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# FISH KILL IN BISCAYNE BAY: A REPORT



MIAMI  
WATERKEEPER



The background of the entire page is a photograph of several stingrays swimming in shallow, clear water. The rays are seen from above, showing their flat, diamond-shaped bodies and long, thin tails. The water is a light brownish-green color, and the bottom appears to be sandy or silty. The lighting is natural, coming from above, creating some shadows on the rays' bodies.

## EXECUTIVE SUMMARY

On the morning of Monday, August 10, 2020, Miami Waterkeeper’s field sampling team noticed about a dozen dead fish at Morningside Park during their weekly water quality monitoring routine. Members of the public and regular visitors to the park soon reported seeing hundreds to thousands of dead fishes in the area.

Over the next five days, these initial observations were followed by hundreds of reports of dead and dying marine organisms from North Miami to Virginia Key, most heavily concentrated in the Julia Tuttle Basin of northern Biscayne Bay. Bottom-dwelling species were most affected, but some water column-associated species were among them. The public submitted photos to Miami Waterkeeper that represented over 27,000 dead fish of at least 56 types. Gulf toadfish represented almost half, 44%, of the total dead fishes photographed.

Reports of fishes exhibiting abnormal behavior, gasping at the surface, and congregating in unusual groups were recorded from Pelican Harbor to Miami Beach for the following five days. Species affected ranged from stingrays to pufferfish to barracuda. Reports came in that “dozens of rays were swimming upside down, gasping for air.” By August 20, severe algae blooms emerged and were reported across large swathes of northern Biscayne Bay.

Response and coordination amongst research groups began with the earliest reports of the fish kill. The scientific community recorded valuable data and observations of unusual events. A [consensus statement](#) with 43 signatories concluded that the likely causative factor of the fish kill was low dissolved oxygen (DO) conditions. Low DO is often associated with high nutrient levels (particularly nitrogen and phosphorus) caused by runoff from septic tanks, sewage leaks, stormwater, fertilizer overuse, as well as decomposing organic matter. Over time, this nutrient pollution can lead to seagrass die-offs, which further limit DO in an ongoing cycle. During the hot summer months, water naturally holds less oxygen. The combination of high temperatures, low wind, and seagrass loss with high levels of chronic nutrient pollution likely contributed to these critically low oxygen conditions and the resulting fish kill. High flows of fresh water from nearby canals, particularly Little River, may have also contributed to the hypoxia.

As many of these pollution inputs have not yet been addressed and seagrass continues to decline, scientists and experts are concerned that another fish kill event will occur in the summer of 2021 and beyond.

## BISCAYNE BAY SCIENCE COORDINATION GROUP

This report was compiled by Miami Waterkeeper with data from the Biscayne Bay Science Coordination (BBSC) group, a group of government, university, and NGO partners that formed to share data during and after the August 2020 Fish Kill. During the acute phase of the fish kill, partners met daily to share information and observations about the ongoing crisis. The group now meets once a month.

The following individuals provided input and feedback on this report:

- Rachel Silverstein, Ph.D., Miami Waterkeeper
- Elizabeth Kelly, Ph.D., Miami Waterkeeper
- Samantha Morejon, Miami Waterkeeper
- Collin Schladweiler, Miami Waterkeeper
- Joseph Serafy, Ph.D. University of Miami
- Prof. Todd A. Crowl, Florida International University
- Prof. Henry Briceño, Florida International University
- Prof. Jayantha Obeysekera, Florida International University
- Prof. Piero Gardinali, Florida International University
- Ross Boucek, Ph.D., Bonefish and Tarpon Trust
- Ana Zangroniz, UF/IFAS Extension & Florida Sea Grant



# SCIENTIFIC AND TECHNICAL FISH KILL DATA AND OBSERVATIONS



Figure 1. Dead fish found at Morningside Park on August, 11, 2020. Photo Credit: Sendit4thesea.



Figure 2. Miami Waterkeeper staff collecting data and observations near Morningside Park with a YSI EXO sonde on a Seakeepers Society vessel.

## Overview (August 10-20, 2020)

Between August 10-15, 2020, the Miami community reported thousands of dead and dying marine life or animals struggling for air across northern Biscayne Bay (Figure 1), impacting both bottom-dwelling and highly mobile fish. Non-profits, research institutions, and government agencies started collecting data when these observations began (Figure 2). Data indicate that low DO levels led to the fish kill, although the contributing role(s) of accompanying toxicants cannot be ruled out.

Miami Waterkeeper tracked all of the public reports of the fish kill and maintained a database for further analysis. Reports of dead and dying marine life concentrated around Morningside Park, Albert Pallot Park, Margaret Pace Park, Baywood Park, Little River/ Belle Meade, Miami Shores Village Bayfront Park/ North Bayshore Park, and 79th Street Causeway/ Pelican Harbor/Normandy Isles (Figure 3). The post-hoc analysis concluded that at least 27,640 fish were killed, representing 56 species.

The first effort to aerate the bay was conducted by the Phillip and Patricia Frost Museum of Science staff on August 13, who installed oxygen hoops in Pelican Harbor to provide oxygen to the congregation of rays reported there (Figure 4). Further efforts to aerate the oxygen-starved areas of Biscayne Bay started on August 15th, when the Port of Miami sent fireboats to spray their hoses to agitate the surface of the water to provide additional aeration (Figure 5). The City of Miami also deployed stormwater pumps as emergency aerators at three affected parks. Anecdotal evidence suggests that these efforts may have had localized, beneficial effects; this warrants further research, as described in detail below.

By August 20th, reports of unusual seafoam and algae blooms accumulated on the water's surface over large areas of northern Biscayne Bay were reported (Figure 6).

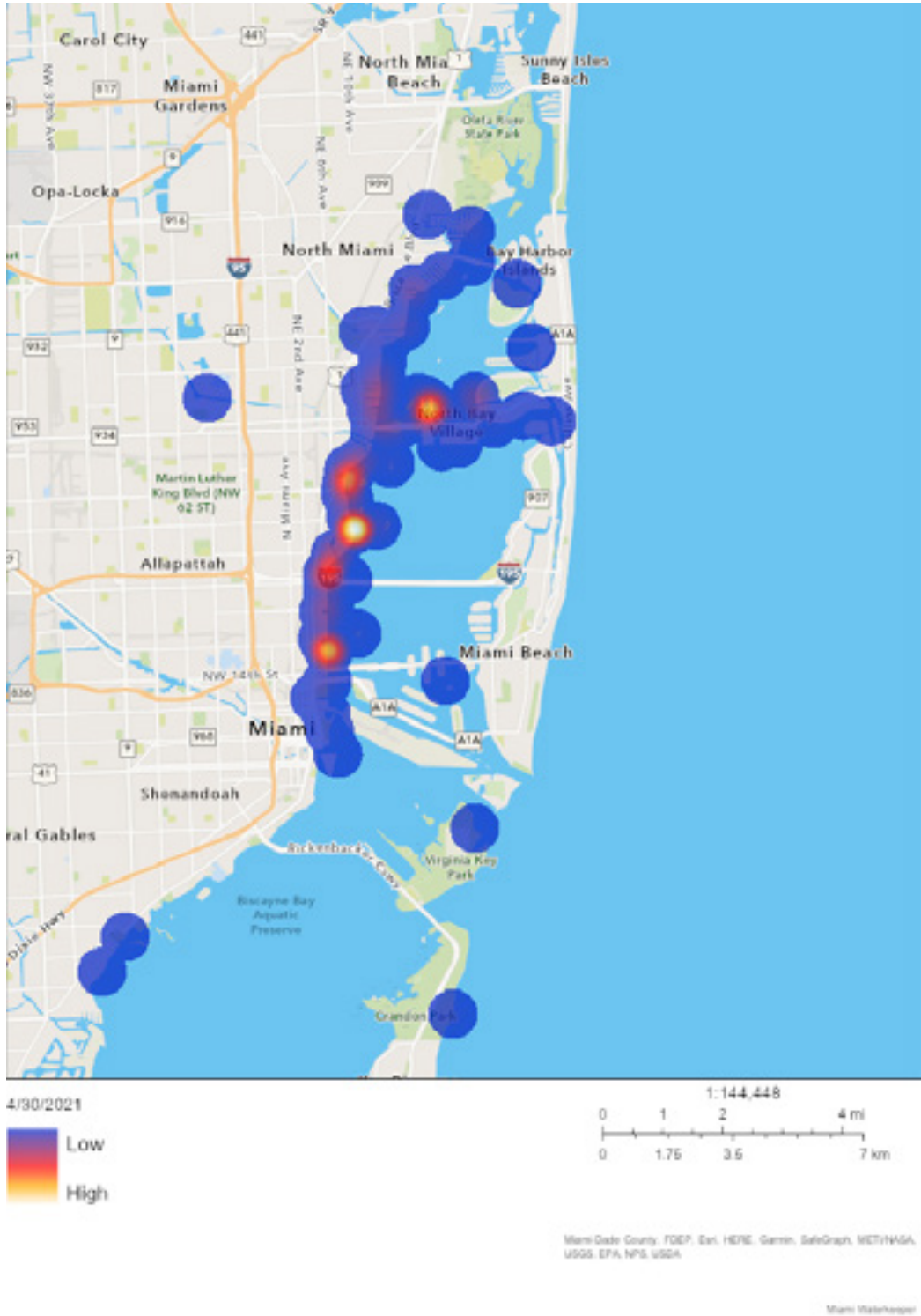


Figure 3. Hotspot map showing the location community reports of the fish kill made to the Miami Waterkeeper between August 10-26, 2020.





Figure 4. Emergency aeration provided by the City of Miami’s stormwater pumps at Morningside Park from August 16-20.



Figure 5. Port of Miami fireboats attempting to aerate Biscayne Bay by agitating the water on August 15, 2020.  
Photo Credit: Christy Raynor.

