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The Effects of a New Bridge on Manatee (Trichechus manatus latirostris) Use of the FPL Discharge Canal at Port Everglades, Florida

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THE EFFECTS OF A NEW BRIDGE ON MANATEE (*TRICHECHUS MANATUS LATIROSTRIS*) USE OF THE FPL DISCHARGE CANAL AT PORT EVERGLADES, FLORIDA

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II. ABSTRACT

The Florida manatee (*Trichechus manatus latirostris*) is an endangered species that migrates to warm water refuges such as natural springs or power plant effluents during the winter months to escape cold water. The Florida Power and Light (FPL) discharge canal in Port Everglades, Ft. Lauderdale, FL., is utilized as a refuge by overwintering manatees. Construction of a new bridge over the FPL effluent canal had a potential effect on manatee usage of the canal. Discharge is often 10-15° C warmer in the winter season than the surrounding waters of the Intracoastal Waterway. Previous data, including age class and cow/calf abundance from pre-bridge winters (2004-2009), were compared with data from winter 2010, during bridge construction and winter 2011, post-bridge construction. No manatees were present at the survey sites during winter until surface water temperatures fell below 22° C. Although monthly mean surface water temperatures were not statistically different between 2008-2009, 2009-2010, and 2010-2011 (21.9±0.4° C, 21.8±1.8° C and 21.4±0.6° C respectively), manatee abundance did vary. 2008-2009 had higher monthly mean numbers of manatees per survey from December through March (29.7, 27.3, 48.1, 2 respectively) than 2009-2010 (0, 30, 10.7, 5 respectively) and 2010-2011 (18.7, 6.7, 0.1, 0 respectively). A Poisson distribution analysis showed a significant difference in adult manatee counts among the study years ($\alpha < 0.05$). No significant differences were found for juveniles and calves. While I cannot decisively state that bridge construction reduced the number of overwintering adult manatees during 2010, there appears to be the potential for an effect.

Keywords: Port Everglades, Florida manatee, construction, *Trichechus manatus latirostris*, conservation, warm-water refuge.

III. <u>STATEMENT OF SIGNIFIGANCE</u>

The purpose of this research was to examine the effects of human impacts, specifically construction, on overwintering populations of Florida manatees (*Trichechus manatus latirostris*) in Port Everglades, Florida. Increase in human populations and the subsequent development of the Florida coastline has led to concerns over declining manatee populations (Bonde et al., 2006). High levels of human activity have also been shown to alter normal manatee behavioral patterns in designated sanctuaries (Miksis-Olds, 2008). The noise that is produced from anthropogenic and natural sources from increased human activity has the potential to affect manatees, with responses ranging from mild changes in behavior to extreme aversion to humans (Miksis-Olds and Wagner, 2011). Interestingly, the survival probabilities of manatees in the Atlantic region are lower and more variable than other regions in Florida (Langtimm et al., 1998; Runge et al., 2004). Manatees living along the Atlantic coast of Florida are more impacted by human activities and encroachment.

For this study, the effects of construction on overwintering manatee populations were quantified by identifying differences in presence/absence, as well as differences in age class composition. Walking observational surveys along the FPL discharge canal in Port Everglades were conducted across multiple years to gather data on manatee presence and absence, age class, and water temperature. By examining the effects of construction, we can further identify and perhaps develop more precise management and conservation plans for the future based on how populations of manatees react to increased human activity.

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V. INTRODUCTION

A. Taxonomy and Species Description

Manatees are marine mammals in the Order Sirenia, which includes two Families, the Trichechidae and the Dugongidae. The West Indian manatee (*Trichechus manatus*), the West African manatee (*Trichechus senegalensis*), and the Amazonian manatee (*Trichechus inunguis*) are all in Trichechidae (Committee on Taxonomy, 2012). The dugong (*Dugong dugong*) and the extinct Steller sea cow (*Hydrodamalis gigas*) are in the Family Dugongidae. All members of this order are fully aquatic, herbivorous mammals that are found in warm shallow coastal waters (Hartman, 1979; Rommel and Reynolds, 2000). Sirenians belong to a group of four other mammalian Orders known as the subungulates, which include elephants, hyraxes, and aardvarks. Subungulates share a number of similar anatomical properties, including dental characteristics, nails and hooves, and the lack of a clavicle bone (Powell, 2002).

The earliest members of the Order Sirenia appeared during the Eocene approximately 50 million years ago. Fossil records show that sirenians have occurred in the waters around the state of Florida for millions of years, descending from hoofed land animals (Domning, 2005). During the Eocene epoch, the Trichechidae and the Dugongidae separated into two separate phyletic lines (Domning, 2001; Domning, 2005).

Historical and fossil evidence place modern manatees in Florida approximately 10,000 years ago, in areas where warm water springs now occur. Manatee remains have been found in aboriginal midden mounds throughout Florida. Manatees were most generally hunted for their protein and fat. Archeological evidence indicates that manatee populations in Florida are as widespread today as they were in the past. From the 16th to the 19th century, manatees were harvested for their oil, meat, and hides (Hilliard, 2011).

Sirenians have large mobile lip pads well equipped for grasping aquatic vegetation. Their mouths have stiff bristles called vibrissae (Gerstein et al., 1999; Reep et al., 2001). Vibrissae have many uses, including tactile exploration, feeding, and interactions with other organisms (Humphrey, 1992; Powell, 2002). Manatees also have molars that are replaced over the course of an individual's lifetime, in order to compensate for wear caused by their vegetative diet. Manatee teeth move from the back of their jaw to the front, where the roots are absorbed and the teeth eventually fall out (Domning, 1983).

The Florida manatee (*Trichechus manatus latirostris*) is one of North America's largest coastal marine mammals, with an average weight of 360 to 540 kilograms. They can weigh upwards of 1580 kilograms, and can grow longer than four meters, with an average length of 3 meters (Rommel and Caplan, 2003). Manatees are K - selected species, because they are long lived (up to 70 years) (Marmontel et al., 1996), slow to grow and reproduce, and expend a large amount of energy caring for their offspring (Bonde, 2009). Unlike other subungulates, manatees usually produce one offspring per pregnancy, and twins are rare- the interval between calves for elephants can be up to five years (Moss, 2001). Newborn manatees have an average length of one meter and weigh more than 27 kilograms and calves often stay with their mother for two years. The age of maturation is estimated at 3-5 years, with young manatees quickly reaching the sub-adult stage and lengths of around two meters (Ronald et al., 1978; Humphrey, 1992). Females tend to be longer and heavier than males.

Manatees are adapted to aquatic life; they do not have external ear pinnae, or ear flaps, and their bodies are fusiform with no hind limbs (Powell, 2002). Manatees have pectoral flippers for steering and stopping (Folkens and Reeves, 2002). They can use their flippers to steer or "walk" along the bottom, touch or guide other manatees, and can grasp or dislodge vegetation. Manatees also have a large "fluke" or "paddle" used for propulsion and steering through the water. An observer can detect a manatee underwater by means of a "footprint," a smooth round pattern in the water made by the paddle, or by an audible noise when it surfaces to breathe. Manatee nostrils have specialized valves that close to keep water out while they are submerged. They can remain submerged, resting on the bottom for as long as 20 minutes before surfacing. Unlike other marine mammals, the lungs and diaphragm of a manatee run along the dorsal plane of the body instead of the transverse plane, which can contribute to death in the instance of a boat strike (Rommel and Reynolds, 2000).

Manatees have a large digestive tract, slow metabolism, and are hind gut fermenters (Burn, 1986; Powell, 2002). An accessory digestive gland produces hydrochloric acid, digestive enzymes, and mucus which aid digestion of plant matter (Reynolds and Rommel, 2009). A slow digestive tract helps them extract the maximum amount of nutrients from their food and allows time for microorganisms to do their work (Irvine, 1983). Manatees must consume large amounts of vegetation per day, about 20 percent of their body weight, in order to maintain their metabolic needs (Rommel and Reynolds, 2000). Their low metabolic rate also influences their distribution, because warm water refuges enable them to reduce their energy costs (Irvine, 1983). Manatees feed on a variety of freshwater, marine, and terrestrial plants. They have been observed preferentially feeding on invertebrates as well (Lefebvre et al., 2000; Lefebvre et al., 2001; Courbis and Worthy, 2003). Though manatees have a physiological requirement to ingest fresh water, food resources from freshwater and estuarine environments are able to supply this (Reich and Worthy, 2006).

Manatees are large and slow moving mammals, with bones that are solid and dense to help them remain submerged. Their large size helps them regulate their body temperature. Manatees are sparsely covered with thick, evenly distributed hairs; they also sometimes have barnacles and algae growing on their skin (Husar, 1978). Manatees are usually mildly social. Group socialization usually occurs during winter months when manatees gather together for warmth and both sexual and non-sexual activity. Males also tend to be more social than females (Hartman, 1971). The only true association among manatees is the bond between the cow and her calf, which comprises the manatee family unit (Jones and Johnson, 1967; Hartman, 1971). Each animal outside the family unit is wholly independent. Young manatees can travel in groups of 15-20 animals, though they do not stay together for significant periods of time (Moore, 1957; Jones and Johnson, 1967). Manatees display social facilitation when they are together in groups, meaning that what one animal does, the rest will follow suit (Hartman, 1971).

B. Conservation

The Florida manatee is a subspecies of the West Indian manatee and is listed as endangered under the United States' Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), as well as Florida Statutes *379.2431(2)(f)*,*370.12(2)*, and *379.2431(2)(g)* (Garrott et al., 1994; Buckingham et al., 1999; Read and Wade, 2000). The responsibility for manatee research, management, and conservation rests with the United States Fish and Wildlife Service (USFWS) and the Florida Fish and Wildlife Conservation Commission (FFWCC). The USFWS is the leading federal agency for manatee recovery (USFWS, 2009).

Florida Statute *370.12(2)(t)*, known as the Florida Manatee Sanctuary Act, requires counties identified in the Governor and Cabinet's October 1989 Policy Directive to develop Manatee Protection Plans (MPPs) that are consistent with Florida Fish and Wildlife Conservation Commission (FFWCC) criteria, with each county submitting these protection plans for approval. This statute also requires each MMP to include a Boat Facility Sighting Plan (Broward County, 2007). Florida Statute *379.2431(2)(f)* established protocols for the FFWCC and county governments to follow when adopting rules for the regulation of motorboat speed and operation in order to maximize manatee safety. Florida Statute *379.2431(2)(g)* determines how the FFWCC must apply protection rules, and outlines the current county-by-county geographic application of the rules (Broward County, 2007; Marine Mammal Commission, 2007).

The current study took place in Port Everglades which is located near Ft. Lauderdale along the southeastern coast of Florida. The power plant effluent is used by large numbers of manatees during the winter (Reynolds and Wilcox, 1985; Packard et al., 1989; Deutsch et al., 2003). They take advantage of the warm water from the port-based Florida Power and Light (FPL) discharge canal, which is often 10-15° C warmer than the surrounding waters of the Intracoastal Waterway (Reynolds and Wilcox, 1985). The port has established a no-entry zone regulated by the FFWCC for the local manatee population. The boundaries of the no entry zone are enforced by local and state law. The warm-water refuge areas from the power plant located within this area are also designated by Broward County as Manatee Essential Habitat (1989 Comprehensive Plan Vol. 4, 13A-42) (Broward County, 2007).

C. Distribution

Manatees are found throughout the southeastern United States from Rhode Island to Texas; in Florida they are restricted to inland and coastal waters on both the east and west coasts (Burn, 1986; Buckingham et al., 1999; FWC, 2011; Alvarez-Aleman et al., 2010). The Florida manatee occupies the northernmost reaches of the species range and does not usually occur outside of Florida, although some vagrants have been documented in the Bahamas (Lefebvre et al., 2001) and recently in Cuba (Alvarez-Alemán et al., 2010). They have a preference for estuarine and fresh water habitats as opposed to haline offshore areas, though they possess the ability to tolerate salinity extremes (Bengtson and Magor, 1979; Garrott et al., 1994; Langtimm and Beck, 2003). Manatees are very mobile and can migrate great distances seasonally, moving to southern locations in the winter. Daily travel rates vary with season, migratory pattern, and sex (Ronald et al., 1978; Hartman, 1979; Deutsch et al., 2003). Adult males travel farther per day than any other age class for most of the warm season, April through October specifically, and during periods of breeding activity throughout the year. Cow-calf pairs arrive at winter sites earlier than other age classes.

Habitat selection by Florida manatees is influenced by a number of variables which include availability of food, thermal conditions, and freshwater resources (Lefebvre et al., 2000; Lefebvre et al., 2001; Courbis and Worthy, 2003; Rommel and

Caplan, 2003). Females with calves prefer different habitats with regard to the relative importance of these factors. Additional factors influencing habitat selection for females with dependent calves include ambient noise, strong currents, or increased foraging requirements (Gannon et al., 2007).

Florida manatees sometimes form dense aggregations in thermal refugia of up to several hundred individuals to thermoregulate during winter cold months (Wright et al., 2002). Warm water refugia are localized areas such as thermal basins, natural springs, or power plant effluents that are usually warmer than the surrounding waterways. Thermal basins are large depressions on the canal floor or other conditions slow the cooling processes of the water leaving pockets of isolated warm water (Laist and Reynolds, 2005b). Most Florida manatees depend on localized warm water refuges in the southern two-thirds of Florida. Manatees are usually consistent with their seasonal movement patterns across multiple years, and demonstrate strong site fidelity to warm season and winter ranges (Deutsch et al., 2003). This has been documented using photo-identification and aerial surveys at aggregation sites (Irvine and Campbell, 1978; Langtimm et al., 2004; Reid et al., 2006; Edwards et al., 2007). When air temperatures occur below 16° C, most manatees in Florida are found in effluent zones (Shane, 1984). Manatees will either stay in the refuge or in close proximity to feed, which is critical for their survival (Zoodsma, 1991).

Although the degree of dependence on thermal refuges is not yet determined (Laist and Reynolds, 2005 a, b), manatees return to warm water sites, such as Crystal River or the Port Everglades FPL discharge canal each winter. This site fidelity, accompanied by existence of traditional migrations and philopatry (returning to the site of one's birth) to specific areas has management implications for the future (Packard et al., 1989, Deutsch et al., 2003; Florida Fish and Wildlife, 2007).

Most warm water discharges are found in central and south Florida. According to Deutsch et al. (2003) the majority of thermal basins are located in the southern one-third of the state. The capacity to sustain large numbers of manatees depends on the size of the refuge. Approximately 60% of manatees on the East Coast of Florida use the effluent from 10 power plants, while 15% use 4 natural warm water springs (Laist and Reynolds, 2005a). The remaining 25% of manatees in Florida are located along the Gulf coast and utilize separate warm water refuges.

Strong patterns of site fidelity to individual refuges or regional networks of refuges both natural and man-made bind Florida manatees into four relatively discrete subpopulations. Manatee populations in Florida are currently defined by the US Fish and Wildlife Service as distinct regional management units (4) (referred to as subpopulations) but are still considered to be a single stock (Figure 1). The Atlantic coast and the Upper East John's River are located on the East coast of Florida, while the northwest and southwest populations are located along the Gulf of Mexico (Haubold et al., 2006; Laist and Reynolds, 2005b; Marine Mammal Commission, 2007). The Atlantic coast subpopulation currently occupies the southern half of the state of Florida and includes Port Everglades.

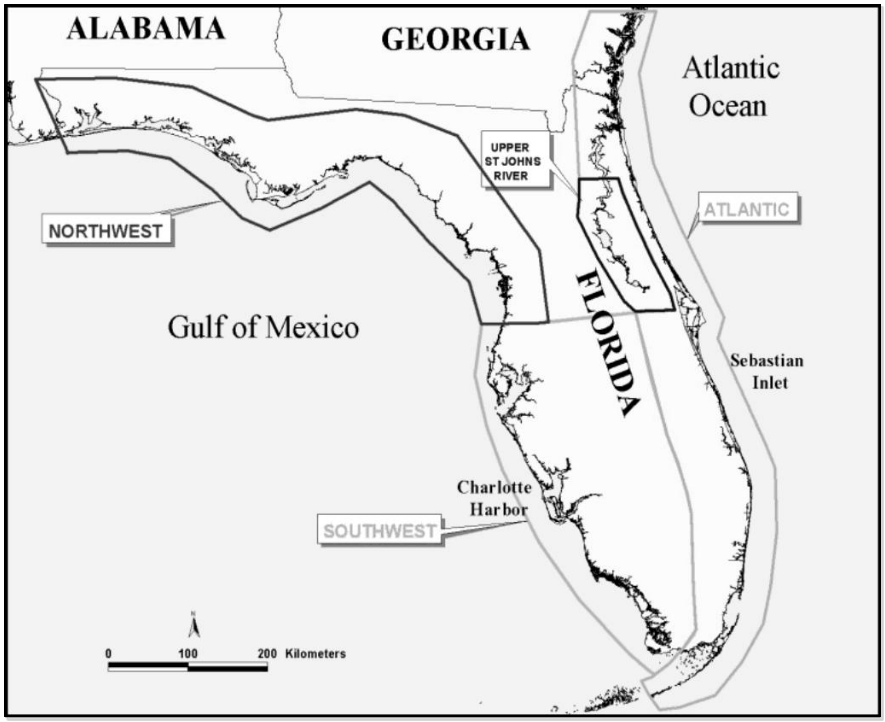

Figure 1: Florida manatees are divided regionally into four distinct management units, or sub populations, as defined by the US Fish and Wildlife Service. The northwest, southwest, upper St. John's River, and Atlantic subpopulations are noted above (US Fish and Wildlife Service, 2009).

The management unit construct was based on studies of regional manatee wintering sights and is useful for assessing population trends and threats that are specific to individual manatee units (Runge et al., 2004). Since significant genetic differences are identified between Florida manatees and manatees in Puerto Rico, with a gene flow barrier between them, the populations are designated as separate stocks (Vianna et al., 2006).

D. Threats

Biologists have collected statistics regarding manatee mortality in the state of Florida since 1974, with data collection conducted by the FFWCC since about 1985. The carcass salvage network has been quite effective, allowing scientists to gain knowledge on the causes of death for many manatees. Categories of death include watercraft, flood gate/canal lock, other human, perinatal, cold stress, natural, and unrecovered. While scientists can determine a number of causes for manatee death in Florida, there are always some that do not fall into any category, thus they are termed "unknown or undetermined" (Fish and Wildlife Research Institute, 2010).

Biological threats to manatees include red tide and morbillivirus. Human activities such as fishing, nutrient and chemical pollution, and impacts on the ozone layer contribute to and exacerbate the effects of red tide and morbillivirus (Gulland and Hall, 2007). Florida red tide is caused by the marine dinoflagellate *Karenia brevis*. During episodic blooms of *K. brevis*, a neurotoxin (brevetoxin) is released into the waters and the air. Exposure to red tide not only results in marine mammal deaths and fish kills but can have adverse affects on humans (Fleming et al., 2005). Red tide is a natural occurrence and has been documented in Florida since the 1800's. Because statistical data regarding manatee mortality were first recorded in the 1970's, there is little to no evidence that red tide had affected manatees before 1980 (no observation of red tide mortality until then). The epizootic nature of the red tide that occurred in 1996 caused the deaths of 151 manatees in Florida in a one month period (Marmontel et al., 1997; Tripp, 2009). The carcasses retrieved from this instance had a normal appearance and showed no signs of distress.

