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A Brief History of Lake Okeechobee: A Narrative of Conflict

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Abstract

Lake Okeechobee is Florida's largest lake, the largest lake in the Southeast United States, and the second largest lake contained entirely within the United States. The history of this inland sea is marked both by natural processes, and more recently human development and intervention. Adventurers can explore this behemoth of a waterway via the Lake Okeechobee Scenic Trail that enriches it, a part of the Florida National Scenic Trail. This paper synthesizes major natural and human-induced perturbations that shaped the lake and ultimately the trail that encircles it to create a narrative of Florida's great lake. The story of Lake Okeechobee is a story of battles, first between the land and sea, then between the lake itself and humankind. For the past few centuries Lake Okeechobee's natural perturbations in water flow and flooding resisted the control of man, until recently when man triumphed, managing to control the flow of water in and out of the lake. Unfortunately, with this new found control a new bio-ecological threat in the form of harmful algal blooms has emerged, which again threatens the health and livelihood of South Floridians. Currently there are new efforts that seek to restore Lake Okeechobee towards a more natural state in an effort to thwart the blooms.

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It's a full moon weekend in February and runners lace up their shoes in preparation. They gather in the agricultural town of Clewiston southeast of Lake Okeechobee. The runners came here to attempt the LOST 118, a 118 mile ultra-marathon on the Lake Okeechobee Scenic Trail (LOST), which encircles the lake and is a part of the greater Florida National Scenic Trail (Figure 1). With a supply crew for each runner providing food and medical care, even the fastest runner will not finish within 24 hours. This is why the race coincides with the full moon to make the trail easier to see at night. Runners who complete the LOST 118 trek through 9 cities and 8 counties en route to the finish line. This ultra-marathon is possible due to the existence of the Lake Okeechobee Scenic Trail, and in many ways the trail is a metaphor for the lake itself. Its scale is enormous; Lake Okeechobee at 1,730 square kilometers (RECOVER 2007) is the largest lake in the Southeastern United States (US) and is too large to see across, its horizon disappearing like an ocean (Figure 2). It's also over-engineered, so most of the race can take place on a paved trail elevated on a levee encircling the lake. Lastly, it's monotonous; there are few changes about the lake from one area to the next, including its depth (consistently about 3m deep), its scenery, or its ecosystems (RECOVER 2007). Similarly the LOST is flat with a similar view for most of the race: an ever expansive lake on one side and either natural areas or agricultural fields on the other, with a rural town every so often.

