# ESTIMATION OF ANTHROPOGENIC AND CATASTROPHIC EFFECTS OF FLORIDA MANATEE (*TRICHECHUS MANATUS LATIROSTRIS*)

An Undergraduate Research Scholars Thesis

by

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Submitted to the Undergraduate Research Scholars program at
Texas A&M University
in partial fulfillment of the requirements for the designation as an

UNDERGRADUATE RESEARCH SCHOLAR

Approved by Research Advisor: Dr. Hsiao-Hsuan Wang

May 2018

Major: Wildlife & Fisheries Sciences

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# ABSTRACT

Estimation of Anthropogenic and Catastrophic Effects of Florida Manatee (*Trichechus manatus latirostris*)

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One of the most endangered marine mammals in the coastal areas of the United States is the Florida manatee (*Trichechus manatus latirostris*). The Florida manatee population has been increasing and decreasing since 1991 along the east and west coast of Florida, respectively, and has a present population of about 6,250. However, the populations have been dramatically fluctuating due to various anthropogenic factors. The major causes of manatee deaths can be broken down into five categories: watercrafts, crushed/drowning by flood gate or canal lock, entanglement, perinatal, and other natural factors (such as disease and natural catastrophe). Unfortunately, three among these five categories are associated with human. Hence, I aim to estimate and compare anthropogenic and natural catastrophic effects on the manatee population dynamics. I will conduct a literature review to obtain the basic demographic data and develop a stage-structure population dynamics model of the Florida manatee. I will use the data from the Florida Fish and Wildlife Conservation Commission synoptic surveys to calculate average mortality rates and a 95% confidence interval of those four scenarios including baseline, anthropogenic threats, cold stress, and perinatal effects. I will simulate each scenario with the worst, average, and better cases from each of their average mortality rates for the next decade.

# ACKNOWLEDGEMENTS

I would like to thank my research advisor Dr. Hsiao-Hsuan Wang, who gave me guidance and confidence throughout this research project. I also want to thank Dr. William E. Grant for his support on this project.

Thank you to my friends and colleagues in the Ecological Systems Laboratory who made my research experience the best I could have asked for. Thanks to the Wildlife and Fisheries department and Applied Biodiversity Program for providing support through funding and encouragement. I also want to extend my gratitude towards LAUNCH who have given me the opportunity to express my research through this thesis.

Finally, I'd like to thank my family who have supported my education through encouragement and love.

# CHAPTER I

# INTRODUCTION

The ocean covers about 70% of the earth and contains many species that thrive together to keep the marine ecosystem alive. A marine ecosystem provides humans with many services such as food, transportation, energy, and recreation (Longo & Clark, 2016). This type of ecosystem has played an important role in human history, yet it remains intangible and is seen as a realm beyond society (Longo & Clark, 2016). The vast amount of biodiversity that exists in the ocean has been affected through the years by humans and is beginning to decline due to over-harvesting, pollution, and direct and indirect impacts of climate change (Hughes et al., 2005). There are many anthropogenic effects that have altered the biodiversity and function of the marine ecosystem, including coastal regions. These coastal regions have become developed into modern economic societies and incorporated into larger cities, which then allows for the coast to become vulnerable to change. The Florida manatee thrives along the coast of Florida and can be seen throughout, especially in the south during their winter migration. Through these anthropogenic effects, and many other factors, the Florida manatee has struggled in maintaining a healthy population.

