Proc. Fla. State Hort. Soc. 121:183–186. 2008.

Fate and Movement of Nitrogen and Phosphorus in Deep Creek in the Lower St. Johns River Basis of Northeast Florida

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Additional index words. Total Maximum Daily Loads, Best Management Practices, dissolved oxygen, blue-green algae

According to the St. Johns River Water Management District, approximately 36% of the pollutant load entering the lower St. Johns River basin is related to human activities. Deep Creek, a tributary in the lower St. Johns River basin, drains approximately 4,000 ha of irrigated cropland in and around Hastings through a system of tail water and drainage canals into Deep Creek. Objectives of this project were to measure water quality and aquatic plant density effects in Deep Creek. Water samples collected were analyzed for nitrate-nitrogen, ammonium-nitrogen, potassium and total phosphorus. Blue-green algae, chlorophyll *a*, dissolved oxygen, pH, specific conductivity and water temperature were measured at 23 sample sites on a weekly schedule in Oct. 2007. Total phosphorus concentration within Deep Creek at the 1st, 13th, and 15th sample locations were significantly higher compared with all other sample sites at 896.4, 930.7, and 896.9 $\mu g \cdot L^{-1}$, respectively. A significant correlation between total phosphorus and chlorophyll *a* was observed. Chlorophyll *a* increased as total phosphorus increased. Alternatively, a significant inverse relationship was observed as nitrate-nitrogen concentrations decreased, chlorophyll *a* increased. Continued data collection will further support Best Management Practices strategies for the Tri-County Agricultural Area of Northeast Florida.

The lower St. Johns River basin encompasses over 713,000 ha, which include the Tri County Agricultural Area of Flagler, Putnam, and St. Johns counties. The lower St. Johns River has been recognized as an impaired water body in need of restoration (St. Johns River Water Management District website). The health of the river today is threatened by nutrient loading due in part to storm water runoff from urban and agricultural areas. The Environmental Protection Agency reports that non-point source pollution from agriculture has impaired 60% of the river miles and half of the lake acreage surveyed by states, territories and tribes (Environmental Protection Agency website). The St. Johns River Water Management District has determined that approximately 36% of the pollutant load entering the river basin today is related to human activities that include agricultural production. According to the St. Johns River Water Management District, 2006, effluent from industrial and wastewater treatment plants in the lower St. Johns River basin is the largest contributor of nutrients into the St. Johns River followed by agriculture in the TCAA and storm water from urban areas. It has generally been accepted that leaching rains are responsible for the majority of nutrient movement out of the 14,000 ha of irrigated row crop production in the Tri-County Agricultural Area. Kidder et al. (1992) defined a leaching rainfall as 7.6 cm of rain in 3 d or 10 cm of rain over 7 d. These leaching rainfall events wash fertilizer out of the crop row and either into the furrow or into the perched water table. Fertilizer washed into the furrow moves in surface water into tail-water or drainage canals and subsequently into the lower St. Johns River watershed and into sensitive environmental areas in the lower St. Johns River basin, particularly the Deep Creek basin. The Deep Creek basin encompasses over 16,800 ha and is a prominent feature in the lower St. Johns River basin which drains approximately 4,200 ha of agricultural land around Hastings, FL.

Consequences of nutrient loading, particularly N and P, into the St. Johns River contribute to algal blooms which prevent the penetration of sunlight through the water and the depletion of O_2. According to the State of Florida Department of Environmental Protection and the Environmental Protection Agency, dissolved O_2 levels should be maintained between 4.0 and 5.0 mg L^{-1}, in the lower St. Johns River basin (Florida Department of Environmental Protection website) and that dissolved O_2 levels may not drop below 4.0 $mg \cdot L^{-1}$ for longer than 24 h. Oxygen depletion is commonly caused by bacterial respiration during algal decays which is detrimental to plant and fish species (Hallegraaeff et al., 2003).