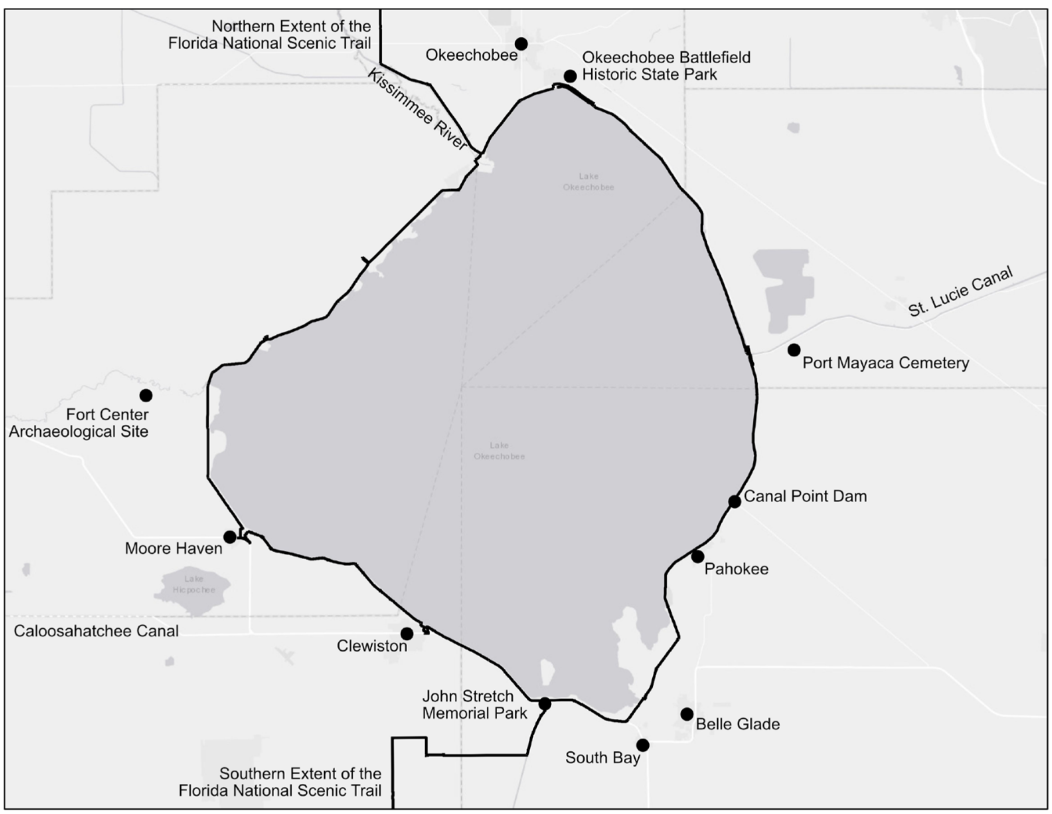

Fig. 1- A map of the Lake Okeechobee Scenic Trail (LOST) that encircles the lake, along with where it intersects with the remainder of the Florida National Scenic Trail, major towns in the area, and other points of interests described in this paper are noted

Fig. 2- The expanse of Lake Okeechobee as seen from the shores of Canal Point

Lake Okeechobee wasn't always this way, although its structure has changed with time even in its natural state. As glaciers melted during the last transition from a glacial to interglacial (current) period ~12,000 years ago, sea level rose worldwide. The Florida peninsula flooded and the southern half of the peninsula became the Okeechobean Sea (Petuch and Roberts 2007). This pre-historical sea stretched from the northern edge of modern-day Lake Okeechobee (thought to have been a river delta at the time) and through the Keys. While the southern half of the Florida peninsula was mostly submerged beneath the Okeechobean Sea, a spattering of islands on the coastal ridges of the east and west edges of the modern peninsula did remained above sea level (Petuch 1987; Petuch and Roberts 2007). Then about 6,000 years ago glacial melt all but stopped and feedback mechanisms pulled sea water back towards low lying areas near the poles (Gornitz 2007). The shift of waters poleward induced a global sea level recession in low latitude areas, including Florida. This resulted in the retreat of Okeechobean Sea and the emergence of the Florida peninsula similar to how we now know it. Left behind in a shallow depression in the middle of Florida was a standing pool of water that would become Lake Okeechobee (RECOVER 2007). At the time, the lake had no defined southern border. Water flowed seamlessly into the Everglades south of it. The lower depth of Lake

Okeechobee compared to the Everglades meant a longer residence time of water in Lake Okeechobee compared to the surrounding areas. Over time during larger gushes of water out of the lake to the south, detritus dominated by sawgrass and water lily was deposited in the shallows south of Lake Okeechobee. This organic-rich detritus slowly decomposed becoming peat and muck, which built up the southern edge of Lake Okeechobee raising the elevation of land to the south and hemming the lake in (Kushlan 1989; Obeysekera et al. 1999).