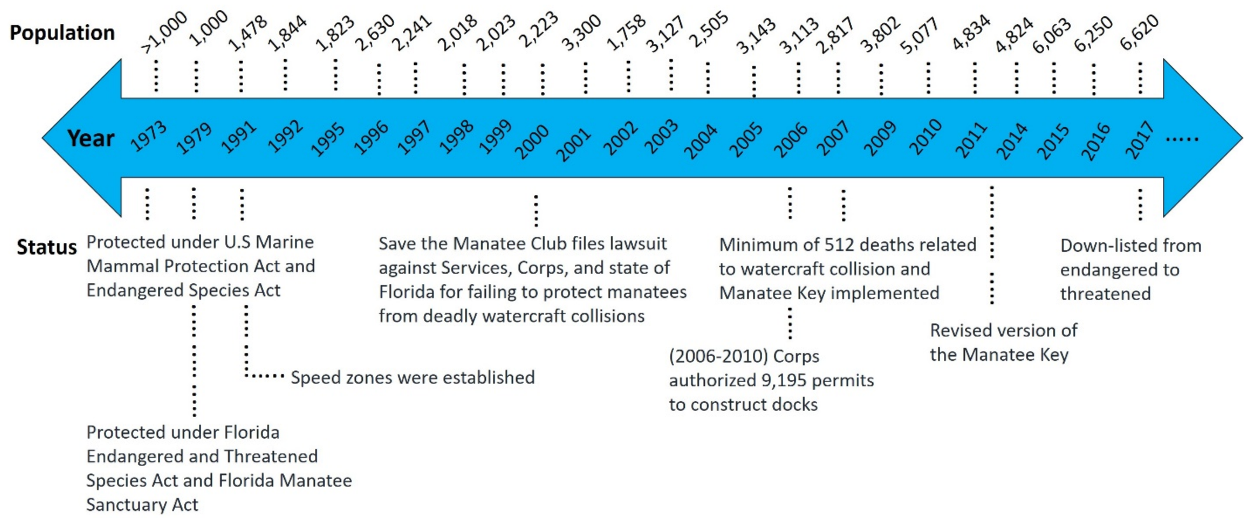


Figure 1: Historical trend of the Florida manatee individual population and their status through the years of 1973-2017.

In 1972 the Florida manatee was protected under the U.S. Marine Mammal Protection Act and the following year the Endangered Species Act (Marmontel et al., 1997) (Fig. 1). This allowed individuals to begin working on their recovery since their approximate population was estimated to be less than 1,000 individuals. In 1977, more laws and regulations were placed on the manatee for their protection, including the Florida Endangered and Threatened Species Act and in the following year the Florida Manatee Sanctuary Act (Marmontel et al., 1997) (Fig. 1). After these were put into place the population of the manatee was recorded at about 1,000 individuals. Around the 1990's the state of Florida established speed zones, which were intended to prevent collisions between watercrafts and the manatees. The population was at about 1,478 at the time and over the next decade their numbers rose to about 2,223 (Manatee Synoptic Surveys) (Fig. 1).

In the year 2000, the Save the Manatee Club (STMC) filed a lawsuit against several individuals including the U.S Fish and Wildlife Service, the Corps, and the state of Florida because they believed they were failing to protect the manatees from watercraft collisions (Center for Biological Diversity, 2017). Between the years 2006 to 2010 the Corps authorized 9,195 permits to construct docks, which have created impacts on the manatee population, even though they claimed to use the Manatee Key to evaluate the potential damages. During these years the population did continue to rise from about 3,113 to 5,077 individuals (Manatee Synoptic Surveys).

Going back a few years, in 2003, the U.S Fish and Wildlife Service underwent an assessment through the Marine Mammal Protection Act to evaluate the effects of watercrafts (Runge et al., 2007). A few years later, in 2006, the U.S Geological Survey (USGS) coordinated with several scientists to develop the Core Biological Model (CBM) in order to efficiently assess the Florida manatee (Runge et al., 2007). The following year they conducted a 5-year review on the status of the Florida manatee population, as required by the Endangered Species Act and years later they developed a new CBM that can be used to estimate the optimum sustainable population level (Runge et la., 2007). Through the years the U.S Fish and Wildlife Services continued to conduct 5-year reviews and the USGS updated the CBM so that the population of this species can be evaluated resourcefully.

Monitoring this species has become a crucial aspect to maintain a healthy population. Since these marine mammals are sensitive to cold temperature, they rely heavily on warm-water refugees to survive through the winter (Laist & Reynolds, 2005). This causes the manatee to congregate around the coast of Florida, which allows for human impacts to occur towards their populations. Even though the reclassification of the West Indian manatee (including the Florida manatee subpopulation) went from endangered to threatened in March 2017, which is a huge step towards a healthy population (U.S. Department of the Interior, 2017), there are still many deaths occurring due to the anthropogenic effects.

As stated in the Endangered Species Act, several criteria must be met, including the removal of threats to their habitat, establishing regulatory mechanisms for protection, and achieving quantitative demographic criteria, to down-list a species (Runge et al., 2004). Thus, the threats towards the Florida manatee need to continue to be assessed to ensure a healthy population of manatees. Simulation models are used widely to assess potential causes of observed patterns and to project future patterns, and several models have simulated the population dynamics of the Florida manatee. In the present study, I developed a simulation model based on literature and data from Manatee Synoptic Surveys to assess the anthropogenic effects on the population of the Florida manatee.