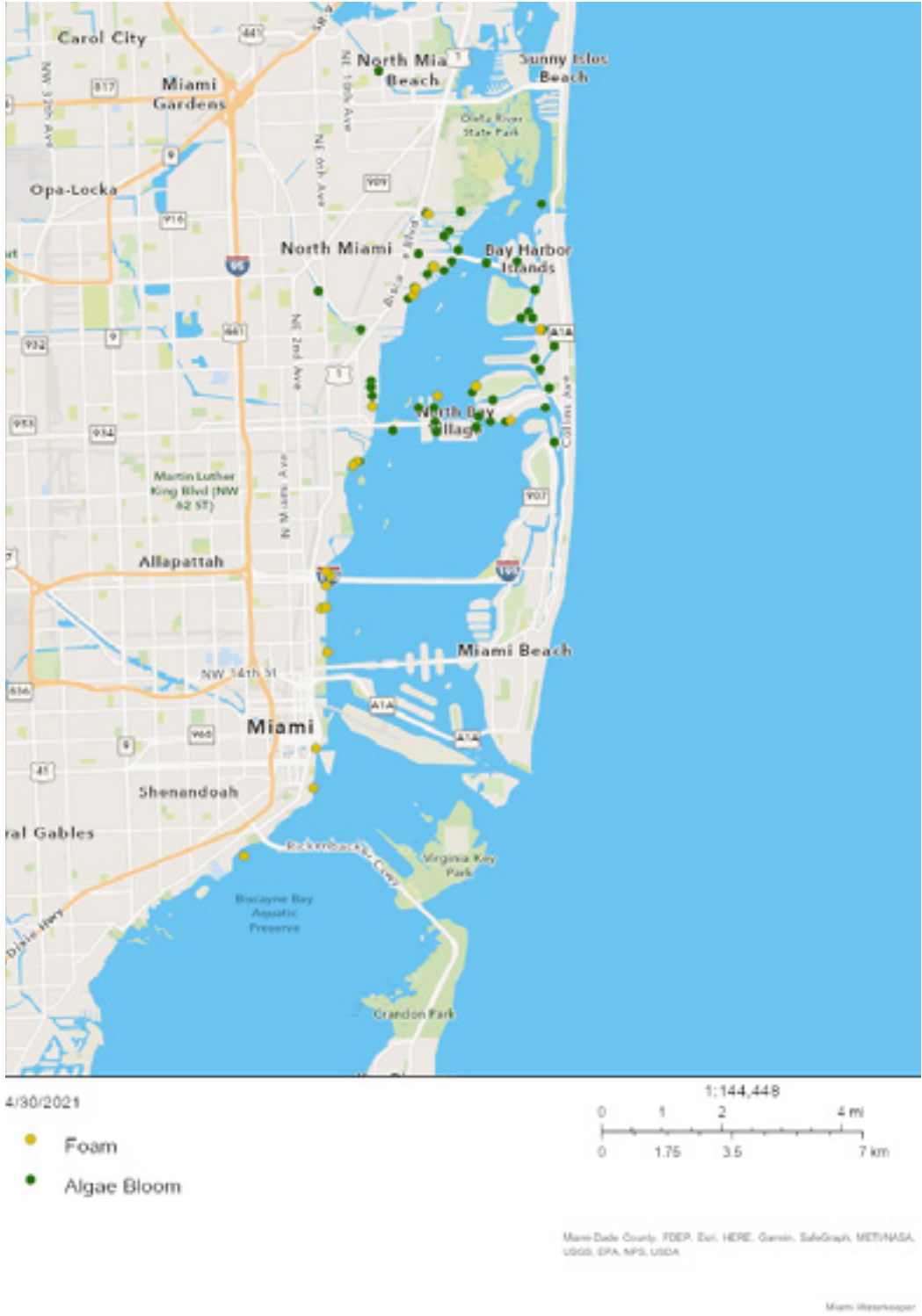


Figure 6. The location of observations of foam and algal blooms from August 20-25, 2020.





Figure 7. Submitted photo from the public that aided in identifying the species impacted by the fish kill. Photo Credit: Antony Williams.

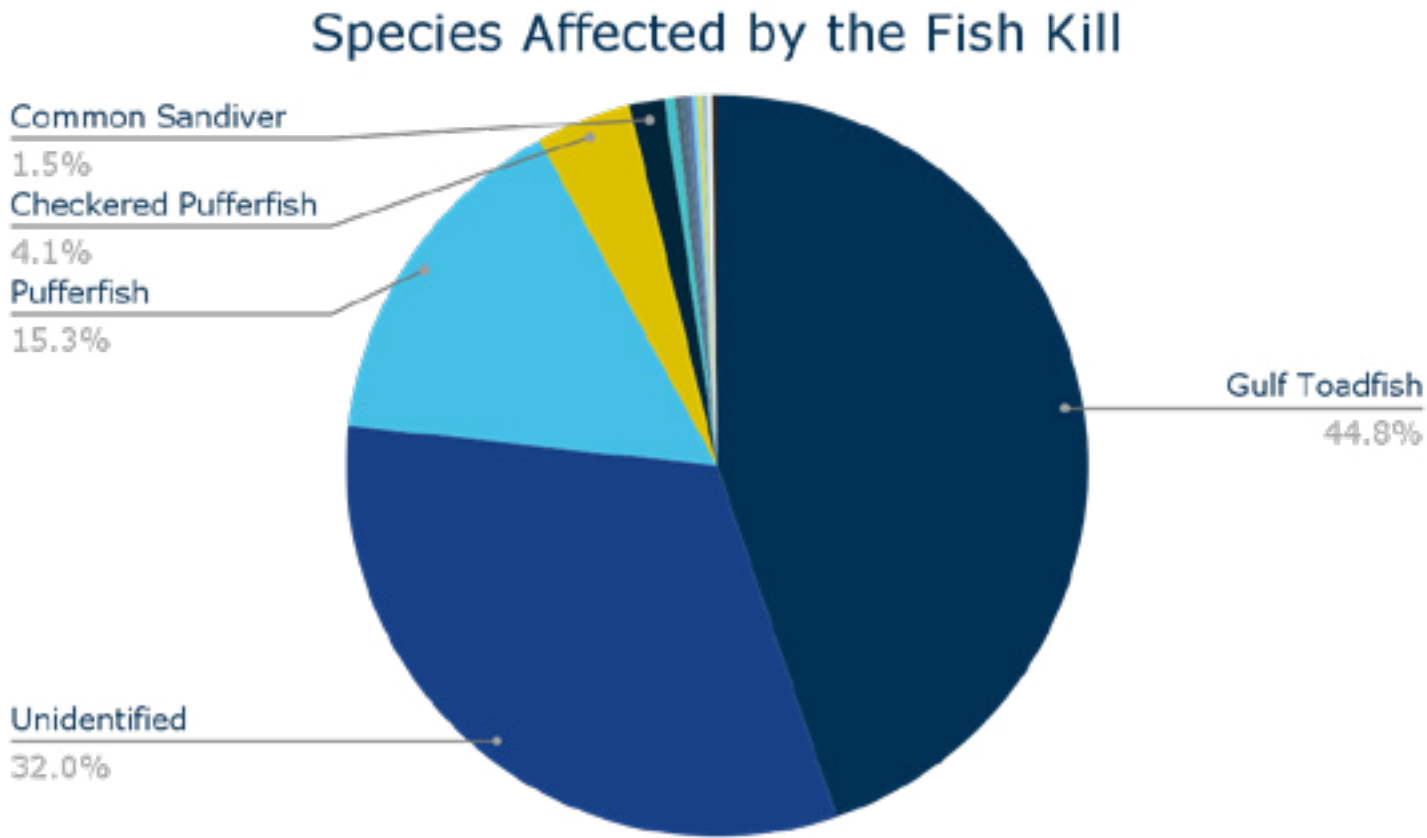


Figure 8. Species affected by the fish kill based on community reports to Miami Waterkeeper from August 10-26, 2020. Affected wildlife numbers were documented from community observations reported to Miami Waterkeeper. This analysis was reconstructed through counts using photographs submitted by the public. Additional individuals or species may have been impacted, but were not photographed, and therefore do not appear in this analysis.

### Species Affected

Miami Waterkeeper staff analyzed a total of 497 digital images and videos that the public submitted. These photos and videos served to enumerate and determine the taxonomic identities of the dead and moribund fishes (Figure 7). Based on the analysis of the images sent to Miami Waterkeeper, at least 27,640 fish and several other organisms are estimated to have been killed, with a total of 56 taxa documented (Table 1). About 44% of the images were dead gulf toadfish, *Opsanus beta*, making them, by far, the most severely affected species (Figure 8). This bottom-dwelling nesting species

is highly site attached and likely do not leave their sites when they encounter stressful conditions. Of the documented fish, 8,835 were unidentified due to a lack of identifiable features in the photo.

These data likely represent the minimum number of fish impacted, as not all fish that were killed were photographed. Affected wildlife might have sunk in place or may have floated to areas where they were not observed. Efforts were taken during analysis to avoid double counting fish and to maintain accurate data.



Species Common Name	Sum of Species
Gulf Toadfish	12373
Unidentified	8835
Pufferfish (nonspecific)	4231
Checkered Pufferfish	1147
Common Sandiver	417
Gulf Flounder	132
Porcupine Fish	74
Unidentified	70
Snake Eel (non specific)	64
Mojarra (nonspecific)	60
White grunt	47
Pinfish	24
Bermuda/Gray Chub	14
Spade Fish	12
Cowfish (non specific)	12
Wrasse (nonspecific)	11
Mangrove Snapper	10
Unknown	9
Marine angelfish	8
Creville Jack	8
Atlantic horseshoe crab	8
Spiny Lobster	6
Stone Crab	5
Sea Robin	5
Gafftopsail catfish	5
Other (<5 observations)	53
<b>Grand Total</b>	<b>27,640</b>

Table 1. Counts of affected fish and wildlife individuals by species from August 10-26, 2020. Affected wildlife numbers were documented from community observations reported to the Miami Waterkeeper. This analysis was reconstructed through counts using photographs submitted by the public. Additional species or individuals may have been impacted, but were not photographed, and therefore do not appear in this analysis.

### Hypoxia Conditions

Scientists and experts reached a consensus that the proximate cause of the fish mortality event was low DO levels, or hypoxia (<2 mg/l DO). In parts of northern Biscayne Bay during this period, several groups recorded severe hypoxia (<1 mg/l DO) and/or anoxia (0 mg/l). DERM conducted their routine monthly “Bay Run” sampling on August 10 near Morningside Park and noted very high water temperature (~90 F) and low DO levels (DERM Representatives 2020). On August 14, DO was near 0% for around five hours at the center of northern Biscayne Bay, between Pelican Harbor and the Julia Tuttle Causeway (Florida International

University [FIU] Institute of Environment National Science Foundation Center of Research Excellence in Science and Technology [CREST] research buoy data and Florida Department of Environmental Protection [DEP] datasonde stations BB14 and JT71, Serafy 2020). DEP Biscayne Bay Aquatic Preserves (BBAP) staff also recorded that oxygen levels dropped to 0% overnight at some of their monitoring locations and in situ sondes (Serafy 2020). At BBAP’s Biscayne Bay 14 (BB14) and Julia Tuttle 71 (JT71) sites (Figure 9), hypoxia persisted intermittently on the same date as the CREST buoys (Figure 10), August 14th. The longest

