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The Effects of an Extended Power Plant Shutdown on the Florida Manatee (Trichechus manatus latirostris) in Port Everglades, Florida

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THE EFFECTS OF AN EXTENDED POWER PLANT SHUTDOWN ON THE FLORIDA MANATEE (*TRICHECHUS MANATUS LATIROSTRIS*) IN PORT EVERGLADES, FLORIDA

By

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ABSTRACT

Florida manatees (*Trichechus manatus latirostris*) seek out warmer waters during winter months when ambient water temperatures drop below 20 degrees Celsius. Over time, manatees have discovered artificial warm water sites from power plant discharges in addition to natural sites such as springs and passive thermal refugia (PTRs). The Florida Power and Light (FPL) Port Everglades power plant in Broward County is one such artificial warm water refuge used by manatees. This plant was shutdown on July 16, 2013, and is expected to remain off line for at least three years during demolition and construction of a new facility. The purpose of this study was to determine changes in habitat usage and other responses to the disruption of a warm water refugia (the closure of a power plant) on Florida manatees within the greater Port Everglades region. From November 15, 2013 to March 31, 2014, manatees were counted at the site via shore line and aerial surveys. Environmental data were collected to determine variables correlated to manatee presence and absense. Two manatees were radio-tagged using remote sensing devices in an effort to identify alternative warm water refugia and feeding areas. Data were collected from state and local organizations and photo-identified manatees were used to analyze for trends in cold stress syndrome (CSS) lesions and watercraft scarring. Results confirmed that manatee presence was positively correlated with heater outlet temperature. Differences did not exist between the results of survey methods between the FPL Port Everglades (PE) and Fort Lauderdale (FL) power plant sites, however, differrences in the aerial survey counts showed an increased presence at the FL site during the colder month of January 2014. Data from tagging identified one manatee that preferred the FL site while another preferred PE, presumably due to more convenient access to feeding grounds in Biscayne Bay. Data from mortality events indicated a low number of CSS and watercraft deaths in Broward County as compared to other parts of the state of Florida. Further monitoring of the study area for the remainder of the shutdown period is recommended, as are improvements in survey design, expansion to include additional environmental data from FL, continued mortality statistic analysis and locating possible PTRs.
Keywords: Florida manatee, warm water refugia, power plant, cold stress syndrome, FPL, Port Everglades, photo-identification, shutdown, mortality

DEDICATION

This thesis is dedicated to Dr. Edward O. Keith, who served as my initial advisor before his untimely death in 2012.

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TABLE OF CONTENTS **PAGE**

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

The Problem: Manatee Dependence on Man-Made Warm Water Effluents

The world's oceans and associated ecosystems are in trouble due to the collapse of marine animal populations and extensive habitat destruction (Balmford *et al*. 2004; Norse 1995). Humans depend on ocean ecosystems for many of their needs (Halpern *et al*. 2008) and have a profound influence on these marine systems (Allison, Lubchenco and Carr 1998). We have altered the ocean both directly and indirecty (Halpern *et al*. 2008). As a result, populations of marine flora and fauna have declined or collapsed. Habitats have been impacted to make room for an increasing world human population (Balmford *et al*. 2004). For example, when a forest habitat is cut down or altered during the city building process, it has been documented that species diversity and wildlife populations tend to be at a loss (Shochal *et al*. 2010). In reponse to our deleterious impacts, the new discipline of "conservation biology" began to emerge in the 1980s (Soule and Wilcox 1980). This was the first scientific discipline with an applied goal: to maintain and conserve the world's biodiversity.

The problem that arises when looking at marine conservation is the lack of understanding about the complexities of marine species and processes that restrict our ability to fully address the many threats facing them. However, over the past decade, improvements have been made that allow for the use of newly developed tools, such as acoustic monitoring and marine protected areas (MPAs), for better understanding conservation of biodiversity (Norse 2005; 1995). Successes in marine conservation must be driven by an ability to assess and understand marine ecosystems and to direct this knowledge towards fact-based conservation solutions (Lacommare 2011).

Sirenians (of the Order Sirenia), which are represented by three living manatee species and a single dugong species, are herbivorous mammals that are found throughout the tropics and subtropics. They are one of many endangered species found in marine ecosystems and are recognized as a flagship species for marine conservation efforts throughout their range (Marsh and Lefebvre 1994; Bonde *et al*. 2004). The Florida subspecies of the West Indian manatee, *Trichechus manatus latirostrus* (Harlan, 1824), which inhabits coastal and freshwater habitats from Texas to New England in summer

(Deutsch *et al*. 2003; Fertl *et al*. 2005), is one of two manatee subspecies at the center of conservation efforts within the borders of the continential United States, the other being the Antillean subspecies, *Trichechus manatus manatus,* located in Puerto Rico. According to the most recent aerial synoptic survey conducted in 2014, 4,824 Florida manatees were counted throughout the state of Florida in various warm water wintering sites (Florida Fish and Wildlife Conservation Commission 2014). The number of manatees counted can vary from year to year mainly due to detection probabilities and trends in population size. In 2012, an aerial survey identified 304 manatees using the warm water discharge canal of the Port Everglades power plant, owned and operated by Florida Power and Light (FPL) (Fleshler 2012).

Due to their physiological need for warmth during winter, the population of Florida manatees using warm water sites, as well as the reliability of warm water sites themselves, are important to the overall conservation of the subspecies throughout their range. This study examined Florida manatee habitat use and their response to a loss of one of two available warm water sources within Broward County. This event provided an opportunity for corporate, regional, state, and federal wildlife managers to develop and establish appropriate conservation guidelines for future disruption of warm water sources currently available to manatees today.

Statement of Purpose

The purpose of this study was to determine changes in habitat usage and other responses to the long-term disruption of a warm water refugia (the closure of a power plant) on Florida manatees within the greater Port Everglades region. Specifically, my objectives were:

1. To determine changes in Florida manatee habitat use and distribution patterns in the Port Everglades region of Broward County during a warm water refuge disruption (closure of a power plant) through the use of count surveys.
2. To determine short-term behavioral responses to a warm water refuge disruption (closure of a power plant) through the use of satellite radio tagging and comparisons of telemetry and count data method results between two southeast Florida power plant sites, one operational and one non-operational.

3. To determine trends in Florida manatee counts using data from previous studies conducted in Port Everglades compared to data collected during this study.

This thesis contributes to our understanding of conservation biology by increasing the knowledge of Florida manatee ecology, specifically on habitat usage and response to warm water refuge loss. It also contributes basic ecological information that can be used by wildlife managers to improve protection of the Florida manatee during future closures of man-made warm water refuges across both the state of Florida and the entire distribution of the subspecies.

Background

Conservation biology addresses the life history of species, communities, and ecosystems that are disturbed (directly or indirectly) by human activities or other agents in order to provide guiding principles and tools for the preservation of biological diversity (Soule 1985). Conservation biology, emerging in the 1980's, was developed as a "crisis" discipline in order to conserve biodiversity (Soule and Wilcox 1980). Biodiversity is classified as the variability among living organisms from all sources and the ecological complexes for which they are dependent (Gray 1997). Initially, there was a focus on conservation of individual species, which was met with some opposition by ecologists who argued that the focus should be on ecosystems rather than individual species. However, neither focus has been very effective in protecting marine species or ecosystems (Zacharias and Roff 2000). According to the Society for Conservation Biology (2013), biodiversity can have either a utilitarian or inherent value, and in some cases, both. Most species are looked at inherently, in that a species in every capacity is valuable, and should be protected from extinction. In a utilitarian value approach, there is a direct benefit to humans that maintains an interaction among all parts of the environment. This can include such things as an economic dependence on a particular fishery or explotative value of harvest. Nearly a decade later in the early 1990s, marine biologists were stunned at the sheer vulnerability of life in the ocean, so the underlying principles of conservation biology were incorporated, adjusted, and applied to species in the ocean and the field of marine conservation biology was born (Soule *et al.* 2005).

Successful conservation strategies include community involvement, defining clear goals and objectives, including all available science, management and monitoring of species populations, and the design of marine protected areas (MPAs) (Lundquist and Granek 2005). There are some challenges to conservation strategies, however. These include inadequate enforcement at all levels (local, regional, national, international, etc.) and overcoming limited or missing scientific information. Legislation also plays a crucial role in conservation biology. Two widely known pieces of legislation impacting marine species are the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA). The MMPA protects all marine mammals and prohibits the take of any marine mammal within U.S. waters and by all U.S. citizens on the ocean seas (National Oceanic and Atmospheric Administration Fisheries 2013). It also prohibits the import of marine mammals and their products unto the U.S. The MMPA was amended in 1994 to include regulations on take for native subsistence in Alaska and for scientific research permits. Recently, this legislation celebrated its 40^{th} anniversary. The ESA of 1973 was passed by Congress in order to protect and recover imperiled species and the ecosystems upon which they depend (U.S. Fish and Wildlife Service 2013). The branch of the government responsible for regulation of marine ecosystems and most of their associated species is the National Marine Fisheries Service (NMFS). The regulatory responsibility for manatees, walruses, sea otters, and polar bears falls under the U.S. Fish and Wildlife Service (USFWS). Under this act, there are two classifications of species: threatened and endangered. A threatened species is a species that is likely to become endangered within the foreseeable future, whereas an endangered species is one in imminent danger of extinction throughout all or a significant portion of its range. While not all marine mammals are listed as threatened or endangered (only 29 species of marine mammals are listed under the ESA) they are all protected under auspecies of the MMPA.

Conservation strategies can be applied to all animals, including marine mammals, such as cetaceans (Gormley *et al.* 2012) and sirenians (Marsh and Lefebvre 1994). For this study, the Florida manatee, *Trichechus manatus latirostris* (Harlan, 1824), in the Order Sirenia, family Trichechidae (Deutsch 2008), was investigated. The Florida subspecies is the largest known population for the West Indian species (Reynolds and Wells 2003). Manatees are aquatic, herbivorous mammals (Deutsch *et al.* 2003; Marsh

and Lefebvre 2004; Ripple 1999) that have a body sparsely covered by small, thick hairs (Reep *et al*. 2002; Scott 2004; Reep and Bonde 2006). They have a broad, rounded paddle-like tail (Folkens and Reeves 2002) that is horizontally flat and used for propulsion, or as a rudder for steering (Scott 2004; Reep and Bonde 2006). Manatees have a flexible upper lip that is used to grasp and guide food into the mouth along with bristles that can also be used for sensory detection (Humphrey 1992; Marshall *et al*. 1998; Reep *et al.* 1998; Reep *et al*. 2001). Being aquatic mammals, manatees can submerge up to fifteen to twenty minutes during sleep or resting (Scott 2004). They have two nostrils located on their snout that have specialized valves that close shut to keep water out while submerged. Manatees can see long distances in clear water due to their small, deep-set eyes that are covered by a protective membrane, but their visual acuity is poor (Bauer *et al*. 2003; Reep and Bonde 2006). They have no visible external ears but instead rely on internal mechanisms for their sense of hearing. This allows for reduced drag within the water (Reep and Bonde 2006). Manatees are generalist herbivores that feed on a variety of vegetation including plants and seagrasses found in freshwater, marine, and terrestrial habitats (Lefebvre *et al.* 2000). They are considered opportunistic generalist herbivorous grazers as well. In order to meet their body's energy demands, they must consume about twenty percent of their body weight per day (Scott 2004; Reep and Bonde 2006).

The Florida manatees, preferring tropical and subtropical habitats, are found throughout the peninsula of Florida at all times of the year (Ripple 1999). They have also been found in coastal areas of Texas, Alabama, Lousiana, and even up as far north along the Atlantic Seaboard to New Jersey and Rhode Island during the summer months. Their primary distribution is along the coastal and inland waterways of Florida (Scott 2004). They may also be detected around inshore estuaries, lagoons, and even long distances up river systems (Douglas 1982; Folkens and Reeves 2002). They prefer areas with warm, shallow, slow moving bodies of water (Douglas 1982). There are four distinct recognized management areas for Florida manatees within the state of Florida (Reynolds and Wells 2003). These are separated primarily by regions in Florida that include: the Northwest, the Southwest, the Atlantic Coast, and the Upper St. Johns River. The Atlantic group is the largest area with an estimated forty-seven percent of the total state-wide winter

manatee population. Port Everglades, the site for this study, is located within this region and is one of two primary wintering sites for manatees in the Southeast, as well as provides refuge for other migrating/transient individuals.

As previously mentioned, manatees require warm water (Douglas 1982; Irvine 1983) encountered in tropical and subtropical regions (Ripple 1999). However, manatees in Florida are subject to exposure to cold water temperatures that occur during the winter months (Hartman 1979). Manatees have a limited tolerance to these cold water temperatures (Irvine 1983; Stith 2010; 2012). They have low internal heat production, little effective blubber insulation, and high thermal conductance that suggests that they are poorly adapted to the cold water temperatures that occur during the winter months in Florida (Irvine 1983). Unable to thermoregulate in colder waters using their physiology (like many cetaceans), manatees are behavioral thermoregulators. When water temperatures drop below 20 degrees Celsius, manatees will seek use of a thermal source and aggregate in areas of warmer water above this temperature threshold (Deutsch *et al.* 2003; Ackerman 1995; Lefebvre *et al.* 1989). They will remain in these areas of warm water for the duration of the cold spell, only leaving for short periods of time to forage (Hartman 1979). These locations are termed warm water refugia and can be found in certain areas of Florida, including fresh water springs and the warm water effuents of power plants (Hartman 1979; Humphry 1992; Scott 2004). Warm water refugia can either be natural (warm water springs and passive thermal basins) or man-made (power plant effluents). Passive thermal refugia (PTR) are being used by manatees now due to the loss of artificial sources of warm water (Packard *et al*. 1989) and the presence of temperature inverted haloclines that provide warmth (Stith 2010; 2012). These sites often consist of fresh water stratifying with warmer salt water forming a distinct halocline and providing temporary sanctuary for manatees above the ambient temperature for a short period of time (Stith 2010; 2012). However, there must be significant salt water stratification maintained by freshwater inflows over the salt wedge for these systems to be useful and their capacity to maintain warm temperatures is limited. Manatees will also travel to warm water regions based on access to local foraging areas (such as seagrass beds), to freshwater for drinking, and to channels that are typically at least two meters deep (Humphrey 1992; Scott 2004). In order to get to these warm water areas, manatees

undergo a short-term migration, using rivers, streams, spring runs, and man-made waterways as corridors of travel (Scott 2004; Reep and Bonde 2006). During these times, manatees can can travel distances up to three hundred kilometers or longer with an average rate of forty-nine kilometers per day (Humphrey 1992; Deutsch *et al.* 2003).

Manatees are affected by prolonged periods of cold and can show signs of distress if they do not reach adequate warm water sources within a timely manner (Scott 2004; Reep and Bonde 2006). Cold Stress Syndrome (CSS), often resulting in death is the primary effect of prolonged cold water exposure to manatees (Bossart *et al.* 2003; Scott 2004; Reep and Bonde 2006). CSS is a “cascading effect” syndrome (Bossart *et al.* 2003). Long-term exposure to cold water can result in reduced activity, slower movements, decreased food consumption, and dehydration that disrupts normal body functions, including metabolic and immunologic processes. Manatees can also develop skin lesions and abscesses along with weight and fat loss and secondary infections (Bossart *et al.* 2003). Basically, the body of the manatee begins to shut down until they find warm water or, ultimately, death occurs. Manatees will begin to feed erratically at temperatures between 15 and 18 degrees Celsius, and will eventually cease consumption altogether (Campbell and Irvine 1981). After a few days, they will begin to shiver, change their behavior, and show signs of anorexia (Bossart 2001). As previously stated, 20 degrees Celsius has been determined as the minimum water temperature that Florida manatees can tolerate before actively seeking sources of warm water (Irvine 1983; Laist and Reynolds 2005a).

Manatees that do not die from CSS are often rescued depending on the severity of signs and transported to an appropriate animal care facility where medical evaluations are conducted and treatment plans are established to provide for the ultimate release of the animal (Walsh and Bossart 1999; Bossart 2001). Treatments include: reversing dehydration by giving the patient water through a tube, feeding the animal a calorie-rich diet gruel that is increased in the amount and consistency over time, treating subsequent lesions, pathogens, and infections with appropriate pharmaceuticals, and providing the stressed animal a warm water habitat to help maintain normal basal body temperature. Once a manatee is deemed ready to be returned to the wild, they are transported to the appropriate site and released. This process can take months to years depending on the

severity of the symptoms and associated treatments. In 2010, an unusual mortality event (UME) occurred from January to April due to lower than normal temperatures from arctic fronts driving south from the northern U.S. and Canada (Barlas *et al.* 2010). During this time frame, Port Everglades reported the largest number of manatees present in its discharge canal at around 700 individuals. Of a total recorded 480 deaths (statewide) during that winter, 252 were clinically determined to be from CSS with another 182 listed as unknown (primarily due to advanced state of decomposition of the bodies precluding accurate assessment during necropsy). These unknown deaths were believed to have also been from CSS but due to the decomposition of the bodies, this could not be confirmed at necopsy. The 252 confirmed deaths from CSS were the largest number of individuals recorded during one season to date.

Boating activities have become common in coastal developed regions over the years with the state of Florida having the highest number of registered boats in the country (Scott 2004). Broward County, Florida, is home to one of the busiest and productive seaports in the world, Port Everglades (Broward County Port Everglades Department 2013a). Not only is the port used for commercial business it is also used as a travel corridor by recreational boaters who travel north and south along the Intracoastal Waterway (ICW), a network of canals, inlets, bays and rivers that runs the length of the eastern Atlantic seaboard of the United States, from Virginia to the Florida Keys. Due to this frequency of travel by boaters, management decisions regarding boating speeds and no entry zones were made with respect to the local MPAs. In areas such as Port Everglades, decisions had to be made that supported both the conservation of an endangered species (the manatee) and the economic needs of the county. A variety of different speed zones were set up along the ICW and throughout the port area and associated channels to achieve this warranted protection (Broward County 2008). There are three main speed/no entry zones listed for the Port Everglades area. In and around the MPA for the endangered Florida manatee is a no-entry zone (this is the site proposed for this study). North of this area is the actual port and inlet to the Atlantic that is listed as a slow speed zone (safe operation speed less than twenty-five miles per hour in designated channel). In order to get from the no-entry zone in the MPA from the port, one must travel south along the ICW. This stretch of water in the ICW is listed as an idle

speed/minimum wake zone during certain times of the year (primarily November through March) and a slow speed zone for the remainder of the year. Further south from the MPA no-entry zone is another MPA designed to protect threatened mangroves that has an associated year round speed limit of 25 mile per hour.