Morbilliviruses are recognized as widespread pathogens affecting pinnipeds and cetaceans, two orders of marine mammals. Morbillivirus first emerged during the 1988 seal epizootic, identified as the phocine distemper virus (PDV). Since that time it has been found in numerous other species of marine mammals (Rima et al., 1995). A study by Duignan et al. (1995) discovered the first evidence of morbillivirus in manatees, which were termed “immunologically naïve” due to their previous remoteness from harmful pathogens. Many separate populations of manatees have been affected, resulting in increased mortalities across all age classes (Rima et al., 1995; Duignan et al., 1995). Human impact such as ocean pollution can cause manatees to be increasingly susceptible to the morbillivirus, which results in an impaired immune system.

Manatees are also very susceptible to hypothermia in temperate latitudes and respond to cold water temperatures very quickly by moving south to warmer waters over periods of days to weeks (Buckingham et al., 1999; Deutsch et al., 2003). Manatees can cover up to 87 km/day during migration (Deutsch et al., 2003). Although their large size and the presence of blood vessels beneath the skin helps them to regulate temperature, a low tolerance for cold forces manatees to seek warm water refuges during winter months when water temperatures drop to levels between 20 and 22° C (Laist and Reynolds, 2005a,b).

Manatees are both adapted to and dependent upon natural and man-made warm water refuges. The importance of these areas has been well documented and has been determined to be among the most important manatee aggregation sites for the Atlantic population (Laist and Reynolds, 2005; Mezich, 2001; Broward County, 2007; Gannon et al., 2007). Manatees utilize these areas during winter months to maintain body heat (Reynolds and Wilcox, 1994; Alvarez-Aleman et al., 2010). Warm water refuges help manatees avoid cold related energy demands and stress related symptoms, although individual attributes such as age and health can affect thermoregulation ability (Bossart et al., 2003; Irvine, 2003; Walsh et al., 2005).

Chronic exposure to cold water will produce a number of disease processes termed cold stress syndrome (CSS) (Bossart et al., 2003). Cold stress syndrome is a disease process caused by multiple factors that compromises metabolic, nutritional, and immunological wellbeing. If a manatee cannot find a thermal refuge, its internal processes start to shut down and abscesses will form on the skin (Deutsch et al., 2003; Rommel and Caplan, 2003). Other common physiological symptoms of cold stress syndrome include weight loss, emaciation, fat atrophy, depletion of lymph organs, gastrointestinal disorders, and internal abscesses (Bossart et al., 2003). Although manatees are usually quite resilient to infections, they face other potential threats in addition to cold stress when they aggregate together, such as epizootic diseases and pollution (Bonde et al., 2006).

Trash and litter are other anthropogenic factors influencing manatee mortality. Manatees can become entangled in discarded fishing gear, resulting in amputated limbs and in severe cases, strangling (Tripp, 2009). Additionally, the wounds left behind by fishing lines or boat injuries can lead to infections which compromise immune function. Not only can the manatee become entangled, but ingesting trash and debris can kill vulnerable individuals through choking, gastro-intestinal blockage, or poisoning. Debris, such as monofilament line, bags, rope, hooks, paper, sponges, and cellophane, has been recovered from manatee stomachs during necropsies (Tripp, 2009).

E. Population Status

The Fish and Wildlife Research Institute (FWRI), a branch of the FFWCC, reported that the highest number of manatees counted in a statewide synoptic survey was 4,834 manatees (in January 2011).

The Florida manatee has no known predators aside from human beings, who no longer actively hunt manatees, but do contribute to the majority of mortalities. Alligators (*Aligator mississippiensis*), crocodiles (*Crocodylus acutus*), and sharks (Selachimorpha) can potentially take calves and scavenge carcasses (D. Odell, Pers. Comm.). The main cause of human-related manatee mortality in Florida since 1976 was boat collisions, comprising more than 30% of documented deaths per year (O'Shea et al., 2001; Read and Wade, 2000; Frisch and Haubold, 2003; Laist and Shaw, 2006). Manatees do have the cognitive and physical abilities to be able to recognize and avoid boats (Gerstein et al., 1999; Nowacek et al., 2004). Boaters are usually unable to observe and avoid manatees in a reliable manner, which prompted resource managers to establish boat speed zones to reduce the number of fatalities in areas where manatees and watercrafts are likely to interact (Laist and Shaw, 2006; Runge et al., 2007). Other deaths resulted from human inflicted trauma, flood gate entrapment, habitat destruction, pollution, debris, and cold winters (Buergelt et al., 1984; Langtimm et al. 1998).

F. Human Interactions

Manatees have three general responses to normal human activity: attraction, habituation, and avoidance. Although manatees are perceived to have a curious nature, they do not in general seek out human interactions. Increased levels of human activity (swimming or snorkeling near the manatees for example) have exacerbated the usual manatee responses (Garrott et al., 1994; Sorice et al., 2006). These changes in manatee responses included decreased resting and suckling and increased swimming (King and Heinen, 2004; Miksis-Olds et al., 2005).

Growing numbers of humans and boats, as well as coastal development, could potentially foreshadow an increase in manatee mortality (Marmontel et al., 1997; Nowacek et al., 2004; Solomon et al., 2004). As the human population grows, it stands to reason there will be a subsequent increase in boat owners living along the coast. Coastlines can be converted into residential properties and recreational areas that would likely bring more boat traffic. The adverse effects of watercraft on manatees are well documented (O'Shea et al., 2001; Gorzelany, 2004; Runge et al., 2007). Mortality due to boat collisions has the potential to affect manatee distributions. Despite the vast number of injuries and deaths that result from watercraft collisions, very few observations of these collisions or of manatee behavior around boats have been made (Wright et al., 1995; Wells et al., 1999). In addition to direct collisions, the increase of registered vessels in Florida have resulted in limitations to available protected space for manatees, increasing levels of harassment, and destruction of seagrass beds (the primary sources of food for manatees) (Gorzelany, 2004).

The increase in the human population and use of waterways utilized by manatees causes a conflict of use between the pressures of growing human populations and the limitations of coastal resources. The collective effects of human related mortalities, as well as loss of habitat, put the long term existence of the Florida manatee at risk (Wells et al., 1999; Flamm et al., 2005; Broward County, 2007). Anthropogenic noise produced from boats and other watercrafts and natural sources have the potential to affect manatees, with responses ranging from mild changes in behavior to extreme aversion (Miksis-Olds, 2008; Miksis-Olds and Wagner, 2011). Interestingly, the survival probabilities of manatees in the Atlantic region are lower and more variable than other regions in Florida, with manatees more impacted by human activities and encroachment (Langtimm et al., 1998; Runge et al., 2004).

Manatees have no visible external ears (Ketten et al., 1992). Through research testing the underwater audiograms of several Florida manatees it was determined that the manatee has a wide range of hearing and greater sensitivity to high frequency sound. Manatees peak hearing sensitivity falls between 16,000 and 18,000 hertz, and the sounds produced by most boats is below 1,000 hertz, which may be outside the lower fringes of the manatee's hearing range (Gerstein, 2002). The inability to hear or locate broadband low-frequency noise, such as that from idling boats, against wild ambient noise, may contribute to collisions (Gerstein et al., 1999; Gerstein, 2002), although research has shown that manatees can clearly hear and avoid boats (Nowacek et al., 2004).

Environmental noise, both anthropogenic and natural, has the potential to interfere with the acoustic communication between manatees. It may mask signals containing potentially important information. Miksis-Olds and Tyack (2008) determined that in areas where noise was elevated, manatee call rates decreased during feeding and other social behaviors. In addition, the extent of each type of call, including chirps and squeaks, was diversely influenced by the presence of calves. Their results suggest that ambient noise levels actually have a measurable effect on manatee vocalizations, and that manatees will modify their communications as a function of noise in explicit behavioral circumstances.

The combined effect of natural and human-related mortalities, along with habitat loss and low reproductive capacity, jeopardize the long-term existence of the Florida manatee populations. Since the Florida manatee is endangered, studies have been conducted to identify the main factors affecting manatee population projections in Florida. The most important variables were found to be adult survival and fecundity (Marmontel et al., 1997; Langtimm and Beck, 2003). The research determined that a 10% increase in adult mortality, or a 10% decrease in reproduction, would result in the population becoming extinct over a 1000 year time scale. It was concluded that conservation and management practices should focus on improving the environmental conditions in areas utilized by manatee populations in Florida (Langtimm et al., 1998; Flamm et al., 2005). Increase in human populations and subsequent development of the Florida coastline has led to concerns of declining manatee populations (Garrott et al., 1994; Bonde et al., 2006). High levels of human activity have also been observed to alter normal manatee behavioral patterns in designated sanctuaries (Miksis-Olds et al., 2004; Miksis-Olds, 2008).

G. Null hypotheses

The expected outcome from the study was construction and subsequent use of a bridge (Appendix 2) over the FPL canal effluent would have an effect on manatee use and age class composition. My first null hypothesis states that the construction of a new bridge over the FPL canal effluent would have no effect on the manatees utilizing the warm water discharge. The first alternative hypothesis states that the construction of a new bridge over the FPL canal effluent would have a negative impact on the manatees utilizing the warm water discharge. My second null hypothesis states that anthropogenic noise/disturbance, post construction, will have no effect on manatee composition. The second alternative hypothesis is that anthropogenic noise would alter the manatee age class composition.

H_o1 = The construction of the bridge over the FPL canal effluent would have no effect on the manatees utilizing the warm water discharge.

H_a1 = The construction of the bridge over the FPL canal effluent would have a negative impact on the manatees utilizing the warm water discharge.

H_o2 = The anthropogenic noise/disturbance, post construction, would have no effect on manatee age class composition.

H_a2 = The anthropogenic noise would have alter the manatee age class composition.

VI. THESIS STATEMENT

The purpose of this research project was to examine the effects of a new bridge (construction and operation) over the Florida Power and Light discharge canal at Port Everglades, Florida on wintering aggregations of Florida manatees (*Trichechus manatus latirostris*). The FPL effluent canal is used as an overwintering warm-water refuge by manatees. I compared pre-bridge (2004-2009), construction phase (November 2009-April 2010), and post-bridge construction data (November 2010-April 2011) to manatee presence or absence, age class, cow/calf pairing and activity during the winter season to determine if there was an effect on the presence/absence and age class of manatees utilizing the area. I also collected baseline data on the number and general age structure of the manatee population wintering in Port Everglades, Florida.

VII. MATERIALS AND METHODS

A. Study Area

This study took place between December 2009-March 2010 and December 2010-April 2011 in Port Everglades, Florida, located along the Atlantic coast in Broward County (Figure 2). Port Everglades is one of the nation's busiest seaports, with more than 5,300 cargo and cruise ships utilizing the area annually (Bell, 2000; US Army Corps, 2010). The Florida Power and Light (FPL) power plant is located within the confines of Port Everglades, and the effluent from this canal was the center for manatee congregation for this study and ones past. The FPL plant has four units with a total production capacity of 1,254 megawatts and a water flow of 800 million gallons per day (FDEP, 2008). Water flow and temperature vary depending on the number of units in usage; all four units are utilized during the peak times of the year (Bell, 2000).

FPL is required by their Manatee Protection Plan to maintain a constant ambient water temperature of 20º C during manatee season, from November 15th to March 30th (Walsh, 2010). The FPL effluent canal extends a total of 1,650 meters from the discharge site to the Intracoastal Waterway. Roughly one km of this area is a designated no entry zone (Bell, 2000). Part of the canal and the manatee lagoon are designated by the State of Florida as a no entry zone (Florida statute), and thus it is a safe haven for manatees during the winter. The effluent from the power plant is usually 10 to 15° C warmer than the surrounding waters in the Intracoastal Waterway during the winter months.

The study was conducted at three sample locations along the FPL effluent canal, chosen for monitoring purposes based on accessibility to the canal and precedents from previous studies. Locations included the Port Everglades Administration building boat dock, the North Bridge overpass and the effluent canal (Figure 3).

Figure 2: Imagery of Florida with Broward County outlined. The insert shows the location of Port Everglades (circle) within the county. Image taken from GoogleEarth.

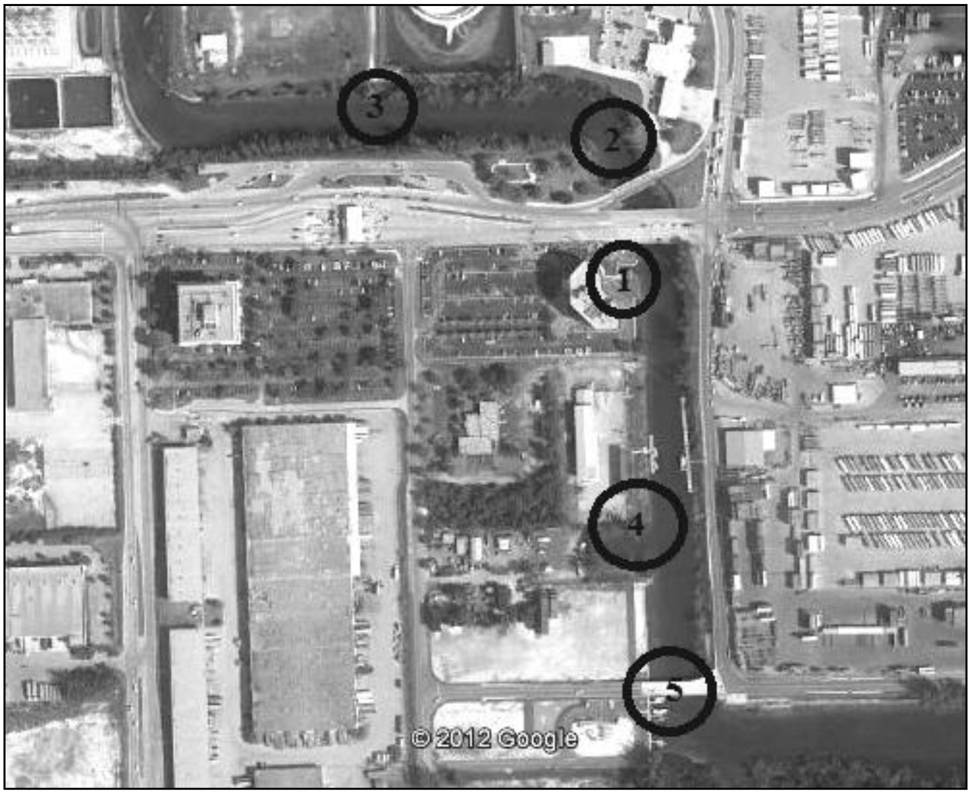

Figure 3: Imagery of Port Everglades cooling canal with manatee observation locations used during the current study, 'Manatee Lagoon,' and new bridge (1- Administration Building, 2- North Bridge, 3- Effluent Canal, 4-'Manatee Lagoon,' 5-'Manatee Crossing' Bridge). Image taken from GoogleEarth.

B. Survey Methods

Walking observation surveys were conducted by past students from December through March 2004 to 2011 (Hilliard, 2011; Rappucci, 2009; Walsh, 2009), although this study took place from December 2009 through March 2011. Data were collected once a day, 3-4 times per week at varying times of day. Observation duration ranged from 45 to 60 minutes, with 15-20 minutes spent at each of the three locations. More or less time was spent at each location depending on the number of manatees present, weather conditions and water visibility.

The total length of the walking observation surveys along the discharge canal was approximately 500 meters, including a small boat dock near the Port Everglades Administration Building. Due to terrain, a large portion of the canal, including the “Manatee Lagoon” located near the mouth of the canal, was inaccessible. The manatee lagoon is a deepened area in the southern portion of the FPL discharge canal (Figure 3).

Polarized sunglasses were utilized by the observer on every survey, to function as glare reducers and thus improve visibility through the water. Polarization enabled more accurate manatee observation and age class determination. Observations were made during the surveys on the number of manatees at each sample location, which were then categorized based on size as adult, juvenile, or calf. Calves were classified as those less than half the length of a closely associated adult (Irvine and Campbell, 1978) and juveniles were classed as individuals of intermediate size not in close proximity to an adult (Bengston and Magor, 1979). In general calves are almost always seen travelling with an adult.

Manatees can rest below the surface for up to 20 minutes before surfacing to breathe. As they surface, they lift their nostrils out of the water, expelling a breath and taking in new air before slowly descending beneath the surface. In addition, manatees swimming beneath the surface of the water may not have been visible at first glance. When they swim, they will leave what is known as a footprint on the surface; a footprint is an oval shaped disturbance on the water where a manatee’s paddle brushes the surface. An observer may be able to follow the pattern of a manatee’s footprint while waiting for the animal to surface and breath. Often, footprints and breath sounds were utilized to locate non-visible manatees in the field. It was important to sit at each survey location for 15-20 minutes to be certain that no resting manatees were overlooked.

Observations also included the activity of the manatees in the area (whether resting, travelling or milling) and the number of cow/calf pairs. Surface water temperatures in degrees Celsius were recorded at the three sample locations during each survey, along with atmospheric and meteorological conditions, tidal state, and ambient air temperature. Surface water temperature was recorded using a Raytek Raynger ST® temperature meter, a portable, handheld thermometer that can read the surface water temperature at several meters distance. This was useful in determining the temperature of areas that were inaccessible without damage to the observer or equipment. Sample daylight times were chosen at random by the surveyor. All information was recorded on a standard Manatee Observation Sheet (Appendix 1) that was modified and expanded from earlier surveys.

C. Abundance Data

A total of 68 walking surveys were conducted during the current study. As the winter season spans the end and beginning of a calendar year, the winter seasons are listed as year 1 (2004-2005), year 2 (2005-2006), year 3 (2006-2007), year 4 (2007-2008), year 5 (2008-2009), year 6 (2009-2010), and year 7 (2010-2011). All data from November year 5 (pre-bridge construction) through April year 7 (post-construction) were used to examine the relative manatee abundance by month as well as season. Data collected from year 1 through year 4 were included in the analyses and were collected by a different set of observers.

Due to incomplete surveys and an unequal number of surveys (per month and/or season), total survey effort (TSE) was used to calculate monthly and seasonal indices. TSE is equivalent to the number of surveys completed during a particular time (during the survey month) (Nabor and Patton, 1989). The total number of manatees that were observed in a particular winter season was divided by the number of surveys conducted during that season. In addition, the total number of manatees observed in a certain month was divided by the number of surveys that were conducted in that month. For example, if 5 surveys were conducted in December of 2004 and a total of 49 manatees were observed, the total survey effort for total manatees in December 2004 would be 49 ÷ 5 = 9.8. There are no units used for total survey effort. The monthly index was used to determine the relative abundance of adults, juveniles and calves observed in each month during the different winter seasons. An average water temperature was also calculated as well as a standard deviation for each month in a season. This was used to examine how changes in water temperature in the different months could affect manatee abundance.

