Last updated: November 10, 2020

Scientific Support for Septic to Sewer Conversion

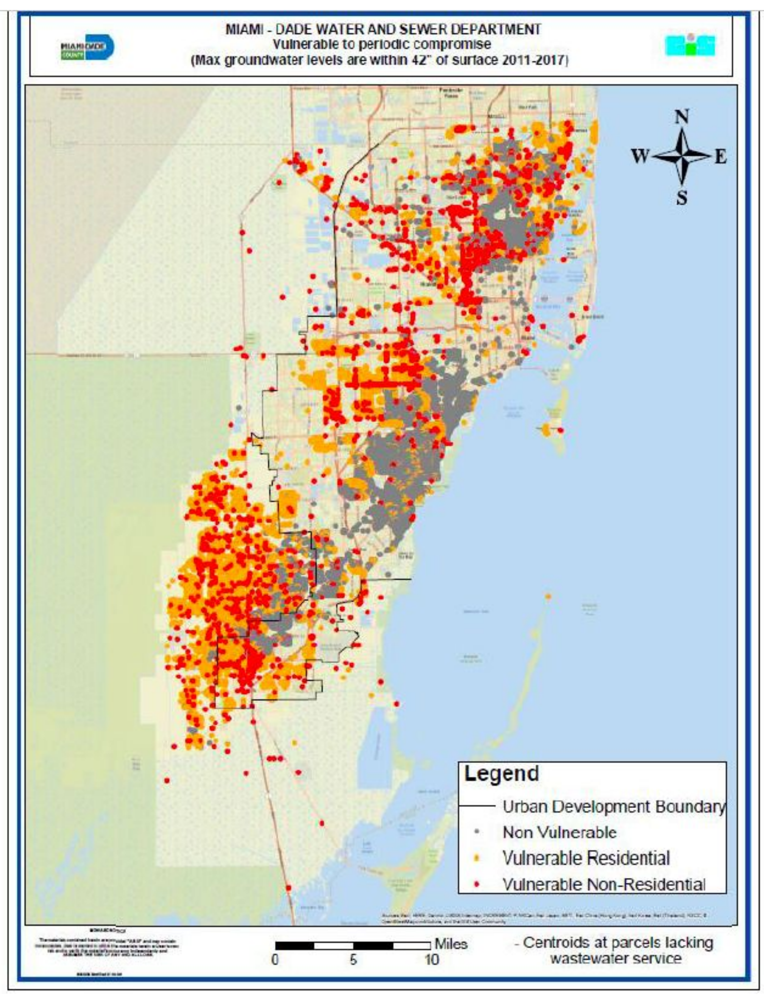
Overview:
Over 100,000 septic systems are located throughout Miami-Dade County. Septic systems are onsite treatment and disposal systems (OSTDS), which filter wastewater on residential and non-residential properties. Sea level rise has meant that the water table is now too high in many areas to achieve sufficient filtration of wastewater by septic tanks. This has left many properties without appropriate waste infrastructure, leading to public health and environmental issues.

I. What is a Septic System and how does it work?

Septic systems treat the wastewater from individual properties by allowing wastewater to filter through the septic tank and eventually through the drainfield, through the soil, and eventually, to the water table (Miami-Dade County 2018). Wastewater entering the tank displaces the water already in the tank, which then moves to the drainfield. As wastewater enters the tank, “light solids” like oils and greases float to the top and heavy solids sink to the bottom. The solids are trapped in the tank and only undergo limited treatment. They only leave the tank when it is cleaned, and the contents are removed. Liquid waste exits the tank through drainpipes to the drainfield. This vertical flow, through which bacteria, viruses, and other pollutants are removed, must occur in at least 2 feet of dry soil, due to the water table, per the EPA (EPA 1984). and the Florida Department of Health (FDOH 1993) to be considered to be properly functioning (Miami-Dade County RER, WASD, DOH 2018). The amount of time the waste spends in dry soil affects the level of filtration and decomposition that occur before it enters the water table.

II. Septic Systems in Miami-Dade County

Septic systems are located throughout Miami-Dade County. The number of these systems in place is estimated to be from around 109,000 to 120,000 (Walsh 2019, Miami-Dade County 2018). Miami-Dade’s geology is made up of highly permeable limestone, which also makes septic tank contamination more likely.



Miami-Dade County Septic Systems, Miami-Dade County RER, WASD, DOH 2018

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With porous limestone conditions, the groundwater is in close exchange with surface waters. The Biscayne aquifer, our groundwater, is shallow and readily susceptible to contamination (USGS 1990). The uniqueness of the Biscayne Bay and the Biscayne Aquifer complicates issues with drainfields, saturation, and flooding. Biscayne Aquifer has higher groundwater seepage rates, higher than even other areas in Florida (Ayres Associates 1989). This means that groundwater can flow into the aquifer without much resistance, and that water carrying nutrient loads and bacteria from septic drainfields are likely to pass into groundwater easily, without even the intended natural filtration through soil and rocks.

