



Guana Water Quality

TWO-YEAR SUMMARY REPORT

July 2017 - June 2019



Friends of GTM
RESEARCH RESERVE

EXECUTIVE SUMMARY

A two-year study of the Guana Lake/Guana River system in Northeast Florida was conducted to establish a baseline of water quality conditions. Guana Lake receives water from the north at Mickler's weir and water periodically exchanges with Guana River through the Guana dam. As such, throughout this study, there was often a distinct latitudinal gradient in salinity within the system (fresh water in the north, brackish to full-strength salinity in the south). A north-south gradient was also observed in sucralose, an indicator of human wastewater originating north of Mickler's weir. Nutrient and phytoplankton concentrations were generally higher in the lake than in the river. Based on biological indicators, state water quality standards, and comparison to a reference site, both waterbodies appear to suffer from excess nutrients. Bacteria levels were generally low with a few extreme exceptions, especially in the middle of the lake.

Continued investigation into the potential sources (and quantity) of nutrients into the Guana system will further our understanding of eutrophication in this and other impounded estuarine systems. As sources and fates of nutrients are determined, remediation strategies can be developed so that Guana Lake and River continue to provide healthy habitat for wildlife and recreation opportunities for our community.

BACKGROUND

The main objective of this study effort was to quantify spatial/temporal variability of selected water quality parameters within the Guana system. Water quality observations in this system have been very limited historically and this study aimed to develop a baseline survey of water quality over a variety of seasonal conditions and a spatial gradient. Secondary objectives included assessing current water quality conditions and studying hydrologic connections at Mickler's weir and Guana dam.

Inspired by momentous community interest in the health of Guana Lake, multiple sponsors, including the Audubon Society and the Friends of the GTM Research Reserve, generously funded an initial year of water quality sampling and subsequent laboratory analyses starting in

July 2017. A partnership between GTM Research Reserve, Northeast Florida Aquatic Preserves, and Florida Fish and Wildlife Conservation Commission (FWC) was formed to collect monthly water samples. Samples were collected from three sites in Guana Lake (Micklers, Lake Middle, Lake South) and two sites in the Guana River (River North and Guana River). After the one-year pilot study, additional resources were provided from FDEP's Division of Environmental Assessment and Restoration (DEAR) and FWC. Starting in July 2018, an additional five sampling sites were added, and all ten sites were sampled for a full year (Figure 1).

Assessment

Florida's Department of Environmental Protection (DEP) determines legal water quality standards for each state waterbody. In the Guana system, there are multiple waterbody types: Guana Lake (also known as Lake Ponte Vedra or Guana River Above Dam) is a Class III Estuary and Guana

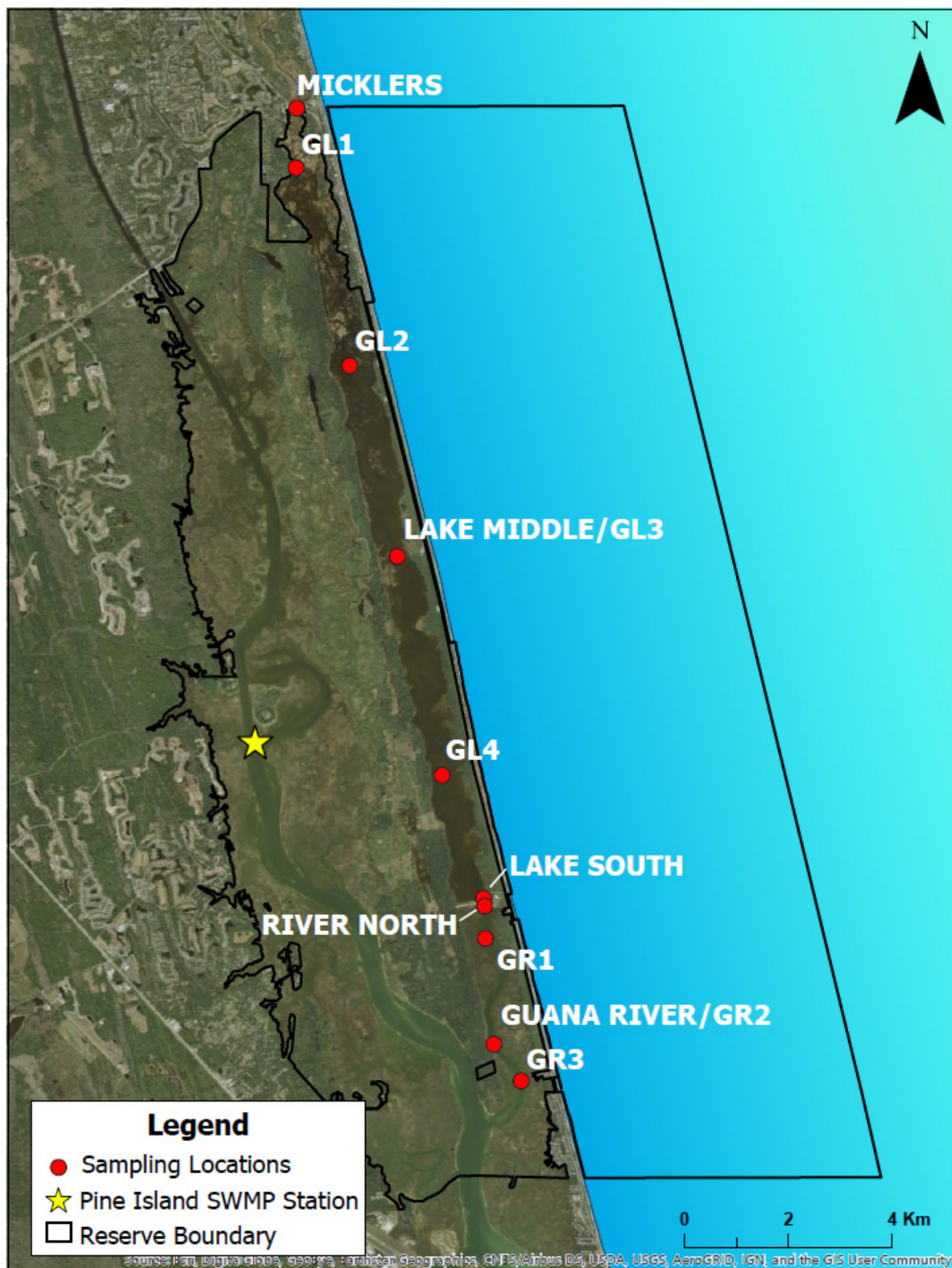


Figure 1: Map of Water Quality Sampling Stations in Guana Lake and River between 2017-2019

River is a Class II Estuary. As such, they have different water quality standards per statutes 62.302.530 - 62.302.533, 62-303.353(2), and 62-303.450(1) (Tables X and X). The threshold levels in Table X and X are included in the figures used in this report.