From this point until the late 19th century Lake Okeechobee adopted its pre-settlement flow conditions, which engineers, scientists, politicians, and activists are now trying to restore. Under these conditions Lake Okeechobee served as the great connector of the Kissimmee River Watershed to the north to the Everglades River of Grass to the south (Douglas 1947; Obeysekera et al. 1999). River water, precipitation, and runoff provided the water and nutrient inputs into the mesotrophic (moderately nutrient rich) to eutrophic (highly nutrient rich) Lake Okeechobee (Brezonik and Engstrom 1998). Growth of macrophytes (large photosynthesizing aquatic plants and algae) and phytoplankton (single celled photosynthesizing algae) would uptake nitrogen and phosphorous present in Lake Okeechobee's water. During the wet season of late spring and summer, the water level of Lake Okeechobee would rise until it spilled over the southern edge, providing a sheet flow of oligotrophic (nutrient poor) water to the Everglades. Despite only episodic overflows, the long hydroperiods (periods of standing water) and transport times ensured the Everglades remained submerged for much of the year. The continuous slow flow of the water prevented the water from becoming stagnant (Obeysekera et al. 1999). The slow but constant flow of water south was aided by the increase in land elevation gradient from 3 cm/km encompassing Lake Okeechobee (Kushlan 1989) to 6.82 cm/km in portions south of the lake (Harshberger 1914). At this time the only connection Lake Okeechobee had with the ocean was through the Everglades itself (Obeysekera et al. 1999).

It was sometime in this pre-settlement era during the interactions between the Seminole Tribes, the early settlers, and the US Army that Florida's inland sea received its official name. Adapted from the native language "Oki" which translates to "big" and "chubi" which translates to “water” were combined phonetically in English to become Okeechobee (SWFWMD, n.d.). Native Americans did not just leave their mark on the lake with their language, but had actually modified the landscape surrounding Lake Okeechobee for ~5,000 years by building massive earthworks such as mounds and ditches hundreds of meters wide (Thompson and Pluckhahn 2012). Such earthworks served multiple purposes in native culture, from burial mounds to trash heaps. One of the best examples of this Native American architecture in South Florida is that of Fort Center located a few miles west of Lake Okeechobee, a site consisting of mounds, canals, dikes, and other water control structures constructed between 450 BC and 1700 AD, shown in Figure 3 (Thompson and Pluckhahn 2012). It is not fully understood how these earthen works impacted the hydrology of Lake Okeechobee and the Everglades to the south. One debated topic is the development of tree islands.

Fig. 3- Various photos of Fort Center: A) a map of Fisheating Creek Wildlife Management Area where Fort Center is located west of Lake Okeechobee, B) an informational placard about the native population that constructed Fort Center overlooking part of the site, C) a general view of some of the archaeological features of Fort Center, D) a view of the northern area of Fisheating Creek Wildlife Management Area. Photo taken by and courtesy of Sara Ayers-Rigsby, Florida Public Archaeological Network.

Tree islands, areas of raised dry ground supported by the roots of clumped trees occur throughout the Everglades system and can impact the flow of water through the Everglades by acting as small barriers to slow down the flow of the shallow surface waters. Native peoples used these remote inland islands as camping grounds, especially when in retreat from the US Army during the ill-fated Seminole Wars of 1817-1858 when the US government sought to remove the Seminole and Miccosukee Tribes from South Florida and relocate them in the Midwest US (Weisman 2014). Some archaeologists hypothesize that by living in the Everglades and around Lake Okeechobee native peoples contributed to the formation of these islands. However, this hypothesis is still hotly debated with advocates both for and against (e.g. Ardren et al. 2016 vs. Bernhardt, 2011). Currently the only obvious evidence of native culture and presence around the lake is the Okeechobee Battlefield Historic State Park on the Northeastern rim of the lake (Figure 4), a testament to the largest skirmish between the Seminoles and Miccosukee tribesmen against the US Army on Christmas Day in 1837, a battle with no clear winner, similar to the outcome of the Seminole Wars themselves. The US government was unsuccessful in removing all of Florida's native population, but those same natives suffered years of oppression and loss of life as a result of the so-called wars. While many

Fig. 4- The Okeechobee Battlefield Historic State Park is a 640 acre park located near the northeastern shore of Lake Okeechobee.

thousands of Native Floridians were killed or removed to reservations in Oklahoma, some were able to elude the armed forces in the Everglades, remaining in their own way as untamed by the US government as Lake Okeechobee itself during that time period (Weisman 2014).