Because all data were normally distributed, no data transformations were required. PRIMER 6 software (PRIMER-E Ltd, Lutton, UK) was used to conduct a Bray-Curtis (Bray and Curtis, 1957) analysis to determine the significance of differences seen in the seasonal index. Regression techniques were performed to ascertain the relationship between monthly and yearly average temperatures and manatee abundance (Hilliard, 2011; Rappucci, 2009; Walsh, 2009) with the resultant regressions compared to data from the current study. There were a total of 42 months of data comparing average temperature and manatee abundance between January 2004 and March 2011 (Hilliard, 2011; Rappucci, 2009; Walsh, 2009).

A power analysis was also used to calculate the minimum sample size that would be required to detect any effect. Power analysis can also be used to calculate the minimum effect size that is likely to be detected in a study using a given sample size. Parametric statistics were used for analysis of presence, absence, age class, and temperature. An analysis of variance test (ANOVA) was used to compare data between years. A Student's t-test was performed on average total numbers versus average age classes to determine the significance of any differences (Zar, 2009).

A Poisson distribution regression model was utilized, where the difference in the number of manatees present was seen as a function of month, year, and water temperature (Hardigan, Pers. Comm, August 2011, Nova Southeastern University.). With the Poisson model, a negative binomial regression was conducted for all analyses. The model included month and year of observation and water temperature. The Poisson regression has the following properties: the results of the experiment can be classified as successes or failures, the average number of successes (μ) that occurred in a particular region is known, and the probability that a success will occur is proportional to the size of the region. The Poisson distribution is used to model the number of evens that occur within a given time interval, and can also be used to test whether mutation frequencies differ from control frequencies (Zar, 2009). The p-value for significance (α) used for all statistics was 0.05.

VIII. <u>RESULTS</u>

A. Temperature Data

No manatees were present at the survey sites during winter until surface water temperatures fell below 22º C. Average daily water temperatures ranged from 17.5º C to 29.6º C. Monthly mean surface water temperatures were not statistically different between years 5, 6, and 7 (21.9±0.4º C, 21.8±1.8º C, and 21.4±0.6º C respectively); however, total manatee abundance did vary significantly (ANOVA, t-test, Poisson $\alpha < 0.05$).

Over the three years of this study, there was no significant difference in the mean ambient water temperature recorded between seasons at the FPL site (ANOVA $\alpha > 0.05$). Average surface water temperatures in degrees Celsius during the winter manatee season from year 1 to year 7 were fairly consistent (Figure 4). The highest seasonal water temperature was seen during year 3 with a high of 24.5 ± 0.4º C SD, while the lowest seasonal water temperature was observed during year 5 (17.5 ± 0.3º C SD). There were no significant differences found between years for average ambient water temperature in Port Everglades, FL. Water temperature versus total manatee abundance shown as total survey effort (TSE) showed an inverse relationship (Figure 5). Higher water temperatures correlated with lower manatee abundance. Years 6 and 7 were exceptions, showing low abundance despite the decrease in water temperatures.

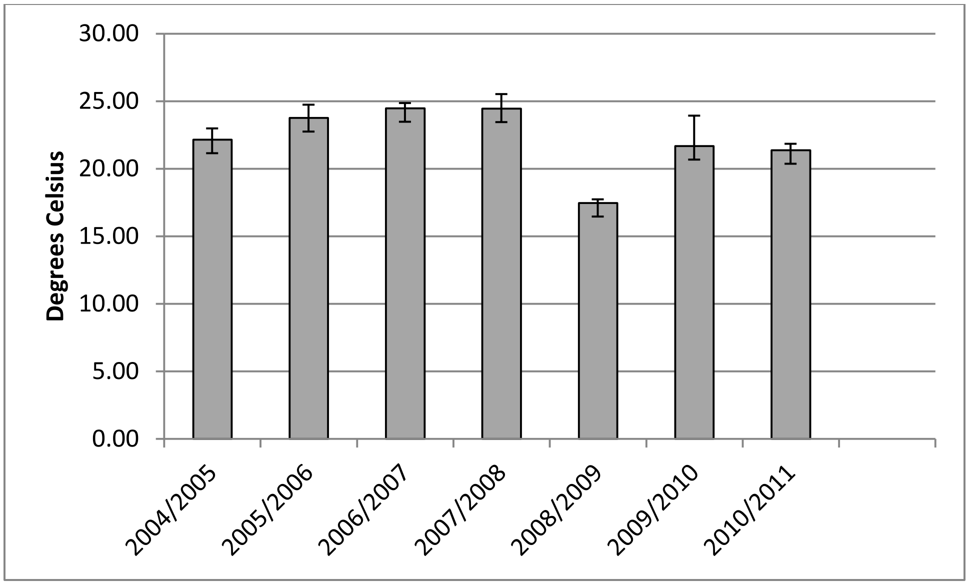

Figure 4: Average water temperatures per winter season 2004-2011in Port Everglades, FL. Error bars show standard deviation. There were no significant differences observed.

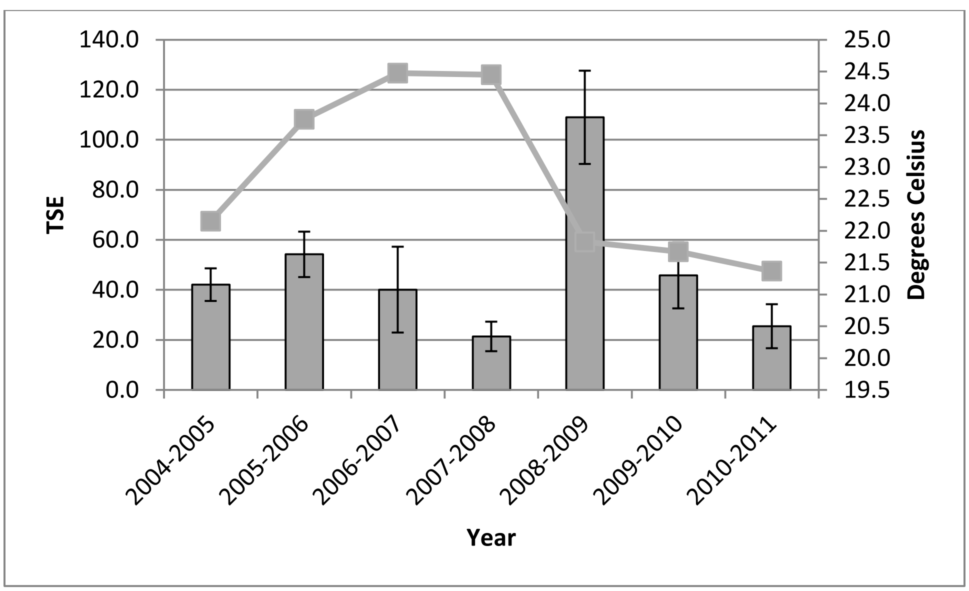

Figure 5: Total abundance as total survey effort per winter season 2004-2011 versus average surface water temperature in Port Everglades, FL. Error bars show standard deviation. Water temperature is noted on the secondary y-axis.

March of year 6 had the lowest monthly water temperature of any winter season (19.6 ± 2.3º C) (Figure 6). Only 15 manatees were observed during this month, which was a decrease in number from the previous month (64 total manatees). Year 6 had the greatest fluctuation in surface water temperature per month, from a high of 24.8º C during December to a low of 19.6º C in March, and an average decrease in temperature of 1.3º C per month. Water temperatures pre- and post-bridge construction (year 5 and year 6, respectively) were not significant (t-test, $\alpha > 0.05$).

B. Abundance Data

Total data were compiled for winter seasons from year 1 to year 7. From year 1 to year 7 a total of 2,827 manatees were observed in the FPL discharge canal. Year 2 (703) and year 6 (819) had the highest actual counts of manatees observed. There were a total of 751 manatees sighted during the 68 surveys conducted between December year 6 and March year 7. Year 5 had higher average numbers of manatees per survey from December through March (monthly mean= 29, 29, 48, 3 respectively) than year 6 (monthly mean= 0, 30, 11, 5 respectively) and year 7 (monthly mean= 19, 7, 0, 0 respectively) for the same months. Due to incomplete surveys and an unequal number of surveys (per month and/or season), total survey effort (TSE) was used to calculate monthly and seasonal indices. TSE is equivalent to the number of surveys completed during a particular time, in this case, the survey month.

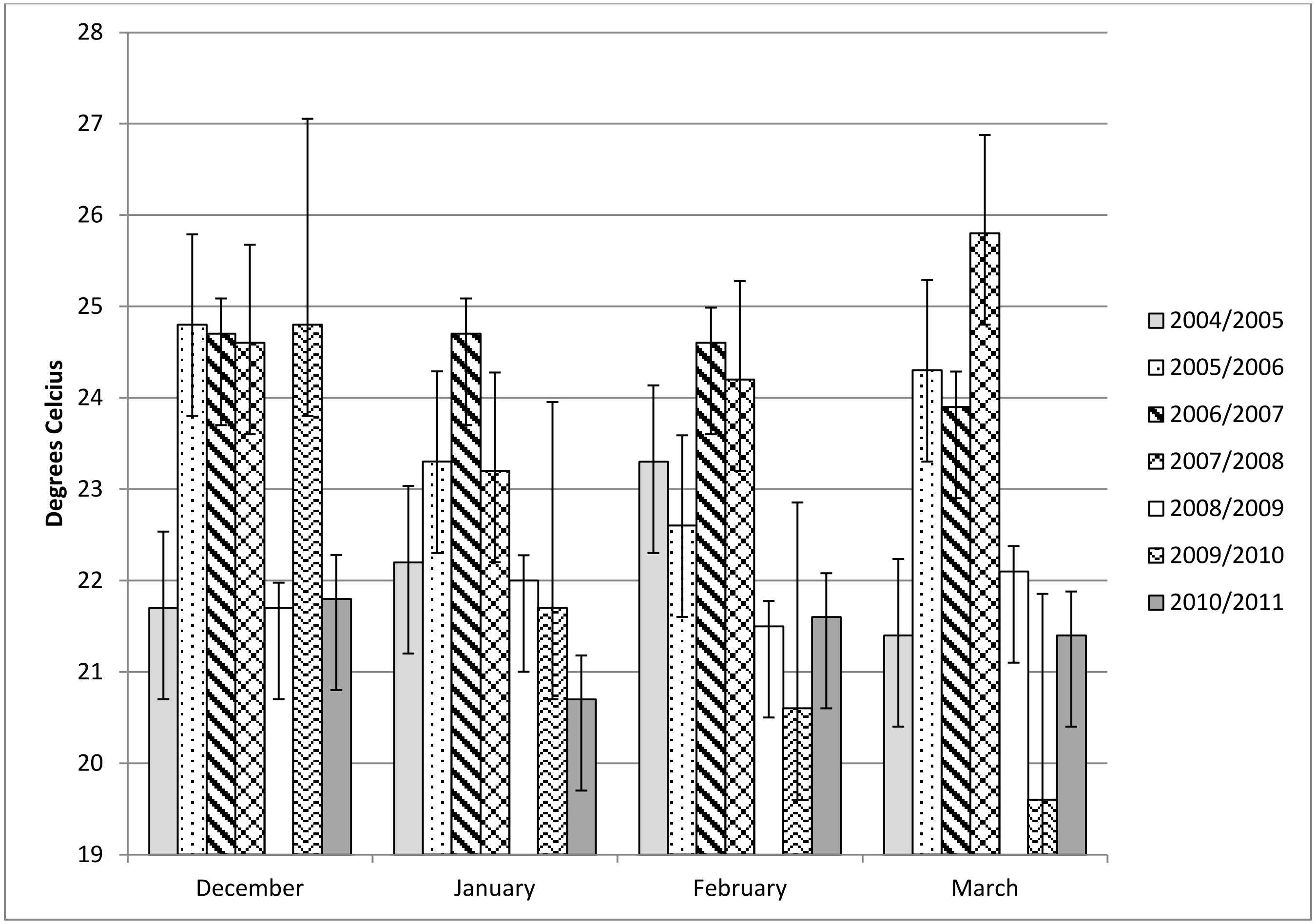

Figure 6: Average monthly water temperatures by month during winter season, 2004-2011, in the FPL discharge canal. Error bars represent standard deviation.

During the post-construction phase (year 5), based on TSE, approximately 109 manatees were observed, with 95 adults (88%), 8 juveniles (7%), and 6 calves (5%). For year 6, based on TSE, approximately 46 manatees were observed during the surveys, 40 adults (86%), 2 juveniles (5%), and 4 calves (9%). The average seasonal water temperature was 22º ± 1.8 C. In year 7, based on TSE, approximately 26 manatees were observed, 17 adults (65%), 4 juveniles (16%), and 5 calves (19%) (Figure 7). The average surface water temperature was 21º C. Error bars show standard deviation. The standard deviations for year 7 were very low and are not visible on the Figure 7 chart area.

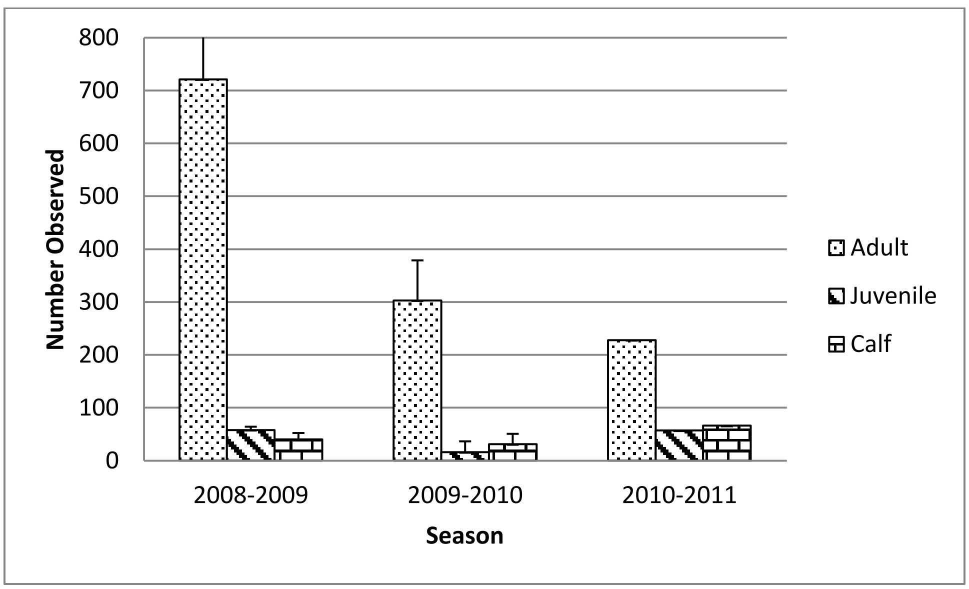

Figure 7: The number of total manatees observed per winter season of years 5, 6, and 7 with error bars showing standard deviation. Error bars for 2010-2011 are present although not visible.

The total number of manatees sighted and counted during the winter season by month from year 1 to year 7 was compiled (Table 1). The highest one month count occurred during February year 5, with a total number of 432 manatees sighted. The lowest total number of manatees counted occurred in year 4 (178), with the highest total number of manatees counted (819) in year 5, both bridge pre-construction years. Counts based on TSE are visible beneath actual count data in Table 1. There were higher counts of adults than any other age class, with significantly lower juvenile and calf counts. Juvenile numbers were lower than observed calves. The number of adults decreased from year 6 to 7, although average ambient water temperatures stayed the same (Figure 7).

Table 1: Total number of manatees observed and counted versus number of manatees based on TSE during the winter season from 2004-2011 in FPL discharge canal.

	Total Number of Manatees						
Month	**2004-2005**	**2005-2006**	**2006-2007**	**2007-2008**	**2008-2009**	**2009-2010**	**2010-2011**
December	49	118	18	2	176	0	243
January	102	328	4	138	203	271	107
February	27	249	214	30	432	64	1
March	8	8	5	8	8	15	0
TOTAL	**186**	**703**	**241**	**178**	**819**	**350**	**351**

	Number of Manatees based on TSE						
Month	**2004-2005**	**2005-2006**	**2006-2007**	**2007-2008**	**2008-2009**	**2009-2010**	**2010-2011**
December	10	7	3	1	29	0	19
January	17	22	0	14	20	30	7
February	14	15	36	5	48	11	0
March	2	1	1	2	3	5	0
TOTAL	**43**	**45**	**40**	**22**	**100**	**46**	**26**

A significant difference in the adult manatee count was observed between year 5 (pre-construction) and year 7 (post-construction) (Poisson $\alpha < 0.05$) (Table 2). During the analysis the counts were controlled for water temperature, month, and year. All data were standardized based on total survey effort. Statistically significant estimates have confidence intervals that do not include zero. There were no statistically significant differences seen for juvenile manatees during the study years based on actual count data or standardized data (Poisson, ANOVA $\alpha > 0.05$) (Table 3).

Table 2: Number of adult manatees observed in FPL discharge canal for 2004-2011 based on TSE with pairwise comparisons and confidence interval of differences. Significant p-values are noted with an asterisk. Confidence intervals that do not include zero are significant ($p < 0.05$).

Total Number of Manatees from 2004-2011				
Year	**Contrast**	**Std. Err.**	**Bonferroni**	**95% Conf. Intervals**
1 vs 2	7.26	6.99	-13.97	28.49
1 vs 3	4.34	7.73	-19.16	27.84
1 vs 4	0.55	7.71	-22.86	23.97
1 vs 5	16.13	6.27	-2.93	25.19
1 vs 6	2.10	6.31	-17.08	21.27
1 vs 7	-4.22	6.43	-23.75	15.31
2 vs 3	-2.92	6.40	-22.37	16.53
2 vs 4	-6.70	7.30	-26.12	12.71
2 vs 5	8.87	7.46	-13.30	31.04
2 vs 6	-5.16	7.80	-27.83	17.51
2 vs 7	-11.47	6.24	-35.18	12.23
3 vs 4	-3.78	8.13	-22.75	15.18
3 vs 5	11.79	8.33	-12.91	36.49
3 vs 6	-2.24	8.73	-27.54	23.06
3 vs 7	-8.55	8.10	-35.08	17.98
4 vs 5	15.57	8.30	-9.03	40.17
4 vs 6	1.54	8.70	-23.66	26.74
4 vs 7	-4.77	8.70	-31.20	21.66
5 vs 6	-14.03	6.24	-33.01	4.96
5 vs 7*	-20.34*	6.31*	-39.50*	-1.19*
6 vs 7	-6.31	6.27	-25.36	12.73

Numeric Label; Years	
1	2004-2005
2	2005-2006
3	2006-2007
4	2007-2008
5	2008-2009
6	2009-2010
7	2010-2011

Table 3: Number of juvenile manatees observed in FPL discharge canal for 2004-2011 based on TSE with pairwise comparisons and confidence interval of differences. Significant p-values are noted with an asterisk. Confidence intervals that do not include zero are significant ($p < 0.05$).

