

Seagrass fatalities in North Biscayne Bay, South Florida due to increases in nutrients and macroalgae in its environment

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ABSTRACT

Biscayne Bay is a subtropical estuary located in South Florida. It is a rich environment containing a multitude of organisms such as seagrass, sponges, and fish. The Biscayne Bay ecosystem is currently undergoing a drastic environmental decline due to seagrass fatalities throughout the area, specifically in North Biscayne Bay. This literature review pinpointed the causes and effects of these seagrass fatalities from analyzed research that has been completed on this subject. The research papers found for this review came from five databases: Google Scholar, the Biscayne Bay Task Force Database (HPI), Gale in Context, Gale Academic OneFile and JSTOR. A total of 245 papers were looked over and 18 articles were left to use for this review. From those papers, it was concluded that the most probable cause of the seagrass fatalities was the pollution runoff from metropolitan areas that stimulated nutrient overloads. These nutrient overloads are factors that cause algal blooms, which in turn cause these seagrass fatalities due to lack of sunlight and resources for photosynthesis. The lack of seagrass regulating the fragile Biscayne Bay environment is also causing an influx of fish deaths, which is bringing about a local economic decline in commercialized fishing. Without the properties of seagrass in Biscayne Bay, it can cause a more drastic environmental meltdown that may not be fixable.

Introduction

Background

Biscayne Bay is a subtropical, shallow estuary located in Miami, Florida's coastal metropolitan area. It is 64 km long and can be up to 3-16 km wide. In this lagoon, Everglades freshwater mixes with Atlantic Ocean salt water, creating brackish water. This brackish water can sustain many species of organisms, such as seagrasses, sponges, coral reef, algae, fish, shrimp, manatees, and dolphins. The shoreline of Biscayne Bay used to be home to mangroves and marsh habitats, however due to Miami's development, most of these areas were lost (*Miami-Dade County*, 2014). And because of that development, it has led to a multitude of contaminants from runoff and sewage going into the Bay, causing a number of problems such as seagrass deaths, fish kills, algal blooms, and water quality degradation (Mooney, 2016). The main issue this investigation will focus on is the details of what are the most probable causes of seagrass deaths and how it affects Biscayne Bay's ecosystem.

Seagrasses are flowering plants, also known as angiosperms, that adapted to live underwater. They're part of the sub-group of plants known as monocotyledons, which are also flowering plants that bear one seed leaf, or a cotyledon. They can be easily classified by their long stalkless leaves with their parallel veins. Seagrasses are not the same as seaweeds, which are less complex non-flowering algal plants. Seagrasses cover large portions of the seafloor in brackish water, which are called seagrass meadows or seagrass beds (Cullen-Unsworth et al., 2018).

Seagrasses provide food and shelter for thousands of organisms such as turtles, cod, herring, seahorses, and manatees. Regarding the food web, seagrasses are considered to be primary consumers because they make their own food through photosynthesis. They also hold together seabed sediments to prevent erosion along the coastline as well as trapping nutrients from runoff in their roots and blades allowing for water clarity (Lirman et al., 2014). Among that, seagrasses need carbon dioxide to survive. Less carbon dioxide in the water leads to a stable pH, preventing ocean acidification and a stable environment for pH sensitive organisms like corals and mollusks.

There are seven species of seagrass that reside in Biscayne Bay: *Thalassia testudinum* (turtle grass) *Syringodium filiforme* (manatee grass) *Halodule wrightii* (shoal grass), *Halophila decipiens* (paddle grass), *Halophila johnsonii* (Johnson's grass), *Halophila engelmannii* (star grass), and *Ruppia maritima* (Widgeon grass, not a true seagrass, however) (Gimenez et al., 2019).

There has been a notable decrease in seagrass population in the North Biscayne Bay area, specifically in the Julia Tuttle Basin. This area used to be dominated by manatee grass, or *Syringodium filiforme*, however, in the last thirty years there have been downward population trends in this species. From 2016-2017, there was a shift between a seagrass dominated environment to an algae dominated one, the algal genera being *Halimeda* (Varona et al., 2018). *Halimeda* is a rapid growing macroalgae that has "colonized" the Julia Tuttle Basin. It is capable of sexual reproduction and asexual propagation. It is able to grow in extremely low light, which is now common in North Biscayne Bay due to eutrophication, which is the pollution of bodies of water due to large increases in nutrients (Collado-Vides et al., 2018) & (Alexander et al., 2005).

