from the time series analysis at the 99.5% confidence interval. Future identification of dolphin composition (resident, migratory, or nomadic) will clarify the presence of a cyclic pattern.

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Table 1. Categorization of bottlenose dolphin behavior for the Biscayne Bay study.

Behaviors	Description	Category Used
Travel	Moving continually in a general direction	Traveling
Feed	Actively pursuing prey; fish in mouth, probable feeding, or fish seen in close proximity to dolphin	Feeding
Social	Contact between dolphins for brief periods of time	Social Activity
Rest/Rafting	Minimum motion at the surface for long periods of time	Resting
Play	Interaction between dolphins	Social Activity
Milling	Staying in the same area for a length of time	Social Activity
Tail Slap	Slap of the tail against surface of water	Tail Slap/Chuffing
Chuffing	Quick exhalation of air from the blowhole	Tail Slap/Chuffing
Leaping	Jumping partially or fully out of the water	Leaping
Boat Avoidance	Continue to travel away from the observation vessel or other vessels	Boat Interaction
Bow Riding/ Wake Jumping	Riding along the bow or stern of vessels	Boat Interaction
Interaction w/ observation vessel	Swimming to, around, or under the research vessel; lifting head out of the water; or turning on side for a better look	Boat Interaction
Unknown	Any behavior not defined above	Unknown
Initial Behavior	Initial dolphin activity upon first sighting of the dolphins	
Behavior during observation	While obtaining photographs, behavior was continuously recorded	

Table 2. Categorization of habitats in Biscayne Bay study area. Initial categories were obtained from the Atlas of Marine Resources Version 1.3b CD (Flamm et al., 2000).

Category	Description	Category Used
BS	Carbonate sand	Carbonate sand
BUd	Bottom unknown;dredged	Dredged bottom
Deep water	Deep Water	Deep water
HS	Hard bottom with perceptible seagrass	Hard bottom / seagrass
SD	Moderately dense continuous beds	Mod. dense seagrass
SDb	Moderately dense continuous beds; banks	Mod. dense seagrass
SDBb	Moderately dense continuous beds w/ blowout; banks	Mod. dense seagrass
SDBd	Moderately dense continuous beds w/ blowout; dredged	Mod. dense seagrass
SPH	Dense patches of seagrass	Dense seagrass patches
SPP	Dominantly sand or mud with scattered seagrass patches	Sand or mud / seagrass
U	Areas where the habitat was undetermined	Unknown

Table 3. Sample of the combined bottlenose dolphin database for the Biscayne Bay study. Behavior and tide type were given numerical values during the survey.

Survey Date	Sighting	Total Best	Zone	Beg. Lat	Beg. Long	Habitat	Beg. Activity	Activity During	Tide
6/7/96	1	3	CBB	25.3997	-80.1496	BS	1	10	4
6/19/96	1	5	SBB	25.2804	-80.1786	CPSD	2	10, 12	2
6/19/96	2	1	SBB	25.3017	-80.1566		1	12	2
6/20/96	1	2	NBB	25.5216	-80.0867		4	10,12	4
7/2/96	1	2	CBB	25.3044	-80.1289		2	2, 10	4
7/2/96	2	9	CBB	25.4026	-80.1188		1	12,2,3,5,9	2
7/22/96	1	1	NBB	25.5203	-80.0815		1	10	4
7/22/96	2	5	NBB	25.5117	-80.088		1	1, 10, 12, 8	4
7/23/96	1	4	SBB	25.1805	-80.2131		1	10	3
8/28/96	1	4	NBB	25.523	-80.0847		2, 6	2, 1, 10, 12	1
8/29/96	1	9	SBB	25.18	-80.22		2, 6	2, 10, 12, 1	4
8/29/96	2	1	SBB	25.2237	-80.1662		1	1, 10, 12	2
8/30/95	1	3	SBB	25.3072	-80.1835	SD	6,2	10,12,9,8,7	1
8/30/96	1	1	CBB	25.3701	-80.1716	CPIH	1	10	4
8/30/96	2	1	CBB	25.371	-80.1645	SD	1	10	4
8/30/96	3	2	CBB	25.3724	-80.1309		2, 4	2, 1, 10	4
8/30/96	4	2	CBB	25.4045	-80.1041		1	1, 10	2

Table 4. The combination of factors for the ANOVA analysis for the Biscayne Bay study.

Habitat		Behavior
	Season	
Depth		Zone

ANOVA analyses

Habitat Category	Behavior Category
Habitat - Season	Behavior - Season
	Behavior - Habitat

Zone Category	Depth Category
Zone - Season	Depth - Season
Zone - Habitat	Depth - Habitat
Zone - Behavior	Depth - Behavior
	Depth - Zone

Table 5. Categorization of seasons throughout the years

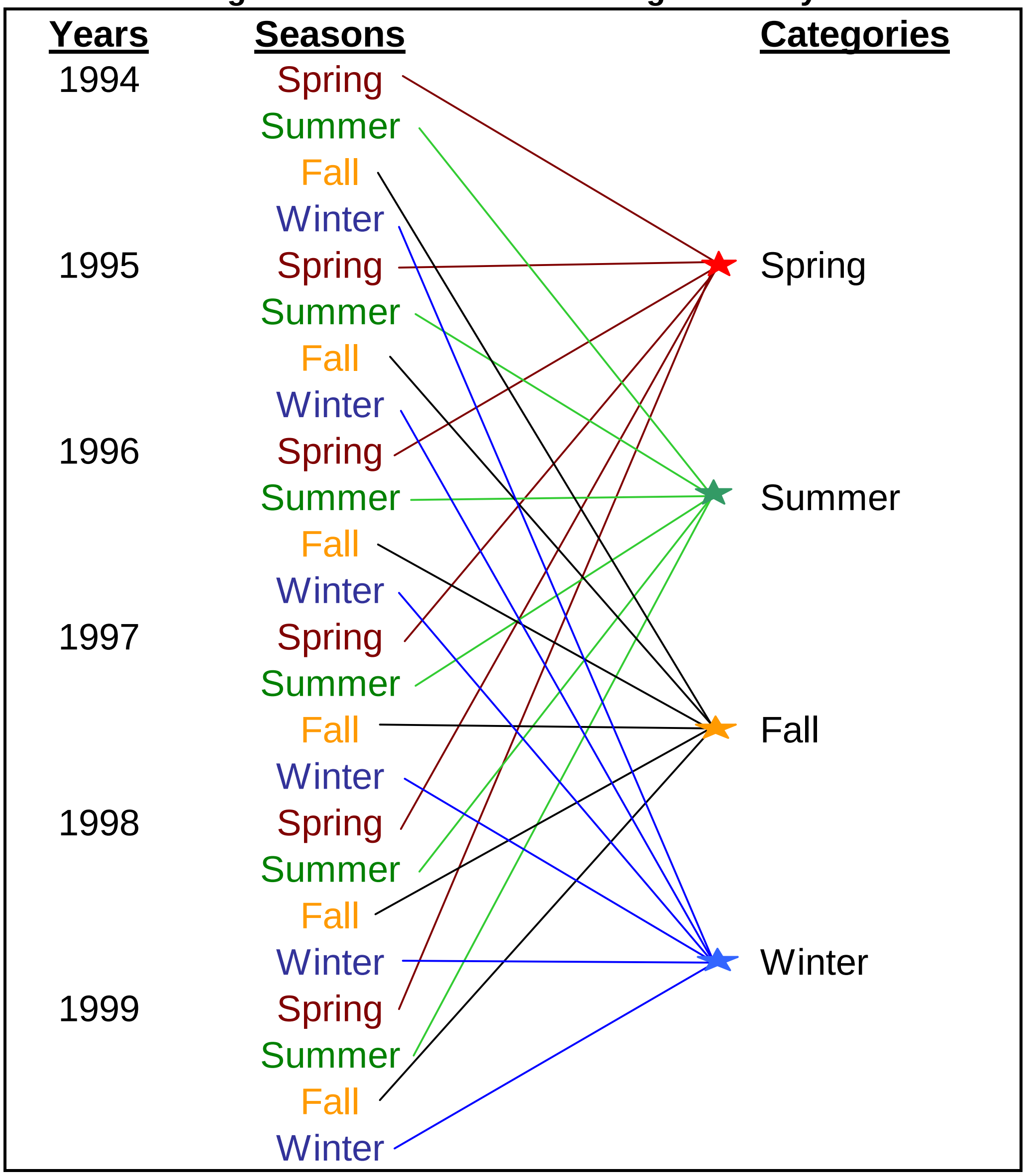


Table 6. Analysis of variance: habitats versus seasons for dolphin sightings

	Carbonate sand	Dense seagrass	Dredged bottom	Hard bottom w/ seagrass	Moderately dense seagrass	Soft bottom w/ seagrass	mean B
Spring	1	3	13	6	33	1	9.5000
Summer	0	2	16	10	32	1	10.1667
Fall	0	1	10	7	26	0	7.3333
Winter	0	2	16	5	31	1	9.1667
mean A	0.2500	2.0000	13.7500	7.0000	30.5000	0.7500	

Total sum	217
Grand mean	9.0417

	df	SS	MS	F	P	
A	5	2729.7083	545.9417	182.8277	P < 0.001	**s**
B	3	26.4697	8.8232	2.9548	0.10 > P > 0.05	**ns**
Remainder	15	44.7917	2.9861			

F critical	
$F_{0.001\ (5,15)}$	7.57
$F_{0.05\ (3,15)}$	3.29

Table 7. Analysis of variance: habitats versus seasons for dolphin numbers

	Carbonate sand	Dense seagrass	Dredged bottom	Hard bottom w/ seagrass	Moderately dense seagrass	Soft bottom w/ seagrass	mean B
Spring	18	14	62	24	190	9	52.8333
Summer	0	4	80	30	148	2	44.0000
Fall	0	7	45	38	143	0	38.8333
Winter	0	5	56	14	146	1	37.0000
mean A	4.5000	7.5000	60.7500	26.5000	156.7500	3.0000	

Total sum	1036
Grand mean	43.1667

	df	SS	MS	F	P	
A	5	71474.8333	14294.9667	113.7633	P < 0.001	**s**
B	3	905.6645	301.8882	2.4025	0.25 > P > 0.10	**ns**
Remainder	15	1884.8311	125.6554			

F critical	
$F_{0.001\ (5,15)}$	7.57
$F_{0.10\ (3,15)}$	2.49

Table 8. Analysis of variance: habitat type versus season for normalized dolphin sightings

Habitat Type	Spr Norm.	Sum Norm.	Fall Norm.	Win Norm.	mean B
Carbonate Sand	0.4979	0.0000	0.0000	0.0000	0.1245
Hard bttm / sgrss	0.0333	0.0555	0.0389	0.0278	0.0389
Soft bttm / sgrss	0.3580	0.3580	0.0000	0.3580	0.2685
Mod. dense	0.1016	0.0985	0.0800	0.0954	0.0939
Dense	0.0807	0.0538	0.0269	0.0538	0.0538
Dredge bttm	0.4821	0.5933	0.1854	1.1495	0.6026
mean A	0.2590	0.1932	0.0552	0.2808	

Total sum	4.7287
Grand mean	0.1970

	df	SS	MS	Fs	P		F critical	
A	3	0.1859	0.0620	1.5857	0.25> P >0.10	**ns**	$F_{.10(3,15)}$	2.49
B	5	0.9240	0.1848	4.7263	0.025> P >0.01	**s**	$F_{.01(5,15)}$	4.56
Remainder	15	0.5861	0.0391					

Table 9. Analysis of variance: habitat type vs season for normalized dolphin numbers

Habitat Type	Spr Norm.	Sum Norm.	Fall Norm.	Win Norm.	mean B
Carbonate sand	8.9628	0	0.0000	0.0000	2.2407
Hard bttm / sgrss	0.1333	0.1666	0.2110	0.0777	0.1472
Soft bttm / sgrss	3.2222	0.7161	0.0000	0.3580	1.0741
Mod. dense	0.5849	0.4556	0.4402	0.4494	0.4825
Dense	0.3768	0.1077	0.1884	0.1346	0.2019
Dredge bottom	2.2991	2.9665	1.6687	2.0766	2.2527
mean A	2.5965	0.7354	0.4181	0.5161	

Total sum	25.5962
Grand mean	1.0665

	df	SS	MS	F	P		F critical	
A	3	19.0433	6.3478	1.9606	.25> P >.10	**ns**	$F_{.10(3,15)}$	2.49
B	5	18.8783	3.7757	1.1662	.50> p >.25	**ns**	$F_{..25(5,15)}$	1.49
Remainder	15	48.5650	3.2377					

Table 10. The number of sightings and percentages per behavior throughout the study period.

Behavior	Sightings (initial)	Percents (initial)	Sightings (during)	Percents (during)
Travel	158	39.6%	121	18.6%
Feeding	127	31.8%	123	18.9%
Social Activity	68	17.0%	71	10.9%
Resting	15	3.8%	19	2.9%
Boat Interaction	6	1.5%	241	37.0%
Leaping	8	2.0%	22	3.4%
Tail slap / chuffing	9	2.3%	46	7.1%
Unknown	8	2.0%	8	1.2%

Table 11. Analysis of variance: dolphin behaviors versus seasons for dolphin sightings

	Travel	Feeding	Social Activity	Resting	Boat Interact.	Leaping	Tail / chuff	Unknown	mean B
Spring	46	28	17	4	1	1	0	1	12.2500
Summer	35	30	13	7	6	2	1	7	12.6250
Fall	27	28	16	3	0	3	1	0	9.7500
Winter	50	41	22	1	2	2	4	0	15.2500
mean A	39.5000	31.7500	17.0000	3.7500	2.2500	2.0000	1.5000	2.0000	

Total sum	399
Grand mean	12.4688

	df	SS	MS	F	P		F critical	
A	7	6571.7188	938.8170	43.7477	P < 0.001	**s**	$F_{0.001\ (7,21)}$	5.56
B	3	121.5938	40.5313	1.8887	0.25 > P > 0.10	**ns**	$F_{0.10\ (3,21)}$	2.36
Remainder	21	450.6563	21.4598					

Table 12. Analysis of variance: dolphin behaviors versus seasons for dolphin numbers

	Travel	Feeding	Social Activity	Resting	Boat Interact.	Leaping	ail slap/chuffi	Unknown	mean B
Spring	299	129	156	37	2	9	0	3	79.3750
Summer	166	127	86	42	31	8	5	32	62.1250
Fall	133	127	135	15	0	21	4	0	54.3750
Winter	278	193	151	6	5	10	22	0	83.1250
mean A	219.0000	144.0000	132.0000	25.0000	9.5000	12.0000	7.7500	8.7500	

Total sum	2232
Grand mean	69.7500

	df	SS	MS	F	P		F critical	
A	7	192785.5000	27540.7857	23.6373	P < 0.001	**s**	$F_{0.001\ (7,21)}$	5.56
B	3	4528.5000	1509.5000	1.2955	0.50 > P > 0.25	**ns**	$F_{0.25\ (3,21)}$	1.48
Remainder	21	24468.0000	1165.1429					

Table 13. Analysis of variance: habitats versus behaviors for dolphin sightings

	Carbonate sand	Dense seagrass	Dredged bottom	Hard bottom w/ seagrass	Moderately dense seagrass	Soft bottom w/ seagrass	mean B
Travel	1	3	26	17	67	1	19.1667
Feeding	0	4	35	3	47	1	15.0000
Social Activity	1	3	11	9	26	2	8.6667
Resting	0	0	3	1	7	0	1.8333
Boat Interact.	0	0	1	1	7	0	1.5000
Leaping	0	1	2	1	2	0	1.0000
Tail slap/chuffing	0	0	1	0	0	0	0.1667
Unknown	0	0	1	2	2	0	0.8333
mean A	0.2500	1.3750	10.0000	4.2500	19.7500	0.5000	

Total sum	289
Grand mean	6.0208

	df	SS	MS	F	P	
A	5	2342.6042	468.5208	2.1005	0.10 > P > 0.05	**ns**
B	7	2308.8202	329.8315	1.4787	0.25 > P > 0.10	**ns**
Remainder	35	7806.9289	223.0551			

F critical	
$F_{0.05\ (5,30)}$	2.53
$F_{0.05\ (5,40)}$	2.45
$F_{0.10\ (7,30)}$	1.93
$F_{0.10\ (7,40)}$	1.87

Table 14. Analysis of variance: habitats versus behaviors for dolphin numbers

	Carbonate sand	Dense seagrass	Dredged bottom	Hard bottom w/ seagrass	Moderately dense seagrass	Soft bottom w/ seagrass	mean B
Travel	18	6	84	58	396	2	94.0000
Feeding	0	15	172	8	191	1	64.5000
Social Activity	18	19	67	52	216	11	63.8333
Resting	0	0	18	3	61	0	13.6667
Boat Interact.	0	0	2	2	34	0	6.3333
Leaping	0	9	20	2	10	0	6.8333
Tail slap/chuffing	0	0	8	0	0	0	1.3333
Unknown	0	0	4	9	7	0	3.3333
mean A	4.5000	6.1250	46.8750	16.7500	114.3750	1.7500	

Total sum	1523
Grand mean	31.7292

	df	SS	MS	F	P	
A	5	76638.8542	15327.7708	4.7249	0.005 > P > 0.001	**s**
B	7	55821.0027	7974.4290	2.4582	0.05 > P > 0.025	**s**
Remainder	35	113540.9360	3244.0267			

F critical	
$F_{0.005\ (5,30)}$	4.23
$F_{0.005\ (5,40)}$	3.99
$F_{0.05\ (7,30)}$	2.33
$F_{0.05\ (7,40)}$	2.25

Table 15. Analysis of variance: habitat type versus behaviors for normalized dolphin numbers

Habitat Type	Travel (norm)	Feed (norm)	Social (norm)	Rest (norm)	Bt Int. (norm)	Leap (norm)	Tail/ (norm)	Unk (norm)	mean B
Carbonate Sand	8.9628	0.00	8.9628	0.00	0.00	0.00	0.00	0.00	2.2407
Hard bttm / sgrss	0.3221	0.0444	0.2888	0.0167	0.0111	0.0111	0.00	0.0500	0.0930
Soft bttm / sgrss	0.7161	0.3580	3.9383	0.00	0.00	0.00	0.00	0.00	0.6266
Mod. dense	1.2190	0.5880	0.6649	0.1878	0.1047	0.0308	0.00	0.0215	0.3521
Dense	0.1615	0.4037	0.5114	0.00	0.00	0.2422	0.00	0.00	0.1649
Dredge bttm	3.1149	6.3780	2.4845	0.6675	0.0742	0.7416	0.2967	0.1483	1.7382
mean A	2.4161	1.2950	2.8084	0.1450	0.0317	0.1717	0.0500	0.0367	

Total sum	41.7269
Grand mean	0.8693

	df	SS	MS	F	P	
A	7	56.4673	8.0668	2.1576	0.10> P >0.05	**ns**
B	5	32.4876	6.4975	1.7379	0.25> P >0.10	**ns**
Remainder	35	130.8528	3.7387			

F critical	
$F_{0.05(7,30)}$	2.33
$F_{0.10(5,30)}$	2.05
$F_{0.05(7,40)}$	2.25
$F_{0.10(5,40)}$	2

Table 16. Analysis of variance: seasons versus zones for sightings

	Spring	Summer	Fall	Winter	mean B
NBB	21	21	18	22	20.5000
CBB	24	31	18	33	26.5000
SBB	26	14	18	16	18.5000
mean A	23.6667	22.0000	18.0000	23.6667	

Total sum	262
Grand mean	21.8333

	df	SS	MS	F	P	
A	3	64.3341	21.4447	0.7629	0.75 > P > 0.50	**ns**
B	2	138.6667	69.3334	2.4664	0.25 > P > 0.10	**ns**
Remainder	6	168.6667	28.1111			

F critical	
$F_{0.50\ (3,6)}$	0.886
$F_{0.10\ (2,6)}$	3.46

Table 17. Analysis of variance: seasons versus zones for dolphin numbers

	Spring	Summer	Fall	Winter	mean B
NBB	103	98	66	86	88.2500
CBB	181	126	91	217	153.7500
SBB	143	62	94	86	96.2500
mean A	142.3333	95.3333	83.6667	129.6667	

Total sum	1353
Grand mean	112.7500

	df	SS	MS	F	P	
A	3	6931.5785	2310.5262	2.0385	0.50 > P > 0.25	**ns**
B	2	10214.0000	5107.0000	4.5057	0.25 > P > 0.10	**ns**
Remainder	6	6800.6667	1133.4445			

F critical	
$F_{0.25\ (3,6)}$	3.15
$F_{0.10\ (2,6)}$	9.00

Table 18. Analysis of variance: habitats versus zones for dolphin sightings

	Carbonate sand	Dense seagrass	Dredged bottom	Hard bottom w/ seagrass	Moderately dense seagrass	Soft bottom w/ seagrass	mean B
NBB	1	0	51	0	14	2	11.3333
CBB	0	5	3	7	47	1	10.5000
SBB	0	3	0	18	51	0	12.0000
mean A	0.3333	2.6667	18.0000	8.3333	37.3333	1.0000	

