Diurnal Movements and Site Fidelity of the Florida Manatee, *Trichechus manatus latirostris*, in Fort Lauderdale, FL.

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DIURNAL MOVEMENTS AND SITE FIDELITY OF THE FLORIDA MANATEE, 
TRICHECHUS MANATUS LATIROSTRIS, IN FORT LAUDERDALE, FL.

By
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Abstract

The diurnal movements of Florida manatees (*Trichechus manatus latirostris*) in warm-water refugia are poorly understood and these may prove critical in accurately estimating populations of these animals. Previous studies indicate that manatee populations in such refuges in Tampa Bay, FL, peak mid-day and decline towards evening when the animals leave to forage. This trend suggests that variation in the timing of aerial manatee population surveys may hamper accurate estimation of the true population size. Aerial survey counts are known to underestimate population size, yet the extent of the underestimation may be greater than expected. In this study data were collected over three seasons from land-based surveys monitoring the presence of manatees in the effluent canal from the Florida Power and Light electricity generating facility in Port Everglades, FL between 15 November and 31 March. My findings indicated there was no significant difference in the number of manatees observed during the seasons studied despite a significant difference in ambient water temperatures. There was a significant correlation in the number of manatees an observer can expect to see based on time of day with the trend indicating there are higher numbers of observable manatees in the morning compared to later in the day. This suggests that early morning aerial counts will more accurately reflect true manatee presence in the Port Everglades power plant. Photographs of individual manatees yielded a total of 58 animals with unique scaring patterns.

**Key words:** manatee, cold stress, warm water refugia, population, Port Everglades, photo-identification, diurnal cycles
Acknowledgments

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Additionally, thanks go to Cathy Beck from the USGS Sirenia Project for showing me how manatees are cataloged statewide in MIPS. Without the indulgence of the management and staff at the Dry Marina in Port Everglades, FL a good portion of my observations would never have been fulfilled. I am sincerely grateful that they allowed me to spend hours sitting at their docks documenting the manatees that visited the area.

I would like to thank my former supervisor, Diane Karol, who was kind enough and flexible enough to allow me to alter my work schedule in order to better accommodate
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Great appreciation goes to Ron Hammack, who provided a second set of eyes for manatee photo identification and is the technical brilliance behind the maps created for this thesis. Finally, immense thanks go to my mother, Esther Walsh.
# Table of Contents

I. Introduction .................................................................................................................. 8
   1. Biology, Migration and Mortality ................................................................. 8
   2. Determining Population Size .......................................................................... 11
   3. Use of Winter Refuges .................................................................................. 15
   4. Broward County and Port Everglades ......................................................... 16
   5. Diurnal Site Usage ......................................................................................... 18
   6. Objectives ...................................................................................................... 20

II. Material and Methods ............................................................................................. 21

III. Results .................................................................................................................... 26

IV. Discussion .............................................................................................................. 33
   1. Background on the Biological Status ......................................................... 39

V. Conclusion ............................................................................................................... 44

VI. Figures
   1. Figure 1: Map of Florida Manatee Recovery Plan Regions (USGS) ...... 13
   2. Figure 2: “Lucy” with calf. Identified at Port Everglades in February 2006 showing boat propeller strikes ........................................... 14
   3. Figure 3: Table of Manatee Observations by Season .............................. 22
   4. Figure 4: Port Everglades Effluent Canal with Highlighted Survey Areas ........................................................................................................ 22
   5. Figure 5: Identifiable Scar Marks on Body of Manatee Used for Photo-identification ........................................................................ 25
   6. Figure 6: Identifiable Scar Marks on Tail of Manatee Used for Photo-identification ........................................................................ 25
   7. Figure 7: Number of Individual Manatees Observed per Season .......... 26
   8. Figure 8: Average Number of Manatees Observed per Season .......... 27
9. Figure 9: 2004-2005 Mean Number of Manatees and Temperature per Month ………………………………………………………………….. 28
10. Figure 10: 2005-2006 Mean Number of Manatees and Temperature per Month ………………………………………………………………. 29
11. Figure 11: 2006-2007 Mean Number of Manatees and Temperature per Month ……………………………………………………………………….. 29
12. Figure 12: Number of Manatees Observed per Time of Day with Trend-line ……………………………………………………………………………………………………. 30
13. Figure 13: Photographic Identification of “Cuban” …………………… 31
14. Figure 14: Photographic Identification of “R2T2” …………………… 31
15. Figure 15: Photographic Identification of “Scruffy” …………………… 32
16. Figure 16: Photographic Identification of “Peach” …………………… 32
17. Figure 17: Photographic Identification of “Vickie” …………………… 32
18. Figure 18: “Lucy Nursing Her Calf” …………………………………… 34
19. Figure 19: Map of Florida Manatee Extent of Occurrence (FWC, 2006) ……………………………………………………………………………………. 41
20. Figure 20: Map of Florida Manatee Area of Occupancy (FWC, 2006) .. 42

VII. Appendix I: Port Everglades Ground Survey Data Sheet …………………… 46
VIII. Appendix II: Manatee Identification Guide ……………………………………… 47
IX. References ………………………………………………………………………….. 62
**Introduction**

An examination of manatee aggregations wintering in Port Everglades, FL was undertaken to attempt to elucidate how manatee aggregations in this area change over time. The goals of this study were to:

* Accumulate baseline data for the number, sex and general age structure of manatees wintering in Port Everglades, FL.

* Determine if manatees exhibit a diurnal pattern of site fidelity in Port Everglades, FL.

* Develop a photographic database of manatees with unique identifying scars.