Transitioning into the late 1800s and early 1900s Lake Okeechobee underwent a metamorphosis that would transform it into the ultra-engineered surface water system it is today. That metamorphosis was led by Hamilton Disston. Disston was a Philadelphia businessman who arranged to buy 4 million acres of semi-submerged land around Lake Okeechobee from the State of Florida in 1881 with the understanding he would drain and develop the land and make it useable (Knetsch 1998). Disston's plan relied heavily on the concept that water flows downhill and if given the opportunity of a steeper slope and closer connection to the ocean other than the Everglades, water from Lake Okeechobee would follow that route and drain the lake. Ultimately, Disston's goal was not to reduce the size of the lake itself, but to prevent its seasonal, southerly overflows, which prevented development of that land. Disston envisioned two outlets that drained Florida's great lake, one to the Gulf of Mexico in the west and the other to the Atlantic Ocean in the east. He started with the westward outlet first in the 1890s. Disston commissioned dredgers to create a canal connecting Lake Okeechobee to the Caloosahatchee River headwaters, eventually draining to the Gulf of Mexico through Ft. Myers (Knetsch 1998; Rivero et al. 2020). This canal had to be dredged multiple times, but was wide and deep enough to allow ship travel. It also lowered the water level of the lake by an astounding 5 ft according to some reports (Rivero et al. 2020). This lower lake stage combined with the thick and relatively sturdy peat and muck embankment along the southern shore of the lake created a definitive southern edge and reduced seasonal flooding. Disston's second attempt at a drainage canal further south was less successful as it continually refilled with muck and silt as it flooded, eventually filling in after only a few miles were completed. It was abandoned in the wake of a recession in 1893. Disston died in 1896 of unknown causes, although a rumor that it was suicide has persevered (Grunwald, 2006).

A new Everglades drainage champion emerged in the early 1900s in the form of Napoleon Bonaparte Broward, the newly elected governor who sought to convince the Florida government, the federal government, and the land owners of South Florida how valuable a drained Everglades would be as potential farm land. Broward might have begun his initiatives while in office, but he continued as spokesperson for drainage long afterwards (for which he was handsomely paid). With Broward's persistence the tide of opinion changed and the state of Florida commissioned the development of four new canals: the Miami River Canal completed in 1913, the North and South New River Canals completed in 1912 and 1913 respectively, the Hillsborough River Canal completed in 1915, and the Lake Worth Canal completed in 1920 (Grunwald, 2006). Inspired by Disston and later Broward, the state did eventually establish a navigable canal connecting Lake Okeechobee

Fig. 5- The lock system at the St. Lucie connection to Lake Okeechobee: A) the lock as viewed from the St. Lucie Canal that raises or lowers boats from the elevation of Lake Okeechobee, B) an outlet for water discharged from the lock to lower the water level within the lock.

eastward to the St. Lucie River (Figure 5) and thereby the Atlantic Ocean in 1926 (Grunwald, 2006; McGoun, 1978). Smaller canals diverting water to other existing waterways and settlements also began to pop up creating a matrix of waterways all drawing on the waters of the inland sea (Rivero et al. 2020). An estimated storage volume of ~3,000 million m3 was lost in Lake Okeechobee as a result of these man-made drainages; however, at best estimates the surface area of the lake remained the same (Rivero et al. 2020).