The Port Everglades area is faced with many anthropogenic threats to manatees, such as recreational and comercial boat use, dredging and shipping traffic, however, the most important impact to consider for manatee longterm health in this area is the closure of the FPL power plant at Port Everglades for a three year period while the company builds a next generation clean energy generating center. This power plant will be closed through 2016 while the facility undergoes upgrading their power generating capabilities to a "greener", more efficient system. This disruption in providing warm water for manatee use created an opportunity to gather information that will be necessary for resource managers to evaluate the effects of the closure and the reduction of warm water available for manatee use.

The primary objective of this thesis study was to determine changes in habitat use and other responses to the long-term disrupton of a warm water refugia, specifically the closure of a FPL's Port Everglades (PE) power plant during the rebuilding process. This study focused on manatees using the Port Everglades area during the winter. Based on previous studies and known manatee behavior, the following hypotheses were aligned with my specific objectives and were tested:

1. There will be significantly less manatees present and counted in the study area during times of cold weather.
2. There will be a significant difference in counts between two FPL power plants (one operational and one non-operational) based upon survey method results (aerial versus land-based) and site locations (PE versus the inland Fort Lauderdale (FL) power plant). A significantly smaller proporation of the radio-tagged individuals will use the PE discharge canal during times of cold weather.
3. When compared with previous study counts, data collected during this study will illustrate a significantly less number of manatees present in the discharge canal during cold weather.

4. Alternatively, it could be expected that: (1) If a large number of manatees are present in the study area during times of cold weather but backup heaters are turned off there are sufficient heat sources within the study area to assist manatee thermoregulation; (2) If radio-tagged individuals are located within the FL power plant discharge canal versus the PE discharge canal then manatees are choosing the heated waters from normal power plant operations over the unheated waters in Port Everglades back-up heaters during the shutdown period (this could also be accounted for due to individual life histories and behavioral theory); and (3) If current study counts show a decline in number of manatees present in the discharge canal during times of cold weather and/or when back-up heaters are turned on, as compared with previous study counts, then it can be assumed that manatees are using other warm water refugia instead of the PE discharge canal (such as the FL power plant).

This study contributes to the broader body of knowledge related to conservation biology by providing information on whether the efforts made during times of warm water loss (through a power plant closure) are effective at providing ample warm water refugia to manatees or whether further actions are needed to be taken under advisement for planning future power plant shutdowns. These data will be of interest to the scientific community for three reasons: (1) There have been studies on the usage of warm water refugia by manatees but there have been few studies done on what actually happens during extended shutdown periods that cause a loss of warm water for more than a few days (Packard *et al*. 1989; Deutsch *et al.* 1999; Laist and Reynolds 2005); (2) We are entering times where the energy needs of producers and consumers are changing and there is a shift to “green”, more efficient methods of energy production; and (3) With changing energy needs comes changing methods of production where it is believed that one day, due to either decommisions or upgrades to cleaner energy plants, that warm water refugia associated with power plants (i.e. the man-made refugia) will cease to exist and manatees will have to rely on limited natural refugia such as warm water springs of Florida or other PTR (Laist and Reynolds 2005b). Manatees are not expected to return to their old habits prior to the opening of power plants in the 1950s. In fact, manatees in

today's world leave their familiar home ranges and travel corridors and, if they did at some point decide to travel to southern Florida waters during winter, the areas they congregate in could not support their large numbers due to limited alternative warm water habitats, food availability, and thermoregulation space (Laist and Reynolds 2005b). These limitations can affect the health, nutrition, and reproduction capabilities of manatees (Glaser and Reynolds 2003). It is the aim of this study to provide scientific information to federal, state, regional, and local managers and officials on actions that are recommended during times of extended power plant shutdowns, as well as in preparation of said closures, that will help conserve the Florida manatee for the long-term. This could include recommendations on establishing non-industry dependent warm water refugia that would discharge warm water in areas specifically designed for manatees to access or establishing new thermal basins and PTR by studying existing thermal strategies (Laist and Reynolds 2005b).

CHAPTER II

METHODS

Study Area

Port Everglades is the site for the FPL Next Generation Clean Energy Center (formerly known as the FPL Port Everglades power plant) discharge canal that extends from the Center's cooling discharge channel to the busy ICW of Port Everglades (Florida Power and Light 2013). The discharge canal is used by transient and resident Florida manatees primarily during the months of November through March as a warm water refuge as they travel from the north during colder weather that lowers water temperatures below 19 degrees Celsius (Broward County Port Everglades Department 2013b). The water is warmed 5 to 8 degrees Celsius higher than the intake water from the ICW and the discharge canal serves as a federal, state and county protected manatee nursery and sanctuary that is regulated with idle-speed and no entry zones, as well as enforced by the U.S. Coast Guard and the Florida Fish and Wildlife Conservation Commission (FWC) Law Enforcement Division. Five fixed land-based survey points were chosen within the discharge canal study area (Figure 1). They include the northeast (NE) stretch of canal extending from the end of FPL property towards Eller Bridge, the Eller Bridge (EB) area

(which included a small Port Authority boat slip used by manatees), the FWC boat dock (BD) stretch of canal, a small, enclosed lagoon area (ML), and a final stretch of canal extending from the lagoon area to the Broward County Sherriff's Department bridge (BC), which also marked the beginning of the state and county regulated Manatee Sanctuary. The stretch of canal along the north side of the sanctuary leading from the BC to the ICW was not surveyed due to inaccessibility by land. The designated "meeting" location for each survey day was chosen to be the BD.

Figure 1. Map of the study area, Port Everglades power plant, and survey sites in Fort Lauderdale, Florida. From north to south, NE=Northeast, EB=Eller Bridge, BD=FWC Boat Dock, ML=Manatee Lagoon, BC=Broward County Sherriff's Department Bridge, and ICW=Intracoastal Waterway while Manatee Sanctuary is a state regulated no-entry sanctuary and nursery for Florida manatees.

Sampling Design

This study was conducted during the annual Broward County manatee season that began on November 15, 2013, and ended on March 31, 2014. Point-based and walking surveys were conducted at and between the five fixed locations (on land) along the west and south sides of the discharge canal in the Port Everglades power plant study area. Surveys were conducted three times per week (on the same days each week) throughout the survey season, beginning at 0900 each day. Use of five fixed land-based survey points (point-based surveys) modified from previous studies conducted on manatees in Belize, were carried out to monitor manatee occurrence by counting the number of individuals sighted during a 20-minute period at each fixed survey point (LaCommare *et al.* 2012). The five permanent, fixed survey points were located using a global positioning system (GPS) device. Polarized sunglasses were used on every survey to reduce glare and improve observer's ability to see through the water's surface. Binoculars were also used to assist with the survey in order to sight manatees at a distance from the scan point. Photographic equipment was used on every survey to document sightings and to contribute to federal, state and local photo-identification databases, such as the USGS Sirenia Project MIPS database. Photographic equipment included a Canon EOS Rebel T3 digital camera body with 35-55mm and 75-300mm zoom lenses equipped with either an ultraviolet (UV), polarized, and/or diffusion filter and various models of megapixel cell phone cameras.

An observer scanned for manatees in a 180 degree semi-circle from the fixed survey point (90 degrees to their left and 90 degrees to their right). A manatee was counted as sighted if the tail, back, nose or entire body was observed. Upon conclusion of each 20-minute fixed-point based survey, the observer conducted a walking survey on their way to a designated "meeting" fixed survey point (Goldman 2010), in this case, the FWC Boat Dock. Observers monitored the waters along their walking route for manatees and, if a sighting occured, the observer stopped their walk and conducted an alternate point scan survey for any other manatees in that area. All sighting information and GPS coordinates for any alternate point scan surveys were recorded. Upon conclusion of the alternate point survey, the observer continued their walk to the "meeting" point. Sighting

criteria were the same as the fixed-point based surveys and included polarized glasses, binoculars, GPS devices, and photographic equipment.

Environmental Data

Field survey data were collected on a survey data sheet (Appendix A) and included the following information: survey date, survey day, survey time and hours, observers, GPS coordinates of point scan surveys (fixed and alternate points), time of sighting (initial and final), location code, number of adults, juvenilles and calves sighted, presence or absence, manatee activity/behavior, water temperature, air temperature, salinity, tidal state, weather conditions, and any other information deemed pertinent by the observer or the project graduate student. Sea surface temperatures were obtained using a Raytek Raynger ST temperature meter. The device, a portable, handheld, infrared (IR) thermometer, recorded water temperature from a distance of several meters away without disturbance to the water's surface. Salinity was obtained using a refractometer in the field. A water sample was collected at each survey point and a few drops were placed on the glass stage of the refractometer. The cover plate was then placed over the stage and the observer looked through the eyepiece (towards the light of the sun, without tilting the instrument) and used the associated salinity scale within the instrument to obtain the designated salinity. Tidal data were obtained from the National Oceanic and Atmospheric Administration's (NOAA) Intracoastal Waterway South Port Everglades tidal monitoring station and air temperature, wind speed and atmospheric pressure were obtained from the NOAA National Data Buoy Center monitoring station in Port Everglades (Figure 2). GPS coordinates were obtained from GPS devices carried by observers. Water temperatures for the PE cooling water intake and discharge regions of the study area were collected from on-going FPL monitoring and recording stations. Telemetry data were collected from the Sea to Shore Alliance and GPS coordinates were incorporated into the ArcGIS system for final map construction and analysis. Prior data from previous Nova Southeastern University (NSU) student surveys were used to determine trends in manatee sightings and distribution before and after shutdown scenarios.

Figure 2. Map of NOAA tidal and atmospheric monitoring stations in relation to the study area.

Remote Sensing

Five manatees were radio tagged with satellite transmitters in February 2013. All five tags either broke free or stopped transmitting within a few weeks of tagging. Two manatees were tagged in January 2014 as replacements, pursuant to a contractual agreement between the Sea to Shore Alliance and FPL. All collected telemetry data were used to determine if, and how often, the tagged manatees were using the discharge canal during the survey season. Manatees were either free tagged in-situ by an experienced swimmer or during a boat-based capture. Free-tagging involved a trained observer entering the water and snorkeling towards a target manatee using standard snorkel equipment and a spotter stationed on land, who provided direction and distance for the in-water observer (Marmontel *et al*. 2012, Chapter 13). Once the in-water observer was

within 1-2 meters of a manatee, they positioned themselves behind the manatee and attempted to place a tag on the manatee by attaching an adjustable belt around its peduncle. Boat-based tagging involved participants stationed on a specially designed net boat large enough for a nylon capture net to be cast out in the water around a sighted manatee (Weigle *et al.* 2001; Bonde *et al*. 2012). The boat was then driven around the manatee in order to encircle the target manatee within the capture net area. The net was equipped with weights on the bottom and floats on the top to cover the depth of the water column in order to prevent the manatee from escaping. The capture team then hauled the net and manatee onto the boat, drove the boat to the boat dock area and physically attached the radio tag assembly to the manatee (Deutsch et al. 2003). After a detailed manatee health assessment following guidelines outlined in Stamper and Bonde (2012) the manatee was then released back into the water near the capture location. For purposes of this thesis study, all free tagging and boat-based tagging events were conducted by Sea to Shore Alliance volunteers and employees under USFWS wildlife research permit (MA37808A). Free tagging and boat-based tagging were used for the initial five tagged manatees. For the additional two manatees tagged in January 2014, only boat-based tagging was used.

Both forms of monitoring involved the same underlying tagging technique for physically attaching a transmitter to the manatee. Attachment occured around the peduncle of the manatee (due to its fusiform body shape) using a standard peduncle belt (Deutsch *et al*. 1998; Lander *et al*. 2001; Reep and Bonde 2006; Marmonel *et al*. 2012). The peduncle belt consisted of various length and ply thickness neoprene belting inside latex tubing. Ply thickness and belt length varied in order to allow a tagged manatee to break free if entanglement occured. Corrodable nuts and bolts allowed for the belts to release over time. Once the belt was brought over the tail of a manatee, it was cinched and fitted snugly around the peduncle. Attached to the belt was a four to six foot flexible plastic nylon rod called a tether. Connected to the end of the tether was a floating housing assembly that contained a radio and satellite transmitter with an associated antenna for transmission. When a manatee was close enough to the surface, the float assembly broke the water's surface and transmitted GPS and abiotic data to polar orbiting Argos satellites. The data were then transmitted back to Earth where it was accessed through

Sea to Shore Alliance computers for downloading and analysis. Connections within the belt assembly and between the tether and belt had weak links associated with them in order to allow for the manatee to break free should the unit become entangled.

Photo-Identification, Body Condition and Mortality

Photgraphs were taken of as many sighted manatees as possible at every available angle. Photographs were analyzed and edited in the lab using Adobe Photoshop Premier Elements 2013 (2013). Photographs for each manatee were grouped together and a "Manatee Identification Sheet" was completed for each individually identifiable manatee, which was assigned a unique identification code consisting of the study site location, date and numbered individual from that site (for example, BD-012414-1 identified a manatee seen in the BD study site on 14 Jan 2014 and the first manatee identified in that location on that day; see Appendix A). All scars and cold stress lesions were drawn on a manatee outline and a code was assigned to each manatee for cold stress and scars. For cold stress, the body condition codes were as follows: (1) Excellent with no lesions, (2) Good with few lesions and (3) Poor with many lesions. For scars, the body condition codes were as follows: (1) Less than two scars on the entire body, (2) Three to five scars on the entire body or at least 25% of the tail missing and (3) More than 5 scars on the entire body or the majority of the tail missing. Mortality data for Cold Stress Syndrome and Watercraft Collision deaths in Broward County and the entire state of Florida were obtained from the Florida FWC Manatee Mortality Statistics website (2014).

Data Analysis

To address Objective 1 (determine changes in Florida manatee habitat use and distribution patterns in the Port Everglades region of Broward County during a warm water refuge disruption (closure of a power plant) through the use of count surveys), I used the presence/absence of manatees in each survey area as the dependent variable and water temperature, air temperature, tidal state, wind speed, atmospheric pressure and salinity as independent variables. The untransformed data (due to non-normality) were analyzed using logistic regression to determine the relatedness of sighting one or more manatees on any given day during the study season based on the independent variables

(Dytham 2003; Zar 1999). This form of regression analysis allowed for the accommodation of both categorical and continuous predictor variables (Floyd 2001; Trexler and Travis 1993). A backwards, stepwise substitution was used to determine the most parsimonious model. The likelihood ratio test and Wald statistic were used to determine the significance of parameters in their ability to explain variation in dependent variables. The Hosemer and Lemeshaw test was used to compare observed and expected probabilities in order to determine if the model was a significant fit to the data (Trexler and Travis, 1993).

To address Objective 2 (determine short-term behavioral responses to a warm water refuge disruption (closure of a power plant) through the use of satellite telemetry and comparisons of count data and method results between two southeast Florida power plant sites, one operational (FL) and one non-operational (PE), I used land-based count data from this study and aerial count data obtained from Dr. Pat Quinn, of the Broward County Manatee Monitoring Program, to determine differences between counts within the Port Everglades study area and compared to aerial counts in the inland Fort Lauderdale power plant cooling lakes using the Mann-Whitney U-test for both analyses (Zar 1999). Satellite location data was used to map locations for two tagged manatees in order to support the results.

To address Objective 3 (determine trends in Florida manatee counts using data from previous studies conducted in Port Everglades compared to data collected during this study), I used manatee counts from the current study and compared these values to previous survey counts in the study area in a Chi-square analysis (in which observed values were the current counts and expected values were the mean survey counts from previous studies between 1999 and 2011) in order to test for differences in the observed and expected counts (Dytham 2003; Zar 1999). The Chi-square analysis tested if there were differences between pre- and post-shutdown counts. All statistical analyses were conducted using JMP 11.0 (JMP 2014).

CHAPTER III

RESULTS

Objective 1: Florida manatee habitat use and distribution patterns in Port Everglades

Over a fifty-two field day period during the 2013-2014 winter season, 268 twenty-minute scan surveys were completed among five fixed survey points (52 surveys at each fixed point) and four surveys at alternate locations. There was a total of 147 manatees sighted during the season with the highest number of sightings occurring in January 2014 (Table 1). Of the total manatees sighted, 75.51% were adults, 8.84% were juveniles, and 15.65% were calves (Figure 3). Table 2 shows the number of manatees sighted in each age class for each month of the season. All sites within the study area exhibited the highest number of manatees in the month of January, with the ML site having the highest number of manatees (Figure 4).

Table 1. Total and monthly number of manatees counted in the 2013-2014 winter season.

Month	Counts
November	0
December	5
January	117
February	15
March	10
TOTAL	147

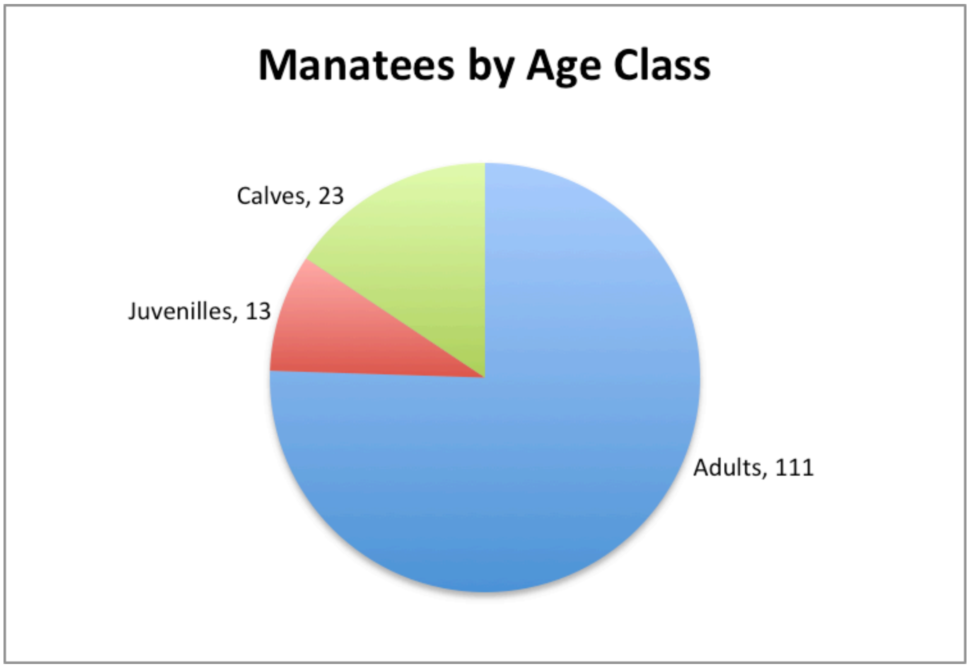

Figure 3. Total number of manatees counted by age class in the 2013-2014 winter season.