Number of Juvenile Manatees from 2004-2011				
Year	**Contrast**	**Std. Err.**	**Bonferroni**	**95% Conf. Intervals**
1 vs 2	-1.67	0.95	-4.57	1.22
1 vs 3	-1.39	1.05	-4.59	1.81
1 vs 4	-1.45	1.05	-4.64	1.75
1 vs 5	-0.39	0.86	-2.99	2.21
1 vs 6	-1.19	0.86	-4.53	0.70
1 vs 7	-1.34	0.88	-4.00	1.32
2 vs 3	0.28	0.87	-2.37	2.94
2 vs 4	0.23	0.87	-2.42	2.88
2 vs 5	1.28	1.00	-1.74	4.31
2 vs 6	-0.24	1.02	-3.33	2.85
2 vs 7	0.34	1.06	-2.90	3.57
3 vs 4	-0.06	0.85	-2.64	2.53
3 vs 5	1.00	1.11	-2.37	4.37
3 vs 6	-0.53	1.14	-3.98	2.92
3 vs 7	0.05	1.19	-3.57	3.67
4 vs 5	1.05	1.10	-2.30	4.41
4 vs 6	-0.47	1.13	-3.91	2.97
4 vs 7	0.11	1.18	-3.50	3.71
5 vs 6	-1.52	0.85	-4.11	1.07
5 vs 6	-0.95	0.86	-3.56	1.67
6 vs 7	0.58	0.85	-2.02	3.17

Numeric Label; Years	
1	2004-2005
2	2005-2006
3	2006-2007
4	2007-2008
5	2008-2009
6	2009-2010
7	2010-2011

For the survey seasons, year 5 pre-construction saw a higher mean adult abundance based on TSE (95) than construction or post-construction phase. The highest number of adult counts per survey effort were seen in year 5 (95), with the lowest counts appearing in year 1 (29), year 4 (17), and year 7(17). For the study years, no other significant differences were seen for adult manatee counts (Figure 8).

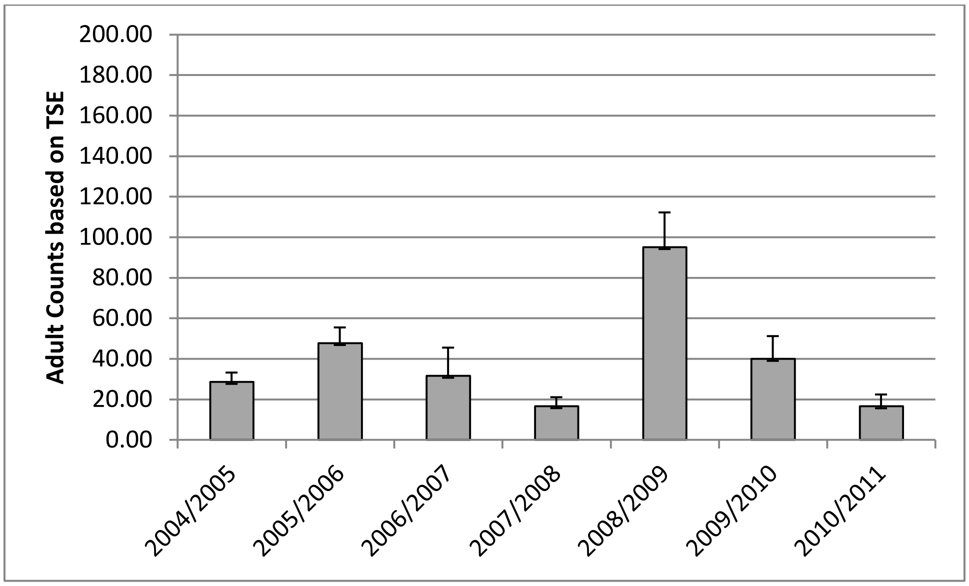

Figure 8: Adult abundance for manatee season based on TSE for 2004 to 2011. Error bars are standard deviation. Data were not transformed and can be found in Table 2.

Low numbers of juvenile and calf age classes were consistently observed for the study years (Table 3, 4, and Figure 9). These data were controlled for water temperature during the analysis. The number of juvenile manatees per survey effort remained constantly low across all winter seasons. Analysis showed no significant difference in juvenile abundance (Poisson α =1.00). The lowest number of juvenile manatees per survey effort was observed during year 6, construction phase (4) (Figure 9).

The total number of calves observed per survey effort showed no trend across seasons. The lowest number of calves were observed during year 1(4) and year 4 (4), with the highest number observed during year 2 (6), year 5 (6), and year 7 (17) (Figure 10). Poisson analysis of standardized count data showed no significant difference of manatee counts across the study years (Table 4).

For all three survey years (years 5, 6, and 7), adult manatees were observed most often (82% of the total count) while calves (9%) and juveniles (9%) were equally observed in low numbers. The number of juvenile manatees and calves varied by month and season, and were always less than the number of adult sightings per survey effort. Only juveniles (1) were observed during March year 7 (Figure 10). Year 5 had the highest total number of manatees observed (Figure 11).

Table 4: Number of manatee calves observed in FPL discharge canal for 2004-2011based on TSE with pairwise comparisons and confidence interval of differences. Significant p-values are noted with an asterisk. Confidence intervals that do not include zero are significant ($p < 0.05$).

Number of Manatee Calves from 2004-2011				
Year	**Contrast**	**Std. Err.**	**Bonferroni 95% Conf. Intervals**	
1 vs 2	0.72	0.86	-1.90	3.34
1 vs 3	0.51	0.95	-2.38	2.41
1 vs 4	-0.37	0.95	-3.25	2.52
1 vs 5	0.45	0.77	-1.90	2.80
1 vs 6	-0.06	0.78	-2.43	2.30
1 vs 7	0.08	0.79	-2.32	2.49
2 vs 3	-0.20	0.79	-2.60	2.19
2 vs 4	-1.09	0.79	-3.48	1.31
2 vs 5	-0.27	0.90	-2.99	2.47
2 vs 6	-0.78	0.92	-3.58	2.01
2 vs 7	-0.63	0.96	-3.56	2.29
3 vs 4	-0.88	0.77	-3.22	1.46
3 vs 5	-0.06	1.00	-3.11	2.98
3 vs 6	-0.58	1.03	-3.70	2.54
3 vs 7	-0.43	1.08	-2.21	2.84
4 vs 5	0.82	1.00	-2.80	3.85
4 vs 6	0.30	1.02	-2.81	3.41
4 vs 7	0.45	1.07	-2.81	3.71
5 vs 6	-0.52	0.77	-2.86	1.82
5 vs 7	-0.37	0.78	-2.73	1.99
6 vs 7	0.15	0.77	-2.20	2.50

Numeric Label; Years

Numeric Label	Years
1	2004-2005
2	2005-2006
3	2006-2007
4	2007-2008
5	2008-2009
6	2009-2010
7	2010-2011

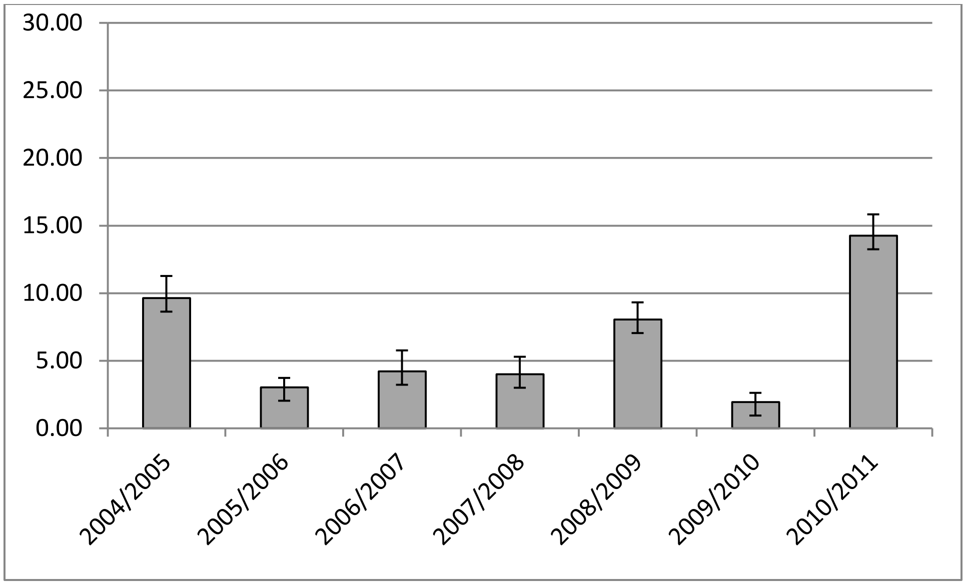

Figure 9: Juvenile abundance for manatee season based on TSE for 2004 to 2011. Error bars are standard deviation. Data were not transformed and can be found in Table 4.

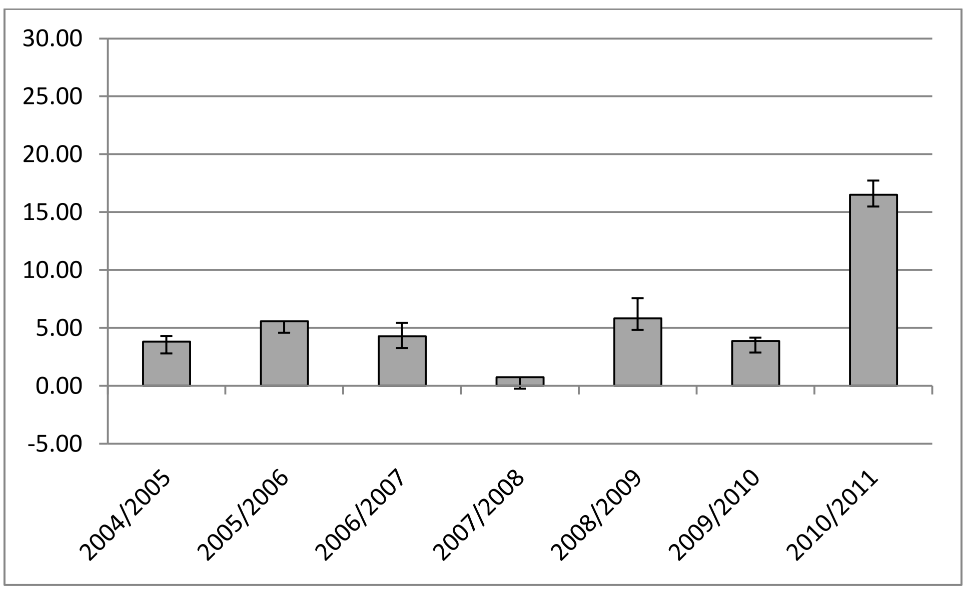

Figure 10: Calf abundance for manatee season based on TSE for 2004 to 2011. Error bars are standard deviation. Data were not transformed and can be found in Table 4.

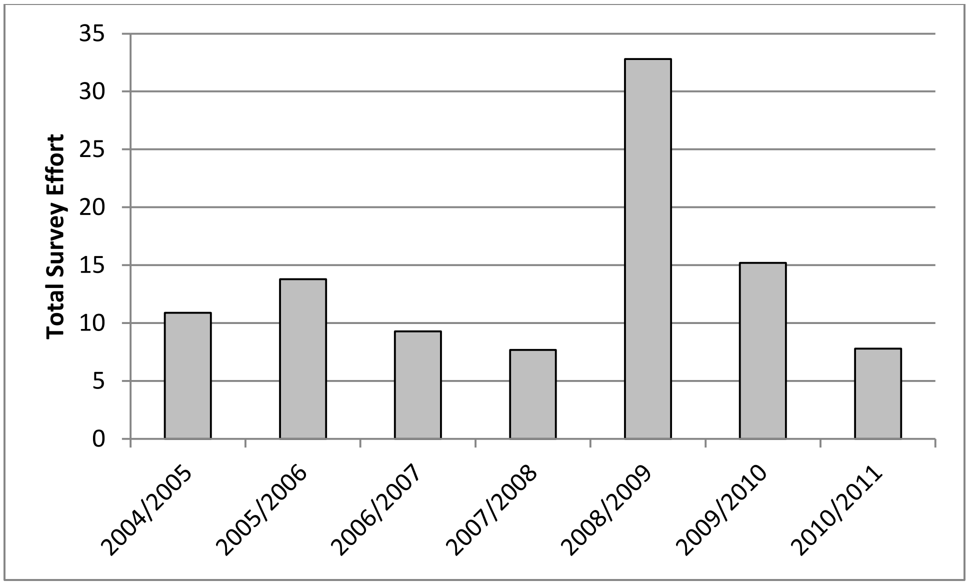

Figure 11: Seasonal index of manatee sightings as total number observed per survey effort for each manatee season for 2004-2011.

March yielded the lowest number of overall sightings reported for any month of the winter seasons (Figure 12). February of year 5 had the greatest number of overall manatees per survey effort for any month of any season (48). February of year 3 also had a high number of total manatees per survey effort (36).

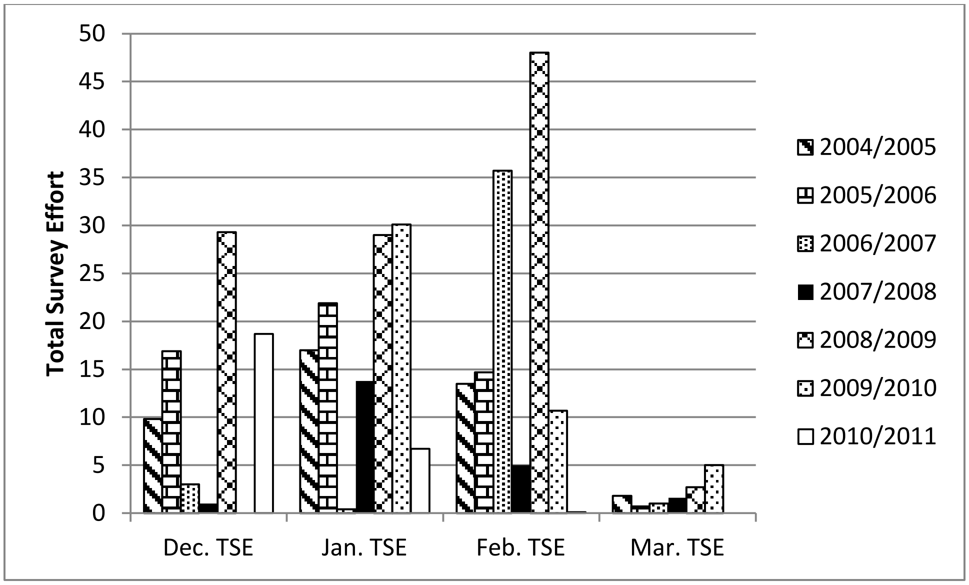

Figure 12: Monthly index of manatee sightings as total number per survey effort by month for each year.

For year 1, the number of adult manatees per survey effort was greater than any other age class observed, with numbers increasing from December to January before decreasing during February. The number of juvenile manatees followed the same trend. The number of adults dramatically decreased from February to March. The observed number of calves per survey effort remained at approximately one individual during these months (Figure 13). A similar trend was noted for year 2. However, there were a greater number of calves observed than juveniles in this instance. The number of juveniles reported remained fairly constant for December and January, and then dropped in February before bottoming off at zero for the month of March (Figure 14). Adults were the only age class observed during March of year 2.

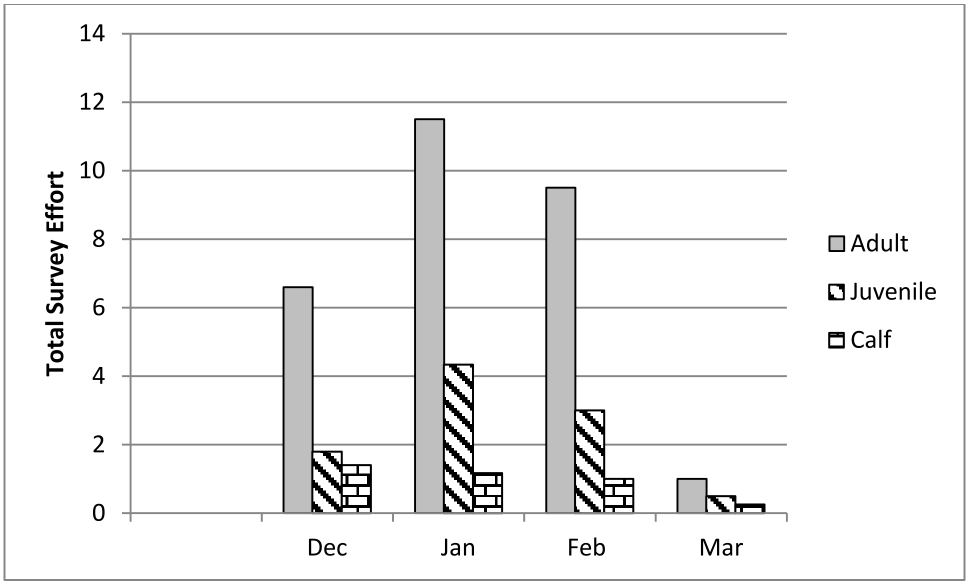

Figure 13: Monthly index of adult, juvenile, and calf manatee sightings as number per survey effort for each month of year 1 (2004-2005).

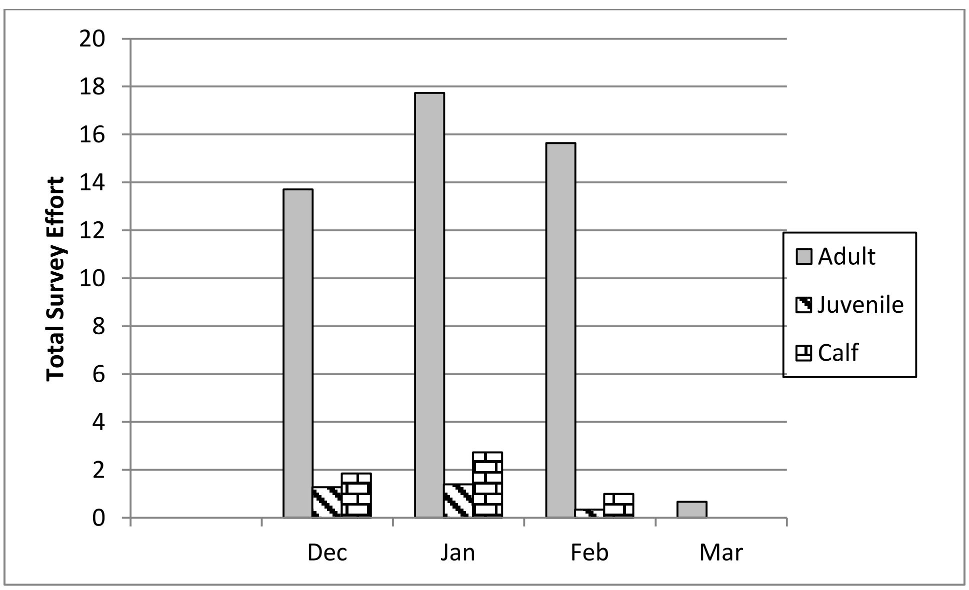

Figure 14: Monthly index of adult, juvenile, and calf manatee sightings as number per survey effort for each month of year 2 (2005-2006).