Materials and Methods

Sample locations. Twenty-three sample sites were located in Deep Creek beginning east of the St. Johns River Water Management District Deep Creek West Regional Stormwater Treatment Facility constructed wetland on George Miller Rd., Hastings, FL (29°42.283´N; 81°28.993´W) traversing west to the St. Johns River (Fig. 1).

Water nutrient samples. Water samples were manually collected at depths of 1, 3 and 5 m from 23 sample sites within Deep Creek and at depths of 0.5 m within the tributaries on a weekly schedule from February through June coinciding with potato production in the Tri-County Agricultural Area; biweekly in Jan. and July through Oct. and every 3 weeks from November through December. Samples were collected at 30.5 m prior, 7.6 m within and 30.5 m post selected tributaries within Deep Creek to the St. Johns River with a Fieldmaster horizontal-style water

Acknowledgments. The authors sincerely thank the St. Johns River Water Management District for supporting this project, and the assistance of Allison Beyer and Steve Green for their continued assistance in data collection.

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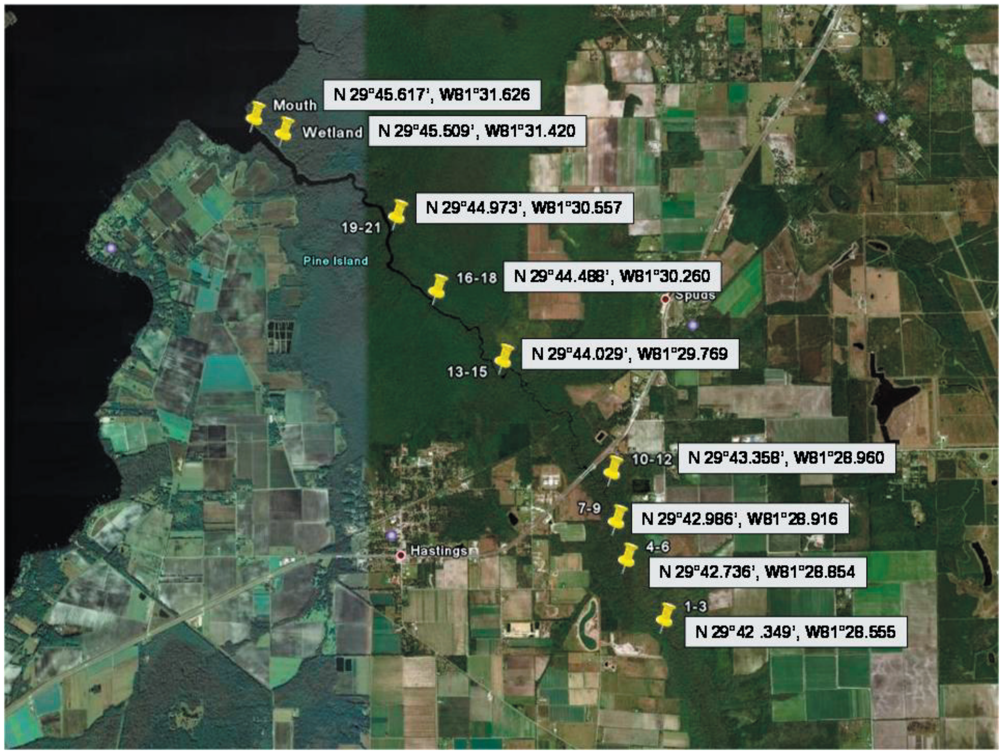


Fig. 1. Deep Creek sample sites 1–12 east of SR 207, Hastings, FL. Deep Creek sample sites 13–23 west of SR 207 to the St. Johns River.

sampler (Forestry Suppliers, Inc., Jackson, MS). Water samples (20 mL) were collected, acidified, frozen at –15 °C, and stored until analyzed for NO_3-N, NH_4-N (EPA method 353.2), Total P (EPA method 365.1) and K, and Mn (EPA method 200.7).