# CHAPTER II

# METHODS

The Florida manatee can be found in warm water environments such as rivers, estuaries, lagoons, bays and even near shore shelves. They are known to inhabit coastal waters and rivers in southeastern U.S and the Gulf of Mexico, as well as near the coast of Texas (Bossart, 1999). They are very sensitive to the water temperature and anything below 68 °F may cause a threat to their survival. Since these marine mammals are sensitive to cold temperature, they rely heavily on warm-water refugees to survive through the winter. There are essentially two types of warm-water refugees that these mammals rely on that either provide a continuous supply of warm water or temporarily retain relatively warm water (Laist & Reynolds, 2005). The use of these warm-water refugees is an important aspect to the survivability of these mammals since they rely so much on the use of them during the cold months. Unfortunately, many of the locations they migrate to are beginning to disappear and they must look for new resources. This makes the coast of Florida a suitable environment during their winter migration range, which can be seen in figure 2.

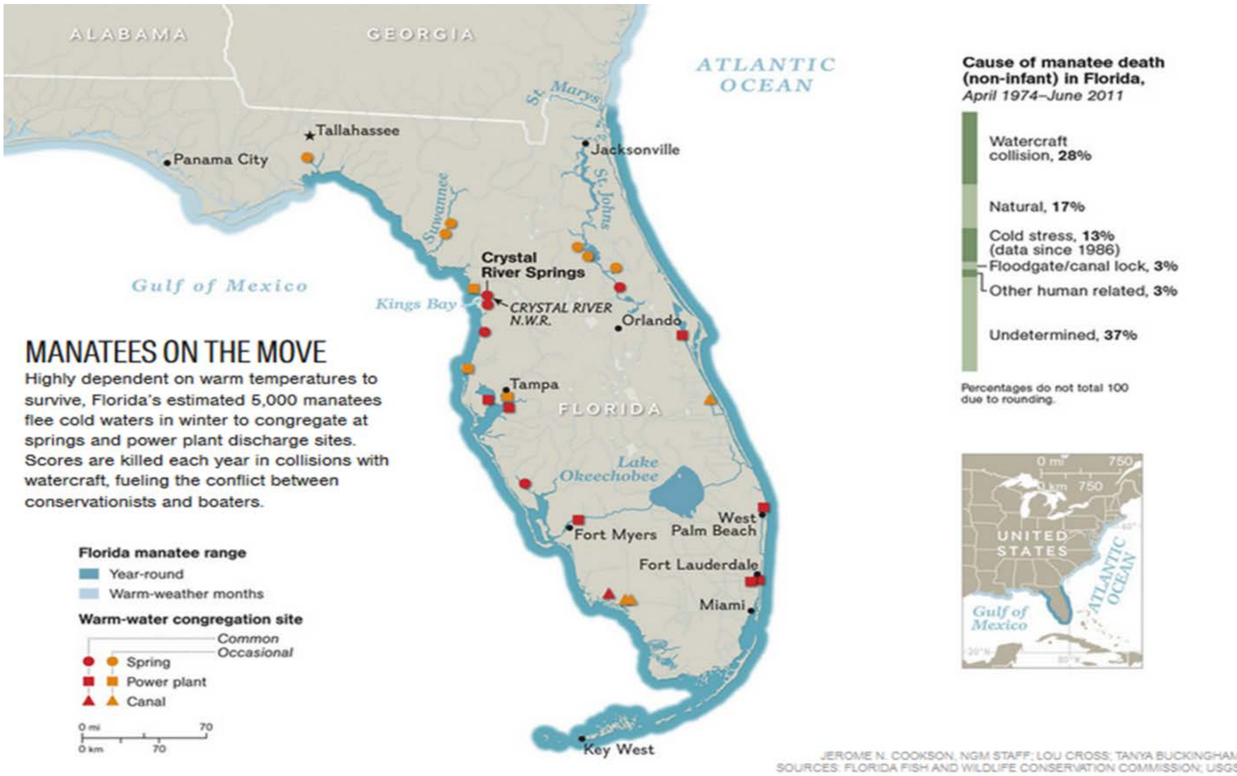


Figure 2: Study area which shows the range, congregation sites, and causes of death of the Florida Manatee (Carylsue, 2017).