Total sum	203
Grand mean	11.2778

	df	SS	MS	F	P	
A	5	3096.9403	619.3881	2.3498	0.25 > P > 0.10	**ns**
B	2	6.7778	3.3889	0.0129	P > 0.75	**ns**
Remainder	10	2635.8873	263.5887			

F critical	
$F_{0.10\ (5,10)}$	2.52
$F_{0.75\ (2,10)}$	4.10

Table 19. Analysis of variance: habitats versus zones for dolphin numbers

	Carbonate sand	Dense seagrass	Dredged bottom	Hard bottom w/ seagrass	Moderately dense seagrass	Soft bottom w/ seagrass	mean B
NBB	18	0	216	0	38	11	47.1667
CBB	0	18	23	32	223	1	49.5000
SBB	0	12	0	63	293	0	61.3333
mean A	6.0000	10.0000	79.6667	31.6667	184.6667	4.0000	

Total sum	948
Grand mean	52.6667

	df	SS	MS	F	P	
A	5	74882.0276	14976.4055	2.3179	0.10 > P > 0.05	**ns**
B	2	692.3391	346.1696	0.0536	P > 0.75	**ns**
Remainder	10	64611.6137	6461.1614			

F critical	
$F_{0.05\ (5,10)}$	2.90
$F_{0.75\ (2,10)}$	0.293

Table 20. Analysis of variance: behavior versus zones for dolphin sightings

	Travel	Feed	Social	Rest	Boat Inter	Leaping	Tail/chuff	Unknown	mean B
NBB	45	44	18	3	1	3	3	0	14.6250
CBB	56	61	17	4	2	4	1	0	18.1250
SBB	48	21	24	4	1	0	0	1	12.3750
mean A	49.6667	42.0000	19.6667	3.6667	1.3333	2.3333	1.3333	0.3333	

Total sum	361
Grand mean	15.0417

	df	SS	MS	F	P		F critical	
A	7	8490.3082	1212.9012	21.6751	P < 0.001	**s**	$F_{0.001\ (7,14)}$	7.08
B	2	134.3319	67.1660	1.2003	0.50 > P > 0.25	**ns**	$F_{0.25\ (2,14)}$	1.44
Remainder	14	783.4165	55.9583					

Table 21. Analysis of variance: dolphin behaviors versus zones for dolphin numbers

	Travel	Feeding	Social Activity	Resting	Boat Interact.	Leaping	Tail /chuff	Unknown	mean B
NBB	171	201	115	16	2	24	17	0	68.2500
CBB	369	263	137	33	10	21	7	0	105.0000
SBB	279	100	181	32	2	0	0	3	74.6250
mean A	273.0000	188.0000	144.3333	27.0000	4.6667	15.0000	8.0000	1.0000	

Total sum	1983
Grand mean	82.6250

	df	SS	MS	F	P		F critical	
A	7	231392.2637	33056.0377	15.4643	P < 0.001	**s**	$F_{0.001\ (7,14)}$	7.08
B	2	6170.2500	3085.1250	1.4433	0.5 > P > 0.25	**ns**	$F_{0.25\ (2,14)}$	1.53
Remainder	14	29926.0833	2137.5774					

Table 22. Analysis of variance: seasons versus depth for dolphin sightings

	Spring	Summer	Fall	Winter	mean B
1 meter	5	5	3	4	4.2500
1.1 - 2	16	24	16	23	19.7500
2.1 - 3	40	30	18	41	32.2500
3.1 - 4	9	17	15	11	13.0000
4.1 + (m)	2	1	3	4	2.5000
mean A	14.4000	15.4000	11.0000	16.6000	

Total sum	287
Grand mean	14.3500

	df	SS	MS	F	P	
A	3	86.9500	28.9833	0.9600	0.50 > P > 0.25	**ns**
B	4	2375.3000	593.8250	19.6685	P < 0.001	**s**
Remainder	12	362.3000	30.1917			

F critical	
$F_{0.25\ (3,12)}$	1.56
$F_{0.001\ (4,12)}$	9.63

Table 23. Analysis of variance: seasons versus depth for dolphin numbers

	Spring	Summer	Fall	Winter	mean B
1 meter	21	13	6	15	13.7500
1.1 - 2	88	104	22	86	75.0000
2.1 - 3	246	120	108	222	174.0000
3.1 - 4	68	115	88	71	85.5000
4.1 + (m)	4	8	10	12	8.5000
mean A	85.4000	72.0000	46.8000	81.2000	

Total sum	1427
Grand mean	71.3500

	df	SS	MS	F	P	
A	3	4487.7500	1495.9167	1.1394	0.50 > P > 0.25	**ns**
B	4	72073.8000	18018.4500	13.7240	P < 0.001	**s**
Remainder	12	15755.0000	1312.9167			

F critical	
$F_{0.25\ (3,12)}$	1.56
$F_{0.001\ (4,12)}$	9.63

Table 24. Analysis of variance: habitats versus depths for dolphin sightings

	Carbonate sand	Dense seagrass	Dredged bottom	Hard bottom w/ seagrass	Moderately dense seagrass	Soft bottom w/ seagrass	mean B
1 meter	0	0	1	3	8	1	2.1667
1.1 - 2	0	3	9	16	46	0	12.3333
2.1 - 3	1	5	29	6	48	2	15.1667
3.1 - 4	0	0	8	2	13	0	3.8333
4.1 + (m)	0	0	8	0	2	0	1.6667
mean A	0.2000	1.6000	11.0000	5.4000	23.4000	0.6000	

Total sum	211
Grand mean	7.0333

	df	SS	MS	F	P	
A	5	2019.3667	403.8733	5.0239	0.005 > P > 0.001	s
B	4	941.7983	235.4496	2.9288	0.05 > P > 0.025	s
Remainder	20	1607.8020	80.3901			

F critical	
$F_{0.005\,(5,20)}$	4.76
$F_{0.05\,(4,20)}$	2.87

Table 25. Analysis of variance: habitats versus depths for dolphin numbers

	Carbonate sand	Dense seagrass	Dredged bottom	Hard bottom w/ seagrass	Moderately dense seagrass	Soft bottom w/ seagrass	mean B
1 meter	0	0	2	7	28	1	6.3333
1.1 - 2	0	7	35	51	205	0	49.6667
2.1 - 3	18	23	141	24	262	11	79.8333
3.1 - 4	0	0	37	18	84	0	23.1667
4.1 + (m)	0	0	28	0	6	0	5.6667
mean A	3.6000	6.0000	48.6000	20.0000	117.0000	2.4000	

Total sum	988
Grand mean	32.9333

	df	SS	MS	F	P	
A	5	49990.2667	9998.0533	5.0371	0.005 > P > 0.001	s
B	4	24156.1838	6039.0460	3.0425	0.05 > P > 0.025	s
Remainder	20	39697.4000	1984.8700			

F critical	
$F_{0.005\,(5,20)}$	4.76
$F_{0.05\,(4,20)}$	2.87

Table 26. Analysis of variance: habitat types versus depths for normalized dolphin sightings

Habitat Type	1mtr (norm)	1.1-2(norm)	2.1-3 (norm)	3.1-4(norm)	4.1+ (norm)	mean B
Carbonate Sand	0.00	0.00	0.4979	0.00	0.00	0.0996
Hard bttm / sgrss	0.0167	0.0888	0.0333	0.0111	0.00	0.0300
Soft bttm / sgrss	0.3580	0.00	0.7161	0.00	0.00	0.2148
Mod. dense	0.0246	0.1416	0.1478	0.0400	0.0062	0.0720
Dense	0.00	0.0807	0.1346	0.00	0.00	0.0431
Dredge bttm	0.0371	0.3337	1.0754	0.2967	0.2967	0.4079
mean A	0.0727	0.1075	0.4342	0.0580	0.0505	

Total sum	4.3369
Grand mean	0.1446

	df	SS	MS	F	P	
A	4	0.6406	0.1602	4.8841	0.01 > P > 0.005	**s**
B	5	0.5249	0.1050	3.2012	0.05 > P > 0.025	**s**
Remainder	20	0.6563	0.0328			

F critical	
$F_{.01(4,20)}$	4.43
$F_{.05(5,20)}$	2.71

Table 27. Analysis of variance: habitat types versus depths for normalized dolphin numbers

Habitat Type	1mtr (norm)	1.1-2(norm)	2.1-3 (norm)	3.1-4 (norm)	4.1+ (norm)	mean B
Carbonate Sand	0.0000	0.00	8.9628	0.00	0.00	1.7926
Hard bttm / sgrss	0.0389	0.2832	0.1333	0.1000	0.00	0.1111
Soft bttm / sgrss	0.3580	0.0000	3.9383	0.00	0.00	0.8593
Mod. dense	0.0862	0.6311	0.8065	0.2586	0.0185	0.3602
Dense	0.0000	0.1884	0.6191	0.00	0.00	0.1615
Dredge bttm	0.0742	1.2979	5.2285	1.3720	1.0383	1.8022
mean A	0.0929	0.4001	3.2814	0.2884	0.1761	

Total sum	25.4336
Grand mean	0.8478

	df	SS	MS	F	P	
A	4	44.7410	11.1853	4.5279	0.01 > P > 0.005	**s**
B	5	15.2757	3.0551	1.2367	0.50 > P > 0.25	**ns**
Remainder	20	49.4056	2.4703			

F critical	
$F_{.01(4,20)}$	4.43
$F_{.25(5,20)}$	1.45

Table 28. Analysis of variance: behaviors versus depths for dolphin sightings

	Travel	Feeding	Social Activity	Resting	Boat Interact.	Leaping	Tail slap/chuff	Unknown	mean B
1 meter	5	9	4	1	0	1	0	0	2.5000
1.1 - 2	45	36	20	1	3	0	1	1	13.3750
2.1 - 3	76	54	30	6	2	4	3	1	22.0000
3.1 - 4	20	24	10	5	2	2	1	3	8.3750
4.1 + (m)	7	4	1	0	1	0	0	0	1.6250
mean A	30.6000	25.4000	13.0000	2.6000	1.6000	1.4000	1.0000	1.0000	

Total sum	383
Grand mean	9.5750

	df	SS	MS	F	P		F critical	
A	7	5151.7750	735.9679	5.7023	P < 0.001	**s**	$F_{0.001\ (7,28)}$	4.93
B	4	2268.1500	567.0375	4.3934	0.01 > P > 0.005	**s**	$F_{0.01\ (4,28)}$	4.07
Remainder	28	3613.8500	129.0661					

Table 29. Analysis of variance: behaviors versus depths for dolphin numbers

	Travel	Feeding	Social Activity	Resting	Boat Interact.	Leaping	Tail slap/chuff	Unknown	mean B
1 meter	23	22	17	3	0	2	0	0	8.3750
1.1 - 2	214	134	141	4	13	0	5	3	64.2500
2.1 - 3	432	274	232	47	4	33	19	3	130.5000
3.1 - 4	165	129	87	39	18	10	4	17	58.6250
4.1 + (m)	22	17	6	0	2	0	0	0	5.8750
mean A	171.2000	115.2000	96.6000	18.6000	7.4000	9.0000	5.6000	4.6000	

Total sum	2141
Grand mean	53.5250

	df	SS	MS	F	P		F critical	
A	7	147634.3750	21090.6250	5.1966	P < 0.001	**s**	$F_{0.001\ (7,28)}$	4.93
B	4	83001.8500	20750.4625	5.1128	P < 0.001	**s**	$F_{0.001\ (4,28)}$	4.93
Remainder	28	113639.7501	4058.5625					

Table 30. Analysis of variance: depths versus zones for dolphin sightings

	1 meter	1.1 - 2 meters	2.1 - 3 meters	3.1 - 4 meters	4.1 + meters	mean B
NBB	2	18	47	7	8	16.4000
CBB	11	22	50	29	2	22.8000
SBB	4	37	30	3	0	14.8000
mean A	5.6667	25.6667	42.3333	13.0000	3.3333	

Total sum	270
Grand mean	18.0000

	df	SS	MS	F	P	
A	4	3129.3305	782.3326	8.6270	0.01 > P > 0.005	**s**
B	2	179.2000	89.6000	0.9881	0.50 > P > 0.25	**ns**
Remainder	8	725.4667	90.6833			

F critical	
$F_{0.01\ (4,8)}$	7.01
$F_{0.25\ (2,8)}$	1.66

Table 31. Analysis of variance: depths versus zones for dolphin numbers

	1 meter	1.1 - 2 meters	2.1 - 3 meters	3.1 - 4 meters	4.1 + meters	mean B
NBB	3	60	238	24	28	70.6000
CBB	30	91	294	194	6	123.0000
SBB	22	177	161	25	0	77.0000
mean A	18.3333	109.3333	231.0000	81.0000	11.3333	

Total sum	1353
Grand mean	90.200

	df	SS	MS	F	P	
A	4	94980.4263	23745.1066	6.7676	0.025 > P > 0.01	**s**
B	2	8171.2000	4085.6000	1.1644	0.50 > P > 0.25	**ns**
Remainder	8	28069.1333	3508.6417			

F critical	
$F_{0.025\ (4,8)}$	5.05
$F_{0.25\ (2,8)}$	1.66

Table 32. Analysis of survey effort and dolphin numbers

Year	# of Surveys	# of Dolphins	Dolphins/Survey
1990	8	116	15
1991	6	69	12
1994	8	69	9
1995	18	182	10
1996	26	234	9
1997	26	232	9
1998	23	178	8
1999	25	331	13
2000	9	125	14

(The years that have surveys throughout the complete year are marked in gray and were used for the statistics below.)

	# of Surveys	# of Dolphins	Dolphins/Survey
Mean	23.60	231.40	9.80
Variance	45.20	15219.20	3.70
Standard Deviation	6.72	123.37	1.92

Table 33. The regression statistics, with ANOVA results, for the time series analysis.

Dependent variable	Square root of dolphin totals
mean	2.493
variance	2.022
n	171

Regression coefficient	0.003
Standard error	0.002
95% confidence	-0.001 to 0.007
Y-intercept	2.169

Source	SS	df	MS	F	P
Total	343.678	170	2.022		
Linear	4.455	1	4.456	2.22	0.138
Deviation	339.222	169	2.007		

Table 34. The summary of lagged autocorrelation statistics on the residuals.

Lag	Corr.	S. E.	Q	p
1	0.007	0.076	0.01	0.9276
2	0.044	0.0758	0.34	0.8434
3	-0.079	0.0756	1.44	0.697
4	0.059	0.0753	2.06	0.725
5	0.077	0.0751	3.1	0.6845
6	-0.033	0.0749	3.3	0.7708
7	0.049	0.0747	3.72	0.8112
8	-0.042	0.0744	4.05	0.8528
9	-0.017	0.0742	4.1	0.9049
10	-0.048	0.074	4.53	0.9204
11	0.12	0.0737	7.18	0.7847
12	-0.017	0.0735	7.23	0.8423
13	-0.039	0.0733	7.51	0.8739
14	-0.082	0.073	8.76	0.8458
15	0.011	0.0728	8.79	0.8884
16	0.092	0.0726	10.38	0.8459
17	0.07	0.0723	11.32	0.8392
18	-0.005	0.0721	11.33	0.8799
19	-0.121	0.0719	14.18	0.7732
20	-0.062	0.0716	14.94	0.7799
21	0.09	0.0714	16.52	0.7397
22	-0.063	0.0711	17.31	0.7458
23	-0.011	0.0709	17.34	0.7923
24	-0.118	0.0707	20.13	0.6895

Table 35. The summary of periodogram and spectral density statistics on the residuals.

	Periodogram	Frequency	Period	Cosine Coeff.	Sine Coeff.	Density
0	0.00	0.00000		0.0000	0.0000	4.248
1	5.2672	0.0059	170.0000	0.2484	-0.0156	4.2716
2	2.2494	0.0118	85.0000	-0.0826	-0.1401	4.3549
3	7.1332	0.0176	56.6667	-0.1794	0.2274	4.4415
4	9.7476	0.0234	42.5000	0.0148	0.3383	4.3944
5	2.0766	0.0294	34.0000	0.1563	-0.0028	4.1931
6	0.1396	0.0353	28.3333	0.0352	0.0200	3.9589
7	3.7706	0.0412	24.2857	-0.1632	-0.1331	3.8385
8	4.9967	0.0471	21.2500	0.0149	-0.2420	3.8493
9	1.6967	0.0529	18.8889	0.1084	-0.0906	4.0199
10	4.7062	0.0588	17.0000	0.0341	0.2328	4.1906
11	8.8567	0.0647	15.4545	0.1178	0.3005	4.1578
12	3.9311	0.0706	14.1667	-0.1103	-0.1846	3.8495
13	1.7880	0.0765	13.0769	-0.0308	0.1417	3.4198
14	3.6591	0.0824	12.1429	0.0165	0.2068	3.0025
15	0.4089	0.08824	11.3333	0.0100	0.0686	2.6699
16	0.5370	0.0941	10.625	0.0453	0.0653	2.5124
17	4.0524	0.1000	10.0000	0.0406	-0.2145	2.5646
18	4.5714	0.1059	9.4444	0.2318	0.0055	237378
19	1.0041	0.1118	8.9474	-0.1087	0.0009	2.9575
20	4.2342	0.1176	8.5000	-0.1653	-0.1500	3.1908
21	2.5544	0.1235	8.0952	-0.1642	0.0555	3.3370
22	3.1851	0.1294	7.7273	-0.0265	0.1917	3.3302
23	3.6800	0.1353	7.3913	-0.0821	-0.1912	3.2521
24	6.5908	0.1412	7.0833	0.0475	-0.2744	3.1682
25	1.4560	0.1471	6.8000	0.0184	-0.1296	3.1917
26	0.5697	0.1529	6.5385	0.0818	0.0041	3.4424
27	1.1069	0.1588	6.2963	-0.0128	-0.1134	3.9821
28	6.9873	0.1647	6.0714	-0.2541	-0.1329	4.7732
29	1.6020	0.1706	5.8621	0.0983	-0.0959	5.5580
30	15.1435	0.1765	5.6667	-0.0706	-0.4161	6.1244
31	1.7250	0.1824	5.4839	0.1185	0.0790	6.2988
32	15.0742	0.1882	5.3125	0.0829	0.4129	5.9795
33	1.2902	0.1941	5.1515	0.106	-0.0627	5.2540
34	0.3552	0.2000	5.0000	0.0584	-0.0276	4.3720
35	6.3511	0.2059	4.8571	-0.2489	-0.1129	3.5629

Table 35 continued. The summary of periodogram and spectral density statistics on the residuals.

	Periodogram	Frequency	Period	Cosine Coeff.	Sine Coeff.	Density
36	1.9611	0.2118	4.7222	-0.0651	-0.1372	3.0291
37	1.1622	0.2176	4.5946	-0.1094	-0.0414	2.9460
38	1.0338	0.2235	4.4737	0.1092	-0.0157	3.3160
39	5.6172	0.2294	4.3590	-0.1742	-0.1890	3.8650
40	1.8197	0.2353	4.2500	0.1118	0.0944	4.2850
41	5.5044	0.2412	4.1463	0.2474	-0.0598	4.5080
42	14.1472	0.2471	4.0476	-0.1523	-0.3785	4.4898
43	0.9165	0.2529	3.9535	0.0806	-0.0655	4.3005
44	0.2339	0.2588	3.8636	-0.0152	0.0502	4.1235
45	1.7062	0.2647	3.7778	-0.0681	0.1242	4.0423
46	3.934	0.2706	3.6957	-0.0527	0.2086	4.0100
47	4.165	0.2765	3.6170	-0.1771	-0.1328	3.9879
48	9.9863	0.2824	3.5417	-0.1941	0.2825	3.9434
49	5.0391	0.2882	3.4694	0.1738	0.1702	3.7044
50	0.3904	0.2941	3.4000	-0.0384	-0.0558	3.2007
51	0.1105	0.3000	3.3333	0.0248	0.0262	2.6044
52	3.0886	0.3059	3.2692	-0.1493	-0.1185	2.1177
53	0.781	0.3118	3.2075	-0.0951	-0.0121	1.8593
54	2.3935	0.3176	3.1481	-0.1395	0.0933	1.8472
55	0.6456	0.3235	3.0909	0.0116	-0.0864	1.9736
56	3.8329	0.3294	3.0357	-0.0933	-0.1908	2.1181
57	1.8978	0.3353	2.9825	0.1431	0.0432	2.2793
58	2.6968	0.3412	2.9310	0.1192	0.1324	2.4753
59	0.8199	0.3471	2.8814	-0.0905	-0.0381	2.6787
60	3.3767	0.3529	2.8333	-0.0232	-0.1980	2.8468
61	3.8918	0.3588	2.7869	-0.0664	-0.2034	2.9358
62	4.7858	0.3647	2.7419	0.2251	-0.0749	3.0170
63	1.4399	0.3706	2.6984	0.1217	-0.0460	3.1465
64	3.7718	0.3765	2.6563	-0.1931	-0.0742	3.2892
65	1.2379	0.3824	2.6154	-0.1056	0.0583	3.4213
66	2.0507	0.3882	2.5758	0.1275	-0.0888	3.4971
67	9.4985	0.3941	2.5373	0.1362	0.3053	3.4713
68	1.9946	0.4000	2.5000	-0.1473	0.0421	3.3350
69	3.6472	0.4059	2.4638	0.0454	0.2021	3.2677
70	2.2817	0.4118	2.4286	-0.1638	0.0014	3.4501

Table 35 continued. The summary of periodogram and spectral density statistics on the residuals.