Automated water quality evaluation. Blue-green algae (cells/mL), chlorophyll a, dissolved O_2 (mg·L^{-1}), pH, specific conductivity (μS·cm^{-1}) and water temperature were measured at 1, 3, and 5 m below the water surface at each sample location within the creek and 0.5 m within the tributaries with a YSI 6600 multiparameter water quality sonde (AMJ Environmental, St. Petersburg, FL).

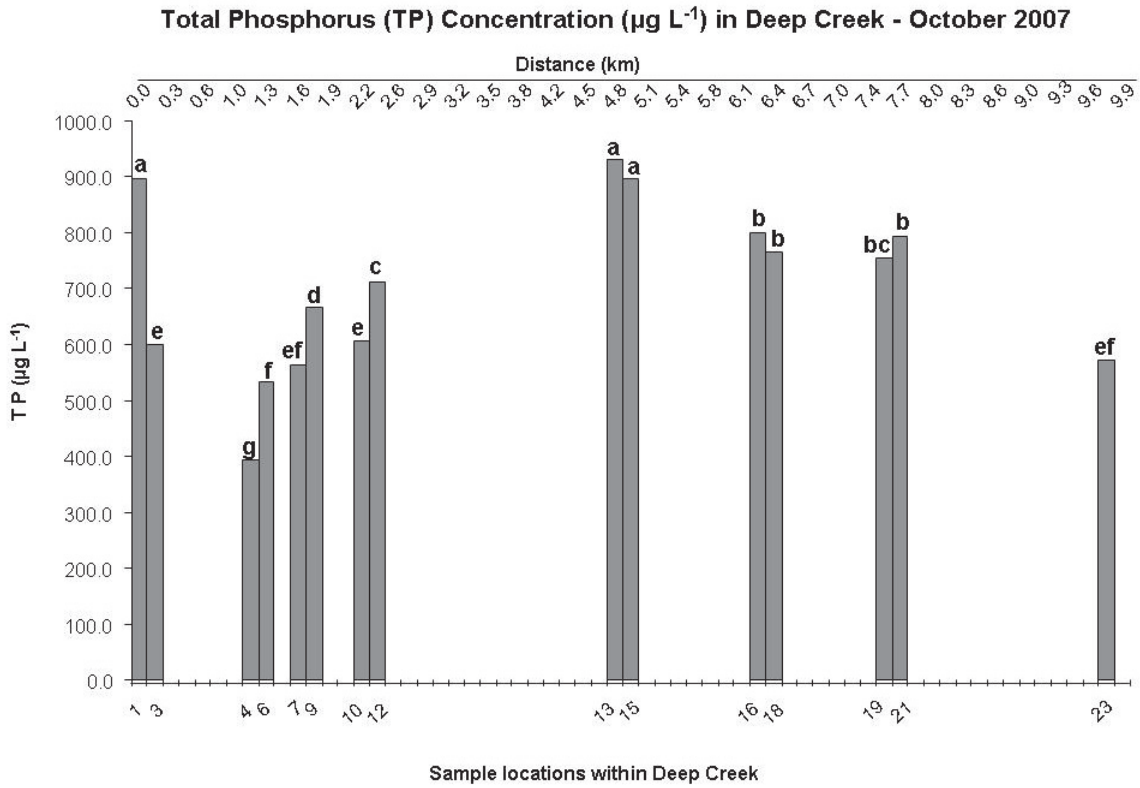
Deep Creek water flow. Water flow in Deep Creek was recorded with a Sontek flow meter managed by the U.S. Geological Society located 29°43.778´N; 81°29.223´W. Water flow in the creek at this site was downloaded from the USGS website at each sample date. Tide predictions were recorded from the National Oceanic and Atmospheric Administration website for tide station # 8720625 at Racy Point, FL on each sample date.

Statistical analysis. A general linear model was used to determine water nutrient concentration for the month of Oct. 2007 using SAS 9.1. Means were separated using Duncan's multiple range test as implemented in SAS (SAS Institute, 2004). Proc Corr was used to determine the correlation between water nutrient parameters total P and NO_3-N and the correlation with blue-green algae, chlorophyll a, dissolved O_2, pH, specific conductivity, and water temperature.