Florida is considered the northernmost range of this species and they may even congregate around warm natural springs, canals, lakes, and even warm areas near electric power plants and other industrial sources to help them cope with the winter temperatures (Bossart, 1999). Most of Florida has a humid sub-tropical weather throughout the year and it is made up of primarily of coniferous (Boreal) forest. While South Florida has a tropical savannah weather, southeast Florida has a tropical monsoon and tropical rainforest weather. Florida usually has an average high temperature of 79.5 °F, an average temperature of 67.6 °F, an average low temperature of 55.7 °F, and an annual precipitation of 59.21 inches of rainfall (Climate Florida, n.d.). As herbivores, the Florida manatee may also consume a variety of plants which include smooth cordgrass, salt marsh, true grasses, and mangrove foliage. Because their habitat includes sub-tropical temperatures they are exposed to a more diverse habitat that includes food resources like seagrass, an important part of the sirenian diet. The grittiness of their diet has allowed for a number of adaptations such as replacement of molars to deal with the relentless wearing down of their teeth, and a cleft lip that has also evolved to support bottom and surface feeding. Their adaptations for forelimb flippers not only help for steering their way through water but aid in their handling of vegetation. They have a leather like epidermis that flakes continuously to help keep algae and barnacles from building up on their backs and causing a disturbance to their mobility (Florida Manatee Facts and Information, n.d). Manatees can live for as long as 60 years but most of the population's life expectancy is only 40 years. Female manatees can give birth to a single calf every 2.5 to 5 years, which can contribute to the mortality rate exceeding their ability to produce new individuals (Bossart, 1999). As large marine mammals, manatees do not encounter many predator threats in the sea. An occasional predator could include large sharks including tiger or bull sharks, American alligators, crocodiles, and very rarely orcas.

In order to explore the anthropogenic effects on the Florida manatee a conceptual model was created through STELLA, where four different types of mortality scenarios were established that incorporated mortality rates from the Florida manatee synoptic surveys collected from 2009 to 2017 (Fish and Wildlife Research Institute, n.d.). The four mortality scenarios that were incorporated into the model include a baseline that was constructed from the 2009 Florida Fish and Wildlife Conservation Commission mortality statistics, human-related threats, cold stress, effects of 2010 oil spill, and natural death. These scenarios were imputed into the model as numbers 1-4, respectively, through a constant labeled mortality scenario which can be seen in figure 3.