	Periodogram	Frequency	Period	Cosine Coeff.	Sine Coeff.	Density
71	0.2847	0.4176	2.3944	0.0040	0.0577	3.8594
72	1.6784	0.4235	2.3611	-0.1335	0.0439	4.4698
73	4.1584	0.4294	2.3288	-0.0585	-0.2133	5.1867
74	17.3984	0.4353	2.2973	-0.1731	-0.4180	5.7180
75	3.3112	0.4412	2.2667	0.0541	0.1898	5.9009
76	4.2784	0.4471	2.2368	-0.1904	-0.1187	5.8623
77	8.2327	0.4529	2.2078	0.2579	0.1742	5.6978
78	1.2331	0.4588	2.1795	-0.0034	-0.1204	5.4431
79	1.3605	0.4647	2.1519	0.0684	-0.1065	5.1770
80	8.3083	0.4706	2.1250	-0.3121	0.0184	4.9644
81	13.0789	0.4765	2.0988	-0.3427	-0.1909	4.6804
82	0.4875	0.4824	2.0732	0.0731	0.0196	4.2023
83	1.3391	0.4884	2.0482	0.0970	0.0796	3.5940
84	1.5572	0.4941	2.0238	-0.1353	-0.0010	3.0298
85	3.7118	0.5000	2.0000	-0.2090	0.0000	2.7944

Table 36. The spectral density results, using Tukey weights, for the time series analysis. When the mean fits within the confidence interval boundries, then the largest peak is not significant.

Sum of Squares (SS) total	324.766		
Mean	3.821		
edf	34.915		
Lower Confidence Interval (CI)	3.649	**Upper Confidence Interval (CI)**	12.793

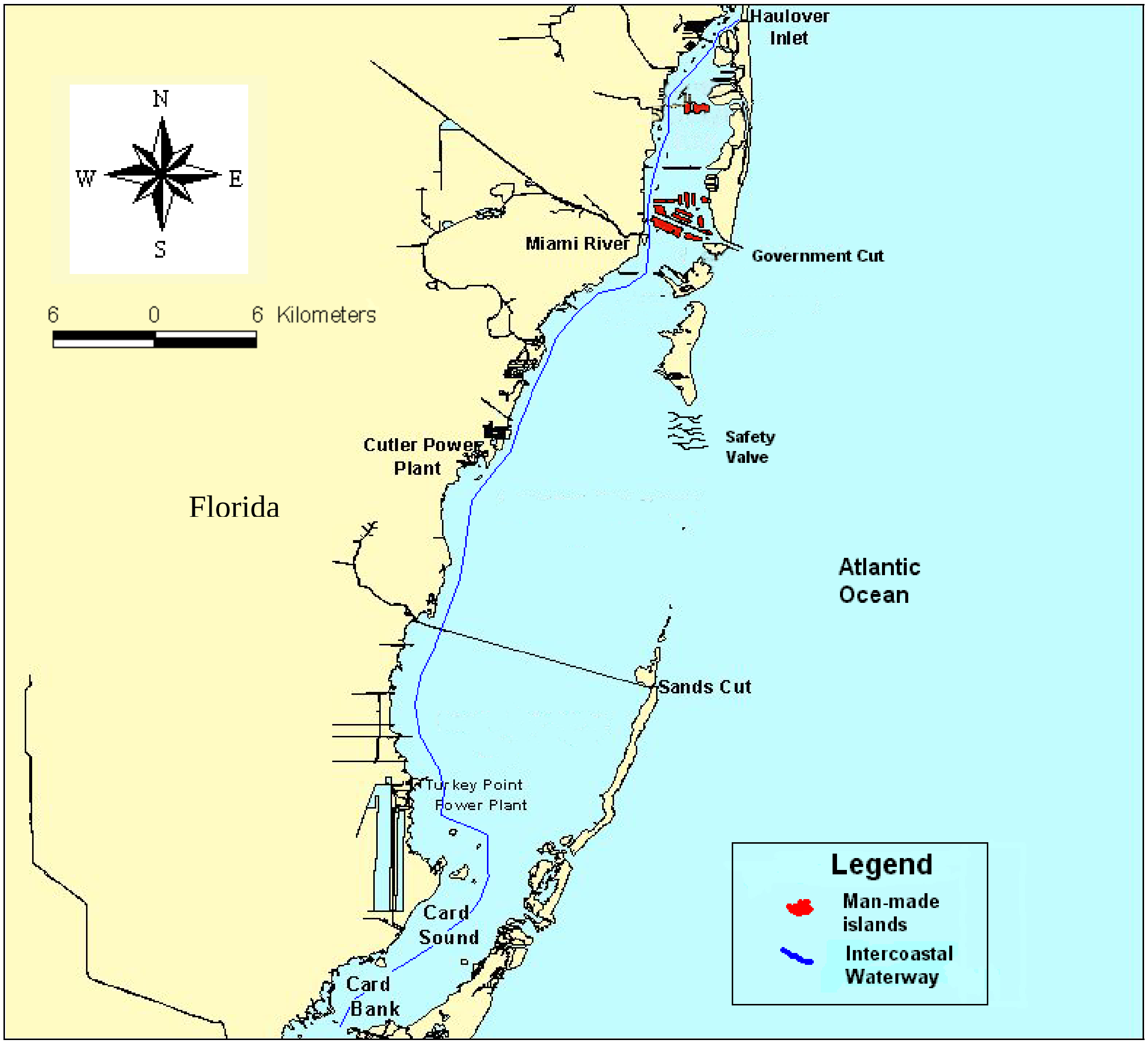


Figure 1. GIS map of the Biscayne Bay study area in southeast Florida. Map coordinates are centered at 25°33'56"N and 80°13'0"W. Distinct features include Intracoastal Waterway, Cutler and Turkey Point power plants, and man-made islands.

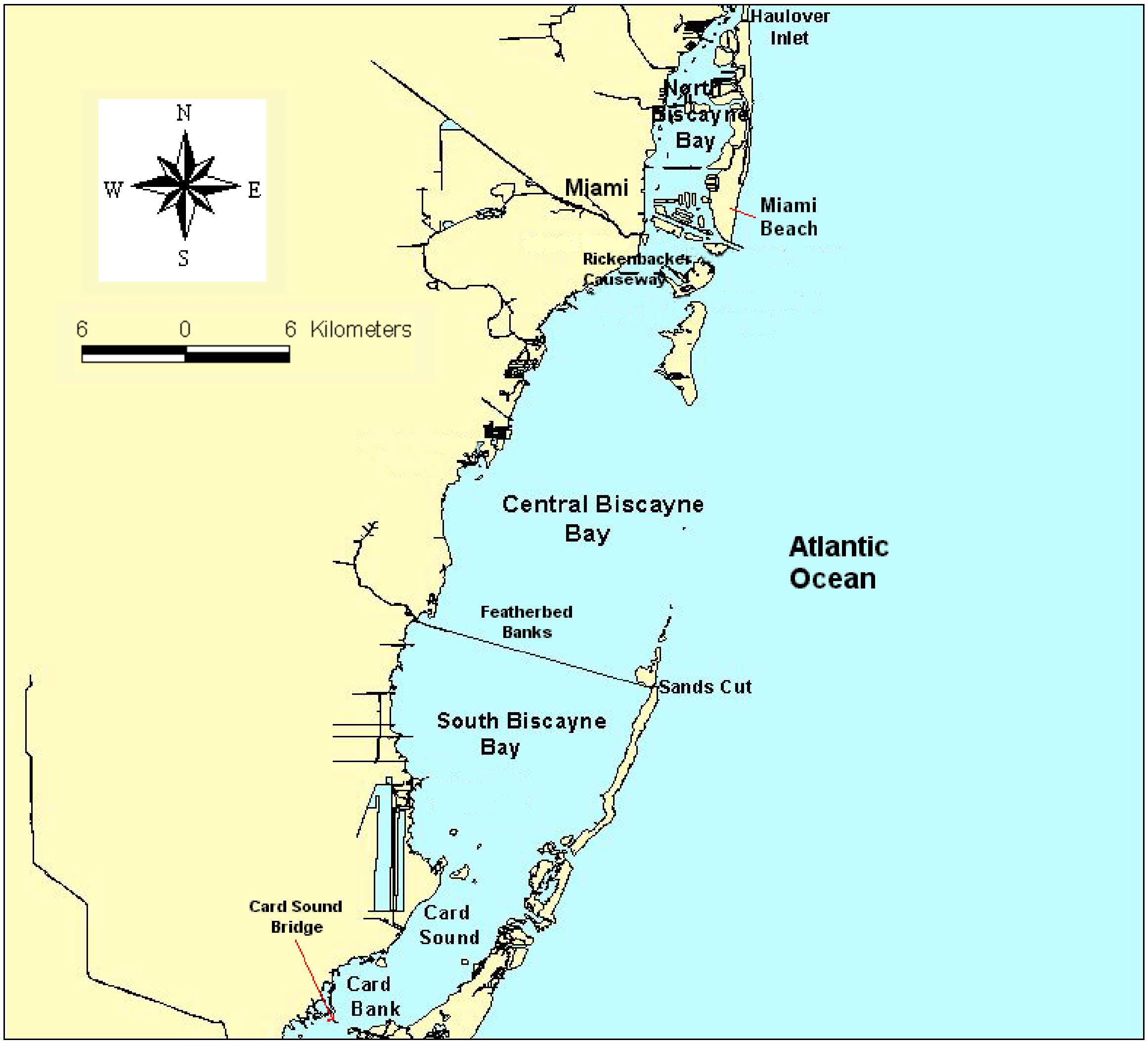


Figure 2. GIS map of Biscayne Bay, FL showing the three zones and their dividers.

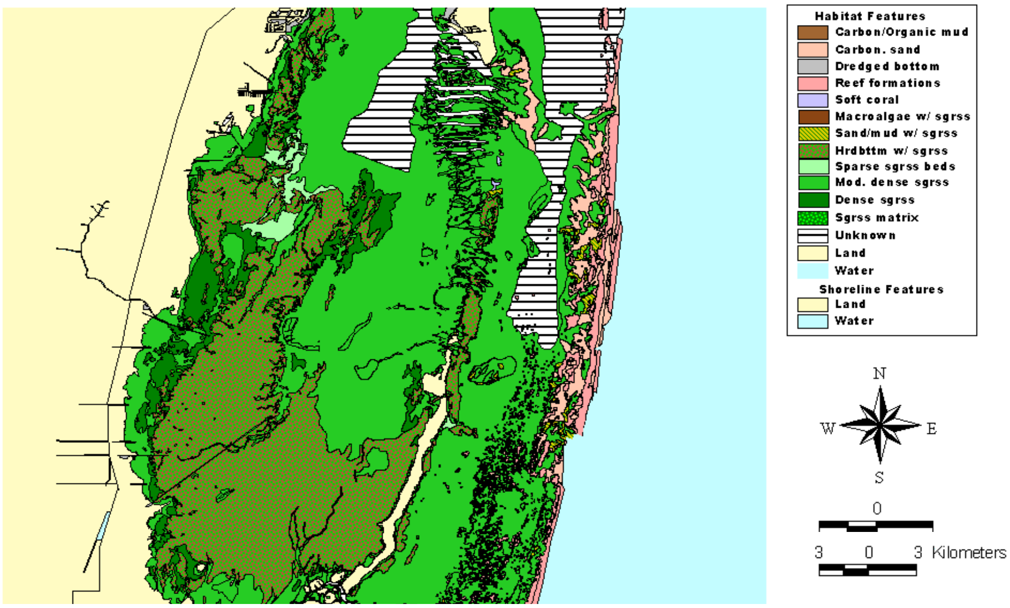


Figure 5. GIS map shows the 1991 – 1992 habitat coverage of Biscayne Bay.

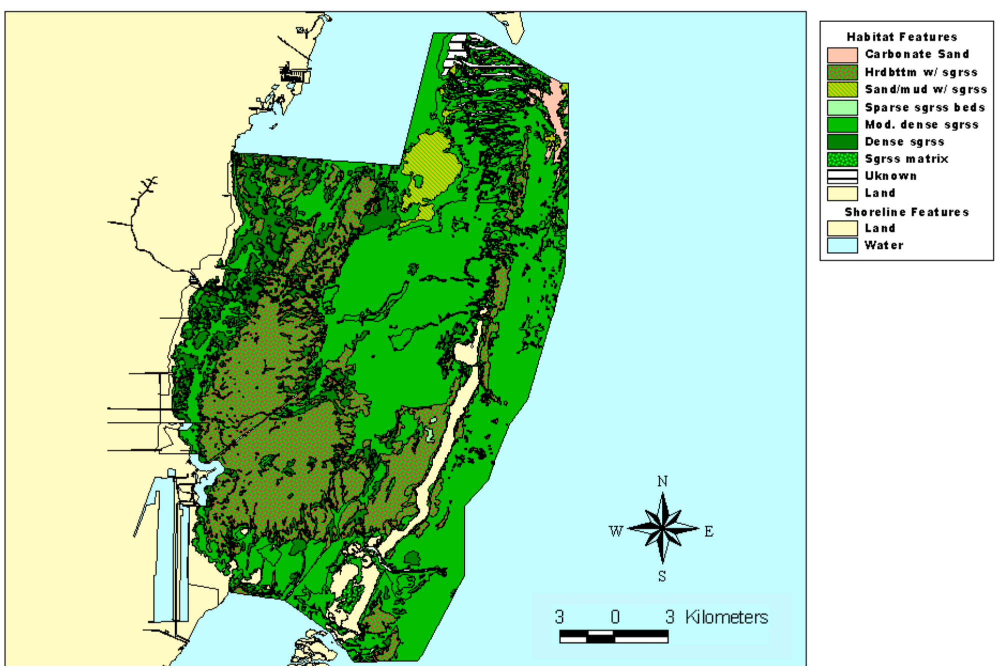
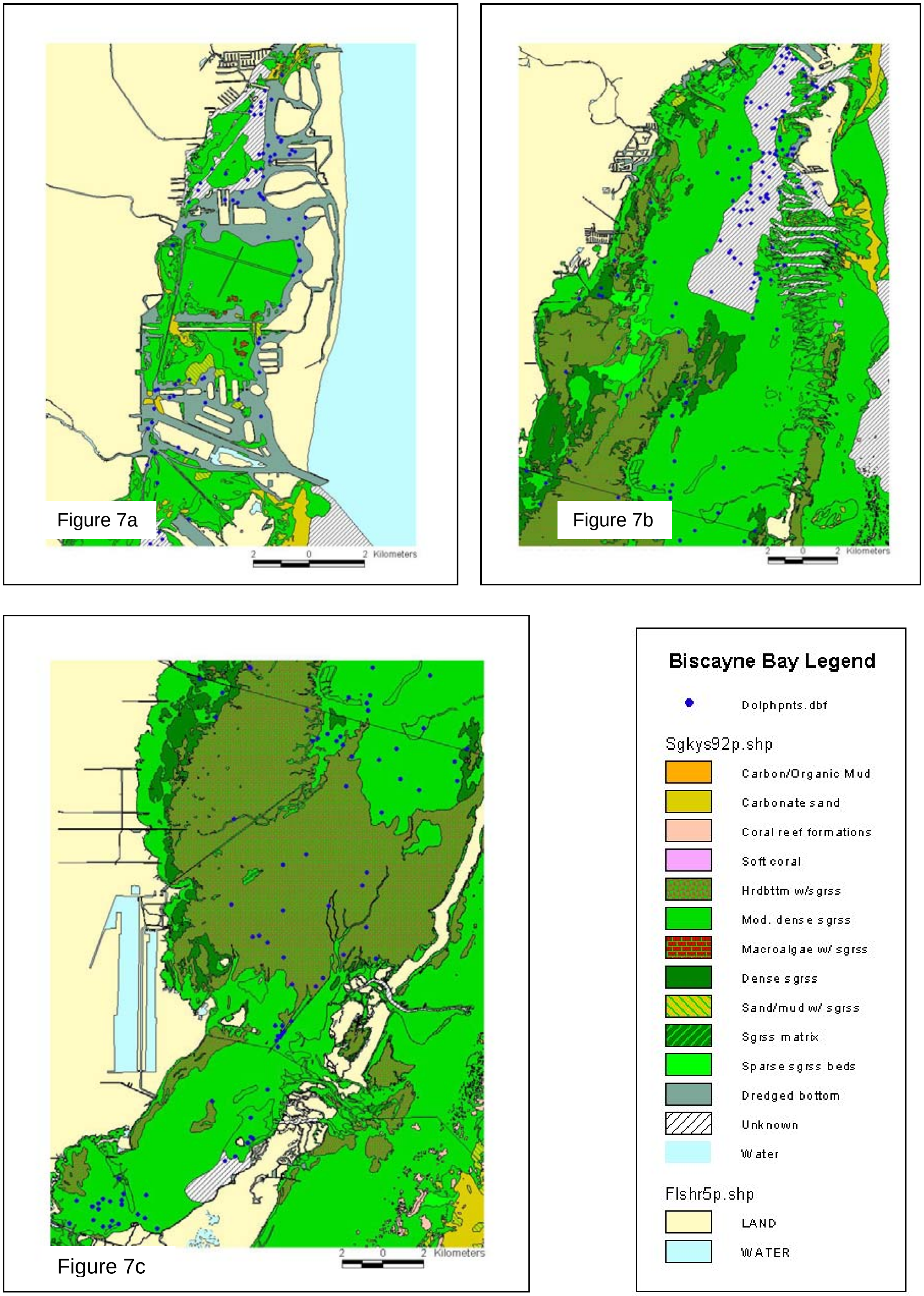


Figure 6. GIS map shows 1997 habitat coverage of Biscayne Bay.



Figures 7a-c. GIS maps of 1991-1992 habitat coverage for North Biscayne Bay (7a), Central Biscayne Bay (7b), and South Biscayne Bay (7c). Dots represent dolphin sightings throughout the zones.

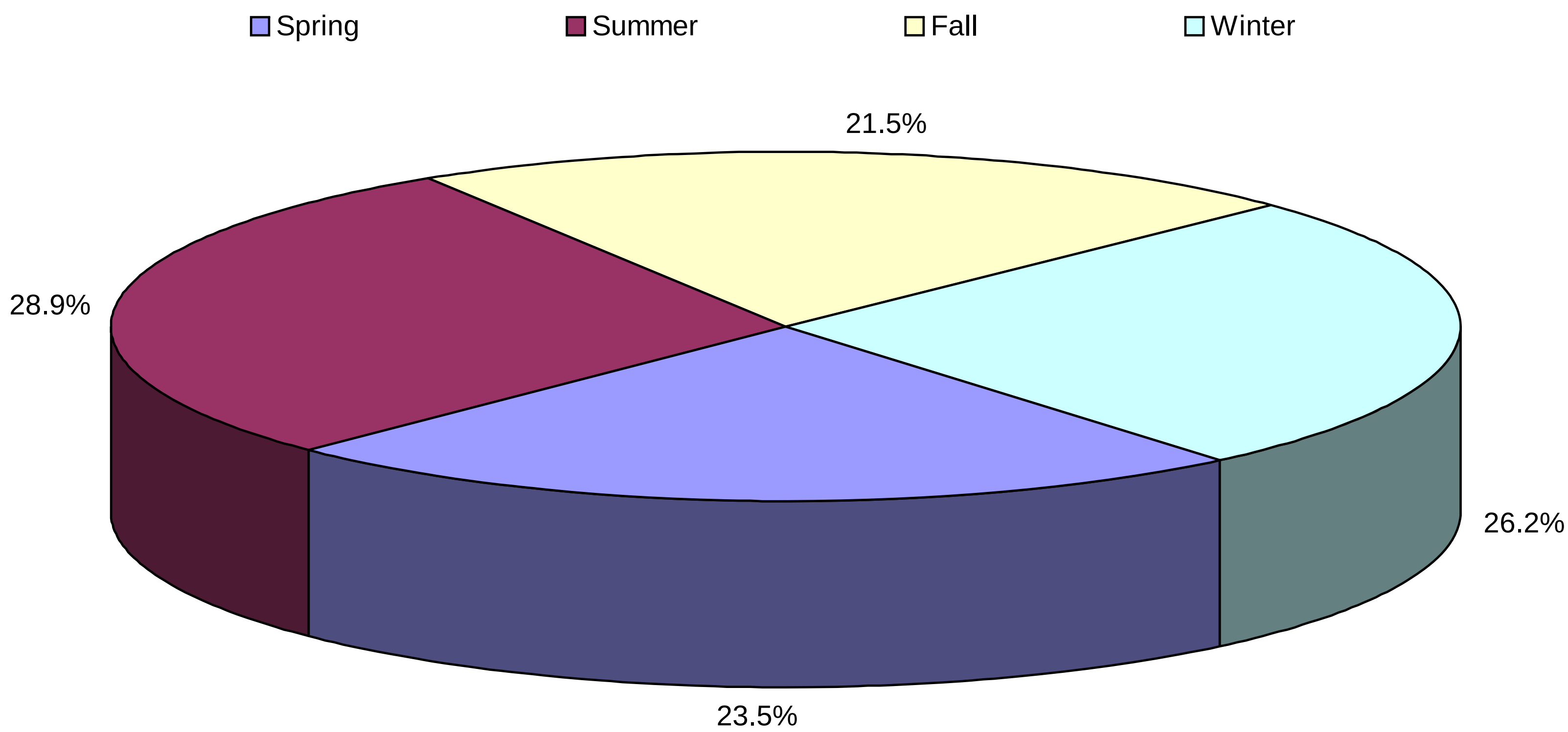


Figure 8. Survey effort per season for the study period: 1990 - 1991, 1994 - 2000.