Table 2.Total monthly number of manatees counted by age class in the 2013-2014 winter season.

Month	Adults	Juveniles	Calves
November	0	0	0
December	5	0	0
January	88	12	17
February	10	1	4
March	8	0	2
Total	111	13	23

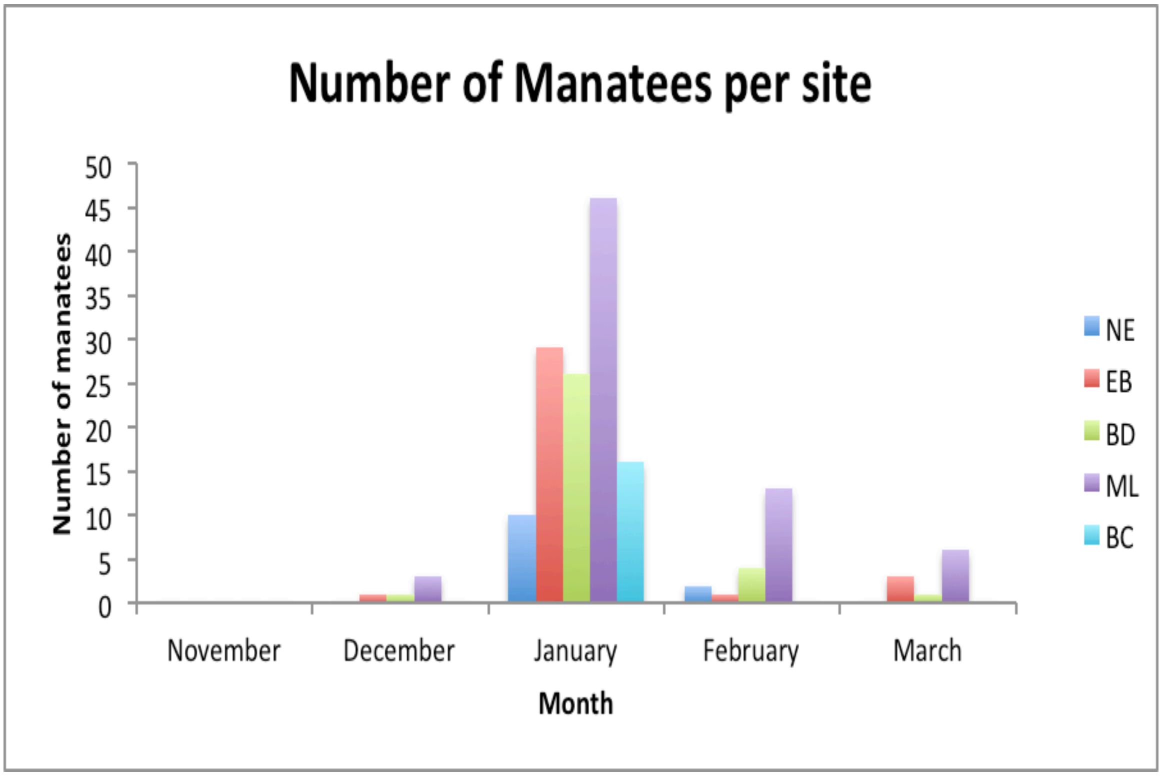

Figure 4. Total number of manatees counted at each survey site per month during the 2013-2014 winter season. Survey sites are as follows: NE=Northeast, EB=Eller Bridge, BD=FWC Boat Dock, ML=Manatee Lagoon and BC=Broward County Sherriff's Department Bridge.

Surface water temperatures were measured at seven sites (five fixed survey points and two points within the FPL owned PE discharge canal). Average site temperature differences for the entire season ranged from 0.1 to 2.9 degrees Celsius (Figure 5) with the lowest temperature average of 20.9 degrees Celsius at BD. Looking at average water temperatures by month, each site experienced the lowest surface water temperature in the month of January, with BD experiencing the lowest temperature average of 19.2 degrees Celsius (Figures 6 through 12).

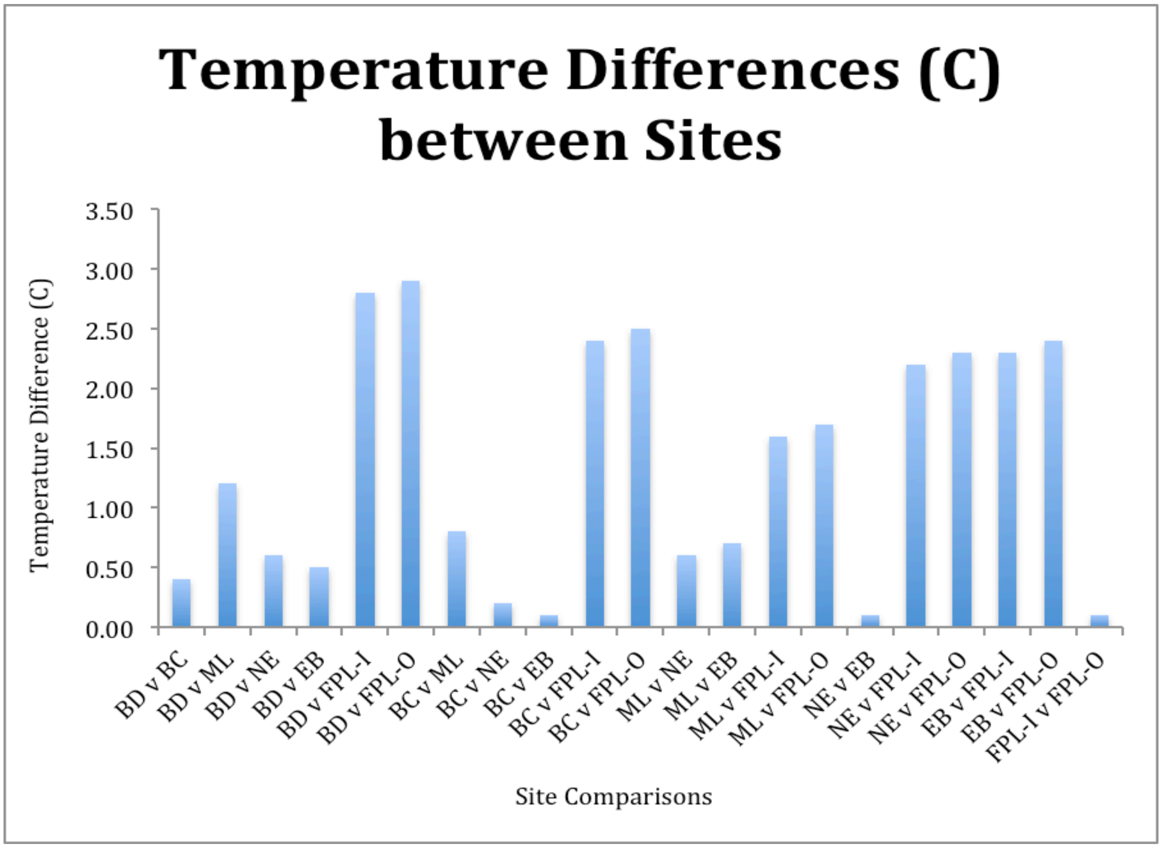

Figure 5. Average temperature differences (C) between survey sites during the 2013-2014 winter season. Survey sites are as follows: NE=Northeast, EB=Eller Bridge, BD=FWC Boat Dock, ML=Manatee Lagoon and BC=Broward County Sherriff's Department Bridge.

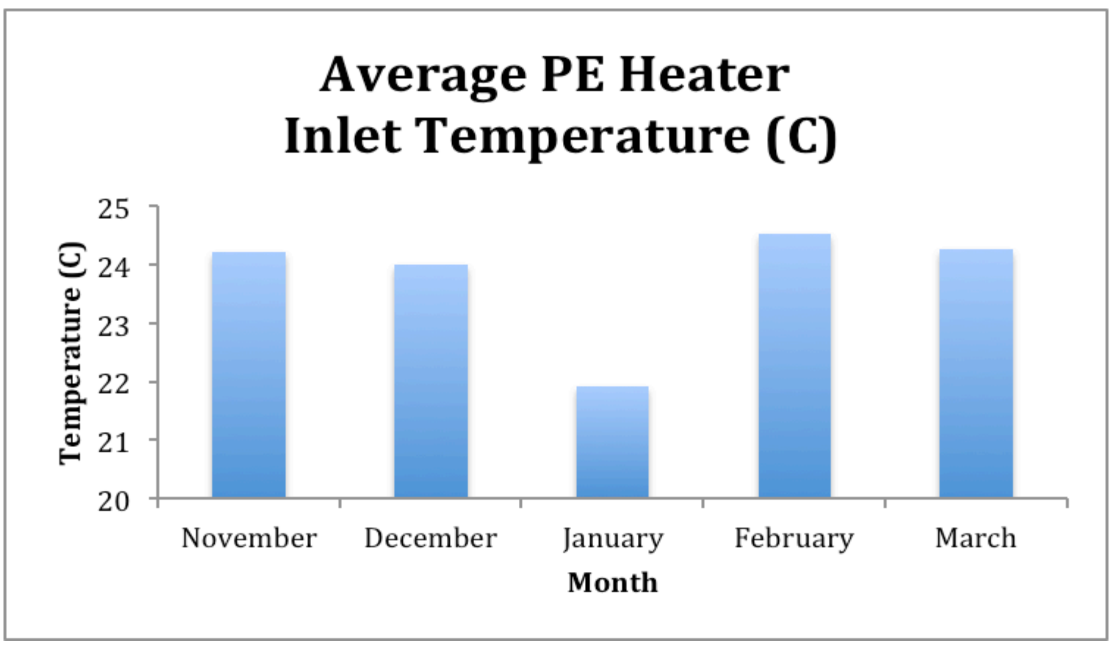

Figure 6. Average monthly temperatures (C) for the FPL heater inlet site.

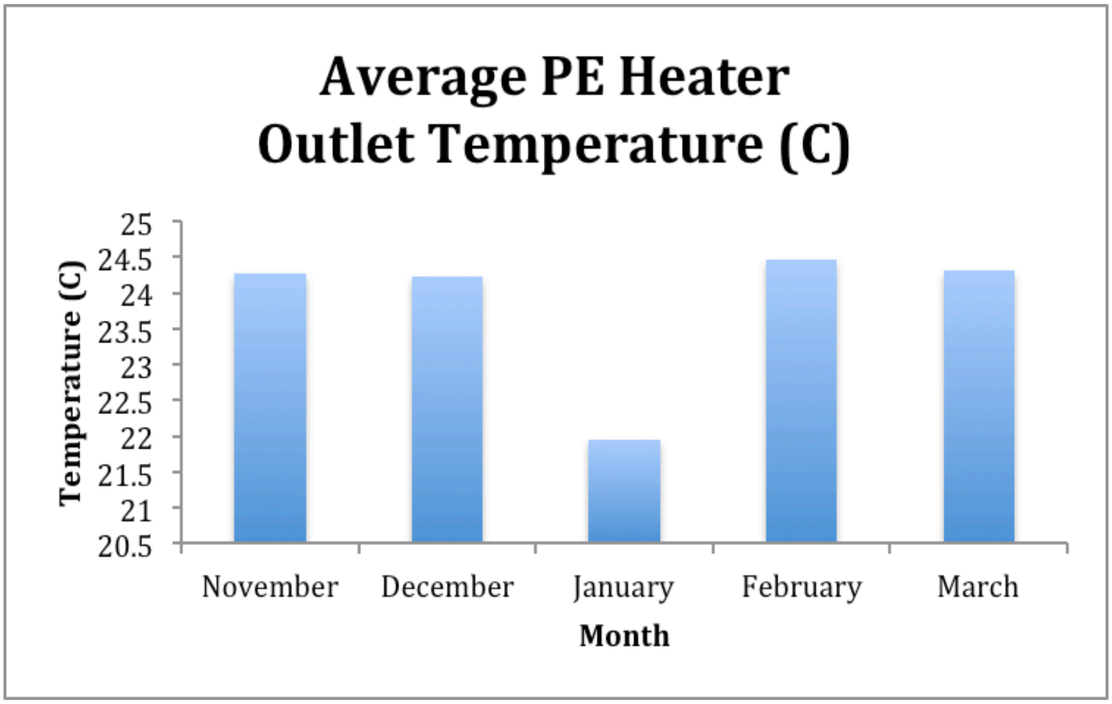

Figure 7. Average monthly temperatures (C) for the FPL heater outlet site.

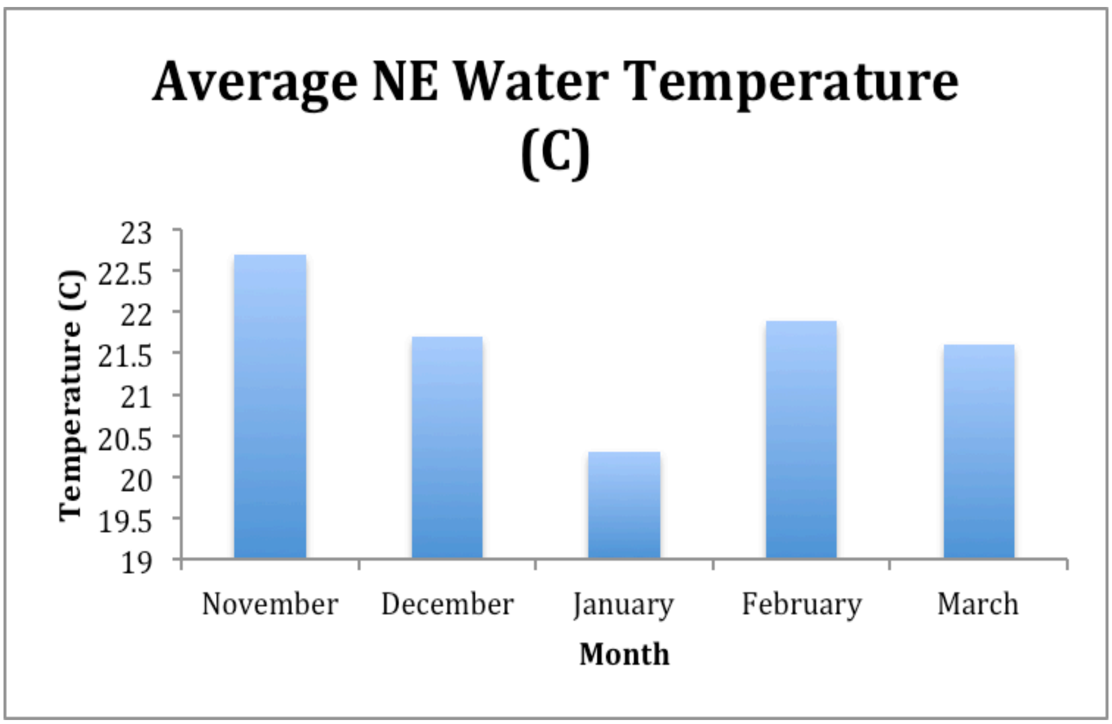

Figure 8. Average monthly temperatures (C) for the Northeast (NE) survey site.

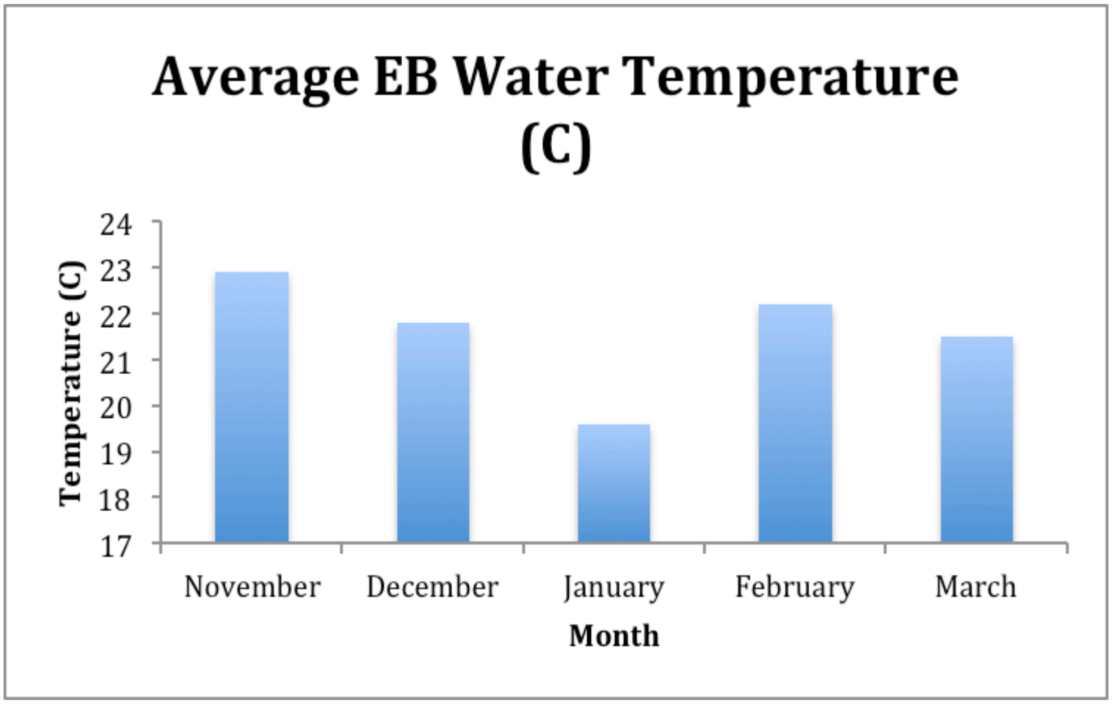

Figure 9. Average monthly temperatures (C) for the Eller Bridge (EB) survey site.