Year 3 differed from other seasons; the number of adult manatees per survey effort decreased to zero in January then dramatically increased to approximately 30 in February, the highest of all previous adult sightings (Figure 15). There were no calves observed in January or March, although all three age classes were observed in February. For year 4 only adults were observed during December. Adult counts rose during January, and then declined in February and March (Figure 16). The highest numbers of juveniles were observed in January, with lower counts for February and March. A small number of calves were reported for January and February before the count decreased to zero in March.

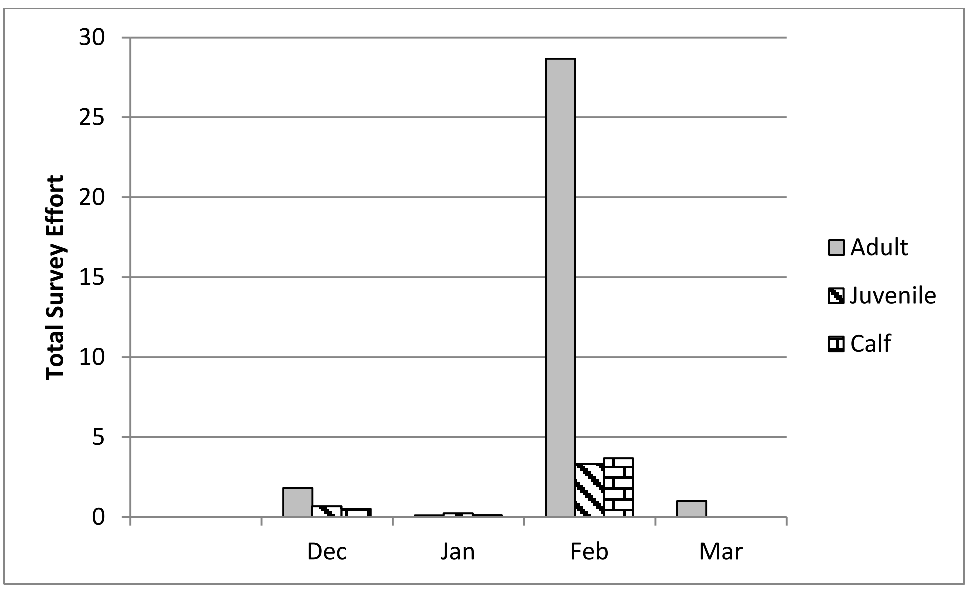

Figure 15: Monthly index of adult, juvenile, and calf manatee sightings as number per survey effort for each month of year 3 (2006-2007).

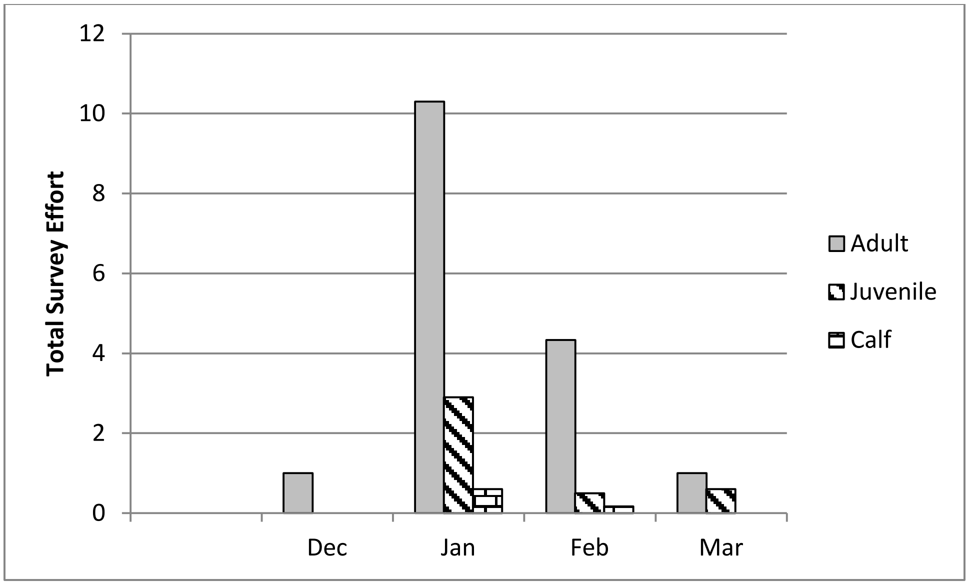

Figure 16: Monthly index of adult, juvenile, and calf manatee sightings as number per survey effort for each month of year 4 (2007-2008).

For year 5, high numbers of adult manatees per survey effort were observed during all months of the season with the exception of March. Numbers of observed juveniles and calves per survey effort behaved similarly. The greatest number of manatee sightings per survey effort was recorded during year 5 (92), with the highest counts reported in February instead of January (Figure 17). From December to March an inverse relation between the number of adults and juveniles per survey effort and temperature was observed with the monthly fluctuations.

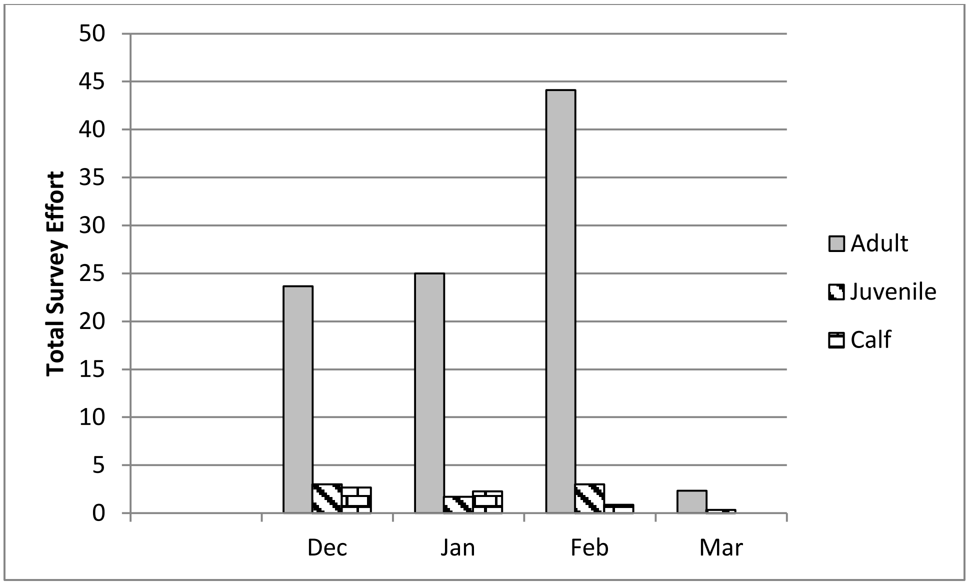

Figure 17: Monthly index of adult, juvenile, and calf manatee sightings as number per survey effort for each month of year 5 (2008-2009).

There were no manatees observed during December, though the adult count jumped drastically from December to January in year 6. The number of adults decreased from January to March. The number of juveniles and calves remained low for each month, with the juvenile count reduced to zero during March (Figure 18). There were high counts of adults compared to other age classes. A higher number of adults were seen than any other age class during year 6.

Year 7 showed a similar trend, with all age class counts decreasing as the months progressed (Figure 19). There were no manatees observed during March of year 7. Only one individual juvenile manatee was sighted in February. December had high counts of each age class, with adults compromising the highest number of manatees observed and juveniles coming in second, followed by calves. The number of juveniles per survey effort decreased during January, with higher number of calves seen than juveniles.

Average ambient water temperatures for each year are almost equal, showing that count trends were not dependent on water temperature.

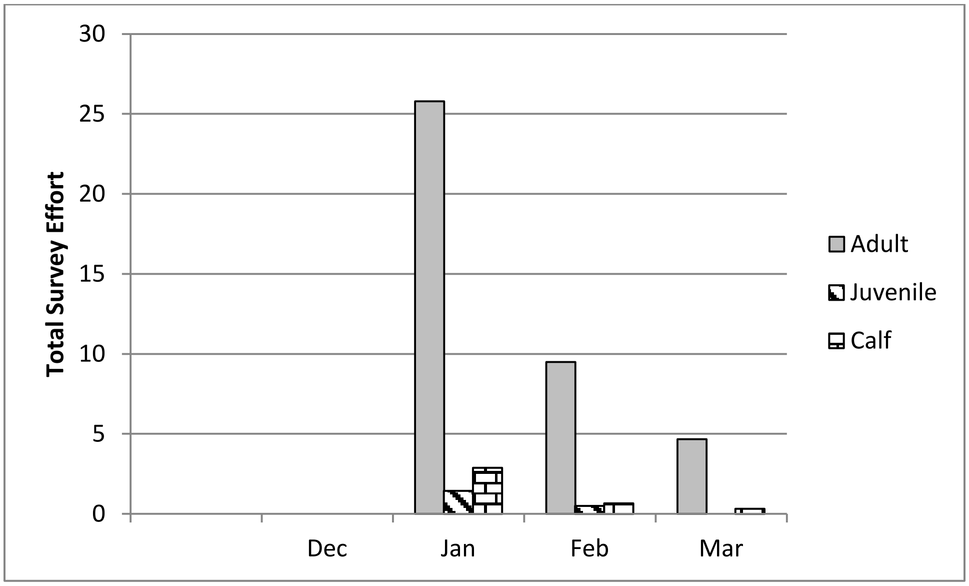

Figure 18: Monthly index of adult, juvenile, and calf manatee sightings as number per survey effort for each month of year 6 (2009-2010).

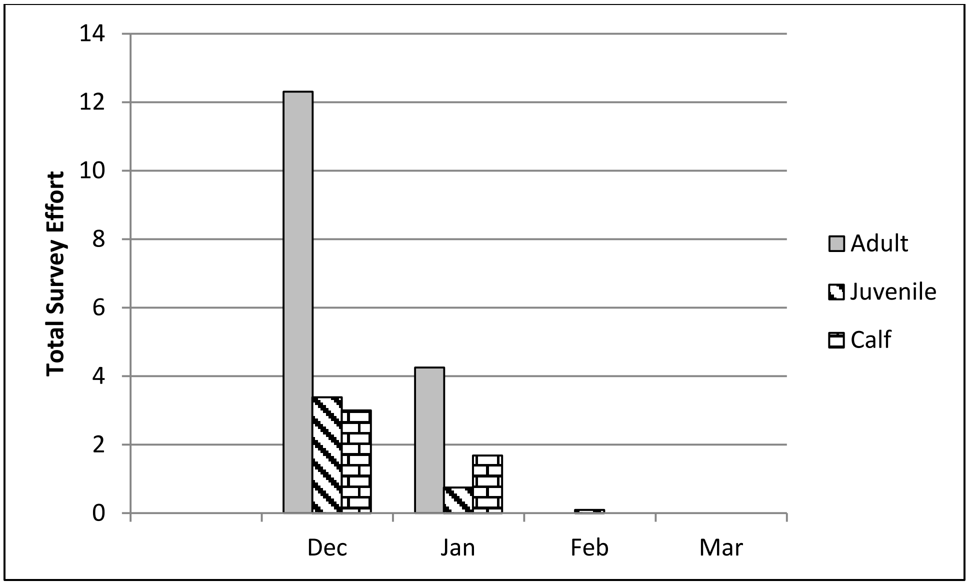

Figure 19: Monthly index of adult, juvenile, and calf manatee sightings as number per survey effort for each month of year 7 (2010-2011).

A Student's t-test was performed in MATLAB for adult manatee counts pre- versus post-construction (year 5 versus year 7). The results were not significant ($\alpha > 0.05$, DF = 12). The R^2 value for the correlation between the parameters of average water temperature and manatee abundance in Port Everglades was approximately 0.5 for the study years. A power analysis was performed, and the expected power was approximately 1.00 and the expected beta level (type II error rate) was 1×10^{-6}. This means that there was a high probability of detecting a change in manatee abundance due to any factor using the data.

IX. <u>DISCUSSION</u>

A. Temperature Data

Water temperature is known to impact the local abundance of the Florida manatee, with results from previous studies showing that deviations from typical migration patterns are related to differences in winter temperatures (Edwards et al., 2007). Weather patterns are also known to impact the migration of manatees (Deutsch et al., 2003). For example, low calf abundance at man-made warm water refuges have been shown to be associated with mild winters (Reynolds and Wilcox, 1994). Over the winter seasons of this study, higher numbers of adult manatees were observed, compared with low numbers of both calves and juveniles. Juveniles are more susceptible to cold-stress, and may stay in their warm water refuges longer to avoid cold-related energy demands (Laist and Reynolds, 2005b).

Manatee movement is closely tied to winter weather and the time at which Florida manatees begin utilizing warm water aggregation sites (Deutsch et al., 2003). Seasonal manatee migrations can vary depending on the incidence of cold fronts, as well as the intensity of the cold. Manatees begin migrating south after a drop in air and water temperatures. In Port Everglades, the majority of animals aggregate by January (Reynolds and Wilcox, 1994). The data fit this pattern for four out of the seven manatee seasons covered by this study (years 1, 2, 4, and 7). For years 3, 5, and 6, the number of manatees observed decreased from December to January. These years had the least temperature fluctuations. Year 3 was consistently warm, while years 5 and 6 showed uninterrupted low temperatures. For example, March of year 6 had the coldest monthly temperature of any season, with a low of 19.6º C, although 15 manatees were observed, a decrease in number from the previous, warmer month (64) (Figure 20). Manatee movement may also be affected by the decommissioning of power plants, although any plants being shut down in Tampa or Jacksonville would have minimal effects on the Port Everglades manatee population.

The results of this study demonstrated that there was no significant difference in mean ambient water temperature between years 5, 6, and 7. This indicated that discharge canal water temperature had little to no effect on the numbers of manatees present at the Florida Power and Light discharge canal in Port Everglades, nor did it affect the age classes of manatees utilizing the warm water refuge during these years. Water temperature changes could not have influenced the number of manatees across the three study years.

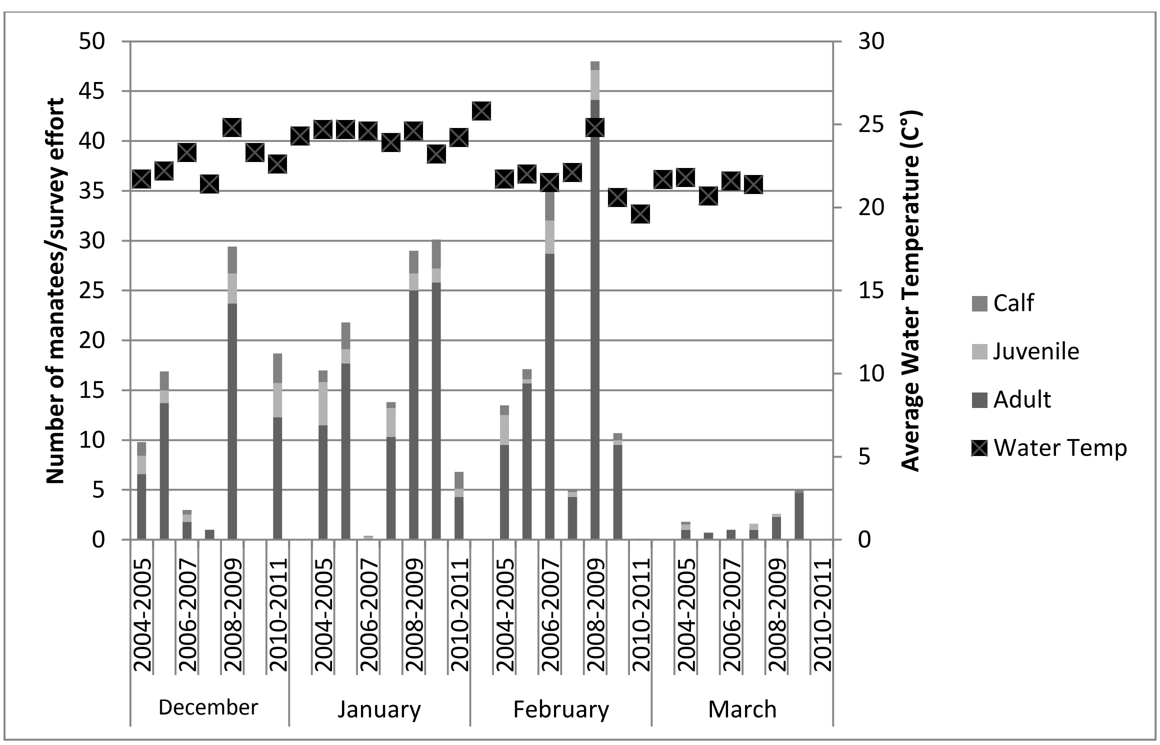

Figure 20: Number of adult, juvenile, and calf manatees per survey effort versus average monthly water temperature in degrees Celsius.

B. Yearly Mortality Statistics

The Florida Wildlife Research Institute (FWRI) compiled data on manatee mortality across winter seasons (December through April) for the past ten years. Year 5 (2008-2009) was reported to have higher numbers of cold-stress related mortalities, with 261 carcasses reported across the state, 74% of the carcasses being recovered from the East Coast. The majority of carcasses reported were calves, approximately 83% of the total number recovered (FWC, 2011). The majority of the manatees that succumbed to CSS were seen in Brevard County. In Brevard, lower than normal water temperature from power plant effluent or longer periods of low temperatures in shallow lagoons and thermal basins may have been a contributing factor to the high number of deaths.

According to the Florida Fish and Wildlife Conservation Commission (FWC), 2010 was one of the coldest winters in the state. The 2010 mortality report for Broward County showed 27 cases of manatee mortality, with 9 caused by CSS. This was higher than any other reported year for Broward County. January 2-13 was the coldest period of the year for parts of south Florida. Average daily air temperatures about 15º to 20º C lower than normal temperatures. February and March were also colder than usual. In Broward County, three cold related deaths were recorded in December, and 244 mortalities were recorded for the entire state. This was approximately ten times the normal five year average (27) for CSS. Almost 172 deaths were observed between January and February, across all age classes (FWC, 2011) (Figure 21).

In Broward County for this study, year 5 had a high number of manatee deaths, with four attributed to CSS (Table 5). Year 6 had the highest number of manatee deaths (27), although only 9 were related to CSS. The majority of deaths from a determined cause were due to watercraft injuries, with the second highest count due to CSS (Figure 21). The greatest total number of deaths (34) during years 5, 6, and 7 fall under the undetermined category, their causes unknown. None of these counts were high enough to have caused a significant difference in the total number of manatees utilizing the Port, nor in the number of adult manatees.

Table 5: Manatee mortality data for Broward County, Florida during the survey years of 2004-2011 based on data from the Florida Fish and Wildlife Conservation Commission. Data were accessed from: (http://research.myfwc.com/manatees/search_summary.asp). Data are illustrated in Figure 20.