Table x: Annual Geometric Mean threshold values for nutrient criteria for Guana Lake (WBID 2320C).

Parameter	Threshold	Criteria
Chlorophyll a (µg/L)	11	annual geometric mean values not to be exceeded more than once in a three-year period
Total Phosphorus (mg/L)	NA	In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna.
Total Nitrogen (mg/L)	NA	In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna.
<i>Enterococci</i> Bacteria (MPN)	130	counts shall not exceed 130 in 10% or more of the samples
Dissolved Oxygen (% sat)	42	The daily average percent DO saturation shall not be below 42 percent saturation in more than 10 percent of the values

A reference site approach was also used to assess water quality in the Guana system. The GTM Research Reserve is part of a national System-Wide Monitoring Program (SWMP) conducted by 29 reserves around the country. The SWMP is based on standardized methods to track long-term change and short-term variability in water quality to study how our estuaries function and change over time at a national scale. The SWMP water quality station located in the Tolomato River (Figure 1) was used as a reference station for this study. Data from the station have been consistently collected since 2002. Caution should be used when comparing water quality in the Guana system to this station, however, since it is deemed impaired for Total Nitrogen by FDEP.

Table x: Annual Geometric Mean threshold values for nutrient criteria for Guana River (WBID 2320).

Parameter	Threshold	Criteria
Chlorophyll a (µg/L)	6.6	annual geometric mean values not to be exceeded more than once in a three-year period
Total Phosphorus (mg/L)	0.105	annual geometric mean values not to be exceeded more than once in a three-year period
Total Nitrogen (mg/L)	0.65	annual geometric mean values not to be exceeded more than once in a three-year period
Fecal coliform Bacteria (MPN)	43	counts shall not exceed a median value of 14 with not more than 10% of the samples exceeding 43
Dissolved Oxygen (% sat)	42	The daily average percent DO saturation shall not be below 42 percent saturation in more than 10 percent of the values

Characterization of Study Area

Northeast Florida has a humid subtropical climate characteristic of the Gulf and Atlantic coastal plain of the southeastern United States. Seasonal variation in temperature within the Reserve follows that of rainfall with a summer period of high temperatures between June and September and a cooler period extending from December through March. The average air temperature recorded at the FDEP-Stevens Tolomato River Platform <http://fldep-stevens.com/station.php?site=8720494> during the timeframe of the sampling was 21.5 (C).

The average annual rainfall is approximately 52 inches (132 cm) per year, with the wet season extending from June through September. During the study period, Hurricane Irma (September 2017) brought abnormally high amounts of precipitation to the area (Figure 1) and the effects of this storm were observed for many months following the event.

The Guana System

The headwaters of the Guana River originate in the Diego Plains drainage area in Ponte Vedra

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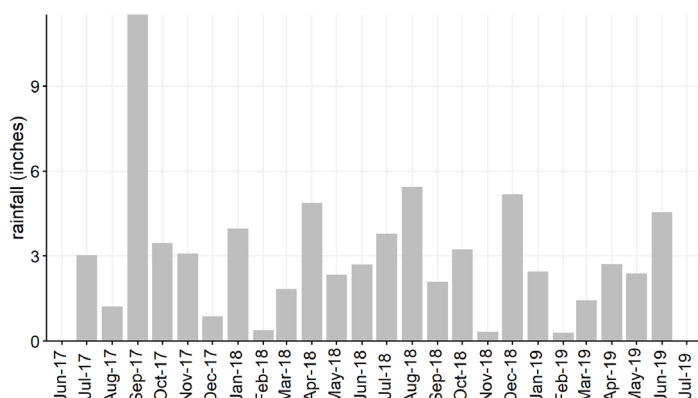


Figure 2: Monthly total rainfall during the study period (July 2017 - June 2019) observed at the Florida Department of Environmental Protection's Tolomato River Station #872-0494 <http://fldep-stevens.com/station.php?site=8720494>.

Beach. This drainage basin encompasses approximately 7,800 acres (3,157 hectares). The Guana River runs parallel to the Tolomato on the seaward side, with the two rivers joining 7 miles (11.3 km) north of the St. Augustine Inlet. The natural hydrology of the Guana system has been altered by water control structures, including weirs, dikes, inland wells, drainage ditches and a dam across a portion of the Guana River. Guana Lake receives water from the north at Mickler's weir and water periodically exchanges with Guana River through the Guana dam depending on water level management and tidal conditions. As such, there was often a distinct latitudinal gradient in salinity within the lake (Figure 2).

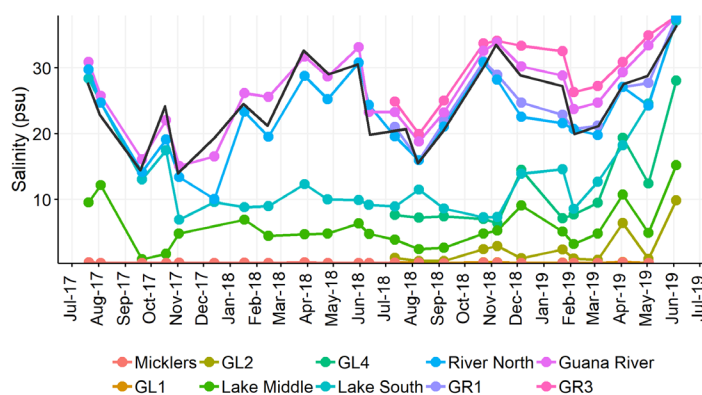


Figure 3: Salinity (psu) measured at each sampling station on the day of water sample collections. Black line represents data collected at the GTMNERR Pine Island System-Wide Monitoring Program station

There was also a spatial salinity gradient in the river (lower salinities closer to the dam), but it was less pronounced than in the lake.