**Biology, Migration and Mortality**

The West Indian manatee, *Trichechus manatus*, consists of two morphologically and genetically distinct subspecies, the Florida manatee, *T. m. latirostris*, and the Antillean manatee, *T. m. manatus* (Domning and Hayek, 1986). Similar to other large marine mammals, manatees are potentially long-lived with a maximum age of approximately 60 years. Females reach sexual maturity at roughly 5 years of age. Breeding occurs during the warm season between April and September and there is a gestation period of 13 months (Reid et al., 1995). Reproductive rates are low, typically with one calf being born every three years and with high female parental investment (two year calf dependency) (Marmontel, 1995; O'Shea and Hartley, 1995; Rathbun et al., 1995; FWC, 2007b). This type of life history requires high and stable adult survival rates
for the continued survival of the species. Seagrasses constitute the majority of the manatee’s diet, supplemented by emergent bank vegetation (Lefebvre et al., 2000).

The Florida manatee inhabits a variety of environments along the Eastern coast of the United States and the Gulf of Mexico, tolerating a broad range of salinities from freshwater rivers to marine coastlines. One individual was found to have traveled 225 km upriver from the Atlantic Ocean (Deutsch et al., 2003). During the warm season (March through November), the majority of the manatee population in the United States is dispersed along the Florida and Georgia coasts with some manatees traveling as far north as Rhode Island (Deutsch et al., 2003). In the Gulf of Mexico, manatees can be found along the coast as far west as Texas (Powell and Rathburn, 1984). However, it is uncertain whether the Texas manatees originate from Florida or from Mexico. During the cold season, when water temperatures drop below 20°C, manatees seek warm-water refuges throughout Florida because they are unable to tolerate prolonged exposure to low temperatures (Deutsch et al., 2003).

When manatees are subjected to water temperatures below 20°C for an extended period they can suffer from cold stress syndrome (Bossart, 2001). Cold stress syndrome produces a variety of lesions, emaciation and infectious diseases of the skin and gastrointestinal tract. Bossart et al. (2002) described cold stress syndrome as a cascade effect wherein chronic exposure to cold water results in lethargy, decreased food intake and dehydration that compromises normal nutritional, metabolic and immunologic functions leading to death.
Manatees are strongly philopatric and their movement patterns demonstrate that they utilize the same seasonal ranges and individuals typically occupy core areas linked by travel corridors (Deutsch et al., 2003). During the warm-water months, the majority of manatees travel north to spring and summer ranges which have a higher quality habitat with better access to fresh water, aquatic vegetation and fewer disturbances from watercraft (Deutsch et al., 2003).

The median waterway distance manatees travel between winter and warm-season use areas is 280 km, but can vary widely (11-831 km) (Deutsch et al., 2003). Manatee ranges do not differ significantly by sex, age class or body size (Deutsch et al., 2003). Based on previous studies by Deutsch et al. (2003) the majority of manatees (38 % of his study, n = 29) conform to a medium-distance central-south migratory type varying in length traveled from 150-400 km. These animals spend their summer season in Central Florida then migrate south during the onset of winter. Port Everglades was the destination for 89 % of these types of migrants. Of the long-distance migrants (12 % of the study, n = 6), 100 % moved at least as far south as Port Everglades. The southeast region and Port Everglades did not have any short-distance migrants or year-round residents (Deutsch et al., 2003).

In June 2006, the number of mature manatees in Florida was estimated to be 2,310 (FWC, 2006). Currently, the Atlantic Coast region sustains 47% of the Florida manatee population and has the greatest potential for impact from manatee-human interactions (Langtimm et al., 2004). This is due to near and long term population threats related to human activities, such as coastal development, poaching, entrapment in pipes
and culverts, entanglements or ingestion of fishing gear or debris all which contribute to manatee mortality.

Statewide, watercraft collisions are the major known cause of manatee mortality. There are more than 50,000 watercraft registered in Broward County (FWC, 2007a). According to the FWC’s searchable Manatee Mortality Database in Broward County, 1974 – 2007, 36 % of a total of 178 manatee mortalities were determined to have been caused by watercraft collisions. This percentage is noticeably higher than the statewide average of 24 % mortality from watercraft collisions (FWC, 2006). Another 28 % of Broward deaths were from undetermined causes, with only 4 % of deaths due to cold stress. However, undetermined causes probably include additional watercraft collisions where the body was too decomposed to identify the cause of death.

**Determining Population Size**

In 1967, the Florida Fish and Wildlife Conservation Committee (FWC) began aerial surveys of manatees to gather information on their distribution and abundance (Edwards et al., 2007). Aerial surveys are the primary source for population data collected on manatee, yet researchers recognize that these surveys underestimate population size (FWC, 2002). Two types of surveys are conducted by FWC, synoptic aerial surveys and aerial distribution surveys. The synoptic surveys are only conducted once a year for a period of 1-3 days following cold fronts and include known manatee winter refuges. These surveys provide minimum counts of the number of manatees using warm water springs and thermal discharge aggregation sites and are not considered a valid estimate of population size or trends (FWC, 2006). Aerial distribution surveys
occur every two weeks over a two year time frame and last approximately 4-6 hours. These surveys are flown to determine seasonal distribution and relative abundance of manatees.

According to Edwards et al. (2007), winter aggregation aerial surveys do not provide valid indices of abundance or accurate population estimates. Additionally, the FWC (2006) has determined that the data are biased in favor of areas with easier accessibility and higher visibility for detecting manatees. In Port Everglades, overhanging vegetation makes accurate aerial surveys difficult and surveys are occasionally terminated prematurely due to heavy air traffic at Ft. Lauderdale International Airport (Reynolds and Wilcox, 1994).

Unfortunately, aerial surveys provide no information beyond the number of manatees at a specific site after the passage of a cold front. This only provides managers with information on manatee distribution over time (Lefebvre et al., 1995). Arial surveys do not provide information on sex ratios, habitat, threats, overall behavior or movement patterns. Furthermore, manatee distribution during mild winter temperatures is not addressed by either the synoptic or aerial surveys. More information is needed regarding age structure, sex ratio and the number and proportion of calves in the population. Full life history information should be the aim of manatee population research leading to the recovery and sustainability of the species.

