THE SPATIAL RELATIONSHIP BETWEEN NORTH AMERICAN MANATEE AND INDUSTRIAL POWER PLANTS

BY
JESSICA GOFF

MASTER OF SCIENCE
GEOGRAPHIC INFORMATION SYSTEMS TECHNOLOGY
FINAL PROJECT

THE UNIVERSITY OF ARIZONA

2022

TABLE OF CONTENTS

LIST OF TABLES **3**
LIST OF FIGURES **4**
LIST OF ABBREVIATIONS 5
ABSTRACT 6
CODE OF ETHICS **7**
INTRODUCTION 8
DATA 13
METHODS 19
RESULTS 22
    HOT SPOT ANALYSIS 22
    COLOCATION ANALYSIS 24
CONCLUSTION 31
REFFERENCES 32

LIST OF TABLES

Table 1.1 Metadata **15**

Table 2.1 Colocation Analysis Neighboring Categories 25

LIST OF FIGURES

Figure 1.1 Mortality of manatees by nature 9

Figure 1.2 Mortality of manatees by watercraft collisions 9

Figure 1.3 Mortality of manatees by cold stress 10

Figure 1.4 Graph of mortality of manatees by power plant type 10

Figure 1.5 Map of Florida **12**

Figure 2.1 Observed Manatee Locations 1991-2019 14

Figure 2.2 Total Manatees Observed per Year 1991-2019 14

Figure 2.3 Manatee Carcass Recovery Locations 15

Figure 2.4 Power Plant Locations in Florida 16

Figure 2.5 Power Plant locations within one mile from water in Florida 17

Figure 3.1 Model Builder **21**

Figure 4.1 Hot Spot Analysis 23

Figure 4.2 Colocation Analysis: 2-mile distance 26

Figure 4.3 Graph of the relationship between Local Colocation Quotient and p-value at 2 miles distance 26

Figure 4.4 Colocation Analysis: 6 miles distance 27

Figure 4.5 Graph of the relationship between Local Colocation Quotient and p-value at 6 miles distance 27

Figure 4.6 Colocation Analysis: 10 miles distance 28

Figure 4.7 Graph of the relationship between Local Colocation Quotient and p-value at 10 miles distance 28

Figure 4.8 Colocation Analysis: 15 miles distance 29

Figure 4.9 Graph of the relationship between Local Colocation Quotient and p-value at 15 miles distance 29

Figure 4.10 Colocation Analysis: 20 miles distance 30

Figure 4.11 Graph of the relationship between Local Colocation Quotient and p-value at 20 miles distance 30

LIST OF ABBREVIATIONS

LCLQ	Local indicator of colocation quotients
CLQ	Colocation quotient
CSS	Cold Stress Syndrome

ABSTRACT

The NPR podcast series *Planet Money* published a special series titled *How Florida's manatees got hooked on fossil fuels*, it talked about how manatees in Florida were dependent on the hot water that power plants are releasing into the ocean and how that might be a cause for an increase in manatee populations. This poses an interesting environmental industrial relation predicament where manatees are in danger of extinction and power plants might be a solution to saving this species, but power plants are also part of environmental degradation and climate change. This study looks at the relationship between power plant sites and observed manatee locations as well as manatee recovery locations throughout the state of Florida. Spatial statistics and hot spot analysis will help understand distribution of manatees and power plants. Point data sets for the years 1991-2019 were used to create density map, hot and cold spot analysis, and colocation analysis that concluded that manatees do conjugate around industrial power plants. However, manatees do cluster more around natural gas power plants as compared to Florida's other leading power plant facilities.

Keywords: Manatee, Power Plants, Climate Change, Colocation Analysis, Hot Spot Analysis, Clustering

CODE OF ETHICS

As a GIS professional our duty is to be open and transparent about what limitations and uncertainty that there might be in the analysis. With that being said, we want to avoid any misleading data that might be presented and be truthful in our findings. It is always best to ask questions on why the data was used a certain way as there are many ways to get to the same result. It is our job to make sure that we are not presenting misleading information or using data that might be biases. Data should be used from reliable sources and credited when need be.

The purpose of this project is to understand the relationship between manatees and power plants in Florida. By using GIS technology, we were able to answer our questions with no biases towards manatees or power plants. The manatee data came from a reliable source, The Florida Fish and Wildlife Conservation Commission. While power plant data came from the Homeland Infrastructure Foundation Level Database. These analyses revolve around only looking at total number of manatees observed over the span of 28 years within a 2 nautical mile radius from Power Plants that are within 1 mile from the water. Even though these analyses may conclude that manatees are conjugating by power plants, the power plants are not the solution to solving the declining manatee population.

INTRODUCTION

One of the gentlest creatures on earth is the West Indian manatee (Trichechus manatus), also known as the North American manatee, which can be found mostly in the shallow waters of Florida but have been known to migrate during the summertime to Alabama, Georgia, and South Carolina. According to the Manatee Synoptic Survey from Florida Fish and Wildlife Conservation Commission, 2019, “Preliminary results from the 2019 synoptic survey show that the highest counts consistently occur in areas with the greatest amount of warm-water habitat from power plants and natural springs such as Tampa Bay (>1000), Lee County (>900) and the Crystal and Homosassa River areas (>800)”. Since there has been an increase in population in the past 30 year, it has caused the U.S. Fish and Wildlife to down list the species from endangered to threatened (Marine Mammal Commission., 2022). There is less than 6,300 in the southeastern United States today (U.S. Fish & Wildlife Service., 2022).

With climate change on the rise, it means that temperatures will increase and decrease as severe weather anomalies are projected to increase (Szekeres, P, et al., 2016). This raises concern due to the few manatees that are left in Florida. When the water drops below 68 degree Fahrenheit, manatees that are exposed can result in cold stress syndrome (CSS; Hardy, Stacie K., et al., 2019). This can lead to many different health concerns like cold stress, diseases from red tides and abuse from watercrafts that would lead to death. Figures 1.1 through 1.3 show how many of these deaths are related to CSS versus other types of deaths like red tides and watercraft collisions. In figure 1.1, visually there is more mortality on the west side of Florida while in figure 1.3 there is more mortality on the east side of Florida. As for figure 1.2

there is visually high mortality across Florida. When comparing the type of mortality to the type of power plant, there tends to be higher rate of mortality caused by red tides around natural gas power plants as shown in figure 1.4.

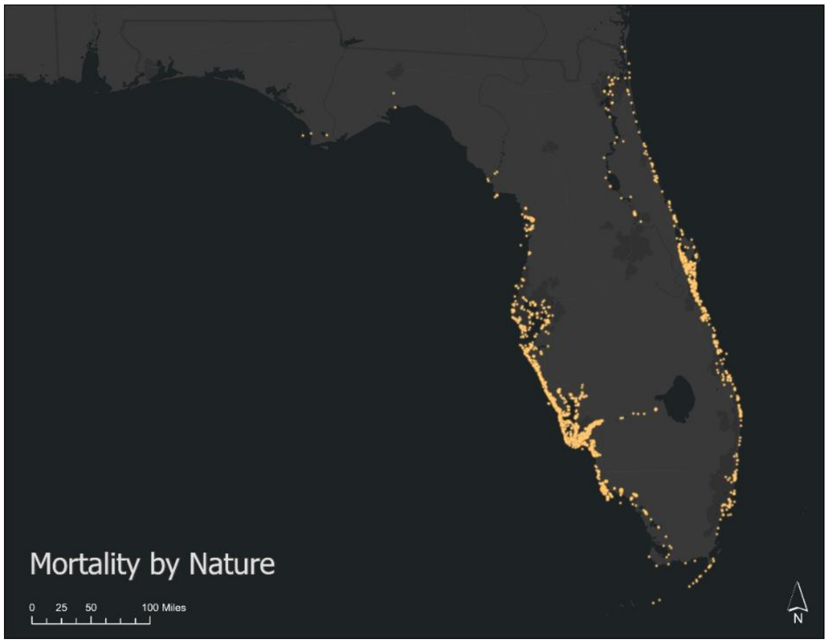

Figure 1.1 Mortality of manatees by nature. (Florida Fish and Wildlife Conservation Commission, 2019).

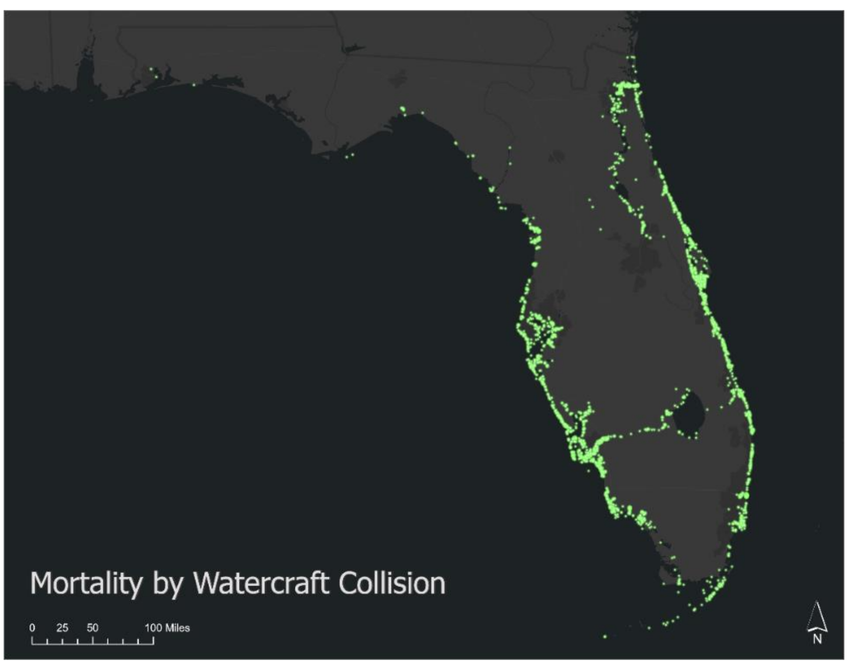

Figure 1.2 Mortality of manatees by watercraft collisions. (Florida Fish and Wildlife Conservation Commission, 2019).