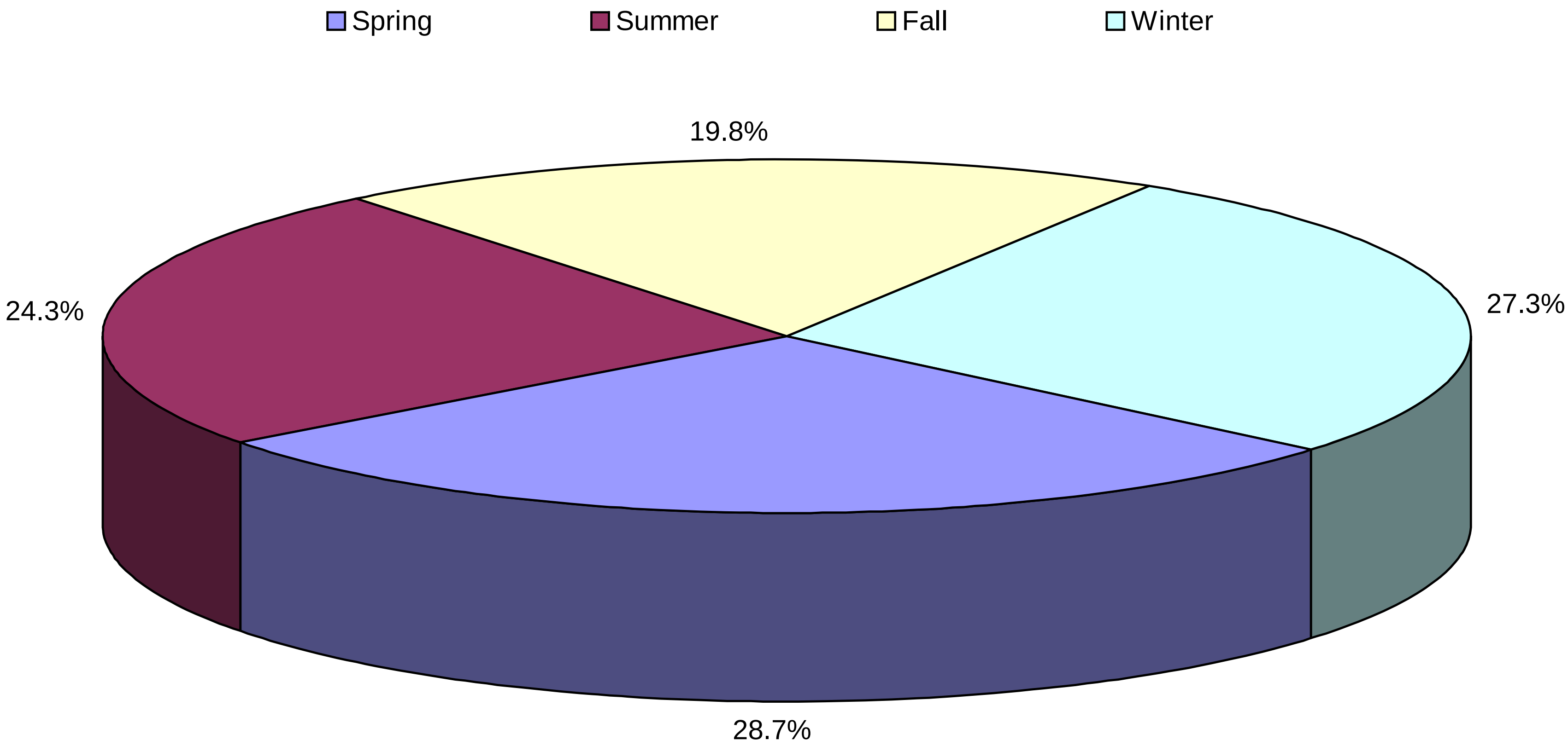


Figure 9. Proportions of bottlenose dolphin numbers, based on seasons of the study period: 1990 - 1991, 1994 - 2000.

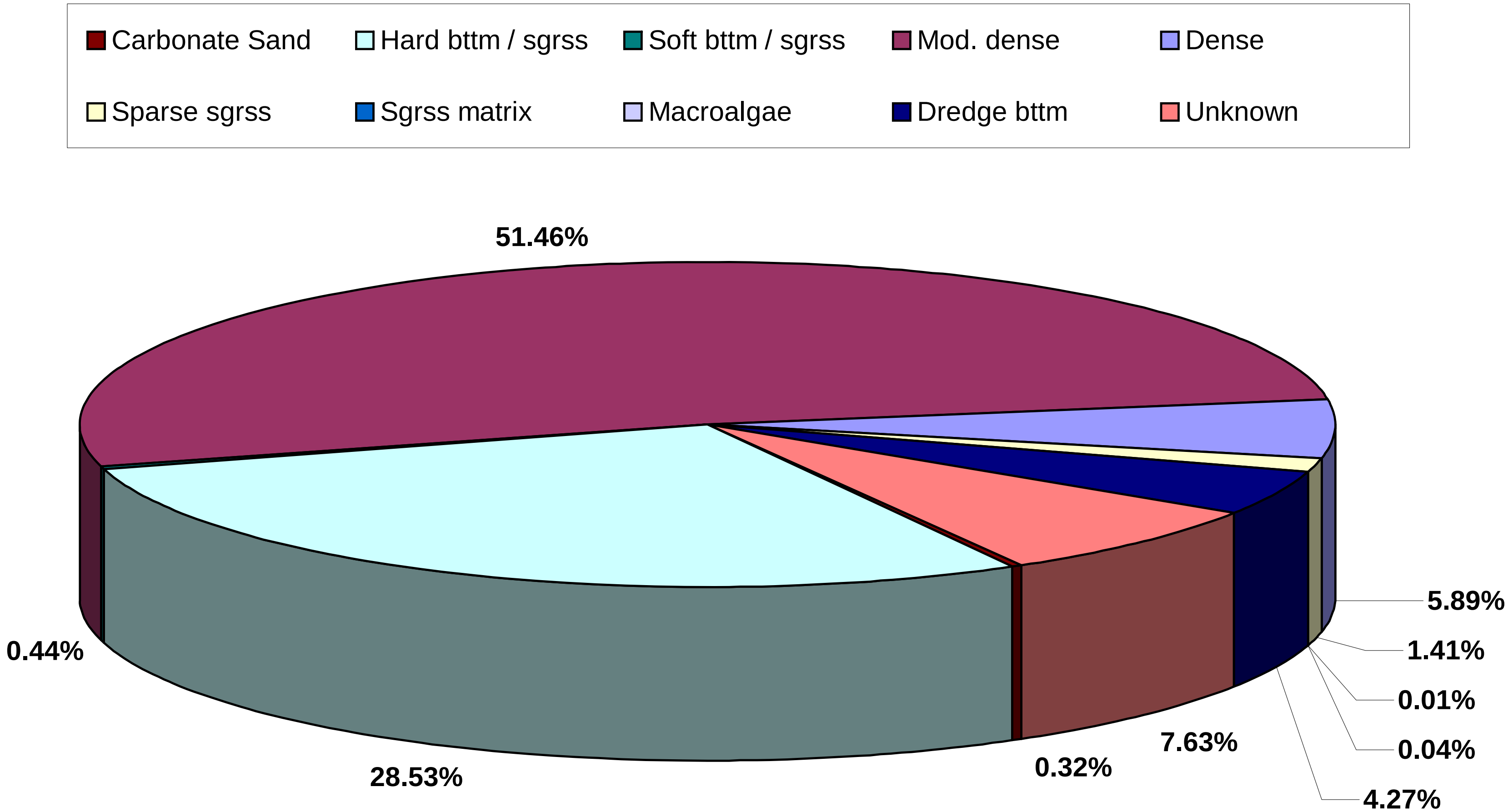


Figure 10. Habitat proportions throughout Biscayne Bay, FL.

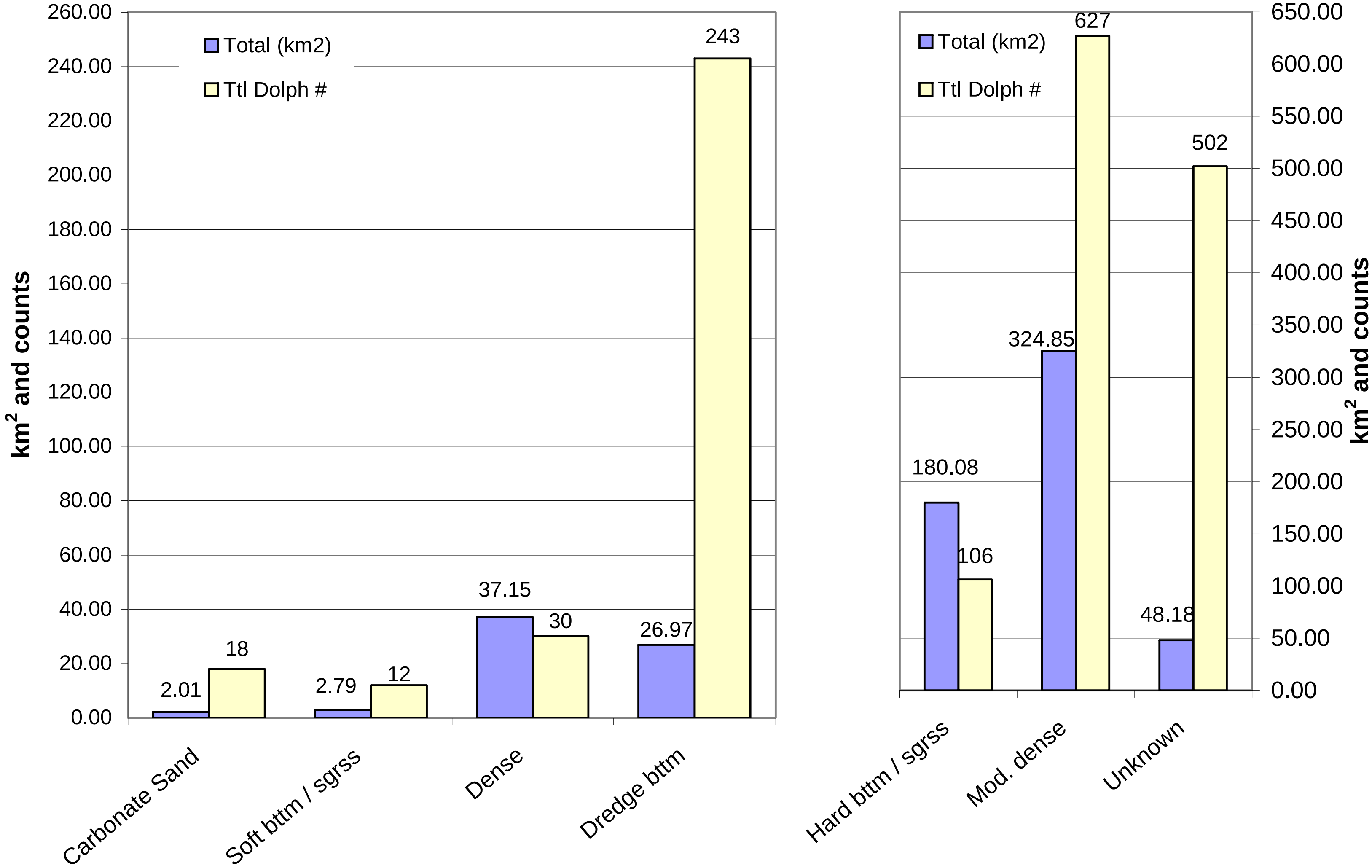


Figure 11. Habitat areas (km2) and bottlenose dolphin numbers throughout Biscayne Bay, FL. Habitat areas were calculated from the 1991-1992 habitat coverage.

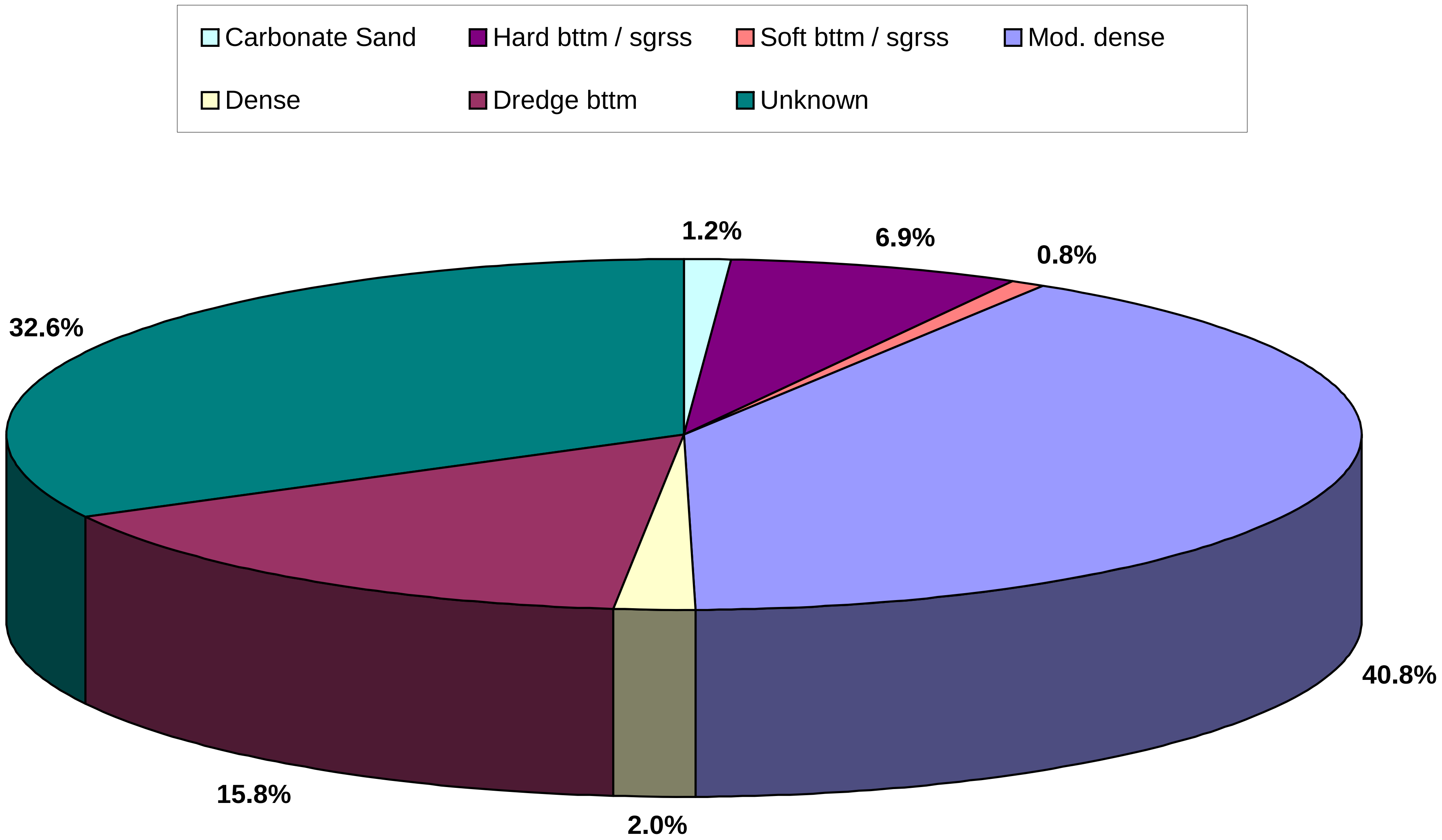


Figure 12. Proportions of bottlenose dolphins per habitat of Biscayne Bay, FL.

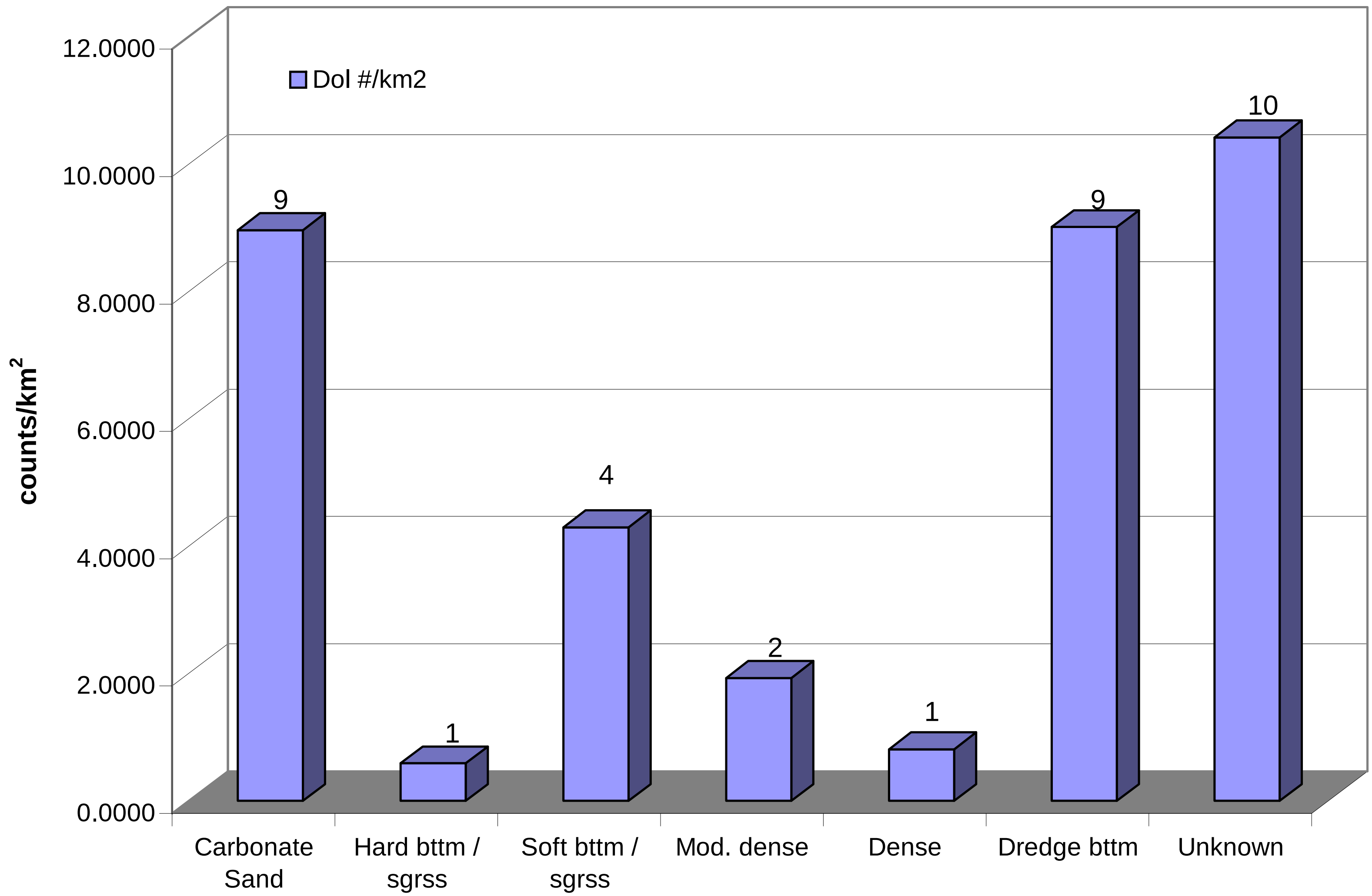


Figure 13. Bottlenose dolphin numbers normalized by habitat area. Habitat areas were calculated from the 1991-1992 habitat coverage.