Manatee Mortality Numbers by Year for Broward County, FL for Study Years: 2004-2011									
Broward County	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Total**
Watercraft	1	2	6	1	3	3	4	2	22
Gate/lock	1	0	0	0	0	0	0	0	1
Human/other	0	0	1	1	0	1	0	1	4
Perinatal	1	1	1	0	3	0	4	3	13
Cold stress	1	1	1	0	1	4	9	0	17
Natural	0	1	2	0	0	3	1	0	8
Undetermined	2	4	4	2	3	4	9	6	34
TOTAL	6	9	15	4	10	15	27	12	**99**

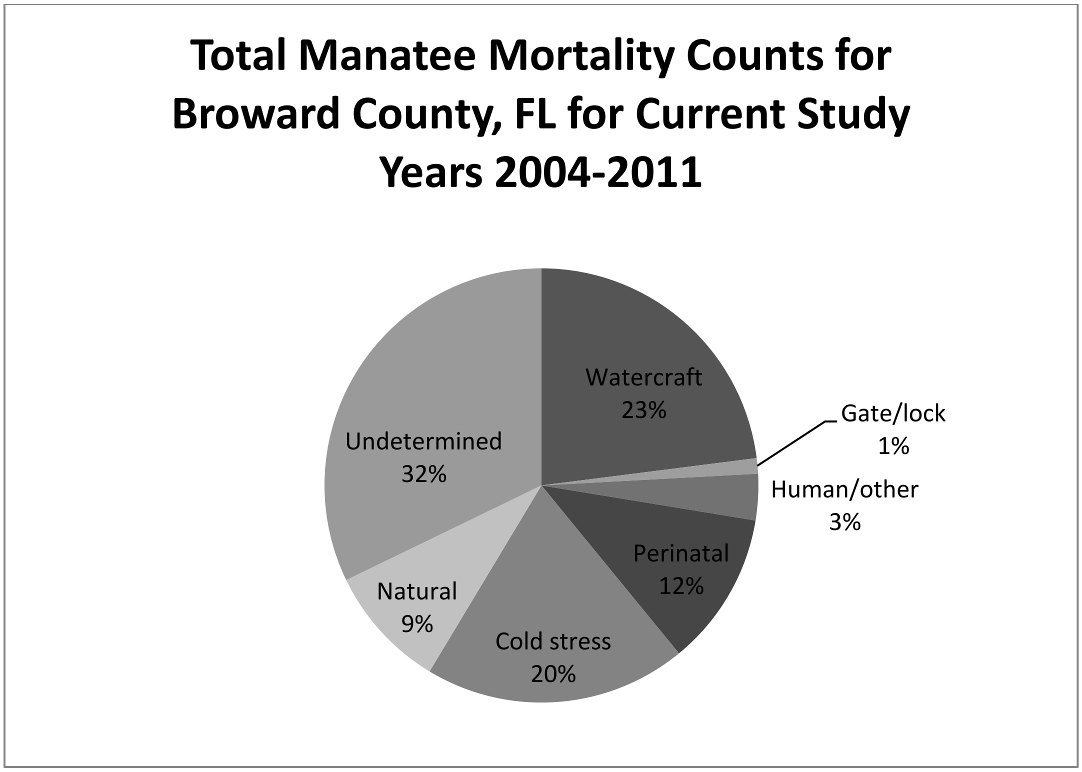

Figure 21: Total number of manatee mortalities reported for Broward County, FL for the years of the current study, 2004-2011, based on data from (http://myfwc.com/research/manatee/rescue-mortality-response/mortality-statistics/)

Although the high numbers of manatee deaths across the state of Florida (a loss of perhaps up to 10% for an endangered species) were a major concern to the FWC, cold related events are natural and do occur. It will take time for scientists to evaluate the extent of the effect of this unusual mortality event (UME) on the Florida manatee populations. The majority of clusters were along the West Coast and near the middle of the state on the East Coast. A nominal number of carcasses were salvaged near Ft. Lauderdale in Broward County (Figure 22).

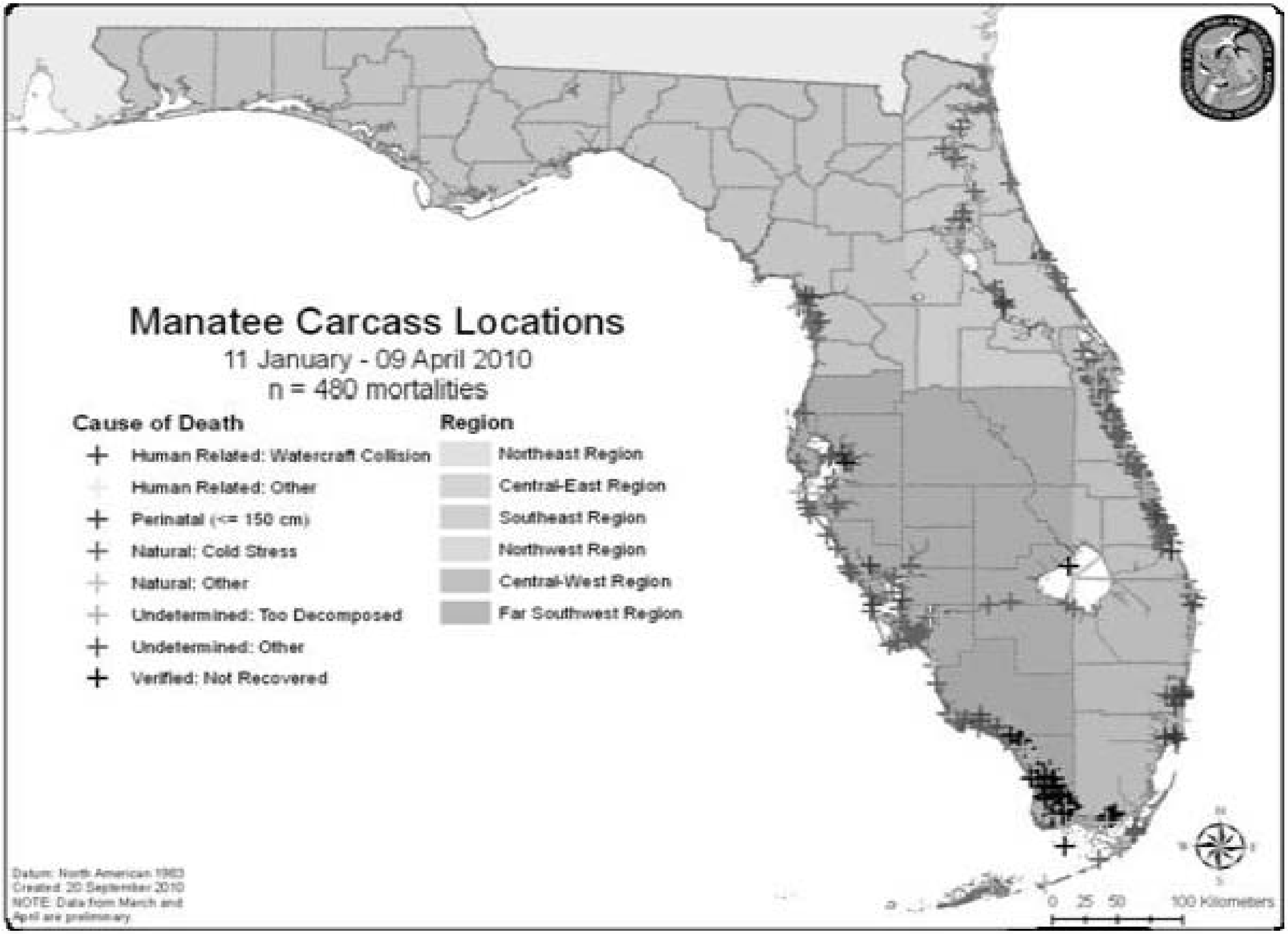

Figure 22: Distribution of manatee carcasses that were retrieved during the 2009-2010 Unusual Mortality Event (UME), as reported in Florida. Image was provided by the FFWCC.

A high number of manatees succumbed to cold-stress syndrome across the state of Florida, on the East Coast and West Coast. There appeared to have been an increase in mortalities for the East Coast in year 5 (pre-construction) (Figure 23). It is necessary to examine morality data to determine if deaths resulting from CSS had an effect on the number of overwintering manatees in the FPL discharge canal.

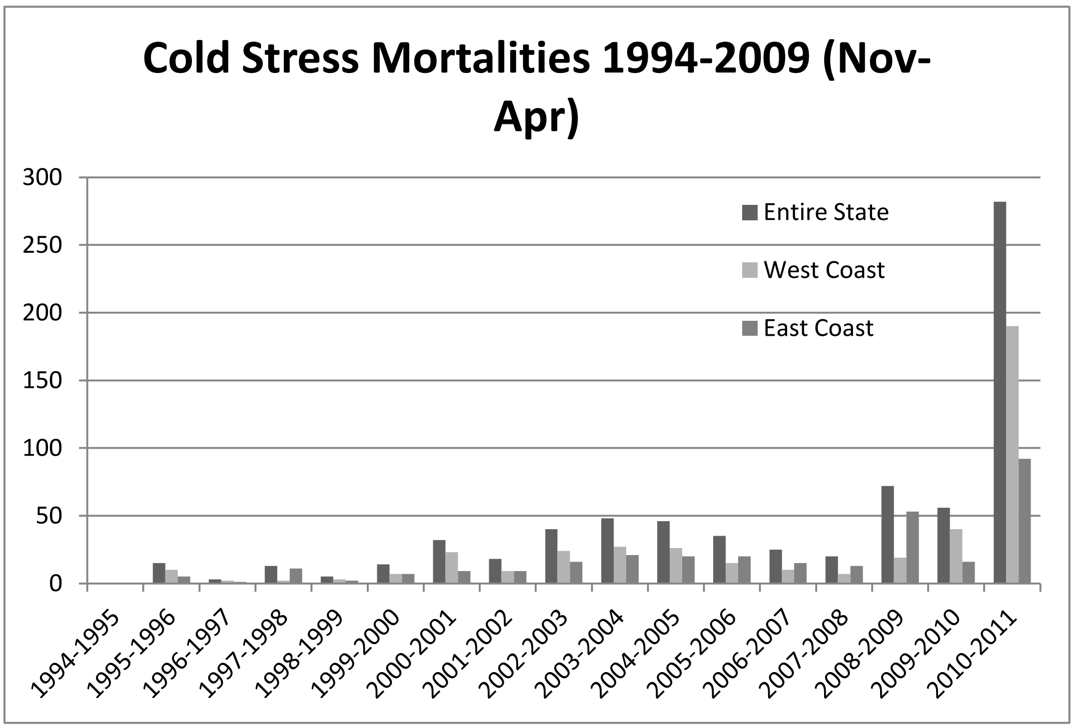

Figure 23: Average number of manatee deaths across age classes due to cold-stress syndrome from 1994-2011. Image was provided by the FWC.

The increase in manatee mortality and carcass counts across winter seasons did not necessarily point towards an increase in mortality rate for manatee populations, although the data compiled can be used to monitor population threats in the future. It is important to preserve and effectively manage warm water habitants in case of circumstances such as the 2009-2010 UME (FWC, 2011). There were no significant differences in water temperature within the FPL discharge canal, and no significant differences in the number of juvenile or manatee calves during the year 6 (Poisson α =1.00). A significant difference in the number of adult manatees observed based on total survey effort (TSE) was reported between years 5 and 7 (ANOVA, Poisson $\alpha < 0.05$).

It cannot be conclusively stated that any deaths resulting from CSS during the survey years had a significant impact on the numbers of adult manatees that utilize the FPL cooling canal during winter. There was a difference in the number of adults from year 5 to year 7, so there is a possibility for an effect. It was important to examine the number of manatee deaths related to cold stress in order to determine if this had any effect on the presence or absence of manatees utilizing Port Everglades. Because there was no significant manatee mortality in Port Everglades during the study years, then we can more likely contribute changes in abundance to bridge construction (Table 5). Since there were no significant mortalities, it appeared that cold-stress and mortality among the Atlantic population of Florida manatee did not impact the presence or absence of manatees in the Port. This supports the conclusion that changes in manatee use of the FPL cooling canal were due to bridge construction.

C. Abundance Data

A wide distribution of manatees in water with low visibility can make determination of population size and abundance difficult. Aerial and synoptic surveys are the best way to gauge population size, and are conducted by counties and wildlife institutes in the state of Florida. Synoptic surveys are winter aerial surveys that cover all of the manatees' winter habitats across the state of Florida, and are done to learn more about distribution, abundance, and habitat usage, and record spatial distribution and seasonal habitat use of manatees (Packard et al., 1985). Synoptic surveys were conducted 27 times from 1991 to 2011 (FWC, 2011). According to Ackerman (1995), aerial surveys were conducted since the late 1960's, and are ideal to count and map manatee distribution as they can span large geographic areas. There are multiple drawbacks to aerial, land, and boat based surveys, including inability to observe and detect accurate population size due to factors such as sun reflection, water quality, and vegetation. Manatees may also be undetectable when they submerge.

The National Marine Fisheries Service (NMFS) prepares marine mammal stock assessment reports (SARs) each year, as part of a requirement from the Marine Mammal Protection Act section 117. These reports are prepared in conjunction with several regional scientific review groups and can be viewed by the public. The U.S. Fish and Wildlife Service (USFWS) create SARs for marine mammals under their jurisdiction, such as manatees, polar bears, sea otters, and walruses. The official 2012 SAR is not available. The SAR for Florida manatees in 2011 gives the best available current count for a minimum population estimate is 3,802 animals. This is based on a single synoptic survey of warm-water refuges in January 2009 by the FWC. The FWC reports that for 2010, the highest total number of manatees observed during a statewide survey was 5,076. This report was released with a disclaimer that this was not a true estimate of the manatee population size in Florida (FWRI, 2010). For 2011, the total number of manatees observed for the state of Florida totaled 4,834, with 2,432 individuals observed in the eastern part and 2,402 in the western part of the state (Table 6).

Table 6: Florida Wildlife Research Institute manatee synoptic survey data for winter seasons of the study years 2004-2011. Data from this table is illustrated in Figure 22. Data accessed from: http://myfwc.com/research/manatee/projects/population-monitoring/synoptic-surveys/

2004-2011 Synoptic Survey Data from Florida Wildlife Research Institute				
Survey year	**Date**	**East**	**West**	**Total**
2004	February 20	1,198	1,307	2,505
2005	January 26	1,594	1,549	3,143
2006	February 13-17	1,639	1,474	3,113
2007	January 30-February 1	1,414	1,403	2,817
2009	January 19-23	2,148	1,654	3,802
2010	January 12-15	2,780	2,296	5,076
2011	January 20 and 24	2,432	2,402	4,834

The highest one month count for the state of Florida occurred during February 2009, with a total number of 432 manatees sighted. This count corresponded with findings from the FWC-FWRI synoptic survey data, although 2012 data is not yet available (Table 6, Figure 24). The highest total number of manatees counted based on total survey effort (TSE) (109) was observed in year 5 and the lowest number (21) was counted during year 4.

A significant difference in the actual number of adult manatees observed was reported between years 5 and 6 (ANOVA, Poisson $\alpha = 0.04$). A higher number of adult manatees were observed during year 5 (95) than in year 6 (40). For the study years, no other significant differences were seen for adult manatee counts. There were also no statistically significant p-values reported for the study years for juvenile manatees and calves. Varying numbers of juvenile and calf age classes in years 5, 6, and 7 may be due to differences in water temperature and cold weather. Juvenile manatees are more susceptible to chronic CSS than any other age class (Bossart et al., 2003).

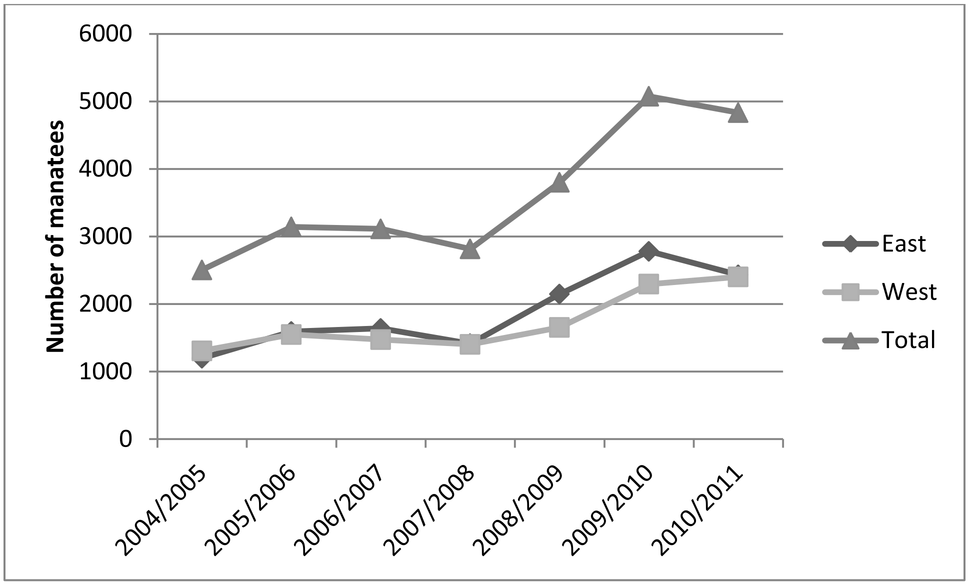

Figure 24: Florida manatee synoptic survey data during winter season for the study years 2004-2011showing East and West Coast counts. This figure illustrates the data located in Table 6.

D. Effects of Development and Roads on Fauna

Development, roads, and traffic have been known to impact both terrestrial and aquatic ecosystems. Studies indicate that the negative effects of roads, development, and traffic on wildlife outweigh the positive effects by a factor of 5. Roads are a large contributor to a loss of biodiversity, and may have a larger impact in the future, as roads are an increasing feature in most countries (Snow et al., 2011). Direct effects include the introduction of invasive or exotic species, increased mortality due to construction and vehicle collisions, population decline, and pollution. Impacts can also include habitat fragmentation, gene pool deterioration, and increased noise (Forman, 2000; Laurian et al., 2008). Roads can impact the physical and chemical environment (Trombulak and Frissell, 2000).

Previous studies have shown that road networks can disturb movement and behavior of terrestrial mammals such as caribou (*Rangifer tarandus*), white-tailed deer (*Odocoileus virginianus*), and wolf (*Canis lupus*). Noise disturbance also has the potential to effect animal movement to adjacent areas. Traffic volume across the United States will vary due to seasonal, weekly, or daily pressures, which could alter animal responses to road networks, and often the effects of roads correspond with the size of the road or the traffic (Gagnon et al., 2007). An example of this can be seen in a study conducted by Ager et al. (2003), which saw that elk (*Cervus canadensis*) in Oregon showed a diurnal pattern of movement relative to forest roads which showed less traffic at night.