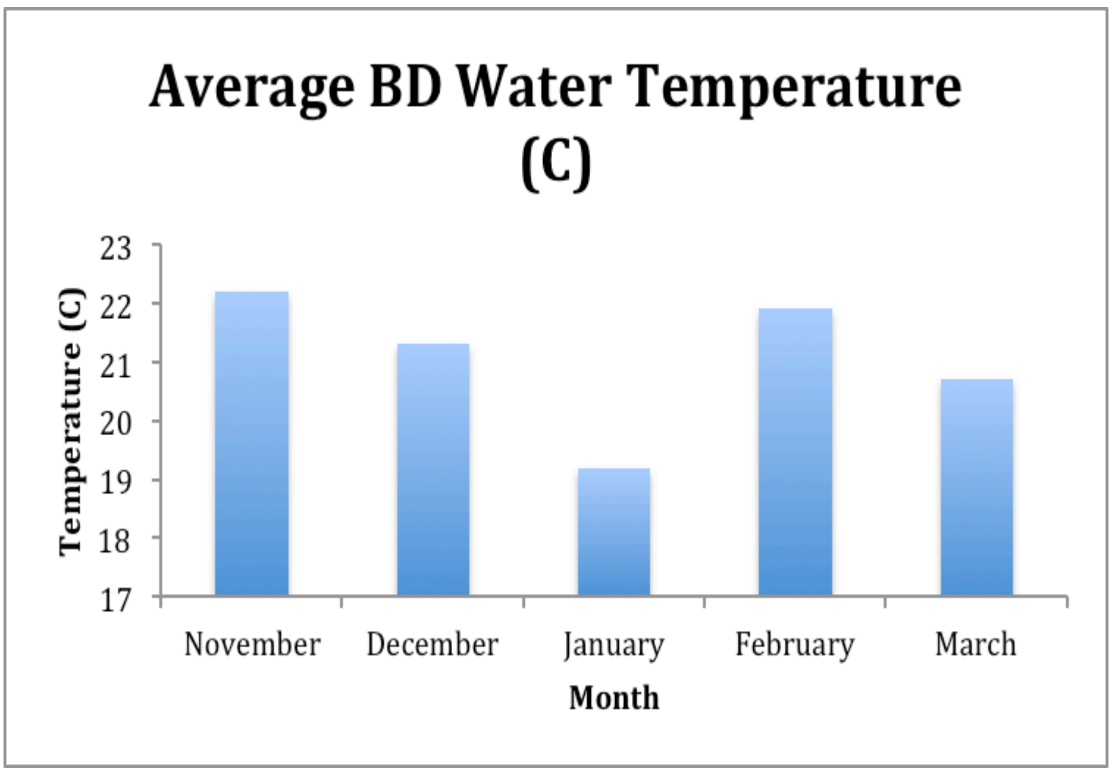

Figure 10. Average monthly temperatures (C) for the FWC Boat Dock (BD) survey site.

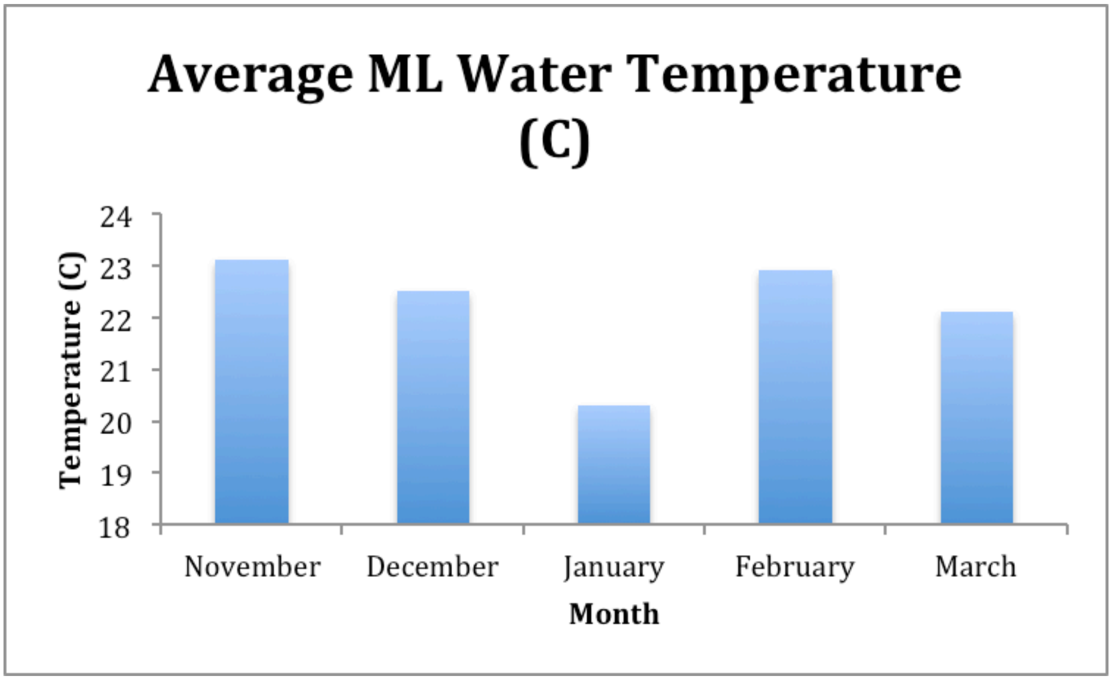

Figure 11. Average monthly temperatures (C) for the Manatee Lagoon (ML) survey site.

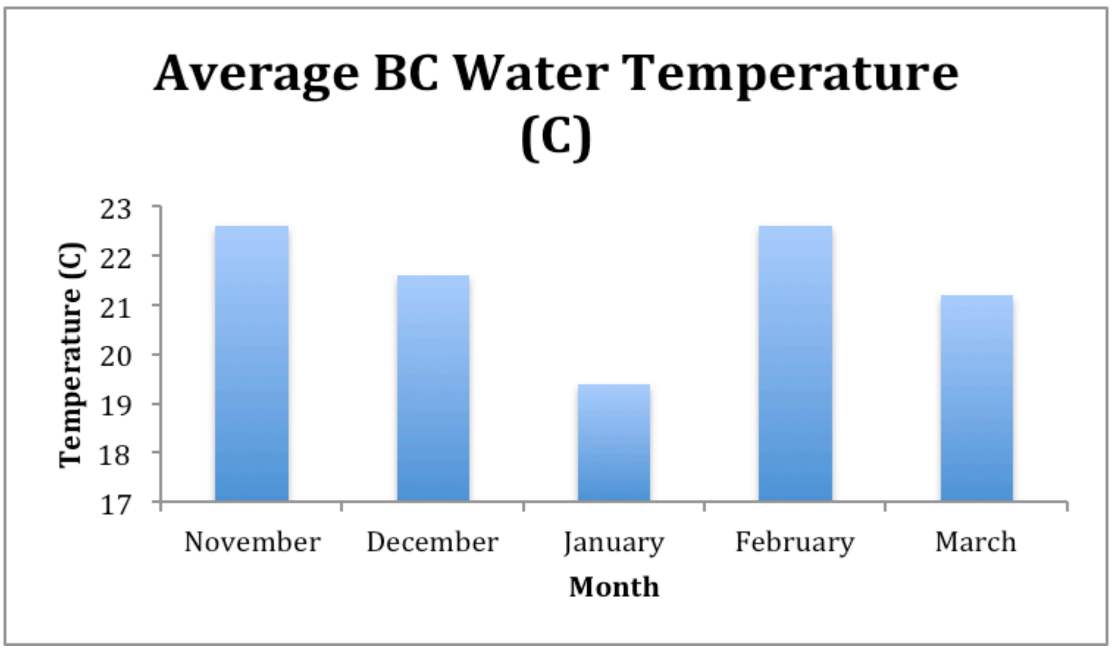

Figure 12. Average monthly temperatures (C) for the Broward County Sherriff's Department Bridge (BC) survey site.

Salinity was also measured, however, only at the five fixed survey points due to limited area access. Average site salinity differences for the season ranged from zero to one parts per thousand (ppt) (Figure 13), with the lowest salinity average of 30 ppt at ML and NE. Looking at average salinity by month, each site experienced the lowest average

in November and an increase month-by-month through the remainder of the season (Figures 14 through 18). NE experienced the lowest salinity average of 22 ppt in November.

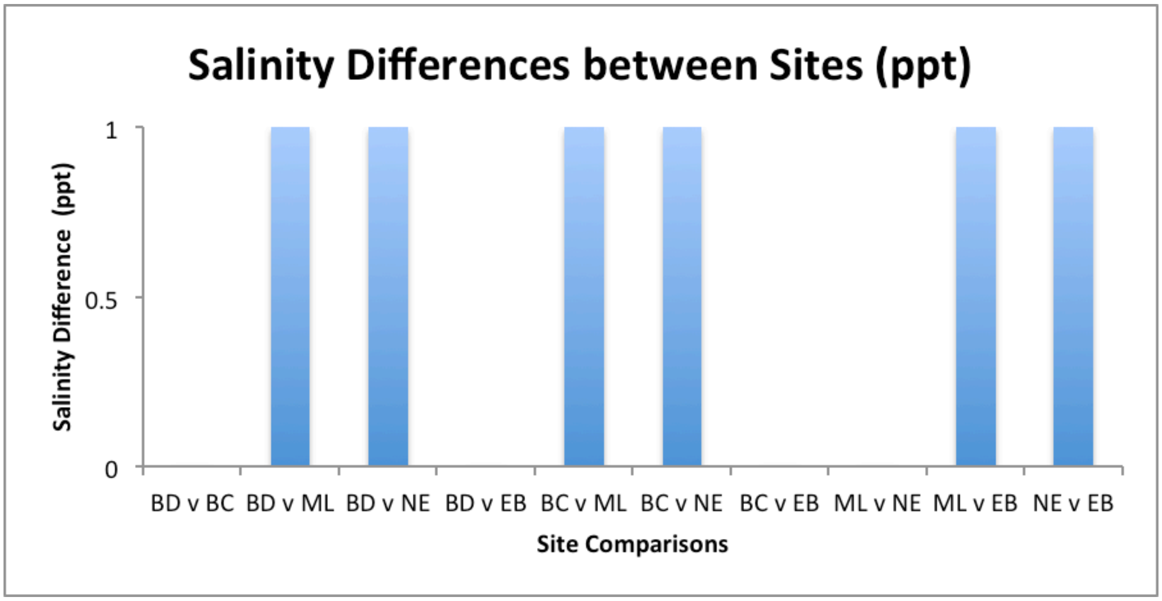

Figure 13. Average salinity differences (ppt) between survey sites during the 2013-2014 winter season. Survey sites are as follows: NE=Northeast, EB=Eller Bridge, BD=FWC Boat Dock, ML=Manatee Lagoon and BC=Broward County Sherriff's Department Bridge.

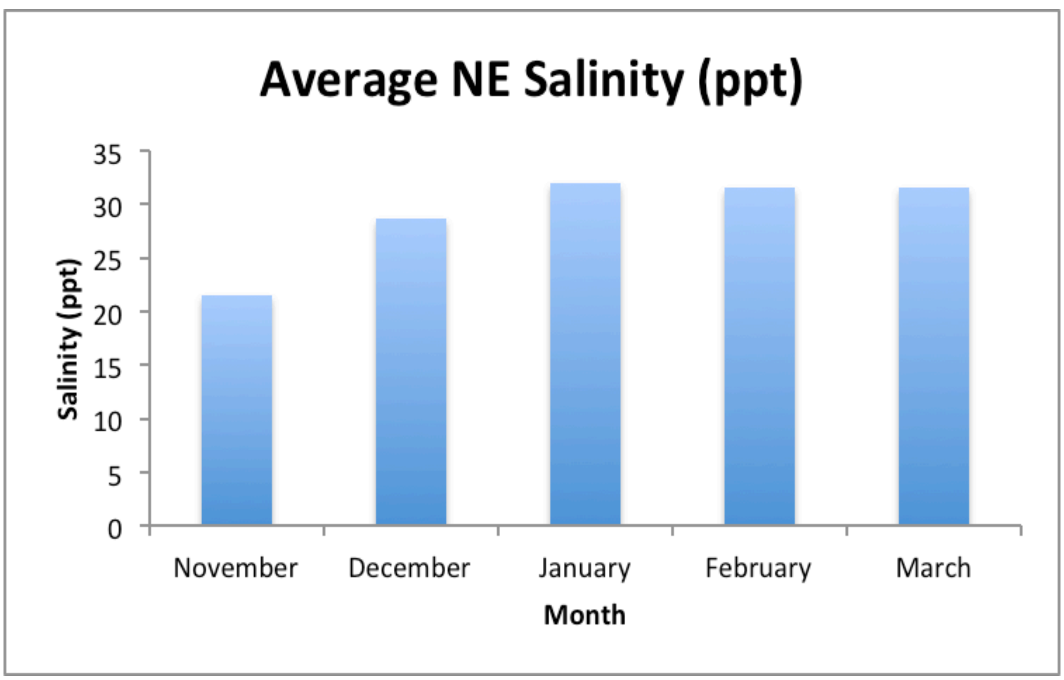

Figure 14. Average monthly salinities (ppt) for the Northeast (NE) survey site.

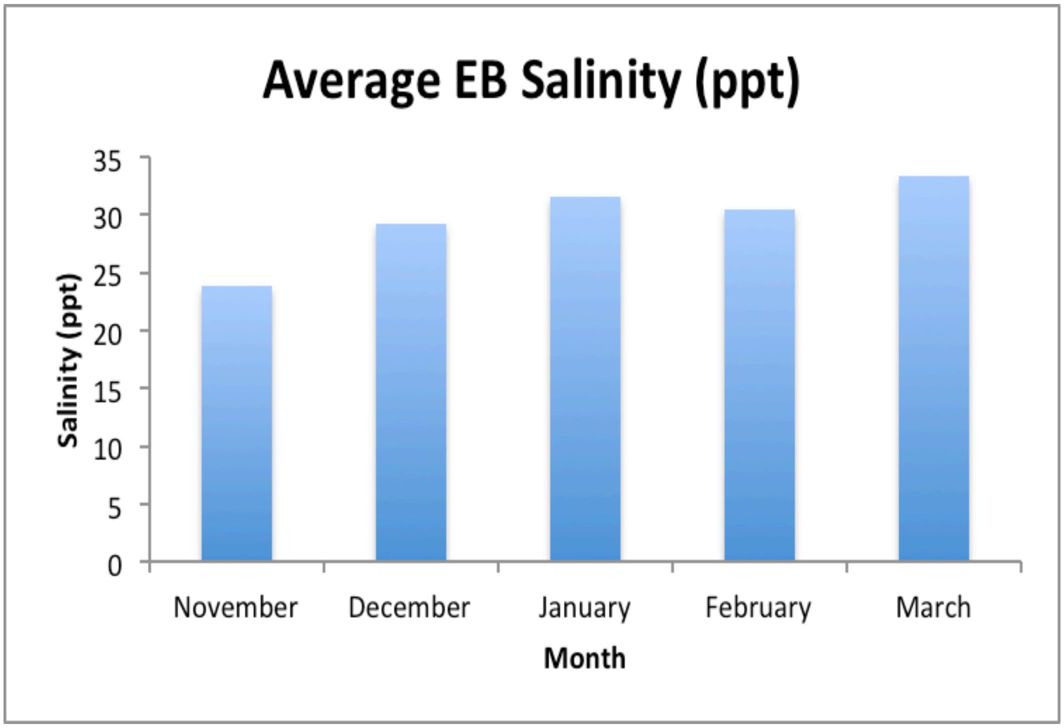

Figure 15. Average monthly salinities (ppt) for the Eller Bridge (EB) survey site.

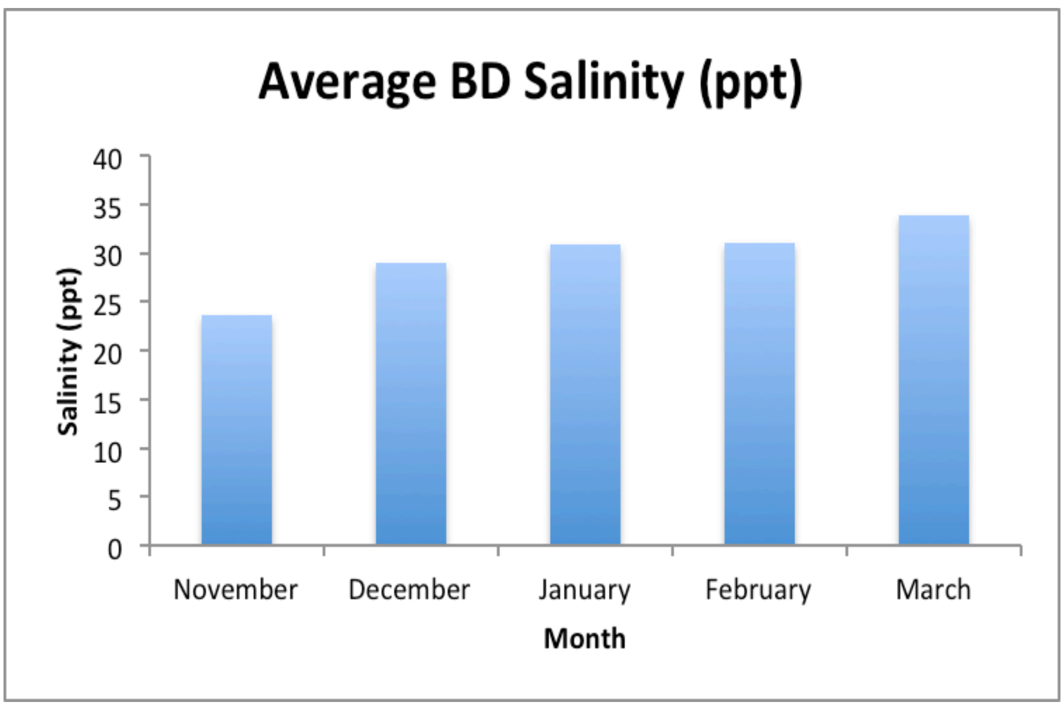

Figure 16. Average monthly salinities (ppt) for the FWC Boat Dock (BD) survey site.