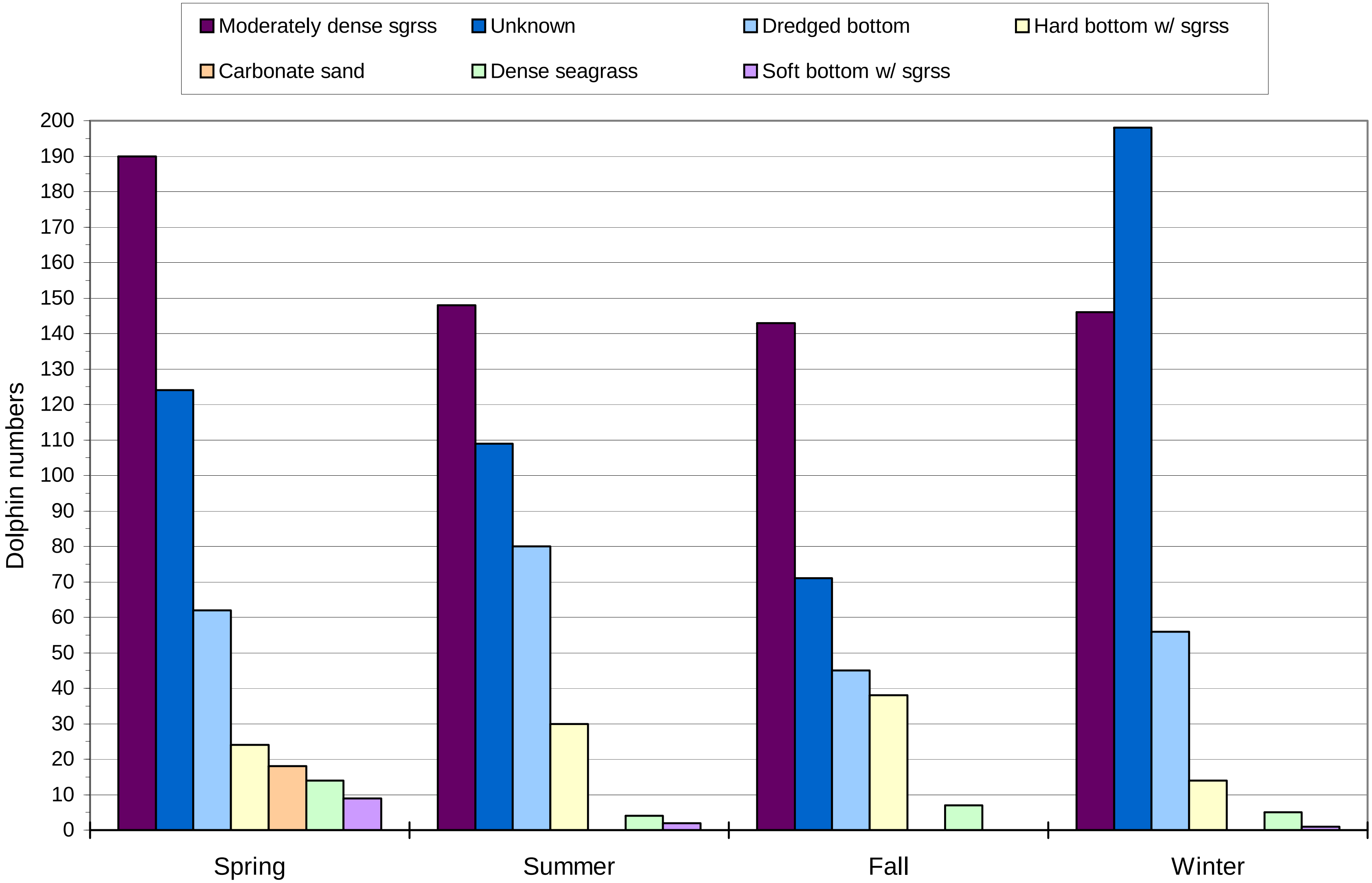
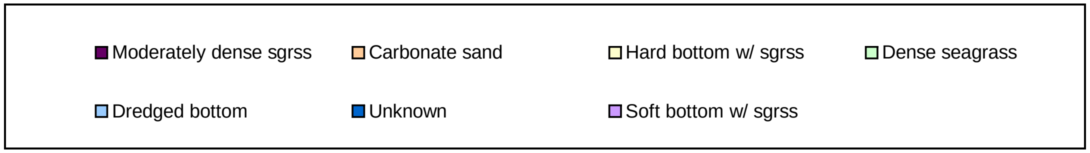


Figure 14. Proportion of bottlenose dolphins based on habitats and seasons.



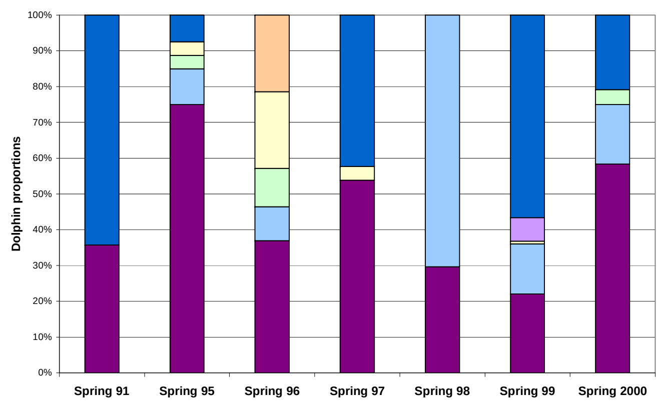


Figure 15a. Proportions of bottlenose dolphins based on habitat and spring seasons throughout the years. No data was collected for the spring seasons of 1990, 1992, 1993, and 1994.

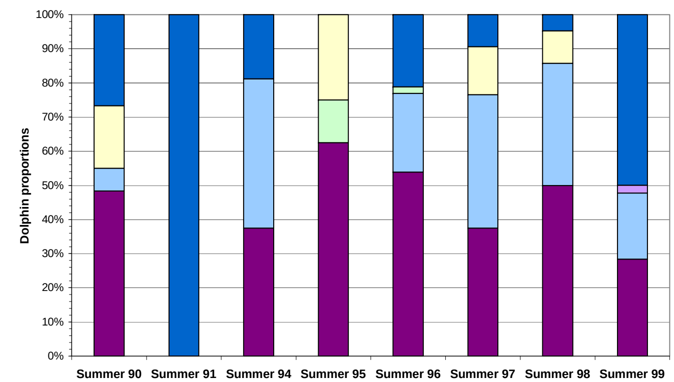


Figure 15b. Proportions of bottlenose dolphins, based on habitat and summer seasons throughout the years. No data was collected for the summer seasons of 1992 and 1993.

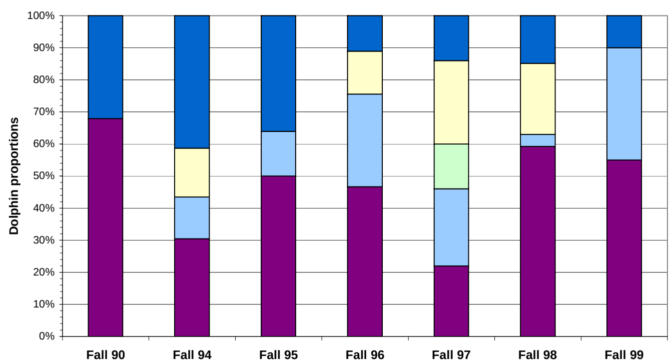


Figure 15c. Proportions of bottlenose dolphins, based on habitat and fall seasons throughout the years. No data was collected for the fall seasons of 1991, 1992, and 1993.

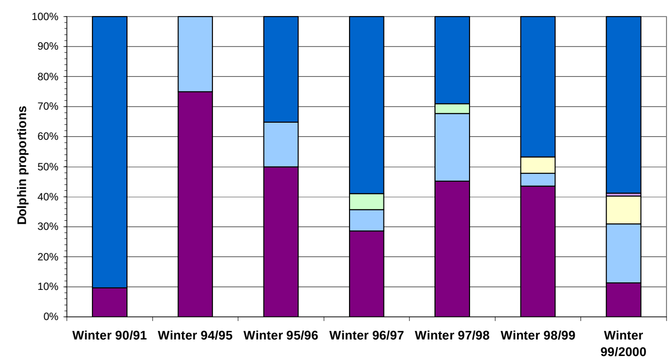
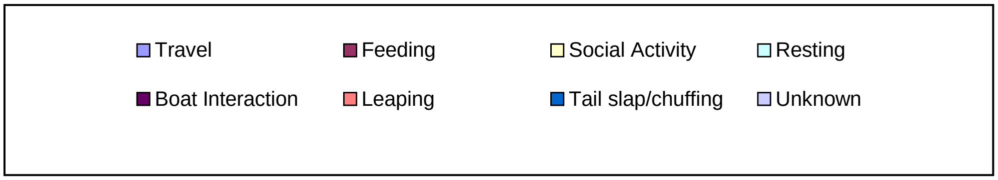


Figure 15d. Proportions of bottlenose dolphins, based on habitat and winter seasons throughout the years. No data was collected for the winter seasons of 1990 and 1992-1994.



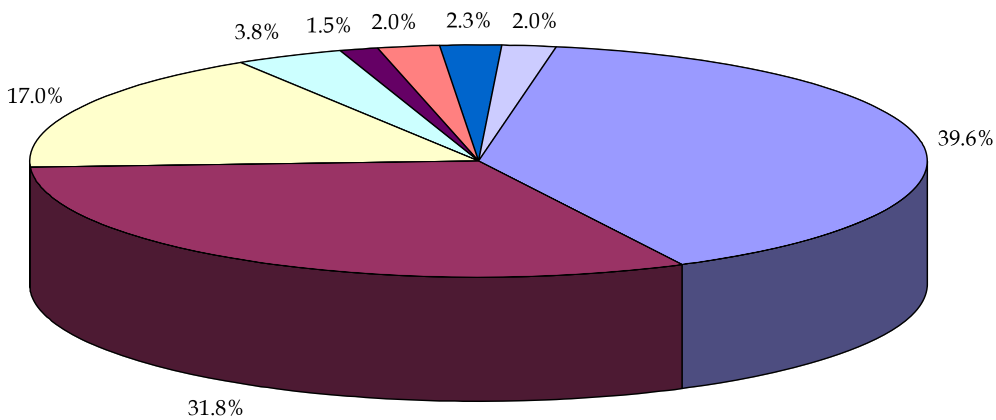


Figure 16. Proportions of bottlenose dolphin sightings for each initial behavior in the Biscayne Bay study area.

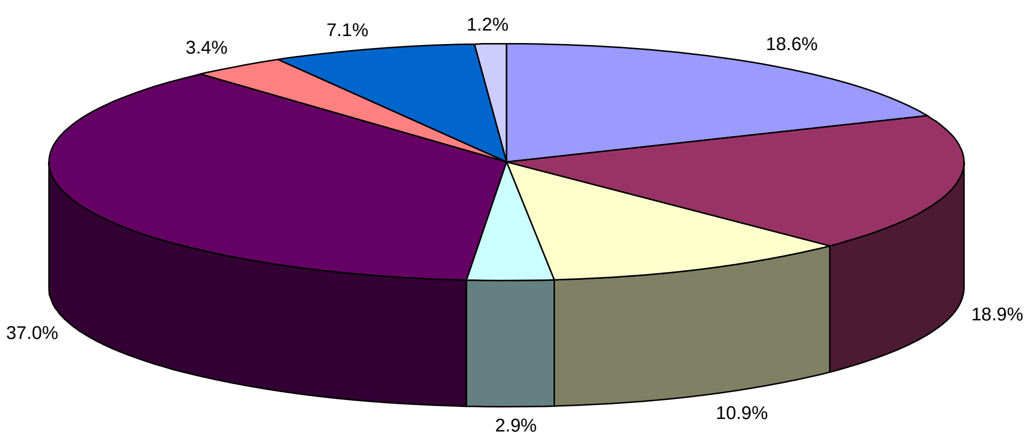


Figure 17. Proportions of bottlenose dolphin sightings for each behavior during observations in Biscayne Bay study area.

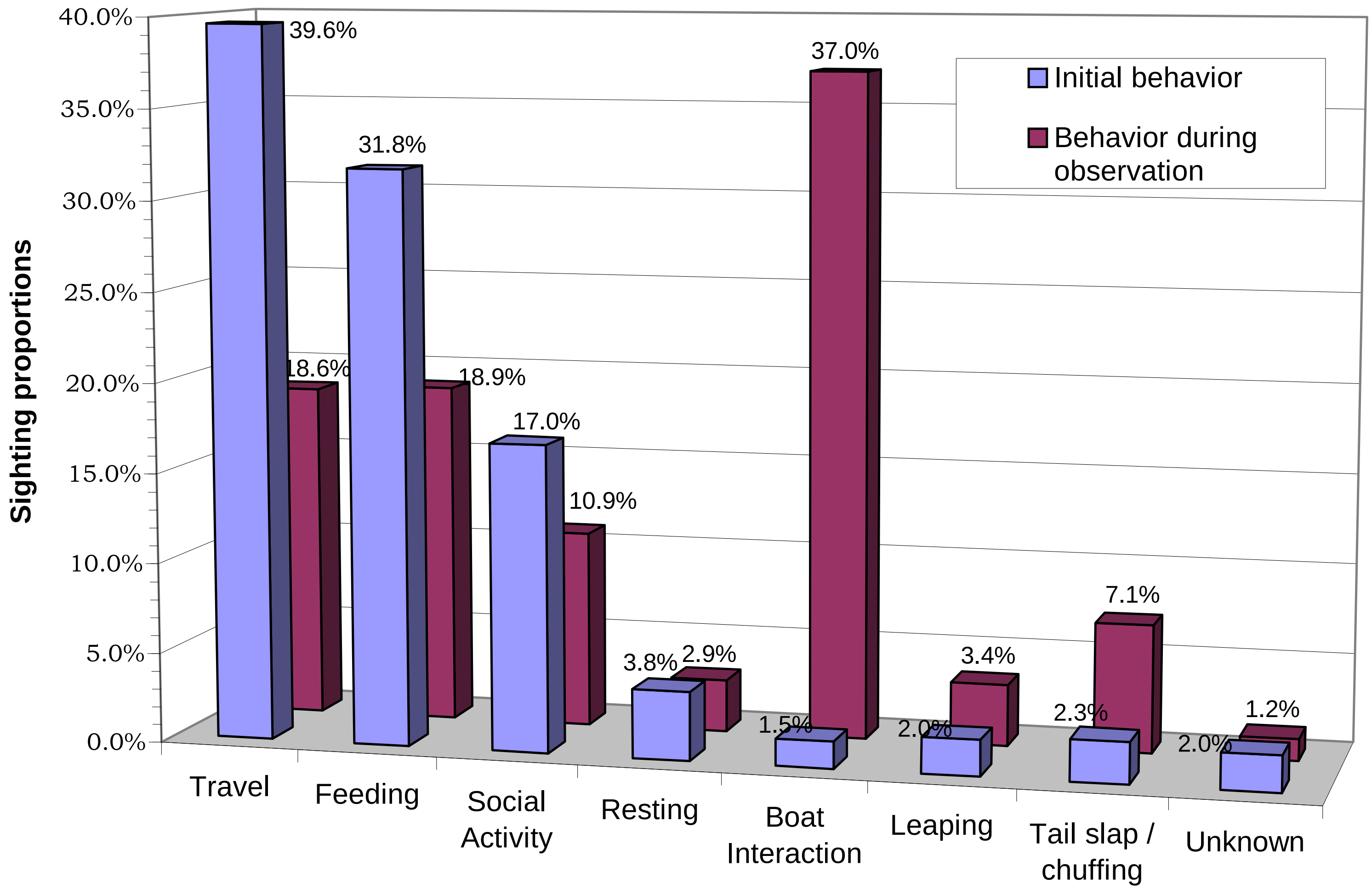


Figure 18. Proportions of dolphin sightings for comparison of initial behaviors and behaviors during the observations for the Biscayne Bay study.

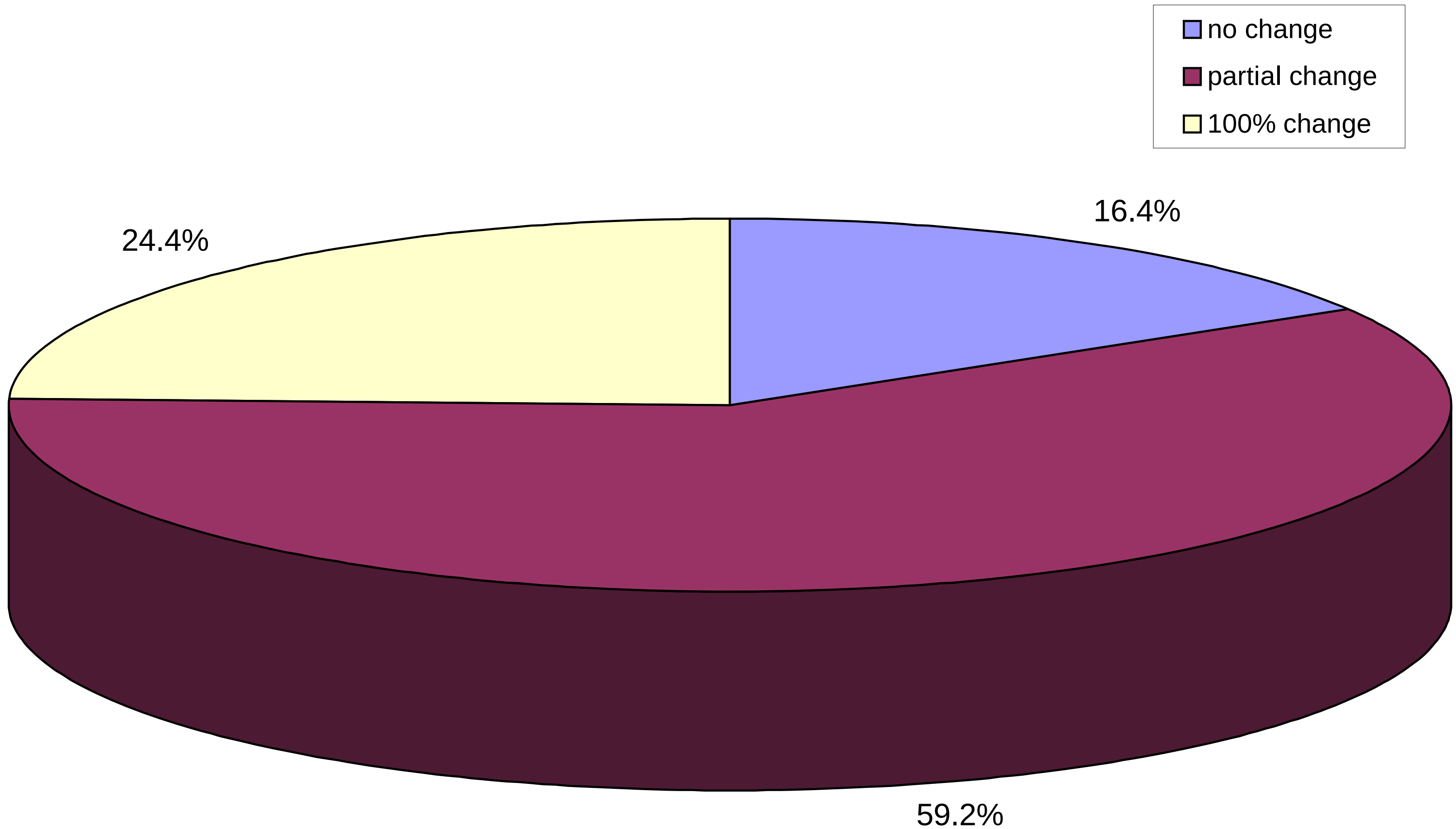


Figure 19. Comparison of changes from initial behavior to behavior during observations based on sightings in Biscayne Bay.

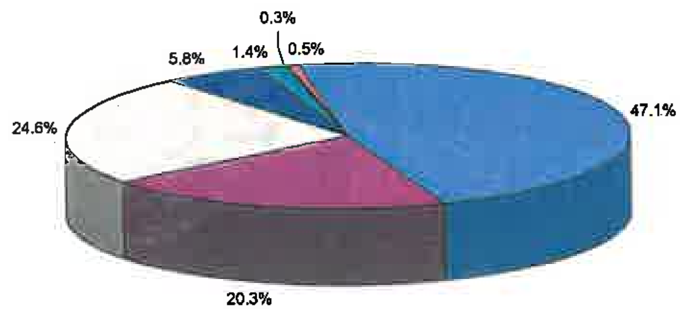


Figure 20a. Proportions of bottlenose dolphin numbers, based on initial behaviors observed during the spring season for the Biscayne Bay study.