Decomposing seagrasses release nutrients that can stimulate algal blooms, which cloud the water, leaving less light for the seagrasses living on the seafloor (Irlandi et al., 2004). Nutrient overloads in phosphorus, nitrogen, and chlorophyll-a have been linked to this seagrass loss (Varona et al., 2018).

The sources of freshwater Biscayne Bay receives are from canal discharge (40%), precipitation (50%), and groundwater discharge (10%) (Sweeney 2019). Causes of the eutrophication, or nutrient overload, in North Biscayne Bay can be the pollution present in these sources of freshwater, as this part of the Bay is prone to the pollution of the Miami metropolitan area. Eutrophication is known to cause increases in chlorophyll, macroalgae, and harmful algal blooms, which in turn cause seagrass loss and hypoxia, or reduced oxygen gas levels in the water (Sweeney 2019). Biscayne Bay is home to recreational opportunities such as fishing and boating. However, there has been an increase in fish kills due to low oxygen levels from eutrophication. Less fish present in the environment is creating a negative impact on the local economy (Lirman et al., 2014). Additionally, the residents that live near the bay are experiencing the unpleasant effects of decomposing fish in their backyard.

Methods

Methodology

In order to find reliable papers to complete this literature review, five databases were looked through instead of four due to a low source output from one database (Google Scholar, Biscayne Bay Task Force Database (HPI), Gale in Context, Gale Academic OneFile and JSTOR). Specific parameters were used and the first fifty papers that appeared under these search terms were documented in a Google Sheet document. The search terms that were used were "Seagrass fatalities Biscayne Bay". The titles of the first fifty papers under the terms were read and were decided whether or not it would be an addition to the research. There was not any specific method when determining whether to keep a title or not. An article was kept based on its title, its abstract was read and certain parameters were used to decide whether it should be added to the "Kept Articles" list. These parameters include: [Keep: seagrass fatalities], [Keep: water quality relating to seagrass deaths], [Keep: algae relating to seagrass deaths], [Discard: not relevant to seagrass], [Discard: not relevant to Biscayne Bay].

When creating the “Kept Articles” list articles were discarded based on more specific parameters. In this list the authors, date of publication, journal and database where it was found, whether or not it would be kept, and more specific search terms (that would be used on the entire article) were added. These new, more specific search terms are: [Downloadable: yes/no], [Algae effects on seagrass: description], [Specific to Biscayne Bay: yes/no], [Seagrass: description]. In the terms that require a description, bullets were added about what the paper was about. If a cell is empty underneath a term, it denotes that the term was not found. Based on the information found from the terms, it was decided whether or not to discard or keep that paper based on these new parameters: [Discard: not relevant to search terms], [Discard: only abstract is available to view], [Keep: relevant to search terms]. The ending list had 18 papers. In the background, other papers were found using more specific queries to cite basic facts not found in these papers.

_____ In the data analysis, it explains each researcher’s methods for the data collection or explains difficult notation that may be used. The analysis is split into two parts: Seagrass & Macroalgae Increase and Seagrass & Nutrient Increase. This makes it easier for the reader to better understand the variables being researched and reviewed.

Procedures

Gather information on studies done on seagrass in Biscayne Bay using methodology stated above
 Make sure these studies have graphs and tables depicting variables in a clear manner
 Reach out to authors of studies asking if they may have updates, background information, and/or data
 Interview authors or Miami-County Biscayne Bay Task Force if necessary
 Organize papers found on a spreadsheet
 Write literature analysis using research