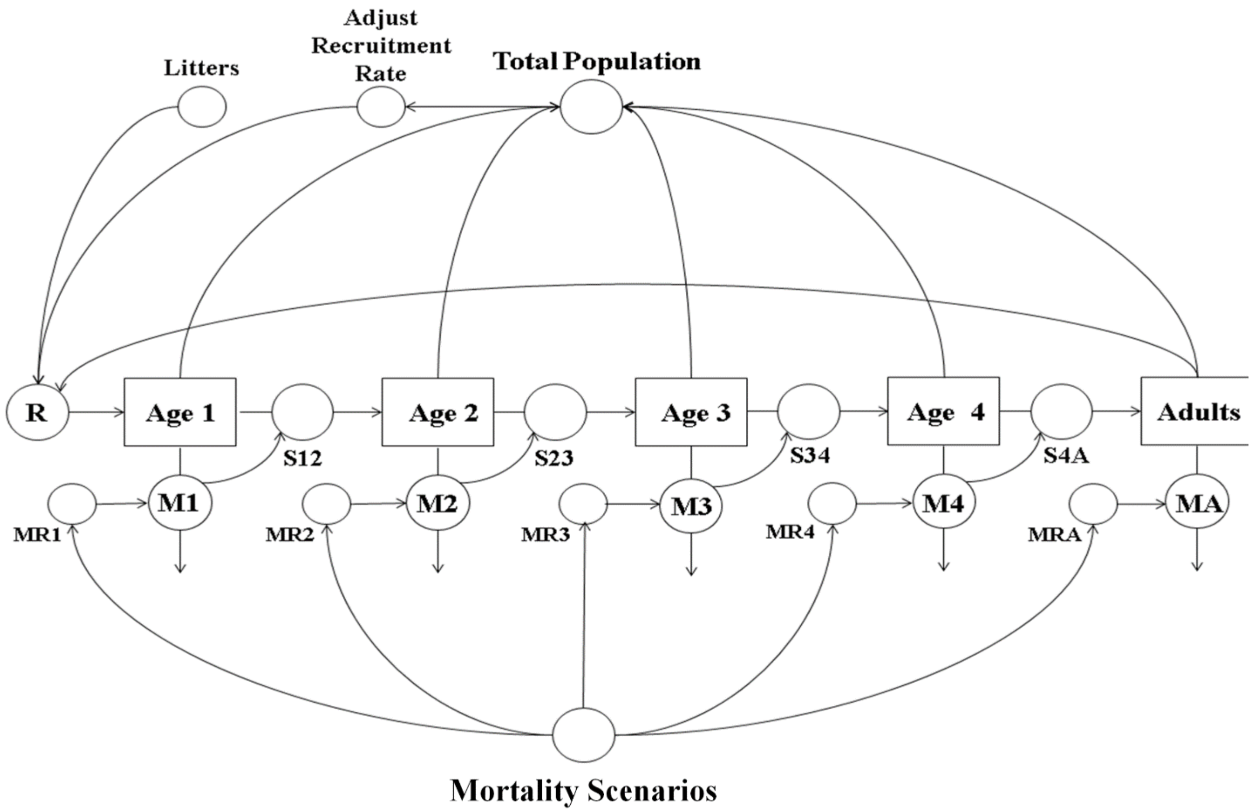


Figure 3: Conceptual model representing the different age classes of the Florida manatee and how they are affected by the different mortality scenarios.

The boxes represent state variables, large arrows represent material transfers, small arrows represent information transfers, circles represent variables and constants (Fig. 3). These mortality scenarios are connected to the constants that account for the mortality rates of each age class which are represented by MR1, MR2, MR3, MR4, and MRA.

If (Environmental Scenarios=1) Then (0.2032) Else If (Environmental Scenarios=2) Then (0.2802) Else (0.3572)

(1)

If (Environmental Scenarios=1) Then (0.0816) Else If (Environmental Scenarios=2) Then (0.1836) Else (0.2856)

(2)

If (Environmental Scenarios=1) Then (0.0607) Else If (Environmental Scenarios=2) Then (0.1405) Else (0.2203)

(3)

If (Environmental Scenarios=1) Then (0.0716) Else If (Environmental Scenarios=2) Then (0.1390) Else (0.2064)

(4)

If (Environmental Scenarios=1) Then (0.07981) Else If (Environmental Scenarios=2) Then (0.09221) Else (0.10461)

(5)

The mortality rates for each age class were calculated using the ratio difference from previous mortality collected from a 1999 literature review and the mortality rates from recent synoptic surveys. These rates are connected to the mortality of each age class, which is leaving the population and is labeled as M1, M2, M3, M4, and MA. The recruitment parameter is established through:

Adults*0.5*Liters*Adjustment Recruitment Rate

(6)

This allows for an accurate number of individuals that are being added to the population over the years. The adjustment rate for the recruitment is established as the rate goes from 1 to 0 the total population increases from 0 to 5000 individuals. The total population is determined by combining the different age class populations:

Age 1+ Age 2+ Age3+ Age 4+ Adults= Total Population

(7)

The survival of each age class is determined by the number of the previous age class minus the mortality of each age class, which is represented by S12, S23, S34, and S4A. The initial population was determined using the most recent Florida Synoptic Survey estimate. All these parameters have been incorporated into the model and were used to establish a better understanding of the anthropogenic effects on the Florida manatee.

# CHAPTER III

# RESULTS

The population dynamics model we developed was used to run four different scenarios based on the information obtained throughout this project. The first scenario that we ran was a baseline population using the most recent population numbers from the Florida synoptic surveys. This scenario ran with an ideal environment and no other factors occurring, which can also be described as a natural death. A baseline population was established to compare how the anthropogenic or catastrophic events affected the population of the Florida manatee in the next 20 years (Fig. 4). As seen in the graph, the population stabilizes around 4,900 individuals in the projected 20 years. This baseline was then used to compare the effect of the other scenarios.