The Florida Manatee Recovery Plan identified four regions as management units to monitor populations: Northwest region, Upper St. Johns River region, Southwest region, and Atlantic Coast region (USFW 2001, Figure 1). These areas differ in habitat,
and individuals associated with these regions tend to return to the same warm water refuges during the winter and occupy core areas during the summer. Individual animals have similar distribution patterns and an exchange of individuals between the regions is considered limited (Langtimm et al., 2004).

Individual manatee identification is based primarily on scar patterns created by propeller strikes and entanglements (Figure 2). The seasonal congregation of manatees at known sites has allowed researchers to develop an extensive database of unique manatee observations, the Manatee Individual Photo-identification System (MIPS). Incorporating animals into MIPS requires a complete photographic record. Only healed and unique scars or features are used for identification (Langtimm et al., 2004). Although most manatees have multiple distinguishing marks, a single feature can be used to identify an
individual. Because calves have relatively few distinct marks, the majority of known animals are juveniles or adults older than 2 years of age (Langtimm et al., 2004). Nearly 2,000 manatees state-wide have been identified from 1978 through 2002 (Beck and Langtimm, 2002).

Figure 2. “Lucy” with calf. Identified at Port Everglades in February 2006 showing boat propeller scars.

Photo-identifications, aerial surveys, synoptic surveys and carcass recoveries comprise the source of population data for all management regions of the Florida Manatee Recovery Plan. As noted by Lantimm (2004), Atlantic region manatee photo identification is difficult because photographs are taken at or near the water surface. In addition to glare from the sun that can distort the image, these photographs tend to document only the dorsal side of the animal, which prevents researchers from identifying their sex.
By estimating the mean survival over a 10 year period, Runge et al. (2004) estimated annual growth rate for the Atlantic manatee population to be 1.0%. However, if the mean survival rates for only 5 years prior to 2004 were used, the estimated annual growth rate was -3.0%. A possible interpretation was that the population was growing at a healthy rate between 1990 and 1995 but a decrease in the survival rate caused the population to decline at about 3% annually from 1995 to 2000. Runge et al. (2004) also reported that all of the aggregation sites were monitored for their study and there were no regions where manatees escaped being monitored. This premise assumed that they accounted for the majority of the manatee population. Their data indicate that it was difficult to precisely determine how manatee populations in the Atlantic Region changed over the 10 year period prior to 2004.

Craig and Reynolds (2004) used a Bayesian approach to determine population growth from aerial counts of manatees at winter aggregation sites in the Atlantic Coast region. They found that the population growth rate increased 5-7% between 1982 and 1989, dropped to 0-4% during 1990 and 1993, and then increased 4-6% after 1994. These two population estimates yielded very different outcomes and it is uncertain, at this time, which is more accurate.

Use of Winter Refuges

Natural warm water refuges were historically limited to inland waterways and springs, but coastal power plants and their heated discharges have made it possible for manatees to remain further north during the winter. The attraction of manatees to industrial warm-water effluents during winter was first described by Moore in 1951 and
has since been well documented by Reynolds and Wilcox (1994) and Deutsch et al. (2003).

Seasonal abundance of manatees in winter refuges, such as industrial effluent canals at power plants, is primarily related to the severity of winter water temperatures. Manatees are able to find refuge at power plants because power plants pump cold water from the surrounding environment and pass it through condensers to cool turbine-generators. They then discharge the warmed water back into the ocean via an effluent canal. There are two warm water power plant refuges in South Florida, Port Everglades’ Florida Power and Light (FPL) facility and an additional FPL facility located in Fort Lauderdale.

**Broward County and Port Everglades**

Broward County is home to one of the nation’s busiest seaports, Port Everglades. More than 5,300 cargo and cruise ships call at this port annually. Located adjacent to Port Everglades is a natural gas and oil fueled Florida Power and Light (FPL) power plant whose warm-water effluent canal is a major center for manatee congregation during the winter.

The plant at Port Everglades consists of four units (two large and two small) with a total production capacity of 1,254 Mega-watts and water flow of 800 million gallons per day (DEP, 2008). However, water flow and temperature vary depending on the number of units in use. Typically, the two large units cycle daily while the two smaller units only run during peak times of the year (Bell, 2000). During manatee season (November 15th – March 30th), FPL is required by their Manatee Protection Plan to
maintain a discharge temperature of 68°F (20°C) if the ambient water temperature at the intake side of the plant falls below 61°F (16°C) (Stacy Foster, personal communication, 19 January 2006). Historically, this plant averaged nine times as many animals per survey as the nearby Fort Lauderdale plant, most likely due its closer proximity to the Intracoastal Waterway (ICW) (Bell, 2000). Bell (2000) believes that the Fort Lauderdale site was probably only used by inland animals during cold weather. However, recent surveys conducted by Broward County have shown that more manatees congregate at the Fort Lauderdale site (Pat Quinn, personal communication, 9 October 2009).

Counts at this FPL site commonly exceed 200 animals and a high of 276 was documented in one survey (Reynolds and Wilcox, 1994). Reid et al. (1991) found that some of the manatees that summer in Jacksonville move south as far as Port Everglades. Between the 1981 and 1986, Reid et al. (1991) documented site fidelity at all major Florida winter aggregation sites. One of the most successful surveys was at Port Everglades where they were able to catalogue 149 individuals and had a 63 % resighting success (based on manatees identified at another location or at the same location in different years) (Reid et al., 1991). Reynolds and Wilcox (1994) noted that good to excellent water clarity assisted in their aerial synoptic survey counts, but that air traffic and low hanging vegetation hindered efforts.

Manatees can be found throughout Broward County and the FPL canal all through the year. However during the cold season (November through March) ambient water temperatures drop causing manatees to migrate south or find northern warm water
refuges. As the population increases, the site provides an opportunity to monitor the animals and acquire a more robust assessment of population dynamics and site usage.