Discussion

Data Analysis: Seagrass Decline & Macroalgae Increases in North Biscayne Bay

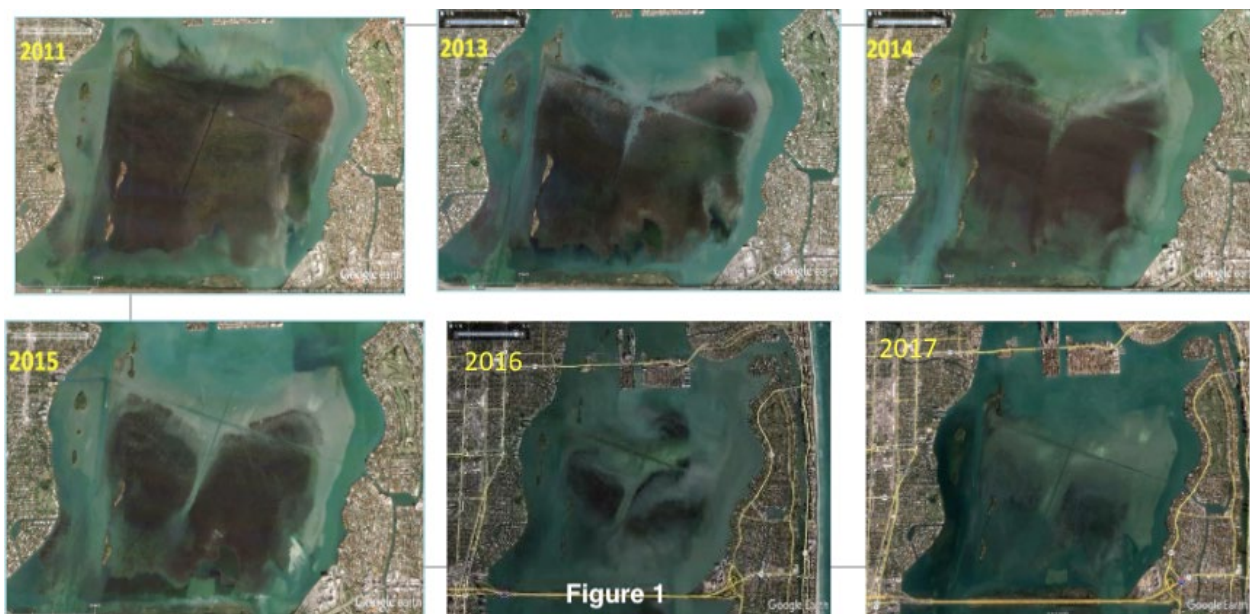


Figure 1: Seagrass loss in the Julia Tuttle Basin, an area in North Biscayne Bay, became increasingly noticeable starting in 2011. In the pictures shown, almost all of the aquatic vegetation present is seen to be almost gone in 2017,

which agrees with the numerical data (Sweeney, 2019). Between 2015-2017, there were a multitude of hurricanes that devastated the Miami area, and pollution from runoff could have been why there was a drastic decrease in seagrass coverage in these years.

BBCA Value	Cover/Abundance
0	absent
0.1	<5% cover with a solitary individual/shoot
0.5	<5% cover with few individuals/shoots (sparse)
1	<5% cover with numerous individuals/shoots
2	≥5% cover and ≤25% cover
3	>25% cover and ≤50% cover
4	>50% cover and ≤75% cover
5	>75% cover

Figure 2 Modified BBCA class scale of cover/abundance.

Figure 2: This table shows the method the Miami-County DERM collected seagrass and algal data. They used the Braun-Blanquet Cover Abundance (BBCA value). This value denotes the visual amount of sample present in the area. The DERM took samples from four 50 cm² quadrants in each station in the Julia Tuttle Basin (Miami-Dade County DERM, 2016).

Figure 3 SAV and sponge coverage for the Julia Tuttle basin based on BBCA average values at 21 stations sampled during 2014 and 2016. TOT = Total Submerged Aquatic Vegetation; TSG = Total Seagrass; Tt = *Thalassia*; Hw = *Halodule*; Sf = *Syringodium*; TMA = Total Macroalgae; TGA = Total Green Algae; TRO = Total Red Algae (Non Drift), TBR = Total Brown Algae; SP = Sponges.

Year	TOT	TSG	Tt	Hw	Sf	TMA	TGA	TRO	TBR	SP
2014	2.94	2.73	0.62	1.10	2.28	0.56	0.47	0.47	0.04	0.18
2016	2.50	1.71	0.18	0.68	0.91	1.19	0.84	0.40	0.10	0.06

Figure 3: In 2014 and 2016, there is a decrease in the seagrass categories while the algal categories increase. Sponges also experienced a decrease in average coverage, proving that these algal blooms are harmful to not only seagrasses but other marine life as well (Miami-County DERM, 2016).