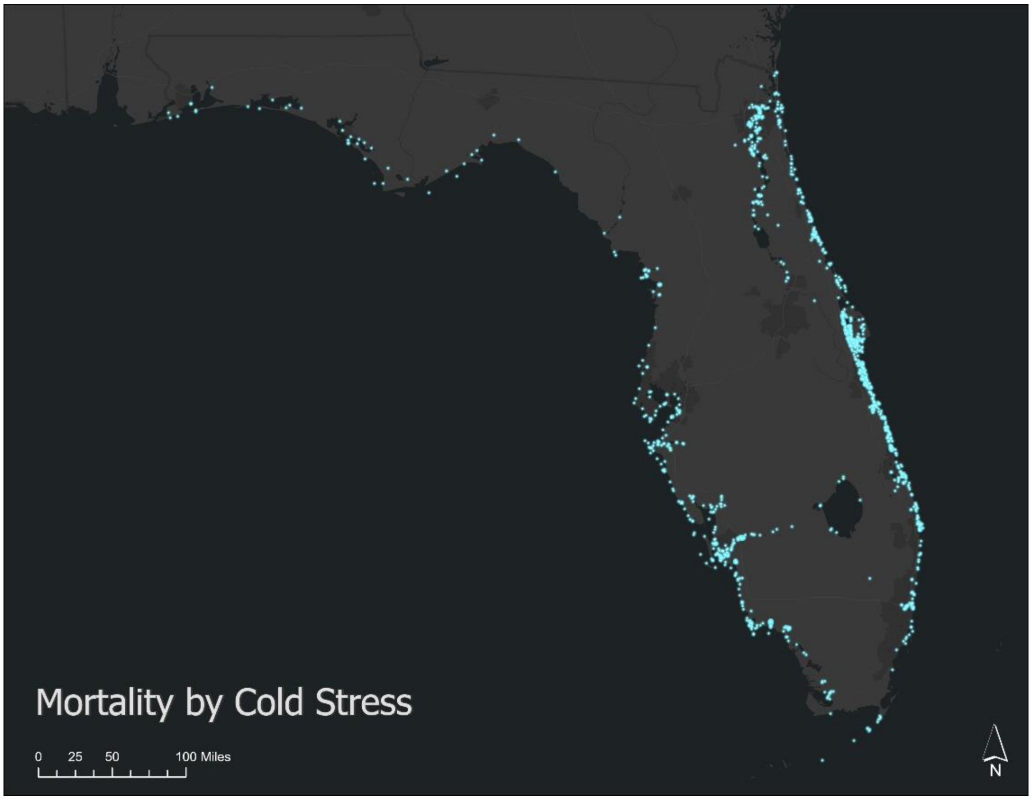

Figure 1.3 Mortality of manatees by cold stress. (Florida Fish and Wildlife Conservation Commission, 2019).

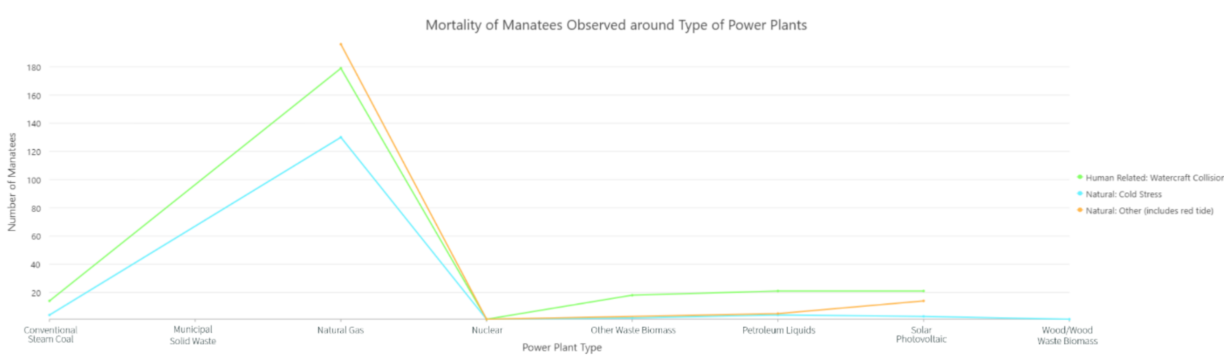

Figure 1.4 Graph of mortality of manatees by power plant type. (Florida Fish and Wildlife Conservation Commission, 2019).

NPR released a podcast episode called "How Florida's manatees got hooked on fossil fuels" that focused on how power companies like Florida Power & Light are emitting hot water into the ocean (Horowitz-Ghazi, Alexi., 2022). While emitting hot water into the ocean can lead to a decrease in fish and other species, one of the only animals that would benefit from this hot water would be the manatees. Manatees need to be in water above 68 degrees Fahrenheit to survive. A 1991 survey, to assess the manatee population, found that there were 1,267 manatees in Florida (U.S. Fish & Wildlife Service., 2022). In 2015, this number increased to around 6,000 and has stayed constant up to the last assessment conducted in 2019 with an estimated 6,300 manatees that have been observed, there was a significant increase since the first assessment in 1991. When layering manatee points and power plant locations on a map, visually you can see clustering near power plant locations. Based on those observations, it seems that there is a spatial relationship between manatees and power plants. It is suggested that about 60% of the manatee population is dependent on the power industry (Horowitz-Ghazi, Alexi., 2022).

The goal of this study is to explore the relationship between manatees and power plants in Florida. The objectives were to (1) learn the spatial relationship between manatees and power plants; (2) understand the type of power plants that manatees are observed near the most by; (3) identify the overall health of manatees observed near the power plants.

STUDY AREA

The study area included the state of Florida and the surrounding body of water (i.e., Gulf of Mexico and Atlantic Ocean; Figure 1.5). Florida has 1,350 miles of coastline which around

825 miles of that is made up of sandy beaches and a population of 19.6 million people. About 15 million of those people live in coastal areas. Florida's three largest sources of power are natural gas, coal, and nuclear.

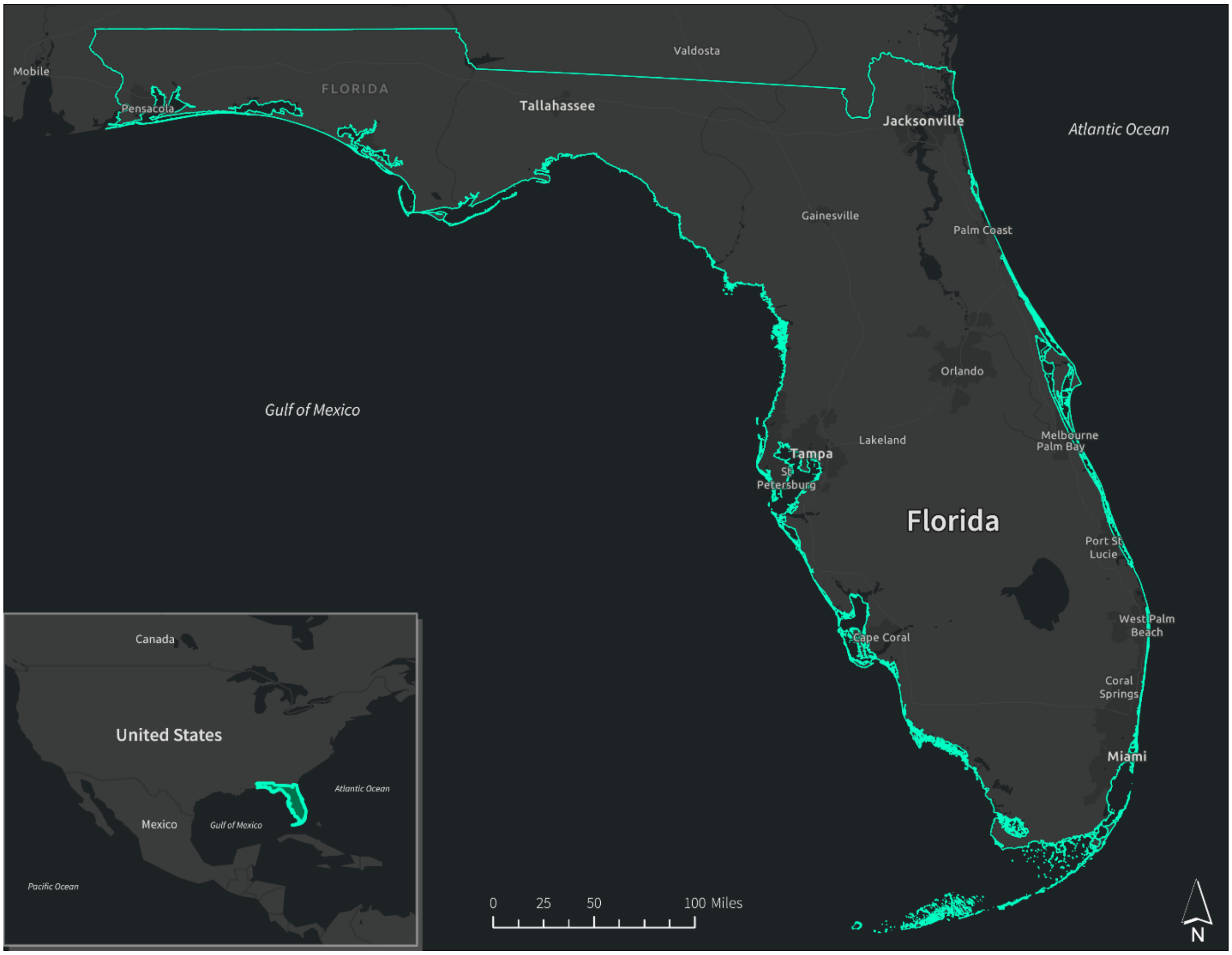

Figure 1.5 Map of Florida.

Areas that manatees are found in are shallow areas like rivers and coastal bodies of water where seagrass can be found. There is currently only one refuge created to specifically protect the manatees in Florida, it's called the Crystal River National Wildlife Refuge which is located about 80 miles north of Tampa. Most areas in Florida during the winter months experience temperatures averaging between 60-70 degree Fahrenheit.

DATA

Data was collected from Florida Fish and Wildlife Conservation Commission, Homeland Infrastructure Foundation Level Database, United States Environmental Protection Agency (EPA), Florida Geographic Information Officer, and Florida Department of Transportation. See table 1.1 to see the metadata associated with this project. All data was publicly available and was downloaded as shapefiles to be then imported into Esri's software called ArcGIS Pro.

The manatee observed points were collected from 1991-2019, and usually data collection was between January and February when it is the coldest time of the year (Figure 2.1, 2.2). This layer provides information about the coldest times in Florida and manatees distribution pattern when the population is gathering near power plants and natural springs in large groups, according to Florida Fish and Wildlife Conservation Commission.