Water temperatures in both the lake and the river follow similar seasonal patterns and do not diverge too much between waterbodies (Figure 3).

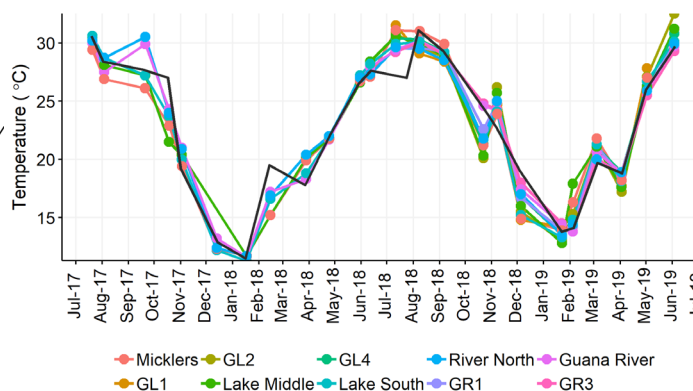


Figure 4: Water temperature (°C) measured at each sampling station on the day of water sample collections. Black line represents data collected at the GTMNERR Pine Island System-Wide Monitoring Program station

Pine Island Reference Station

The Tolomato River Basin is about 18 miles (29 km) in length with a drainage area of approximately 53,802 acres (21,773 hectares); it converges with the Matanzas River and Salt Run from the south before flowing into the Atlantic Ocean at the St. Augustine Inlet. The Pine Island station is at Channel Marker 25 (30.05085, -81.367467) in the Tolomato River. This site is located within the Guana River Marsh Aquatic Preserve in the northern section of the GTMNERR. Channel Marker 25 is adjacent to Pine Island near the mouth of Deep Creek, which provides freshwater drainage from silviculture-dominated uplands in the northwestern portion of the Tolomato River basin. The average depth at this site is approximately 3.3 m with a tidal range of about 1.6 m; the bottom type is muddy sand. Salinity ranged from 7.2 to 34.5 psu during 2018.

Guana Dam

The FWC maintains water and salinity levels of Guana Lake through the use of swing gates in Guana Dam. The gates allow for controlled discharge and recharge of the lake while still maintaining two-way flow. The lake drawdown usually begins mid-February and last through April. During this period, lake water is discharged through the dam at a rate of approximately six inches per month until desired water levels are reached. Lake recharge usually takes place between July and October with the intent of maintaining marine strength salinity at the south end of the lake and a salinity of 8-12 ppt at Six Mile Landing, which is near the GL2 Site.

In 2018 the dam was closed for construction, and water exchange between the lake and river ceased. The first closure occurred at the end of March and lasted for roughly three months. During this time, the lake side underwent little change in salinity levels. Mid-July the dam was reopened for a month and an initial lake discharge followed by a brief recharge was performed. This reopening lead to the convergence of salinity levels between the river sites and Lake South (Figure X). Salinity levels on the river side dropped by an average of 20.30% across all river sites.

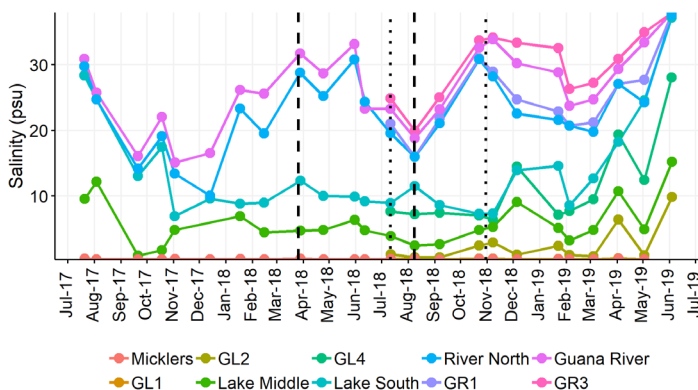


Figure 5: Salinity (psu) measured at each sampling station on the day of water sample collections. Vertical lines indicate status of the Guana Dam during construction in 2018. Dashed lines are when the dam was closed off for construction and the dotted lines are when it was opened again for water exchange.

This sudden change in salinity can be attributed to discharge of mesohaline waters into the river as well as an increase in rainfall during the summer months. The lake side also saw a change in salinity; however, Lake South, which lies just north of the dam, was the only noticeably impacted site. Lake South salinity levels increased from 8.93 ppt to 11.49 ppt, a 29% increase.

The dam was closed again in August and remained closed until October. After the second closure, salinity levels between the river sites and Lake South diverged. The river side salinities increased to or above previous levels, while the Lake South site decreased to its prior salinity level. With reopening of the dam at the end of October, the converging effect between the two sides was not as drastic for the river sites. River levels did decrease across all sites, but the major difference was seen on the lake side. Whereas with the first reopening only Lake South seemed to be affected, the second reopening resulted in significant increases at Lake South, GL4, and Lake Middle (91%, 107%, 89% increase, respectively). The difference between the two reopenings was a result of the how the dam structure was setup for water exchange. Instead of a discharge, the second reopening was immediately followed with a lake recharge which allowed for more exchange of polyhaline waters from Guana River.

METHODS

Monthly, all samples were obtained during the same ebb tide of each sampling day and within one day of GTM Research Reserve collections for nutrient analyses at the SWMP stations. No distinction was made between neap and spring tide conditions. All water samples were sent to ALS Environmental Labs in Jacksonville, FL for nutrient and bacterial analyses with the exception of July, September, and December 2018 and February and May

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2019, which were sent to the Florida Department of Environmental Protection (FDEP) Central Laboratory in Tallahassee, FL. In September 2018 and February 2019, additional samples were taken and sent to Source Molecular Labs in Miami, FL for bacteria source tracking. For more specific information regarding methodology, a spreadsheet and a detailed metadata report are available upon request..

All of the data included in the calculations and figures have been provisionally reviewed by GTMNERR staff. Included in the dataset are laboratory remarks, which use the FDEP lab codes, and flags, which are determined using the National Estuarine Research Reserve System's Centralized Data Management Office. The Data Management Manual can be downloaded from <http://cdmo.baruch.sc.edu/request-manuals/>. For any further questions, please reach out to the project's principal investigator, Dr. Nikki Dix (Nikki.Dix@floridadep.gov).