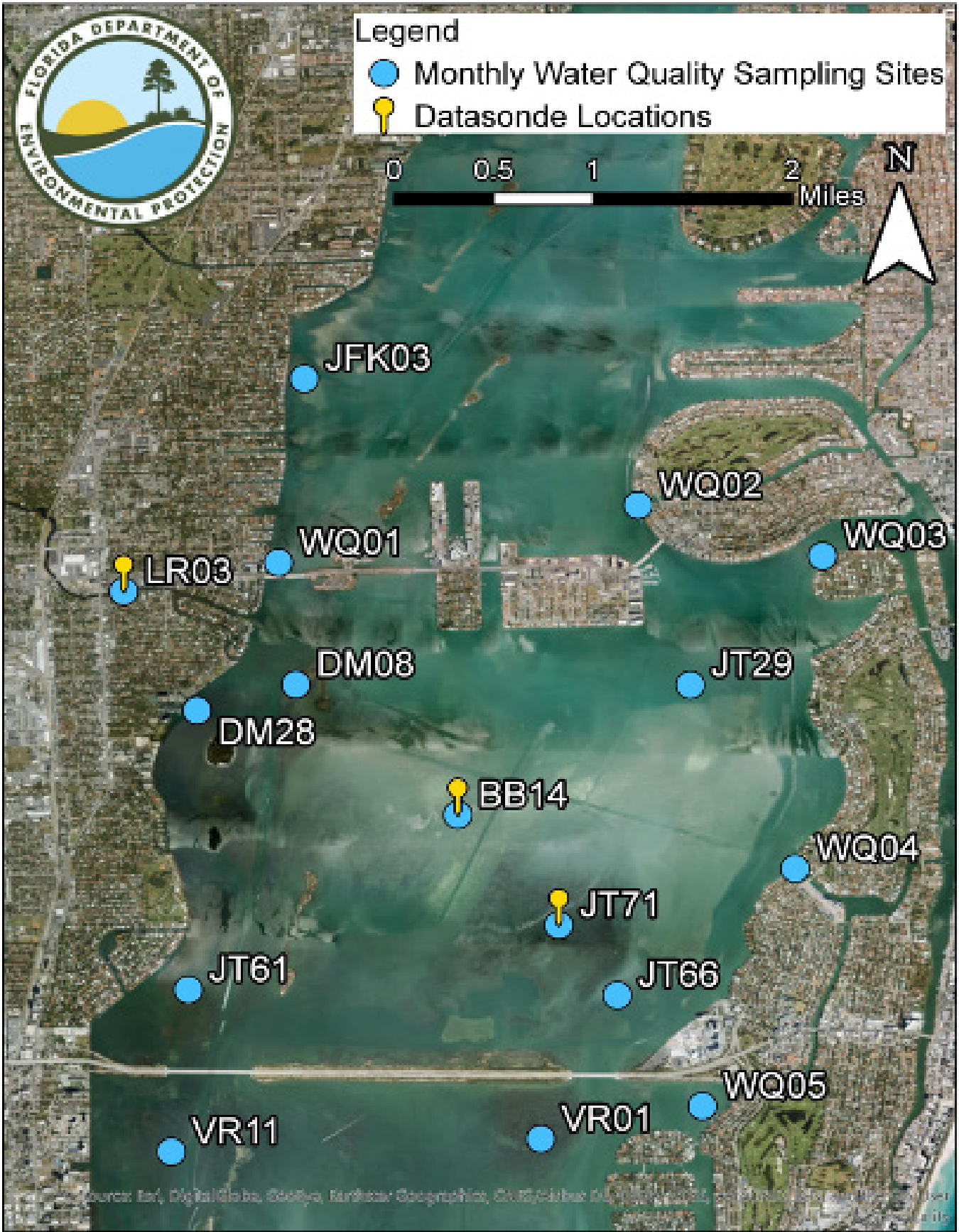


Figure 9. DEP Biscayne Bay Aquatic Preserve fixed monitoring sites in northern Biscayne Bay. Blue circles indicate locations at which water samples are collected monthly. Analysis is conducted for nutrients, chlorophyll a, sweeteners, herbicides, fungicides, insecticides, and pharmaceuticals. Yellow points are the locations of permanently placed data sondes. Analysis from the sondes include physical parameters like depth, conductivity and salinity, DO, turbidity, total suspended solids, total dissolved solids, pH, and temperature. Hypoxia was recorded at the Little River (LR03) and BB14 and JT71 sites, near the Julia Tuttle Causeway. BB14 and JT71 are vegetated, but LR03 is not.

period of hypoxia lasted for five hours. At BB14 and JT17, both of which are vegetated, hypoxia had a diurnal signature, becoming most acute at night time and dawn (Serafy 2020, Figure 11). These are times when living vegetation is consuming oxygen, but not producing it via photosynthesis. By contrast, there is no such diurnal pattern for the hypoxic events at Little River (LR03), which is devoid of vegetation (DEP 2020). This is particularly interesting, as the August 10 hypoxic period at BB14 preceded the August 10-17th event at LR03, which could indicate that the hypoxic conditions initiated in the Bay and moved toward the shore.

FIU CREST also conducted extensive transects of the northern Bay with their autonomous vehicle fleet equipped with Xylem EXO Sondes (Figure 12) and Simrad Ek80 fisheries echosounders, which were towed near the water surface. Data can be visualized at this [site](#). Analysis of DO on August 14 and August 15 revealed that the DO levels were lower on the 14th, especially near the JFK Causeway and Pelican Harbor. DO had increased near the JFK Causeway and Pelican Harbor when another transect of the area was performed on the 15th. On August 27, FIU Institute of Environment CREST [research buoys](#) were relocated to the northern Bay to capture conditions in real-time. One buoy was located south of the Biscayne Canal (north of Biscayne Bay station JFK03) and the other was southeast of North Bay Village (at Biscayne Bay station JT29) (Figure 13).

Chris Langdon from the University of Miami (UM) conducted DO, salinity, and temperature profiles of the water column near Morningside Park and found evidence of stratification (Figure 14). On August 14, Langdon collected several oxygen profiles in the vicinity

of Morningside Park, the site with the most abundant fish deaths reported in North Biscayne Bay. Oxygen levels were normal at the surface, but just inches below the surface, levels fell to 1 mg/L and stayed at level all the way to the bottom. Levels below 2 mg/L are known to be stressful to many fish and invertebrate species. Langdon also recorded a layer of fresher, less salty water at the surface (Figure 14). Subsequent sampling traced the probable source of this layer of fresh water back to the points where the Little River and Biscayne Canals empty into the bay. Flow data over the last 40 years from the four canals in the northern Biscayne Bay show steadily increased flow during the wet season (~day 140-300, approximately the end of May through the end of October, Figure 15A), decreasing as the dry season approaches. However, in 2020, canals experienced several sharp pulses of anomalously high flow during year days 150-300 (Figure 15B). The second large flow pulse coincided with the August 2020 fish kill, and the third pulse with the subsequent October fish kill (October 2-5th). This sudden input of fresh water, lasting just a few days, in combination with other contributing factors (i.e., high temperature, low winds, sediment suspension, eutrophication, and a benthic community largely devoid of photosynthesizing seagrasses), could have generated a fresh water lens at the surface which prevented mixing and exacerbated the hypoxic conditions that led to the fish kill. These data provide support for the conclusion that low DO measurements resulted in the fish mortality and abnormal behavior of wildlife. Hypoxia is a common cause of fish kills worldwide (EPA, NOAA, FDEP) , typically linked to high nutrient loads, including those from the watershed and from large quantities of decaying organic material.



Figure 10. FIU CREST buoy reading showing the drop in DO to 0 on August 14, southeast of North Bay Village. The blue line indicates the concentration of DO, black is chlorophyll-a, green is the temperature, and orange is the percentage of DO.

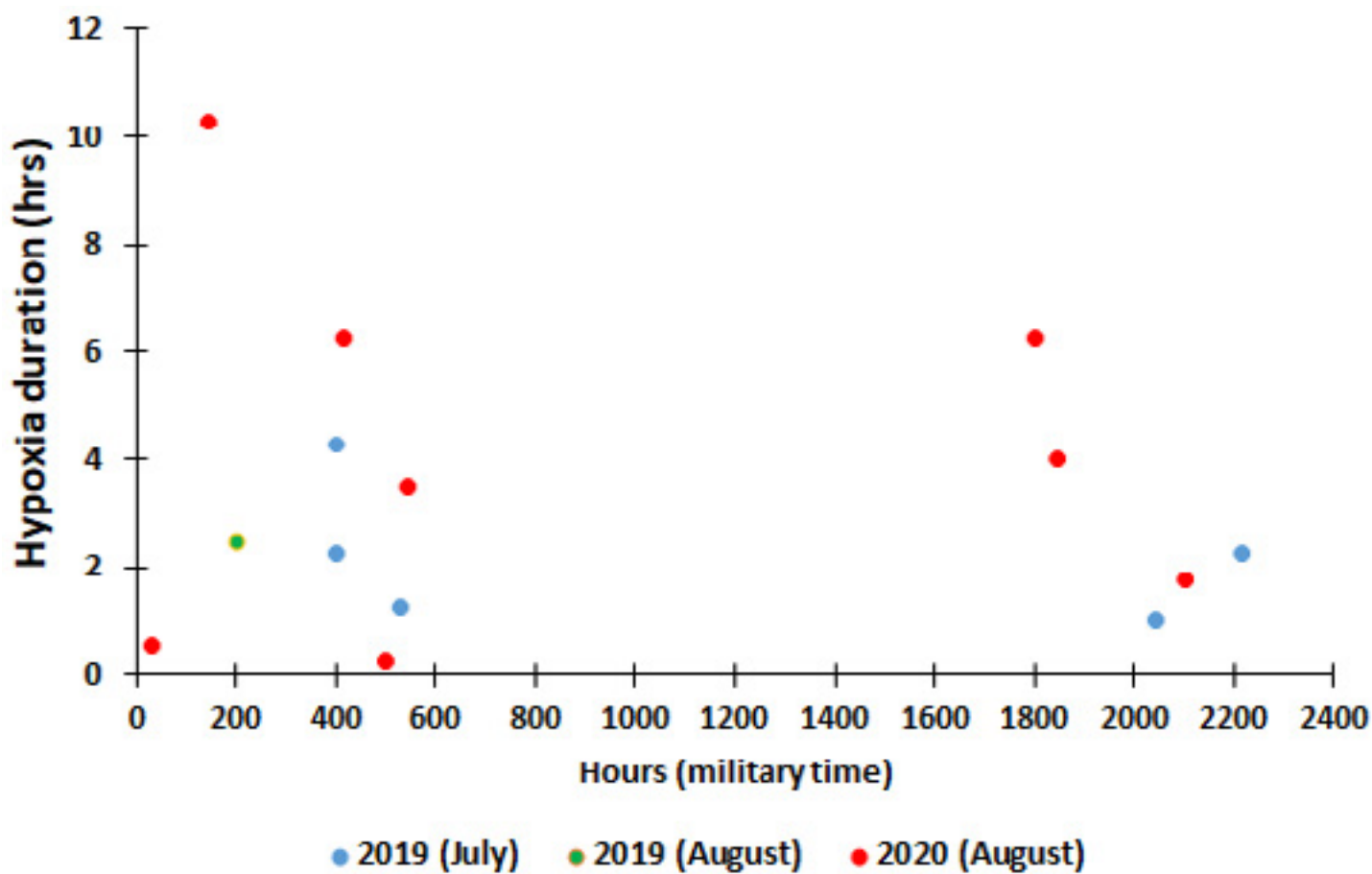


Figure 11. Hypoxic durations in hours at BBAP site BB14 for July 2019, August 2019, and August 2020, demonstrate the occurrence of these events overnight at this vegetated site, at dawn and dusk (Serafy 2020).of DO, black is chlorophyll-a, green is the temperature, and orange is the percentage of DO.



Figure 12. FIU researchers with Xylem EXO sondes that were moved to northern Biscayne Bay in response to the fish kill. Data is available in real time at <https://crestcache.fiu.edu/research/research-buoys/index.html>