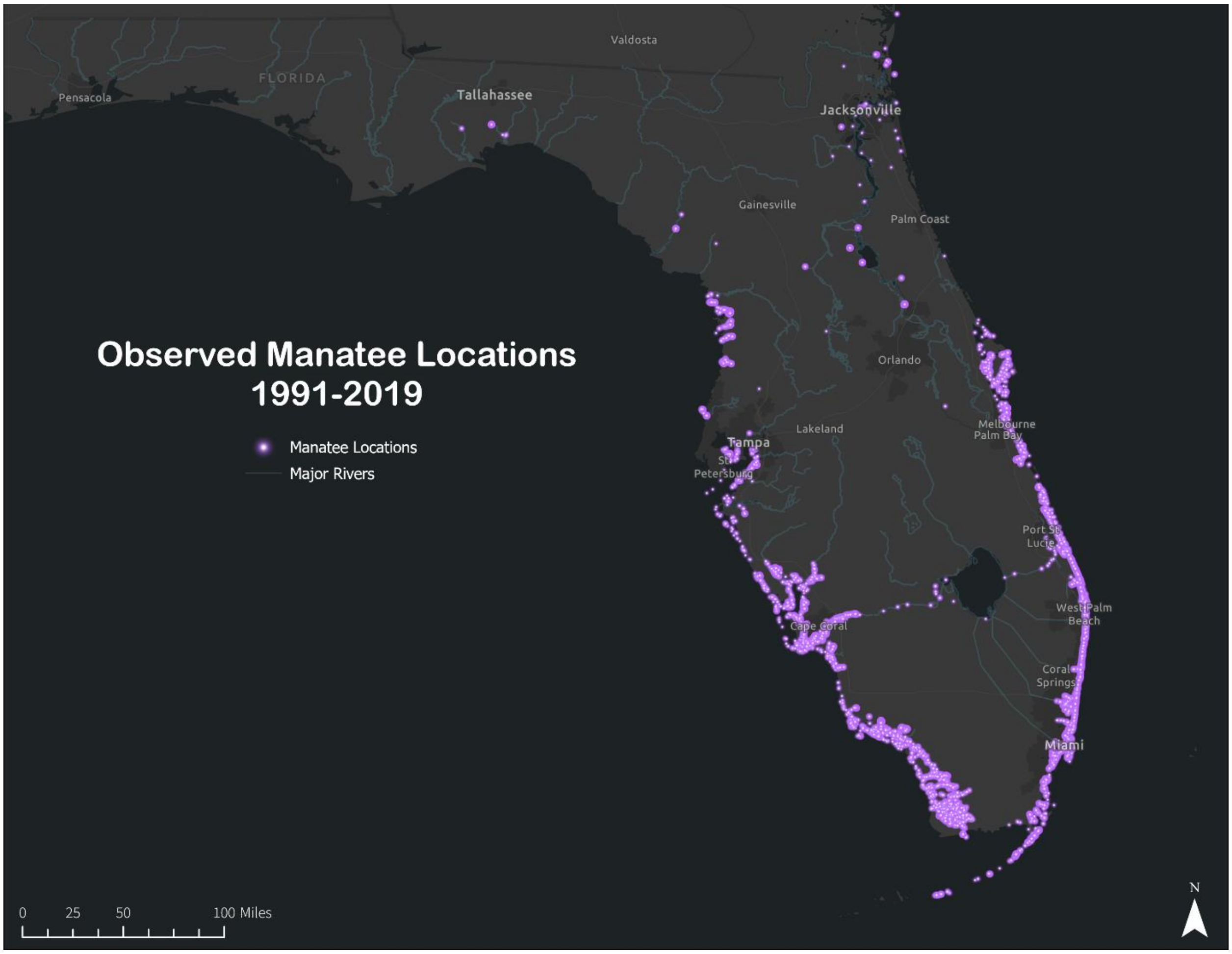

Figure 2.1 Observed Manatee Locations 1991-2019. (Florida Fish and Wildlife Conservation Commission, 2019).

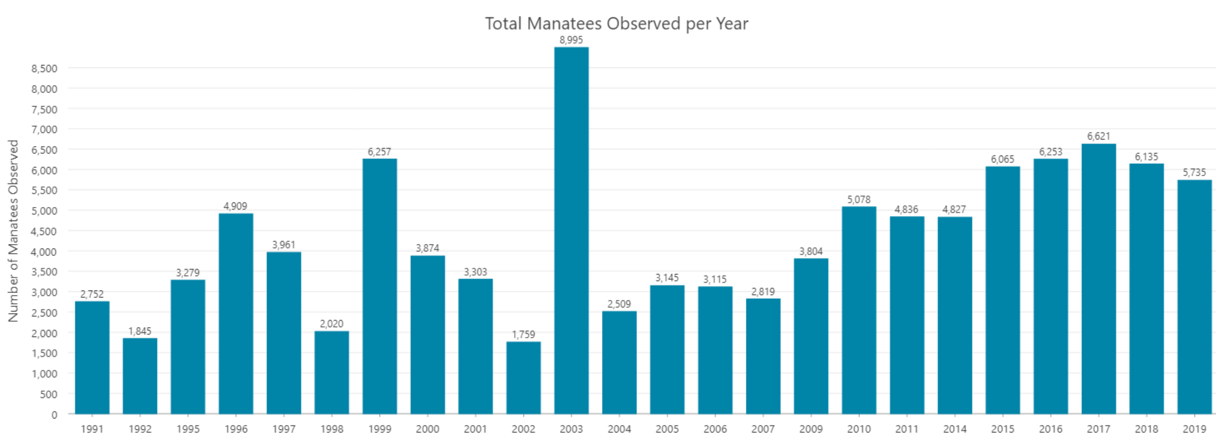

Figure 2.2 Total Manatees Observed per Year 1991-2019. (Florida Fish and Wildlife Conservation Commission, 2019).

Also, from Florida Fish and Wildlife Conservation, manatee carcass recovery locations data sets which recorded attributes like cause of death from 2000-2020 (Figure 2.3). The types of attributes focused on in this project was natural/red tides, cold stress, and human/watercraft collisions.

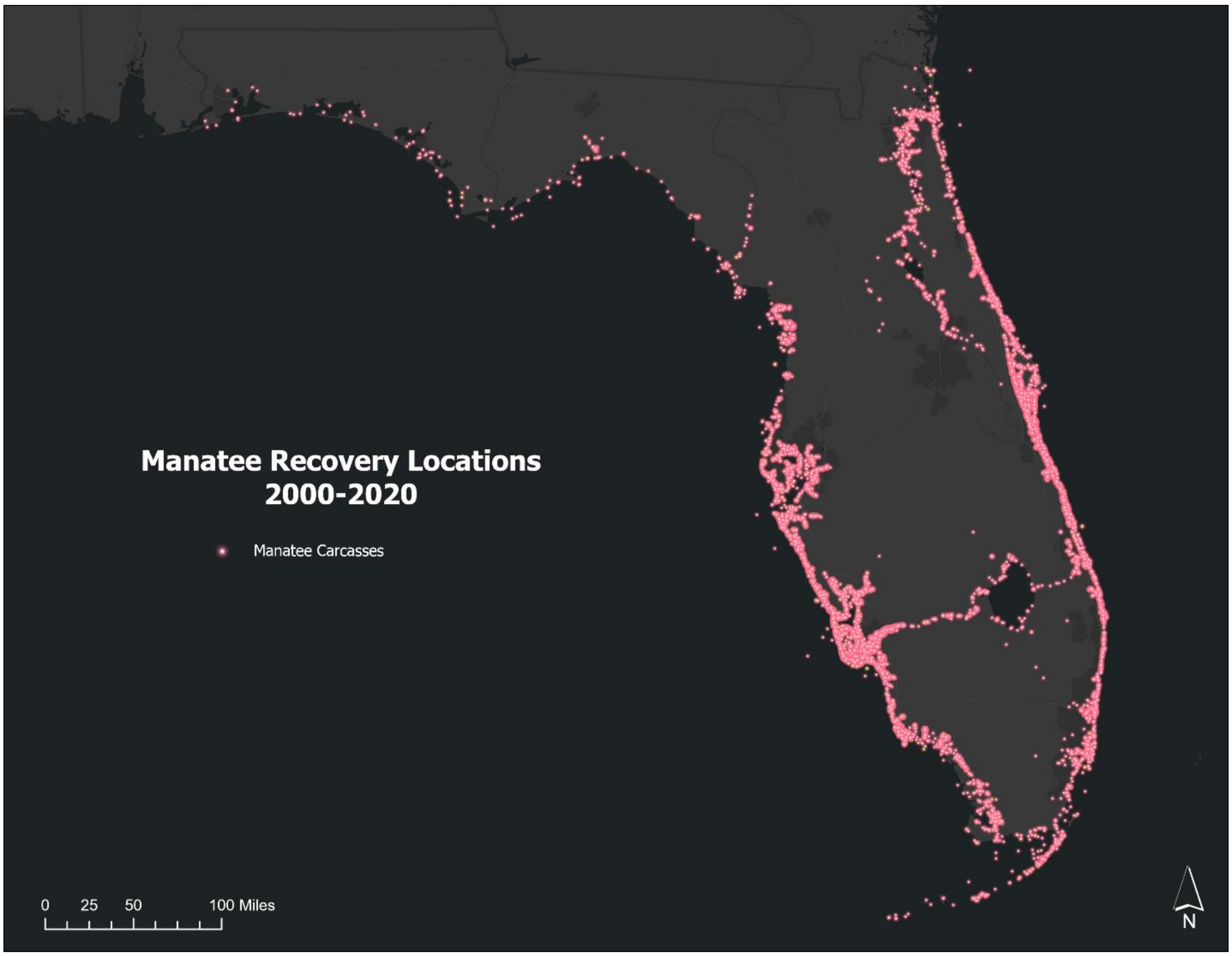

Figure 2.3 Map of manatee carcass recovery locations. Data came from the Florida Fish and Wildlife Conservation Commission.

Power Plant location is a feature class/shapefile that represents power plants for the whole United States. It was then clipped to Florida's boundaries (Figure 2.4). For this project, the focus was on the type of power plant which was then coded to a numerical domain to work within the types of analysis that was conducted (Figure 2.5).