The construction and expansion of road networks poses a variety of risks, which include but are not limited to increased wildlife-vehicle collisions (Ballok et al., 2010; McCollister and Van Manen, 2010). Construction of roads can jeopardize the biological integrity of the ecosystem, as well as impact the density and diversity of various wildlife communities. The most obvious direct impact is the increased mortality of terrestrial organisms (McCollister and Van Manen, 2010). Not only are acres of land or bodies of water that support plants, animals, and other organisms destroyed, but the physical conditions of the soil also have the potential to be altered. Studies have shown that road construction increases soil compaction, which may in turn decrease the survival of soil biota. Sediments and chemicals, such as road salts in high latitude climates, can be released into the surrounding ecosystem as well as transferred to streams and other water sources. The suspended sediment may decrease aquatic productivity or result in increased mortality of organisms (Trombulak and Frissell, 2000). In terrestrial systems, a response to road construction or other human activities may increase the amount of energy that migratory species, such as birds, have to expend or reduce their ability to utilize resources in a particular area. These disturbances have the potential to lead to a decline in body condition and decreased fitness (Tarr et al., 2010).

Response to road noise is just one part of a pattern of road avoidance by animals. Destruction from building roads and pollutants will only extend outward from the construction site for a short distance compared to the noise brought on by traffic (Forman and Alexander, 1998). Noise from increased traffic also poses an issue for many organisms, particularly songbirds. Increased levels of road noise can reduce the distance over which acoustic signals can be heard by organisms. With higher levels of noise, communication between birds decreases, which could lead to a low abundance of organisms near roads and behavioral avoidances (Fahrig and Rytwinksi, 2009). One study showed that near highways, 60% of bird species had lower population density, with species richness was reduced as the birds gradually migrated away from the road. The noise level at which songbird population density begin to decline was found to be 42 to 48 decibels. Theories pertaining to the impacts of road noise on birds and other sensitive terrestrial species include a loss of hearing, an increase in stress hormones, sensitivity to varying frequencies, decreased communication, and altered behavior (Forman and Alexander, 1998).

It has been noted through multiple studies that road construction and subsequent usage of roads and highways have a major impact on local wildlife in both terrestrial and aquatic ecosystems. It is therefore quite possible that construction of the bridge in Port Everglades may impact manatee usage of the FPL discharge canal either through an increase in pollutants into the water body or road noise.

E. Construction Effects

The construction of the intermodal bridge in Port Everglades was part of their 5-year capital improvement master/vision plan that addressed the Port's infrastructure and facility needs. EAC Consulting, Inc., was in charge of the bridge construction over the FPL discharge canal in Port Everglades, which has been titled "Manatee Crossing." EAC planned, designed, and supervised construction of this new bridge. Trucks were able to move inside the Port without having to exit and then re-enter through the security checkpoints, which served to expedite cargo traffic. The project was funded in part by the Florida Department of Transportation, and was a capital improvement project by Broward County's Department of Public Works Seaport Engineering and Construction Division (EAC Consulting). The name of the bridge was supposed to honor the Port's commitment to the manatees that take refuge in the warm water effluent from the FPL plant, which runs directly under the bridge. Construction was completed after one year, and maintains accessible waterways for manatees. Images taken with Google Earth show pre-construction, construction phase, and post-construction of the intermodal bridge (Appendix C). There were no barges or boats utilized during bridge construction (E. Keith, pers. comm.).

EAC Consulting, Inc., stated that the bridge was part of the designated manatee habitat within the Port, but there was no public release of information concerning the preventative measures taken to ensure conservation of overwintering manatees during bridge construction. Construction began in May 2009 and ended in June 2010, although there are no public details as to specific times for building demolition, site clearing, or pile driving. Though it was not explicitly stated, EAC Consulting should have acted under the standard manatee construction conditions for the State of Florida, which are available from the Florida Department of Environmental Protection. Examples of these conditions include prohibition of harm and harassment, collision avoidance, "no wake/idle" speeds in the construction area, and suspension of dredge and equipment operation when manatees are within 100 yards of the construction area.

The results of this current study on the effects of bridge construction on overwinter manatees appear to support the first alternative hypothesis, which states that construction of a new bridge over the FPL effluent would have an effect on the presence and absence of manatees utilizing the warm water discharge. A significant difference in the number of actual adult manatees was detected through statistical analysis for year 5 (pre-construction) versus year 7 (post-construction). Because FWC data of cold related mortalities during these years did not appear to correlate with the difference in observed number of manatees, it can be postulated that the difference in adult and total counts occurred due to some anthropogenic factor. The second null hypothesis, which stated that anthropogenic noise/disturbance, post construction, will have no effect on manatee composition and related activities, was rejected. Construction projects of this magnitude are considered to possibly affect manatees either directly or indirectly, though not in an adverse fashion (FWC, 2011). Thus far, little research has been done on the effects of construction activities and bridge operation on manatee aggregations overwintering in heavily trafficked areas.

F. Power plants and the Florida manatee

As a species that demonstrates strong site fidelity and philopatry, the Florida manatee returns year after year to the same warm water aggregation sites. Manatees are usually consistent with their seasonal movement patterns across multiple years. This is well documented using photo-identification and aerial surveys at aggregation sites (Reid et al., 2006; Edwards et al., 2007). Manatees depend on the continued existence of sites such as the FPL effluent canal in Port Everglades.

Without the constant input of warm water, manatees will likely stay in their usual range instead of seeking another refuge, though the temperatures and exposure periods that manatees can tolerate without death or illness are unclear. Factors such as body size, health condition and nutritional state play a role in determining an individuals' reaction to the cold. Power plant decommissioning can be detrimental to large hordes of overwintering manatees. Though a number of individuals may migrate to more southern locations in the event of a power plant decommissioning, many others may succumb to cold-related mortalities (Laist and Reynolds, 2005a,b).

Such an event may prove likely for the manatee populations of Port Everglades. The FPL plant is scheduled to be decommissioned in 2013. The company will invest approximately $1 billion (US) to replace the outdated plant with a more efficient one that will generate more electricity while reducing air pollution emissions by more than 90 percent (Fleshler, 2011). While the project has been met with resistance, little word has been released to the public on the effects to the overwintering manatee populations. Project managers have stated that, while the warm water discharge from a plant would usually be drawn to a halt with the plant's operation, FPL hopes to install a system which will allow the effluent to continue for the duration of the project. A similar system was put in place during a rehabilitation project in the FPL plant in Riviera Beach (Fleshler, 2011; FPL, 2011).

The company does not expect any undesirable effects to any federally or state-listed endangered species in conjunction with the modernization project. Since manatees utilize the warm water discharges from the plant, FPL plans to work directly with state and federal wildlife agencies in order to insure the continued safety of manatees during the site construction and the first few months of operation of the new plant. In fact, the plant installed a temporary system to heat the water for the manatees during winter seasons, which will be put into action during the construction phase. FPL states that it will comply with other manatee-related conditions to ensure the protection of the local manatee aggregations (FPL, 2011; Fleshler, 2011).

G. Conservation and Legal Status

Manatees have been legally protected in Florida since 1893. Concern for manatees goes back to 1907. Florida law established that any person who killed or armed a manatee would face a large fine for doing so. In 1976, the manatee was officially listed as an endangered species, thusly protected under the United States Endangered Species Act of 1973, the U.S. Marine Mammal Protection Act of 1972, the Florida Endangered and Threatened Species Act of 1977, and the Manatee Sanctuary Act of 1978 (Garrott et al., 1994; Buckingham et al., 1999; Read and Wade, 2000). Manatees are believed to have an excessive rate of mortality, most assumedly due to interactions with humans, which has placed them on the endangered species list.

The Florida manatee is considered to be a "strategic stock" under the Marine Mammal Protection Act. Under this ruling it was deemed unlawful to harass, hunt, capture, or kill, any manatees, import them or any byproducts, or to use any port under U.S. jurisdiction for any purposes connected to the take or importation of manatees. The Endangered Species Act of 1973 also forbids the "take" of endangered species. Under this regulation, this includes habitat modifications that are dangerous to wildlife, designation of areas termed as "critical habitat," as well as allows the federal government to place certain habitats under conservation (O'Shea et al., 1995). The Manatee Sanctuary Act protects Florida manatees from harassment, and anyone convicted of violating the state law can face a large fine or imprisonment. Convictions at a federal level carry a steeper punishment of up to $50,000 and/or one year in jail. Even innocuous gestures such as feeding manatees and giving them fresh water fall under the category of harassment.

When the public was asked to take a survey to determine the value of manatee preservation, results showed that the benefits of preservation far exceeded the development benefits of coastal construction, upwards of $8-9 million dollars (Solomon et al, 2004). Though long term prospects are still uncertain, there are measurable benefits that come from increased protection of manatees, including increased local tourism as well as the "ecological services" achieved by manatees. Manatees, in addition to eating sea grass, also consume hydra which would otherwise clog up commercial waterways and cost thousands of dollars to dredge.

In the future, there is a need to first and foremost identify and evaluate the potential management substitutions in order to prevent the effects of power plant cessation on manatee populations. Steps must also be taken to slow or stop the withdrawal of groundwater from natural springs and aquifers. Strategies or policies must also be put into place to develop long term as well as temporary approaches to preserve the network of natural warm water winter habitats used by the subpopulations of manatees found in Florida. Lastly, long term funding sources must be identified for management and research (Laist and Reynolds 2005a).

Possible survey errors must be recognized for this study. According to Garrott et al. (1994), walking surveys and other such studies of larger marine mammals have a detection probability of one-half to two-thirds of all animals present. Manatees can remain submerged, resting or searching for food, for long periods of time. Water clarity is affected by turbidity as well as overhanging plants, which can affect how many manatees are reported by the observer. Observer error must be acknowledged in this instance. In this study, only one observer was present for all walking surveys. The presence of multiple observers would have increased the likelihood of sighting all manatees in the area, and could have covered a larger range. Multiple observers could have also confirmed sightings and verified age classes of manatees reported. Improvements to this study would have included the use of an underwater hydrophone, a survey of traffic in the area (specifically that of the new bridge), and multiple observers present, assuming no financial restrictions.

X. SUMMARY AND CONCLUSIONS

While it cannot be conclusively stated that bridge construction had an impact on manatee populations overwintering in Port Everglades, Florida, there appeared to be a correlation between construction and adult manatee presence. This allowed the rejection of the first null hypothesis and lent support to the first alternative hypothesis, which stated that construction of a new bridge over the FPL effluent would affect the manatees utilizing the warm water discharge. The second null hypothesis, which stated that anthropogenic noise/disturbance, post construction, would have no effect on manatee composition and related activity, was rejected, and the second alternative hypothesis accepted.

No significant difference was apparent between juvenile and calf presence at the effluent canal during the survey years. Although there was a higher than average number of deaths in year 5 and an unusual mortality event (UME) during year 6 (post-construction and construction phase respectively), the presence of juvenile and calf age classes remained consistently low. It cannot be verified that the difference in adult manatees observed during these years correlates with this cold related event. Average water temperature within the FPL discharge canal during survey years were fairly consistent across the winter months and appeared to have had little or no effect on the presence or absence of manatees utilizing the canal.

Walking surveys for Port Everglades conducted over multiple winter seasons may serve to elucidate general trends in population size and structure, which can be used as an index on the growth or reduction of the local population. Walking surveys, along with aerial and synoptic surveys, can provide scientists and researchers with important data relating to manatee populations and social structure, as well as the effects of varying abiotic factors.

The Florida manatee is a species that practices philopatry (returning to the place of one's birth) as well as demonstrating a strong sense of site fidelity. Efforts must be made to conserve known warm water refuges, for manatees to return to the same site year after year even if the power plants are shut down. As an endangered species, research must be conducted so that future management strategies can be put in place. Conservation and observation of threats to manatee habitats are of utmost importance. More research into the effect of construction, both residential and recreational, near manatee habitats and overwintering grounds should be performed to ensure the growth of this species. While this was not performed during the current study, for future studies hydrophones should be utilized to measure underwater sound pre, during, and post construction. Future studies on bridge construction should also include traffic studies to document bridge use. Additionally, steps should be taken to ensure the continued existence of warm water refuges, such as FPL discharge canals, upon which manatees have come to rely.

XI. REFERENCES

Ager, A.A., Johnson, B.K., Kern, J.W., and J.G. Kie. 2003. Daily and seasonal movements and habitat use by female Rocky Mountain elk and mule deer. Journal of Mammalogy 84: 1076-1088.

Alvarez-Aleman, A., Beck C.A., and J.A. Powell. 2010. First report of a Florida manatee (*Trichechus manatus latirostris*) in Cuba. Aquatic Mammals 36(1): 148-153.

Ballók, Z., Náhlik, A., and T. Tari. 2010. Effects of building a highway and wildlife crossings in a Red Deer (*Cervus elaphus*) habitat in Hungary. Acta Silvatica & Lignaria Hungarica-An International Journal Forest, Wood, and Environmental Sciences 6: 67-74.

Bell, J.T. 2000. Characterization and analysis of artificial warm-water refugia and their use by the Florida manatee (*Trichechus manatus latirostris*) on the east coast of Florida. Master's Thesis, Duke University, Durham, NC 55pp.

Bengtson, J.L., and D. Magor. 1979. A survey of manatees in Belize. Journal of Mammalogy 60: 230-232.

Bonde, R.K**.** 2009. Population genetics and conservation of the Florida manatee: past, present, and future. PhD Dissertation, University of Florida, Gainesville, Florida. 144pp.

Bonde, R.K., Aguirre, A.A., and J. Powell. 2006. Manatees as sentinels of marine ecosystem health: are they the 2000-pound canaries? Ecohealth 1(3): 255-262.

Bossart, G. D., Meisner, R. A., Rommel, S. A., Ghim, S. J., and A. B. Jenson. 2003. Pathological features of the Florida manatee cold stress syndrome. Aquatic Mammals 29(1): 9-17.

Bray J.R., and J.T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecological Monographs 27: 325–349.

Broward County. 2007. Broward County manatee protection plan. Broward County Environmental Protection Department Biological Resources Division. 12,13 pp. http://www.broward.org/Manatees/Documents/broward_mpp_v1.1.pdf. Accessed on January 28, 2011.

Buckingham, C.M, Lefebvre, L.W., Schaefer, J.M., and H.I. Kochman. 1999. Manatee response to boating activity in a thermal refuge. Wildlife Society Bulletin 27(2): 514-522.

Buergelt, C.D., R.K. Bonde, and C.A. Beck. 1984. Pathological findings in manatees in Florida. Journal of the American Veterinary Medical Association 185: 1331-1334.

Burn, D.M. 1986. The digestive strategy and efficiency of the West Indian manatee, (*Trichechus manatus*). Comparative Biochemistry and Physiology Part A: Physiology 85: 139-142

Carroll, R.L. 1988. Introduction to the Sirenia: dugongs and manatees. Vertebrate Paleontology and Evolution. W.H. Freeman and Co., NY.

Committee on Taxonomy. 2012. List of marine mammal species and subspecies. Society for Marine Mammalogy, www.marinemammalscience.org, consulted on [19 July 2012].

Courbis, S.S., and G.A.J. Worthy. 2003. Opportunistic carnivory by Florida manatees (*Trichechus manatus latirostris*). Aquatic Mammals 29(1): 104-107.

Deutsch, C.J., Reid, J.P., Bonde, R.K., Easton, D.E., Kochman, H.I. and T.J. O'Shea. 2003. Seasonal movements, migratory behavior, and site fidelity of West Indian manatees along the Atlantic coast of the United States. Wildlife Monographs 151: 1-77.

Domning, D.P. 1983. Marching teeth of the manatee. Natural History 92(5): 8, 10-11.

Domning, D.P. 2001. Evolution of the Sirenia and Desmotylia. Pages 151-167 *in*: J.M. Mazin and V. de Buffrenil, eds., Secondary Adaptations of Tetrapods to Life in Water. Verlag Dr. Friedrich Pfeil, Munchen, Germany.

Domning, D.P. 2005. Fossil Sirenia of the West Atlantic and Caribbean region. VII. Pleistocene *Trichechus manatus* Linnaeus, 1758. Journal of Vertebrate Paleontology 25(3): 685-701.

Duignan, P.J., House, C., Walsh, M.T., Campbell, T., Bossart, G.D., Duffy, N., Fernandes, P.J., Rima, B.K., Wright, S., and J.R. Geraci. 1995. Morbillivirus infection in manatees. Marine Mammal Science 11(4): 441-451.

EAC Consulting, Inc. "Manatee Crossing Bridge over the FPL Discharge Canal." Accessed on October 18, 2011. Retrieved from http://www.eacconsult.com/section_details.aspx?section_id=sec_001&category_id=ser_002&project_id=pro_0000272.

Edwards, H.H., Pollock, K.H., Ackerman, B.B., Reynolds, J.E. III, and J.A. Powell. 2007. Estimation of detection probability in manatee aerial surveys at a winter aggregation site. Journal of Wildlife Management 71: 2052-2060.

Fahrig, L. and T. Rytwinski. 2009. Effects of roads on animal abundance: an empirical review and synthesis. Ecology and Society 14(1): 21 pp.

Flamm, R.O., Weigle, B.L., Wright, I.E., Ross, M., and S. Aglietti. 2005. Estimation of manatee (*Trichechus manatus latirostris*) places and movement corridors using telemetry data. Ecological Applications 15: 1415-1426.

Fleming, L.E., Backer, L.C., and D.G. Baden. 2005. Overview of aerosolized Florida red tide toxins: Exposures and effects. Environmental Health Perspective 113(5): 618-620.

Fleshler, D. 2011, July 18. FPL plans to demolish Port Everglades Plant. *Sun Sentinel*. Retrieved from http://articles.sun-sentinel.com/2011-07-18/news/fl-power-plant-20110718_1_port-everglades-plant-fpl-plans-daniela-banu

Florida Department of Environmental Protection. 2001. Standard Manatee Construction Conditions. Accessed February 15, 2011. Retrieved from http://bcs.dep.state.fl.us/env-prmt/monroe/issued/0207625_Key_West_Channels_Maintenance_Dredging/002-EM/Permit%20Mod%20%2808-12-03%29/Standard%20Manatee%20Construction%20Conditions%20%2808-12-03%29.pdf.

Florida Department of Environmental Protection (DEP). 2008. Effluent Quality Assessment FPL Port Everglades Plant Broward County NPDES #FL0001538. Accessed February 15, 2011. Retrieved from ftp://ftp.dep.state.fl.us/pub/labs/lds/reports/8104.pdf.

Florida Fish and Wildlife Conservation Commission. 2007. Florida manatee management plan. Florida Fish and Wildlife Conservation Commission, Tallahassee, FL. 267 pp. Accessed on February 15, 2011. Retrieved from http://myfwc.com/media/214332/Manatee_Mgmt_Plan.pdf

Florida Fish and Wildlife Conservation Commission. 2011. Cold-related mortality event winter 2009-2010. Florida Fish and Wildlife Conservation Commission. Accessed on February 15, 2011. Retrieved from http://myfwc.com/research/manatee/rescue-mortality-response/mortality-statistics/cold-related-2009-2010/.

Florida Fish and Wildlife Conservation Commission. 2011. Preliminary manatee mortality report. Florida Fish and Wildlife Conservation Commission. Available from http://myfwc.com/media/1317276/yearly.pdf

Florida Power and Light. 2011. Ten year power plant site plan, 2011-2020. Submitted to Florida Public Service Commission, Miami, Florida, April 2011. Accessed October 15, 2011. Retrieved from https://www.frcc.com/Planning/Shared%20Documents/FRCC%20Presentations%20and%20Utility%20Site%20Plans/2011/2011_TYSP_FPL.pdf.