Septic systems are in place on both residential and non-residential properties. The density of septic tanks is also an issue in Miami-Dade County (Bicki et al 1984). Many of these areas of dense septic tanks are located adjacent to waterways known to have high levels of nutrients and FIBs. (Miami-Dade County 2018) For example, the Coral Gables Waterway, Little River, and the Miami River have high levels of nitrogen and phosphorus. Both are located near areas in Biscayne Bay algae blooms (Millette et al. 2019, Miami-Dade County RER, WASD, DOH 2018).

Approximately ~60,000 septic tanks are in unincorporated Dade. Approximately 83,000 septic tanks are in so-called "doughnut neighborhoods", which are without County or municipal water and sewer service, but which are in close proximity to these services.

III. A Brief History of Septic Systems in Miami-Dade

Miami-Dade developed quickly, with homes and development expanding faster than the regional sewer system. As a result, properties were built on septic systems, with the intention to connect these properties to the sewer system when it was eventually built. A Miami-Dade ordinance mandates that property owners abandon septic tanks within 90 days from the date on which a public sewer line was constructed within a "feasible distance." (Miami-Dade County Code, Chapters 24 and 32.) However, Miami-Dade

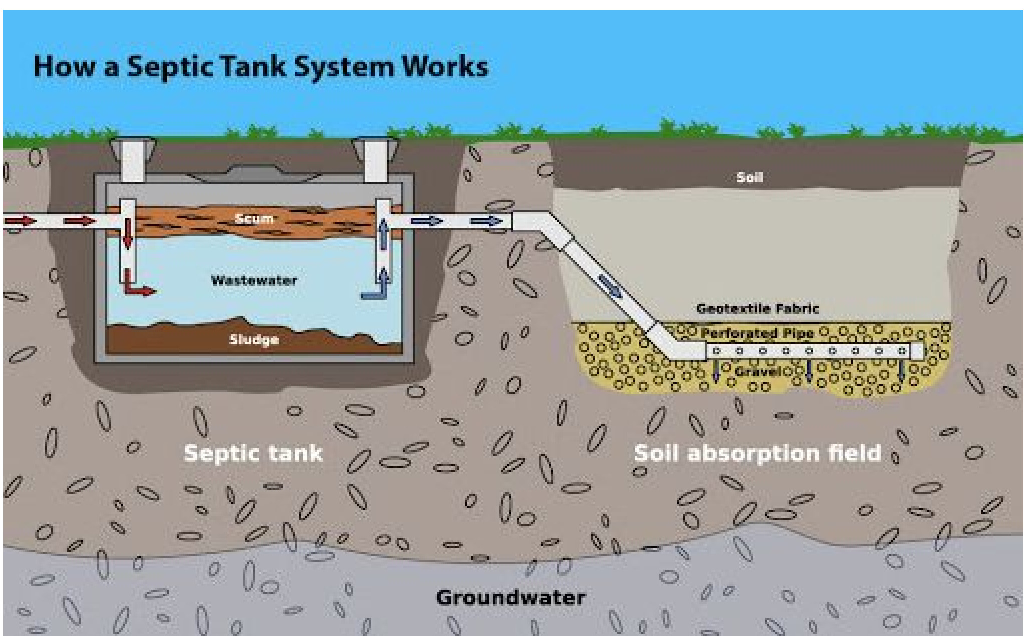


Diagram of septic tank function. SOS Liquid Waste.

County has granted over 95% of the exemptions to this ordinance (Miami Waterkeeper internal review 2020). As a result, over 12,000 septic tanks immediately abut sewer mains in Miami-Dade today (Miami-Dade Water and Sewer Department 2020). These exemptions are mostly due to "economic hardship" because the County relies upon homeowners to pay the cost of the hookups, which is typically an economic hardship. Other modes of funding these hookups must be found to avoid burdening the homeowners with connection charges that could near $15,000 (per WASD connection charges).

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 Environmental Protection Agency) 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." (Page 26). They further stated that no new septic tanks should be constructed, saying "Inclusion in a county-wide sewage collection and treatment system of all areas presently served by individual septic tanks. Approved plans for sewage collection systems for these areas should be prepared by August 1, 1971 and coordinated with design and construction of adequate sewage treatment facilities. No permits should be granted for future construction of septic tank systems." (Page 28).

The report further stated that "Conclusions developed from a comparative study of canals in areas served by sewers and by septic tanks state that higher BOD and lower D.O. in the lower levels and luxuriant algae growth in the surface layer of canals in the septic tank area can be attributed to septic tank effluent. Thus, there is evidence that, in addition to causing a health hazard, septic tanks may contribute to the total load of pollution material carried by the waterways in their drainage area." (page 58)

The need for a comprehensive inventory of septic tanks was also stated in the report. "An accurate inventory of all municipal and industrial waste sources and a determination of the waste load which each contributes to the waterways and their treatment plant performance are a first and very basic requirement." (Page 60) That inventory still has not been established.