The relatively good visibility of the water at Port Everglades and the ready availability of animals provide an excellent occasion to clearly view the manatees, reducing availability bias and perception bias (Edwards et al., 2007). Manatees may remain submerged for up to 20 minutes, hampering aerial survey estimates (Hartman, 1979). However, at Port Everglades the resting areas are in relatively shallow water with low turbidity, enabling observations while the animals are still submerged. This eliminates the problem of only being able to observe the animals at the surface. According to Lefebvre et al. (1995) the closer a surveyor can get to what is being counted, the smaller the bias.

**Diurnal Site Usage**

It is unknown at this time if manatees exhibit a diurnal pattern of site usage. Hartman (1979) found no correlations between the animals’ behavior and the time of day. Bengtson (1983) also did not report any pattern in manatee food consumption and time of day, but did mention that between January and March animals would leave for a minimum of three hours at a time to reach their feeding destination. According to Irvine (1983), manatees have exceptionally low metabolic rates and show no circadian rhythm in metabolic rate. Normal body temperature has been reported at 97.5° F (Irvine, 1983). His results indicated that manatee thermostability was not influenced by overnight exposure to cold air and suggested that they may forage in cold water (≤16° C) if they can then digest their food in warmer waters. If manatees can sustain limited overnight
exposure to cold water and do not demonstrate circadian rhythms, then there may not be a
diurnal cycle to their resting/feeding patterns. However, preliminary work by Dr. Chip
Deutsch in Tampa Bay, FL indicated that manatee aggregations peak mid-day in warm-
water refugia and are smallest in the evening when the animals leave to feed (Deutsch,
personal communication, 13 December 2005). Deutsch’s work suggests that manatees
may exhibit a circadian rhythm and thus a diurnal pattern of site usage with regards to
feeding.

Powell et al. (1981) observed that manatees in Volusia County timed their
activities to avoid harassment by boaters. The manatees were able to change their daily
behavior patterns to best avoid boat strikes. If present, the establishment of a cyclical or
diurnal pattern of site usage would suggest that the time of day manatee population
surveys are conducted is critical to accurately estimating the true population size. For
instance, in the St. John’s River region, manatee surveys were conducted in the
afternoons between 13:30 and 17:30 (Packard et al., 1985). If the manatees in the St.
John’s River follow similar site residence patterns as those in Tampa Bay, these surveys
may have begun after the evening exodus and thus do not truly reflect the total
population. Although it is currently thought that manatee population numbers are
underestimated, the extent of the underestimation may be more disparate than anticipated
due to inconsistency in sample timing and a lack of information about a diurnal cycle in
the use of refugia.

In Kings Bay, Crystal River, Citrus County, average manatee counts had a
tendency to decrease outside established sanctuaries and increase within the South Bay
sanctuaries as the morning progressed (Buckingham et al., 1999). However, this movement of manatees toward the sanctuaries appears to be correlated to the increased amount in boat traffic during the day. In that study, the researchers did not report any daily movements of the animals outside of the Crystal River system. An abundance of vegetation within South Bay may alleviate the manatee’s need to leave the area to forage. Jimenez (2005) observed manatees during the day and night in Northeastern Costa Rica and Southern Nicaragua. Of nine observations, seven were viewed during the day and two detected at night. Morning observations were conducted between 05:00 - 08:00, while evening surveys were carried out between 16:00 - 18:00. However, manatees in this area do not have to leave the river system due to changes in water temperatures or to forage for food and many of the sites are protected from boat traffic.

**Objectives**

For my study, manatee counts were conducted throughout the winter manatee season (November 15th – March 31st) in an attempt to collect baseline data on the population of the manatees in Port Everglades. The use of ground surveys reduces the bias inherent in aerial surveys and aerial distribution surveys. The diurnal site usage of manatees at Port Everglades was investigated in an attempt to better define the time of day manatee surveys should be conducted. Because Broward County contains one of the most vulnerable populations it is imperative that these animals be closely monitored to determine how their populations are changing over time. To facilitate the long term goal of monitoring the population, a photographic scar identification database was developed.
**Materials and Methods**

A library of data for Port Everglades and the surrounding Intra-Coastal Waterway (ICW) has been compiled from boat surveys which started in May 1999 and from foot surveys along the effluent canal which began in 2000. Data collected from ground surveys during the 2004–2005 (20), 2005–2006 (51) and 2006-2007 (31) seasons were compared across seasons and years to determine if there was any trend in population size of the manatees found wintering in Port Everglades.

The Port Everglades discharge canal extends a total of 1,650 m from the discharge site to the ICW, approximately 1 km of which is a no entry zone. The total length of the foot surveys along the discharge canal was approximately 500 m (due to terrain, a portion of the canal is visible but inaccessible). Additionally a 28 ha, “Manatee Lagoon” is located near the mouth of the canal, which is also inaccessible (Bell, 2000).

Beginning 16 November 2004 through 25 March 2007, ground surveys of the FPL discharge canal at Port Everglades were undertaken approximately three times a week during manatee season (Appendix I). These surveys lasted approximately 30 to 60 minutes, depending on the number of manatees and the water visibility. A total of 102 observations were made over the three seasons (Figure 3).

For monitoring purposes, the canal was divided into four regions: Dry Marina (DM), the Port Everglades Administration Office (AO), the north Eller Drive bridge (NB) and the discharge canal area (EC) (Figure 4). Although these locations are not equal in area, due to site restrictions it is most convenient to divide the survey locale in this manner. Surveys prior to the 2005-2006 season were initiated at the Port Everglades
Administration Office. Subsequent surveys began at the Dry Marina. All surveys followed the canal north/west to the point where the canal meets the restricted-access power plant property (Figure 4).

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Figure 3. Table of Manatee Observations by Season.

Figure 4. Port Everglades Effluent Canal with Highlighted Survey Areas.