PHYSICAL AND CHEMICAL INDICATORS OF WATER QUALITY

Dissolved oxygen (% saturation)

Dissolved oxygen (DO) is a key indicator of habitat quality for aquatic organisms as it represents the oxygen available to organisms for breathing. The amount of DO in the water varies naturally due to daily and seasonal changes in tides, wind, temperature, salinity, photosynthesis, and respiration. Mixing of water by tides and wind increase the rate of oxygen diffusion from the air into the water. Temperature and salinity affect the solubility of oxygen in water; there is an inverse relationship between temperature/salinity and DO. Photosynthesis by aquatic plants, macroalgae, and phytoplankton increases DO, while respiration (metabolism) by all

organisms depletes DO. Therefore, the amount of DO at a given time represents the balance of atmospheric diffusion, solubility, photosynthesis and respiration. DO levels below ~50-70% saturation are stressful to aquatic animals, while levels below ~30% can be deadly. A lack of oxygen in bottom waters can also cause sediment to release dissolved nutrients.

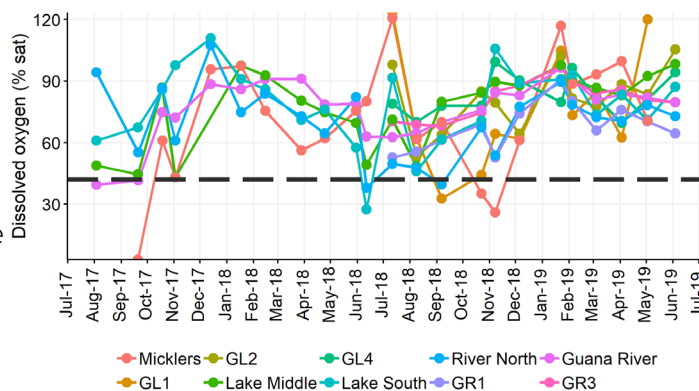


Figure 6: Dissolved oxygen (% saturation) measured at each sampling station on the day of water sample collections. Horizontal line represents the Florida state threshold criteria of 38% saturation for both Class II and III estuarine waters.

In the two years of DO data from Guana Lake and River, site differences were minimal. Low, potentially stressful levels of DO were observed in the summer and fall of 2017-2018.

Turbidity

Turbidity is a measurement of how cloudy, or murky, water is. It is affected by the amount of suspended particles, like sediment and algae. Turbid waters allow less light to penetrate the water column, which can limit photosynthesis.

During the second year of sampling, turbidity was measured when samples were sent to the FDEP lab in Tallahassee. From this limited dataset, the only apparent pattern is highest levels in the middle and southern portions of the lake. The state standard for turbidity is 29 above natural background conditions. Since the primary objective of this study was to determine baseline conditions, future work will be able to assess this

parameter as a water quality indicator.

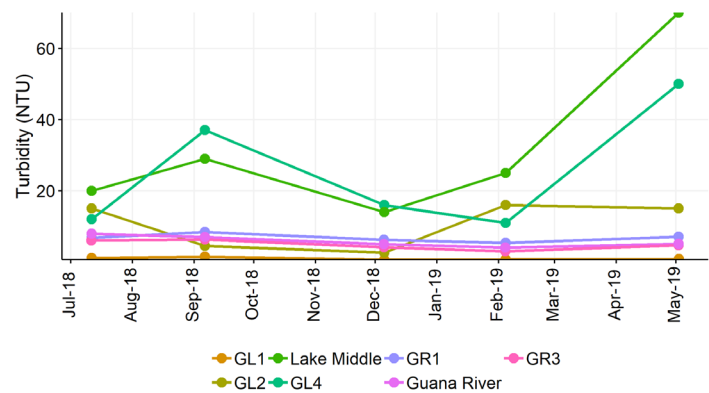


Figure 7: Turbidity (NTU) collected in the Guana system during the second year of water quality sampling. Samples were not sent for sites near water quality control structures.

Sucralose and Acetaminophen

Sucralose is an artificial sweetener that passes through human bodies mostly undegraded. It is also not degraded in wastewater treatment processes. For these reasons, sucralose is a good indicator of human wastewater influence. In a study of wastewater treatment facilities across Florida, FDEP (2018) found an average of 37 ug/L sucralose in influent and 41 ug/L in effluent. Therefore, while the presence of sucralose indicates human wastewater influence, it does not indicate whether the wastewater has been treated.

Acetaminophen is a pain reliever that does get removed by wastewater treatment processes. FDEP (2018) found an average of 89.8 ug/L acetaminophen in influent and 0.01 ug/L in effluent. They also found that acetaminophen was a strong predictor of raw, untreated sewage. Therefore, presence of sucralose coupled with absence of acetaminophen is an indication of treated domestic wastewater.

In this study, a clear north-south gradient in sucralose concentrations was observed (Table X and Figure X), while acetaminophen was not detected. These results suggest the existence of a treated domestic wastewater source north of

Mickler's weir.

Table x: Sucralose (µg/L) values collected at sites within the Guana Lake and River.

Site	September 2018	February 2019
GL1	1.60	2.10
GL2	1.40	1.50
Lake Middle	0.87	1.20
GL4	0.51	0.69
GR1	0.26	0.38
Guana River	0.22	0.30
GR3	0.22	0.19

Nutrients:

Nutrients are key indicators of water quality. Phosphorus and nitrogen are the most essential nutrients for plants to grow. In small amounts they are beneficial to many ecosystems. Thus, they are used in many agricultural and gardening practices for that same purpose. Nutrients enter our waterways via freshwater runoff or groundwater inputs, where they are taken up by aquatic plants for reproduction and growth. Too much nitrogen and phosphorus may lead to eutrophication, which is the feeding of a waterbody, resulting in an increase in algal biomass and a decrease in dissolved oxygen. Eutrophication can also cause blooms of toxic algae harmful to fish, shellfish, and humans. In a 2004 national assessment, 65 percent of assessed estuaries in the United States were moderately to highly affected by nutrient pollution (Bricker et al. 2007). The major sources of nutrient pollution in Northeast Florida include wastewater treatment facility effluent and re-use water, leaky septic systems, and fertilizer runoff.