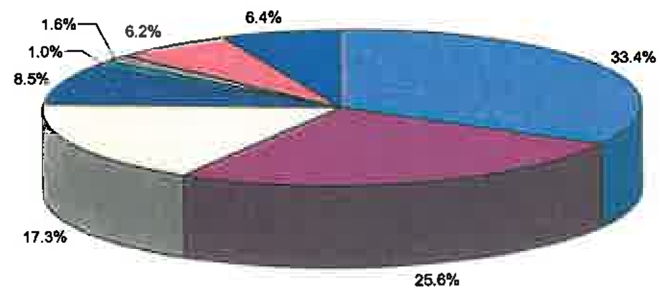


Figure 20b. Proportions of bottlenose dolphin numbers, based on initial behaviors observed during the summer season for the Biscayne Bay study.

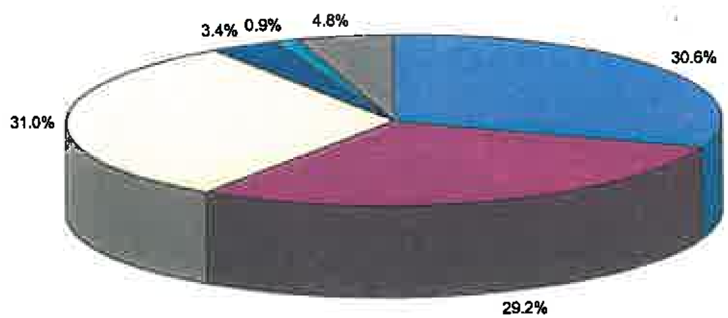


Figure 20c. Proportions of bottlenose dolphin numbers, based on initial behaviors observed during the fall season for the Biscayne Bay study.

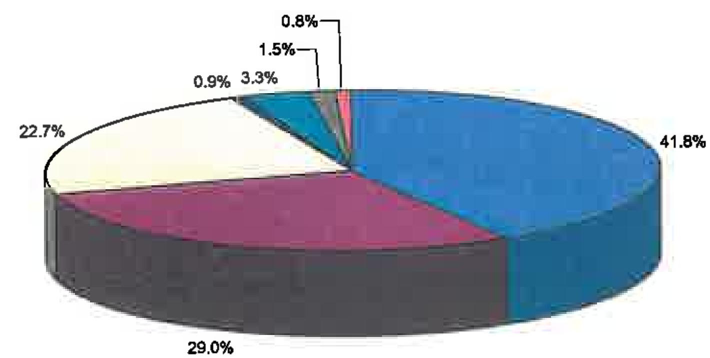


Figure 20d. Proportions of bottlenose dolphin numbers, based on initial behaviors observed during the winter season of the Biscayne Bay study.

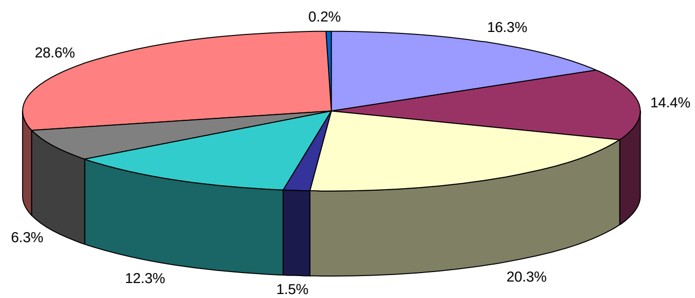


Figure 21a. Proportions of bottlenose dolphin numbers, based on behaviors during observations throughout the spring season of the Biscayne Bay study period.

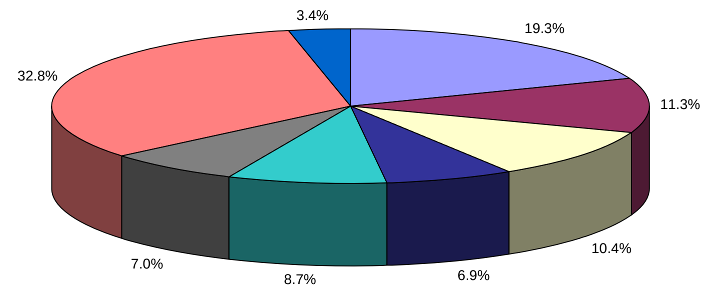


Figure 21b. Proportions of bottlenose dolphin numbers, based on behaviors during observations throughout the summer season of the Biscayne Bay study period.

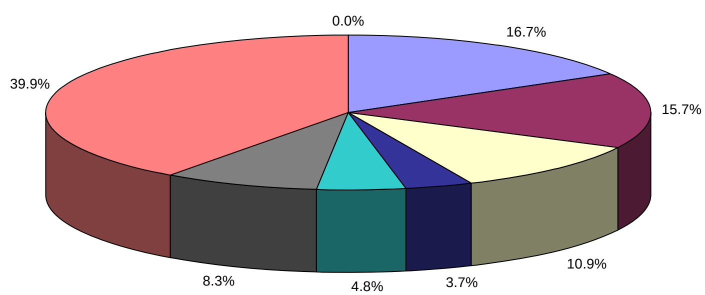


Figure 21c. Proportions of bottlenose dolphin numbers, based on behaviors during observations throughout the fall season of the Biscayne Bay study period.

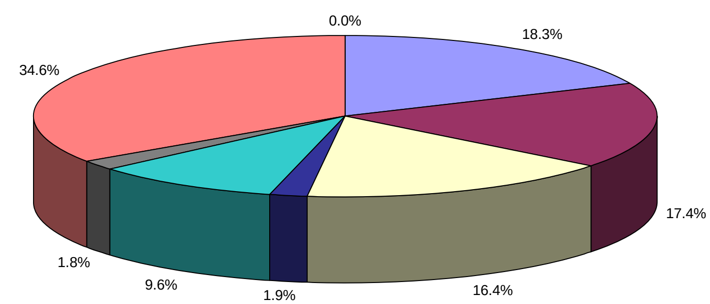


Figure 21d. Proportions of bottlenose dolphin numbers, based on behaviors during observations throughout the winter season of the Biscayne Bay study period.

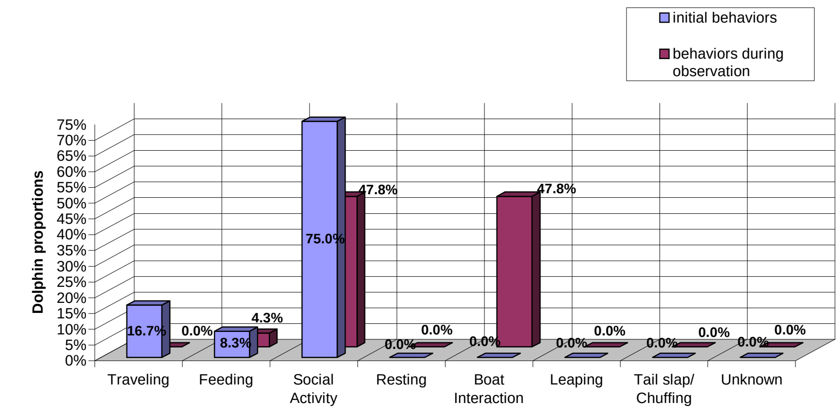


Figure 22a. Proportions of bottlenose dolphin numbers per initial behavior compared to behavior during observations in soft bottom / seagrass areas of Biscayne Bay.

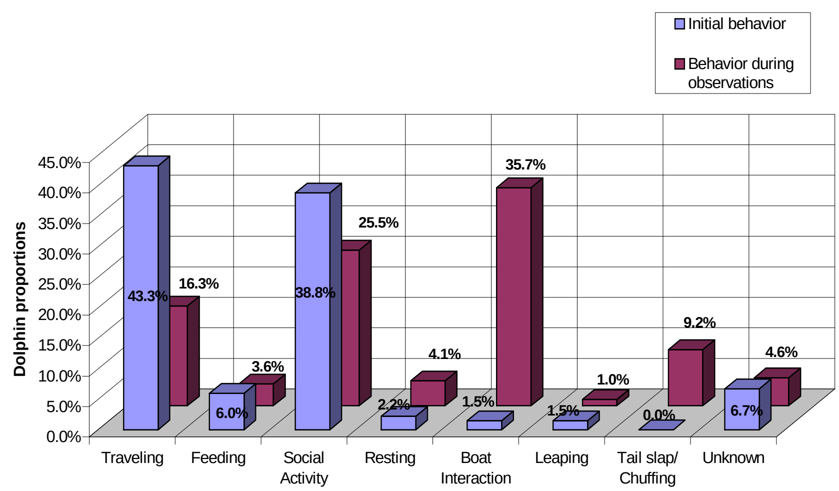


Figure 22b. Proportions of bottlenose dolphin numbers per initial behavior compared to behavior during observations in hard bottom / seagrass areas of Biscayne Bay.

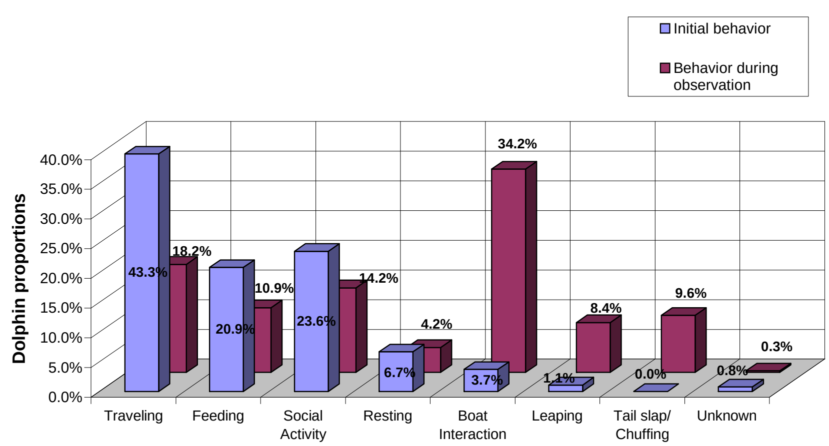


Figure 22c. Proportions of bottlenose dolphin numbers per initial behavior compared to behavior during observations in moderately dense seagrass areas of Biscayne Bay.

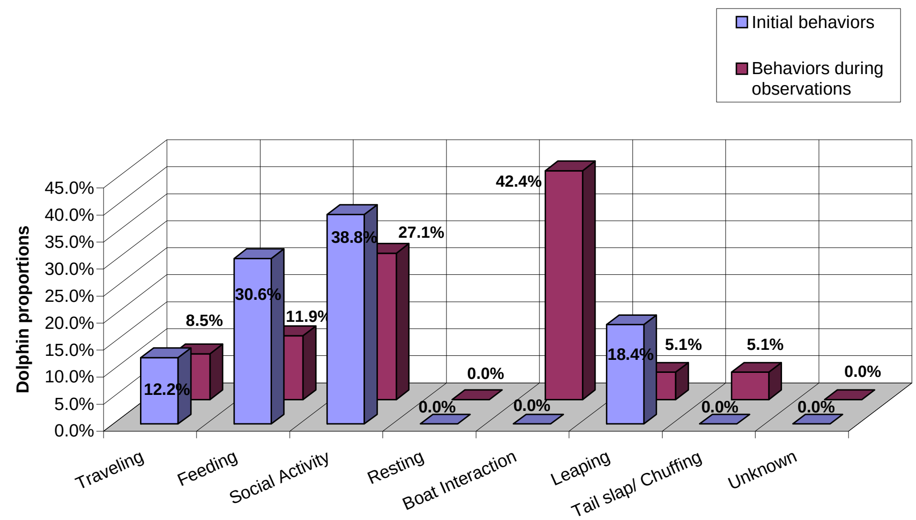


Figure 22d. Proportions of bottlenose dolphin numbers per initial behavior compared to behavior during observations in dense seagrass areas of Biscayne Bay.

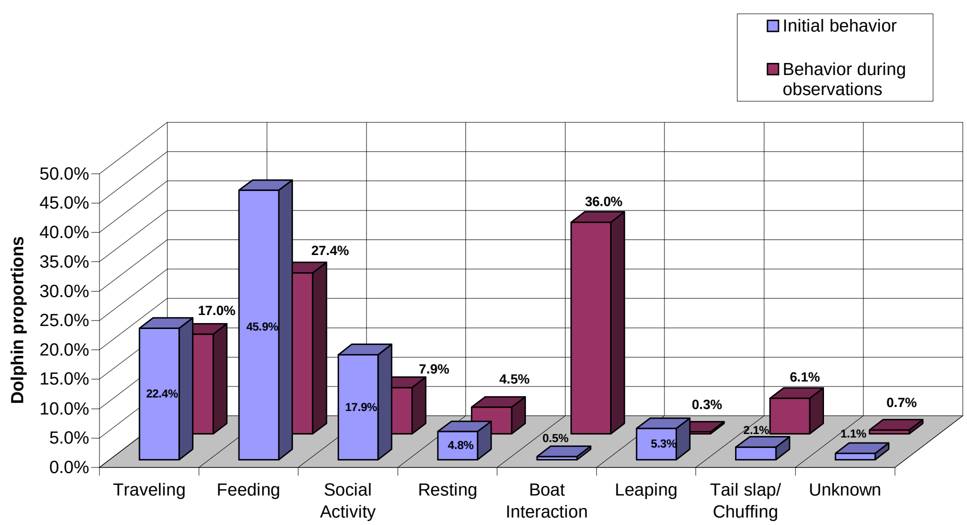


Figure 22e. Proportions of bottlenose dolphin numbers per initial behavior compared to behavior during observations in dredged bottom areas of Biscayne Bay.

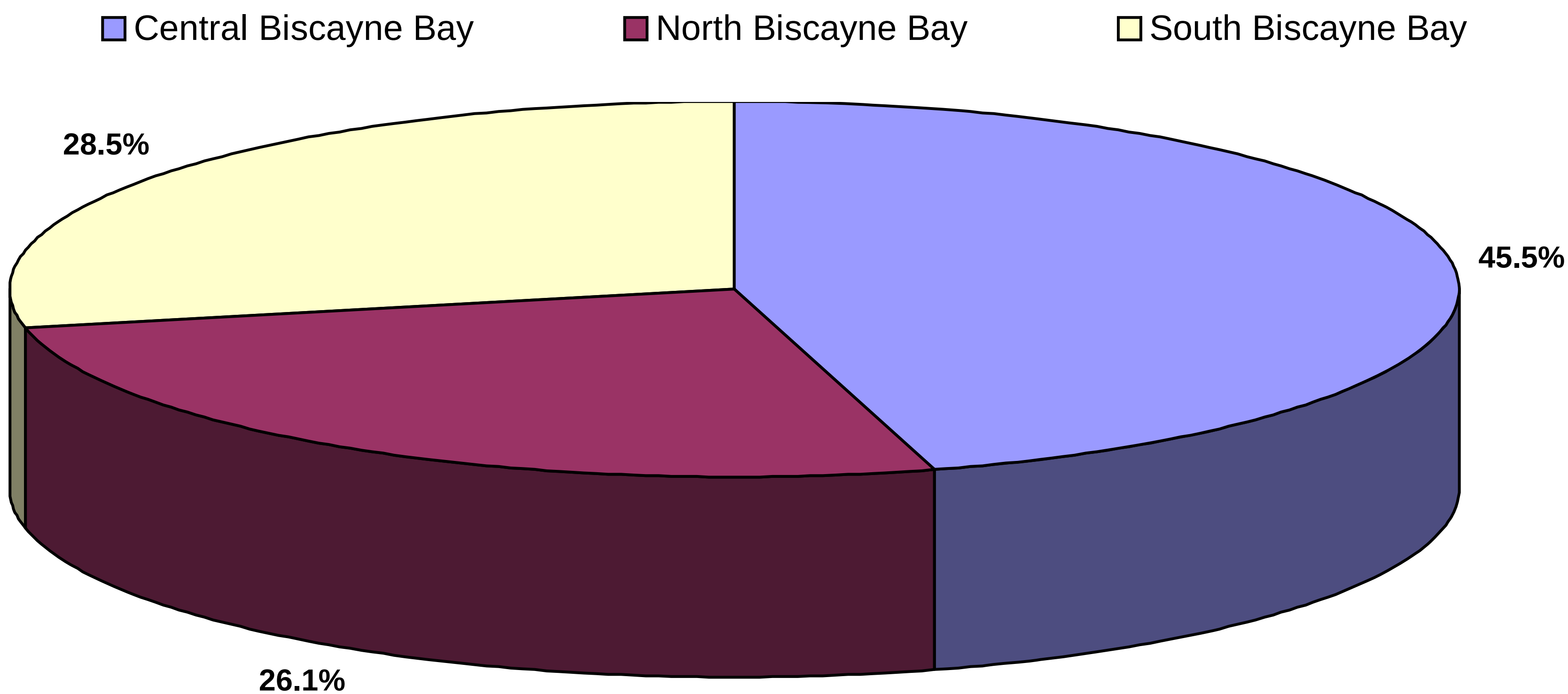


Figure 23. Proportions of bottlenose dolphin numbers, based on the zones of Biscayne Bay, FL.

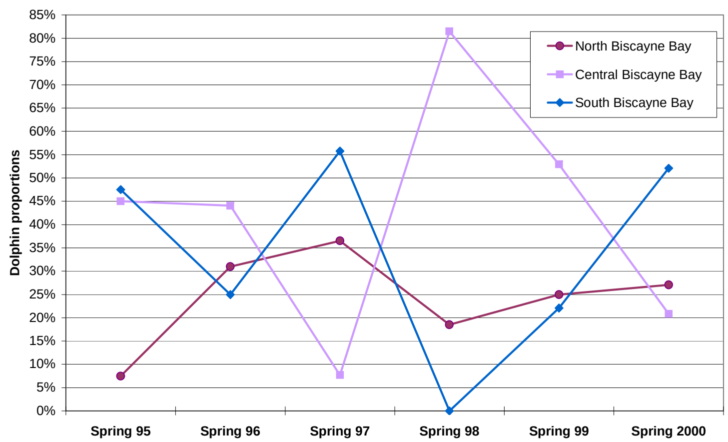


Figure 24a. Proportions of bottlenose dolphin numbers, based on the zones of Biscayne Bay throughout the spring seasons of the study period.

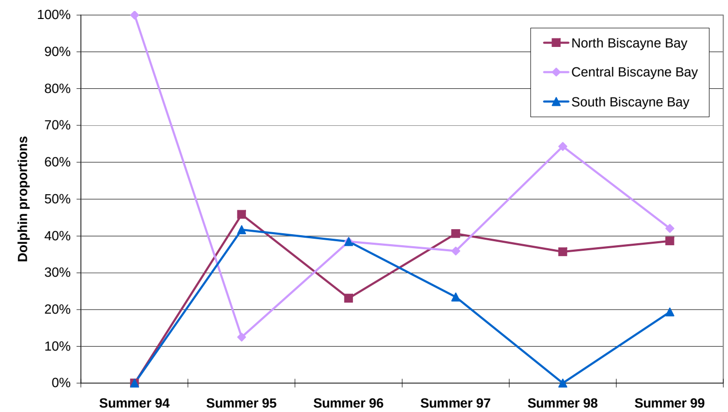


Figure 24b. Proportions of bottlenose dolphin numbers, based on the zones of Biscayne Bay throughout the summer seasons of the study period.

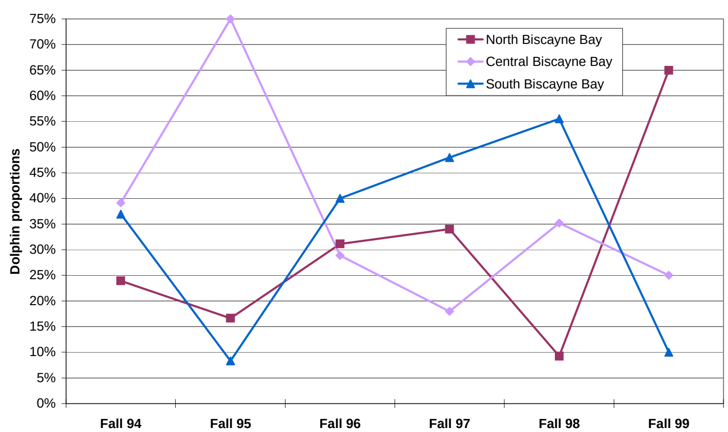


Figure 24c. Proportions of bottlenose dolphin numbers, based on the zones of Biscayne Bay throughout the fall seasons of the study period.