During this era of taming Lake Okeechobee through enhanced drainage, people became more confident in settling the lands around the lake, especially to the south which was no longer seasonally flooded. For example, in 1915 James A. Moore, a real estate investor originally from Seattle, Washington acquired a 98,000-acre section of land southwest of Lake Okeechobee from the family of a surveyor paid in land for documenting Disston's Florida purchase. Moore founded a boom town that was quickly occupied by hundreds of settlers who worked the surrounding land as sugar cane farmers and cattle ranchers. Moore Haven, as it came to be known, gained the official status of a city in 1917 and continued to grow when a railroad line was extended to its shores in 1918 (Hartig and Piland 1995). Moore Haven was typical of the other boom towns encircling the lake, fueled by rich soil and sugar. Clewiston, South Bay, and Belle Glade all have similar stories. However, Disston, Broward and the state's own efforts to subdue Lake Okeechobee were insufficient, and ultimately had devastating consequences for these boom towns. In its early years Moore Haven suffered a series of disasters including fires and floods that eventually led to the State of Florida's construction of an earthen dike encircling the southern portion of the lake in 1924. This 5-9 feet tall dike made of muck and rocks had to be restored multiple times by locals within two years of its initial construction (Mykle 2006).

However, none of these disasters were as serious as the 1926 Miami Hurricane and the 1928 Okeechobee Hurricane. Best estimates based on wind data and reports of locals suggest that the 1926 Miami Hurricane was a category 4 storm that threw 15 feet waves off Lake Okeechobee. This "black wall of water" washed away homes, businesses, railroad infrastructure, and people. Approximately 150 people who lived south of the lake in Moore Haven and other outlying towns died, and due to the swampy conditions, many bodies were not recovered or were unrecognizable. A mass grave of 26-50 of the victims exists unmarked in the Sebring Cemetery some 70 miles north of Moore Haven; bodies were recovered to Sebring as that was the source of most first responders (Wickham and Rimoldi Ibanez 2020). The damage of the 1926 Miami Hurricane paled in comparison to the 1928 Okeechobee Hurricane only two years later. While the center of the 1926 Hurricane trashed Miami and then crossed the Florida peninsula south of Lake Okeechobee through the largely uninhabited southern Everglades, the 1928 category 4 hurricane eye traveled inward from Palm Beach County, directly over the lake before turning northward (Pfost 2003). Again, the small earthen dike could not contain the storm surge of water and various communities along the big lake's southern shore were swept away for a second time by flood waters. With many of the inhabitants of the region

Fig. 6- The mass grave containing 1600 victims of the Okeechobee 1928 Hurricane in Port Mayaca: A) entirety of the mass grave, B) close up of the road side marker, C) close up of the mass grave site in the cemetery.

being laborers living in substandard housing, the death toll mounted to 2,500 to 3,000, mostly in western Palm Beach County around the lake. A true death count is hard to pinpoint as many of the dead were migrant or immigrant African American farmworkers for whom no official paperwork was maintained and who made up approximately 75% of the people living in that area (Sterghos Brochu 2003). Of the fatalities 2,343 are interred in mass graves in Martin and Palm Beach Counties, although many bodies were not recovered due to lack of funding (Pfost 2003). The largest of these mass graves was built in the Port Mayaca Cemetery on the Northeastern side of the lake, where an estimated 1,600 individuals were buried (Figure 6). Those who did survive clung to trees, climbed water towers, and bailed out barges floating on the lake (Sterghos Brochu 2003). In both these hurricanes, the shallowness of Lake Okeechobee contributed to the ability of the water to pile up and break the inadequate dike along the southern shore with powerful waves.