Nitrogen

During this study, nitrogen concentrations were higher in Guana Lake than in Guana River. The highest concentrations were observed in the middle portion of the lake. In the river concentrations were highest near the dam.

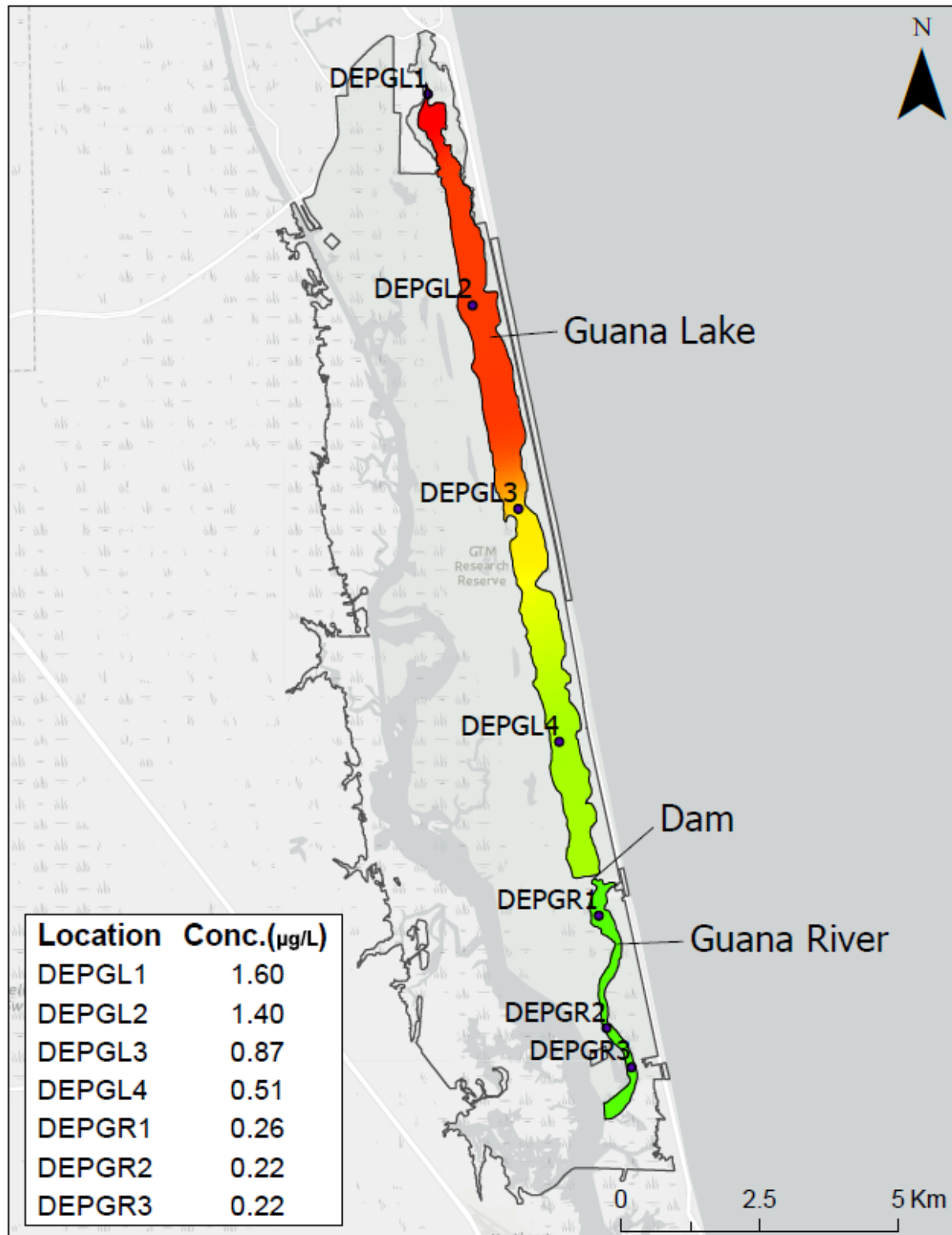


Figure x: Map of sucralose interpolated between sampling locations in the Guana system in September 2018. (Site GL3 = Lake Middle, Site GR2 = Guana River)

Temporal patterns were slightly different in the lake than in the river. In the river, nitrogen values oscillated with wet/dry seasons. Values in the lake were more sporadic. In both the lake and the river, nitrogen was consistently higher than at the Pine Island reference site.

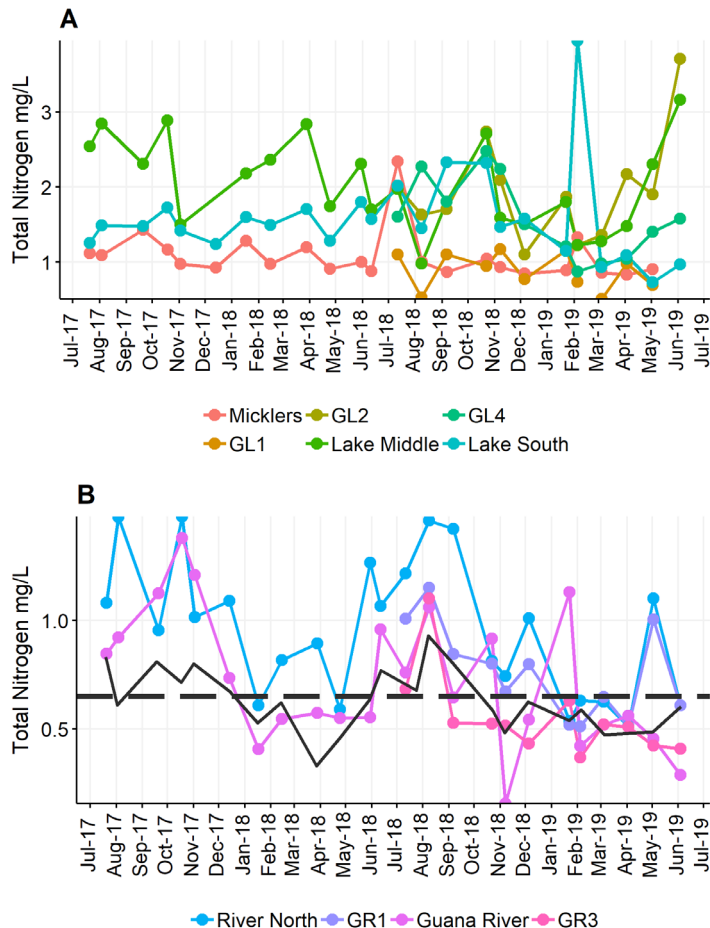


Figure x: Total Nitrogen (mg/L) collected at each sampling station on the day of water sample collections in the lake (A) and river (B). Horizontal line represents the Florida state threshold criteria for Class II estuarine waters (0.65 mg/L). Note different y-axes.