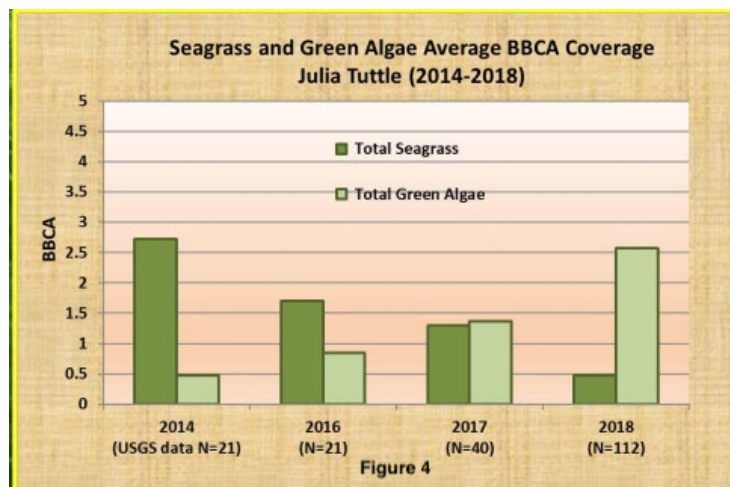


Figure 4: The Julia Tuttle Basin shifted from a seagrass dominated community to an algae dominated community from 2014 to 2018 (Varona et al., 2018).

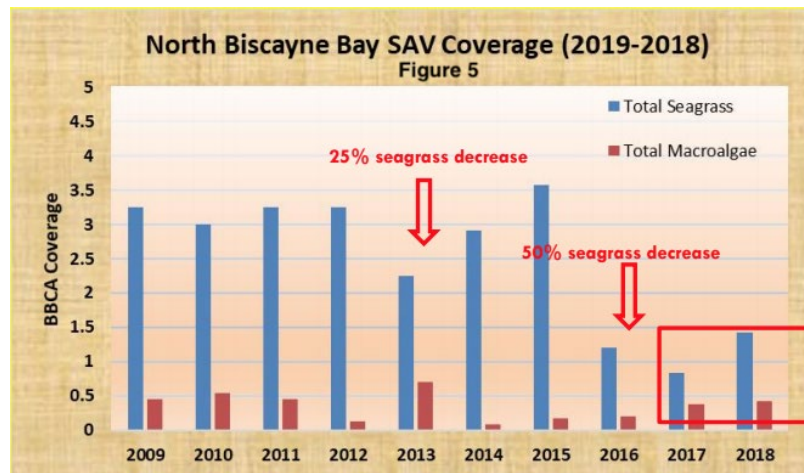


Figure 5: This study follows up on the previous study, except they examine the broader North Biscayne Bay area. In 2012-2013, there was a 25% decrease in seagrass coverage, followed by an increase in population from 2013-2015, with macroalgae levels also increasing. In 2016 there was a sharp decrease in seagrass populations with macroalgae increasing (Varona et al., 2018).

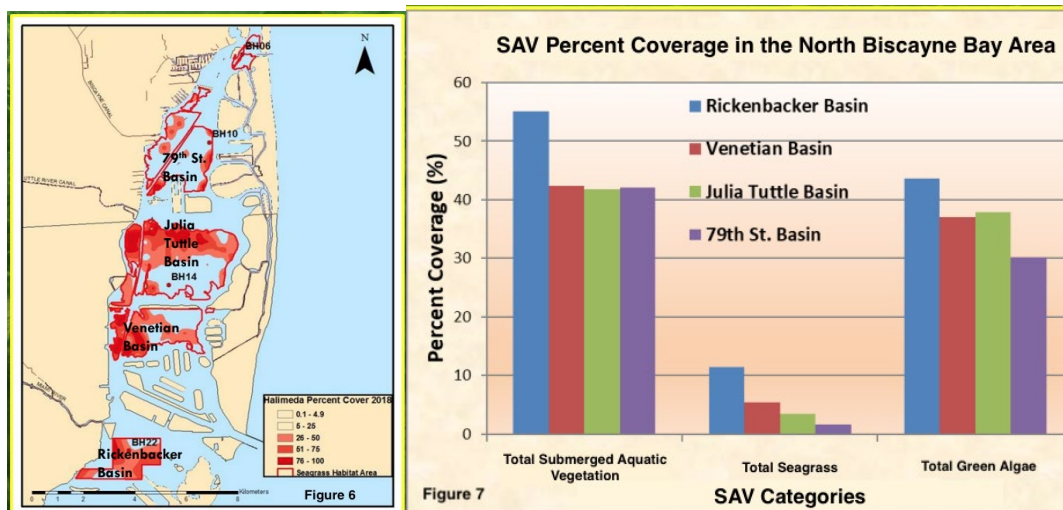


Figure 6 & 7: In the year 2018, North Biscayne Bay made a shift from a seagrass dominated environment to an algal dominated environment. This may be due to the fact that in previous years there were a multitude of hurricanes and tropical storms that increased the flow of pollution from metropolitan canals. These influxes of nutrients cause algal blooms in its respected areas. (Varona et al., 2018)