The sheer destruction and death of these 1920s hurricanes prompted a response from the federal government in the form of a massive dike rising 31 feet above sea level in the Rivers and Harbors act of 1930 (Seventy-First Congress 1930). The resultant Herbert Hoover Dike marked the beginning of the involvement of the Army Corps of Engineers in managing the water flow of Lake Okeechobe, the authority that still retains primary responsibility of flood controls around the lake (Rivero et al. 2020). Despite the impressive new 143 miles of levee that constituted the Hoover Dike, it became apparent in the late 1940s after years of above average rainfall that more than a dike was needed to ease flooding in the region (Army Corps of Engineers n.d.; South Florida Water Management District, n.d.). Subsequently, in 1948 the US Congress again intervened creating the Central and Southern Florida Project whose aim was to systematically create infrastructure and to actively manage the lakes, rivers, and canals (including Lake Okeechobee) of South Florida, through the Rivers and Harbors Act of 1948 (Eightieth Congress 1948). Engineers recognized that managing the Everglades system piece-meal was an ineffective Band-Aid to flood prevention, and to truly conquer the lake, everything from the Kissimmee River to the north, the Caloosahatchee and St. Lucie Rivers to the east and west, several other minor canals and associated dams encompassing the southern portions of the lake (e.g. Figure 7), and the Everglades to the south all needed to be accounted for. Today, canal water levels are adjusted to manage for tides and navigation, and water is preemptively released from Lake Okeechobee into the Everglades and adjoining canals before the first winds of hurricanes even touch the shoreline of either coast of Florida.

As the Army Corps of Engineers took over management of Lake Okeechobee's watery portions, in time its stewardship would extend to the land surrounding the lake as well. This expansion and ongoing upgrades to the Hoover Dike coincided with the development of the idea of national trail systems with the National Trail Systems Act of 1968 (Ninetieth Congress

Fig. 7- One of several smaller water control structures (a dam) that discharge water from Lake Okeechobee to help maintain water levels. This structure is located on the West Palm Beach Canal at Canal Point on the Southeastern portion of the lake: A) a panorama of the lake side of the structure where water passively enters, B) a panorama of the canal side of the same structure where water discharges to the West Palm Beach Canal, C) the Lake Okeechobee Scenic Trail traversing the top of the dam, D) water discharging from the dam to the canal as viewed from the Lake Okeechobee Scenic Trail.

1968). The dike's elevation above the lake and all surrounding areas provided an intuitive perch for those wishing for a scenic walk or view of the sunset in the 1960s ("Lake Okeechobee Scenic Trail" n.d.). Over the course of the 1980s the Army Corps developed a mostly paved 110-mile trail encompassing the lake ("Lake Okeechobee Scenic Trail" n.d.), with facilities including 14 campgrounds and water filling stations. This new trail was named the Lake Okeechobee Scenic Trail (LOST) and became part of the Florida National Scenic Trail in 1993, and therein a part of the National Trail system (Army Corps of Engineers, n.d.; One Hundred Eleventh Congress 2009). The Florida National Scenic Trail connects at the most southern location of the lake in John Stretch Memorial Park where old pump equipment from water control structures on the lake are on display (Figure 8). Hikers can then either venture around the lake on the LOST along the eastern or western shore of the lake until reaching the northern extension of the Florida National Scenic Trail to the west of the city of Okeechobee that lies on the lake's north shore, skirting the Kissimmee River for several miles before branching off to the north.