Phosphorus

Phosphorus concentrations during this study were generally highest in the northern and middle regions of Guana Lake. In those areas, phosphorus was higher than at the reference site. Concentrations in the river were similar to the reference site and highest near the dam. Peaks in phosphorus in the river occurred after peaks in the lake and generally corresponded

with wet/dry season cycles.

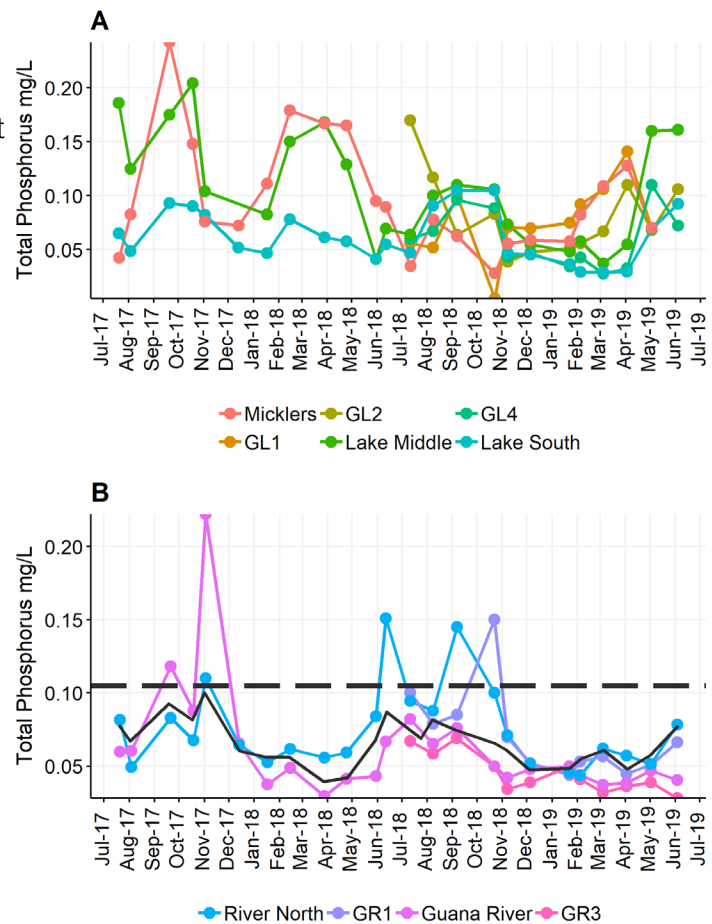


Figure x: Total Phosphorus (mg/L) collected at each sampling station on the day of water sample collections in the lake (A) and river (B). Horizontal line represents the Florida state threshold criteria for Class II estuarine waters (0.105 mg/L). Note different y-axes.

BIOLOGICAL INDICATORS

Phytoplankton Pigments

Phytoplankton, microscopic algae, are the base of aquatic food webs. They, like terrestrial plants, are photosynthetic (containing pigments like chlorophyll *a*) and can harness the energy from the sun to create their own food. Phytoplankton are eaten by zooplankton (microscopic animals) and small fish, which, in turn, are eaten by larger animals. A healthy amount of phytoplankton

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sustains an ecosystem, while an overabundance can cause oxygen depletion (a result of bacterial decomposition) and toxic blooms. The amount (biomass) of phytoplankton is estimated by measuring chlorophyll *a* concentration.

Chlorophyll *a* in Guana Lake during this study was consistently elevated in the middle of the lake, where peaks occurred in fall and spring seasons (Figure X).

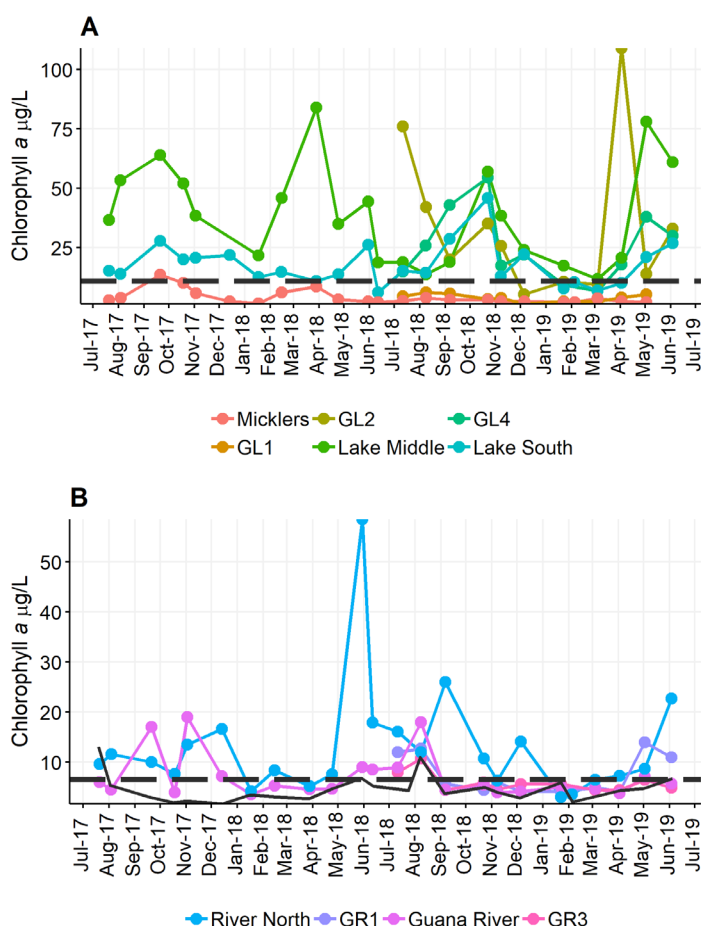


Figure x: Chlorophyll *a* ($\mu\text{g/L}$) concentrations (with pheophytin correction) collected at each sampling station on the day of water sample collections in the lake (A) and river (B). Horizontal lines represent the Florida state threshold criteria for Class II (6.6 $\mu\text{g/L}$) and Class III (11 $\mu\text{g/L}$) estuarine waters. Note different y-axes.