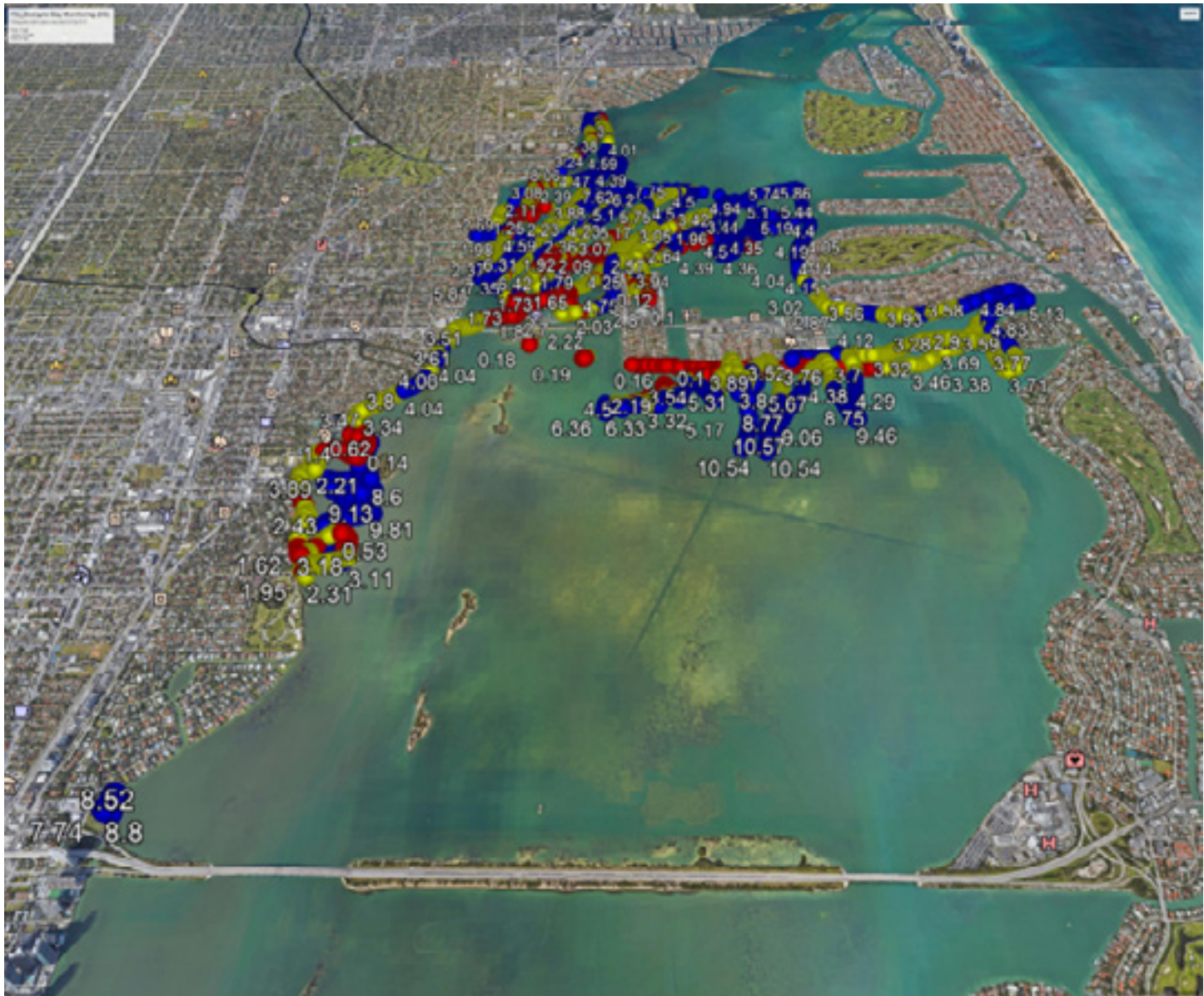


Figure 13. FIU CREST transects of the northern Biscayne Bay, conducted with Xylem EXO Sondes and Simrad Ek80 fisheries echosounders towed near the water surface. DO was low on August 14 and August 15th, especially near the 79th Street Causeway and Pelican Harbor (center of image). The red lines indicate DO < 2 ml/L, yellow indicates DO between 2 to 4 mg/L and blue indicates DO > 4 mg/L.

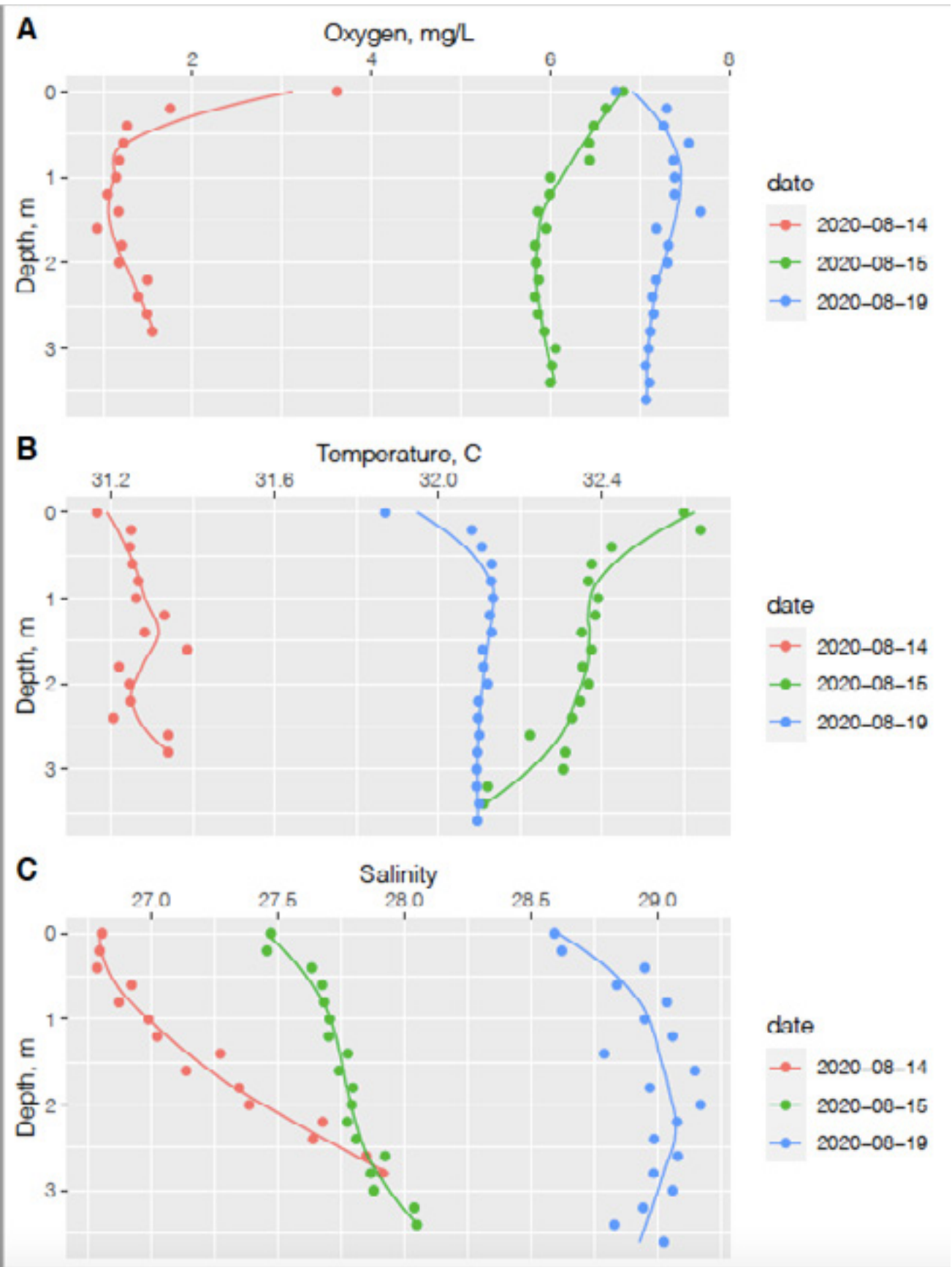


Figure 14. Profiles of oxygen, temperature, and salinity at Morningside Park for August 14-19, 2020 (Langdon, 2020). On August 14, low DO was stratified, with higher DO and low salinity water at the surface, decreasing with depth. By the 15th and the 19th, DO was consistent throughout the water column; the salinity stratification lessened by the 15th and was gone by the 19th. Temperatures were higher on the 15th and the 19th, suggesting that low DO conditions were not directly related to temperature. A fresh water lens may have been at the surface on the 14th, preventing mixing and exacerbating low DO conditions. This breakup of stratification may have been aided by aeration efforts by the City of Miami near this site on August 15.



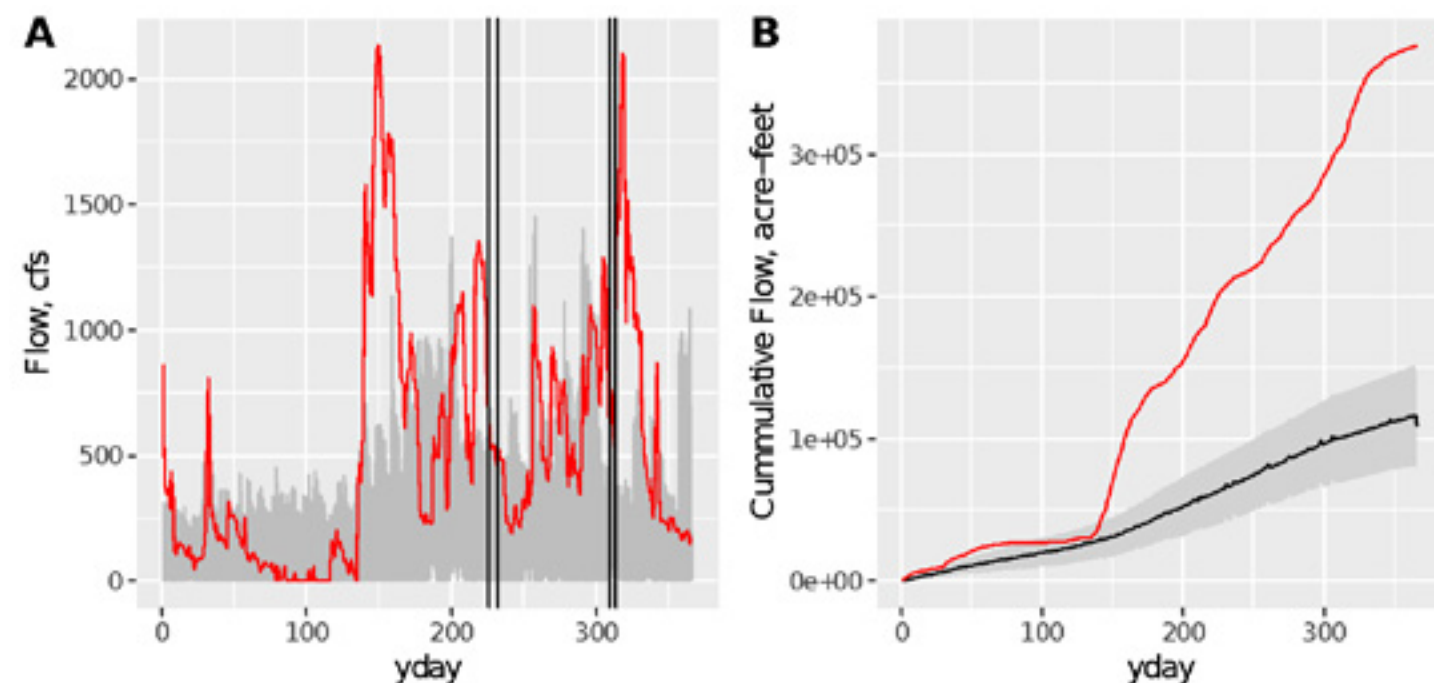


Figure 15 A. Daily flow of the Little River by year day, 1985-2019 (gray) and 2020 (red). Black vertical lines delineate the Aug 14-20 and Oct 5-9, 2020 fish kill events in north Biscayne Bay. B. Cumulative flow of the Little River for 1985-2019 shown by the black line and 2020 by the red line. The confidence interval for the average annual cumulative flow is shown in gray.