Results and Discussion

Water nutrient concentration. Total rainfall for the month of Oct. was 14.3 cm. Total P (μg·L^{-1}) and nitrate-N (mg·L^{-1}) concentrations within Deep Creek were significantly different among sample sites for the month of Oct. 2007. Total P concentration within Deep Creek at the 1st, 13th, and 15th sample locations were significantly higher compared with all other sample sites with total P concentrations of 896.4, 930.7, and 896.9 μg·L^{-1}, respectively. Total P concentrations within the tributary (14th sample site; 1131.5 μg·L^{-1}) (data not shown) most likely contributed to the significantly higher total P concentrations at the 13th and 15th sample sites (Fig. 2a). The tributary (sample site 14) located within this sub-basin drains approximately 33% and 17% urban and field crops, respectively, compared with an average of 45% and 10% urban and field crops, respectively, for the other sub-basins (tributaries) sampled. Higher urban density in this area may also suggest the higher total P concentrations in this section of Deep Creek. Average total P concentration in Deep Creek over the reported period was 698 μg·L^{-1}. Lillie and Mason (1983) devised a water quality index for total P concentrations for Wisconsin's natural lakes and impoundments. They reported that water bodies with a total P concentration between 0.01 and 50 μg·L^{-1} were considered excellent to fair, while water bodies with total P concentration above 50 μg·L^{-1} were poor, and those above 150 μg·L^{-1} were considered very poor. Nitrate-N concentrations were also significantly higher at sample site 13 in Deep Creek at 0.8 mg·L^{-1} (Fig. 2b).

A significant correlation ($P \le 0.0382$) between total P and chlorophyll a was observed. Chlorophyll a increased as total P increased. Alternatively, a significant inverse relationship was observed between NO_3-N concentration and chlorophyll a. As NO_3-N concentration decreased, chlorophyll a increased ($P \le 0.0045$). Additionally, as total P concentration decreased, NO_3-N concentration increased ($P \le 0.0001$). This may also explain the inverse relationship of chlorophyll a to NO_3-N concentration. There was no significant correlation between total P and blue-



