Stormwater Treatment Areas For Improving Water Quality in the Everglades

David Goldstein and Alan L. Wright,
Everglades Research & Education Center, Belle Glade, FL

Introduction

Water quality in the Everglades ecosystem has varied drastically throughout the last 200 years. As a result of human interaction with the Everglades, water quality has deteriorated, causing disruptions to the natural ecosystem. Of primary concern, elevated concentrations of phosphorus (P) flowing into the Everglades has been implicated in causing ill effects in the Everglades ecosystem. Stormwater Treatment Areas (STAs) were designed and first implemented by to the South Florida Water Management District to reduce the excessive levels of P by filtering the water flowing into the Everglades. This paper is intended to provide an in-depth analysis of the effects of STAs on water quality improvements observed in the Everglades over the past 20 years.

Phosphorus Requirements

According to the Everglades Forever Act and per the Florida Administrative Code, subsection 62-302.540, all Class III waters within the Everglades Protected Area are required to maintain P concentrations of 10 parts per billion to ensure the wellbeing of native flora and fauna species indigenous to the Everglades ecosystem (Florida Department of Environmental Protection, 2004).

Dissolved Oxygen Requirements

The Florida Administrative Code, subsection 62-302.530 outlines that all Class III fresh waters should maintain a dissolved oxygen level of no less than 5.0 mg/L. Despite large fluctuations in dissolved oxygen resulting from periphyton and macrophyte populations undergoing photosynthesis and respiration within the Everglades, dissolved oxygen levels still must be maintained at this level (Florida Department of Environmental Protection, 2003).

History of Hydrology in the Everglades

The Everglades of today, a labyrinth of interconnected wetlands, is just a fraction of its original size. Historically, the Everglades consisted of nearly nine million acres of wet prairies, cypress swamps, coastal lagoons and bays that demonstrated resilience to environmental stressors. The development of the Everglades, beginning in the late 1800s, has encompassed the construction of complex canal systems that transports water from the Kissimmee River Valley, through Lake Okeechobee, into Water Conservation Areas and ultimately into Everglades National Park, thereby artificially accomplishing the necessary flow of water that once occurred naturally in South Florida (USGS, 1999).

In its unaltered state, the Everglades system was regulated by the gradual flow of water that transcended from the Kissimmee River Basin down to Florida Bay and out into the Gulf of Mexico. By the early 1900s, human intervention had begun the transformation of the Everglades from the historic wetland land use into agricultural and urban uses that disrupted the natural flow of water and nutrient cycling. In order to cultivate crops and establish settlements, flood control and water displacement became the core focus of Everglades management. Despite the changing landscape, it was not until the construction of the Tamiami Trail, which was completed in 1928, that the natural flow of water throughout this landscape was completely disrupted. The inability for water to flow from Lake Okeechobee to Florida Bay has had a major impact on the ecology of this region.

The Everglades, in its natural state, is a P -limited ecosystem, but inputs from fertilizer use in the Everglades Agricultural Area and urban waste water discharges have resulted in significant water quality issues throughout the Everglades ecosystem. Phosphorus enrichment has resulted in the thriving of vegetation that out competes native species which are relied upon for the survival of fish and wildlife. In addition to the effects on native flora, elevated P levels often lead to chemical and biological changes that adversely affect natural systems (U.S. EPA, 2011).

Water quality concerns are also evidenced by the reduced availability of dissolved oxygen in the water column. In historic Everglades wetlands, photosynthesis from submerged aquatic vegetation and periphyton provided an ample supply of oxygen to the water. When dissolved oxygen levels drop below 2 mg/L, fish begin to perish adversely affecting the entire food web of the ecosystem.

Stormwater Treatment Areas

Stormwater Treatment Areas are manmade wetlands designed to filter aquatic pollutants flowing from urban and agricultural lands prior to reaching sensitive wetland ecosystems. The successful performance of these areas is dictated by several key variables: vegetation type, inflow water quality and hydraulic loading, as well as the intensity, duration and timing of flow events.

In Southern Florida, STAs are comprised of six distinct locations that are designed to intercept stormwater discharge, a point source for nutrient enrichment prior to reaching the Everglades wetlands. In addition to filtering water, STAs serve as a storage basin to ensure water availability in times of drought, provide valuable habitat for wildlife species, and allow for scientific discovery and experimentation (SFWMD, 2013).