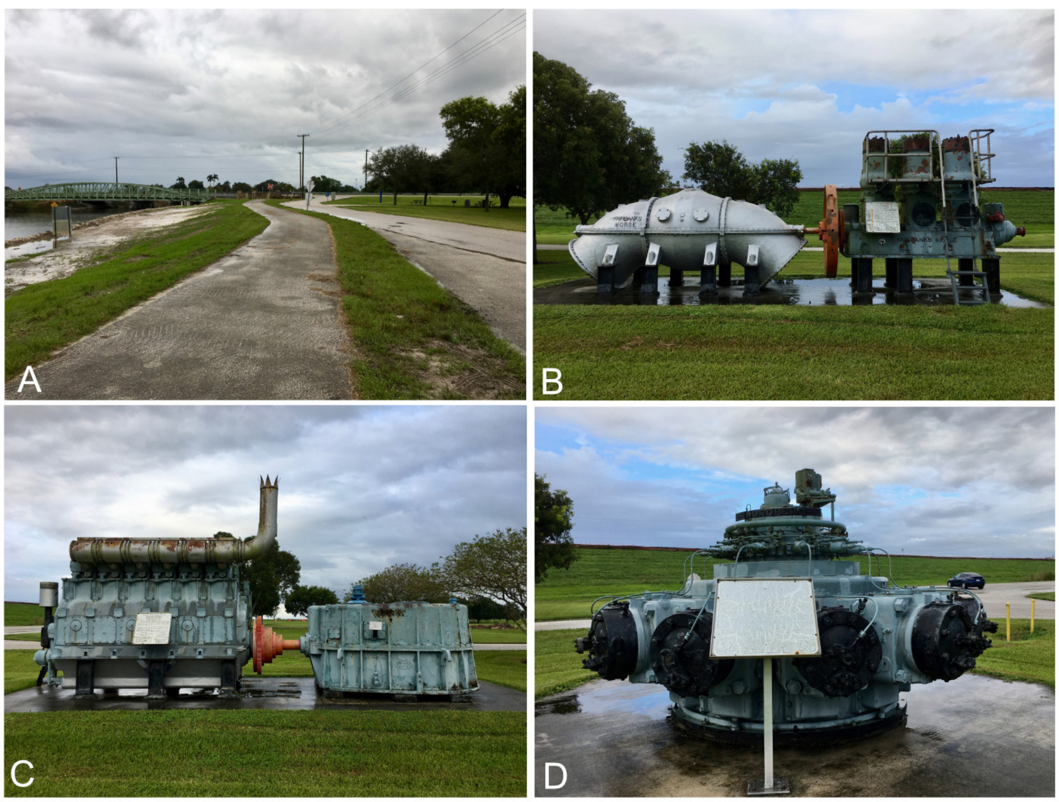

Fig. 8- Various areas of John Stretch Memorial Park: A) where the Lake Okeechobee Scenic Trail intersects the Florida National Scenic Trail, B-D) various retired pumping devices from water control structures around Lake Okeechobee with signs too degraded to read.

With the taming of the water levels and flow patterns in and around Lake Okeechobee that have allowed for safe settlement of the area and a booming agricultural industry of mostly sugar cane, new issues have arisen for the lake and its human neighbors, most urgently the recurrent harmful algal blooms. These algal blooms proliferate nearly every spring since the 1970s, dissipating typically between late July and December (Havens et al. 1994). However, such blooms have occasionally been observed to last years, such as one massive bloom that began in 2016 which prompted Florida to declare a state of emergency (Kramer et al. 2018). The blooms are dominated by cyanobacteria, also known as blue green algae, that cover the surface of the lake with green scum. Although cyanobacteria are a natural part of many marine and freshwater ecosystems that contribute to the health of ecosystems by turning carbon dioxide into oxygen, when blooms of cyanobacteria occur, they can (although not always) release neuro and other toxins, harmful to both the wildlife and humans (Dawson 1998). These harmful algal blooms are so common and so commonly excrete toxins in Lake Okeechobee that signs warning of the blooms are common around the lake at popular fishing spots (e.g. Figure 9).

Fig. 9- A sign near the St. Lucie Canal on Lake Okeechobee warning of the recurrent harmful algal blooms that contaminate the environment with neuro and other toxins.