After creating a strategic plan to clean up the septic and sewer systems in Dade County in 1971, the federal government gave $500 million for the County to build its three sewage treatment plants and to eliminate septic systems from the County by 1990. The sewage treatment plants were built, but the septic systems remain. Homes adjacent to sewer mains continue to rely on aging septic tanks. This issue remains urgent for Miami-Dade County.

While Miami-Dade County passed the 1970 ordinance mandating that all septic tanks be connected to sewer mains within 90 days of construction (Sections 32-76 to 32-82), today there are still 12,000 septic tanks immediately adjacent to sewer mains that are not connected (WASD 2020). Many of these areas of septic are located near waterways known to have high levels of nutrients and FIBs. For example, the Coral Gables Waterway and the Miami River have high levels of nitrogen and phosphorus. Both are located near areas in Biscayne Bay algae blooms (Millette et al. 2019). In the north Bay, nutrient loading from surface runoff and groundwater contributed to canals contributes both nitrogen and phosphorus.

IV. Septic Systems & Northern Biscayne Bay

It is estimated that nearly half of the County's septic systems can be found in urbanized areas within the northern part of Biscayne Bay, in areas like North Miami Beach, Biscayne Park, Miami Shores and Miami Gardens. North Bay, ranging from Haulover to the Rickenbacker, 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 2020). In the North Bay, septic tanks are sited very closely to one another in small lots (about ¼ to 1/8 of an acre). North Bay is also fed by the Miami River, Little River, Arch Creek, and Snake Creek canals, where nutrient loading from 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 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 (L. Eldredge (BBAP) presentation to Biscayne Bay Task Force, January 2019, Caccia and Boyer 2007).

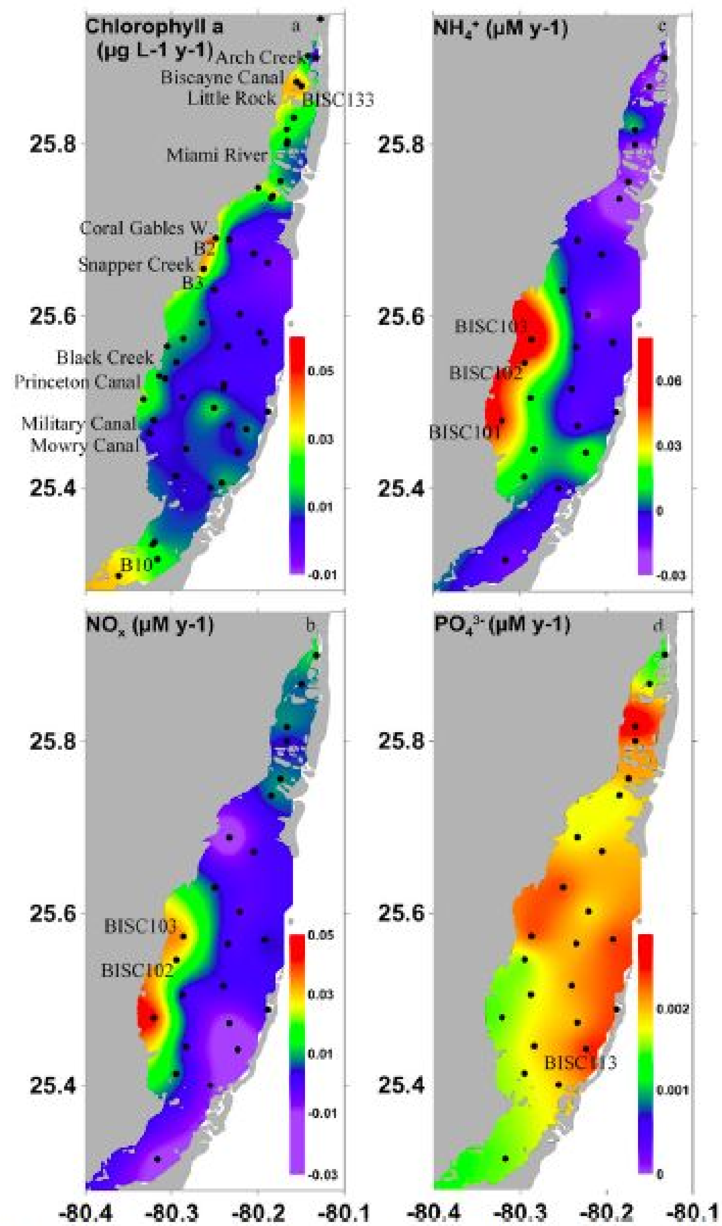


Fig. 6 The annual rate of change in a chlorophyll *a* ($\mu g\ L^{-1}\ year^{-1}$), **b** NO_x ($\mu M\ year^{-1}$), **c** NH_4^+ ($\mu M\ year^{-1}$), and **d** PO_4^{3-} ($\mu M\ year^{-1}$) concentrations at individual stations throughout Biscayne Bay. Specific stations mentioned in the results are labeled on the maps