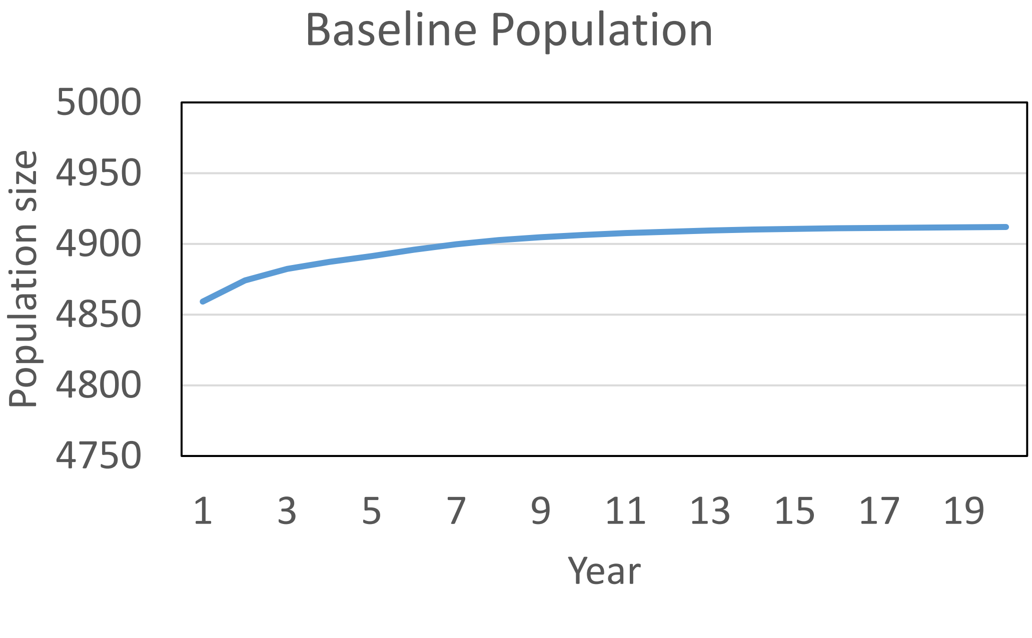


Figure 4: Baseline population of the Florida manatee projected over a period of 20 years and based off the most current population numbers obtained from the Florida synoptic surveys.

The second scenario we ran was to estimate the occurrence of another oil spill and how the population might be affected. The model ran several times to replicate the results and obtain the best outcome. Each line on the graph represents a different trail, however the light blue line represents the baseline scenario in each of the following graphs. This scenario was conducted with a 10% probability of another oil spill occurring, since we knew that an oil spill has previously occurred (Fig. 5). It can be seen that the oil damage didn't affect the population drastically. The population fluctuated slightly, however the number of individuals remained close to the baseline population and did not deviate dramatically. When the probability of another oil spill occurring was approximated at a 10% chance, the population dropped about 1% from 4900 to 4850.