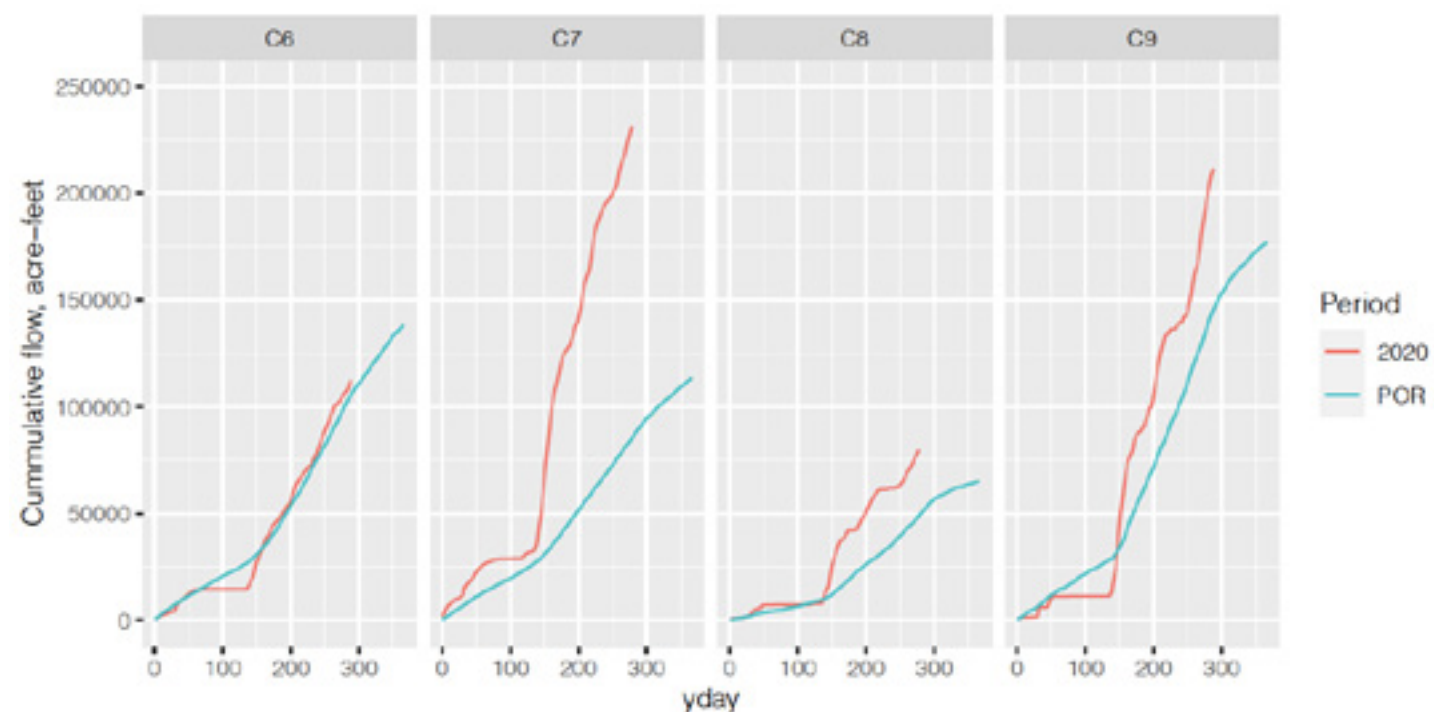


Figure 16. The cumulative flow of the C6, C7, C8, and C9 canals in 2020 (red) and the climatological (1987-2019) average for each canal into North Bay (Langdon 2020, from South Florida Water Management District data). This figure shows that the difference between 2020 flows and the historical average was that the bulk of the canal water that was entering north Biscayne Bay in 2020 came from C7 (Little River) instead of C6 and C9.

## High Flow Rates from the Little River Canal

Through analysis of data from the South Florida Water Management District (SFWMD), several scientists noticed that the fish kill had been preceded by anomalously high flow rates from the Little River Canal (C7), beginning in May 2020 (Figure 15). These flow rates exceed any flow rate over the last 30 years (Figure 16) and came later in the year and in larger pulses than in prior years. Higher flow rates were not observed in the adjacent Miami River (C6) or the Biscayne Canal (C8). These abnormally high flow rates cannot be explained by increased rainfall (NOAA database, Langdon 2020, Figure 17).

The SFWMD reported that there were no management changes that would have affected flow rates in the Little River canal (SFWMD representatives 2020). They also reported that the G72 salinity control structure allowing flow into the Little River has been closed for the past three years. SFWMD indicated that this increase in flow rate must, therefore, be due to local runoff and possibly due to elevated groundwater levels prior to rain events. However, this sudden influx in discharges from just the Little River Canal (and not, for example, the Biscayne Canal) remains unexplained. An analysis of annual discharges from the Little River and the rainfall within the basin indicated unusually high runoff/rainfall ratios, leading to a concern that the flow-rating curve at the outlet structure is likely inaccurate. The accuracy of

the estimated flow rates depends on the algorithm. This calculation, which uses water level measurements at the structure, is a direct assessment of discharges for long periods using flow sensors is not practical. This concern has been elevated to SFWMD staff who are investigating the accuracy of the rating curves (Obeysekera 2021). To date, there has not been any resolution to this concern. SFWMD is investigating the flow rating curve at the S-27 structure for any errors.

If accurate, these high flow rates from the Little River may have exacerbated low DO conditions by creating a freshwater lens, which reduced water column circulation and led to hypoxia. Additionally, as the Little River has high nutrient levels and other contaminants, this high flow could have worsened nutrient pollution and bacteria levels in this area.

Prof. Briceño and Reinaldo Garcia from FIU's Institute of Environment are implementing the Environmental Protection Agency (EPA)-funded Biscayne Bay Operational Hydrodynamic and Water Quality Model. The model provides high-resolution dynamics, including velocities, water depths, erosion/deposition patterns, and concentrations of pollutants. When this model is finalized, it will help understand the hydrodynamics of the region and possible conditions that led to the fish kill.



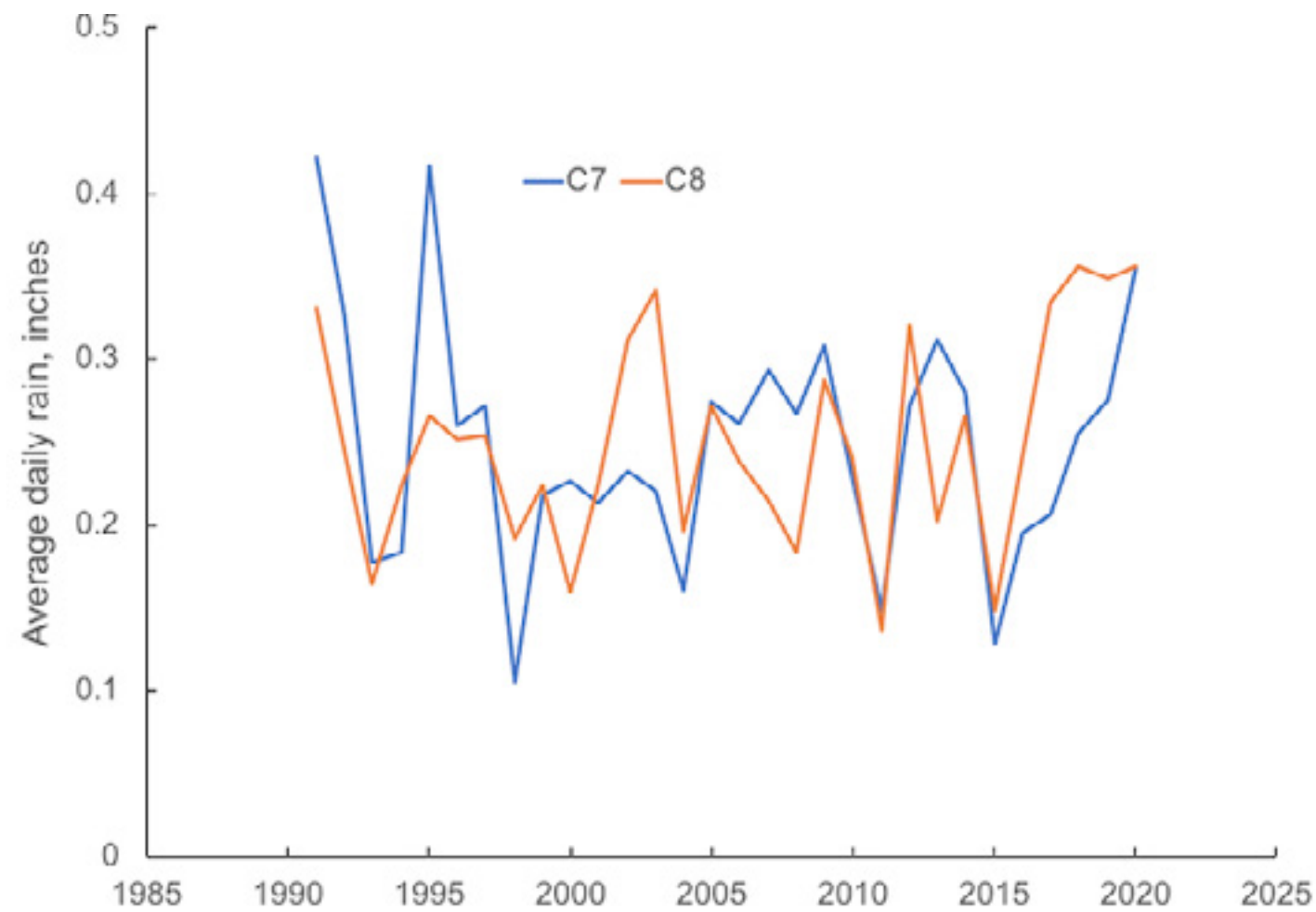


Figure 17. Average rainfall between 1990 - 2020 along the Little River (C7) and Biscayne Canal (C8). This figure indicates that rainfall was not anomalous in 2020, nor was it different between the C7 and C8 basins. This indicates that rainfall does not explain the difference between flow rates in the C7 and C8 canals shown in Figures 15 and 16 (Langdon 2020). However, there is a suggestion that runoff rates could be higher and an as-yet-unexplained groundwater effect is still possible.

### Algae Bloom Data and Observations

As the fish kill event began dissipating, severe algae blooms were reported in widespread areas across northern Biscayne Bay, from August 20th - August 25th (Figure 6). These reports came in an apparent diurnal cycle of white or brown “foam” (Figure 18) in the morning that turned green by the afternoon (Figure 19). The blooms disappeared overnight, likely sinking, and returned in the morning for several days. Samples analyzed by FIU (Collado-Vides 2020, Frankovich 2020) and Florida Fish and Wildlife Conservation Commission

(FWC 2020) reported that the primary taxon was a diatom (*Chaetoceros* spp.). Diatoms are single-celled eukaryotes, usually plankton, that are classified as algae.

As it occurred after the fish kill and not before, the dense algal blooms are thought to result from the events that led to the fish kill and not a cause, (although *Chaetoceros* can cause fish kills). Likely, as fish and other biomass decomposed, an influx of nutrients was released, which fueled the severe blooms.



Figure 18. White “foam” that was observed early in the day (August 21, 2020), and later turned green by the afternoon. Photo Credit: Michelle Salem.





Figure 19. A) (left) Thick algae mat at 12000 N Bayshore Drive on August 21, 2020. Photo Credit: Adam Cohen. B) (above) Algae pictured East of Harbour Island on August 21, 2020. Photo Credit: Denise O'Brien.

### Interventions to Address Acute Hypoxia

Measurements (e.g., FIU, UM, Miami Waterkeeper, DERM, DEP) found low DO, specifically near Pelican Harbor/79th Street Causeway and the Little River/Belle Meade area during the fish kill event. Fishes, especially skates and pufferfishes, were observed to be congregating at the surface, exhibiting abnormal behavior, and struggling to breathe at Pelican Harbor, Morningside Park, Albert Pallot Park, and Margaret Pace Park. The fishes were at the shoreline and their behaviors were described as “gasping” (Figure 20).

In response, oxygen pumps were installed at Pelican Harbor marina by the Phillip and Patricia Frost Museum of Science staff to provide oxygen to the congregated marine life, particularly various species of rays (Figure 21). On August 15, 2020, in an effort to improve DO conditions, Miami Waterkeeper requested emergency aeration efforts from PortMiami and City of Miami. In coordination with Miami Dade County and PortMiami, fireboats were sent to oxygen-starved areas of the Bay near North Bay Village (Figure 5). As these boats were deployed in an emergency mode, researchers were not fully prepared with a complete experimental design to measure their efficacy. However, anecdotal evidence

collected by FIU CREST researchers suggests that this was an effective temporary measure in the immediate area. Where the fireboats were operating, surface DO was measured at 30%, while about 100 yards away, DO was only 15% (Schonhof 2020). However, this could have been due to a pre-existing difference in DO levels rather than the operation of the fireboats. We recommend future controlled studies to investigate an ameliorative effect, if any. Similarly, the City of Miami deployed stormwater pumps as aerators at Morningside Park, Albert Pallot Park, and Margaret Pace Park between August 16 and August 20 (Figure 4); monitoring occurred only at Morningside Park. DEP observed that DO levels near Morningside Park increased with the aeration efforts, but that turbidity levels also increased (FDEP BBAP 2020). Langdon found that DO levels increased at this location after the commencement of aeration (Figure 14). Critically, he also recorded that the salinity stratification initially observed at this site began to break up with the initiation of aeration, showing that the water column was becoming more mixed. Mortality reports and reports of wildlife struggling for oxygen slowed or stopped in these areas after interventions,



according to Miami Waterkeeper reports from the public.