V. Sea Level Rise and Septic Systems

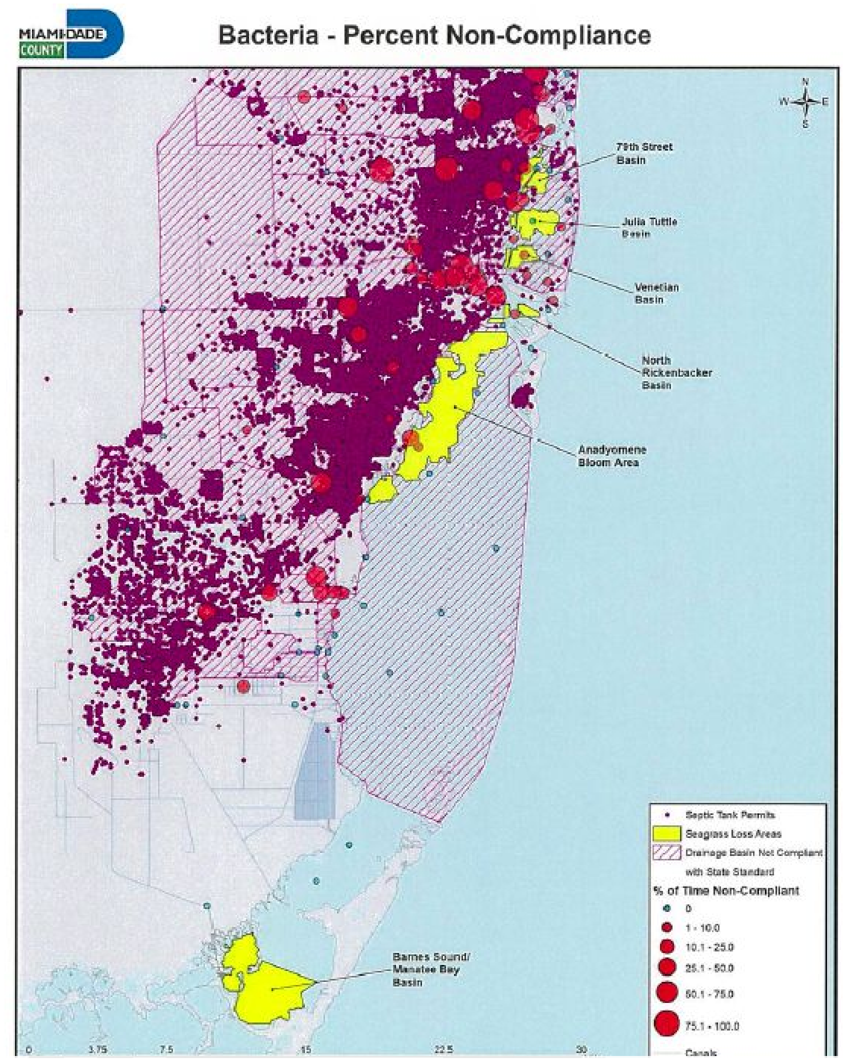
The EPA requires that at least two feet of unsaturated soil remain between the bottom of the septic tank and the water table (EPA 1984). However, in the Miami-Dade County "Septic Systems Vulnerable to Sea Level Rise" report (Miami-Dade County 2018), it is stated that over 50% of the septic tanks in the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

Flooding and higher water tables compromise the ability of onsite sewage treatment and disposal systems (OSTDS) to dispose of treated effluent and to remove contaminants found in wastewater (Miami Dade County Septic Vulnerability Report Nov 2018). These systems are designed for the aeration of effluent enabled by unsaturated (dry) soil. Therefore, the depth of unsaturated soil is of great importance to this process. As soil becomes saturated, however, effluent moves more through the soil more quickly and is not given the necessary treatment time for the removal of pollutants. Bacteria and viruses from OSTDS can travel for great distances in saturated soil and end up in groundwater (Hain and O'Brien 1979, Viraraghavan 1978).