Data Analysis: Seagrass Decline & Nutrient Increases in Biscayne Bay

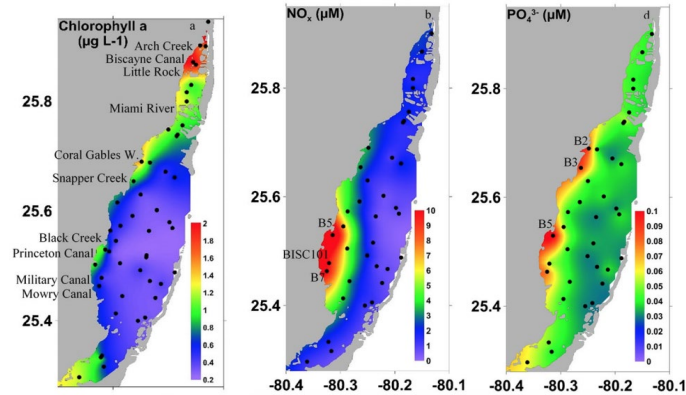


Figure 8: The nutrients being taken into account in this investigation are Chlorophyll-a, nitrate/nitride, and phosphate. Near the coast especially, high levels of these nutrients were recorded. This may be due to the large amounts of runoff from the city canals. Runoff contains large amounts of pollution and higher than normal concentrations of these nutrients. In the areas that have higher amounts of nutrients, such as high Chlorophyll-a in North Biscayne Bay, seagrass loss has been documented (Millette et al., 2019).

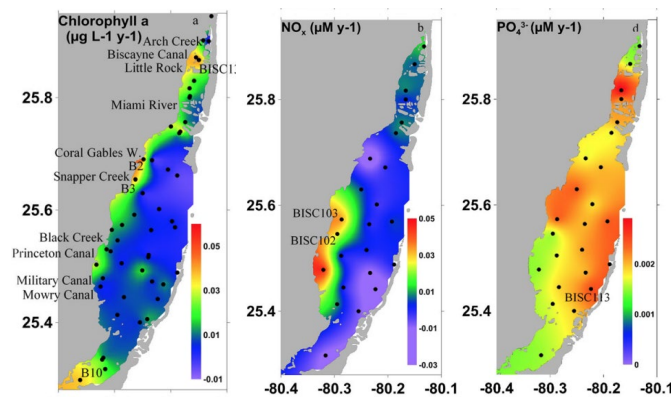
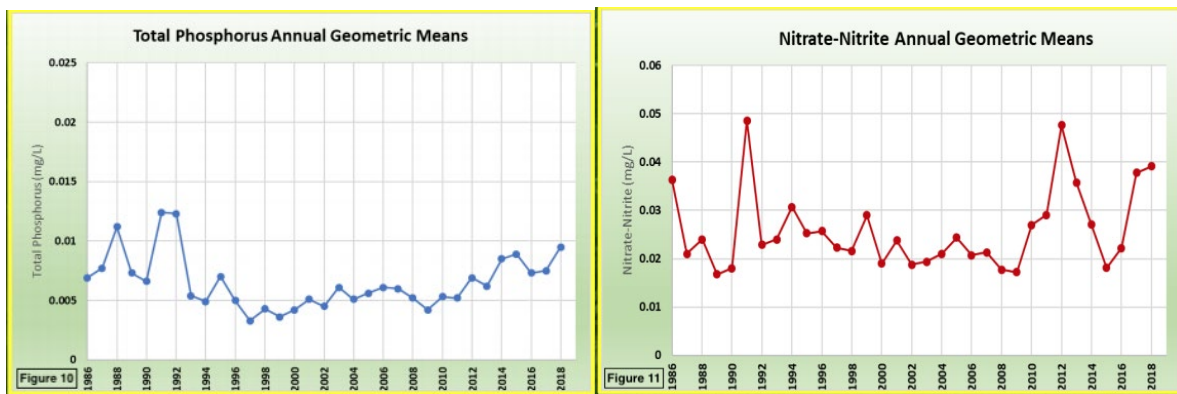
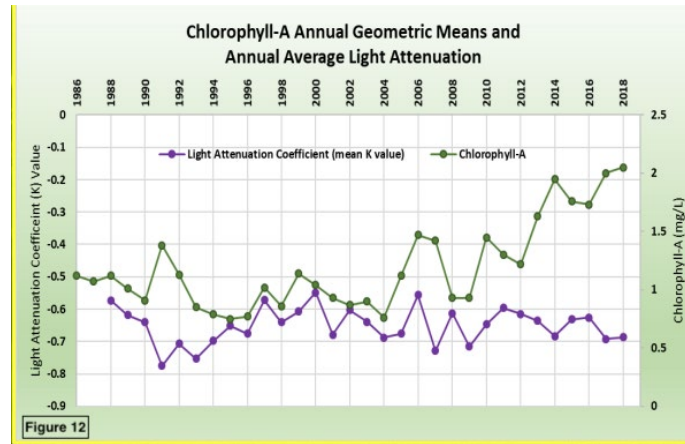