Surface temperature readings were taken using a Raytek Raynger ST (Santa Cruz, California) hand held infrared thermometer at four set locations in each region (DM: 26.1615 N, 80.0989 W; AO: 26.0819 N, 80.1202 W; NB: 26.0826 N, 80.1205 W; EC: 26.0827 N, 80.1234 W). Additionally, ambient water temperatures for Port Everglades
were provided by Terra Hernandez, Environmental Services at FPL. Water temperatures on the intake side of the plant are taken by FPL every three hours as part of their Manatee Protection Plan. Manatees were counted along the effluent and classified based on size/age class: adult, juvenile or calf for each area (Appendix 1). Size classifications were based on Marmontel (1993); adults > 275 cm, juveniles between 176 cm and 274 cm and calves under 176 cm. Because the majority of animals in the canal were resting, the possibility of double counting animals was minimal. A Kodak Easy Share 3.2 megapixel (Rochester, NY) digital camera was used to document manatee scar patterns in an effort to identify individuals.

During the 2005-2006 season, additional hourly surveys were conducted once a week along the 106 m dock at the Dry Marina. Surveys began at the southern most portion of the Dry Marina then proceeded northwards up the canal to the “no access” area near the mouth of the effluent canal. These hourly foot surveys took approximately 30 minutes to complete and typically began at 8:00 a.m. The hourly foot surveys were repeated every hour (±5 min.) on the hour. An hourly survey day ranged in duration from 3 hours to 10 hours, with a mode of 10 hours and an average survey day lasting 8.2 hours. The docks of the Dry Marina were chosen for this survey because of the ease of observing animals and the frequency of manatees visiting this site. Starting at the south end of the marina, counts of manatees seen in the area were recorded along with age/size class information and water surface temperature. Effort was made to note the movement of manatees (either north into the PE effluent canal or south out into the ICW).
A linear regression analysis was used to analyze the diurnal survey data as this is an appropriate test used to determine the relationship between one or more independent variables compared to a dependent variable. It is a predictive analysis which can be used to forecast a value for the dependent variable related to the independent variable. Because many counts were small (often there were no sightings of manatees) the data were transformed by $\sqrt{X+1}$ (after Packard et al., 1989).

Digital photographs were analyzed using Imatch 3.6 (Digital Image Management Solutions, Usingen, Germany) image management tool. Manatees were categorized based on their scar patterns. Scar location categories were broadly divided by whether the majority of the scar appeared on the body and head or on the tail. Scars found on the body were further divided depending on whether the preponderance of the scar occurred on the left, middle or right segment of the body (Figure 5).

Tail scars were categorized depending on whether the majority of the scar was on the left or right side. Identifying marks on the tail were further divided based on whether they were a scar or a deformity (Figure 6). This system insured that each visible scar or deformity could be classified and individuals with multiple identifying characteristics could be cross listed.
Figure 5. Identifiable scar marks on body of manatee used for photo-identification.

Figure 6. Identifiable scar mark and deformity on tail of manatee used for photo-identification.
Distinct animals were assigned a name for ease of reference. In general, these names have not been incorporated in MIPS. Images were compared based on assigned categories. Positive matches were verified independently by two observers after Langtimm et al. (2004).

**Results**

In 2004-2005, 182 manatees were observed during the surveys, 124 adults (68 %), 41 (23 %) juveniles and 17 (9 %) calves with an average of 9.1 manatees per survey (Figure 7). The average seasonal water temperature was 23.9° C. In 2005-2006, 667 manatees were observed, 559 adults (84 %), 36 juveniles (7 %) and 72 calves (11 %) with an average number of sightings of 13.1 animals per survey (Figure 7). Average ambient water temperature was 23.9° C. During the 2006-2007 season there were 267 manatees observed, comprising 209 adults (78 %), 26 juveniles (10%) and 32 calves (12 %) with an average of 8.6 manatees per survey (Figure 7).

![Number of Individual Manatees Observed per Season](image)

Figure 7. Number of Individual Manatees Observed per Season.
Over the three seasons studied, there was a significant difference in the mean ambient water temperature recorded between seasons at the FPL site using an ANOVA single factor test with 2 degrees of freedom and a p value of \(8.81 \times 10^{-25}\). Further analysis of the data using a Tukey test indicates there was a significant difference in the mean temperatures between 2005-2006 and 2006-2007. The lowest temperature recorded was 17.7°C on 14 December 2004. However, when the mean number of manatees observed was compared between seasons, there was not a significant difference in the number observed with 2 degrees of freedom and a p value of 0.465 (Figure 8).

![Average Number of Manatees Observed per Season](image)

Figure 8. Average Number of Manatees Observed per Season.

As expected, for the 2004-2005 and 2006-2007 seasons, the number of manatees observed in the effluent canal increased as water temperature decreased (Figure 9 and Figure 11). However, during 2005-2006 there was not the expected corresponding expected spike in manatee observations (Figure 10). For 2005-2006 and 2006-2007, the
The greatest number of manatees observed occurred in February (Figure 10 and Figure 11). The peak number of manatees observed for the 2004-2005 season occurred in January (Figure 9).

![2004-2005 Mean Number of Manatees and Temperature per Month](image)

Figure 9. 2004-2005 Mean Number of Manatees and Temperature per Month.
Figure 10. 2005-2006 Mean Number of Manatees and Temperature per Month.

Figure 11. 2006-2007 Mean Number of Manatees and Temperature per Month.
When considering manatee distribution along the discharge canal, across all seasons, there is a significant difference in the mean number of manatees found in each region. Data analyzed using ANOVA with 3 degrees of freedom yielded a p value of $1.87 \times 10^{-7}$. The greatest portion of manatees, 80.3%, was observed at the Dry Marina or the Administration office.

Figure 12 shows the relationship of mature manatees sighted and time of day. Linear regression resulted in a two tailed p value of $1.8^{-53}$ which was significantly smaller than the alpha value of 0.05. The slope (-2.692) was significantly different from zero. There was a relationship between the time of observation and the number of manatees expected with more sightings early in the day.