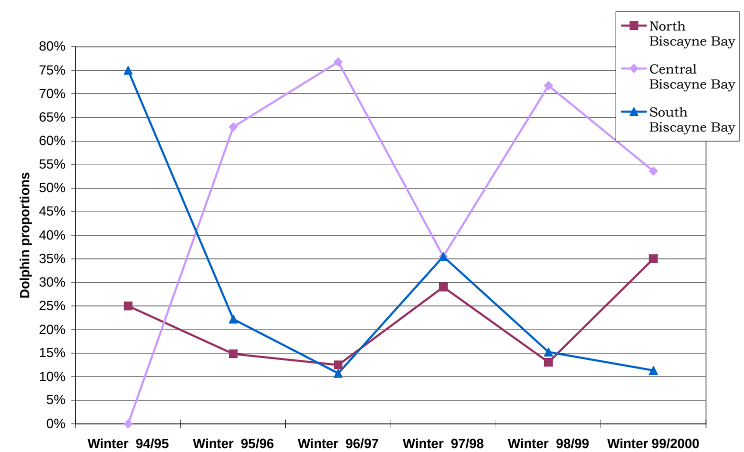


Figure 24d. Proportions of bottlenose dolphin numbers, based on the zones of Biscayne Bay throughout the winter seasons of the study period.

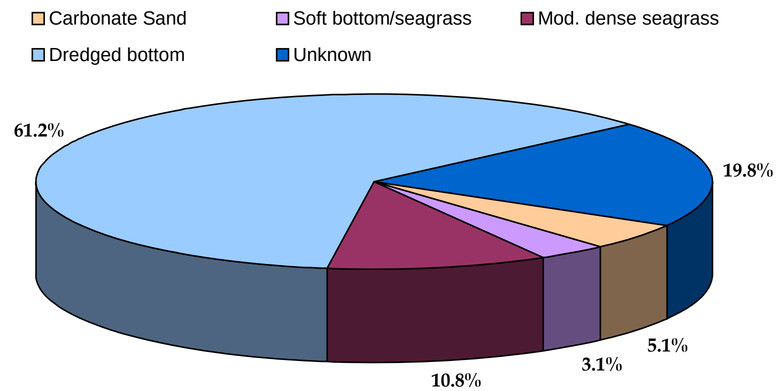


Figure 25a. Proportions of bottlenose dolphin numbers, based on the habitats in North Biscayne Bay, throughout the study period.

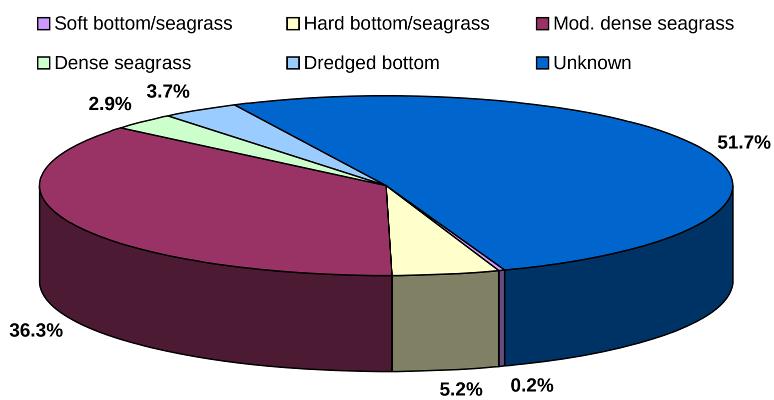


Figure 25b. Proportions of bottlenose dolphin numbers, based on the habitats in Central Biscayne Bay, throughout the study period.

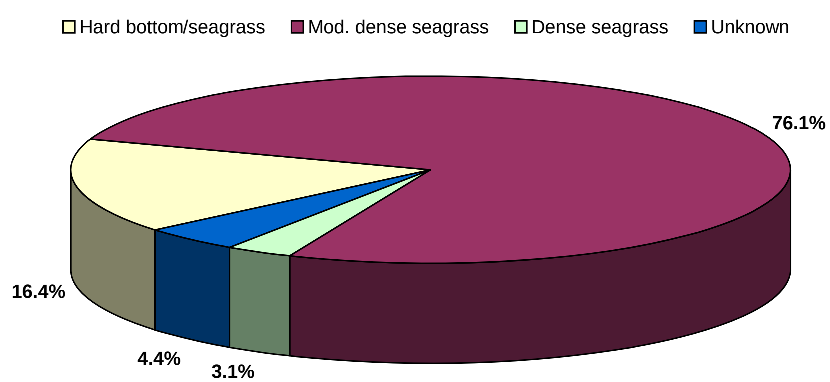


Figure 25c. Proportions of bottlenose dolphins numbers, based on the habitats in South Biscayne Bay, throughout the study period.

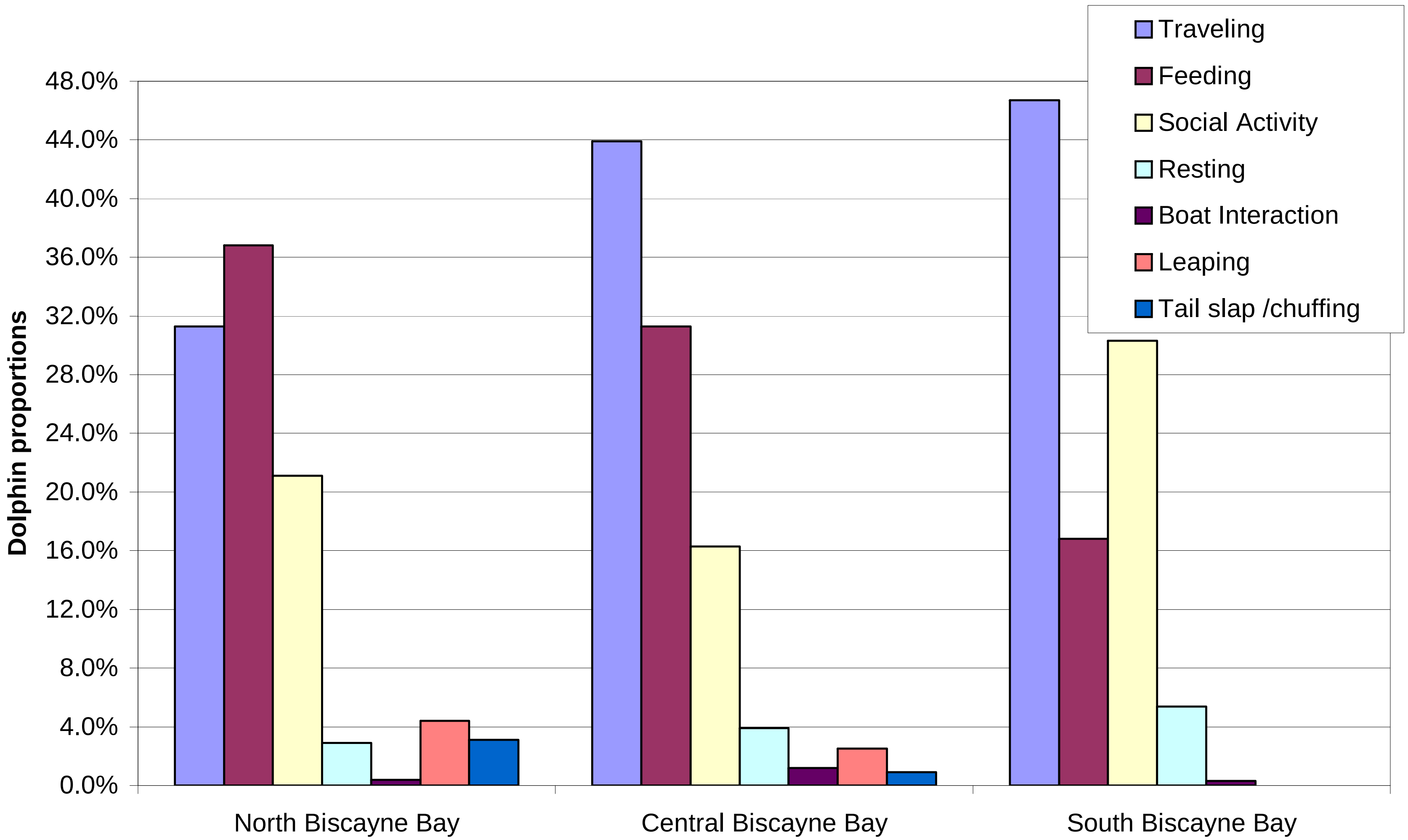


Figure 26. Proportions of bottlenose dolphin numbers, based on the zones and behaviors throughout the study area.

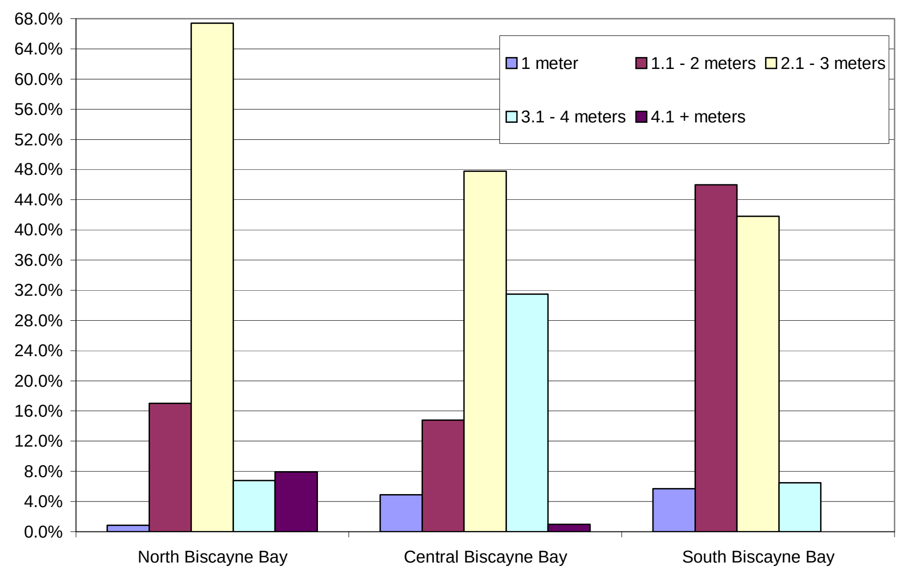


Figure 27a. Frequencies of dolphin occurrences per depth for each zone

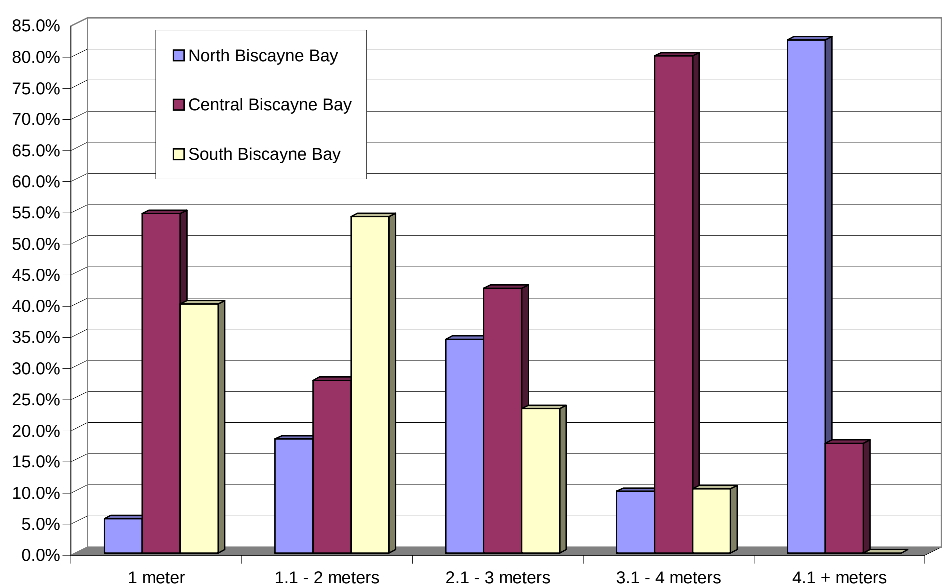


Figure 27b. Frequencies of dolphin occurrences per zone for each depth.

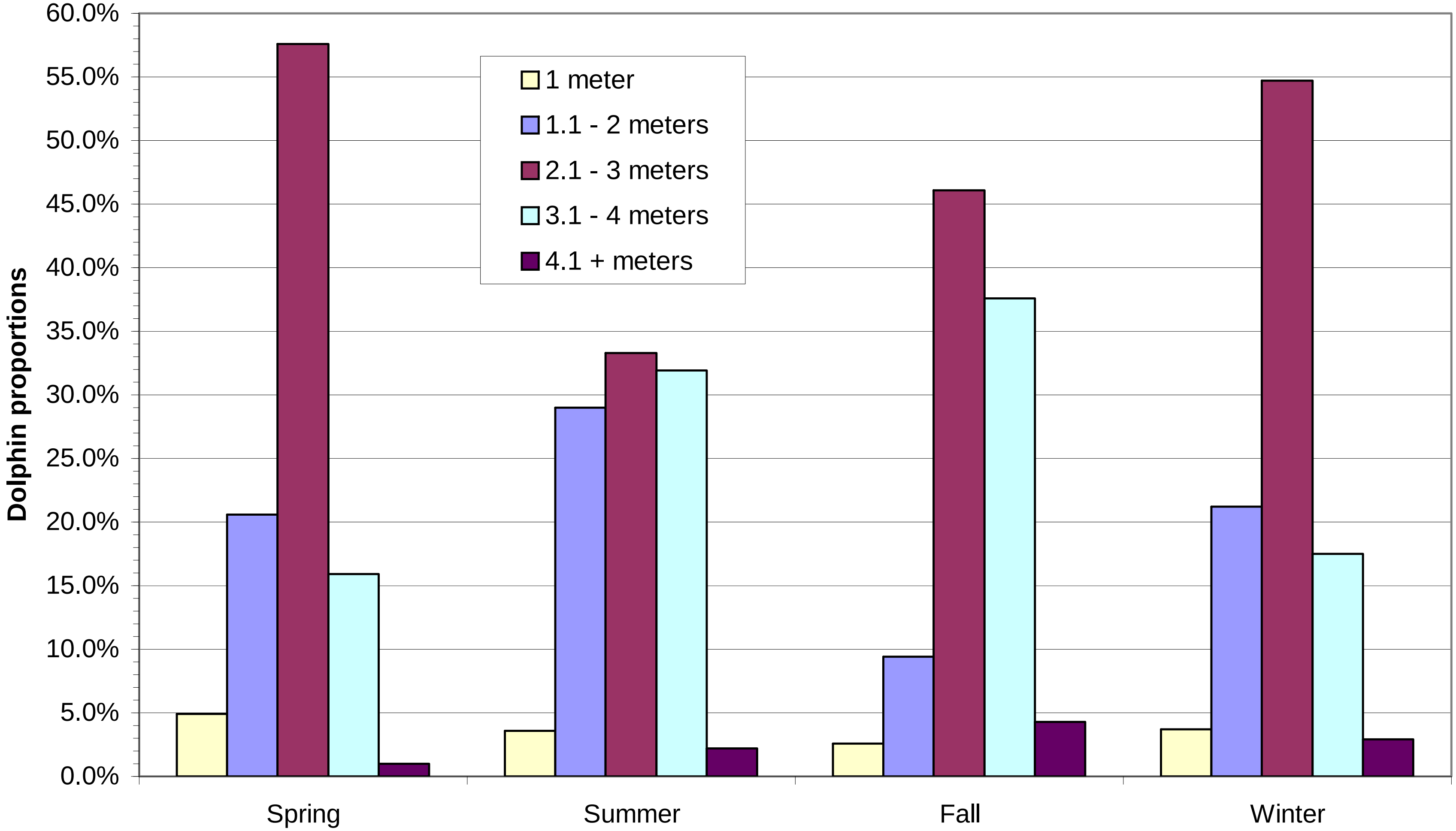


Figure 28. Proportions of bottlenose dolphin numbers, based on seasons throughout the study period.

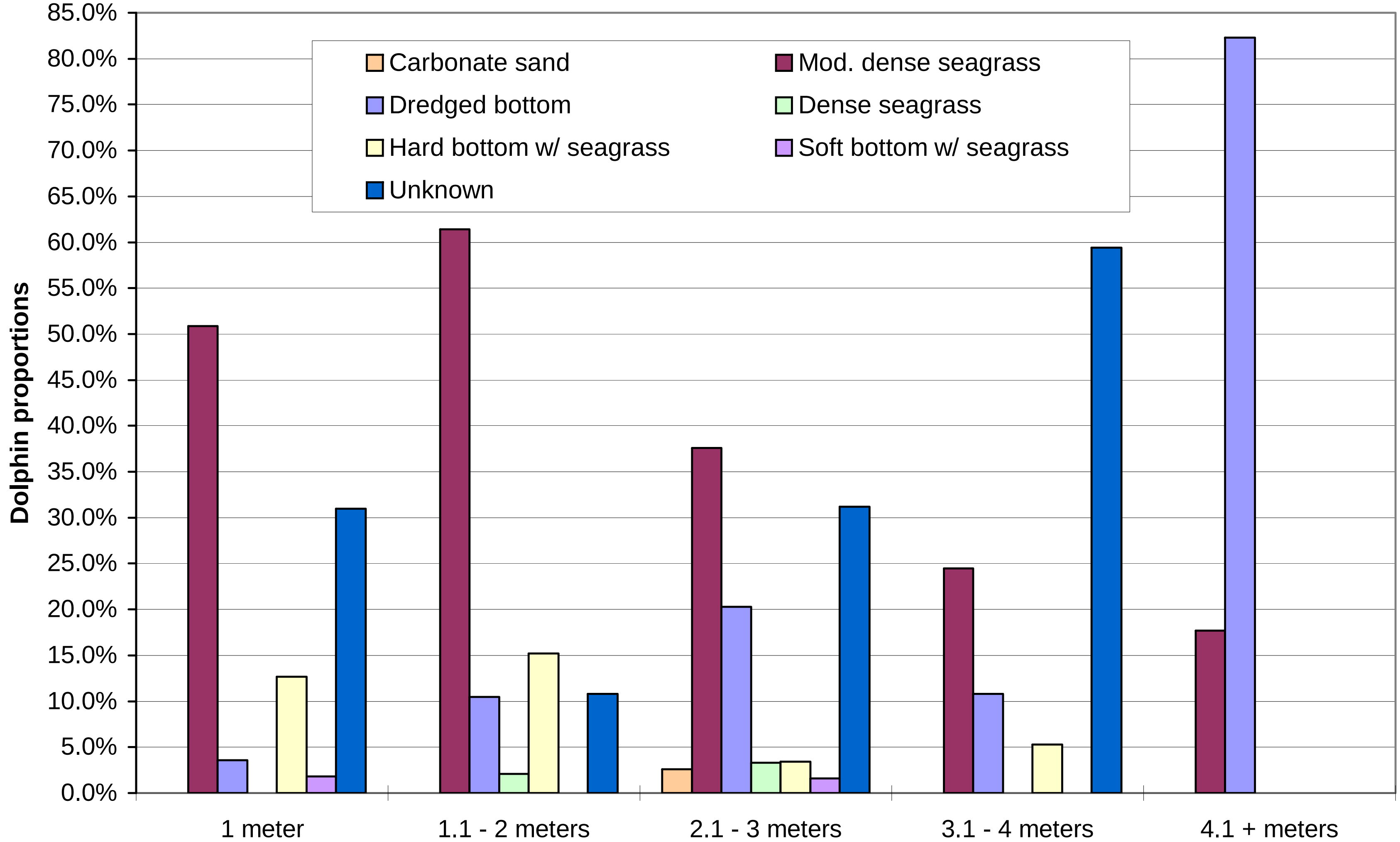


Figure 29. Proportions of bottlenose dolphin numbers, based on the habitats and depth ranges of the study area.