The base of the algal bloom problem in Florida's big lake is a nutrient and water flow problem. Cyanobacteria as plant-like photosynthesizing algae thrive when nitrogen and phosphorous are abundant. The microbes will increase in size and abundance until one of these two nutrients becomes deplete, becoming a limiting factor (Lecher and Mackey 2018). In marine environments cyanobacteria are typically limited by nitrogen (Lecher and Mackey 2018). However, in the naturally phosphorous limited Everglades system, phosphorous loading that alleviates limitation can be as much of a problem as nitrogen loading, especially as phosphorous loading to the lake has increased in recent times (Havens et al. 2003; Brezonik and Engstrom 1998). Between 1973 and 2003 phosphorous concentration in Lake Okeechobee steadily increased from ~50 ug/L (micrograms per liter) to >100 ug/L; this equates to 189 metric tons of phosphorous present in the lake in 1973 and 525 metric tons in 2003 (Havens & James, 2005). Furthermore, reduced waterflow out of the lake can compound these issues, as many types of algae can only bloom when dispersion by water movement is limited, creating feedback effects (Havens et al., 1994). Despite this seemingly simple problem, the solution is much more complex. Pinpointing where the bulk of the nitrogen and phosphorous nutrients are coming from into the lake and how to stop their arrival has been the focus of many scientific studies that disagree on the dominant source of nutrients to the lake (e.g. Canfield and Hoyer 1988; Khare et al. 2019; Hiscock, Thourot, and Zhang 2003). The simple answer may at first appear that nutrients are running off of the sugar cane fields that are heavily fertilized, but the question remains how and where they enter the lake? Surface water systems such a canals and rivers and groundwater discharge are both possible culprits, but the magnitude of nutrient loading from each of these sources is not fully known. Furthermore, simply discharging the water to the surrounding canals only perpetuates the problem from the lake into the canals and coastal estuaries further downstream (Kelly et al. 2020).

Despite the persistence of the harmful algal blooms, just as persistent have been the efforts to prevent and mitigate them. In the 1980s, the Southwest Florida Water Management District determined that phosphorous concentrations in Lake Okeechobee should be less than 40 ug/L, a concentration only seen prior to the 1970s (Canfield et al., 2020; Havens & James, 2005). The Lake Okeechobee Technical Advisory Committee (LOTAC) overseen by the legislature and motivated by an especially large bloom in 1986 suggested the best way to achieve this goal was to reduce phosphorous inputs into the lake by 40%, mainly by targeting agricultural pollution and runoff. These goals were adopted in 1987 by the Florida government in the Surface Water Improvement Act (Canfield et al., 2020). Some of the efforts are visible north of and around the lake, such as the decrease in dairy farms from ~50 to less than half of that number more recently (bovine waste is rich in phosphorous), and the introduction of reclamation fields that clean nutrient-rich agricultural water by letting plants and the soil absorb it (Staletovich, 2016). Despite the visible changes to agriculture and the landscape around Lake Okeechobee, hurdles still exist that prevent phosphorous concentrations decreasing to required levels. One barrier to achieving these state-mandated phosphorous concentration and loading goals is that much of the phosphorous loaded into the lake becomes stored in the sediment and can be resuspended into the water column due to strong winds or storms (Brezonik & Engstrom, 1998). Indeed in 2000 the State of Florida legislature passed the Lake Okeechobee Protection Act, which set a deadline for meeting the phosphorous loading and concentration requirements by 2015, but both phosphorous concentration and loading to the lake regularly exceed these requirements (Canfield et al., 2020). Meanwhile, in the lake and its canals the algal blooms persist.

More recently in 2019 Governor Ron DeSantis commission the Blue-Green Algae Taskforce consisting of phycologists from around the state to tackle the issue of blooms in Lake Okeechobee (Gross 2019). On their recommendation over $5 million was designated by the state to be awarded as research grants to better understand the culprits of the blooms and not yet explored solutions (Nicol 2020). Furthermore, a facility to remove phosphorous from one of the most nutrient-polluted canals on the northern edge of the lake by simulating natural wetland processes is currently under development (South Florida Water Management District 2020). Solutions extend beyond the lake however; in October of 2020 a federal judge mandated that the Army Corps of Engineers consider impacts to downstream ecosystems when discharging water from the lake, a ruling that will prevent the corps from simply releasing water into the surrounding canals to disperse the blooms (Staletovich 2020).

Despite the lake's impressive history of quashing humanity's attempts to thwart its natural tendencies prior to the mid 20th century, it is extremely unlikely that Lake Okeechobee will revert to its original state under human management. However, with the degradation of Florida's largest lake finally being taking seriously under consideration by state officials, there is reasonable hope for a return to a healthier ecosystem status in the future, and a more enjoyable experience for those who choose to conquer the LOST that surrounds it.

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