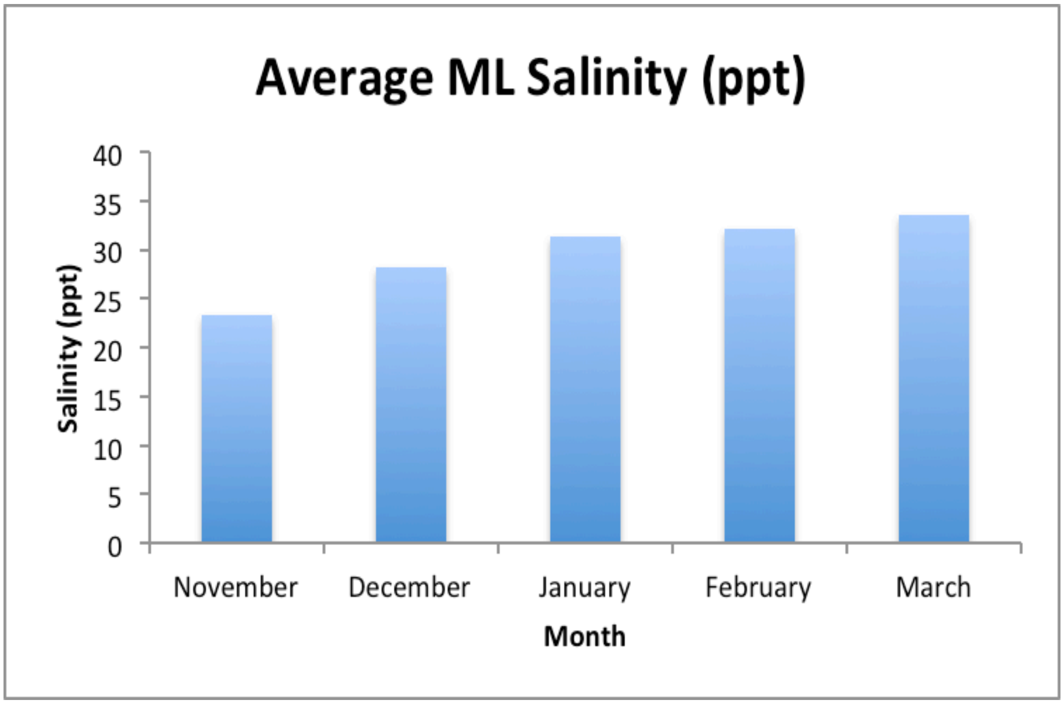

Figure 17. Average monthly salinities (ppt) for the Manatee Lagoon (ML) survey site.

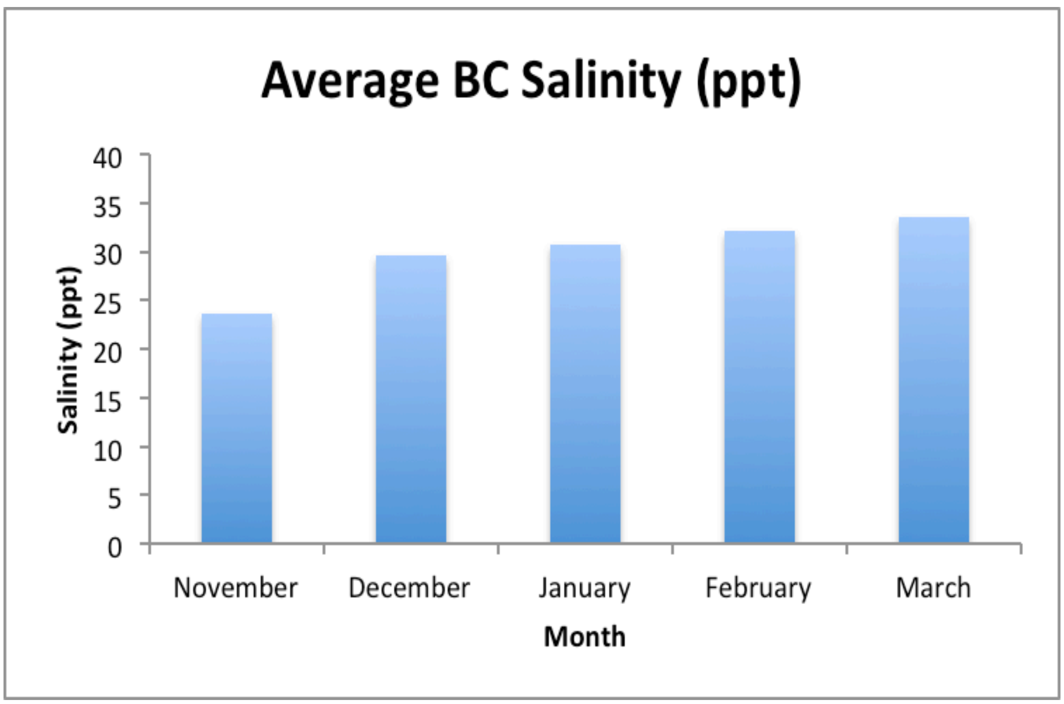

Figure 18. Average monthly salinities (ppt) for the Broward County Sherriff's Department (BC) survey site.

Air temperature, wind speed, atmospheric pressure, and tidal height were measured at two NOAA measuring stations within Port Everglades (see Figure 2). Average air temperatures ranged from 19.97 to 24.26 degrees Celsius with the lowest

temperature average in January (Figure 19). Average wind speed ranged from 3.84 to 4.64 meters per second with the highest wind speeds detected in November (Figure 20). Average atmospheric pressure oscillated above and below 30.00 inHg with the lowest pressure recorded in March (Figure 21). Average tidal height ranged from 0.4 to 0.7 meters above sea level with February showing the lowest average height of 0.4 meters above sea level (Figure 22).

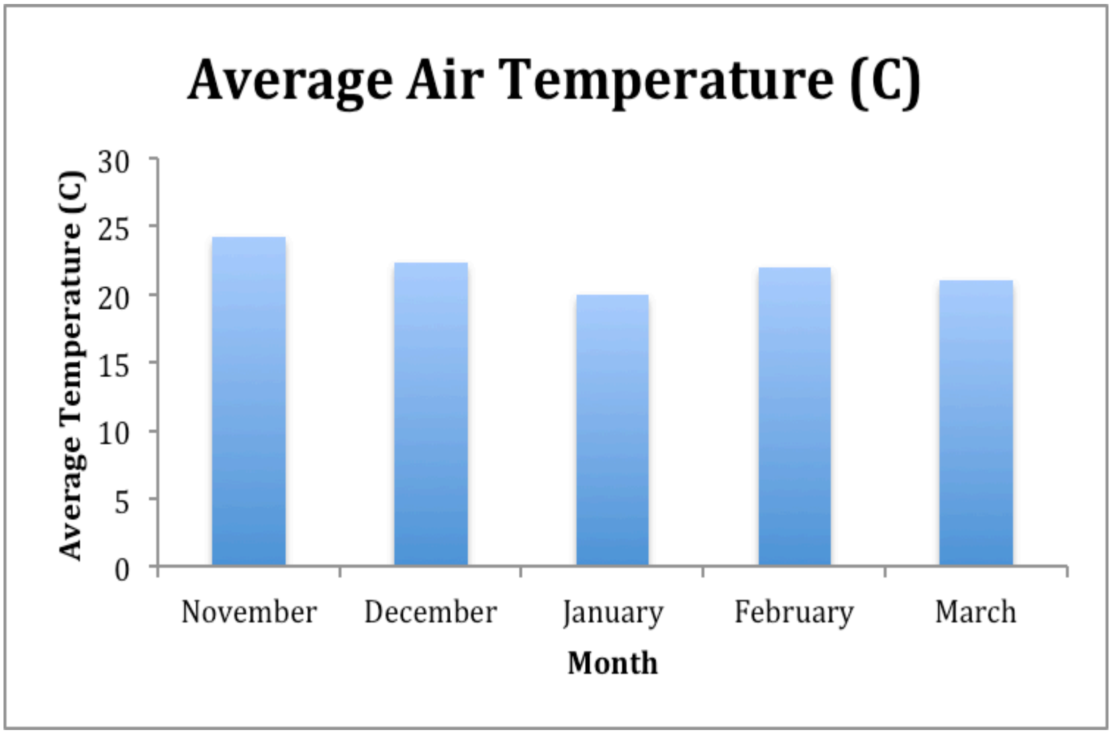

Figure 19. Average monthly air temperatures (C) for Port Everglades study area during the 2013-2014 winter season

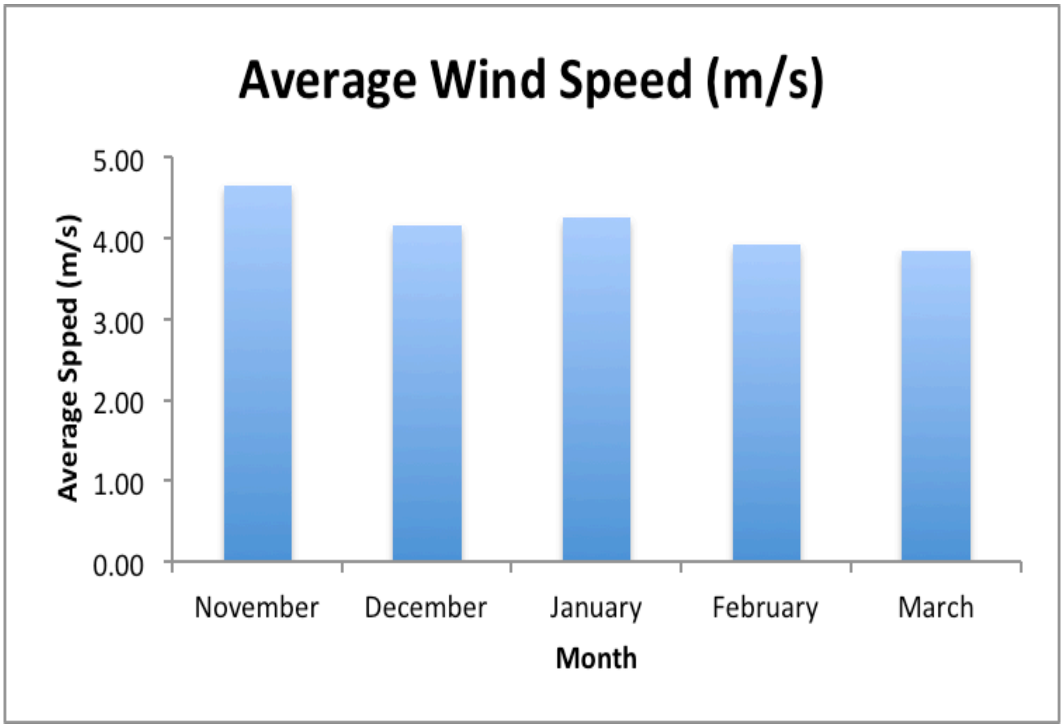

Figure 20. Average monthly wind speeds (m/s) for Port Everglades study area during the 2013-2014 winter season.

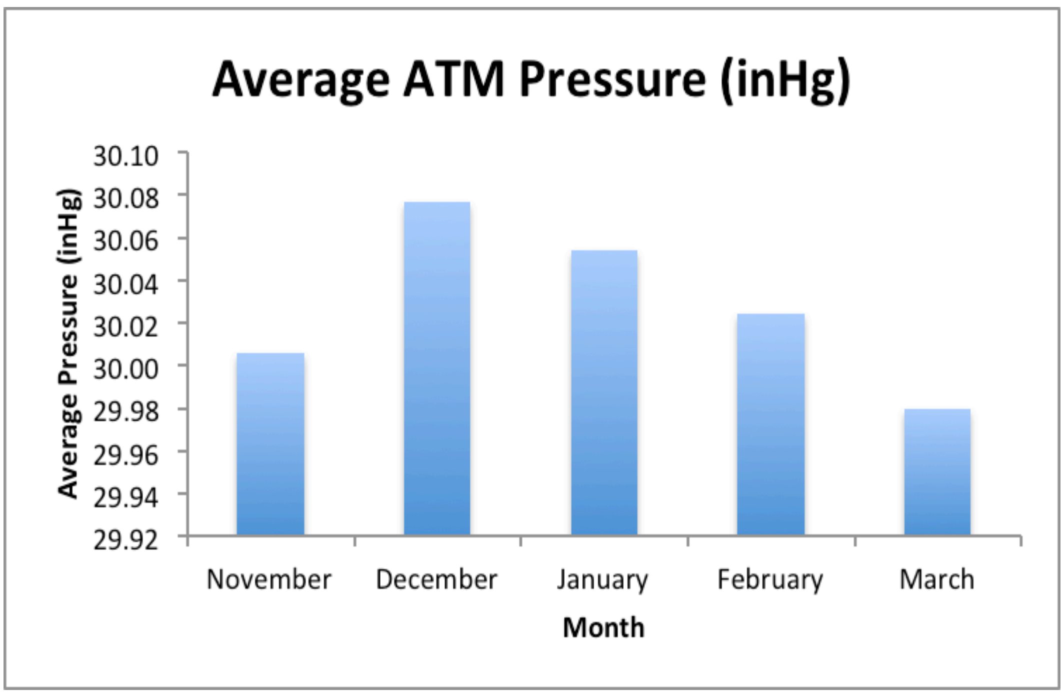

Figure 21. Average monthly atmospheric pressures (inHg) for Port Everglades study area during the 2013-2014 winter season.

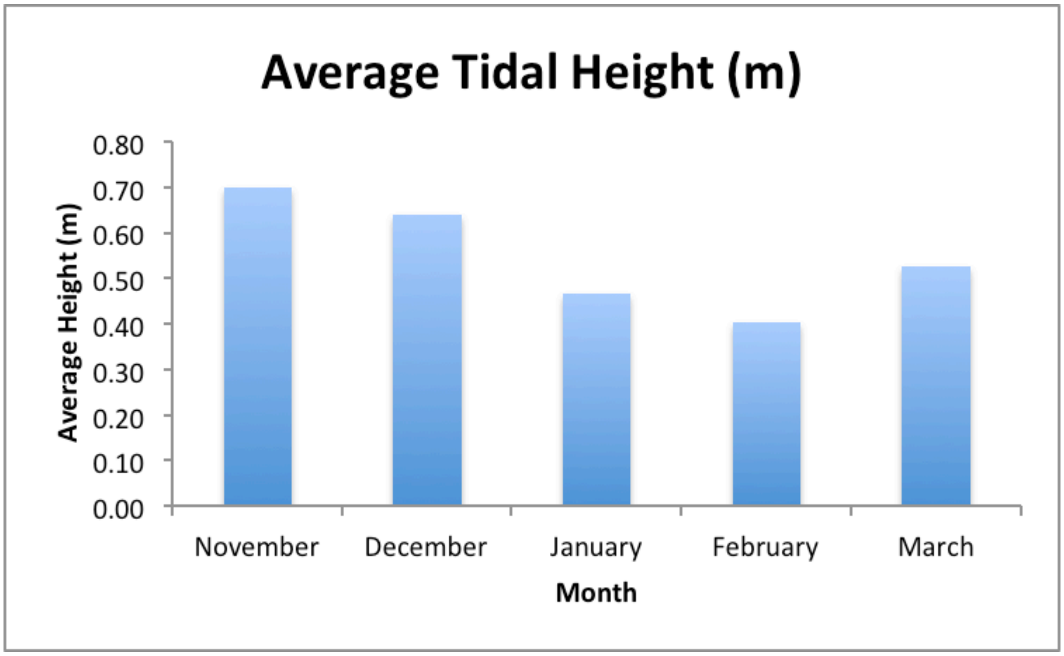

Figure 22. Average monthly tidal heights (m) for Port Everglades study area during the 2013-2014 winter season.

Sixteen individual manatees were identified from photo-identification of 1,811 photographs taken. Fourteen individuals were coded as Cold Stress Body Condition Code 1 (Figure 23) with only two coded for few cold stress lesions. Nine individuals were coded as Scar Body Condition Code 1 and 5 as Scar Body Condition Code 3 (Figure 24). Mortality data from the Florida Fish and Wildlife Commission (2014) only reported one mortality in Broward County due to Cold Stress (Figure 25) and two from Watercraft (Figure 26). Figures 25 and 26 also present the manatee mortalities for all other counties in the state of Florida for Cold Stress and Watercraft, respectively, with the highest number of Cold Stress mortalities occurring in January (Figure 25) and the highest number of Watercraft mortalities in November (Figure 26).

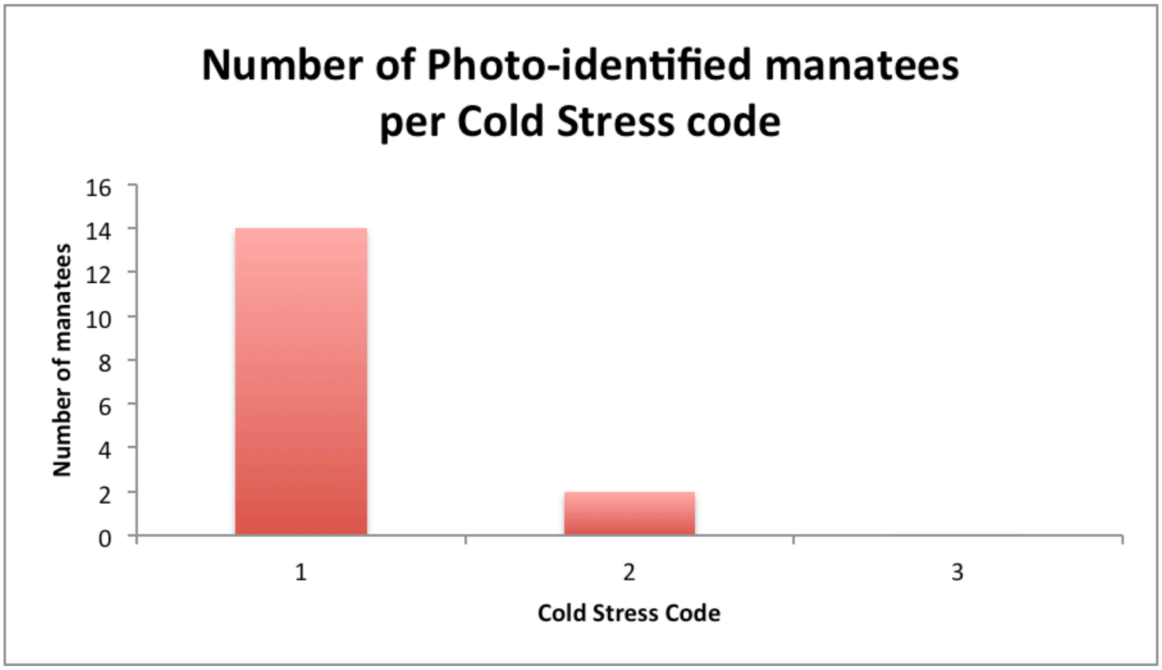

Figure 23. Total number of photo-identified manatees per Cold Stress code in Port Everglades during the 2013-2014 winter season. Cold Stress codes are as follows: 1=Excellent with no lesions, 2=Good with few lesions and 3=Poor with many lesions.