With construction beginning in 1994, there are presently 57,000 acres of STAs in the State of Florida that were designed and developed to reduce P concentrations in the Everglades ecosystem to reach the Florida Department of Environmental Protection's standard requirement of 10 parts per billion, and to increase dissolved oxygen levels to above 5.0 mg/L. The State of Florida has invested nearly two billion dollars for the improvement of water quality through new and improved infrastructure, including the creation of STAs. As a result of these improvements, water flow entering the Everglades ecosystem that once contained P concentrations as high as 170 parts per billion are now being discharged at concentration levels as low as 12 parts per billion. Despite positive results being documented in many of the STAs, work still needs to be done to reduce total P concentrations to reach the 10 parts per billion standard (SFWMD, 2013).

Importance of Stormwater Treatment Areas

Stormwater Treatment Areas are important to the health of the Everglades ecosystem, and P removal is their primary purpose. The filtration of water that is funneled through each strategically-designed vegetation cell is designed to provide the necessary absorption of nutrients prior to entering Everglades wetlands. Excess P in water is the driving force behind algae blooms that can kill fish and aquatic invertebrates, and which has an adverse effect on the entire food chain in the Everglades. Excess P also results in native grasses, primarily *Cladium*, to die off, which results in proliferation of invasive species, such as *Typha.* As a result of excessive *Typha* establishment, submerged vegetation and periphyton can be blocked from photosynthesizing and dissolved oxygen levels may decrease, contributing to unstable conditions for aquatic fauna.

Stormwater Treatment Areas provide a key component to Everglades restoration. Presently, Lake Okeechobee is holding over 190,000 tons of legacy P within its soil as a result of agricultural operations in the surrounding region. Stormwater Treatment Areas serve as the filter between the pollutants of the Lake Okeechobee basin and the Everglades Protected Area. The result of the abundance of stored P on water quality may continue for years to come as the legacy phosphorous is gradually released into the water column and flows south into the STAs. Stormwater Treatment Areas are not the only way to remove P out of an aquatic system. However, they are the most effective method of producing the ideal balance of water attributes needed for the health of the Everglades with the least amount of negative side effects.

Sustainability

The sustainability of the Everglades is dependent on the stability of its water quality and the ecological balance good water quality will support. To best assess the long term sustainability of the Everglades, an assessment of the effects of STAs on water quality in the Everglades must be validated. The Comprehensive Everglades Restoration Plan involves a variety of projects designed to reestablish a natural flow of water in the Everglades ecosystem. While engineers work to remove roads and fill canals to restore part of the natural topography to the Everglades, growing concerns over the quality of water emerge.

Despite the primary goal of STAs being the reduction in total P concentrations, dissolved oxygen is of importance when discussing water quality and long term sustainability in the Everglades watershed. In a natural state, dissolved oxygen fluctuations are a normal occurrence throughout the diel cycle. However, in nutrient-enriched waters, organic matter generation resulting from emergent aquatic vegetation creates an unsustainable level of sediment oxygen demand during the night hours, in addition to crowding out submerged aquatic vegetation during daylight hours, thereby reducing their levels of photosynthesis and contributing less total dissolved oxygen in the water column (Florida Department of Environmental Protection, 2003).

Through the reduction of nutrient enrichment, STAs play a strong role in stabilizing dissolved oxygen levels throughout the Everglades Protected Area, in addition to reducing total P concentrations. Resulting from conditions closely related to oligotrophic scenarios, native species allow the conditions closely relating historic diel patterns of photosynthesis and respiration to regulate dissolved oxygen within the EPA requirements of no less than 5.0 mg/L.

Stormwater Treatment Area Vegetation

The vegetation found in STAs can be classified as one of three primary types: emergent aquatic vegetation, submerged aquatic vegetation and floating aquatic vegetation. See Table 1 below for a breakdown of vegetative types found in STAs. Many STAs in South Florida are comprised of emergent aquatic vegetation due to effectiveness at nutrient removal, with the dominate vegetative species being *Typha*. (Wetland Solutions, Inc., 2009).

Vegetation selection in South Florida's STAs was based upon the Everglades Nutrient Removal Project, which set the path for P removal utilizing STAs. Analyses from this project revealed that *Typha* successfully removed P from contaminated inflows. Due to its ability to withstand continuous flooding, *Typha* is an optimal choice for STAs designed to reduce phosphorous concentration and for accreting organic matter (Wetland Solutions, Inc., 2009).

