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Limnological characteristics of a subtropical constructed wetland in south Florida (USA)

Binhe Gu[a,*], *Michael J. Chimney*[b], *Jana Newman*[b], *Martha K. Nungesser*[a]

[a] *Everglades Division (MSC-4440), South Florida Water Management District, 3301 Gun Club Road, West Palm Beach, FL 33406, USA*
[b] *STA Management Division (MSC-4470), South Florida Water Management District, 3301 Gun Club Road, West Palm Beach, FL 33406, USA*

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ABSTRACT

The Everglades Nutrient Removal Project (ENRP) was a 1544 ha constructed wetland built by the South Florida Water Management District as part of Everglades restoration efforts. The limnology of this wetland is characterized over its 60-month operational history. The ENRP received agricultural runoff containing high levels of C, N, P and other dissolved constituents; had moderately high alkalinity with a circumneutral pH; and had low to moderate DO. The ENRP provided substantial treatment (concentration reduction from inflow to outflow) for Al, Fe, NH_4, NO_x, SRP, TP, TSS and turbidity (high-treatment variables), while Secchi depth increased markedly. These changes were judged biologically significant. Dissolved oxygen, and water temperature had well defined annual cycles, while some level of seasonality was noted for Al, alkalinity, Ca, conductivity, DOC, Fe, hardness, K, Mg, Mn, Na, NH_4, pH, Secchi depth, SiO_2, TOC, TN, turbidity, and TSS. The ENRP was P limited based on TN:TP molar ratios. Dissolved ions were dominated by Ca, Cl, Na, and HCO_3; the stoichiometric balance of both major and minor ions was similar throughout the wetland. The downstream settling of TSS was associated with increased light penetration, but did not appear important in sediment accretion. The adsorption of P to Ca, and perhaps Al and Fe, precipitates is thought to have been an important nutrient removal mechanism. Although there was little net reduction in DOC, we speculate that some incoming material was degraded and replaced by new DOC produced within the wetland.

1. Introduction

Constructed wetlands are often designed to reduce the concentration of water-borne contaminants, enhance other aspects of water quality, or provide flood protection (Brix, 1998; Reed et al., 1995; Kadlec and Knight, 1996; Mitsch et al., 1998). These artificial ecosystems also are built to restore habitat and provide valuable wildlife and public use areas (Feierabend, 1989; Saether, 1989; Gearheart and Higley, 1993; Brix, 1998). Research conducted on these systems has focused largely on their ability to remove pollutants from surface waters (e.g., Hammer, 1989; Moshiri, 1993). However, other water quality variables, e.g., pH, dissolved oxygen, turbidity, and dissolved and suspended solids, influence wetland health and functioning (Wetzel, 2001). Furthermore, the discharge from constructed wetlands can affect downstream water bodies. Despite the importance of the above-mentioned variables, the limnology of wetlands has usually been characterized only for natural systems (e.g., Dierberg and Brezonik, 1984; Walker, 1991; Whigham and Jordan, 2003).

* *Corresponding author*. Tel.: +1 561 682 2556.
E-mail address: bgu@sfwmd.gov (B. Gu).

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State and Federal governments have initiated a multi-billion dollar effort to restore the Everglades, a vast freshwater marsh located in South Florida (USA). This enormous undertaking includes converting large tracts of farmland into treatment wetlands referred to as stormwater treatment areas (STAs). The STAs are intended to reduce the phosphorus (P) concentration of agricultural runoff, thereby reducing P loading to the Everglades (Chimney and Goforth, 2001; Goforth, 2001). The Everglades Nutrient Removal Project (ENRP) was a constructed wetland operated by the South Florida Water Management District (District or SFWMD) that served as a prototype STA (Chimney and Goforth, 2006).

This paper describes aspects of the limnology of the ENRP over its 5-year operating period-of-record (POR). The analyses presented herein focus on treatment performance of the entire wetland, i.e., chemical and physical differences between the inflow and outflow. More detailed evaluations of the hydrology, nutrient dynamics and biogeochemical processes in this system are presented in companion papers in this issue (Chimney and Pietro, 2006; Chimney et al., 2006; Nungesser and Chimney, 2006; McCormick et al., 2006; Pietro et al., 2006), are in preparation or have been published elsewhere (Guardo, 1999; Moustafa, 1999; Choi and Harvey, 2000; Newman and Pietro, 2001; Nungesser and Chimney, 2001). The data collected during this study contribute to our understanding of the biogeochemistry of the ENRP and provides insight into factors that may influence treatment performance of the STAs.