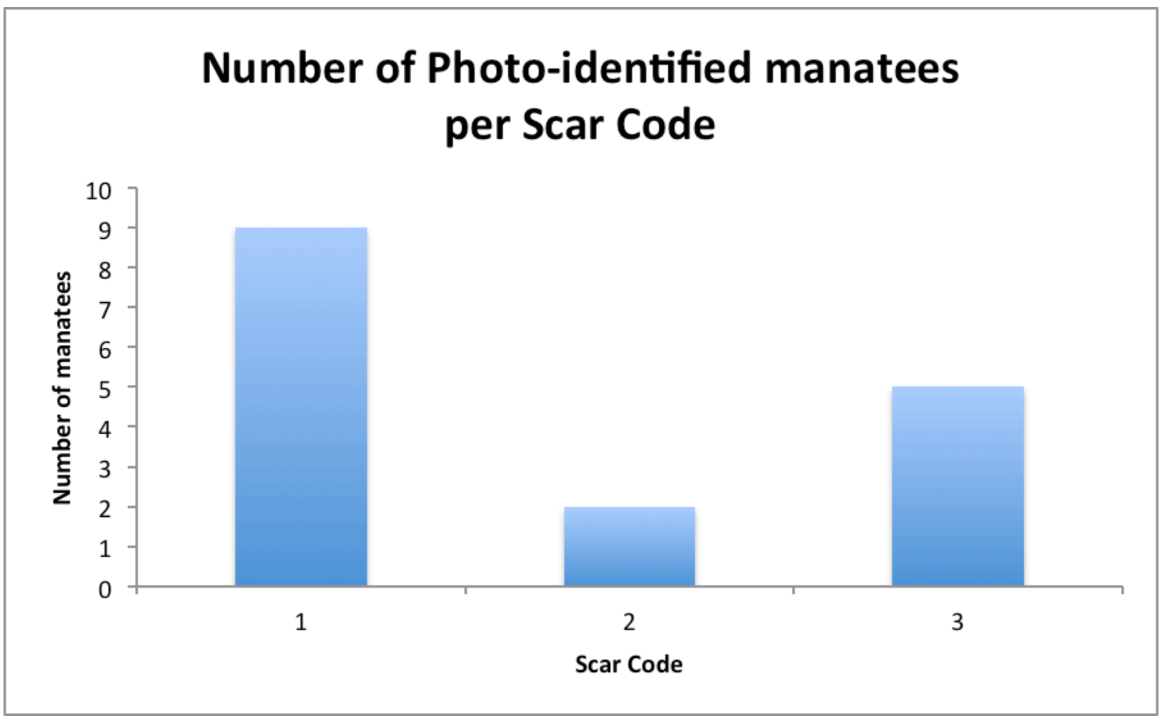

Figure 24. Total number of photo-identified manatees per Scar Code in Port Everglades during the 2013-2014 winter season. Scar Codes are as follows: 1=Less than two scars on the entire body, 2=Three to five scars on the entire body or at least 25% of the tail missing and 3=More than five scars on the entire body or the majority of the tail missing.

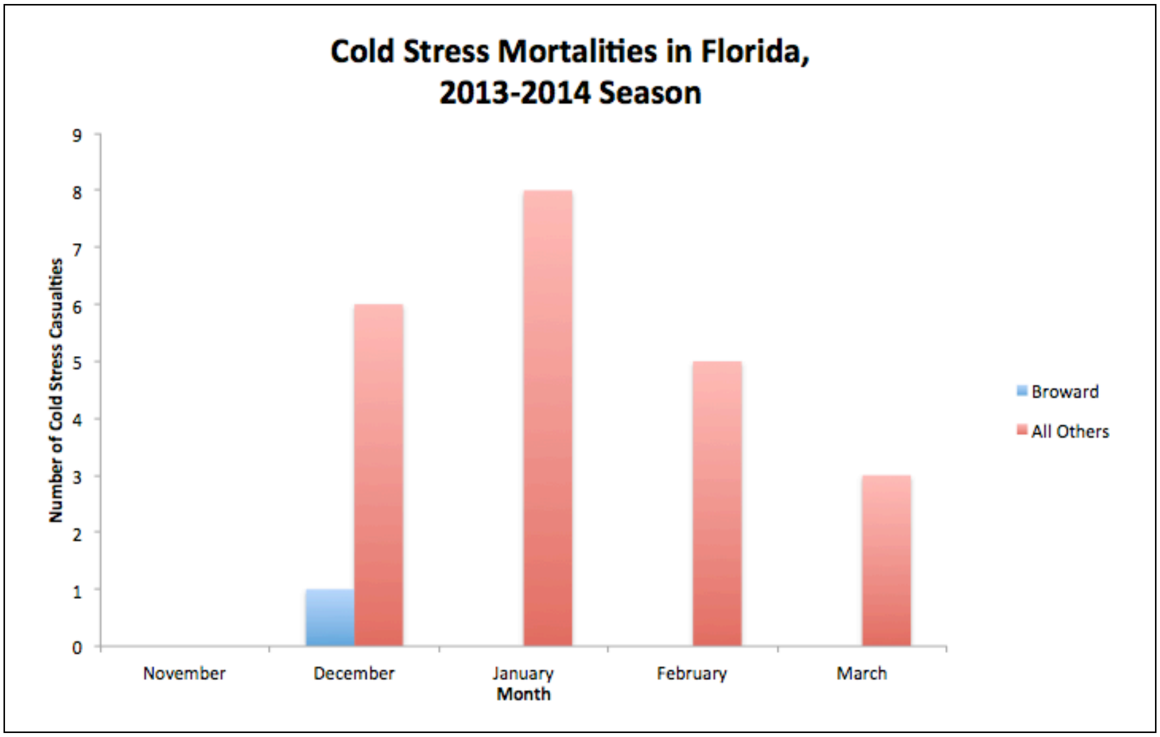

Figure 25. Total number of manatee cold stress mortalities in Broward County and the state of Florida during the 2013-2014 winter season.

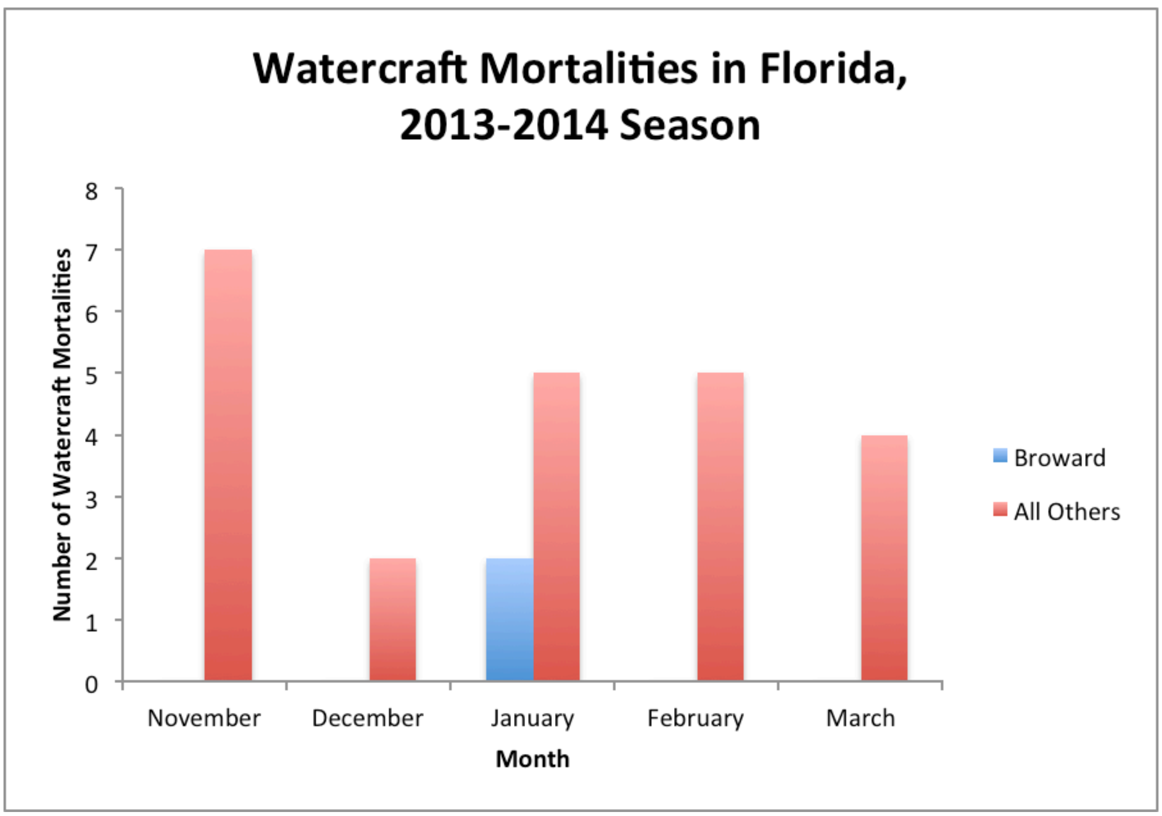

Figure 26. Total number of manatee watercraft mortalities in Broward County and the state of Florida during the 2013-2014 winter season.

Results from the logistic regression analysis are reported in Table 3 and Figure 27. PE Heater Discharge Temperature was the most important variable explaining the presence of one or more manatees within the study area. The change in log likelihood for this variable was 6.05 with p=0.014. PE Heater Discharge Temperature explained a significant portion of the variation in the presence of one or more manatees (Wald= 5.12 with p=0.024). The associated coefficient of -0.461 resulted in an odds ratio of 0.631 (0.406, 0.915). Therefor, a one unit increase in PE Heater Discharge Temperature decreased the odds of one or more manatees being present in the study area by 36.9%. The Hosemer and Lemeshaw test statistic was 13.501 and a p-value of 0.096 indicating the overall model was a good fit to the data. The unadjusted R-square was 0.084. The

Variables in the Model n=52 Unadjusted R square = 0.084	Change in -2 Log Likelihood	df	Significance of Change	Wald Statistic	Significance of Wald
Dependent Variable Manatee presence/absence					
Independent Variable PE Heater Discharge Temperature	6.05	1	0.014*	5.119	0.024*
PE Heater Discharge Temperature					
Coefficient	-0.461				
Odds Ratio	0.631				
95% Confidence Interval	(0.406,0.915)				
Hosemer and Lemeshaw Statistic	13.501				
Hosemer and Lemeshaw df	8				
Hosemer and Lemeshaw Significance	0.096				

Table 3. Assessment of the logistic regression model relating presence/absence of manatees to PE heater discharge temperature (N=52, Unadjusted R-square = 0.084). Significant variable was PE heater discharge temperature term.

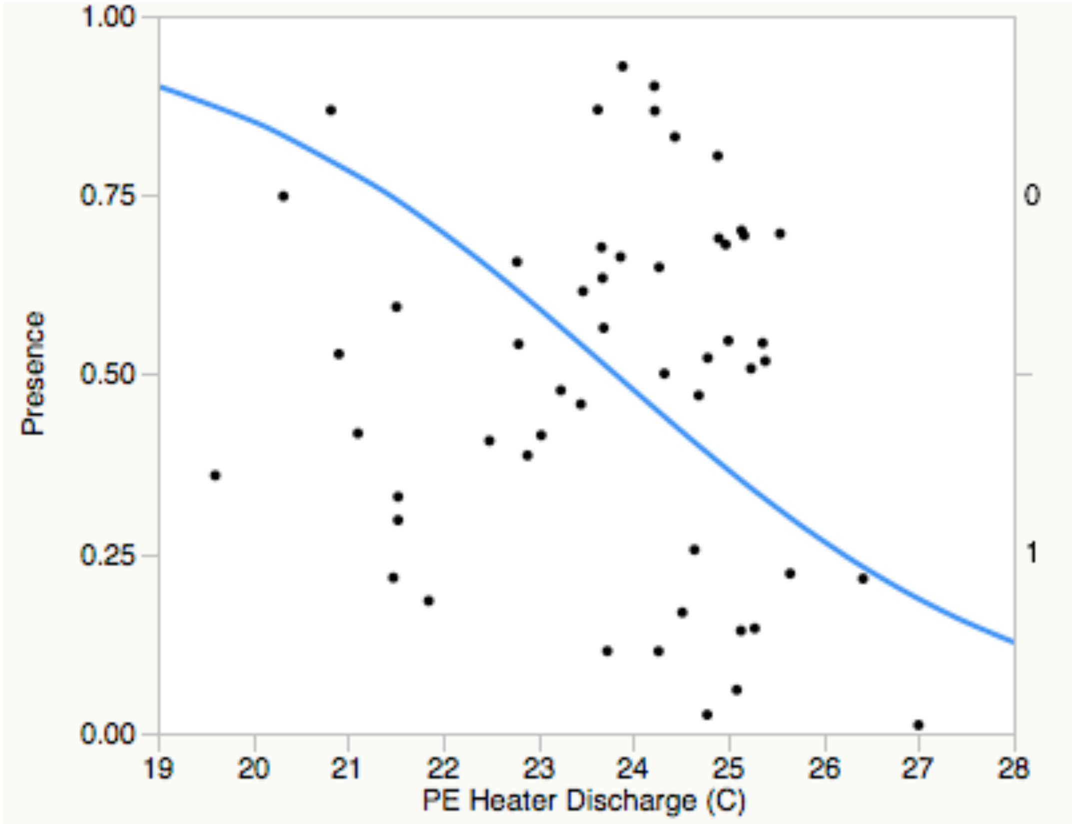

Figure 27. Logistic regression model relating presence/absence of manatees to PE heater discharge temperature. Presence from 0 to 1 where 0 = absent and 1 = present.

expected presence of one or more manatees within the study area was very similar to the observed presence. This provided further indication that the model was a good fit to the data.

Objective 2: Short-term behavioral responses to a warm water refuge disruption

Results from the Mann-Whitney U-test for the comparison between the land-based counts and aerial counts on same day surveys are presented in Table 4. The U-value was 22.5 with a p-value of 0.777. The critical U-value was eight. Differences between the land-based and aerial counts were non-significant on days that both surveys occurred. Results from the Mann-Whitney U-test for the comparison between the aerial counts by site are also shown in Table 4. The U-value was 23 with a p-value less than 0.001. The critical U-value was 87. A significant difference between the aerial counts at the PE Discharge Canal and inland Fort Lauderdale Cooling Lakes locations resulted.

Mann-Whitney U-Test Type	U-value	df	Significance
Land Counts vs Aerial Counts n=7	22.5	1	0.777
Aerial Counts PE vs FLI n=17	23	1	<.001*

Table 4. Assessment of Mann-Whitney U-Tests for survey methods within Port Everglades (N = 7) and aerial counts between Port Everglades and Fort Lauderdale sites (N = 17).

Objective 3: Trends in Florida manatee counts

Results from the chi-square analysis comparing observed manatee counts to expected counts (based on the average number of manatees observed from 1999 through 2011) are shown in Table 5. The associated chi-square value was 60.433 with a p-value less than 0.001. The critical chi-square value was 9.490. A significant difference between the 2013-2014 season counts and the average season counts resulted. The observed lower counts in the 2013-2014 season provided further indication of the significant difference between the 2013-2014 season and average winter season counts.

Month	Observed	Expected	Chi-Square Value	df	Significance
November	0	3			
December	25	50			
January	127	147			
February	15	86			
March	10	6	60.433	4	<0.001*

Table 5. Assessment of chi-square analysis between 2013-2014 winter season and 1999-2012 average season counts.

CHAPTER IV
DISCUSSION AND CONCLUSION

These data indicate that manatee usage of the PE discharge canal winter habitat changed due to the disruption of a warm water refugia (the closure of a power plant). Manatee presence and counts were lower than expected during times of cold weather in the study area. There was a significant difference in counts between the PE discharge canal and the inland Fort Lauderdale cooling lakes habitats. It was also observed that tagged manatees used both FPL habitats during cold weather. The number of manatees

counted in the PE discharge canal winter habitat was found to be different than the average count over the previous 12-year period.

The PE heater discharge temperature was found to be the most important variable in determining the presence of one or more manatees within the study area. As heater discharge temperatures decreased, the presence of one or more manatees in the study area increased. The temperatures at which presence increased above the fifty percent mark were 23.9 degrees Celsius or less. Average PE heater discharge temperatures in November, December, February and March remained above 23.9 degrees Celsius resulting in reduced presence during those months. However, during January, heater discharge and ambient water temperatures dropped below 23.9 degrees Celsius resulting in an increased presence of manatees in the study area. Manatees were present at one or more of the five survey sites on every survey day in January with the lowest heater discharge temperature reaching 19.4 degrees Celsius. This equated to one or more manatees being sighted within the study area 93 percent of the time on that particular survey day. This aligned with my expectations that as water temperatures decreased due to cold weather, manatee presence within the study area would increase, but only if adequate PE discharge temperature was maintained.

Manatees have a low thermoregulatory ability (Irvine, 1983) and thus need warm water during times of cold weather to maintain a consistent body temperature (Deutsch *et al.* 2003; Ackerman, 1985; Lefebvre *et al.* 1989). Both natural and artificial warm water refugia have provided manatees with a winter habitat used to combat cold weather effects and provide for a better thermoregulatory ability during winter (Hartman, 1979; Irvine, 1983; Shane, 1984; O'Shea *et al.* 1985; Edwards *et al.* 2005). Past studies (Packard and Mulholland, 1983; Shane, 1984; Garrot *et al.* 1994) support this study's findings that, as waters become colder due to winter weather, manatees will migrate to and use warm water sites, thus increasing their presence, which results in more manatees being detected. In South Florida, the primary sites for warm water are artificial in nature (i.e. power plant effluent discharges). As previously discussed, the waters discharged from an operational power plant heat the surrounding waters by 5 to 8 degrees Celsius higher than the current ambient water temperatures in the area (Broward County Port Everglades

Department, 2013b). This provides manatees opportunity to thermoregulate during the winter.