Fish and Wildlife Research Institute. 2010. Fish and wildlife research institute: Research: Florida manatee. Florida Fish and Wildlife Conservation Commission. St. Petersburg, Florida. Accessed on February 15, 2011. Retrieved from http://myfwc.com/research/manatee/projects/population-monitoring/synoptic-surveys/

Folkens, P.A., and R.R. Reeves. 2002. Guide to marine mammals of the world. National Audubon Society field guide series. 1st ed. New York: A.A. Knopf.

Forman, R.T.T. 2000. Estimate of area affected ecologically by the road system in the United States. Conservation Biology 14: 31-35.

Forman, R.T.T. and L.E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29: 207-231.

Frisch, K., and E. Haubold. 2003. Florida manatee avoidance technology: a pilot program by the Florida Fish and Wildlife Conservation Commission. Journal of the Acoustical Society of America 114(4): 2415 pp.

Gagnon, J.W., Theimer, T.C., Dodd, N.L., Boe, S., and R.E. Schweinsburg. 2007. Traffic volume alters elk distribution and highway crossings in Arizona. Journal of Wildlife Management 71(7): 2318-2323.

Gannon, J.G., Scolardi, K.M., and J.E. Reynolds III. 2007. Habitat selection by manatees in Sarasota Bay, Florida. Marine Mammal Science 23: 133-143.

Garrott, R.A., Ackerman, B.B., Cary, J.R., Heisey, D.M., Reynolds, J.E., Rose, P.M, and J.R. Wilcox. 1994. Trends in counts of Florida manatees at winter aggregation sites. The Journal of Wildlife Management 58(4): 642-654.

Gerstein, E.R., Gerstein, L., Forsythe, S.E., and J.E. Blue. 1999. The underwater audiogram of the West Indian manatee (*Trichechus manatus*). Journal of Acoustical Society of America 105(6): 3575-3582.

Gerstein, E.R. 2002. Manatees, bioacoustics and boats. American Scientist 90: 154-163.

Gorzelany, J.F. 2004. Evaluation of boater compliance with manatee speed zones along the Gulf Coast of Florida. Coastal Management. 32: 215-226.

Gulland, F.M.D. and A.J. Hall. 2007. Is marine mammal health deteriorating? Trends in the global reporting of marine mammal disease. EcoHealth 4(2): 135-150.

Hartman, D.S. 1971. Behavior and ecology of the Florida manatee (*Trichechus manatus latirostris*) at Crystal River, Citrus County. Cornell University, Ithaca, NY, Ph.D. Thesis. 285 p.

Hartman, D.S. 1979. Ecology and behavior of the manatee (*Trichechus manatus*) in Florida. American Society of Mammalogists Special Publication Number 5. Lawrence, KS. 153pp.

Haubold, E.M., Deutsch, C., and C. Fonnesbeck. 2006. Final biological status review of the Florida manatee (*Trichechus manatus latirostris*). Florida Fish and Wildlife Conservation Commission, St. Petersburg, FL. 10 pp + appendices. Accessed on March 3, 2011. Retrieved from http://myfwc.com/media/201862/finalreport_3230.pdf.

Hilliard, J.M. 2010. Seasonal Aggregations of the Florida manatee (*Trichechus manatus latirostris*) in the Port Everglades and Intracoastal regions of Fort Lauderdale, Florida. M.S. Thesis, Nova Southeastern University Oceanographic Center, Dania Beach, FL. 103pp.

Humphrey, S.R. 1992. Rare and endangered biota of Florida, Ed. By Stephen R. Humphrey. Gainesville: University Press of Florida. 190-200pp.

Husar, S.L. 1978. *Trichechus manatus*. Mammalian species no. 93: 1-5.

Irvine, A.B., and H.W. Campbell. 1978. Aerial census of the West Indian manatee, *Trichechus manatus*, in the southeastern United States. Journal of Mammalogy 59: 613-617.

Irvine, A.B. 1983. Manatee metabolism and its influence on distribution in Florida. Biological Conservation 25(4): 315-334.

Jones, J.K., and R.R. Johnson. 1967. Sirenians. In Anderson, S., and J.K. Jones Jr. Recent Mammals of the World: a synopsis of families. Ronald Press, NY. 366-373.

Ketten, D.R., Odell, D.K. and D.P. Domning. 1992. Structure, Function, and adaptation of the manatee ear. In Marine Mammal Sensory Systems (Edited by J. Thomas, et. al.) Plenum Press, New York. 77-95pp. Accessed on June 19, 2011. Retrieved from http://csi.whoi.edu/sites/default/files/literature/Full%20Text_33.pdf

King, J.M, and J.T. Heinen. 2003. An assessment of the behavior of overwintering manatees as influenced by interactions with tourists at two sites in Central Florida. Biological Conservation 117(3): 227-234.

Laist, D.W., and J.E. Reynolds III. 2005a. Florida manatees, warm-water refuges, and an uncertain future. Coastal Management 33: 279-295.

Laist, D.W., and J.E. Reynolds III. 2005b. Influence of power plants and other warm-water refuges on Florida manatees. Marine Mammal Science 21(4): 739-764.

Laist, D.W. and C. Shaw. 2006. Preliminary evidence that boat speed restrictions reduce deaths of Florida manatees. Marine Mammal Science 22: 472-479.

Langtimm, C.A., O'Shea, T.J., Pradel, R., and C.A. Beck. 1998. Estimates of annual survival probabilities for adult Florida manatees (*Trichechus manatus latirostris*). Ecology 79: 981-997.

Langtimm, C.A. and C.A. Beck. 2003. Lower survival probabilities for adult Florida manatees in years with intense coastal storms. Ecological Applications 13: 257-268.

Langtimm, C.A., Beck, C.A., Edwards, H.H., Fick-Child, K.J., Ackerman, B.B., Barton, S.L., and W.C. Hartley. 2004. Survival estimates for Florida manatees from the photo-identification of individuals. Marine Mammal Science 20(3): 438-463.

Laurian, C., Dussault, C., Ouellet, J.P, Courtois, R., Poulin, M., and L. Breton. 2008. Behavior of moose relative to a road network. Journal of Wildlife Management 72(7): 1550-1557.

Lefebvre, L.W., Reid, J.P., Kentworthy, W.J., and J.A. Powell. 2000. Characterizing manatee habitat use and seagrass grazing in Florida and Puerto Rico: implications for conservation and management. Pacific Conservation Biology 5: 289-298.

Lefebvre, L.W., Marmontel, M., Reid, J.P., Rathbun, G.B., and D.P. Domning. 2001. Status and biogeography of the West Indian manatee. Pages 425-474 *in* C.A. Woods and F.E. Sergile, eds. Biogeography of the West Indies, patterns and perspectives. Second edition. CRC Press, Boca Raton, FL.

Marine Mammal Commission. 2007. Marine Mammal Commission Annual Report to Congress 2007. Marine Mammal Commission, Washington, D.C. 72 pp. Accessed on March 3, 2011. Retrieved from http://www.mmc.gov/reports/annual/pdf/2007annualreport.pdf

Marmontel, M., O'Shea, T.J., Kochman, H.I., and S. R. Humphrey. 1996. Age determination in manatees using growth-layer-group counts in bone. Marine Mammal Science 12:54–88.

Marmontel, M., Humphrey, S.R. and T.J. O'Shea. 1997. Population viability analysis of the Florida manatee (*Trichechus manatus latirostris*), 1976-1991. Conservation Biology 11: 467-481.

McCollister, M.F., and F.T. Van Manen. 2010. Effectiveness of wildlife underpasses and fencing to reduce wildlife-vehicle collisions. Journal of Wildlife Management 74(8): 1722-1731.

Mezich, R.R. 2001. Manatees and Florida Power & Light's Lauderdale and Port Everglades Power Plants. Prepared for Florida Fish and Wildlife Conservation Commission. Tallahassee, Florida. Unpublished technical report.

Miksis-Olds, J.L., Miller, J.H., and P.L. Tyack. 2004. The Acoustic Environment of the Florida Manatee: Correlation with Level of Habitat Use. Journal of the Acoustical Society of America 115(5): 2558 pp.

Miksis-Olds, J.L., Donaghay, P.L., Miller, J.H., and P.L. Tyack. 2005. Environmental Noise Levels Affect the Activity Budget of the Florida Manatee. Journal of the Acoustical Society of America 118(3): 1910 pp.

Miksis-Olds, J.L. 2008. Effects of environmental noise on the Florida manatee *Trichechus manatus latirostris*. Bioacoustics 17(1-3): 176-178.

Miksis-Olds, J.L. and T. Wagner. 2011. Behavioral Response of Manatees to Variations in Environmental Sound Levels. Marine Mammal Science 27(1): 130-148.

Moore, J.C. 1957. Newborn young of a captive manatee. Journal of Mammalogy, 38: 137-138.

Moss, C. 2001. The demography of an African elephant (*Loxodonta africana*) population in Amboseli, Kenya. Journal of Zoology 255:145-156.

Nabor, P. and G.W. Patton. 1989. Aerial studies of the West Indian manatee (*Trichechus manatus*) from Anna Maria Florida to northern Charlotte Harbor including the Myakka River: recommended habitat protection and manatee management strategies. Mote Marine Lab Technical Report Number 134. Sarasota, FL. Unpublished. Retrieved from <http://isurus.mote.org/techreps/134/134.pdf>

Nowacek, S.M., Wells, R.S., Owen, E.C., Speakman, T.R., Flamm, R.O., and Nowacek D.P. 2004. Florida manatees, *Trichechus manatus latirostris*, respond to approaching vessels. Biological Conservation 119: 517-523.

O'Shea, T. J. 1995. Waterborne recreation and the Florida manatee. In: Knight, R. L., and K.J. Gutzwiller. Wildlife and recreationists: Coexistence through management and research. Covelo, CA: Island Press. p. 297-311.

O’Shea, T. J., L. W. Lefebvre, and C. Beck. 2001. Florida manatees: Perspectives on populations, pain, and protection. Pages 31-43, In *CRC Handbook of Marine Mammal Medicine*, 2nd ed., ed. L. A. Dierauf and F. M. D. Gulland, Boca Raton: CRC Press.

Packard, J.M., Frohlich, R.K., Reynolds, J.E., and J.R. Wilcox. 1989. Manatee response to interruption of a thermal effluent. The Journal of Wildlife Management 53(3): 692-700.

Powell, J. 2002. Manatees: Natural History and Conservation. Voyageur Press, Stillwater, Minnesota. Pages 1-72.

Rappucci, Gina. 2010. Effect of the tidal cycle on the Florida manatee (*Trichechus manatus latirostris*) at the Port Everglades Power Plant. Unpublished master’s thesis. Nova Southeastern University Oceanographic Center, Dania Beach, FL. Pages 1-34.

Read, A.J., and P.R. Wade. 2000. Status of marine mammals in the United States. Conservation Biology 14: 929-940.

Reep, R.L., Stoll, M.L., Marshall, C.D., Homer, B.L., and D.A. Samuelson. 2001. Microanatomy of facial vibrissae in the Florida manatee: the basis for specialized sensory function and oripulation. Brain, Behavior and Evolution 58: 1-14.

Reich, K.J. and G.A.J. Worthy. 2006. An isotopic assessment of the feeding habits of free-ranging manatees. Marine Ecology Progress Series 322: 303-309.

Reid, J.P., Rathbun, G.B. and J.R. Wilcox. 2006. Distribution patterns of individually identifiable West Indian manatees (*Trichechus manatus*) in Florida. Marine Mammal Science 7(2): 180-190.

Reynolds, J.E., III, and J.R. Wilcox. 1985. Abundance of West Indian manatees (*Trichechus manatus*) around selected Florida power plants following winter cold fronts, 1982-1083. Bulletin of Marine Science 36: 413-422.

Reynolds, J.E., III, and J.R. Wilcox. 1994. Observations of Florida manatees (*Trichechus manatus latirostris*) around selected power plants in winter. Marine Mammal Science 10: 163-177.

Rima, B.K., Wishaupt, R.G.A., Welsh, M.J., and J.A.P. Earle. 1995. The evolution of morbilliviruses: A comparison of nucleocapsid gene sequences including a porpoise morbillivirus. Veterinary Microbiology 44(2-4): 127-134.

Rommel, S.A., and J.E. Reynolds, III. 2000. Diaphragm structure and function in the Florida manatee (*Trichechus manatus latirostris*). The Anatomical Record 259: 41-51.

Rommel, S.A., and H. Caplan. 2003. Vascular adaptations for heat conservation in the tail of Florida manatees (*Trichechus manatus latirostris*). Journal of Anatomy 202: 343-353.

Ronald, K., Selley, L.J., and E.C. Amoroso. 1978. Biological synopsis of the manatee. College of Biological Science, University of Guelph, Ontario, Canada. 1-112pp.

Runge M.C., C.A. Langtimm, and W.L. Kendall. 2004. A stage-based model of manatee population dynamics. Marine Mammal Science 20(3):361-385.

Runge, M.C., Sanders-Reed, C.A., Langtimm, C.A., and C.J. Fonnesbeck. 2007. A quantitative threats analysis for the Florida manatee (*Trichechus manatus latirostris*). USGS Open-File Report (OFR) 2007-1086, 1-34. Accessed on February 15, 2011. Retrieved from http://www.pwrc.usgs.gov/resshow/manatee/documents/OFR2007-1086.pdf

Shane, S.H. 1984. Manatee use of power plant effluents in Brevard County, Florida. Florida Scientist 47(3): 180-186.

Snow, N.P., Andelt, W.F., Stanley, T.R., and L. Munson. 2011. Effects of roads on survival of San Clemente Island foxes. The Journal of Wildlife Management 76(2): 243-252.

Solomon, B.D., Corey-Luse, C.M and K.E. Halvorsen. 2004. The Florida manatee and eco-tourism: toward a safe minimum standard. Ecological Economics 50(1-2): 101-115.

Sorice, M.G., Shafer, C.S., and R.B Ditton. 2006. Managing endangered species within the use-preservation paradox: the Florida manatee (*Trichechus manatus latirostris*) as a tourism attraction. Environmental Management 37(1): 69-83.

Tarr, N.M., Simons, T.R., and K.H. Pollock. 2010. An experimental assessment of vehicle disturbance effects on migratory shorebirds. Journal of Wildlife Management 74(8): 1776-1783.

Tripp, K. 2009. Manatees: Ancient marine mammals in a modern coastal environment. Ocean Challenge 16(2): 14-22.

Trombulak, S.C. and C.A. Frissell. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14(1): 18-30.

U.S. Army Corps of Engineers. 2010. American Recovery & Reinvestment Act Program: Port Everglades, FL. Accessed on October 18, 2011. Retrieved from: http://www.saj.usace.army.mil/Documents/FactSheets/ARRA/I_113180_PortEverglades_COMPLETED.pdf.

U.S. Fish and Wildlife Service. 2009. West Indian manatee (*Trichechus manatus*) and Florida stock (Florida subspecies, *Trichechus manatus latirostris*). Stock Assessment Report. Jacksonville, FL. Accessed on January 28, 2011. Retrieved from http://fws.gov/northflorida/Manatee/SARS/20091230_rpt_Final_Florida_Manatee_SAR.pdf.

Vianna, J.A., Bonde, R.K., Caballero, S., Giraldo, J.P., Lima, R.P., Clark, A., Marmontel, M., Morales-Vela, B., de Sousa, M.J., Parr, L., Rodriguez-Lopez, M.A., Mignucci-Giannonni, A.A., Powell, J.A. and F.R. Santos. 2006. Phylogeography, phylogeny, and hybridization in trichechid sirenians: implications for manatee conservation. Molecular Ecology 15:433-447.

Walsh, C.J., Luer, C.A., and D.R. Noyes. 2004. Effects of environmental stressors on lymphocyte proliferation in Florida manatees, *Trichechus manatus latirostris*. Veterinary Immunology and Immunopathology 103(3-4): 247-256.

Walsh, K. 2009. Diurnal movements and site fidelity of the Florida manatee (*Trichechus manatus latirostris*) in Fort Lauderdale, FL. M.S. Thesis, Nova Southeastern University Oceanographic Center, Dania Beach, FL. 51pp.

Wells, R.S., Nowacek, S.M, and R.O. Flamm. 1999. Manatee behavioral responses to vessel approaches: 1999. Final report to the Florida Fish and Wildlife Conservation Commission, Mote Marine Laboratory Technical Report No. 748: 1-9.

Wright, S.D., Ackermann, B.B., and H.F. Percival. 1995. Analysis of watercraft-related mortality of manatees in Florida, 1979-1991. Pages 259-268 in O'Shea, T.J., Ackerman, B.B., and H.F. Percival (eds). Population biology of the Florida manatee. National Biological Service Information and Technology Report 1, Ft. Collins, CO. 289pp.

Wright, I.E., Reynolds, J.E., Ackerman, B.B., Ward, L.I., Weigle, B.L., and W.A. Szelistowski. 2002. Trends in manatee (*Trichechus manatus latirostris*) counts and habitat use in Tampa Bay, 1987-1994: implications for conservation. Marine Mammal Science 18: 259-274.

Zar, J.H. 2009. Biostatistical Analysis, Fifth Edition. Prentice Hall. 585-592.

Zoodsma, B.J. 1991. Distribution and behavioral ecology of manatees in southeastern Georgia. U.S. Department of the Interior, National Park Service. Accessed on January 28, 2011. Retrieved from http://ufdc.ufl.edu/UF00073923/00001. .

XII. APPENDICES

A. Appendix 1: Sample Survey Sheet for Manatee observation

PORT EVERGLADES MANATEE WALKING SURVEYS 2010-2011

NOVA SOUTHEASTERN UNIVERSITY -OCEANOGRAPHIC CENTER

SURVEY DATE ___/___/___ SURVEY HOURS: ___:___ to ___:___

OBSERVERS:____

ADMIN OFFICE 26.08190 -80.12020

TIME: ________ H_2O TEMPERATURE: __________ ACTIVITY: ____

ADULTS: ___________________ JUV: ________ CALVES: ______

COMMENTS:

NORTH BRIDGE 26.08264 -80.12053

TIME: ________ H_2O TEMPERATURE: __________ ACTIVITY: ____

ADULTS: ___________________ JUV: ________ CALVES: ______

COMMENTS:

EFFLUENT CANAL 26.08271 -80.12348

TIME: ________ H_2O TEMPERATURE: __________ ACTIVITY: ____

ADULTS: ___________________ JUV: ________ CALVES: ______

COMMENTS:

B. Appendix 2: Photograph of the new bridge "Manatee Crossing," constructed over the Port Everglades discharge canal.

C. **Appendix 3**: Pre-, during-, and post-construction imagery of the “Manatee Crossing” bridge constructed over the Port Everglades FPL discharge canal. Images taken from GoogleEarth.

Pre-Construction

During-Construction

Post-Construction