Stormwater Treatment Areas in South Florida also contain cells of submerged aquatic vegetation, which are structured as open-water marsh systems. Positive results of P removal have been observed with this vegetation type as well. The most desirable subaquatic species for P removal have been found to be *Naja guadalupensis* and *Ceratophyllum demersum* (Wetland Solutions, Inc., 2009).

How Stormwater Treatment Areas Affect Water Quality

The effectiveness of STAs has been monitored since their inception. Water that is contaminated with excess P and nitrogen is channeled into STAs where it encounters plots of emergent aquatic vegetation and/or submerged aquatic vegetation. By monitoring the concentration of total and inorganic P levels in the inflow and comparing them to the concentrations in the outflow, the improvements in water quality can be documented (Juston and DeBusk, 2006).

Variation in the effectiveness of STAs occurs due to a variety of factors in addition to vegetative fluctuations. Phosphorus reduction may be inconsistent due to water being continuously present in some STAs, or pumped in periodically. A continuously hydrated Stormwater Treatment Area will typically be more productive at eliminating excess nutrients (Juston and DeBusk, 2006). The soil type and prior land use of the STAs also influences their effectiveness at P removal.

Periphyton-based STAs have been introduced in South Florida to test its effectiveness for P concentration reduction. Periphyton testing in laboratories has demonstrated an ability to reduce total P concentrations levels down to the required 10 parts per billion in traveling a distance of only 100 feet (USACE, 2003). In 2004, construction of the first periphyton-based STA began, and in 2007 was operational. Scientists are analyzing the data being collected to best plan how to use periphyton in larger scale restoration projects throughout the STAs (Brown and Wright, 2013).

Case Study 1

The research article, *Phosphorus Mass Load and Outflow Concentration Relationships in Stormwater Treatment Areas for Everglades Research* by Juston and DeBusk (2006), addresses P enrichment to water being directed from the Everglades Agricultural Area into STA-1W, STA-2, STA-5 and STA-6 (Figure 1).

The STAs least effective at P removal were those that had been recently farmed. STAs that were constructed on historic wetlands were the most productive at improving water quality metrics due to less legacy nutrients present in the soil compared to recently farmed lands. Additionally, the findings of the study revealed that emergent aquatic vegetation was more effective than submerged aquatic vegetation (Juston and DeBusk, 2006).

Analysis of the hydrology of the STAs demonstrated that STA-5 and STA-6 were not continuously flooded, whereas STA-1W and STA-2 were continuously flooded. The study showed a high level of consistency of P removal among continuously flooded STAs. However, in non-continuously flooded cells, consistency of P removal was observed after four months of steady flooding (Juston and DeBusk, 2006).

Case Study 2

The research article, *Temporal and Spatial Patterns of Internal Phosphorus Recycling in a South Florida (USA) Stormwater Treatment Area* by Dierberg et al. (2012), evaluated Cell 1 of STA-2 over a 15-month period. The cell in this study was historically a marsh wetland and has never been farmed, but had been drained and flooded on an intermittent basis. Cell 1 encompasses approximately 20% of the entire acreage of STA-2 and is dominated by emergent aquatic vegetation. During the study period, high variability of total P concentrations was observed on the inflow into Cell 1. The outflow, however, had very consistent results within the target range, thereby demonstrating the positive success of this Cell in filtering both total and inorganic P. Data provided by the South Florida Water Management District and analyzed by the authors of that research also revealed that Cell 1 was the only of the four cells in STA-2 that maintained the outflow requirement for total P of 10 parts per billion during the study period (Dierberg et al., 2012).

Conclusions

The results of Stormwater Treatment Area monitoring have provided researchers with evidence that water quality is improving as a direct result of their operation. To further produce consistent long-term success, efforts are being undertaken to create STAs in the northern Everglades. The goal is to reduce P levels being discharged into Lake Okeechobee and therefore reduce the total concentrations of P being discharged into the present day Everglades STAs and ultimately into the Everglades Protected Areas (SFWMD, 2010).

A trend can be established demonstrating a relationship between improved water quality and the use of STAs as a buffer between input sources flowing from the Everglades Agricultural Area into the Everglades wetlands. Despite varying degrees of effectiveness resulting from land use prior to becoming STAs, a positive impact on water quality can be identified, including the reduction of P levels and stabilization of dissolved oxygen levels to meet the Florida Department of Environmental Protection’s requirements as described in the Everglades Forever Act.

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Table 1: The chart provides an aerial analysis of vegetative communities observed within the STAs (Table provided by Wetland Solutions, Inc., 2009).