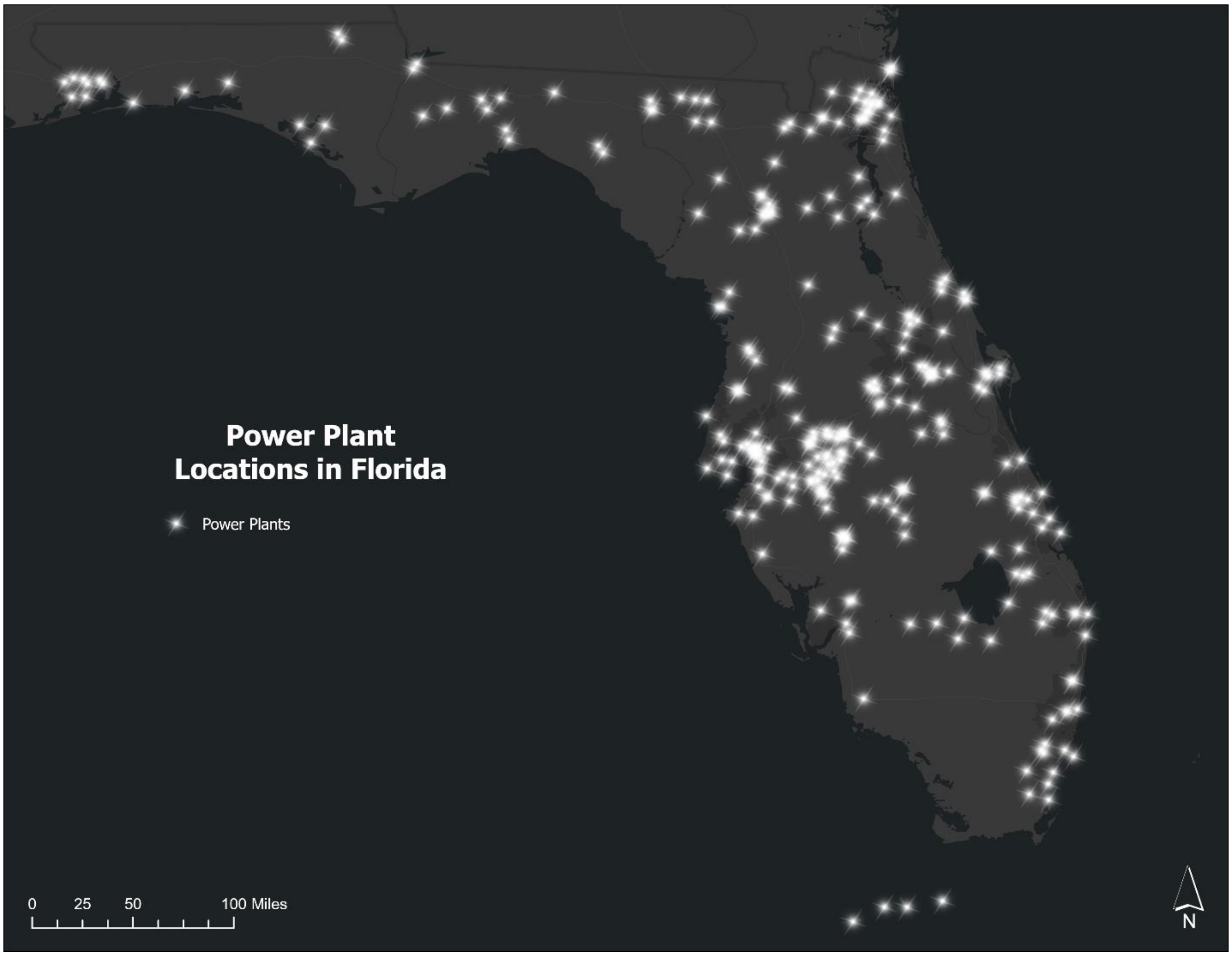

Figure 2.4 Map of Power Plant Locations in Florida using the Homeland Infrastructure Foundation geospatial data.

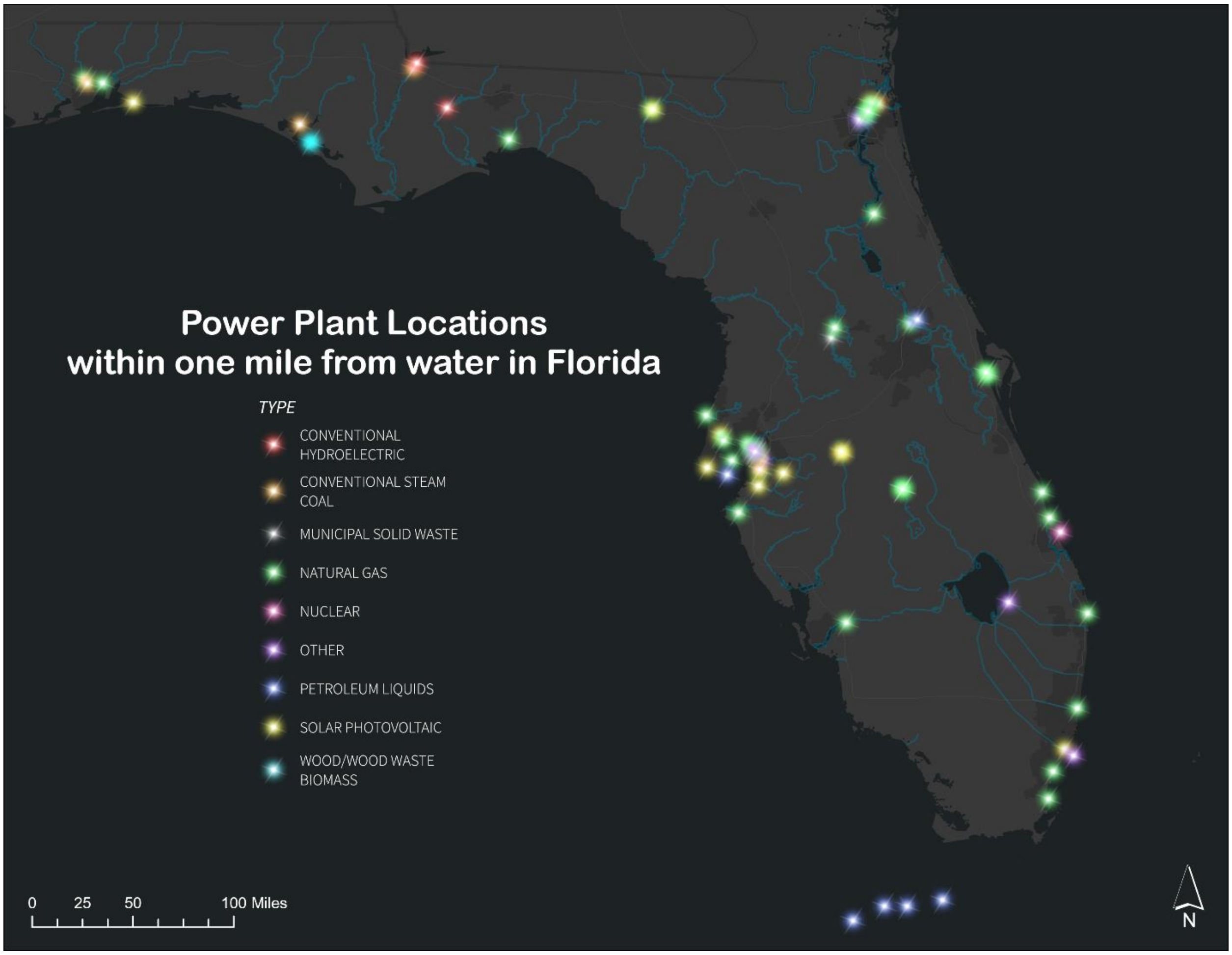

Figure 2.5 Power Plant locations within one mile from water in Florida.

Table 1.1 Metadata

Dataset	Year	Author	URL	Description	Horizontal Datum	Projection	Data Type
Manatee Synoptic Survey Observation locations	2019	The Florida Fish and Wildlife Conservation Commission	https://myfwc.com/research/manatee/research/population-monitoring/2019-synoptic-survey/	*An annual winter survey, Jan. 28 to Feb. 2, 2019. This is referred to as the synoptic survey and it is conducted following cold weather in years that meet our criteria.*	WGS84	None	Points
Manatee carcass Recovery Locations in Florida	2021	The Florida Fish and Wildlife Conservation Commission	https://geodata.myfwc.com/datasets/myfwc::manatee-carcass-recovery-locations-in-florida/about	The primary use of this data set is to display manatee carcass recovery or verification locations and associated attributes, such as cause of death.	WGS84	None	Points
Power Plants in Florida	2016	Homeland Infrastructure Foundation	Environmental Protection Agency (EPA) Facility Registry Service (FRS) Power Plants | HIFLD Open Data (arcgis.com)	This feature class represents power plants. Power plants are all the land and land rights, structures and improvements, boiler or reactor vessel equipment, engines and engine-driven generators, turbo generator units, accessory electric equipment, and miscellaneous power plant equipment are grouped together for each individual facility.	WGS84	None	Point
Major Rivers	2021	Florida Geographic Information Officer	https://geodata.floridagio.gov/datasets/major-rivers-lines/explore?location=27.503514%2C-80.784268%2C9.00	Major rivers in Florida	WGS84	None	Lines
Detailed Florida State Boundary	2019	Florida Department of Transportation	https://hub.arcgis.com/datasets/519e0a0ed5984bedba53695e1f56c1ee	Florida state boundary	WGS84	None	Polygon

METHODS

For this study, tools from Esri's ArcGIS Pro were used to produce a hot spot analysis and colocated analysis to determine the relationship between manatees and power plants in Florida. By utilizing the hot spot analysis, it allows us to look at clustering patterns and see if its locations are known to have power plants. A colocation analysis looks at the spatial association between feature classes while a hot spot analysis looks at cluster patterns. It allows us to see if there is any spatial relationship between the two feature classes and see if there might be a random factor. Summarize within tool was applied to clean up the data and to compare feature classes which helped to produce the results for the three main objectives.

The hot spot analysis was used to determine cold and hot spot clustering patterns for manatees observed. The Hot Spot Analysis tool calculates the Getis-Ord Gi statistic which means that it tells where there are high or low clustering spatially (Esri., 2022). The Gi statistic produces z-scores and p-values that are then represented visually. Hot spots with a 99% confidence have a high z-score and a low p-value. Cold spots have the opposite. Hot or cold spots with a 99% confidence indicate that there is less than a 1% chance that the clustering is at random.