VI. Bacteria contamination

Bacteria in waterways near septic fields

Fecal indicator bacteria (FIB), bacteria that are used as indicators of pathogenic bacteria to determine water quality and impacts on human health, are also commonly found in high concentrations in septic fields or even in the surficial soil. According to the DOH (Miami-Dade County 2018), as both healthy and ill people shed bacteria on the order of millions in waste, contact with such waste can result in shigellosis, salmonella, hepatitis A, viral gastroenteritis, and other human viral diseases. Some pathogens survive outside of the body, whether for a number of days or a number of years. They can tolerate and even thrive in the environment, when they find an acceptable balance of temperature, moisture, salinity, nutrients. This is frequently found in septic drain fields. When drain fields do not work properly, due to flooding or higher water tables, therefore, bacteria and viruses are therefore more likely to be transported to groundwater (Miami-Dade



Miami-Dade County Septic Tank Permits, Seagrass Loss Areas and Percent Bacterial Exceedance. From Miami-Dade County Report on Decline of Seagrass and Hardbottom Habitat in Biscayne Bay 2019.

County 2018). Miami-Dade County reported that "within the next 25 years, ...the number of residential systems that may be periodically compromised during storms or wet years" could be expected to "significantly increase from approximately 56% today (56,349 parcels) to more than 64% by 2040 (67,234). The highest risk areas are those where parcels are compromised under average conditions as these are vulnerable a significant portion of the year. While sea level rise will increase the number of affected properties, there are already almost 1,000 properties likely failing under current conditions."

In addition to groundwater contamination, if an area with already-saturated soil becomes inundated due to wet season flooding or a rainfall or tidal event, hydraulic failure may occur. This is when the water table rises, flooding the drainfield, and the wastewater floats to the surface. There may also be noticeable backups in plumbing in the house or building to which the septic system is connected. Untreated septic material could then be present in the floodwater. This septic material can also be present in well water, where properties have both a septic system and a well. The shallow water withdrawal performed by wells can become contaminated by septic material. This contamination of drinking water is an issue of public health.
The Biscayne Aquifer is made up of highly permeable limestone. Free interchange of freshwater and saltwater is possible; freshwater at the bottom of the aquifer flows upward and then discharges seaward along the saltwater front. The aquifer is shallow and readily susceptible to contamination (USGS 1990). The uniqueness of the Biscayne Bay and the Biscayne Aquifer complicates issues with drainfields, saturation, and flooding. Biscayne Aquifer has higher groundwater seepage rates, higher than even other areas in Florida (Ayres Associates 1989). This means that groundwater can flow into the aquifer without much resistance.

Given all of this, the DOH (Miami-Dade County 2018) noted that areas with OSTDS constructed before 1983 could be sensitive to groundwater rise and should be considered a priority.

VII. Nutrient Pollution

As a shallow, tropical estuary, Biscayne Bay is particularly sensitive to nutrient pollution. FDEP has designated the Biscayne Bay as impaired for chlorophyll *a* (FDEP 2017). Chlorophyll *a* is an indicator of algae, which can result from nutrients such as nitrogen and phosphorus. Biscayne Bay was also selected by the National Oceanic and Atmospheric Administration (NOAA) as one of 10 nationwide Habitat Focus Areas (HFA). HFAs are specially-designated areas of high economic and environmental importance to the nation, selected due to nutrient pollution, namely nitrogen.

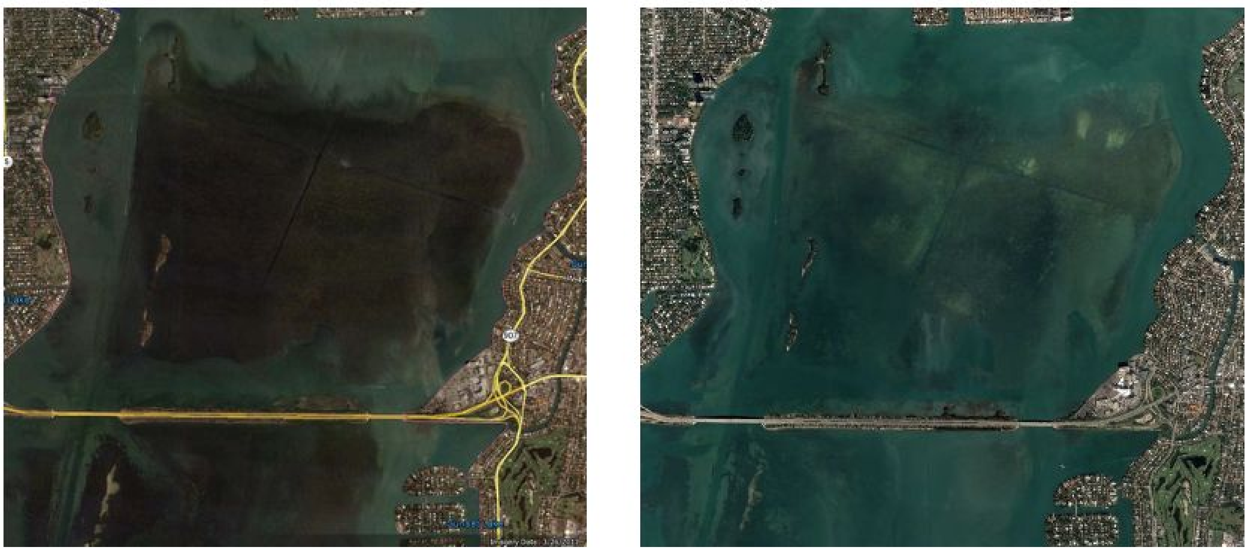
Nitrogen and phosphorus are known to be particularly problematic for water quality (Paerl et al 2011) because they can lead to algae blooms. Algae blooms can occur when there are too many nutrients in the water (Havens 2003, Havens and Walker 2002, Heisler 2008, Lapointe 2017). Nutrients, like nitrogen and phosphorus fertilize the microscopic algae and cause their populations to explode, leading to an algae bloom, when the clear water turns green or brown and suffocates or shades out aquatic plants and animals. The central Biscayne Bay has been experiencing an ongoing macroalgae algae bloom since around 2010 (Miami-Dade County 2019 Seagrass Report, Collado-Vides et al. 2016).