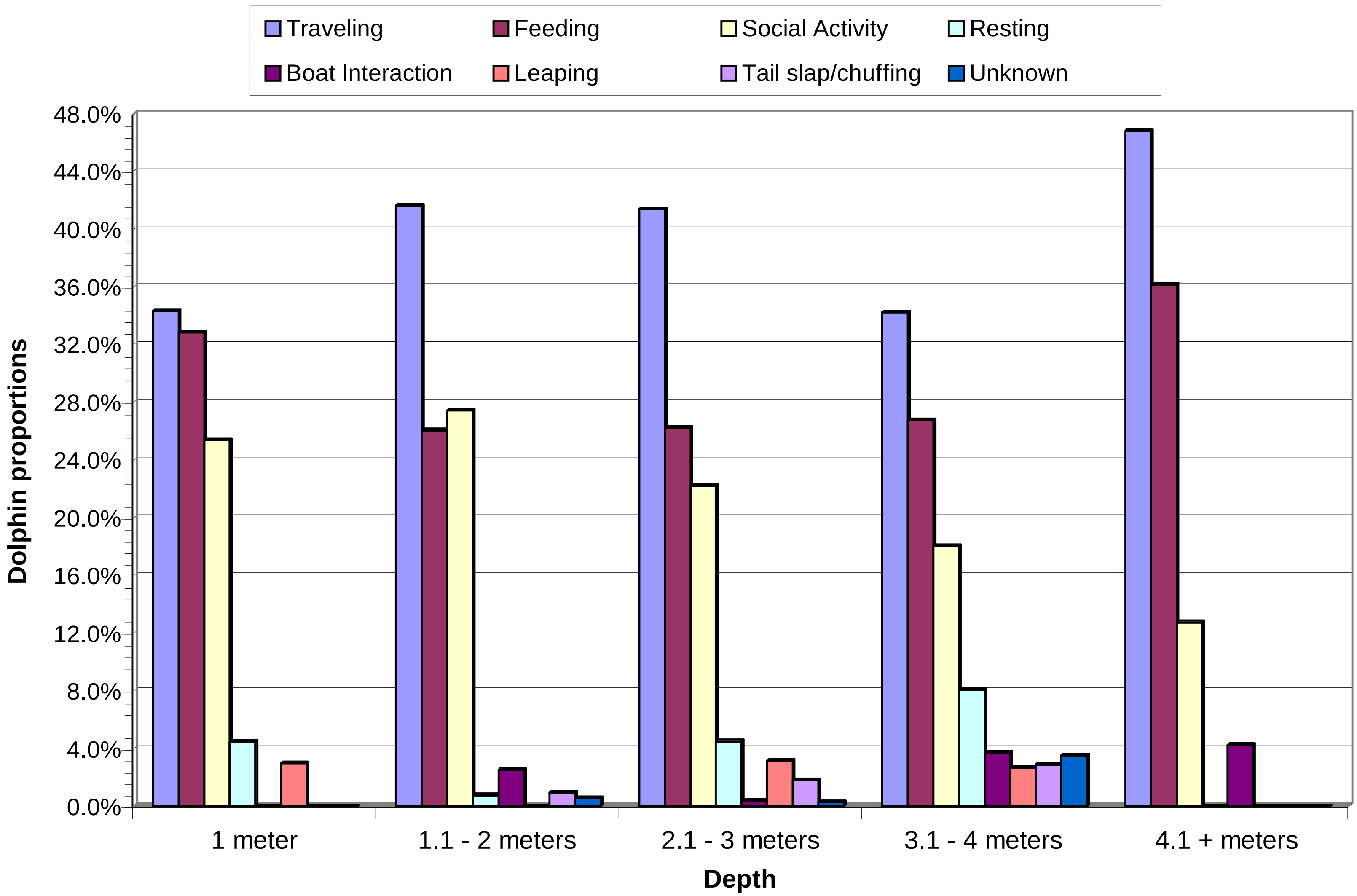


Figure 30. Proportions of bottlenose dolphin numbers, based on depth ranges and initial behaviors.

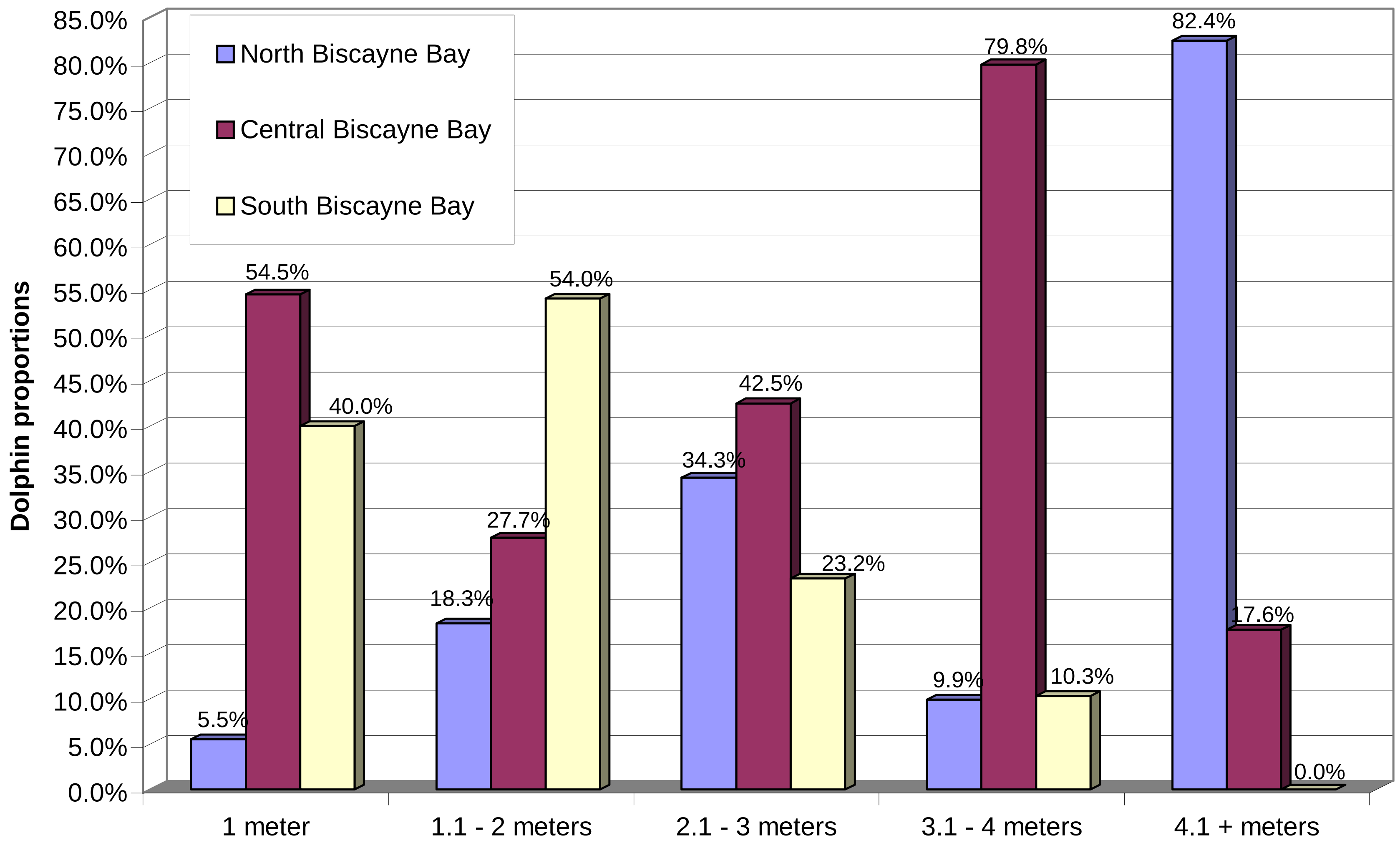


Figure 31. Proportions of bottlenose dolphin numbers, based on the zones and depth ranges throughout the study area.

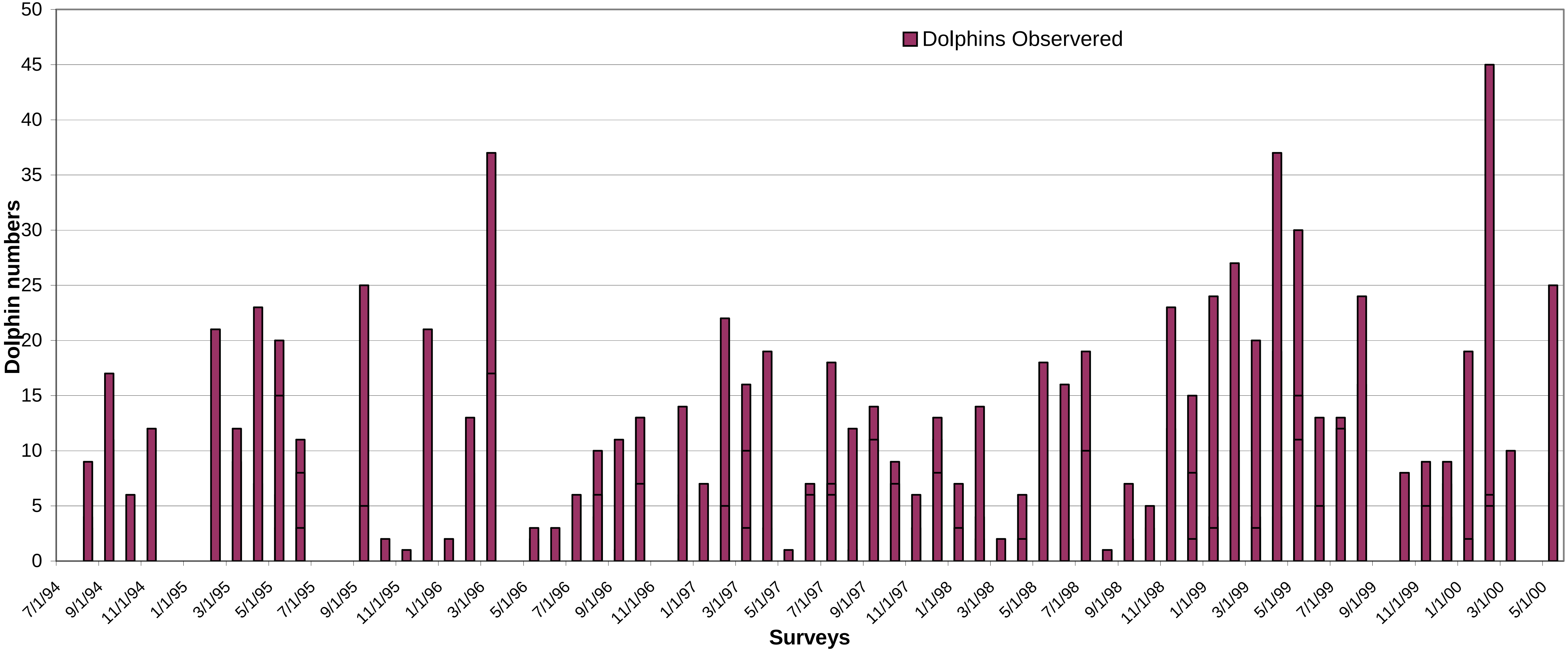


Figure 32. The preliminary results for the number of dolphins sighted in Biscayne Bay from 1994 - 2000.

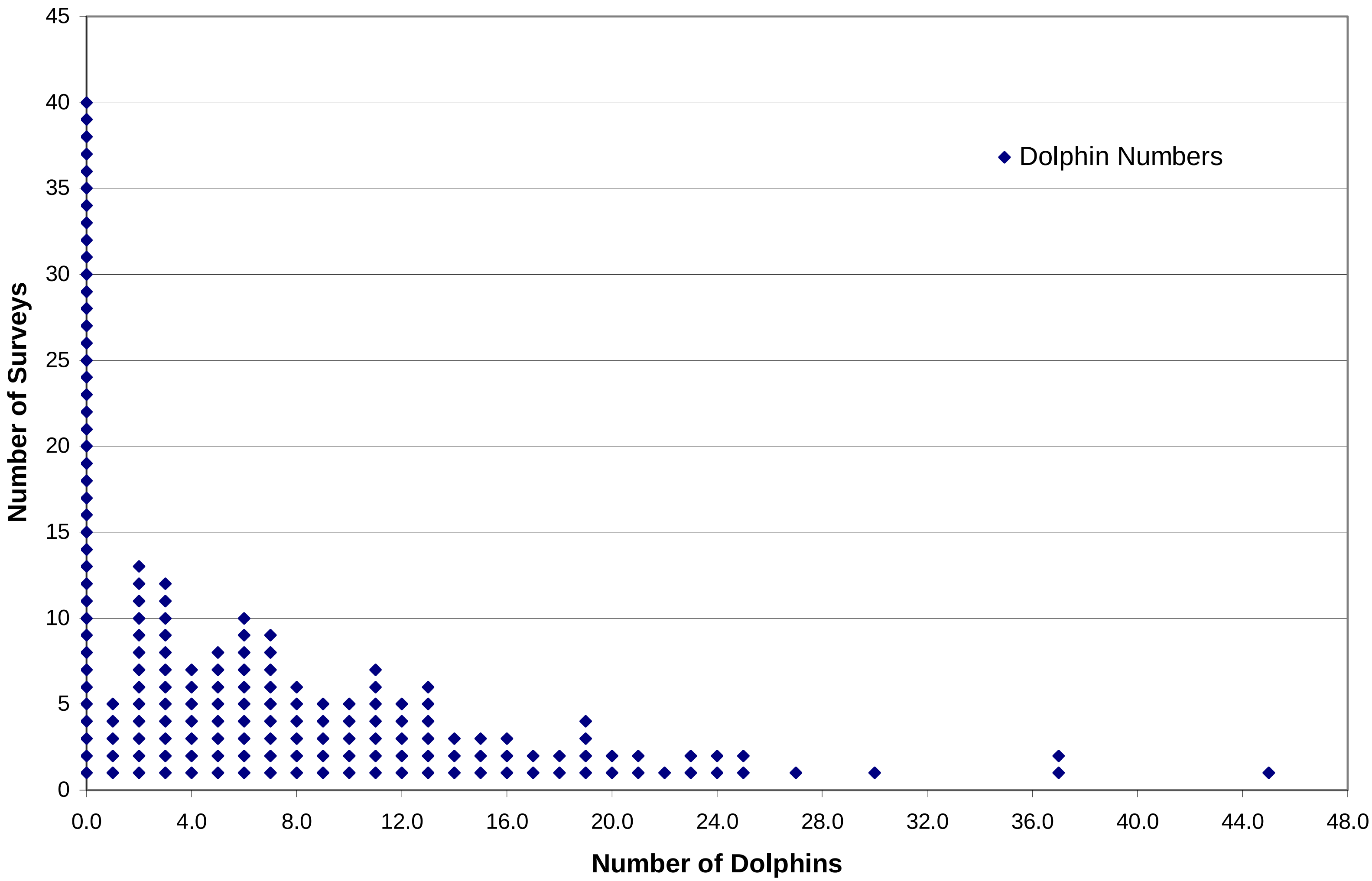


Figure 33. The histogram is based on the number of dolphins per survey in Biscayne Bay from 1994 - 2000.

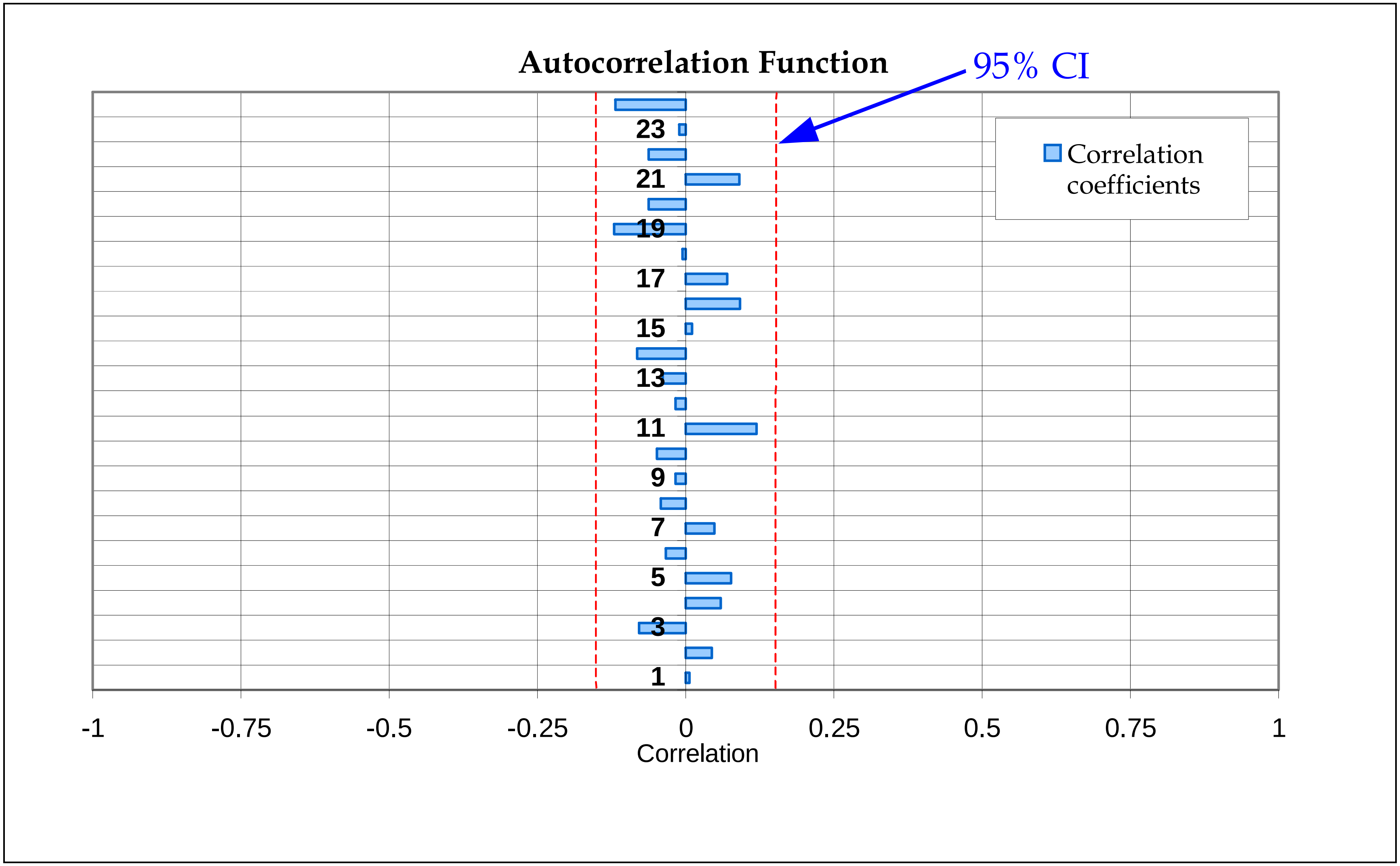
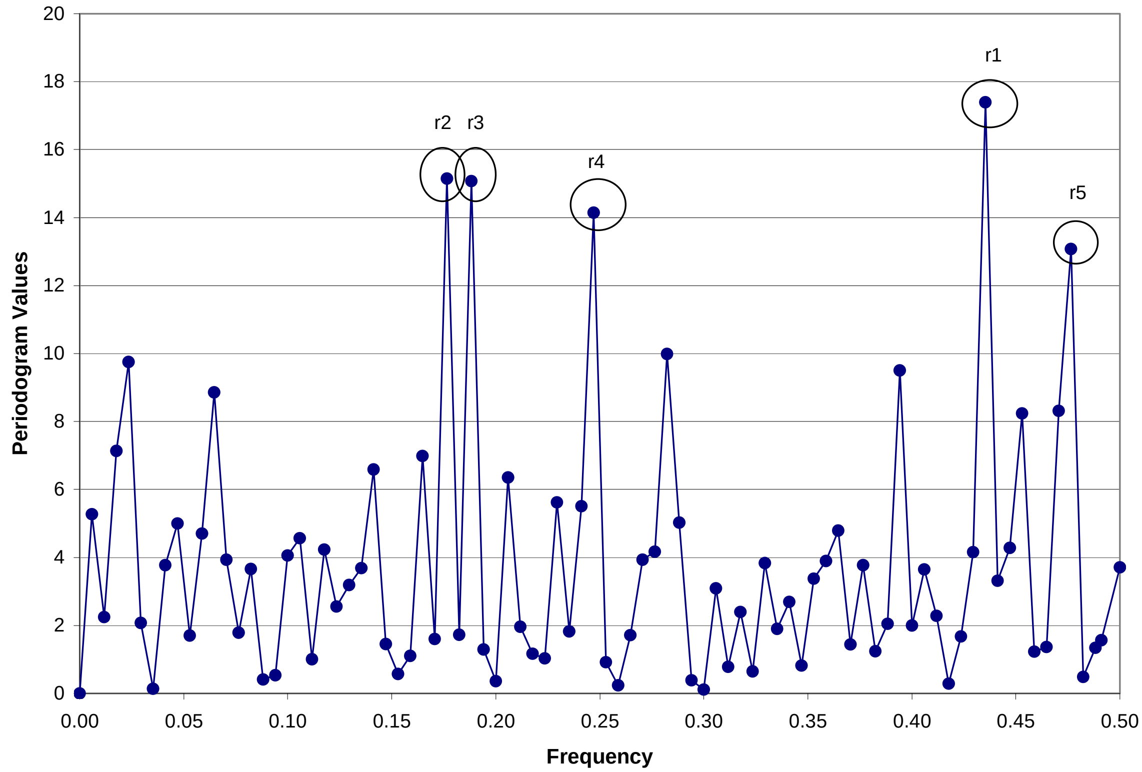


Figure 34. Lagged correlation was conducted at 24 lags. Since none of the lags crossed the 95% confidence interval, the data is considered “white noise”.



Fisher Test

g = periodogram value / periodogram total

peak #	g	critical value	
r1 calculation	= 0.05357	.08546	peaks are not significant
r2 calculation	= 0.04662	.06222	
r3 calculation	= 0.04640	.05224	
r4 calculation	= 0.04357	.04612	
r5 calculation	= 0.04028	.04178	

Figure 35. Periodogram and Fisher test on the residuals of the time series analysis