![Number of Manatees per Time of Day](chart.png)

Figure 12. Number of Manatees Observed per Time of Day with Trend-line.
Of 394 photographs, 58 individual manatees with distinct scaring patterns were identified over two seasons. The 58 distinct manatees represent approximately 6% of the total number of manatees photographed during the 2005-2006 and 2006-2007 seasons. No identifiable manatees were observed during both seasons. Five manatees were observed twice on different days within the same season. The manatee “Cuban” was seen on 11 Feb 2006 and 12 Feb 2006 (Figure 13), “R2T2” on 31 Dec 2005 and 26 Jan 2006 (Figure 14), “Scruffy” on 31 Dec 2005 and 8 Jan 2006 (Figure 15), “Peach” on 10 Feb 2007 and 12 Feb 2007 (Figure 16) and “Vickie” on 10 Feb 2007 and 11 Feb 2007 (Figure 17).

Figure 13. Photographic Identification of “Cuban”.

Figure 14. Photographic Identification of “R2T2”.
There were 109 manatees that either did not have distinctive scarring patterns or there was only one photo taken of the individual. There were seven “unidentified” individuals. These have been classified in this manner because although there were multiple pictures taken of them they did not have sufficiently unique or distinctive scarring patterns that could be used to re-identify them.

Photographs have also been shared with the national database MIPS. Although “Lucy” and her calf were not resighted in Port Everglades, MIPS were able to match the photos with a “unique unknown” already in their database.
Discussion

The results demonstrate that there was no significant difference in the mean number of manatees observed over the three seasons studied; 2004-2005, 2005-2006, and 2006-2007. Although there was a significant difference in mean ambient water temperature, the difference in water temperatures did not significantly affect the numbers of manatees sighted at Port Everglades. This is most likely attributable to the severity of the temperature change. The lowest recorded temperature for the area was 17.7°C on 14 December 2004. This is not far below the temperature threshold of 20°C when manatees have typically been seen to move to warmer waters. Additionally, the mean temperature for the 2004-2005 season was 23.9°C which is above the critical 20°C threshold. As would be expected, the peak number of manatees observed coincided with the coldest seasonal temperatures.

There was a greater likelihood of observing manatees at the Dry Marina or the Administration Office. Just over 80% of all observations were made at one of these areas with the remainder of the observations occurring along the rest of the canal. While the explanation of the distribution is not clear, there may be several factors contributing to their choice of these areas. Firstly, the manatees have more access to fresh water. Fresh water hoses at the Dry Marina were used throughout the day and the manatees have access to water via the run-off system and from hoses inadvertently kept on and dangled into the surrounding water. Observation at the Dry Marina is much easier than through out the rest of the canal. The Administration Office also has run-off drainage leading into the canal. There was no access to fresh water observed in either the North Bridge or
Effluent Canal regions. Additionally, both of these locations are closer to the Intra-
coastal waterway and the thus the ocean. Proximity to the open ocean and foraging
grounds may contribute to site preferences. Finally, both the Administration Office and
the Dry Marine are built with areas sheltered from the normal flow of the canal water. It
may be easier for the manatees to rest in these areas with less current than to rest in areas
where they would have to actively resist a current.

Unfortunately, it was impossible to get an accurate determination of the sex ratio
of the animals wintering in Port Everglades. Because observations were made from the
surface and hardly any of the animals rolled over during observations, the sex of few
animals was determined. Gender could only be determined when a mature female was
seen repeatedly in close proximity to or nursing a calf. The best example was “Lucy”
who was observed and photographically documented nursing her calf (Figure 18).
Determining the sex ratio of manatee populations is a common and ongoing problem for
biological managers.

Figure 18. “Lucy” Nursing Her Calf.
The majority of the animals observed were mature adults and approximately 10 %
were calves. The greater percentage of juveniles observed in 2004-2005 is most likely
attributed to observer bias due to an inconsistency in estimating the size of the juveniles.
Categorizing manatees as calves or juveniles can be somewhat open to interpretation as
there is a great deal of estimation during observation. Typically, a calf is considered “…
animals less than half the length of a closely associated animal.” (Reynolds and Wilcox,
1994, p.166). Individuals greater than half the length of a closely associated animal but
smaller than the full length of a closely associated adult were considered juveniles. Since
this classification is dependent on estimates of closely associated animals situational and
observer biases can impact the classification of animals in this size class.

My data indicate that there was a diurnal relationship in site usage for the
manatees wintering in Port Everglades. It has been proposed by Dr. Chip Deutsch that
manatee populations in refugia in Tampa Bay, FL peak around noon; and leave the
refuges in the evening to feed. However in Port Everglades, I determined that there were
more manatees in the early morning hours than in the afternoon or evening. Analysis of
these data indicates that there is a statistical difference in the mean number of animals
with regards to the time of day, with more animals being observed in the morning. This
suggests that the time of day manatee observations are conducted may be important in
order to correctly estimate the population.

Circadian patterns of behavior are controlled by a neural network located in the
suprachiasmatic nucleus in the base of the hypothalamus (Perrin et al., 2008). Circadian
rhythm and photoperiods are directly linked with pituitary and pineal gland hormone
secretions (Perrin et al., 2008). Melatonin, produced primarily in the pineal gland, is the most common hormone associated with photoperiodism in mammals. Other marine mammals with predominant pineal glands, such as southern elephant seals, have demonstrated circadian rhythms (Griffiths et al., 1979; Barrell and Montgomery, 1989). Factors involved with the observance of circadian rhythms include forced activity and rest and nutritional cues (feeding behavior) (Arendt, 1995).