Nutrients in waterways near septic fields

Nutrients have been associated with waterways and groundwater near septic fields in many studies. Studies in both Jupiter, Florida (Lapointe et al. 1995) and in the Florida Keys (Lapointe et al. 1990) found similar associations between nutrients and septic fields, as did Badruzzaman 2012, Chin 2019, and Briggs et al 2007. With geologic and environmental conditions in Miami-Dade County that are very similar to the conditions in these other areas of Florida, it is likely that these same associations occur in Miami-Dade County.

Seagrass Die-Off

This algae bloom has been associated with a seagrass die-off at the mouth of the Gables Waterway (Miami-Dade County 2019 Seagrass Report, Collado-Vides et al. 2013). Millette et al. 2019, using DERM's long-term (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. This shift is especially notable in the North Biscayne Bay, near the Julia Tuttle Causeway, where seagrass loss can be seen temporally and spatially through satellite images of the area.



Eldridge, 2019 North Bay Seagrass Die Off. Presentation to BBTF

Millette et al. 2019, using DERM's long-term dataset (over 20 years), 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.

Fish Kill

This nutrient pollution may have been an important factor in the fish kill in northern Biscayne Bay that occurred in August 2020. Algae and bacteria, fed by septics, stormwater, sewage leaks, and fertilizer overuse, can lead to low levels of oxygen, especially at night when photosynthesis does not occur. There is then not enough oxygen in the water for fish and other wildlife, resulting in a fish kill. The North Bay fish kill lasted for about a week, resulting in thousands of dead fish on private property, recreational areas during the week. In the weeks after the fish kill, dead seagrass, seafoam and algae blooms washed ashore.

Chin 2019 found that the main sources of nutrients to the canals that discharge to the Bay are groundwater inflow and direct surface runoff. Septic tanks have been cited as one of the prime contributors to groundwater nutrient levels and nutrient enrichment to the estuary (Chin 2019). Septic tanks were also implicated in the contribution of nutrients to the estuary in Swart 2013, which used stable isotopic signature research and found enriched delta values of nitrogen, indicating these values were likely driven by anthropogenic activity. In a related pilot study of isotopic tracers for nutrient pollution in Biscayne Bay water and sediments with Miami Waterkeeper and Beta Analytic, results indicated that "the potential sources of pollution emanate from the coast of Miami-Dade County, with hot spots at Little River Canal and the Coral Gables Waterway. Bacterial hits and nitrate concentration values agreed well and have some overlap that may be able to link effluent pollution to an isotopic fingerprint that may be used to trace the extent to which and the sources of pollution entering Biscayne Bay." (Beta Analytic 2020)

Walsh 2019 also concluded that "there are not adequate water quality monitoring locations in septic tank areas, and not frequent enough sampling events, to fully understand the dynamics of septic tank effluent discharge impacts to the environment."

Lessons from other Areas and Projects

This contamination has likely led to increased algae, loss of seagrass, lowered oxygen levels, and now also fish kills. Associations between nutrients in waterways and groundwater and nearby septic fields have been found in multiple areas in Florida studies: Lapointe et al. 1995 in Jupiter, Florida; Briggs et al 2007 in the Wekiva River in Central Florida; Badruzzaman 2012 in surface waters throughout the state, Chin 2019 in the North Biscayne Bay; and Lapointe et al.1990 in the Florida Keys.