The City of Miami also deployed their contracted Scavenger vessel along their shoreline to both clean up fish carcasses and to aerate the water (Figure 24). The Scavenger was concentrated near the Brickell area and near Albert Pallo Park.

Miami Waterkeeper also recorded that fecal indicator bacteria (FIB) levels (enterococci), which had been steadily increasing every day of the fish kill (likely due to the decomposition of dead matter), began to decrease with the onset of aeration (Figure 22). On the first day of the fish kill, bacteria counts in the two samples collected were 41 MPN and 97 MPN at Morningside Park. By August 13, the bacteria count had spiked to 423 MPN; on August 14, 1236 MPN were recorded. Once oxygenation began, FIB levels dropped to dry season levels at this site, 10 MPN. This reduction could be due to the increased circulation in the area due to aeration. Morningside Park generally does not have a lot of wave action, which allows for enterococci to proliferate in the sediment. Enterococci can then remain in the sediment

until a rain or wind event flushes them out, resulting in large spikes. With the consistent wave action from the pumps, the enterococci were likely flushed from the sediments. Even after the pumps were removed, the lower levels of enterococci remained for a few weeks before gradually returning to baseline wet season levels for the Morningside Park site.

While none of these data were the result of a controlled study, taken together, data suggest that these interventions did seem to alleviate the anoxia and possibly distress to marine life, and may have decreased bacteria levels. After these interventions were deployed, no additional dead fish were reported in those areas.

However, it is crucial to note that aeration is not the desired solution to preventing or addressing fish kill events. Rather, it is treating the “symptom” of low DO rather than the “disease”, nutrient pollution. Instead, resources should be put towards addressing the root causes of the fish kill to prevent future low DO conditions.



Figure 20. Congregating fishes and rays at Pelican Harbor on August 13, 2020, before the Phillip and Patricia Frost Museum of Science staff added aeration. Photo Credit: Logan Fazio.

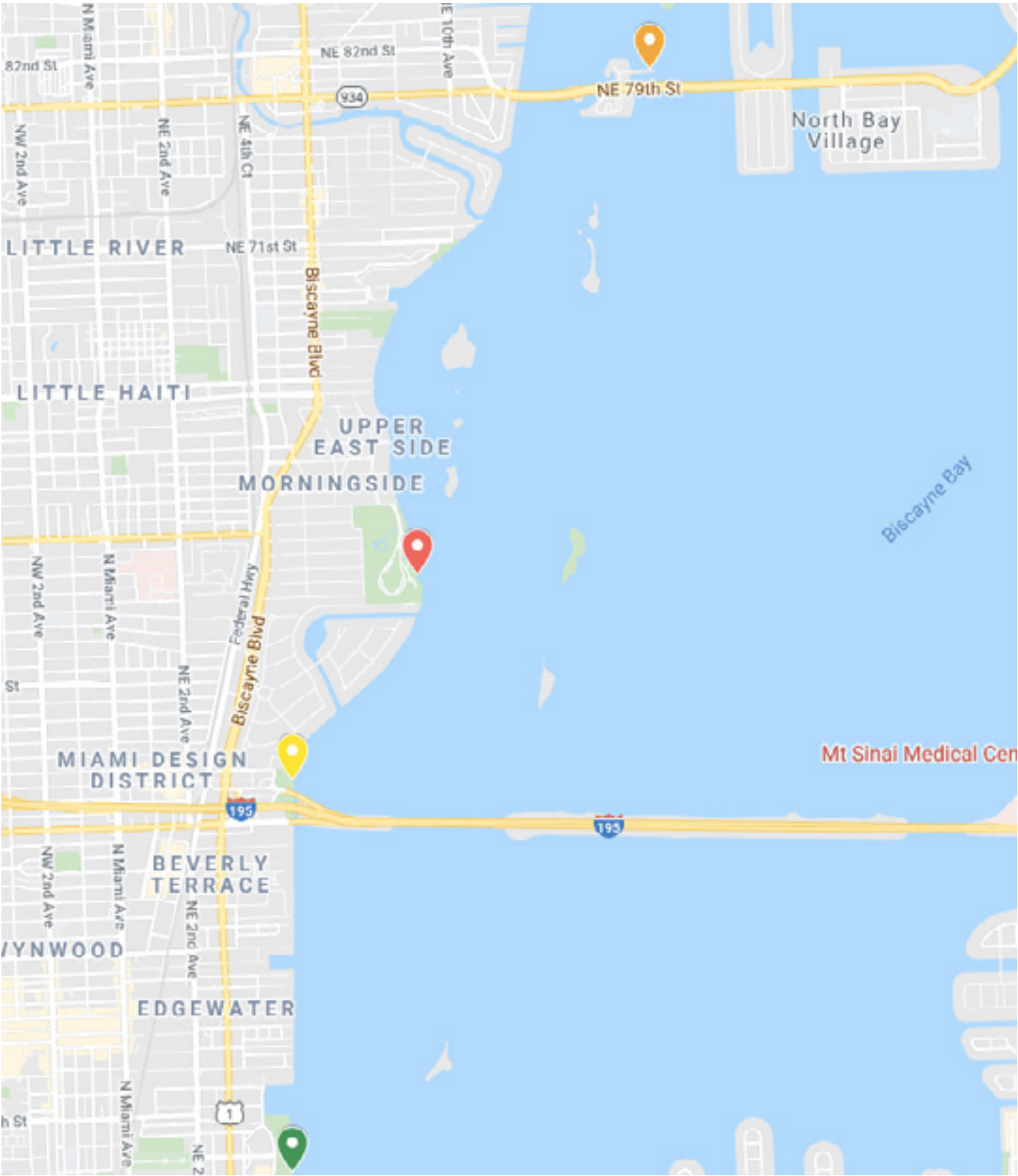


Figure 21. Locations where pumps were deployed from 8/16/20 to 8/20/20, to add emergency oxygenation for sea life in the Biscayne Bay, August 2020. Pumps were added at 3 City of Miami Parks using the City’s stormwater pump system modified for aeration. At Pelican Harbor, the Frost Science Museum set up aeration via oxygen tanks on August 13, 2020. Miami Dade County fire boats also operated near North Bay Village on the morning of August 15th.



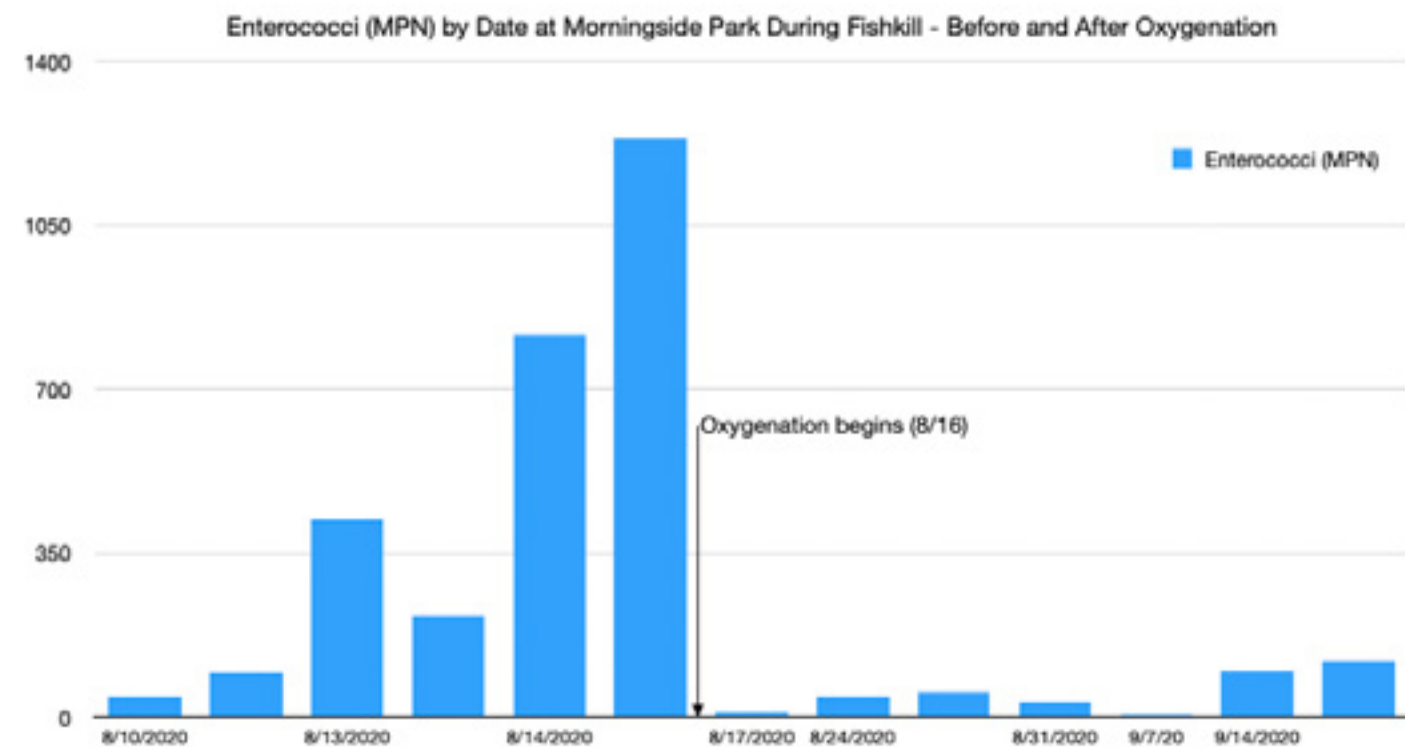


Figure 22. Numbers of enterococci in samples collected at Morningside Park, 8/10/20 - 9/14/20, as part of the Miami Waterkeeper Water Quality Monitoring Program, demonstrating a drop in enterococci following aeration intervention. An aeration pump was activated at this site (8/16), at the sampling location.



Figure 23. Members of the public volunteering to clean up dead fish from the Bay. Photo Credit: Cody Eggenberger.





Figure 24. The City of Miami's contracted scavenger vessel removing floating fish carcasses on August 17. Photo Credit: Kathryn Angleton.

**Clean-Up Efforts**

Animal carcasses began to gather on the shorelines and decompose, further exacerbating water quality problems. Dozens of members of the public volunteered to clean up fish at accessible areas and by kayak and paddleboard (Figure 23). The City of Miami's Scavenger vessel also assisted in removing floating fish carcasses

(Figure 24). Miami Waterkeeper collaborated with Fertile Earth Worm Farm and the City of Miami to coordinate composting the decaying fish. Designated compost bins were placed at Morningside Park, Albert Pallot Park, and Margaret Pace Park to further clean up efforts (Figure 25).



Figure 25. A trash bag filled with dead and decaying fish resulting from the fish kill event.



Clean-Up Efforts

Summer 2019 Fish Kill

According to data collected by DEP, a smaller fish kill preceded the August 2020 event in 2019. Severe hypoxic events, with DO less than 1 mg/L, were recorded at BB14 and JT71 (Figure 26). Anoxic events also were recorded. These events occurred at night, dawn, or dusk, in the same pattern that would occur in 2020 (Figure 11). At BB14, an event that was both anoxic and hypoxic occurred from July 7-10, 2019. This event also demonstrated a diurnal pattern. Anoxic events occurred on July 8 and 9th, lasting for about 2-3 hours. From August 20, 2019 through August 22, 2019, another diurnal anoxic/hypoxic event occurred. A continuous anoxic event also happened on August 21 for around 30 minutes.

