Impact of storm water treatment area discharge on P concentrations of L40 canal using generalized linear mixed model approach

Manohardeep S. Josan[1], Samira H. Daroub[1], Timothy A. Lang[1], Orlando Diaz[2] and Michael G. Waldon[3]

[1]Everglades Research and Education Center, Belle Glade, FL; [2]South Florida Water Management District, West Palm Beach, FL; [3]U.S. Fish and Wildlife Service, Lafayette, LA

INTRODUCTION

Phosphorus (P) is the most limiting nutrient in Everglades' wetlands, its role in the eutrophication of the Arthur R. Marshall Loxahatchee National Wildlife Refuge, hereafter called refuge, led to a Federal environmental lawsuit. This prompted the South Florida Water Management District (SFWMD) to construct seven wetlands, called the storm water treatment areas (STAs). The function of STAs is to treat P enriched runoff received from the Everglades Agricultural Area (EAA) and urban communities. Storm water runoff primarily from the EAA and surrounding urban communities is pumped into the canal system where it flows to STAs and mixes into the rainwater-dominated interior of the refuge. The refuge is designated to maintain the remnant Everglades' ecosystem to its historic ecological conditions. High drainage outflow from STA-1E can change distribution and concentrations of P along the L40 canal. Since its operation in 2006, STA-1E has retained a significant amount of total-P that otherwise can impact the refuge (SFWMD, 2010). Therefore, it was hypothesized that flow from STA-1E has higher P and other dissolved nutrients than the background levels found in the refuge. In addition, discharge from STA-1E has the potential to impact the water quality of perimeter canal L40, subsequently affecting considerable area inside the refuge.

OBJECTIVES

- To investigate the patterns of drainage flow, TP concentrations and TP loads of STA-1E discharge.
- To evaluate the effect of drainage (flow and noflow) from STA-1E, season (dry and wet), wateryear, and distance (from the discharge structure of STA-1E) on L40 canal and refuge water quality.

MATERIALS & METHODS

- Twelve sampling locations; three above and nine below the STA-1E discharge structure S362 were selected for the water quality survey study (Fig. 1). Data were categorized into 3 wateryears (WY) (WY2007=May 1, 2006-April 30, 2007; WY2008=May 1, 2007-April 30, 2008; WY2009=May 1, 2008-April 30, 2009). We conducted 9, 8, and 12 water surveys in WY2007, WY2008, and WY2009 respectively. For each sampling period one grab water sample was collected from the middle of the canal at each site.
- Water discharge data from the S362 structure were obtained from the SFWMD data web portal, DBHYDRO, for the 3 water years. Sampling dates were selected on the basis of drainage schedule of STA-1E outflow structure S362. Monthly averages of flow, P concentrations and P loads were calculated.
- Water surveys were categorized into noflow and flow drainage condition, and into wet & dry seasons. All water samples were analyzed for total-P (TP) using EPA method 365.1.
- Analysis of variance was performed on TP data using PROC GLIMMIX in SAS 9.2. The fixed effects quantify the overall effects of drainage, distance, wateryear, and season; the random effects quantify the effects of repeated measures taken on each sampling station. Distance was used as a second order term to accommodate non-linear effect of sampling locations from the discharge structure. The variance function was blocked by sampling stations. Data was log-transformed, and the linearity of the continuous variables was tested by plotting both studentized residuals and Pearson residuals of the response variable. Restricted maximum likelihood used as a default estimation technique since we provided the log function and auto regressive covariance structure. In the model building we also used an R-side random statement to account for over dispersion.

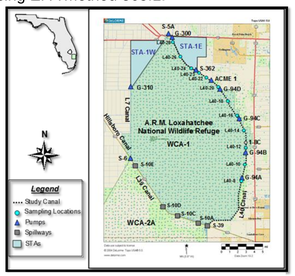

Figure 1. Sampling locations and main structures in the L40 canal.

RESULTS & DISCUSSION

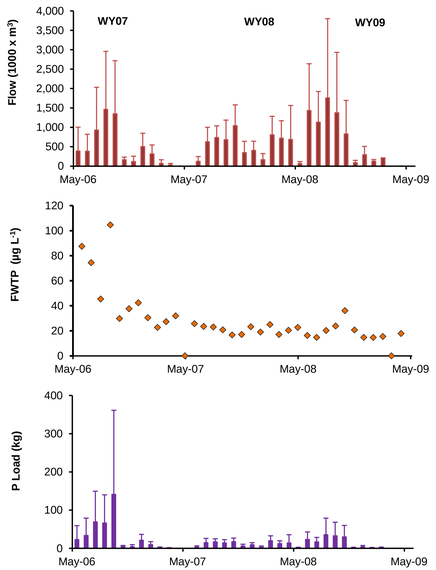

Figure 2. Monthly average drainage flows, flow weighted total-P (FWTP) concentrations, and P loads from STA-1E (structure S362) during the study period. *Error bars* represent the standard deviation of the mean.

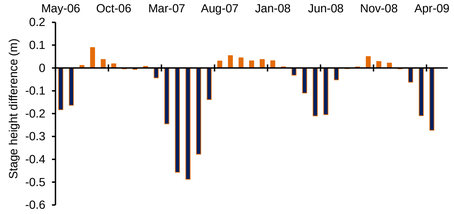

Figure 3. Time series of stage height, m msl (NGVD 1929), difference between the canal water elevation and refuge water elevation.