Temporary heating modules were constructed at the PE power plant and placed in the discharge canal. However, the trigger temperature for the heaters to begin heating was 17.2 degrees Celsius. During the winter season, water temperatures monitored in the PE discharge canal never fell below 21.7 degrees Celsius, thus heaters were always operational during times of cold weather, however, were never utilized. Along the five survey sites just downstream of the discharge canal, however, water temperatures during cold periods fell below the 20.6 degree Celsius manatee tolerance threshold on many occasions. The difference in downstream temperatures was attributed primarily to the exposure during cold weather in the area, but also to shading by trees along the banks of study area. The upper PE discharge canal was not shaded by trees as the PE power plant and surrounding structures were completely demolished. This afforded direct sunlight to help warm surface waters. The slightly higher temperatures in the discharge canal were also attributed to the design of the discharge canal itself. The discharge canal begins with a dead end and allows for flow out to the study area when effluent is discharging water during normal operations. It also allows for the tidal effects to bring colder water into the channel to mix with the discharge canal water. During normal operations this would continue to increase the temperature of the discharge waters slightly. Since the plant is non-operational, the only exchange of water was facilitated by tides, which brought in cooler waters that pooled at the end of the discharge canal. These waters heated slightly from exposure to direct sunlight, thus maintaining minimal temperature thresholds that prevented heater modules from turning on.

Alternatively, it could be expected that if a large number of manatees were present within the study area during times of cold weather then back-up heaters were most likely in operation and sufficiently heating the study site waters. However, as stated earlier, back-up heaters were not triggered during the survey season. Due to this, we expected to have a high presence of manatees on days that temperatures were between the trigger temperature of 17.2 degrees Celsius and the 23.89 degrees Celsius temperature expected from the logistic regression model. This was the case for the surveys during January. Manatee presence was determined to be fifty percent or more on each survey

day in January, as stated earlier. However, it can be seen that there was a decrease from the average and all prior seasons, thus indicating that unheated waters did not attract a large number of manatees to the site. Unpublished data from the Florida Power and Light Corporation (2009) documented that manatee counts increased greatly when heaters were on at their Riviera Beach (RB) power plant as compared to days when heaters were off. RB was also shut down for a period of three years and heaters were triggered at a higher threshold temperature due to this plant being the only source for manatees to use that was operating in West Palm Beach County. The closest plants to RB are the PE and FL plants in Broward County. This provided a good comparison between two sites: one where heaters were used at a higher trigger temperature with no alternate location for selection by manatees for their warm water needs and the other, where heaters were not used at a lower trigger temperature with an alternate location available nearby for warm water.

Land-based counts used during this study, when compared to aerial based counts in the same area, provided no significant difference. This meant that both methods of sighting and counting manatees were effective and led to similar results. Land-based surveys took place on the same day as aerial surveys performed by Broward County for seven individual days within the season. Manatees sighted and counted during both survey methods were consistent except for two days where aerial surveys sighted higher numbers of manatees in the study area. Survey method is important, mostly due to cost effectiveness. However, both methods have limitations in detection (discussed later), leading to preference based on the needs of the study and availability of funds. This result did not align with my expectations. It was expected that there would be a significant difference between survey method results in the study area.

Aerial surveys allow for a better view of a study area from above and, depending on water depths and clarity, manatees can be seen more accurately (Hartman, 1979; Packard *et al.* 1985, 1986; Lefebvre and Kochman, 1991; Garrot *et al.* 1994, 1995; Craig and Reynolds, 2004). Some factors, however, may confound and mask accurate counts when conducting aerial surveys. Manatees resting at the bottom can be missed if waters are dark or too deep (Packard *et al.* 1986; Marsh and Sinclair, 1989; Lefebvre *et al.* 1995; Pollack *et al.* 2004; Edwards *et al.* 2005; Pollack *et al.* 2006). Manatees can also be missed during detection when trees and shrubbery are overhanging the water (Garrot *et*

al. 1994). This was the case for my study as overhanging trees and shrubbery fringed the study site in many areas. Due to the lack of effluent discharge into the canal from the PE plant, water clarity was poor. Effluent helps to mix waters in the study site along with slight tidal mixing. However, with no effluent assisting, tidal mixing was not enough to overcome and allow for better clarity. Waters were dark and turbid. Manatees could only be viewed if they were within a few feet of the surface.

When examining any type of count data, the concept of observer bias should be considered (Packard *et al.* 1984; Garrot *et al.* 1994). Two types of bias are known: within-observer and between observer (Martin and Bateson, 1993; Lehner, 1996). For this study, within-observer bias measures the extent to which one observer counts the same number of manatees when counting on different occasions. Between observer bias measures the extent to which two or more observers obtain similar counts during similar viewing opportunities on the same survey. Observer bias is important to consider as it could result in inaccurate counts. All observers were trained in manatee detection. Observers were shown to look for manatee "footprints", manatee snouts breaking the surface for breathing, backs arching when manatees deep dive, full bodies at or near the surface when manatees were basking in the sunlight or milling and other forms of sight identification. Observers were also instructed on how to listen for sounds when a manatee takes a breath at the surface. Observers conducted surveys based on their training, experience, and number of accurately counted manatees present during previous surveys conducted in the study area. It should be noted that the large differences in counts on the two survey days previously mentioned were also due to timing of the surveys. Land-based surveys were conducted in the early morning, while aerial surveys were conducted in the afternoon. This would cause a difference in counts due to the length of time between survey methods, daily activity patterns of manatees, angle of light, and wind differences. These differences could not be attributed to any kind of observer bias, however.

When looking at the differences between two sites using aerial surveys, a significant difference was identified. Broward County is unique in that it has two power plant locations. One occurs at the PE study site and the other is located inland on a cooling lake fed by the New River. Both locations discharge warm water year round.

However, with the closure of PE, the FL plant was the only site reliably discharging warm water during the study season. Manatees are known for migrating prior to and during times of cold weather and returning to the same warm water refugia each year (Hartman, 1979; Powell and Rathbun, 1989; Deutsch *et al*. 2003; Flamm *et al.* 2005). However, with the closure of PE, manatees that regularly migrated to PE were expected to migrate to the nearby, warmer FL cooling lake. The significant difference found between sites was well documented through collaboration with the Broward County Manatee Monitoring Program (BCMMP). Aerial surveys conducted by BCMMP showed a higher presence and counts in FL than in PE. When compared to the prior season when both plants were operational, manatee presence and counts were also lower in PE and higher in FL during the study season (Broward County, unpublished data). A record 688 manatees was counted on January 24, 2014, in FL versus only 53 in PE. This indicates that more manatees preferred FL to PE, most likely due to the reliability of warmer water. This aligned with my expectation that there would be a significant difference between sites and that counts would be greater at FL due to the continuous discharge of warm water.

Figures 28 through 32 depict location maps of two tagged manatees (Glinda and Slates, both females) from 08 January through 31 March 2014, based on data provided by and attributed to the Sea to Shore Alliance and the Florida Power and Light Corporation. Both manatees were tagged and released in PE on 08 January 2014. When looking at locations generated for the Fort Lauderdale region, the manatee known as Glinda spent 53.11% of her time in PE and the associated Manatee Sanctuary, 6.94% travelling to and from FL, and 39.95% in FL (Figure 28). Interestingly, Glinda did not actually go into the cooling lake itself but stayed around the intake canal for the plant and the fringing creek between the plant and Pond Apple Slough. She also took the southern route through the Dania Cut-off Canal to FL. It is believed that, even though she did not physically go into the cooling lakes, she most likely felt the effects of the warm water in the creek area due to flow connectivity with the cooling lake and through water flowing out of the lake through the New River from the immediate north. Slates presented a different case than Glinda. Slates took the northern route through the New River to get to FL (Figure 29). This accounted for a 5.10% travel time from PE to FL. Slates only spent 0.97% of her

time in the PE/Manatee Sanctuary area and 93.93% in FL. It was expected that both tagged manatees would use FL more than PE, however, the findings of this study showed that both sites were still used even though PE is non-operational. This observation could be an indication of the strong site fidelity that manatees have and retain for long periods of time throughout their lives (Reep and Bonde, 2006).

Juveniles do not have the physiological thermoregulatory abilities of a fully-grown adult and thus require more time in warm water refugia than an adult (O'Shea *et al.* 1985). Slates, a juvenile female, was not likely accustomed to the colder waters yet and thus needed more time than Glinda, an adult female, in the warmer waters of FL. Another indication of the age difference between Glinda and Slates was their travel range. Both Glinda and Slates look to be resident manatees of the Banana River population, in Brevard County (Figures 30 and 31). When cold weather arrived in January, both manatees likely travelled south through the ICW to PE and FL. However, Glinda also travelled further south through the ICW and spent a large period of time in Miami's Biscayne Bay (Figure 32). It is known that manatees travel to Biscayne Bay to feed on seagrasses in the area (Packard, 1984; Reynolds and Wilcox, 1994). Slates did not travel further south than PE in Fort Lauderdale and likely did not know of this feeding area. Both manatees, when warmer weather arrived, returned to the Banana River system some 275 km to the north.

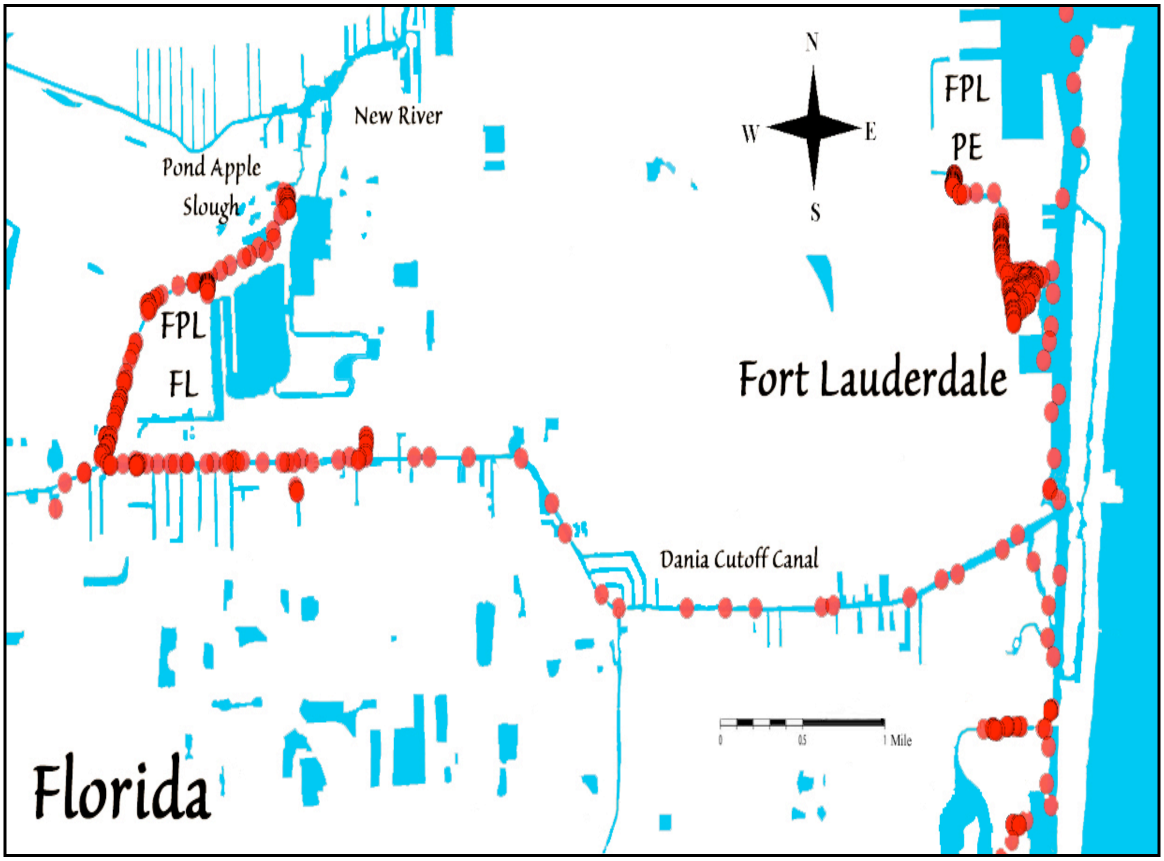

Figure 28. Map of tagged manatee TPE011 (Glinda) locations in Fort Lauderdale, Florida during January and February 2014. Glinda travelled through the Dania Cutoff Canal from FPL Port Everglades (FPL PE) to Fort Lauderdale (FPL FL) plant. Equal amounts of time were spent between FPL PE and FPL FL. Red circles indicate GPS locations of tagged manatee during the indicated time period.

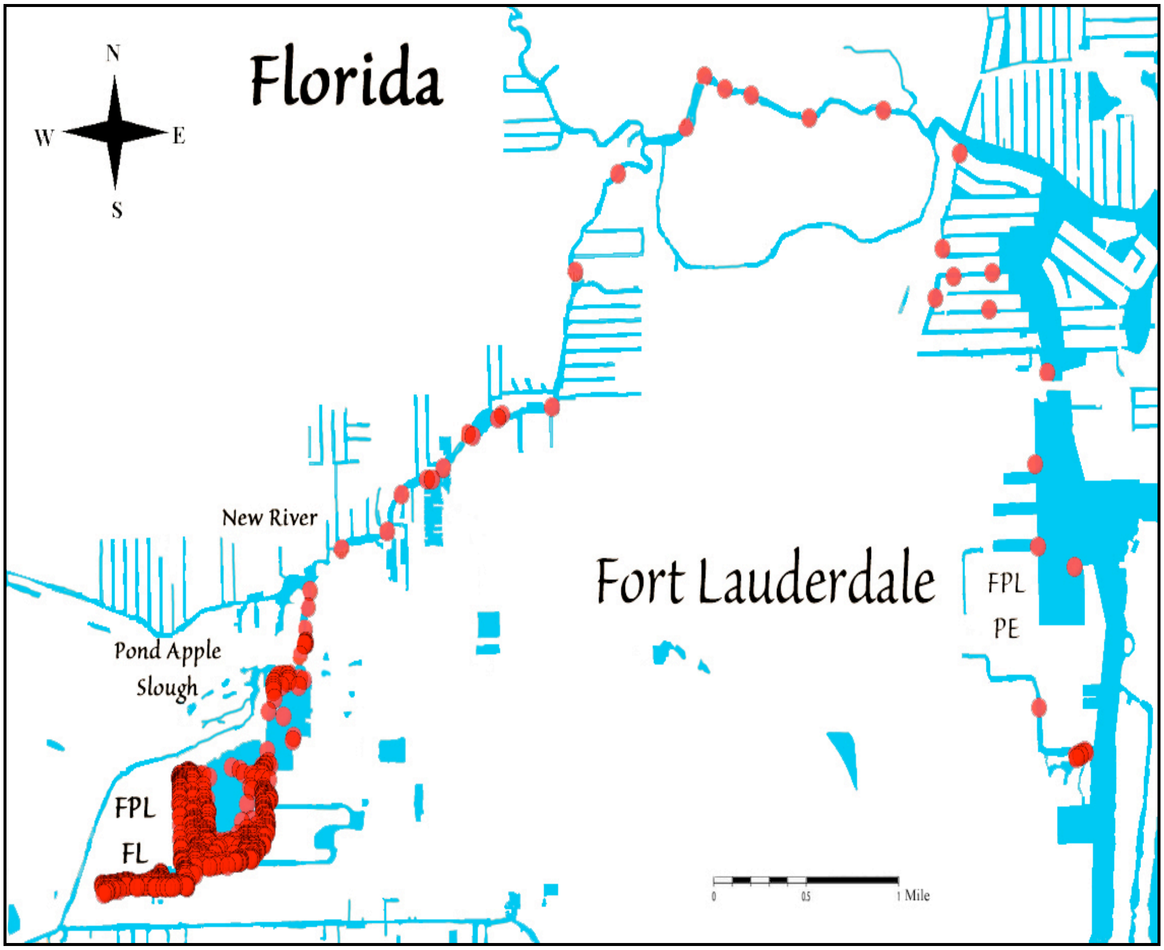

Figure 29. Map of tagged manatee TPE012 (Slates) locations in Fort Lauderdale, Florida during January and February. Slates travelled from the FPL Port Everglades plant (FPL PE) to the FPL Fort Lauderdale plant (FPL FL) through the New River. More time was spent in FPL FL than FPL PE. Red circles indicate GPS locations of tagged manatee during the indicated time period.