STA	Date	EMG	FA	SAV	SHRUB	OTHER	Water Year	Average Depth (cm)
1-E	Feb-05	34.4	0.3	53.0	4.1	8.3	--	--
1-E	Mar-06	28.5	0.0	57.1	1.5	12.9	2006	29
1-W	Apr-99	50.0	6.6	37.4	6.0	0.0	1998	60
1-W	Jan-02	24.7	11.7	59.1	4.4	0.0	2001	54
1-W	Feb-05	21.5	1.8	68.8	4.2	3.6	2004	59
1-W	Mar-06	33.6	0.1	38.9	9.2	18.3	2005	60
2	Dec-03	65.3	0.2	34.5	--	0.1	2002	45
2	Feb-05	63.0	0.2	34.8	0.0	2.1	2004	45
2	Mar-06	60.6	0.1	37.5	0.1	1.8	2005	45
3/4	Feb-05	65.3	1.5	22.0	8.1	3.2	--	--
3/4	Mar-06	45.0	0.3	30.8	8.6	15.3	2006	52
5	Dec-03	46.0	3.6	45.4	5.0	0.0	2002	49
5	Feb-05	46.4	0.5	47.5	5.7	0.0	2004	59
5	Mar-06	46.5	1.1	43.6	1.8	7.0	2005	59
6	Dec-03	67.9	0.9	25.4	5.8	0.0	2002	48
6	Feb-05	71.4	0.4	18.6	9.5	0.1	2004	56
6	Mar-06	68.0	--	12.8	19.0	0.2	2005	56

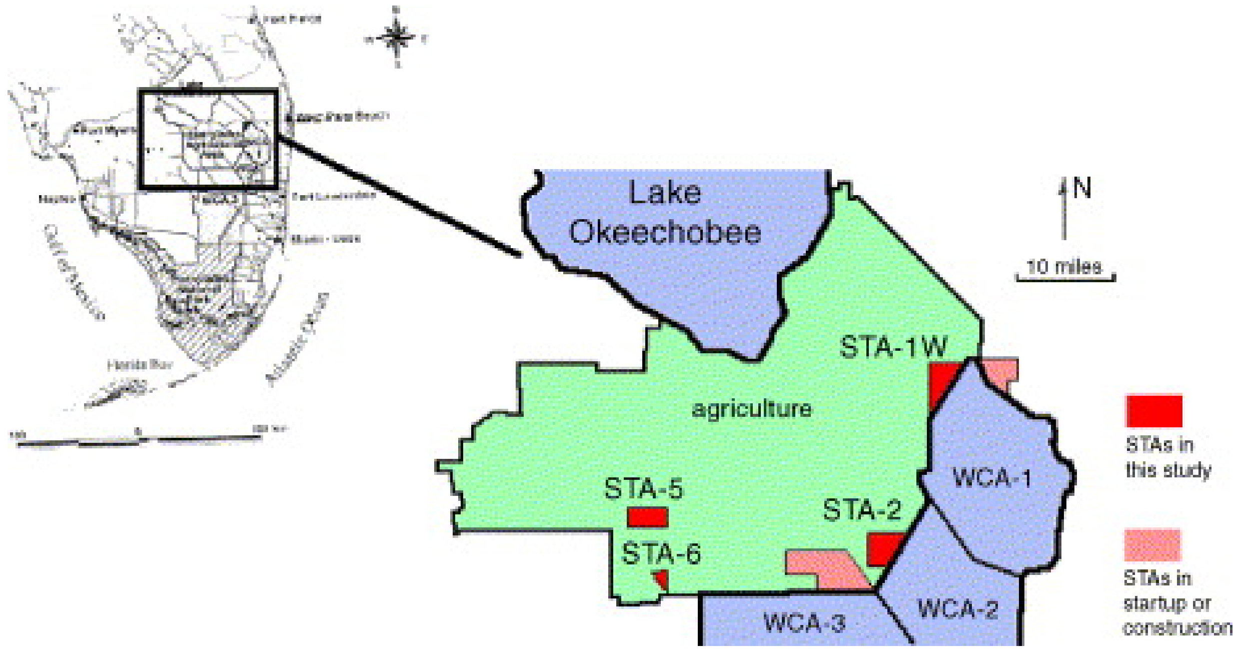

Figure 1. Map of Stormwater Treatment Areas discussed in Case Study 1 (Juston and DeBusk, 2006)