Other Contributing Factors

Seagrass Declines

Seagrasses are marine flowering plants that live in high light marine environments around the world. They comprise a key habitat in Biscayne Bay, forming meadows that are home to a diverse set of species. Seagrasses have extensive root systems that stabilize the sediment and keep the waters clear. Seagrasses are also effective carbon sinks and provide oxygenation to the water column. They are also a key food source for turtles, manatees, and other herbivores.

Historically, the Bay seafloor was covered in lush seagrass meadows. However, eutrophication, or nutrient pollution, of Miami’s waterways have diminished the coverage of seagrass beds in Biscayne Bay over the last 10-20 years. Seagrass has declined in the Tuttle seagrass bed (near the Julia Tuttle Causeway, the southern end of many of the fish kill sightings, near Albert Pallot Park) since around June of 2015 (Figure 27) (Eldredge 2019). Seagrass cover decreased by up to 89% in northern Biscayne Bay, according to a 2019 report from a Miami-Dade County seagrass and hard-bottom habitat study (Figure 28) (Miami-Dade County 2019).

Seagrass declines are often associated with eutrophication (Chin 2020, Caccia and Boyer 2007). The report indicates that nutrient pollution is likely entering Biscayne Bay from the canals, representing mostly urban groundwater and runoff. Over half of the freshwater entering Biscayne Bay flows through northern canals, including the Miami River, Little River, Biscayne Canal,

October 2020 Fish Kill

By the beginning of September, the worst of the crisis seemed to be over. The fishes were no longer exhibiting acute mortality, and reports of algae and foam began to wane. However, a subsequent, smaller fish kill occurred during October 3rd - 5th 2020, near Haulover and North Bay Village. Around 40-50 dead pufferfish and toadfish were reported at Haulover and 10-20 dead pufferfish and toadfish were reported at North Bay Village. Algae were sighted and sampled on October 5th at Albert Pallot Park, Bay Vista Boulevard, Harbor Island, and Museum Park Baywalk. The analysis found that the algae were again primarily composed of the diatom *Pseudo-nitzschia* spp., and dinoflagellates (*Gyrodinium* spp, *Heterocapsa* spp, and *Prorocentrum rhathymum*).

Arch Creek, Snake Creek, and the Oleta River. Urban runoff and groundwater are often contaminated with industrial waste, fertilizers, pet waste, sewage leaks, septic tank leachate, and more. Caccia and Boyer estimate that 74% of the ammonium, a nitrogen species associated with human waste, is entering Biscayne Bay from Snake Creek, Miami River, and Little River alone.

The loss of seagrass means that less oxygen is produced during photosynthesis by the seagrasses. Therefore, areas devoid of vegetation are more vulnerable to hypoxia. The production of oxygen by seagrass during the day may explain why DO levels dip at night, when vegetation is using oxygen, but not producing it. Therefore, areas with vegetation exhibited more of a diurnal cycle than barren areas (Eldredge 2020).

Some areas that have experienced seagrass declines have had a resurgence of macroalgae, such as *Halimeda* (Eldredge 2019). These algae may produce oxygen, but it is not clear whether they are as productive as seagrass.

Tissue analysis of seagrass and algae has demonstrated higher nitrogen signatures in the North Biscayne Bay, by the mainland, and Tuttle Causeway (Eldredge 2019). Carbon and sulfur levels were similar. Elevated ammonia, chlorophyll-a, organic carbon, TP, TSS, and TN were found at LR03B and LR03S: both Little River sites. Chlorophyll-a was also elevated at these same sites (Eldredge 2020). In this same area, a historically dense seagrass community, manatee grass (*Syringodium filiforme*), known to be resilient under nutrient loading,

Hypoxia = <=1 mg/L

Obs	yr.mo	n	# hypo_DO	% hypo_DO	Max Dur (hrs)
1	2019.01	1306	0	0.0000	0.00
2	2019.02	2688	0	0.0000	0.00
3	2019.03	2285	0	0.0000	0.00
4	2019.04	2880	0	0.0000	0.00
5	2019.05	2856	0	0.0000	0.00
6	2019.06	2766	0	0.0000	0.00
7	2019.07	2976	44	0.0148	4.25
8	2019.08	2691	10	0.0037	2.50
9	2019.09	2443	0	0.0000	0.00
10	2019.1	2647	0	0.0000	0.00
11	2019.11	2676	0	0.0000	0.00
12	2019.12	2784	0	0.0000	0.00
13	2020.01	2481	0	0.0000	0.00
14	2020.02	2098	0	0.0000	0.00
15	2020.03	2781	0	0.0000	0.00
16	2020.04	1377	0	0.0000	0.00
17	2020.05	1296	0	0.0000	0.00
18	2020.06	1573	0	0.0000	0.00
19	2020.07	346	0	0.0000	0.00
20	2020.08	1677	131	0.0781	10.25

Figure 26. Hypoxic events, dates, and durations at BBAP site BB14 for July 2019, August 2019, and August 2020. This figure provides the number of hypoxic readings during the month, the percent of time where DO was less than or equal to 1 mg/L, and the total duration of hours for that month (Serafy 2020).





Figure 27. Areas of seagrass loss observed between December 30, 2011, and January 23, 2016. (via Google Earth).

was found to have been reduced by approximately 77%. This die-off was attributed to a lack of oxygen to sustain the seagrass beds (Miami-Dade County 2019).

#### Nutrient Pollution

Ultimately, the fish kill can be traced back to an underlying stressor on the ecosystem: nutrient pollution, particularly phosphorus. Nutrients and bacteria enter the Biscayne Bay through canals, sewage leaks, septic tanks, stormwater runoff, and groundwater. Biscayne Bay has been designated by the Florida DEP as impaired for nutrients (FDEP 2017). Nutrients, especially phosphorus, are particularly problematic for oligotrophic estuaries like Biscayne Bay because they are adapted to be low nutrient environments. Nutrients overfertilize aquatic and marine algae to bloom and block sunlight from seagrass and lead to seagrass declines. In extreme cases, algae blooms can lead to fish kills when they decompose and leave no available oxygen for fish. Additionally, in areas where seagrass has been lost (Figure 28), less oxygen can be produced (depending on the production by algae). The loss of seagrass also results in the loss of ecosystem services such as carbon sequestration, sediment stabilization, and the prevention of the resuspension of legacy organic material. Taken together, this leaves an ecosystem vulnerable to hypoxic events.

Millette et al. 2019, using DERM's more than 20-year dataset, demonstrated that Biscayne Bay is at the precipice of a regime shift from a seagrass-dominated to an algae-dominated environment due to nutrient pollution (Figure 29). Millette et al. found that phosphorus is increasing rapidly in Biscayne Bay, and so is chlorophyll a, a pigment that is an indicator of the presence of algae.

#### Septic Tanks

Septic systems treat the wastewater from individual properties by allowing wastewater to travel through the septic tank and eventually through the drainfield, through the soil, and eventually, to the water table (Miami-Dade County 2018). Between 109,000 and 120,000 septic systems are located throughout Miami-Dade County (Walsh 2019, Miami-Dade County 2018). Miami-Dade's geology is highly permeable limestone, making septic tank-derived contamination more likely (USGS 1990). Septic tanks leach nutrients and bacteria into the water table where they can enter canals and Biscayne Bay. Chin 2019 found that the main sources of nutrients to the canals that discharge to the Bay are groundwater inflow and direct surface runoff (Figure 30). Septic tanks have been cited as one of the prime contributors to groundwater nutrient levels and nutrient enrichment to the estuary (Chin 2019).

Nearly half of the County's septic systems are estimated to be found in urbanized areas within the northern part of Biscayne Bay, in locations like North Miami Beach, Biscayne Park, Miami Shores, and Miami Gardens. Northern Biscayne Bay ranges from Haulover to the Rickenbacker and makes up about 10% of Biscayne Bay. This area is also known to have the highest levels of chlorophyll-a, a proxy for algae growth in the water (Chin 2019). In the northern Bay, septic tanks are sited very close to one another in small lots (about 1/4 to 1/8 of an acre). The northern Bay is also fed by the Miami River, Little River, Arch Creek, and Snake Creek canals, where nutrient loading from these canals contributes both nitrogen and phosphorus (Caccia and Boyer 2007). These canals receive both surface runoff and groundwater carrying nutrient loads from the land surrounding them. Chin 2019 estimated the number of septic tanks near waterways in the County to be around