Improvements in water quality, both nutrient and FIB, have been notable following abandonment of septic tanks and conversion to sewer systems in other locations, such as the Florida Keys. The Florida Keys is one of the largest conversion projects. This regional conversion project of almost all of the municipalities in the Keys is currently being finalized; it has been underway since 1999. Barreras et al. 2019 noted that water quality at the Keys beaches improved through a combination of beach management efforts and connection of residences to sewer systems, even in the face of sea level rise and climate change. In an evaluation of 18 years of fecal indicator bacteria levels at Florida Keys beaches, Kelly et al (2020) found that upgrades to failing wastewater infrastructure, including conversion from septic to sewer for homes, allowed for a gradual drop in FIB exceedances at nearby beaches as upgrades were completed during the period of study. This analysis provides guidance on the combined impact of local environmental conditions and failing wastewater infrastructure on FIB exceedances. Guidance and multiple case studies are also described in the detailed

Jones Edmunds/Florida Water Environment Association "Septic to Sewer Guidance Document."

Recommendations have been made by both Federal and state agencies to remove septic from Miami-Dade County since the 1970s. The impact of septic on the environment in Miami-Dade County has been known for 50 years.
1970 Pollution of the Waters of United States (FQWA 1970)
1973 Greeley and Hansen Master Plan for Metropolitan Dade County, Florida (Greeley and Hansen 1973)
1984 Florida Department of Health released "Impact of on-site sewage disposal systems on surface and ground water quality." (FDOH 1984)
1993 Florida Department of Health released "Onsite sewage disposal system research in Florida. An evaluation of current OSDS practices in Florida." (FDOH 1993)

Based on the research done in Miami-Dade County for the past 50 years, compromised septic tanks are causing nutrient and bacteria contamination in Biscayne Bay. **We echo the recommendations made to the Biscayne Bay Task Force by the Biscayne Bay Aquatic Preserve (BBAP):**

Short-Term

1. Stop the sourcing of nitrogen and phosphorus and marine debris before they reach the Bay.
2. Expedite sewer infrastructure upgrades.

Medium-Term

1. Reduce Wastewater and Stormwater inputs.
2. Increase and incentivize septic to sewer conversions.
3. Upgrade Sewer infrastructure.

Priority Areas for Septic to Sewer Conversion:
Little River
Miami River
Arch Creek/Biscayne Canal
Coral Gables Waterway

Citations:

Ayres Associates. 1989 **Onsite Sewage Disposal System Research in Florida – Performance Monitoring and Ground Water Quality Impacts of OSDSs in Subdivision Developments.** Prepared for Florida Department of Health and Rehabilitative Services, Tallahassee, Florida.

Badruzzaman M, Pinzon J, Oppenheimer J, Jacangelo JG. (2012). **Sources of nutrients impacting surface waters in Florida: A review**. Journal of Environmental Management 109, 80-92.

Beta Analytic Preliminary Report to Miami Waterkeeper, 2020. **Isotopic Tracers for N Pollution in Biscayne Bay Water and Sediments.**

Barreras Jr H, Kelly EA, Kumar N, Solo-Gabriele HM. 2019. **Assessment of local and regional strategies to control bacteria levels at beaches with consideration of impacts from climate change** Marine Pollution Bulletin 138, 249–259

Bicki TJ, Brown RB, Collins ME, Mansell RS, Rothwell DF 1984 IFAS Soil Science OSDS Report to Florida Department of Health and Rehabilitative Services Under Contract number LC170

Briggs GR, Roeder E, and Ursin E Bureau of Onsite Sewage Programs, Division of Environmental Health, Florida Department of Health. (2007). **Nitrogen impact of onsite sewage treatment and disposal systems in the Wekiva study area.**

Caccia V and Boyer J 2007. **A Nutrient Loading Budget for Biscayne Bay, Florida**. Marine Pollution Bulletin 54 994-1008

Chin DA 2019. **Source Identification of Nutrient Impairment in North Biscayne Bay, Florida, USA**

Miami-Dade County Environmental Quality Control Board (EQCB). (2018). **Order No. 18-22.**

Environmental Protection Agency (EPA). (1973). **Environmental impact statement, North Dade County Florida**. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi/9100PD1B.PDF?Dockey=9100PD1B.PDF .

Environmental Protection Agency (EPA), Septic systems overview. Available at: https://www.epa.gov/septic/septic-systems-overview.

Florida Department of Health (FDOH). (1984). **Impact of on-site sewage disposal systems on surface and ground water quality.** Available at: http://www.floridahealth.gov/environmentalhealth/onsite-sewage/research/_documents/research-reports/_documents/impact-ostds.pdf .

Florida Department of Health (FDOH) (1993). **Onsite sewage disposal system research in Florida. An evaluation of current OSDS practices in Florida.**

Florida Department of Environmental Protection (FDEP) 2017
https://floridadep.gov/dear/watershed-assessment-section/content/lists-impaired-waters-group-4-basins

Greeley and Hansen. 1973. **Water quality management plan for Metropolitan Dade County.**

Hain, K.E., and R.T. Obrien. 1979. **The survival of enteric viruses in Septic tanks and septic tank drainfields**. Water Resources Res. Inst. Rept. No. 108, New Mexico Water Resources Res. Inst., New Mexico State Univ., las Cruces, New Mexico.