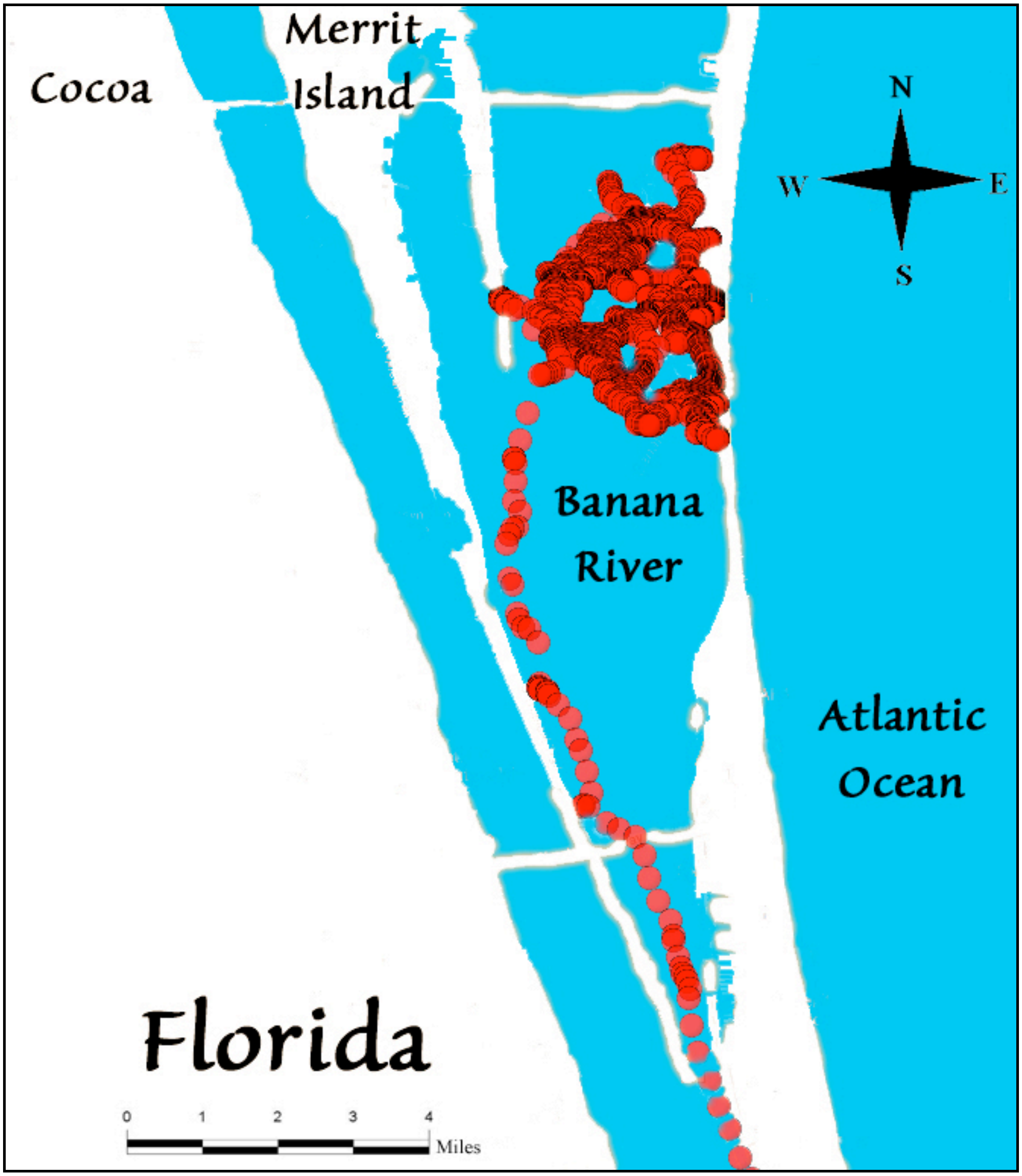

Figure 30. Map of tagged manatee TPE011 (Glinda) locations in Banana River, Florida during March 2014. Glinda returned to the Banana River at the end of the season and is presumed to be from that population. Red circles indicate GPS locations of tagged manatee during the indicated time period.

Figure 31. Map of tagged manatee TPE012 (Slates) locations in Banana River, Florida during March 2014. Slates returned to the Banana River at the end of the season and is presumed to be from that population. Red circles indicate GPS locations of tagged manatee during the indicated time period.

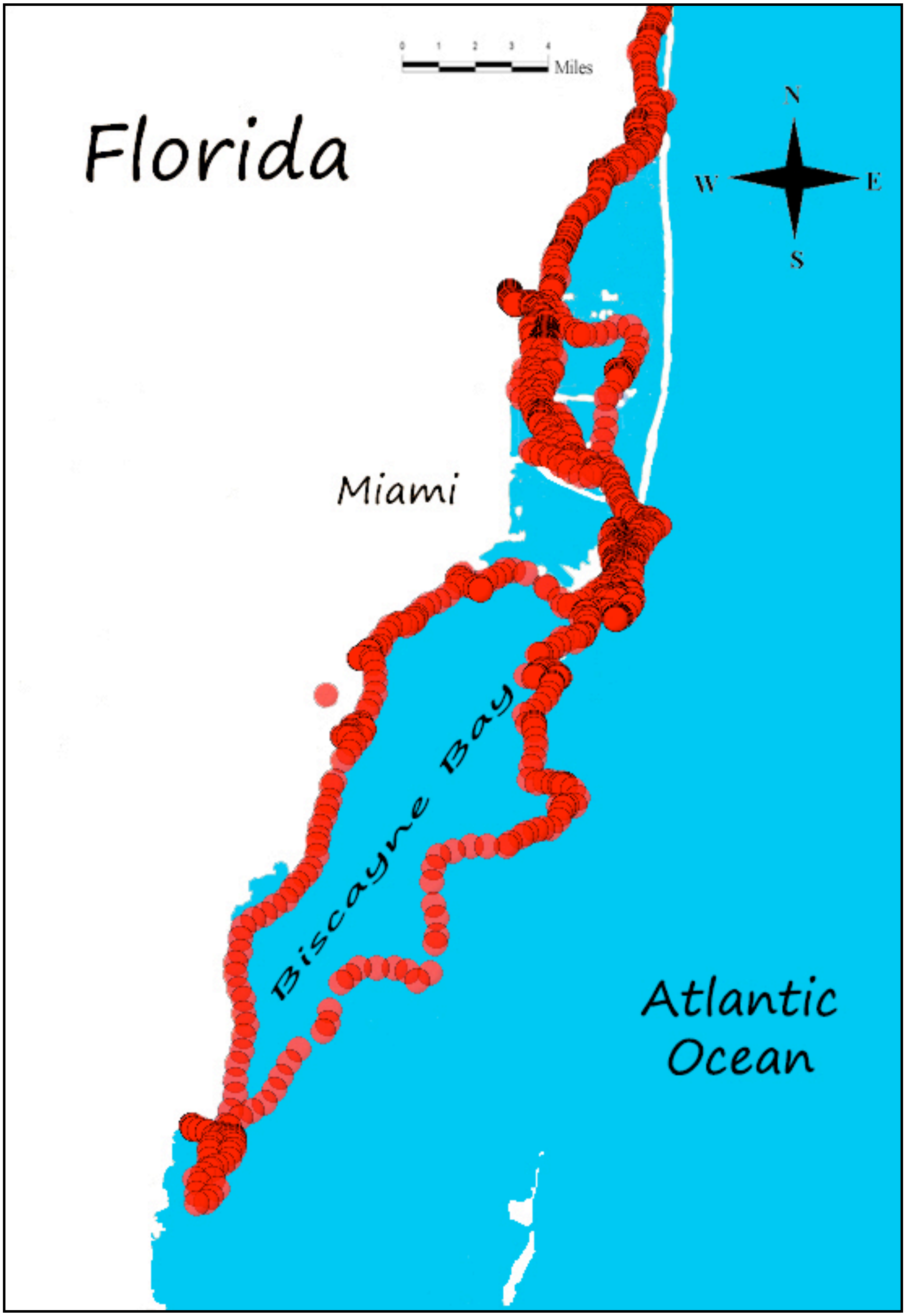

Figure 32. Map of tagged manatee TPE011 (Glinda) locations in Biscayne Bay, Florida during January and February 2014. Glinda spent a large amount of time feeding in this region due to its abundant seagrass beds. Red circles indicate GPS locations of tagged manatee during the indicated time period.

It could also be expected, alternatively, that if tagged manatees were located at FL versus PE, then manatees were choosing heated waters from normal power plant operations over unheated waters from a non-operational plant. Slates was a prime example for this alternative hypothesis. Slates spent less time in PE and travelling than Glinda did. It can be assumed that Slates preferred the warmer waters of FL to PE or was not aware of the historic reliability of PE. But this can also be attributed to the previously mentioned fact that Slates was a juvenile and her preference for warmer waters could be accounted for based on her individual life history and behavior (Packard *et al.* 1989; Flamm *et al.* 2005).

A significant difference was also detected between land-based counts in the survey season as compared to average 1999-2012 manatee counts in the study area. This difference was supported by a lower number of counts in PE during the survey season as compared to the average. This aligned with the expectation that there would be significantly fewer manatees in PE than in previous seasons that was based on the average. This is important as manatee numbers were hypothesized to decrease in PE based on the non-availability of a warm water refuge. This resulted in a reduced usage of PE by manatees and is the basis for this study and its recommendations for the future.

If we examined each individual year we would expect to see variations, most notably in January (however, some years experienced the onset of cold weather in February). In some years, counts from this season were more and some were less than prior individual years. The overall trend detected, however, is that the survey season had a lower number of manatees counted in each month. This could be attributed to two factors: the loss of a warm water refuge and changing weather patterns. In the logistic regression model, weather (air temperature, wind speed, and atmospheric pressure) was not proven to be a significant factor, so it can be assumed that the reason for lower counts during this survey season was the loss of warm water in PE due to the closure of the power plant.

An alternate theory for this could also be that manatees used other warm water refugia instead of PE. As stated earlier, Fort Lauderdale has two power plant locations and manatees could use both or just one. The Mann Whitney U-test (Table 4) showed that there was a significant difference between site locations based on aerial survey counts.

FL had significantly more manatees than PE on each survey day, especially during colder weather. Figures 28 and 29 support this as they documented that both Glinda and Slates used the FL cooling lakes, with Slates using the FL cooling lake and the surrounding area. Results of this study confirm both the third objective's hypothesis and its alternative.

Photo-identification played a part in this study as it allows for the identification of individual manatees and their sighting histories (Beck and Reid, 1995; Longtimm *et al.* 2004). Documented individuals can be matched to identified individuals in the MIPS database to determine where they originated from, their site fidelities, and where they have been in order to establish life history patterns and behaviors (Beck and Reid, 1995). Photo identification can also be used to determine if and when manatees became cold-stressed or when they acquire new features or scars. Photos can also allow for determinations by researchers on potential rescue events for emergency capture, care, and rehabilitation.

With any study that arises from the loss of some factor or event that is necessary to prolong a species' survival, the effects must be valued along with other scientific results. While no statistical analysis was done on mortalities in Broward County, trends were evident that may have identified negatives that could occur due to the closure of a power plant. Two of the most widely known causes of manatee death in Florida are watercraft strikes and CSS (Hartman, 1974; Campbell and Powell, 1976; O'Shea *et al.* 1985; Ackerman *et al.* 1995; Wright *et al.* 1995; Bossart *et al.* 2003; Scott, 2004; Reep and Bonde, 2006). Manatees identified during this study in PE showed very little to no signs of cold stress. However, manatees did display evidence of high numbers of prior inflicted boat and propeller scarring on their bodies, with some manatees having scars that were fresh or in the process of healing. When mortality data from the Florida Fish and Wildlife Conservation Commission (2014) were examined, there were minimal number of manatee deaths listed from Broward County attributed to CSS and watercraft strikes. This could suggest that the closure of the PE power plant did not have an effect on deaths related to these two categories. Numbers of manatee deaths for the study season were lower than previous seasons, thus identifying a decreasing trend in CSS and watercraft mortalities within the county. This could be due to emigration of manatees

outside of the area and it is possible that manatees could have died in other areas due to the disruption of warm water refugia, however this was not documented. CSS mortality occurred in December, which was associated with the season's winter weather, while watercraft mortality occurred in January. CSS is known to occur during times of cold weather (Laist and Reynolds, 2005b) while watercraft strikes usually occur with increases in boat traffic due to summer and holiday seasons.

The purpose of this study was to determine changes in habitat usage and other responses to the disruption of a warm water refugia (the closure of a power plant) on Florida manatees within the greater Port Everglades region. This study provided a base-line model for determining presence of one or more manatees in PE based on changes in heater discharge water temperature. It also provided an analysis of different count method results to use during winter survey seasons in PE, as well as other areas that were alternative sites for warm water refugia. This study also determined how, through radio tracking data analysis, manatee usage of various habitats could be determined as well as potential site-fidelity locations that manatees utilized during winter seasons. It also provided trends in counts over previous years based on power plant operations and closures.

This study was one of the first of its kind. As previously stated, power plants will likely not be present in the future due to cleaner, "greener" methods of operation and, as we move forward with technological advances, eliminate the artificial warm water refugia that Florida manatees use (Laist and Reynolds, 2005b). It is imperative to know how manatees behave and respond to these changes. Also, importantly, how they choose alternative warm water sites and what we can do to create or acknowledge additional warm water sites for their future winter usage. The information presented in this study can be used by wildlife managers to improve protection of the Florida manatee during future power plant closures, as well as total decommissioning of power plants in the future. This study also identified whether or not efforts made during the shutdown of PE were sufficient or whether improvements needed to be made.

There were a few limitations that should be addressed from this study, the first being number of observers. No survey study is successful without the help of volunteer observers. During this study, there were only enough observers to maintain one at each of

the five survey sites. This reduced the ability to account for observer bias and obtain additional photo identification records. Another limitation was the number of manatees tagged. While data obtained from Glinda and Slates displayed interesting and applicable trends, if more manatees were tagged it could be determined whether any additional warm water areas were being utilized. Additionally, feeding grounds and locations where the animals originated from could be utilized in order to determine which Florida populations are using particular warm water refugia. Basic field equipment also presented a limitation in this study. While accurate abiotic data were obtained, a more precise value could have caused other factors to be more relevant in the study. Timing was also a limitation. Aerial surveys conducted in the afternoon provided higher numbers of counts than morning land-based surveys. This could have provided a more significant difference in the statistical analyses if an even greater number of manatees were detected through aerial versus land-based surveys. One final limitation that played a factor was access. Some areas could not be accessed due to port and/or corporate entry restrictions. Had these areas been open to assist in the study, more manatees could have potentially been sighted to obtain more accurate counts within the study area.

Continued research on the effects of power plant closures are needed to construct a clear and sound final recommendation to wildlife managers. The limitations of the study should be corrected for future studies of this kind during the next two years of plant closure as well as for at least 3 years of study when the plant begins normal operations again. More observers should be present in order to conduct bias analyses. More precise instrumentation should be used to determine if an abiotic factor could actually be a determining variable in a more advanced presence model. Surveys should be conducted in the morning and afternoon, both land and aerial based. Additional manatees should be tagged each season to determine other potential warm water refugia, feeding zones, travel corridors, and areas of origination. Restricted areas should be considered in expanding survey site locations to account for additional manatee presence. It is also recommended that the study site be expanded for land-based and boat-based surveys for FL and that abiotic data be taken for FL to construct any significant models for manatee usage of that region during times of PE non-operation. It is also recommended that continued mortality trend analysis occur based on CSS and boat strikes for Broward County in order to assess

if threats are growing or declining in significance. One final recommendation is for further studies to be conducted on newly studied passive thermal refugia (PTRs) that could provide future winter aggregation sites for Florida manatees (Packard *et al.* 1989; Stith *et al*. 2010, 2012).

Manatee winter habitat usage has changed due to the loss of warm water refugia through the closing of a power plant in the Port Everglades area of Broward County. This study determined that as PE heater discharge water temperatures decreased, manatee presence increased. Significant differences were also detected in counts between PE and FL and between telemetry data showing manatee preferences for warm water sites based on previous experience, life histories and behavior. Manatee counts were also found to be significantly different than prior seasons averages due to the loss of warm water in PE. Although the findings presented here are specific to Port Everglades and may not be applicable to other power plant sites with no alternative warm water refugia, this study is the first of its kind in providing for the adjustment and creation of management plans for the further protection of the Florida manatee during periods of warm water loss, be they through maintenance closures or plant decommissions.

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APPENDIX A: SAMPLE DATA SHEETS

Location Code: ML

Date: ____/____/_______ GPS Coordinates: 26.079722, -80.120206

Day (circle one): M T Th

Survey Time: ____:____ am/pm to ____:_____ am/pm TOTAL Time: ______:______

Observer(s): ____

Time of Initial Sighting: ____:____ am/pm Time of Final Sighting: ____:____ am/pm

Counts: Presence:

Adults		Present? Y or N	
Juveniles		Absent? Y or N	
Calves		X	X

Water Temperature: ____________° C Salinity____________________ppt

Air Temperature: ____________° C

Weather Conditions: ____

Tidal State: ____

Behaviors Observed (List in fixed (F) or alternate (A) scan point and code form):

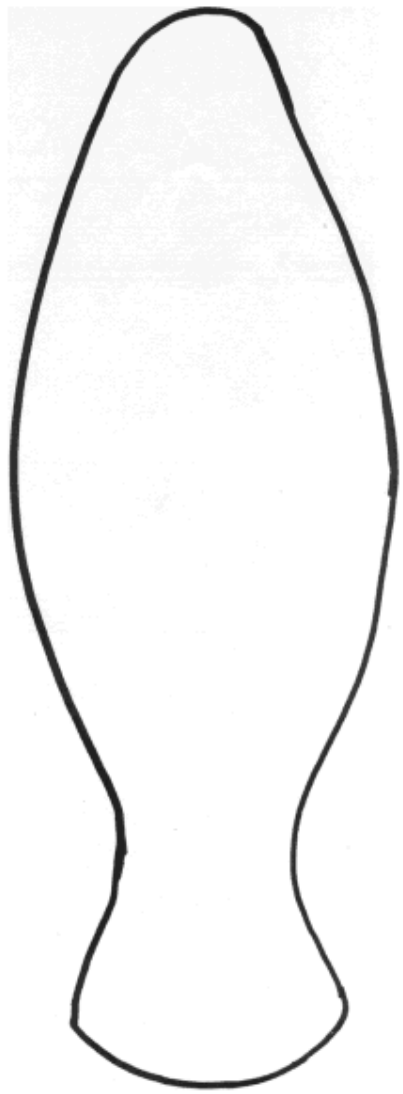
<u>Codes</u>: Feeding (X-F), Resting (X-R), Socializing (X-S), Traveling (X-T), Milling (X-M), Playing (X-P), Other (X-O then describe), or Undetermined (X-U) where X is F or A.

Alternate Scans (if conducting walking survey(s) to additional locations):

GPS Coordinates	Water Temp/Air Temp, °C	Salinity, PSU	Tidal State	Adults	Juveniles	Calves
	/					
	/					
	/					

Manatee Identification Sheet

Instructions: Based on all survey photographs of a particular manatee, draw all noticeable features that identify the particular manatee on the template below (you may draw in flippers as needed). Also, fill out all information in the appropriate spaces below.



Manatee Location Code and ID: ______________________

Body Condition Code for CSS/Scarring: ___________/____________

(For CSS: 1- Excellent, 2- Good with few lesions, 3- Poor with many lesions; For Scarring: 1- Less than two scars on the entire body, 2- Three to five scars on the entire body or at least 25% of the tail missing, 3- More than 5 scars on the entire body or the majority of the tail missing)

Number of photographs used in identification: _____________