Figure 9: The rate of change of Chlorophyll-a and nitrate/nitrite is higher than normal in the coastal regions due to pollution from canal drainage. According to these investigations, it is widely accepted that the deterioration in the water quality is in fact tied to the seagrass die off. Seagrasses are sensitive to these changes even though they can withstand high salinity rates (Millette et al., 2019).





Figures 10-12: The annual nutrient geometric means have been steadily increasing the last 10 years, for the most part. The increase in chlorophyll-a has been tied to higher levels of macroalgae and lower levels of light in the area (Varona et al., 2018). Seagrasses need light in order to perform photosynthesis, and if this nutrient increase is an obstacle for that necessity, the seagrass will perish. The researcher did not perform much analysis of figures 10 and 11, so the reason for the drop in nitrate/nitrite concentration from 2012-2016 could not be determined.

Conclusion

The issue of seagrass fatalities in North Biscayne Bay is caused by a number of factors, all of which are correlated to each other. An increase of nutrients from pollution from coastal cities allows for algal blooms to be stimulated in these areas (Kelbe et al., 2019). A conclusion of when these nutrient increases precisely occurred could not be reached due to the lack of specific dates of when each data point was collected. Based on background research, however, it can be noted that the seasonal variations that occur during hurricane season could be causing the large amounts of nutrient influx. Climate change is causing more tropical storms to form which is why there may be a large decrease in seagrass populations tied to increases in the nutrients noted (McKay et al., 2001). From 2015-2016, there was a 50% decrease in seagrass coverage, with an increase in algal coverage (Varona et al., 2018). In these years Hurricane Matthew and Hurricane Irma made drastic landfall in Miami, and pollution from the metropolitan area most likely entered the bay, causing nutrient increases in phosphate, chlorophyll-a, & nitrate/nitrite, which in turn caused algae blooms, and because of this, North Biscayne Bay (which is in the Miami area) has the highest number of seagrass deaths and fish kills from pollution from the Miami metropolitan area (Eldredge et al., 2019). These blooms cloud the water and remove the seagrass's source of light to use for photosynthesis. Noted by the data, the Julia Tuttle Basin in North Biscayne Bay shifted from a seagrass dominated environment to an algae dominated environment, and the lack of seagrass to maintain nutrient and oxygen levels do cause fish kills. These fish kills damage the local economy and the ecosystem (Varona et al., 2018) (Lirman et al., 2014).

Limitations

There were no noted inconsistencies between each investigation that was used in the data analysis. All the material that was used was consistent with each other and agreed with the points and data that was made. However, it would have been more efficient if the researchers provided when they collected each sample in the year and month, so the correlation between when storms occurred and the dates at which nutrient samples were at their heights could be analyzed. Because of this lack of data, the conclusion that runoff from storms increased nutrient flow could not be specifically reached. But there was enough data and information to provide an adequate conclusion. Future research

is currently being conducted as noted by the Miami-Dade county increasing their funding for water quality initiatives in Biscayne Bay. The county and state contributed a total of \$20 million to preserve the Bay, as well as for additional research (*Florida and Miami-Dade*, 2020).

Acknowledgments

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Figure 4, 5, 6, 7, 10, 11, 12