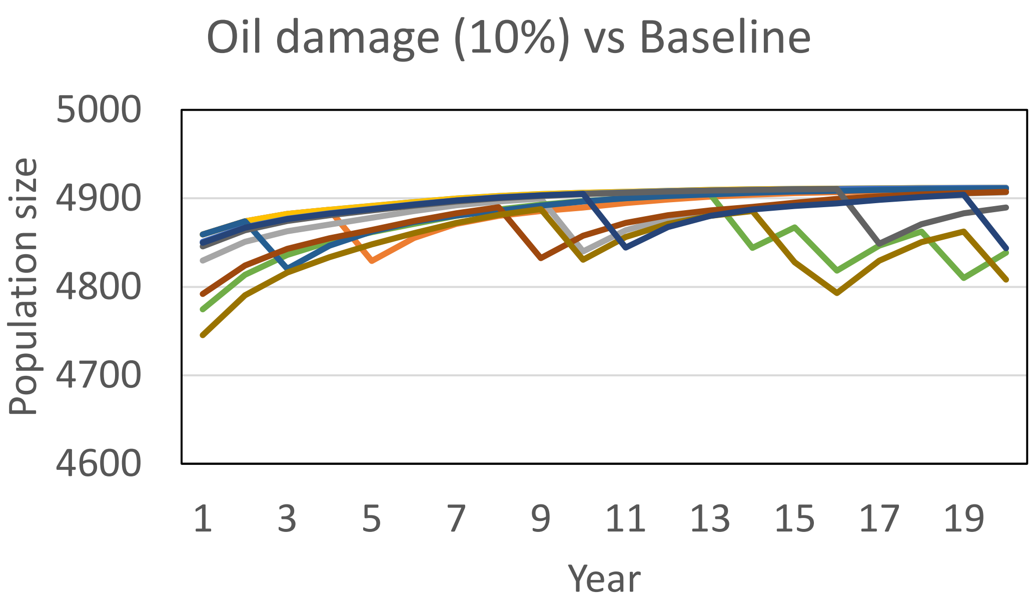


Figure 5: Baseline population compared to the population affected by oil damage with a 10% chance of occurring each year for a period of 20 years.

The third scenario we ran was to determine how cold stress would affect the population. This was predicted with a probability of cold temperatures below 68 degrees Fahrenheit occurring 35% of the time based off of Florida's average temperature for the past 10 years. The light blue line represents the baseline scenario and all other lines are different trails. This graph compares the cold damage against the baseline population, which demonstrates how drastically the change in temperature can affect the population. Throughout the 20-year predictions made by the model, it can be seen that there are large fluctuations that drop largely from the baseline population. Some trials predicted the cold stress to damage the population so drastically that their numbers dropped below half of the current estimates. While the model ran with a probability of cold stress occurring 35% of the time based on the temperature averages in Florida for the past 10 years, the population decreased 24% from 4900 to 3750.

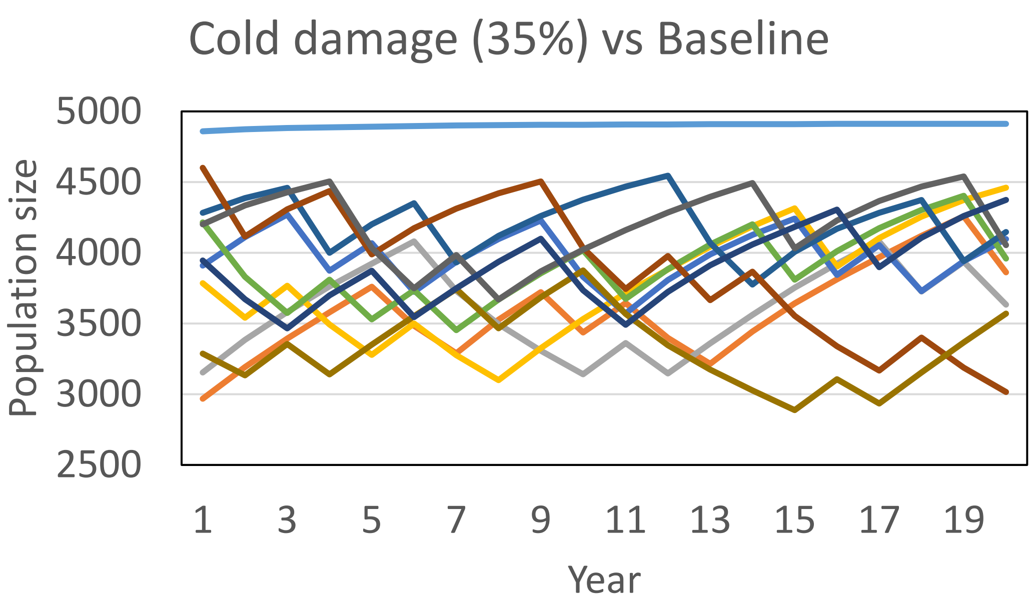


Figure 6: Baseline population compared to the cold damage effects on the Florida manatee population with a 35% of the temperature reaching below 68 degrees over a period of 20 years.

The final scenario that we ran was to determine the amount of human disturbance that affects the manatee population (Fig. 7). This included watercraft mortality, canal systems, and crushing by gates and lock systems. Human disturbance occurs on a daily basis so we ran the model using a 90% probability of these instances occurring in the next 20 years. It can be seen in this graph that the light blue line represents the baseline scenario and all other lines are trials.  In this scenario the human disturbance caused the population to have an initial decrease but stabilized over the predicted 20 years. Because the human disturbance was constant in Florida with a 90% chance of occurring, the population decreased 7% from 4900 to 4550.