The next step was to determine the relationship between power plants and manatees. To enable this, power plants that were near water had to be identified. This was accomplished by creating a 1-mile buffer around the ocean and all major rivers. By using spatial join achieved separating power plants that were not within the criteria for this project.

The colocation analysis looks at local patterns of spatial association between two-point features by using the colocation quotient statistic (Esri., 2022). The colocation quotient statistic is calculated by evaluating individual points from the category of interest and determining if the neighboring category is found within its neighborhood. In this case the category of interest would be the manatees and the neighboring category would be the power plants.

To understand the spatial relationship of manatees and power plants, Esri Model Builder within ArcGIS Pro was utilized to create 5 different colocation analysis (Figure 3.1). Since the distance would be evaluated, the neighborhood type was changed to be distance band. Setting the distance bands to 2, 6, 10, 15, 20 miles. The distance band ensures that the scale of analysis is the same across all neighborhoods in the study area (Esri., 2022). This process ensures there is an understanding of the measurements of spatial association by creating local colocation quotients (LCLQ) values. A LCLQ value of 1 indicates that the power plant is likely to have manatees as neighbors, as expected throughout the distribution of power plants. A LCLQ value greater than 1 indicates that it is more likely to have manatees as neighbors as compared to a random distribution. Whereas a LCLQ value of less than 1 indicates that it is less likely to have manatees as neighbors as compared to a random distribution. LCLQ bins were created at the end of the analysis with five categories; Colocated – Significant indicates manatees are attracted to power plants and that it is not due to randomness, Colocated – Not Significant indicates manatees are attracted to power plants but is more likely to be random, Isolated – Significant indicates manatees are not attracted to power plants and it is not due to randomness, Isolated – Not Significant indicates manatees are not attracted to power plants and it is more likely to be due to randomness.

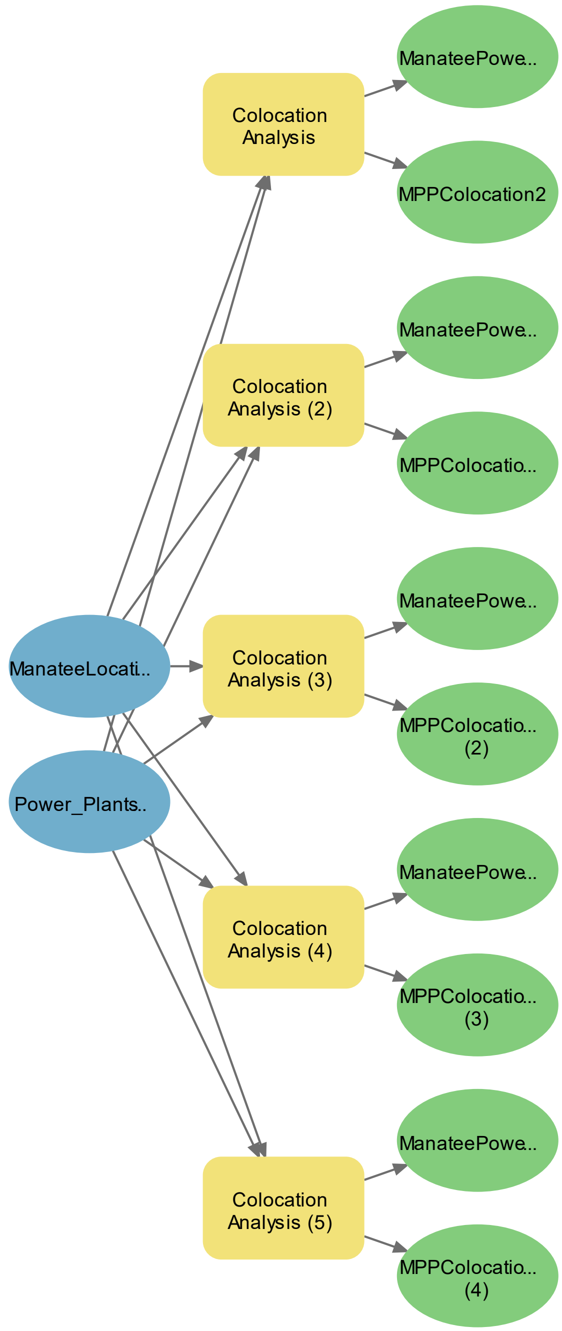

Figure 3.1 Model Builder used to create five Colocation Analysis at different distances. Testing if the category manatees tend to be attracted to the category power plants.

RESULTS

HOT SPOT ANALYSIS

The Hot Spot Analysis (Getis Ordi Gi) generated a map that showed where high and low values of manatee clusters existed around the Florida coastline. The z-score and p-value was used to determine if the null hypothesis could be rejected or not. With the Hot Spot Analysis overlayed with the power plant locations as shown in figure 4.1, manatees that were near power plants had hot spots with 99% confidence and an associated z-score of less than -2.58 or greater than +2.58 and a p-value of < 0.01. This means that there is a good probability that there is a geospatial relationship between manatees and power plants and therefore the null hypothesis can be rejected.

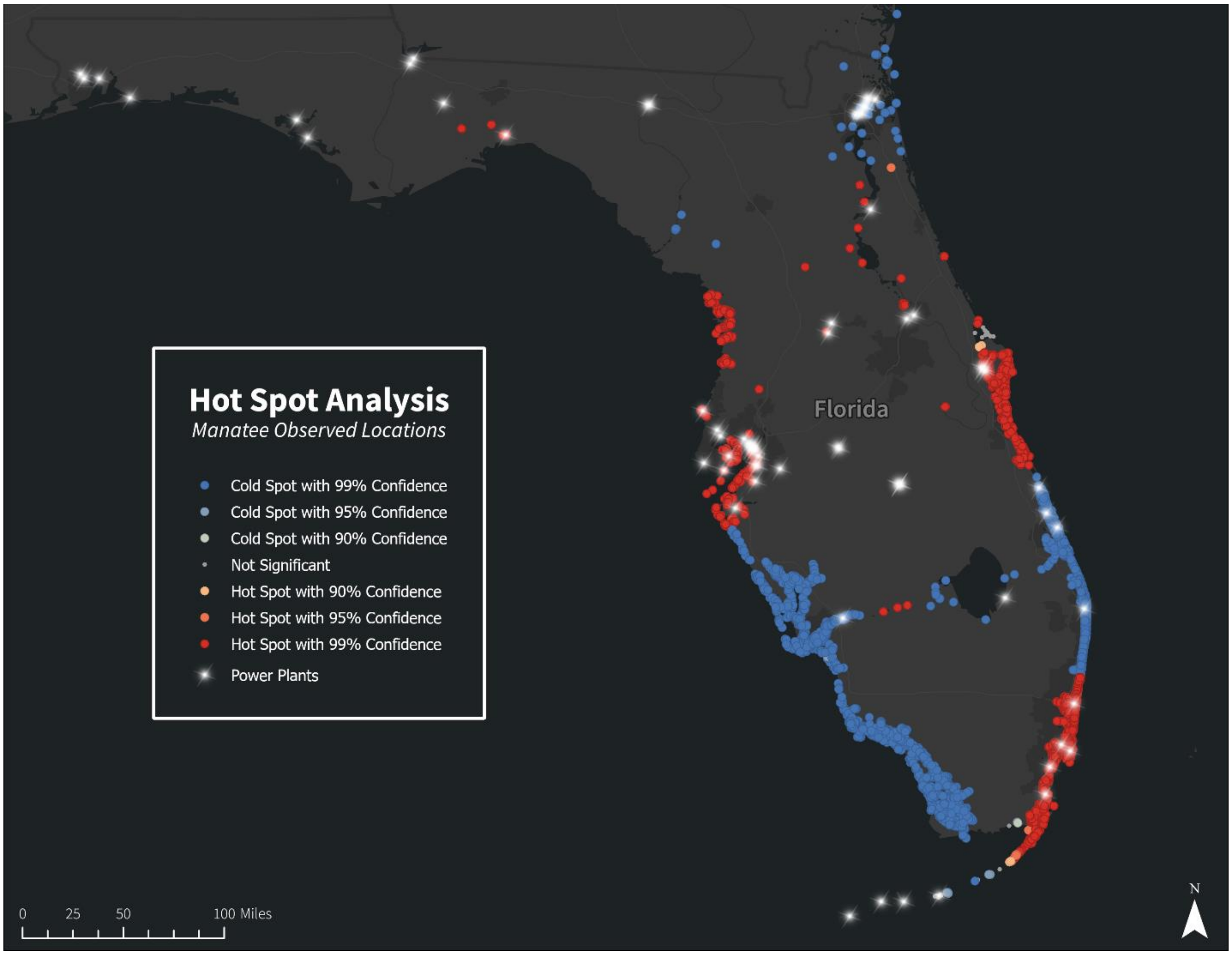

Figure 4.1 Hot Spot Analysis showing the confidence levels for years 1991 to 2019.

The spatial autocorrelation report generated by the Hot Spot analysis indicated that the data is significantly clustered with a z-source of 89.72 and that there is a less than 1% likelihood that the clustered pattern could be the result of random chance. Therefore, it is acceptable to reject the null hypothesis of complete spatial randomness.

COLOCATION ANALYSIS

When the colocation analysis was run, it results in a quotient score for each of the features of interest, this is called the local colocation quotients (LCLQ) which are binned and are given a p-value. On the map displays six different types of LCLQ assigned according to the feature as shown in table 2.1. What determines which LCLQ type each point depends on both the location colocation quotients and the p-value. It is determining those values are based on if the manatee points are individually for colocation with the presence of power plant points that are found within its neighborhood. If power plant points are within a neighborhood of any manatee points, then the global proportion of power plant points will have a high colocation quotient. If there are manatee points neighboring other manatee points with no power plant points nearby then the colocation will be Isolated (Esri, 2022).

Table 2.1 Colocation Analysis Neighboring Categories (ESRI, 2022).

Symbol	LCLQ Bin	LCLQ Type	Description
●	0	Colocated - Significant	Local colocation quotient is greater than 1 with a p-value less than 0.05.
●	1	Colocated - Not Significant	Local colocation quotient is greater than 1 with a p-value greater than 0.05.
●	2	Isolated - Significant	Local colocation quotient is equal to or less than 1 with a p-value less than 0.05.
●	3	Isolated - Not Significant	Local colocation quotient is equal to or less than 1 with a p-value greater than 0.05.
●	4	Undefined	The feature did not have any other features within its neighborhood or bandwidth equal to 0.