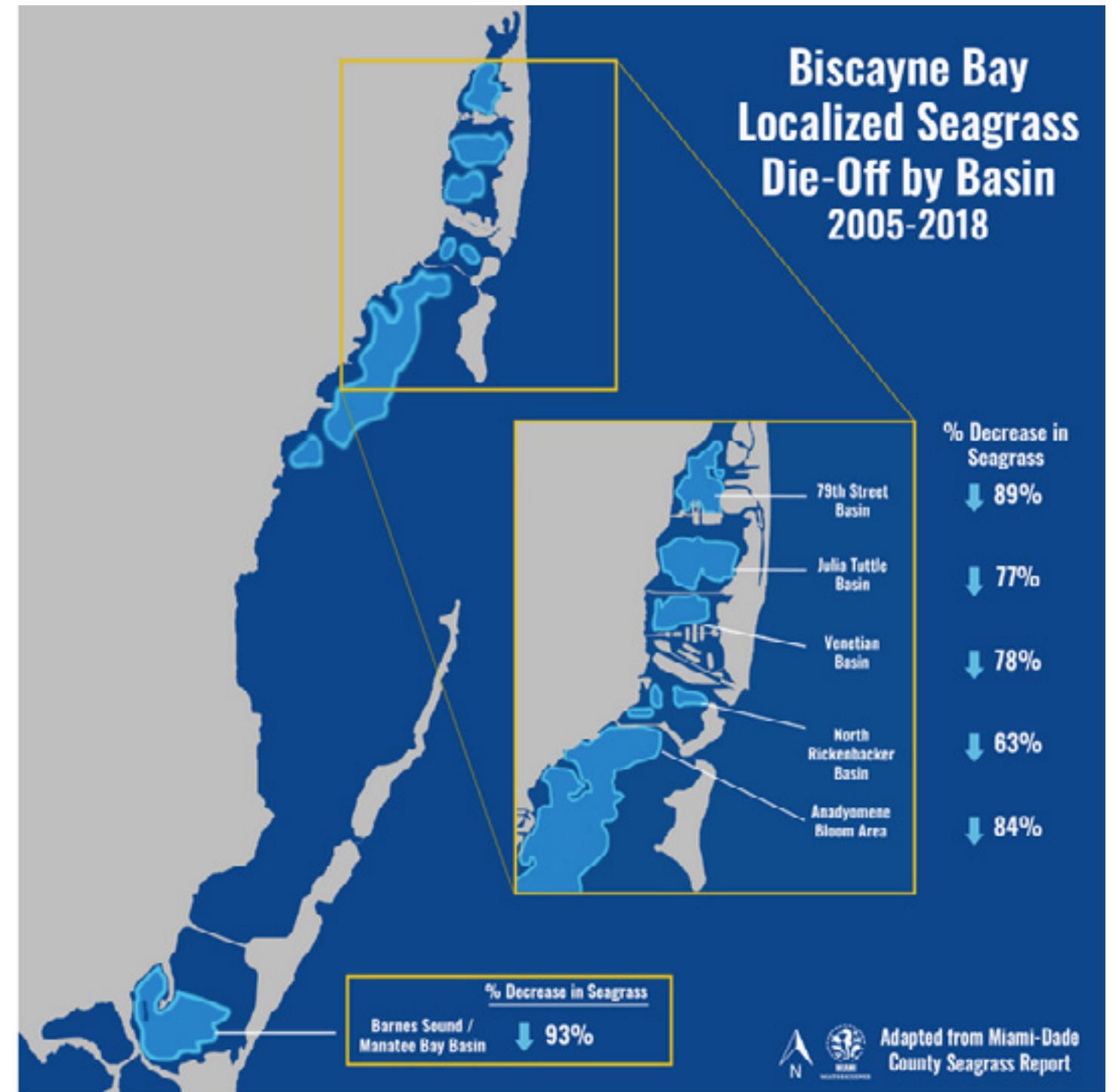
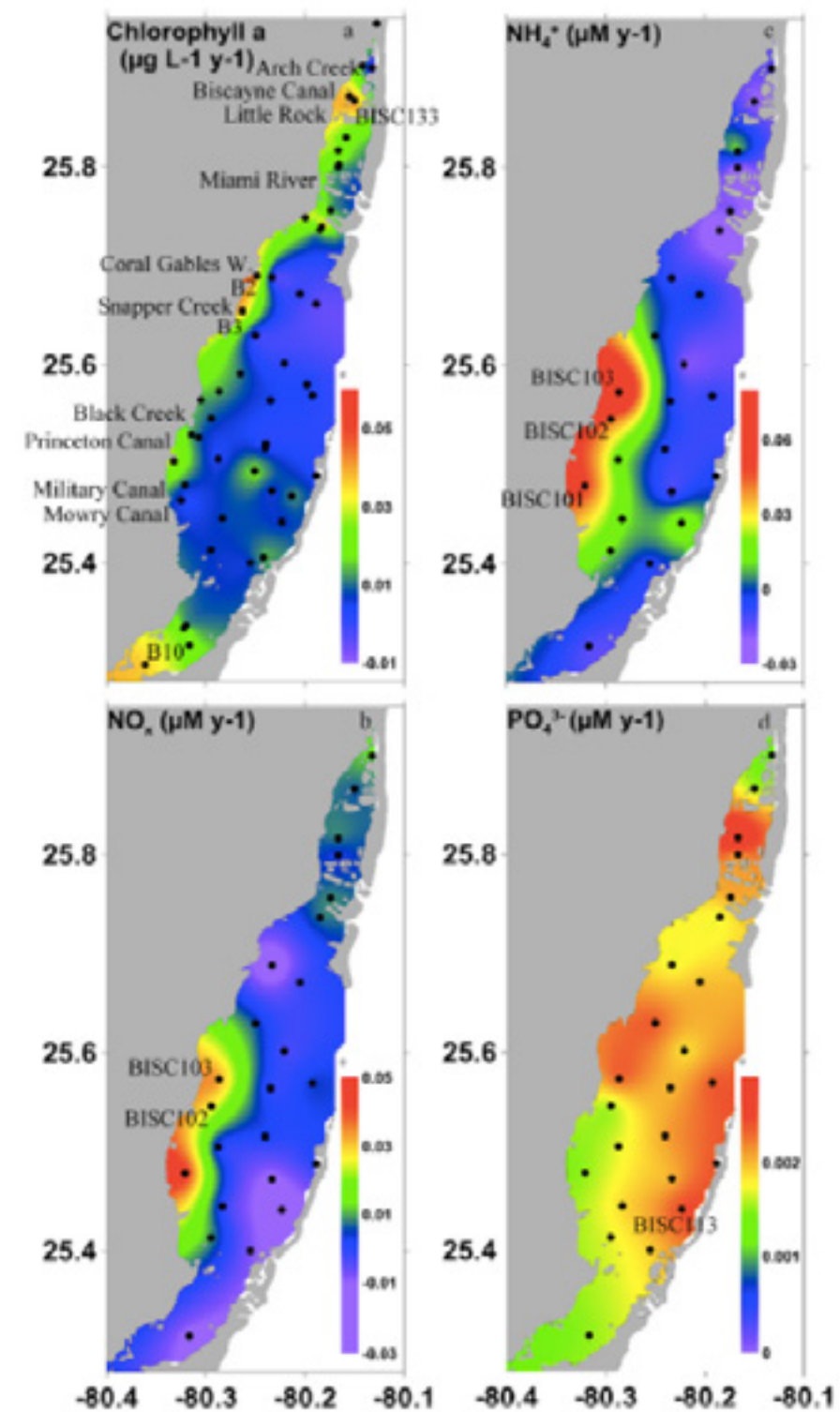


Figure 28. Areas of seagrass loss based on the Miami-Dade County Seagrass Report (2019).





**Fig. 6** The annual rate of change in a chlorophyll  $a$  ( $\mu\text{g L}^{-1} \text{ year}^{-1}$ ), b  $\text{NO}_x$  ( $\mu\text{M year}^{-1}$ ), c  $\text{NH}_4^+$  ( $\mu\text{M year}^{-1}$ ), and d  $\text{PO}_4^{3-}$  ( $\mu\text{M year}^{-1}$ ) concentrations at individual stations throughout Biscayne Bay. Specific stations mentioned in the results are labeled on the maps

**Biscayne Bay Chlorophyll  $a$  and nutrients. Waterways contributing land-based pollution and Biscayne Bay monitoring stations labeled.**

Figure 29. Biscayne Bay Chlorophyll  $a$  and nutrients. Waterways contributing land-based pollution and Biscayne Bay monitoring stations labeled. From Millette et al. 2019.

45,000. Approximately 40,000 of these are sited near canals that drain into the North and Central Bay. Little River has also been identified as having high nutrient levels (Eldredge 2019, Caccia and Boyer 2007).

Septic systems have been polluting Biscayne Bay for over 70 years. In 1970, the Federal government conducted a study on the Pollution of the Water of Dade County (USDOI, FWQA 1970) at the request of the Florida Governor. Using the Florida State Air and Water Pollution Control Board and Federal Water Quality Administration (a precursor to the EPA) data, the report found, "Septic tanks, widely used in Dade County, are public health hazards and contribute to over-fertilization and algal nuisances in adjacent waterways." They further stated that no new septic tanks should be constructed.

Sea level rise is also making the septic contamination issue worse. The EPA requires that at least two feet of unsaturated soil remain between the bottom of the septic tank and the water table (EPA 1984). However, in the Miami-Dade County "Septic Systems Vulnerable to Sea Level Rise" report (Miami-Dade County RER, WASD, DOH 2018), it is stated that over 50% of the septic tanks in the County are already compromised part of the year because they do not have enough dry soil between the septic tank and the water table.

In order to prevent further nutrient and bacteria contamination of Biscayne Bay, it is imperative to hook up urban septic tanks to sewer lines.

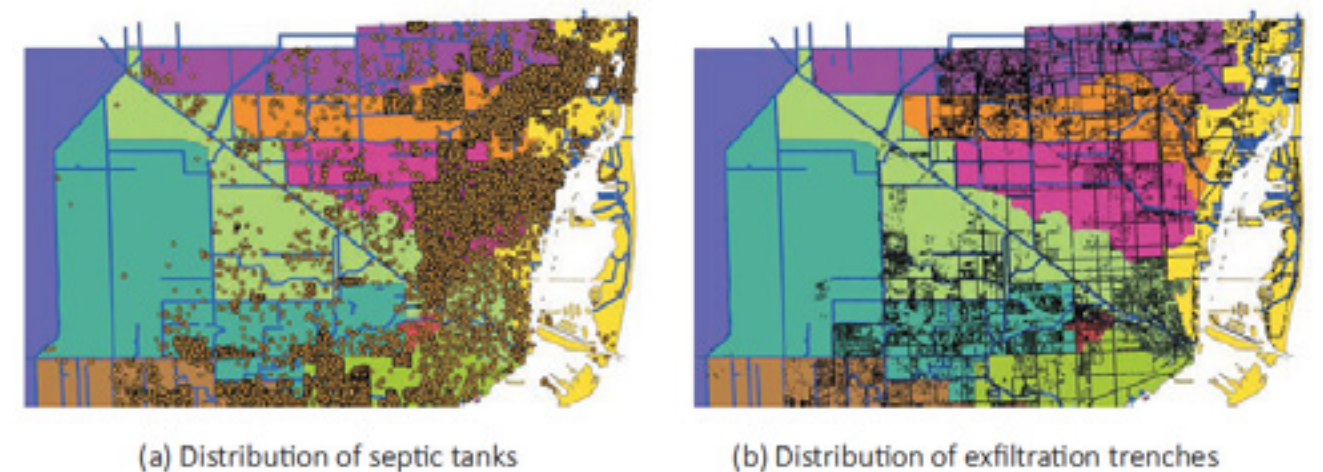


Figure 30. Drainage infrastructure map from Chin 2019, showing septic tanks (a) and exfiltration trenches (b) near Biscayne Bay.



Research Priorities

Miami Waterkeeper convened daily calls during the August 2020 fish kill event with what has become the Biscayne Bay Science Coordination Group. These calls are now continuing as monthly calls with the scientific community to coordinate research priorities, monitoring, data collection, and analysis efforts. The group is actively preparing to collect additional data if a future fish kill situation occurs. Increased monitoring in northern Biscayne Bay, of both water quality and fish population levels, has emerged as a priority research area. Specifically, the need for real-time, continuous monitoring of parameters such as salinity, temperature, and DO. Furthermore, the expansion of ongoing monitoring programs for water quality and aquatic vegetation, such as those led by DERM and BBAP, is a priority. Scientists have also identified the need to monitor fish diversity, abundance, and distribution in north Biscayne Bay, as the last studies were conducted over 20 years ago.

One of the most significant, outstanding questions about the fish kills is the influence of the Little River Canal’s high flow rates. The SFWMD is checking its formulas and the coordination group continues to test hypotheses. Professor Henry Briceño is working to complete a 2-D circulation model of northern Biscayne Bay. Miami Waterkeeper is initiating an EPA-funded monitoring program of 10 sites in Northern Biscayne to investigate linkages between FIB and nutrients along with partners at FIU, NOAA, Beta Analytic, and UM. Prof. Langdon (UM) is conducting ongoing monitoring of water column profiles around northern Biscayne Bay.

The scientific community must also develop a Fish Kill Response plan to prepare for possible future events. Based on our experience and analyses in 2020, a plan for long-term future work components and a short-term response method in the case of another fish kill event.

Preventing a Future Fish Kill

Preventing a future fish kill should be aimed at reducing nutrient pollution in Biscayne Bay. In April 2021, Miami-Dade County adopted a strong residential fertilizer ordinance that will go into effect in the Fall of 2021. Future efforts will focus on outreach and education about smart fertilizer use. Other priorities include septic

Recommendations for Future Work

1. Obtain funding to expand for ongoing water characteristics (salinity, temperature, dissolved oxygen) and water quality (N, P, S, Chl-a, FIB, and other source indicators) monitoring of northern Biscayne Bay, particularly whole-water column profiles and in situ monitoring platforms
2. Study of flow rates out of Miami River, Little River, Biscayne Canal, Oleta River, and Arch Creek Current/hydrodynamic study and model (Prof. Henry Briceño, FIU). Place submerged acoustic doppler profilers (ADP) near the salinity control structures or other relevant waterways for accurate flow measurement.
3. Monitor nutrient and other parameters from land-based sources of pollution (e.g., Miami River, Little River, Biscayne Canal, Oleta River, Arch Creek)
4. Determine threshold conditions for temperature, wind, FIBs, nutrient levels, accumulations of algae/foam, and other environmental variables, which could “predict” conditions leading to hypoxia and fish kills
5. Document long-term goals to improve water quality (Septic, sewer, stormwater, fertilizer) and support these efforts with sound science
6. Conduct northern Biscayne Bay fish population surveys. For example, repeating the DERM-funded trawl surveys conducted during the 1980s and the state-funded trawl surveys 1990s would provide both the current status of these resources as well as the longer-term historical perspective.
7. Convene a Greater Biscayne Bay Watershed workshop and produce a Special Publication providing a comprehensive history of data collection, analyses, and synthesis.

to sewer conversion, sewer retrofits, and stormwater treatment. Large build-ups of sargassum, which decompose inside of Biscayne Bay, can also lead to low DO conditions and possible fish kills. Management plans for sargassum should be developed with this potential impact in mind.

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