Chlorophyll *a* concentrations in Guana River were lower than in the lake, but were occasionally elevated near the dam.

Bacteria

Fecal indicator bacteria (FIB) are bacteria such as *Escherichia coli* (*E. coli*) and *Enterococcus*, which live in the gut of warm-blooded animals and are introduced into the environment through fecal matter. Most FIB are harmless to humans, but the presence of FIB indicates that pathogens also found in fecal matter, which are harmful to humans, may also be present.

Fecal coliform bacteria levels reached their maximum in both the lake and the river after Hurricane Irma (Figures X and X). Peak fecal

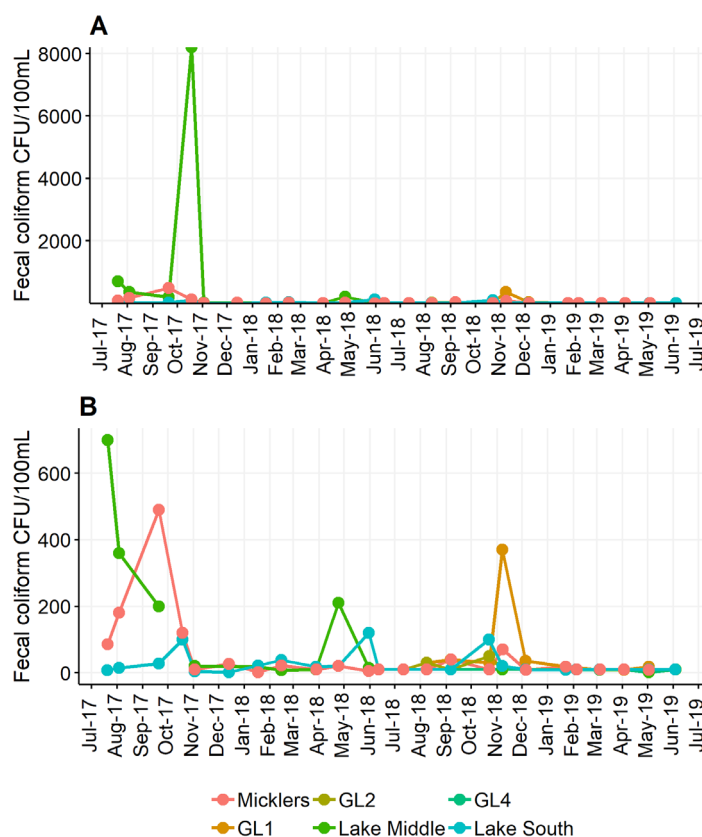


Figure x: Fecal coliform (MPN/100mL) concentrations collected at each sampling station on the day of water sample collections in the lake. A: all the data with extreme values; B: extreme values removed. Note different y-axes.

coliform values were slightly delayed and much higher than values at the Pine Island SWMP station. In October 2017 in the middle of the lake, the fecal coliform concentration reached over 8000 CFU, which was more than ten times

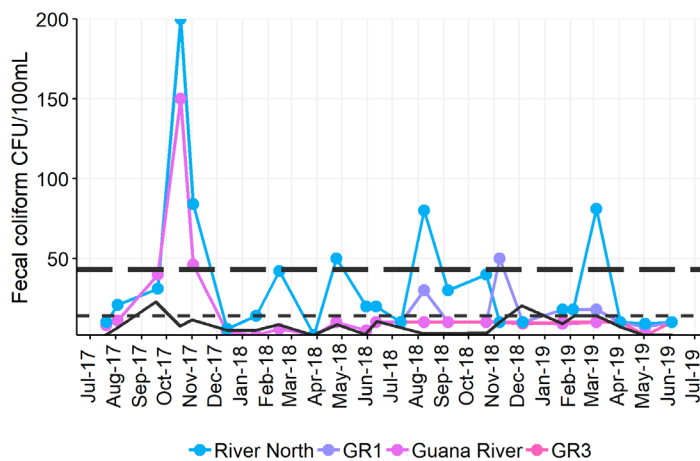


Figure x: Fecal coliform (MPN/100mL) concentrations collected at each sampling station on the day of water sample collections in the river (B). Horizontal lines represent the Florida state threshold criteria for Class II estuarine waters (43 MPN/100mL).

higher than any other value observed during the two-year period. The maximum *Enterococci*

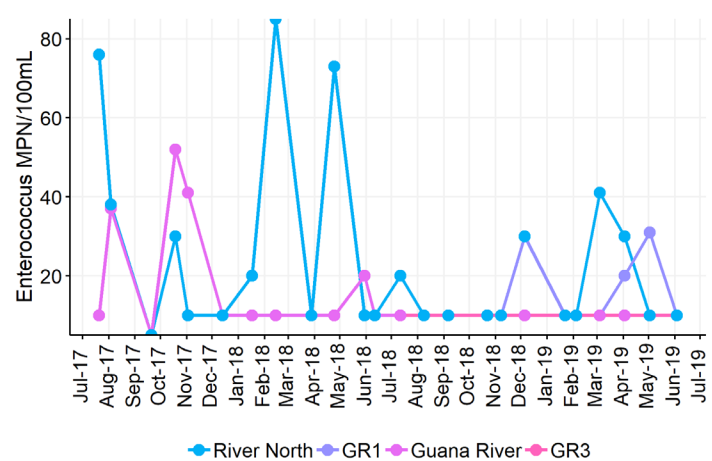


Figure x: Enterococcus (MPN/100mL) concentrations collected at each sampling station on the day of water sample collections in the river (B). Horizontal lines represent the Florida state threshold criteria for Class II estuarine waters (43 MPN/100mL).

bacteria concentration was observed in the middle of the lake in August 2018, which corresponds with the time period of construction activities on Guana dam.