For this analysis I decided to run five analyses, each one having different distance bands. First, I started with a distance of 2 miles as shown in figure 4.2. Most of the manatee points are classified at Isolated – Not Significant indicating that manatees are not attracted to power plants with a few areas showing colocated – significant. As the distance band increases (Figures 4.3 through 4.8), more manatee points become colocated – significant but still see a significant number of isolated points. When looking at the 15-mile distance band (Figure 4.9), we start to see more of a relationship between LCLQ and the p-value indicating that there are more neighboring manatee and power plant points.

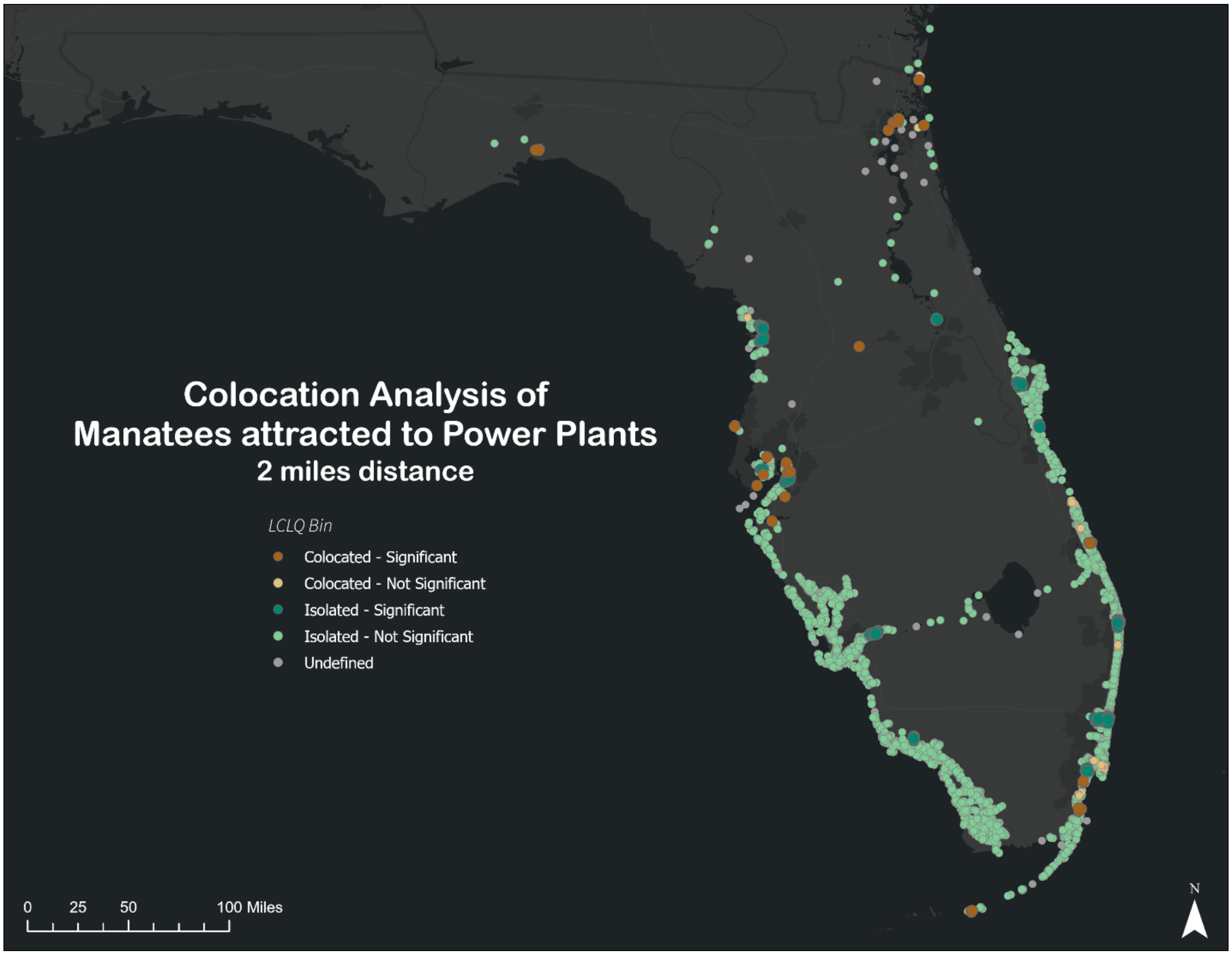

Figure 4.2 Colocation Analysis: 2-mile distance. Testing if manatees tend to be attracted to power plant locations.

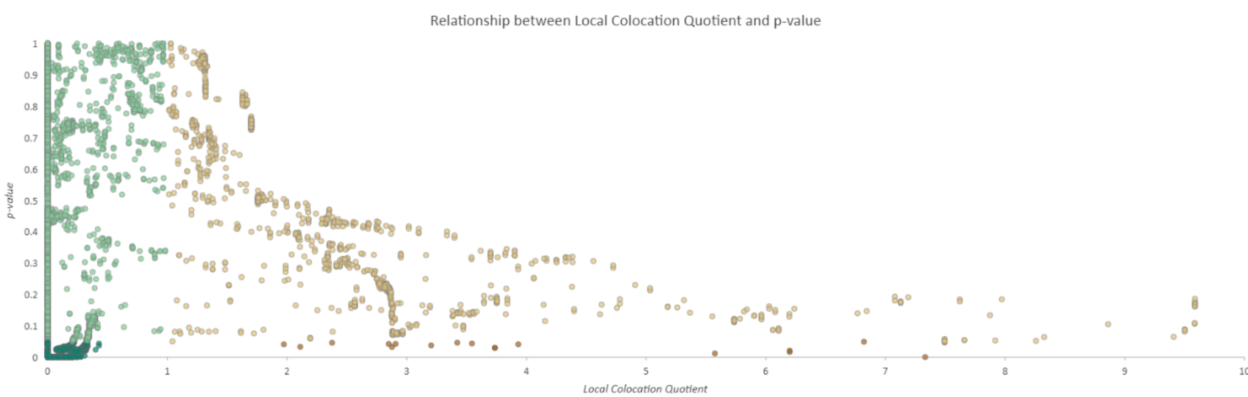

Figure 4.3 Graph of the relationship between Local Colocation Quotient and p-value at 2-mile distance.

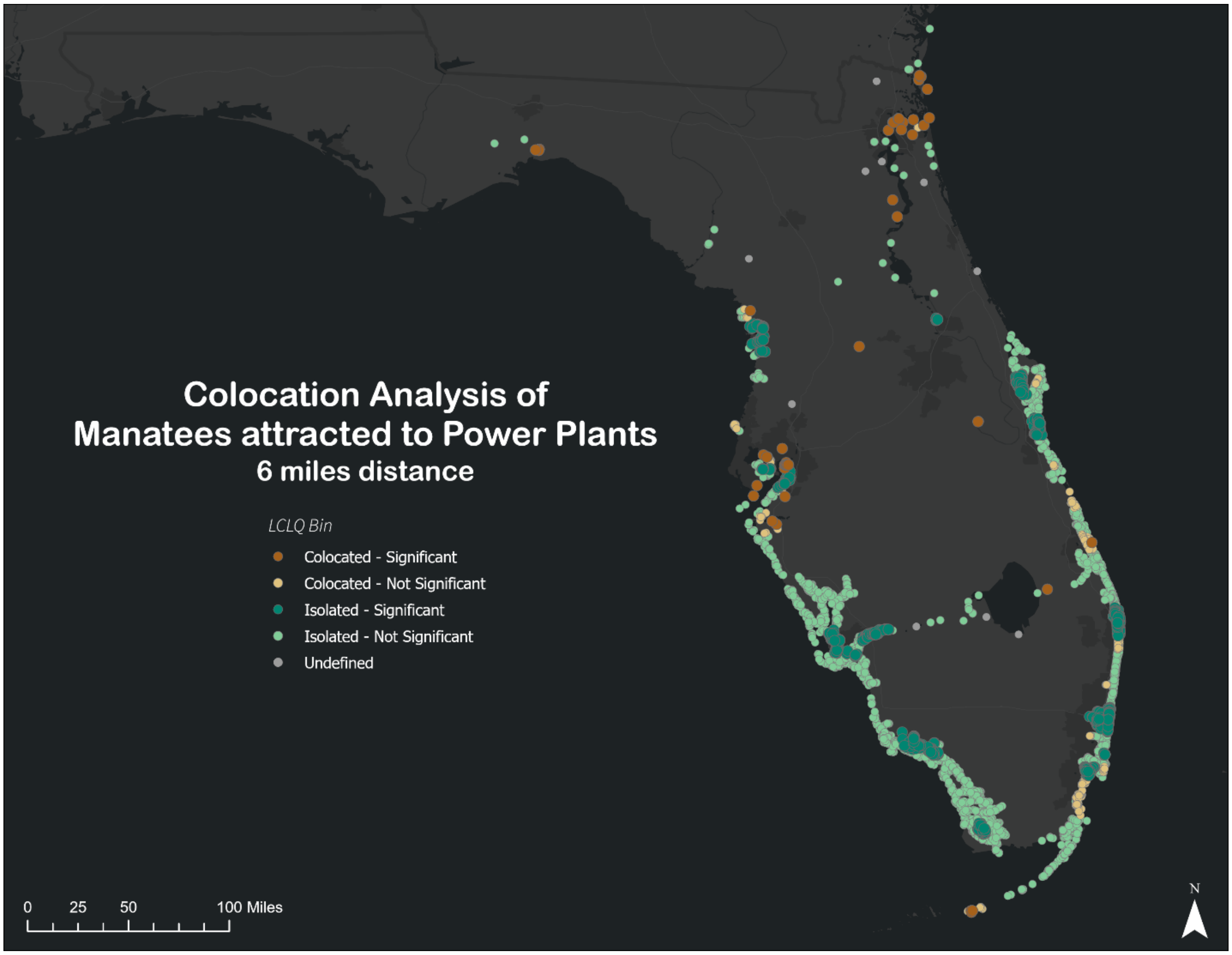

Figure 4.4 Colocation Analysis: 6 miles distance. Testing if manatees tend to be attracted to power plant locations.