Although the data demonstrate that there is a daily pattern to manatee movements in Port Everglades, at this time it is uncertain what is driving the pattern. In 1875, Chapman mentions detection of the pineal gland and peduncle under the velum interpositum. However, Chapman’s paper is based on a single animal and there are no accompanying illustrations for additional researchers to reference. Ralph et al. (1985) determined through gross examination that the Florida manatee did not have pineal body and through histological examination a lack of pinealocytes. However, the absence of the pineal gland does not mean that some functions associated with the gland could be duplicated by other organs, Ralph, et al. (1985) suggested that it is unlikely that all functions would be duplicated by other organs.

It has been shown that dugongs (Dugong dugong), a close relative of the manatee, are able to modify their diurnal behaviors based on environmental pressures. Typically, it has been found that tides primarily drive an alternating diurnal cycle of feeding and idling. However, where dugongs are regularly hunted they come inshore to feed at night and do not feed during the day (Anderson, 1981).
On three occasions, synoptic surveys at the FPL Canaveral plant (PCC) and Orlando utilities Commission (located just outside PCC) found more manatees during the late-morning surveys (11:00) compared to the number of manatees sighted during the early morning surveys (08:00) (Reynolds and Wilcox, 1994). The discrepancy was because in the early morning manatees rested on the bottom in very turbid foamy water, but during the late morning they rested at the surface and there was a better sun angle.

Deutsch et al. (2003) and Reynolds and Wilcox (1994) have said that in Tampa Bay and Orlando, respectively, manatee numbers appear to peak mid-day. These observations are different than what was found in Port Everglades. Ambient water temperature is the probable factor leading to a difference in site usage. In Port Everglades the ambient water temperature rarely dips below 20° C and does not stay below 20°C for a significant amount of time. Manatees in this area are probably not as dependent on the warm water outflow of the power plant and thus are not as constrained in their movements.

In 1985 Caldwell and Caldwell supposed that manatees do not necessarily return to the same refuge in winter. This observation was supported by Reid et al. (1991) who found that manatees change winter aggregation sites between and during winter seasons. Results from this study suggest that manatees do not automatically return to the same winter refuge, either between or during seasons, because only 12% of identified manatees were resighted. However, scar patterns can alter dramatically in a short period of time and can change in size, color and texture (Rommel et al., 2007). Specifically, the
marks on “R2T2” (Figure 14), observed during the 2005-2006 season, were faint and may have completely vanished in subsequent seasons.

The movement of submerged animals and their different rates of surfacing make it difficult to accurately count and photograph manatees from the ground (Packard et al., 1985). Although water clarity in Port Everglades is typically excellent, manatees can only be accurately photographed when they are approximately 0.5 to 1.0 meter below the surface. Glare from the sun on the surface of the water, mottling of the water by shade from trees or disturbance of substrate can negatively affect photographs. In 2007, Edwards et al. (2007) determined that the probability a visible manatee would be detected by ground observers ranged from 65 % to 75 %.

There are two types of visibility bias when undertaking surveys: perception bias and availability bias (Marsh and Sinclair, 1989). Perception bias occurs when animals are visible within the survey area but are missed by the observer. Availability bias is when animals are within the survey but not visible by the observer.

The diurnal data from this study may suggest that an increased enforcement of manatee speed zones in Port Everglades during the times when the manatees are leaving the refuge (9:00-10:00) could contribute to a reduction in boat strikes. However, it is unknown at this time when boat strikes are most likely to occur as the majority of recovered carcasses in the area are too badly decomposed to determine when injury or death occurred (FWC, 2008). John Fiore (personal communication, 9 October 2009), indicated that the primary goal of law enforcement throughout the ICW is to maintain boater safety and not to specifically address manatee speed zone.
More information on the movement of manatees around refuges is critical for better protection of the species and focusing law enforcement efforts. Monitoring when the animals use the refuge during the day could be a key component in targeting enforcement activities. To better understand manatee diurnal movements, surveys of the area should be continued to enhance the dataset obtained in this study. The use of satellite tracking has already been used in conjunction with long distance migrations and would prove useful in determining short term daily movements.

**Background on State Biological Status**

The Florida manatee was last evaluated by a biological status review in 2007. In the biological status review of 2003 the species met the criteria to be listed as endangered (FWC, 2006). In 2005 the FWC adopted new criteria for conducting biological status reviews and the standing of Florida manatee was reviewed under these new criteria. Under the new criteria the species has been down-listed to threatened. The State of Florida categorizes the risk of extinction by the designation of Endangered, Threatened, or Species of Special Concern (FWC, 2006). The Florida manatee must meet at least one of the five criteria to warrant listing under any of these categories. The five criteria are:

A. Population reduction,

B. Extent of occurrence and area of occupancy,

C. Population size and trends,

D. Number of mature individuals,

E. Probability of extinction.
Criterion A requires the assessment of population reduction of the Florida manatee over the past, future, or a time period for ten years or three generations, whichever is longer. Future population changes are calculated using a stage-structured matrix projection model which incorporates key parameters such as survival rates, breeding rates, demographic stochasticity and carrying capacity (FWC, 2006). In order to list an animal as endangered (EN), a past or future population reduction of at least 80% of the species’ population would be required. A population reduction of 50% lists the species as threatened (TH), while a 30% reduction would result in a listing of species of special concern (SC). However, if the cause of the population reduction is reversible or the cause has ceased, the criteria for listing are 90% for endangered, 70% for threatened and 50% for species of special concern (FWC, 2006).

Criterion B is an estimate of the total range and area occupied by the Florida manatee. Extent occurrence is the habitat area within Florida, including large bays, estuaries and rivers, in which the manatee can occur (Figure 19). Since the manatee does not occupy all the areas within its range, the area of occupancy was determined as the essential area required to sustain the population (Figure 20). The area of occupancy was best described by areas where manatees congregated during the coldest days of the year. It has been established that:

…requirements for listing under this criterion as extent of occurrence must be less than 40 square miles (EN), 2000 square miles (TH) or 7700 square miles (SC); or the area of occupancy must be less than 4 square
miles (EN), 200 square miles (TH), or 770 square miles (SC) (FWC, 2006).