2. Methods

2.1. Study site

The ENRP was a 1544 ha constructed wetland located in Palm Beach County, Florida (26°38′N, 80°25′W). The primary inflow to the ENRP was runoff from the 2830 km^2 Everglades Agricultural Area (EAA) that entered the wetland through an inflow pump station (inflow) and exited through an outflow pump station (outflow) (see Chimney and Goforth, 2006). The interior of the ENRP was divided into a series of interior cells separated by levees. The ENRP operated from August 1994 through July 1999, when it was incorporated into the boundary of a larger STA (STA-1 West). The predominant vegetation was cattail (*Typha latifolia* and *T. domingensis*) mixed with other emergent and floating aquatic macrophyte species. One interior cell was actively maintained as a submersed aquatic vegetation (SAV) community dominated by southern naiad (*Najas guadalupensis*) interspersed with coontail (*Ceratophyllum demersum*) and pondweed (*Potamogeton illinoensis*). Select physical and biological characteristics of the ENRP are summarized in Table 1. A history and description of the ENRP are provided in Guardo et al. (1995) and Chimney and Goforth (2006).

Table 1 – Physical characteristics of the Everglades Nutrient Removal Project

Variable	
Surface area (ha)	1544
Mean water depth (m)	0.6
Mean hydraulic retention time (days)	17.7
Mean hydraulic loading rate (m yr^{-1})	11.4
Plant cover—SAV[a] (%)	41.3
Plant cover—other species (%)	58.7

[a] Submersed aquatic vegetation and areas of open water.

2.2. Data collection

2.2.1. Flow

Flow in the ENRP was monitored on a continuous basis at the inflow and outflow based on motor speed and a rating curve developed for each pump station (Guardo et al., 1995).

2.2.2. Meteorology

Air temperature, wind speed, and photosynthetically active radiation (PAR) were measured continuously at an on-site automated weather station (Guardo et al., 1995). Rainfall was monitored by a network of tipping-bucket collectors within the wetland (Abtew et al., 1995; Guardo et al., 1995).

2.2.3. Water quality

Water samples were collected from the inflow and outflow and analyzed following standard methods for alkalinity, aluminum (Al), ammonia-nitrogen (NH_4), calcium (Ca), chloride (Cl), dissolved organic carbon (DOC), hardness, iron (Fe), manganese (Mn), magnesium (Mg), nitrite + nitrate-nitrogen (NO_x), potassium (K), silica (SiO_2), sodium (Na), soluble reactive phosphorus (SRP), sulfate (SO_4), total Kjeldahl nitrogen (TKN), total organic carbon (TOC), total phosphorus (TP), total suspended solids (TSS), and turbidity. Surface measurements of water temperature, conductivity, dissolved oxygen (DO), and pH were made weekly at both sampling sites with a Hydrolab® datasonde (Hydrolab-Hach Co., Loveland, CO). Samples for TP were collected weekly with autosamplers operated on a flow-proportioned basis. Grab sample were collected for SRP in conjunction with TP sampling. Biweekly grab samples were collected for all other chemical constituents. Secchi depth was measured either weekly or biweekly with a 20-cm diameter black and white disk. Due to excavation associated with the construction of both pump stations, water depth in the immediate vicinity of these locations was several *m* deeper than out in the marsh.

2.3. Data analysis and presentation

A combination of descriptive and inferential statistics together with exploratory graphical techniques (du Toit et al., 1986; Jacoby, 1998) were employed to (1) assess the level of treatment in the ENRP for each water quality variable, (2) identify seasonality or trends over the POR (POR trends) and (3) describe relationships among variables and sampling locations. All analyses were performed with monthly or quarterly means calculated from the weekly/biweekly data. Statistics were calculated with JMP (Version 5, SAS Institute Inc., Cary, NC), SAS (Release 8.02, SAS Institute Inc., Cary, NC), SYSTAT (Version 10.2, SYSTAT Software Inc., Richmond, CA) or SigmaPlot (Version 8.02, SPSS Inc., Chicago, IL). The level of significance (α) was set at 0.05 for all analyses.