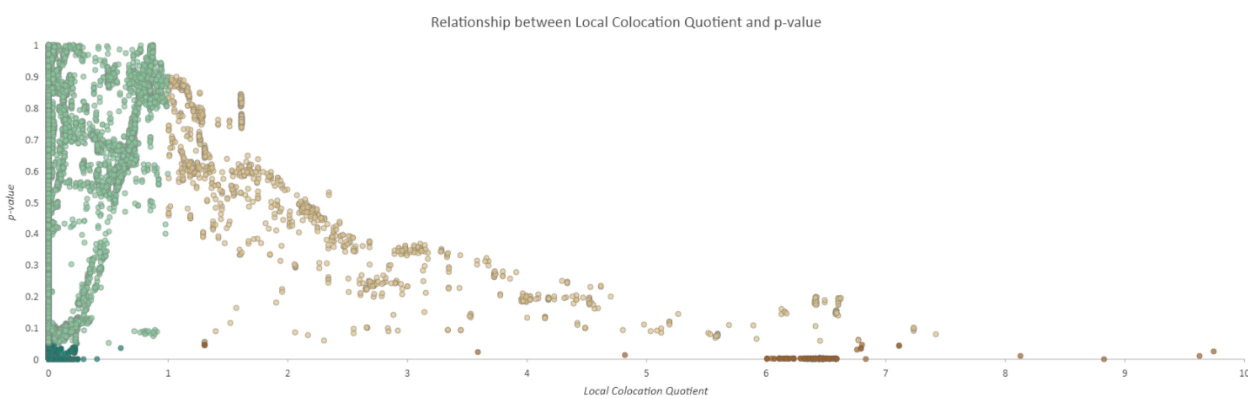

Figure 4.5 Graph of the relationship between Local Colocation Quotient and p-value at 6 miles distance.

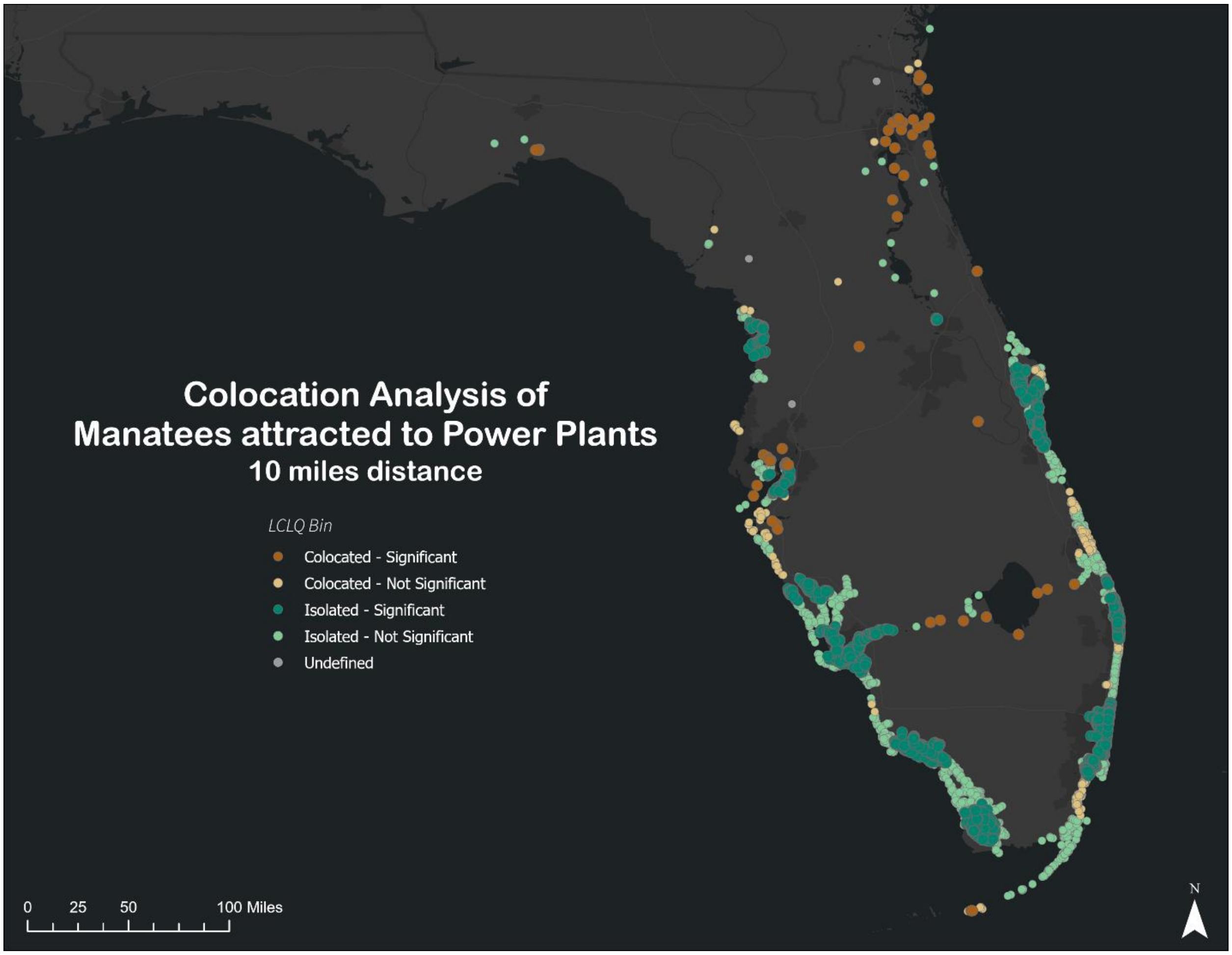

Figure 4.6 Colocation Analysis: 10 miles distance. Testing if manatees tend to be attracted to power plant locations.

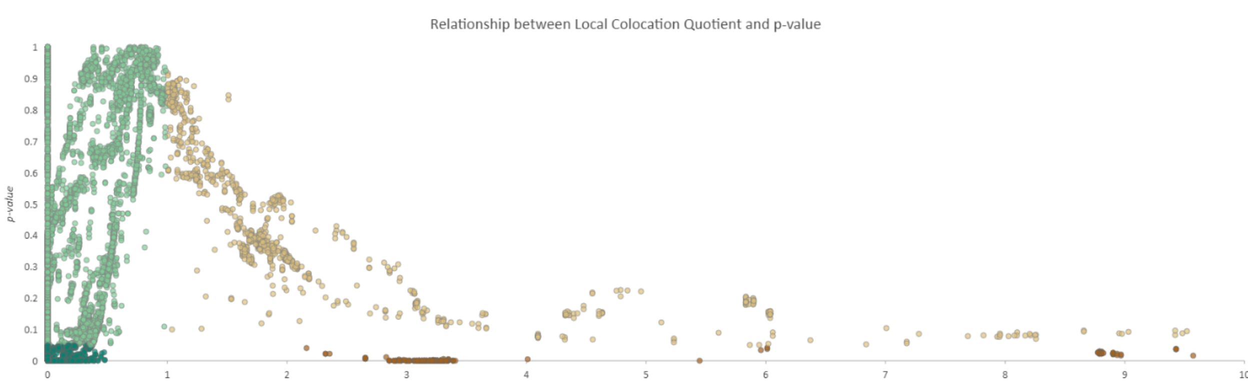

Figure 4.7 Graph of the relationship between Local Colocation Quotient and p-value at 10 miles distance.

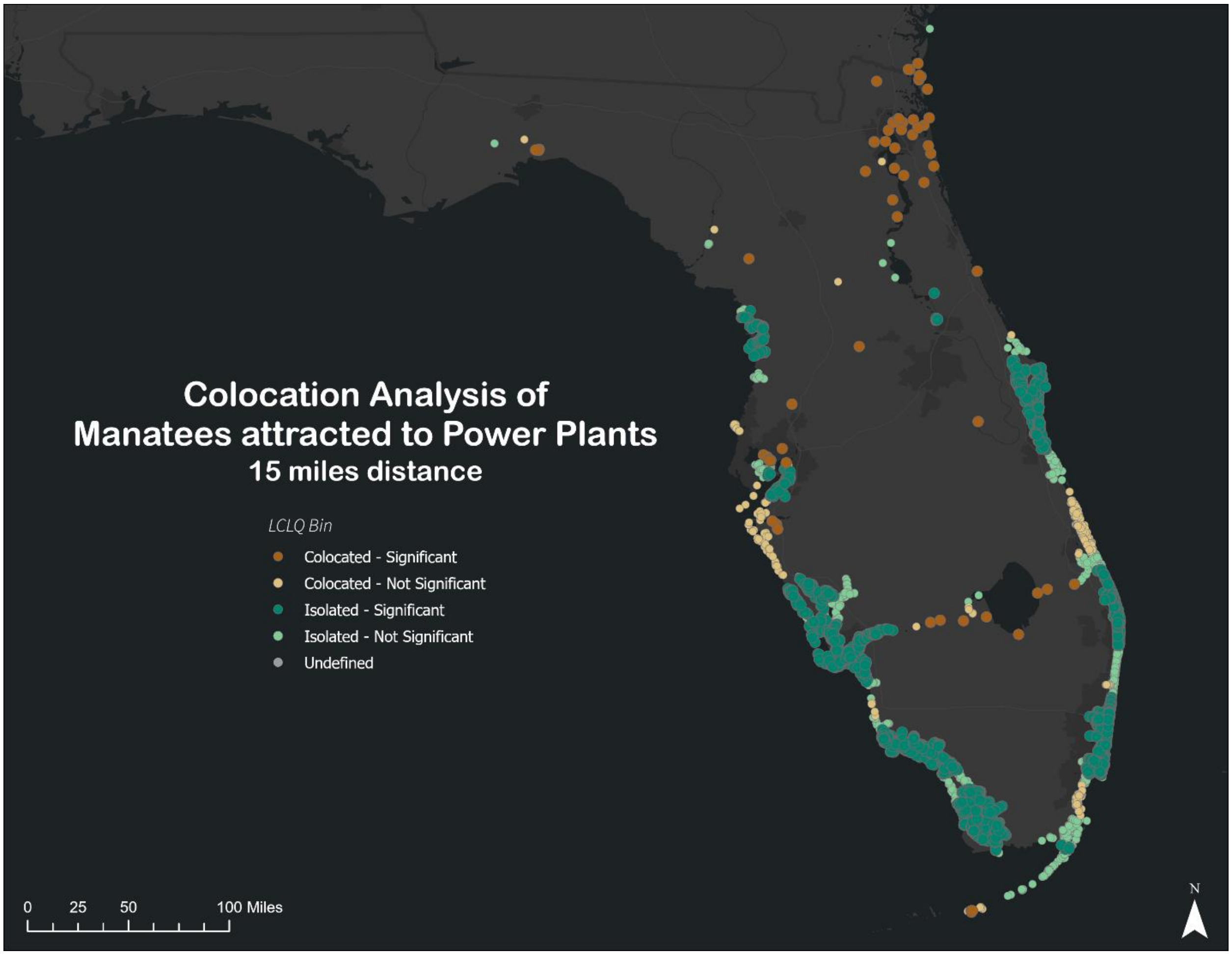

Figure 4.8 Colocation Analysis: 15 miles distance. Testing if manatees tend to be attracted to power plant locations.