Additionally, at least two of three other conditions must be met:

1) Severely fragmented or known to exist at no more than one (EN), five (TH), or ten (SC) locations.

2) Continuing decline of observed, inferred, or projected in any of the following: (a) extent of occurrence; (b) area of occupancy; (c) area, extent, and/or quality of habitat; (d) number of locations or subpopulations; or (e) number of mature individuals.

3) Extreme fluctuations in any of the following: (a) extent of occurrence; (b) area of occupancy; (c) number of locations or subpopulations; (d) number of mature individuals.

Figure 19. Map of Florida Manatee Extent of Occurrence (FWC, 2006).
Current population size and trends are the focus of criterion C. To meet the conditions of Criterion C “…the number of mature individuals must be less than 250 (EN), 2500 (TH), or 10000 (SC)”. One of the following sub-criteria must also be met:“(1) an estimated population decline of at least 25 % over one generation (EN), 20 % over two generations (TH), or 10 % over three generations (SC); or (2) an observed,
projected, or inferred decline in number of mature individuals, and either (a) no subpopulation estimated to contain more than 50 (EN), 250 (TH), or 1000 mature individuals (SC) or at least 90 % (EN), 95 % (TH), or 100 % (SC) of mature individuals in one subpopulation or (b) extreme fluctuations in number of mature individuals” (FWC, 2006).

Criterion D is to determine if the population of mature individuals is extremely small. “To meet this criterion for listing, the range-wide population estimate for the species must be no more than 50 (EN), 250 (TH), or 1000 (SC) mature individuals” (FWC, 2006). Another way to meet the criteria for species of special concern is if the population occupies an area less than eight square miles or less than five locations.

Estimates of the probability of a species’ extinction in the wild within specific time-frames are the focus of Criterion E. “The probability of extinction would have to be at least 50 % within the next three generations to qualify as EN, 20 % within the next five generations to qualify as TH, or 10 % within the next 100 years to qualify as SC” (FWC, 2006).

The Florida manatee meets the prerequisites for two of the five established criteria and according to these criteria should be listed as threatened. According to the FWC (2006), there was a 12.1 % chance of a 50 % decline in the next three manatee generations and there was a 46.5 % chance of a 30 % decline during the same period, fulfilling benchmarks of threatened in Criterion A. The extent of occurrence is approximately 7500 mi² and the area of occupancy ranges from 100-300 mi². The panel
agreed that the manatee population met the condition of a decline in area of occupancy, but did not believe the evidence supported severe fragmentation or limited numbers of locations, thus not qualifying the population for listed status under criterion B. The number of mature manatees in Florida was calculated at 2,310 and there is a 55.5% probability of a 20% reduction in population over the next two generations qualifying the species as threatened under Criterion C (FWC, 2006). However, a mature population of 2,310 individuals occupying an area of 100-300 mi² does not qualify the manatee for listing under Criterion D (FWC, 2006). The statewide estimates for the probability of extinction are unlikely to approach the benchmarks established by Criterion E, therefore the Florida manatee does not qualify for listing under this criterion.

According to the most recent review of the biological status of the Florida manatee, although the population is threatened, the threat is not great enough to warrant classification as endangered. As this recategorization might indicate a major change in community perception toward manatee population levels, it is important to collect and assess as much manatee population data as possible to ensure that the species is listed appropriately.

**Conclusion**

This study was able to compile a broad base of information on the number, general age structure and site usage of manatees wintering in Port Everglades, FL. There was no observable significant difference across years in the number or the age structure
of manatees wintering in the area. Additional studies should be undertaken to determine the sex of animals.

A diurnal site pattern of usage was established. It is uncertain at this time what factors contribute to the afternoon exodus from the site. Correctly timing manatee surveys throughout the State may be crucial in obtaining more accurate population counts. Depending on the location, manatee numbers may differ significantly based on time of day. Further research should focus on water temperature and feeding patterns to elucidate what is causing diurnal manatee movement in this area.

Individual photographic identification was successful. There were 58 unique individuals identified in this study. The markings on these manatees should make them easy to re-identify by MIPS and in future studies.

Given the most recent review of manatee populations and the species down listing, it is important to acknowledge that there is still an insufficient amount of information about manatee populations. Greater effort should be undertaken to devise more accurate methods for surveying manatee aggregations.
Appendix I

PORT EVERGLADES MANATEE GROUND SURVEYS 2007-2008
NOVA SOUTHEASTERN UNIVERSITY - OCEANOGRAPHIC CENTER

SURVEY DATE ___/___/___ SURVEY HOURS: ___ :___ to ___:___
OBSERVERS: ________________________________________________

DRIY MARINA  -26.16153  80.09891
TIME: _______   H₂O TEMPERATURE: _________  ACTIVITY: ____
ADULTS: ___________________  JUV: ______  CALVES: ______
COMMENTS: __________________________________________________

ADMIN OFFICE  -26.08190  80.12020
TIME: _______   H₂O TEMPERATURE: _________  ACTIVITY: ____
ADULTS: ___________________  JUV: ______  CALVES: ______
COMMENTS: __________________________________________________

NORTH BRIDGE  -26.08264  80.12053
TIME: _______   H₂O TEMPERATURE: _________  ACTIVITY: ____
ADULTS: ___________________  JUV: ______  CALVES: ______
COMMENTS: __________________________________________________

EFFLUENT CANAL  -26.08271  80.12348
TIME: _______   H₂O TEMPERATURE: _________  ACTIVITY: ____
ADULTS: ___________________  JUV: ______  CALVES: ______
COMMENTS: __________________________________________________
## Appendix II

### Manatee Identification Guide

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<th>Date photographed</th>
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<p>|        |      | 12 February 2007 |
|        | Pi   | 26 November 2006 |
|        | Poe  | 12 February 2007 |</p>
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