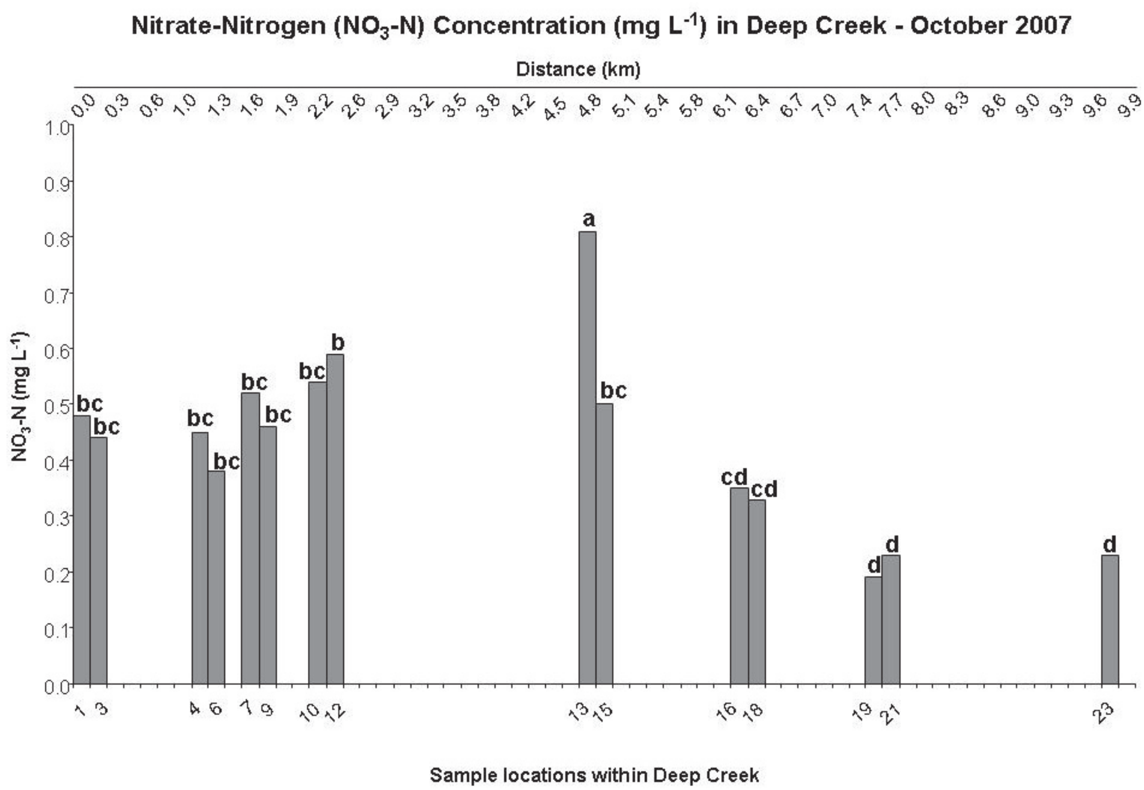


Fig. 2. (**a, top**) Total P and (**b, bottom**) Nitrate-N concentrations at sample sites within Deep Creek. Sample sites within tributaries were not displayed graphically and designated as (sample site #s 2, 5, 8, 11, 14, 17, and 23). Sample site #22 was not displayed graphically due to inaccessibility of the tributary and inability to collect data during the month of October.

Table 1. Water quality parameters—temperature, pH; specific conductivity (SC), chlorophyll a, blue-green algae (BGA), and dissolved O_2 (DO)—in Deep Creek, FL, Oct. 2007.

Sample date	Temp (°C)	pH	SC (μs·cm^{-1})	Chlorophyll a (RFU)	BGA (mg·L^{-1})	DO (mg·L^{-1})
3 Oct. 2007	24.8 c[z]	6.9 b	423 d	3.9 b	1693 b	4.1 a
4 Oct. 2007	25.4 a	6.8 c	448 c	3.5 c	1687 b	3.1 b
11 Oct. 2007	25.1 b	7.1 a	620 b	4.6 a	2583 a	1.9 d
31 Oct. 2007	22.1 d	7.1 a	670 a	2.9 d	1423 c	2.4 c
Std Err	0.14	0.01	13.80	0.07	63.1	0.15
CV	0.06	0.33	0.38	4.15	11.5	15.9
R^2	0.99	0.99	0.99	0.98	0.97	0.97

[z]Means followed by a different letter are significant at the $P \leq 0.05$ using Duncan's multiple range test.

green algae concentrations ($P \leq 0.8885$). Although nonsignificant, an increasing trend in blue-green algae concentration was noted as NO_3-N concentration decreased ($P \leq 0.0827$).

Automated water quality evaluation. Chlorophyll a and blue-green algae concentrations were significantly higher on the 11 Oct. sample date compared with all other sample dates at 4.6 relative reflective units and 2,583 mg·L^{-1}, respectively. Dissolved O_2 concentrations on 11 Oct. were significantly lower (1.9 mg·L^{-1}) compared with all other sample dates (Table 1). The Florida Department of Environmental Protection and the Environmental Protection Agency have determined that dissolved O_2 levels in the lower St. Johns River basin should be maintained between 4.0 and 5.0 mg·L^{-1} (Florida Department of Environmental Protection and Environmental Protections Agency website). Due to the elevated total P concentrations in Deep Creek, the Deep Creek basin was most likely N limited during the sampling period of this study. Continued data collection will determine if the Deep Creek basin is N limited throughout the year. While no overall conclusion can be determined at this time, continued data collection will facilitate the understanding of the dynamics of nutrient transport in the Deep Creek basin and its effects on the St. Johns River.

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