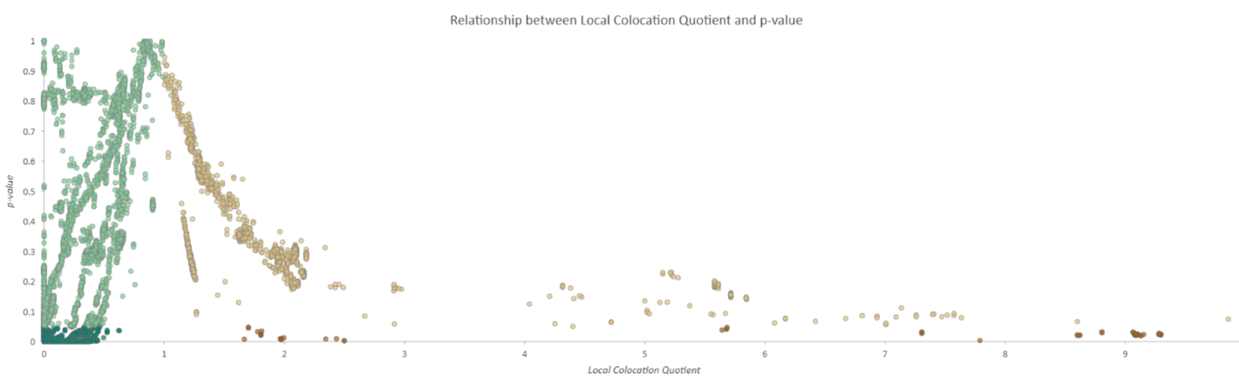

Figure 4.9 Graph of the relationship between Local Colocation Quotient and p-value at 15 miles distance.

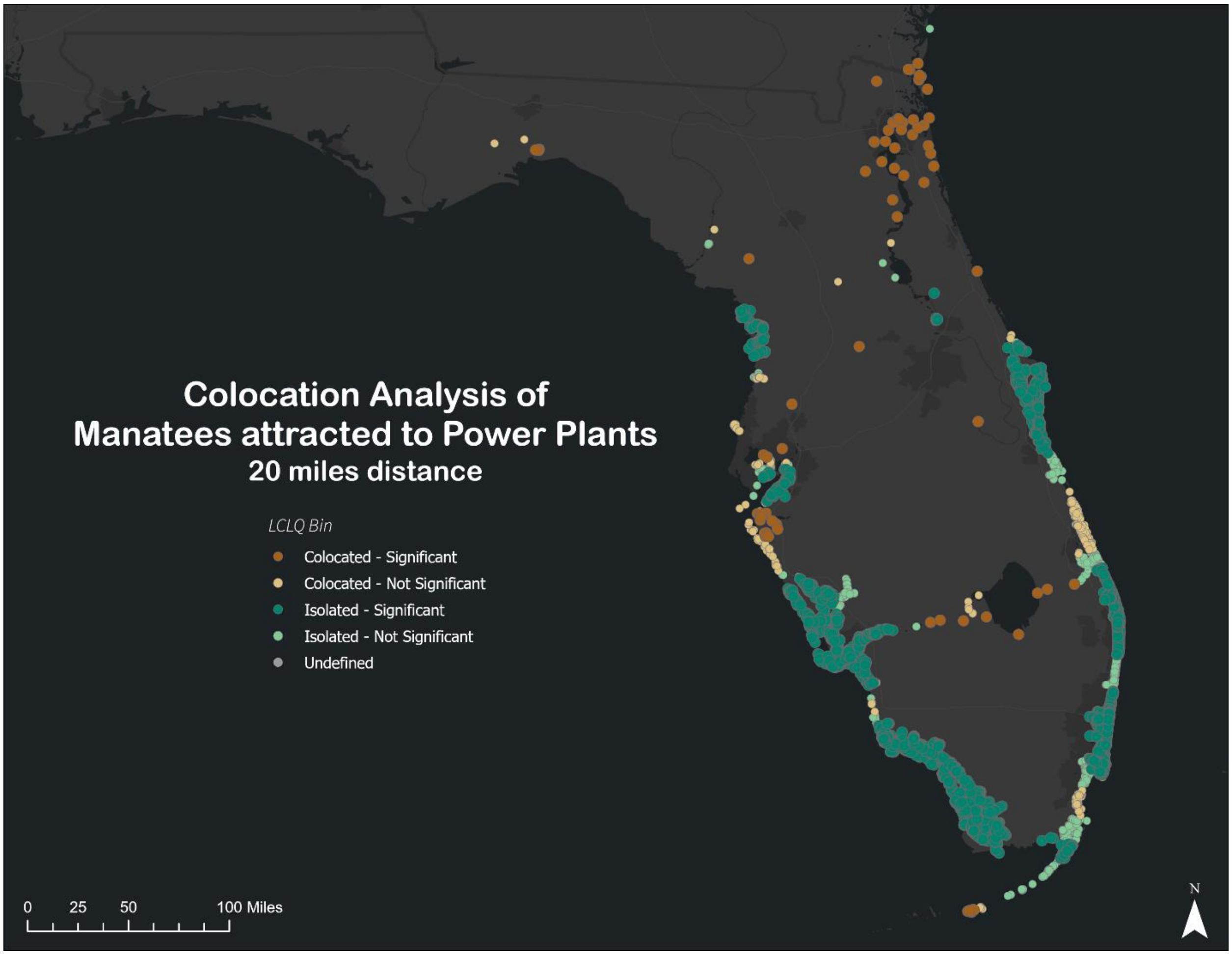

Figure 4.10 Colocation Analysis: 20 miles distance. Testing if manatees tend to be attracted to power plant locations.

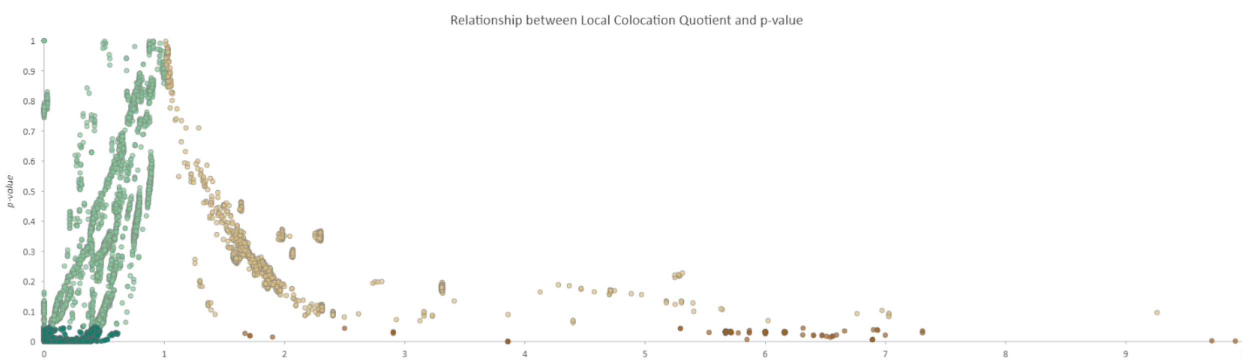

Figure 4.11 Graph of the relationship between Local Colocation Quotient and p-value at 20 miles distance.

CONCLUSTION

For this study, there were three objectives regarding the spatial relationship between manatees and power plants over the course of 1991-2019. First, we looked at a hot spot analysis to determine where in Florida there was clustering of manatee points and learned that geospatially there are hot spots where there are known power plant locations. Next, we looked at five colocation analysis with different distance bands and discovered that although there are more isolated points than colocated, we are seeing a good portion of colocated in areas that showed in the hot spot analysis. Second, we used the summarize within and spatial join to discover that more manatees are observed around natural gas power plants than any other type of power plant in Florida. Third, we used the same power plant data, but this time looked at the mortality of manatees and used the spatial join tool to figure out the relationship between the type of power plant and type of mortality in manatees. Natural causes like red tides and natural gas had the highest rate out of all of them. The highest number of mortalities at natural gas power plants could be explained by the number of manatees observed by natural gas power plants.

Even though there has been other study conducted about the spatial relationship between manatees and power plants in Florida, this project cannot confidently say if "manatees are hooked on power plants" according to the NPR's podcast series Plant Money. If I were to continue investigating, I would look at sea temperatures and real time tracking. Manatees are a mammal species that migrates to find water temperatures needed for their survival. This could easily skew the current data provided in this project.

REFFERENCES

ESRI. (2022). Colocation Analysis (Spatial Statistics). https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/colocationanalysis.htm

ESRI. (2022.) Hot Spot Analysis (Getis-Ord Gi*) (Spatial Statistics). https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/hot-spotanalysis.htm

ESRI. (2022). What is a z-score? What is a p-value?. https://pro.arcgis.com/en/proapp/latest/tool-reference/spatial-statistics/what-is-a-z-score-what-is-a-pvalue.htm

Florida Fish and Wildlife Conservation Commission. (2019). 2019 *Manatee Synoptic Survey.* https://myfwc.com/research/manatee/research/population-monitoring/2019-synoptic-survey/

Hardy, Stacie K., et al. (2019) "Cold-Related Florida Manatee Mortality in Relation to Air and Water Temperatures." https://doi.org/10.1371/journal.pone.0225048

Horowitz-Ghazi, Alexi. (2022) "Planet Money: How Florida's Manatees Got Hooked on Fossil Fuels." *NPR*, https://www.npr.org/2022/05/13/1098735684/planet-money-how-floridas-manatees-got-hooked-on-fossil-fuels

Marine Mammal Commission. (2022). https://www.mmc.gov/priority-topics/species-of-concern/florida-manatee/

Szekeres, P, et al. (2016) "On the Neglected Cold Side of Climate Change and What It Means to Fish." *https://www.int-res.com/articles/cr2016/69/c069p239.pdf*

U.S. Fish & Wildlife Service. (2022). *Manatee (Trichechus Manatus).* https://www.fws.gov/species/manatee-trichechus-manatus