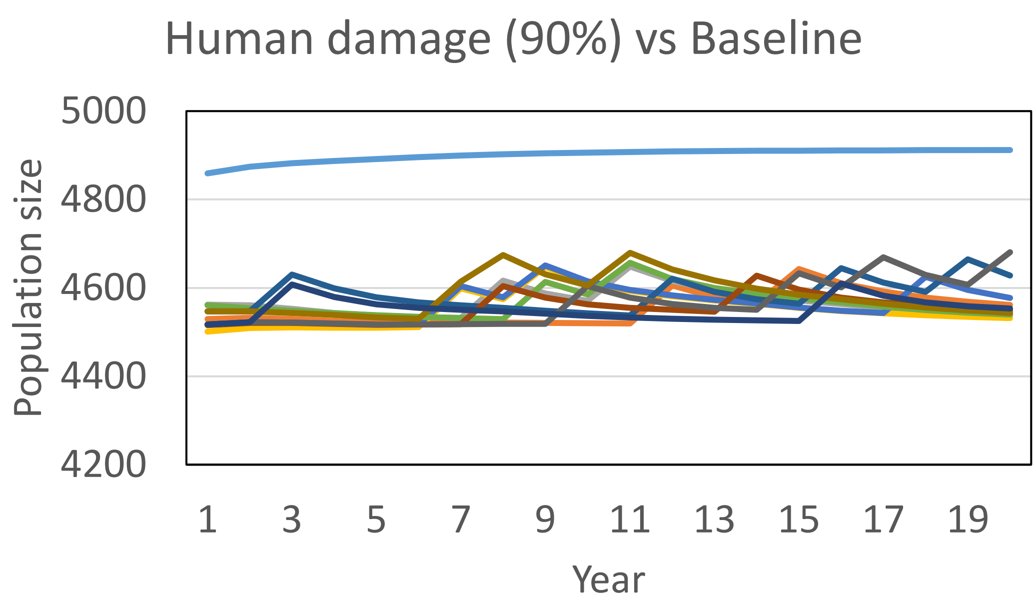


Figure 7: Baseline population compared to human disturbance occurring at a 90% chance over a period of 20 years.

When comparing all four scenarios based on our results, the leading factors affecting the manatee population are cold stress followed by human factors and oil damage. Even though the Florida manatee was reclassified from an endangered to a threatened species under the federal

Endangered Species Act in early 2017, the long-term monitoring and effective protections are still needed to ensure an increasing population.

# CHAPTER IV

# CONCLUSION

The Florida manatee have experienced an amazing comeback since the day they were listed as an endangered species in 1973. Laws and regulations have been established and enforced, which have allowed for their population numbers to increase over the past thirty-five years. These laws have been steered towards regulating the anthropogenic factors that have affected the species. Through this population model we have discovered that humans may not be the factor impacting this species the most. It has been understood for years that human factors, such as watercrafts, canal locks, and flood gates, were continuing to affect the population and were causing them to struggle to recover from past exploitations. However, using this population dynamics model, we have revealed another factor that may cause this population to struggle in the future. Cold stress can be brought upon these manatees when the temperature reaches anywhere below 68 degrees Fahrenheit. Looking back at the average temperatures in the past 10 years for Florida, there are few occasions where it reaches below 68 degrees Fahrenheit, which led us to predict that this would occurr 35% of the time. With the model it was predicted that the population would decrease by 24% in the next 20 years. This was the largest fluctuation seen throughout all four scenarios. Humans may not have created the largest impact on the population but they still nonetheless affected them in some way. With a 90% chance of human conflict occurring in the next 20 years the population would experience a 7% decrease in individuals.

These findings can be used to establish new laws and regulations that commit to exploring ways to create warm water refugees in which the manatee can survive the cold temperatures. It is important to continue and educate the public on why these majestic creatures are important to the ocean ecosystem. The manatee has down-listed from endangered to threatened, but that doesn't mean their population is at its best. Even after they've reached numbers where they can be taken off the IUCN list, it is still important to conserve the ecosystem they live in. One wrong move and their population can collapse once more. Educating the public is the most reliable way to continue the protection of this species. Knowing that cold stress may be the major factor affecting the population in the future is just the beginning of creating new ways to conserve the Florida manatee.

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