Havens KE 2003 **Phosphorus–Algal Bloom Relationships in Large Lakes of South Florida: Implications for Establishing Nutrient Criteria**, Lake and Reservoir Management,19:3, 222-228, DOI: 10.1080/07438140309354087

Havens KE and Walker Jr. WW 2002 **Development of a Total Phosphorus Concentration Goal in the TMDL Process for Lake Okeechobee, Florida (USA)**, Lake and Reservoir Management, 18:3, 227-238, DOI: 10.1080/07438140209354151

Heisler J, Glibert PM, Burkholder JM, Anderson DM, Cochlan W, Dennison WC, Dortch Q, Gobler CJ, Heil CA, Humphries E, Lewitus A, Magnien R, Marshall HG, Sellner K, Stockwell DA, Stoecker DK, Suddleson M, 2008 **Eutrophication and harmful algal blooms: A scientific consensus**, Harmful Algae, Volume 8, Issue 1, Pages 3-13, ISSN 1568-9883, https://doi.org/10.1016/j.hal.2008.08.006.(http://www.sciencedirect.com/science/article/pii/S1568988308001066)

Katz BG, Griffin DW, McMahon PB, Harden HS, Wade E , Hicks RW, Chanton JP, 2010. **Fate of effluent-borne contaminants beneath septic tank drainfield overlying a karst aquifer.** J. Environ. Qual. 39. 1181–1195

Kelly E, Gidley M, Sinigalliano C, Kumar N, Solo-Gabriele HM (2020) **Impact of Wastewater Infrastructure Improvements on Beach Water Fecal Indicator Bacteria Levels in Monroe County, Florida.** Science of the Total Environment
https://doi.org/10.1016/j.scitotenv.2020.143024

Lapointe BE, Herren LW, Paule AL 2017. **Septic systems contribute to nutrient pollution and harmful algal blooms in the St. Lucie Estuary, Southeast Florida, USA** Harmful Algae 70 1–22

Lapointe, BE. Krupa, S. 1995a. **Jupiter Creek septic tank/water quality investigation. Final Report** Loxahatchee River Environmental Control District, Jupiter, FL 96 pp

Lapointe, BE O'Connell, JD Garrett, GS 1990. **Nutrient couplings between onsite sewage disposal systems, groundwaters, and nearshore surface waters of the Florida Keys.** Biogeochemistry 10, 289–307

Miami-Dade County Code. **Chapters 24, 32.**

Miami-Dade County RER, WASD, DOH 2018. **Septic Systems Vulnerable to Sea Level Rise, Final Report in Support of Resolution No. R-911-16.**

Miami-Dade County, Directive No. 171537 2019. **Report on the Findings of the County's Study on the Decline of Seagrass and Hardbottom Habitat in Biscayne Bay**.

Miami-Dade Water and Sewer Department 2020 **WASD Sanitary Sewer System Performance and Asset Management.** Presentation to Biscayne Bay Task Force.

Millette NC, Kelble C, Linhoss A, Ashby S, Visser L 2019. **Using Spatial Variability in the Rate of Change of Chlorophyll *a* to Improve Water Quality Management in a Subtropical Oligotrophic Estuary**. Estuaries and Coasts 42 1792-1803

Paerl HW, Hall NS, Calandrino ES. 2011. **Controlling harmful cyanobacterial blooms in a world experiencing anthropogenic and climatic-induced change,** Science of The Total Environment, Volume 409, Issue 10, Pages 1739-1745, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2011.02.001.

Reay, W.G., 2006. **Septic tank impacts on ground water quality and nearshore sediment nutrient flux.** Ground Water 42 (7). 1079–1089.

Swart, P. K. et al. (2013). Applied Geochemistry, 38, 134-146.

USGS 1990. Groundwater Atlas of the United States Alabama, Florida, Georgia, South Carolina HA 730-G https://pubs.usgs.gov/ha/ha730/ch_g/G-text4.html (viewed 6/25/2020)

Viraraghavan, T. 1978. **Travel of microorganisms from a septic tile. Water, Air, and Soil Poll.** 9:355-362

Walsh V, 2019, **Septic Systems Vulnerability to Sea Level Rise Water Quality Analysis – Ongoing Efforts.** Presentation to Biscayne Bay Task Force.

United States Department of the Interior, Federal Water Quality Administration (FWQA) (1970) **Pollution of the Waters of Dade County, Florida**.

US Department of Interior (DOI). (1975). **Ground-water quality in selected areas serviced by septic tanks, Dade County, Florida, geological survey.** Open-file report 75-607.

US Department of Interior (DOI). (1973). **Resource and land information for south Dade County, Florida, geological survey.** Investigation I-850.