Bacterial levels at the stations generally did not exceed the water quality standards for their associated waterbody. However, high levels were observed in months following large rainfall events, such as Hurricane Irma in the October 2017 sampling event.

ASSESSMENT USING STATE CRITERIA

According FDEP water quality criteria, both waterbodies appear to suffer from excess nutrients. Guana Lake exceeded the chlorophyll a threshold (11 ug/L) both years (Table X) and Guana River slightly exceeded its threshold (6.6 ug/L) in the first year (Table X). Guana River also exceeded the state Total Nitrogen threshold (0.65 mg/L) the first year.

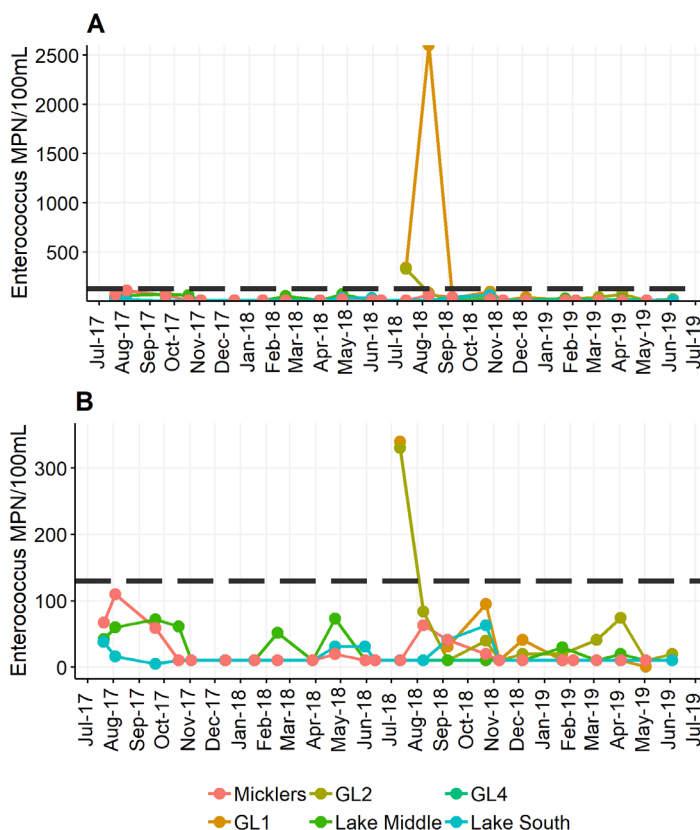


Figure x: Enterococcus (MPN/100mL) concentrations collected at each sampling station on the day of water sample collections in the lake. A: all the data with extreme values; B: extreme values removed. Note different y-axes.

Table x: Annual Geometric Means for water quality parameters collected in Guana Lake. ‘Year 1’ (July 2017-June 2018), only data collected at the Lake Middle site. ‘Year 2’ (July 2018 - June 2019), all open water lake sites.

Parameter	Year 1 AGM	Year 2 AGM	Year 1 Median	Year 2 Median
Chlorophyll a	41.42	15.43	44.5	18
DO (% saturation)	65.81	79.16	72.2	82
Enterococci	26.32	18.25	42	10
Fecal Coliform	74.19	12.25	20	10
Total Nitrogen	2.24	1.50	2.31	1.57
Total Phosphorus	0.12	0.07	0.13	0.07

Table x: Annual Geometric Means and Medians for water quality parameters collected in Guana River used in assessment by Florida Department of Environmental Protection. ‘Year 1’ (July 2017-June 2018), only includes data collected at the Lake Middle site. ‘Year 2’ (July 2018 - June 2019), all open water lake sites are presented.

Parameter	Year 1 AGM	Year 2 AGM	Year 1 Median	Year 2 Median
Chlorophyll a	6.68	6.03	5.65	5.5
DO (% saturation)	70.64	75.21	78.60	77.75
Enterococci	14.39	10.93	10	10
Fecal Coliform	10.13	10.03	9	10
Total Nitrogen	0.76	0.55	0.79	0.51
Total Phosphorus	0.06	0.05	0.06	0.05

Table x: Annual Geometric Means and Medians for water quality parameters collected at the GTMNERR System-Wide Monitoring Program Pine Island Station.

Parameter	Year 1 AGM	Year 2 AGM	Year 1 Median	Year 2 Median
Chlorophyll a	3.75	4.43	3.30	4.35
Fecal Coliform	6.06	5.82	7	6
Total Nitrogen	0.63	0.59	0.65	0.59
Total Phosphorus	0.07	0.06	0.07	0.06

DISCUSSION

This two-year study of the Guana Lake/Guana River system in Northeast Florida established a baseline of water quality conditions. There was often a distinct latitudinal gradient in salinity within the system (fresh water in the north, brackish to full-strength salinity in the south). A north-south gradient was also observed in sucralose, an indicator of human wastewater originating north of Mickler’s weir. Nutrient and phytoplankton concentrations were generally higher in the lake than in the river. Based on biological indicators, state water quality standards, and comparison to a reference site, both waterbodies appear to suffer from excess nutrients. Bacteria levels were generally low with a few extreme exceptions, especially in the middle of the lake.

Continued investigation into the potential sources (and quantity) of nutrients into the Guana system will further our understanding of eutrophication in this and other impounded estuarine systems. Guana is an ideal system to study the effects and sources of eutrophication due to clear input (water control structure at Mickler Road) and output (Guana Dam) points and a gradient of land development from north to south throughout the watershed. As sources and fates of nutrients are determined, remediation strategies can be developed so that Guana Lake and River continue to provide healthy habitat for wildlife and recreation opportunities for our community.

Funding is in place for at least one more full year of monthly water sampling at ten sites. The Friends of GTM have sponsored a graduate research assistant to lead monitoring activities, manage and analyze data, and disseminate findings to stakeholders. Future work will include incorporation of more biological indicators of water quality. GTM Research Reserve and Northeast Florida Aquatic Preserves have been

monitoring plankton community composition, oyster reefs, and small fish and invertebrate communities. Plans are also in place to install a weather station on Guana dam and flow gauges in the weir and the dam. Management of the Guana system to maximize water quality and habitat quality will be informed by studying hydrologic connections within the system, from the headwaters in Ponte Vedra to the Tolomato River estuary.