STA-1E drainage behavior and total-P loads

- During WY2007, S362 discharged 1.2x10^8 m^3 of water into the L40 canal with a TP load of 8.6 mt and a FWTP concentration of 71 µg l^{-1} (Fig. 2). For WY2008, the volume of treated water discharged into the L40 canal was 1.6x10^8 m^3, with a total-P load of 3.1 mt and a FWTP concentration of 20 µg l^{-1}. During WY2008, S362 discharged 28% more treated water into the L40 canal than the WY2007; however, there was a reduction of 64% in total-P loads (SFWMD, 2009). Whereas, during the WY2009, the volume of treated water discharged into the L40 canal were 1.8x10^8 m^3, with a total-P load of 3.9 mt and a FWTP concentration of 21 µg l^{-1} (SFWMD, 2010). During same time period, S362 released 18% more treated water into the L40 canal than the previous water year and resulted in an increased total-P load (24%). Comparing with WY2007, there was a 54% reduction in total-P load during the WY2009.
- STA-1E discharged more treated water during WYs2008 and 2009 due to increase in received runoff from Wellington Acme Basin B, which resulted in a larger watershed (SFWMD, 2010), although 2008 & 2009 were the drought years.
- During the three wateryears, L40 canal stage exceeded by a maximum of 0.1 m, while refuge stage exceeded by a maximum of 0.5 m (Fig. 3). The positive change between canal and refuge stage height has been linked to the canal water intrusion (Harwell et al., 2005, USFWS 2007), which can impact the refuge water quality significantly, especially interior sections ranging from 0.0-1.1 miles (Table 2).

Impact of STA-1E drainage flow on L40 total-P concentrations

- Average TP concentrations during the WY2007 were significantly higher than during WYs 2008 & 2009 (Table 1 & 3). The lower TP concentrations during the WYs 2008-2009, can be attributed to multiple factors such as (a) improved STA-1E performance with time (Fig. 2), (b) general recovery of STA-1E from the damaged caused by the WY2005 hurricanes, (c) better water management strategies adopted during 2008 and 2009 in the STA-1E.
- Overall the canal water TP concentrations during the wet seasons were higher (54.3 µg l^{-1} ± 32.7) than the TP concentrations in dry seasons (34.3 µg l^{-1} ± 19.3). During the wet seasons in WY2007 and WY2008 the TP concentrations in surface water was significantly higher ($p<0.05$) as compared to the dry seasons (Table 1). However, during WY2009 the surface water TP values were lower in wet season (33.2 µg l^{-1} ± 14.2) as compared to the dry season in WY2009 (36.4 µg l^{-1} ± 22.6).
- Seasonal changes and drainage flow from the STA-1E had the most significant impact on the total-P concentrations of L40 canal. During WY2007, TP concentrations declined significantly with distance from discharge structure (Table 3).

Table 1. Effect of drainage and season in the L40 canal water total-P concentrations (µg l^{-1}).

	Drainage		Season	
	Flow	Noflow	Dry	Wet
Overall	48.3^a	39.7^a	34.3^a	54.3^b
WY2007	69.5^a	51.4^b	43.4^a	74.1^b
WY2008	38.1^a	28.8^b	24.5^a	50.8^b
WY2009	31.0^a	37.5^b	36.4^a	33.2^a

$p<0.05$, mean separation by Tukey's HSD, data were log-transformed, however, actual values are presented.

Table 2. Surface water TP (µg l^{-1}) along a transect extended from the L40 canal to the refuge interior.

Distance (m)	Total-P†
0	37.5(23.3)
0.6	21.0(18.9)
1.1	11.2(8.1)
2.1	7.47(2.1)
3.9	7.38(1.6)

† average values for three water years; standard deviation in parenthesis.

Table 3. Final generalized linear mixed model for log total-P concentrations (µg l^{-1}) based on L40 canal water samples collected during different drainage conditions.

Parameters	b	S.E. (b)	95% CI of b	P
Intercept	3.508	0.090	-	<0.0001
Wateryear[a] (WY)				
2007	0.506	0.102	0.295, 0.717	<0.0001
2008	-0.335	0.123	-0.589, -0.079	0.0125
2009	0.0	-	-	-
Interaction terms[b]				
Distance x drainage				
Distance x Flow	0.024	0.009	0.005, 0.042	0.011
Season x drainage				
Dry x Flow	-0.812	0.107	-1.045, -0.577	<0.0001
Distance x wateryear				
Distance x WY2007	-0.028	0.009	-0.048, -0.009	0.003
Distance x WY2008	-0.009	0.011	-0.029, 0.012	0.408
Drainage x wateryear				
Flow x WY2007	0.512	0.125	0.253, 0.771	0.001
Flow x WY2008	0.746	0.142	0.452, 1.040	<0.0001
Sampling station variance estimates	0.143 (0.058)			
Residual variance	0.196 (0.015)			

[a] Wateryear: May through April. [b] The terms present in the interaction with zero *b* are not shown. Non-significant parameters are not presented.

CONCLUSIONS

- Environmental factors such as rainfall distribution (dry or wet season), intensity, and occurrence of major events such as tropical storms play a key role on the drainage frequency & intensity of perimeter canals of refuge.
- Stabilization of STA-1E with time improved water quality of L40 canal. Interior refuge sections along the L40 canal were impacted (had high total-P concentrations) as compared inner parts during the three WYs.
- Periodic measurement of canal sediment properties will further our understanding on the effects of various discharge events from STA drainage structures and downstream sediment movement.

ACKNOWLEDGEMENTS

Funding and collaboration by the U.S Fish and Wildlife Service personnel of the Arthur R. Marshall Loxahatchee National Wildlife Refuge is greatly appreciated. Project was also supported by the Florida Agricultural Experiment Station.