Nutrient Dynamics of an Actively Farmed Delta Peat Island

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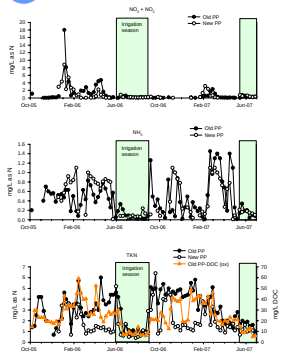
1 Introduction

This poster presents data from a CALFED funded study (ERP-02-P08) between Ducks Unlimited, the Nature Conservancy and DWR. Due to the difficulties of access, and/or lack of actual pumping measurements, quantifying nutrient loads produced by in-Delta agriculture are lacking. Because there is no data, researchers have often been forced to estimate loads by pairing estimates of flows collected in one year with concentration data collected in another. Power usage records to estimate flow are hampered by not knowing pump efficiencies. This study addresses this gap by directly measuring flow and concentration, providing a highly accurate estimate of nutrient loading from an actively farmed Delta Peat Island.

2 Materials and Methods

The data from this study quantified nutrient loading from samples collected between October 2005 to June 2007. This allowed comparisons between 2 year types-2006 which was classified as wet, and 2007, which was classified as critical. A total of 173 grab samples were collected from the 2 pump stations. Samples were collected weekly from the 2 pump stations on the island for nitrate + nitrite, ammonia, Total Kjeldahl nitrogen (TKN), total phosphate, and dissolved orthophosphate. Flow data was collected every 15 minutes from each of the 4 pipes at the 2 pump stations. Of the 2 pump stations, the new pump station was not active until the 2006 summer irrigation season.

3 Results-Nitrogen Patterns

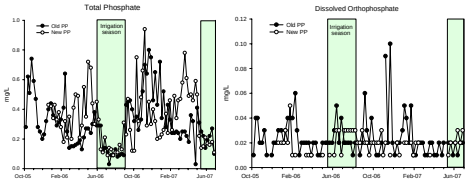


$NO_3 + NO_2$ patterns were similar between wet and critical years, however actual concentrations were different between the 2 year types. In both year types, highest concentrations occurred when the species were mobilized by rainfall or pumping. The lowest concentrations were always observed during the irrigation season.

Like other nitrogen species, NH_3 levels fell dramatically soon after the application of irrigation water, however unlike $NO_3 + NO_2$, NH_3 levels following the irrigation season increased. Increases corresponded to non-detects for $NO_3 + NO_2$, suggesting -among other things- that the turnover from oxic surface water to anoxic groundwater reduced nitrate to N_2 or NH_3.

Like NH_3, TKN also increased following the summer irrigation season. TKN measurements were well correlated with organic carbon patterns, especially at the old pumping plant (Pearson's r = 0.71).

4 Results-Phosphate Patterns



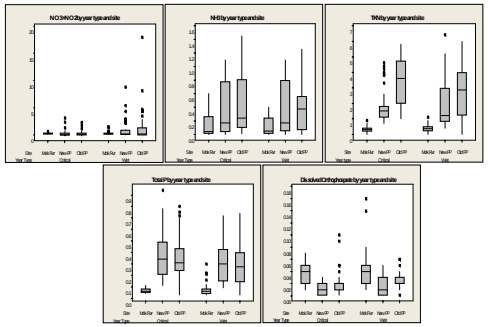
Like nitrogen species, total phosphate concentrations fell at the start of the irrigation season and began to increase after the last application of irrigation water.

Relative to other nutrient species, dissolved orthophosphate generally showed less variability.

In addition to seasonal patterns, median concentrations from Oct. 05-Jun. 07 (mg/L as N or P) are shown in the table below.

	$NO_3 + NO_2$	NH_3	TKN	Total Phosphate	Dissolved Orthophosphate
Old Pumping Plant	0.12	0.29	3.00	0.28	0.02
New Pumping Plant	0.07	0.17	1.40	0.32	0.01
Mokelumne River	0.18	0.04	0.3	0.06	0.04

5 Results-Wet vs. Critical Year Types



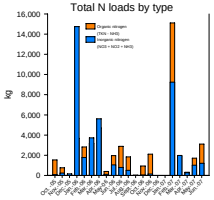
Although samples were collected in completely opposite year types (wet vs. critical), year type often had little impact on observed nutrient concentrations. For example, regardless of the site, ammonia and total phosphorus median concentrations were not significantly different between the 2 year types (p at least 0.81 and 0.06, NH_3 & total P respectively, Mann-Whitney). Other species showed some statistical differences, but there was no pattern associated with site (for example, at the new pumping plant $NO_3 + NO_2$ median concentrations were significantly different (p = 0.0051, Mann-Whitney), but differences were not seen at the old pumping plant. Conversely, TKN, wet season median concentrations at the old pumping plant were significantly different from those measured in the dry (p = 0.025, Mann-Whitney), but this difference between year types was not observed at the new pumping plant.

6 Results-Loading Patterns

Actual loads were calculated every 7 days when discrete samples were collected. The remaining daily loads were calculated using actual flow measurements and interpolation between weekly concentration values. Loads calculated over the entire study period are presented below, however a full water year was only collected for the 2006 WY, therefore loading metrics are only presented for this water year.

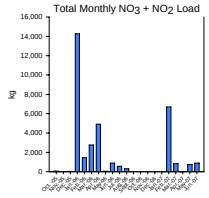
With the exception of orthophosphate, the greatest nutrient loads were observed during the winter.

Nitrogen Loads



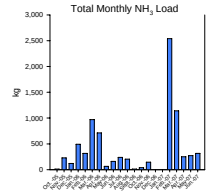
Total N discharged in 2006 calendar year represented approximately 28% of the nitrogen fertilizer applied to the island.

Total inorganic N discharge in 2006 WY = 28,814 kg
Total organic N discharged in 2006 WY = 23,854 kg



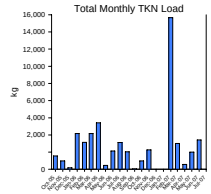
During the wet winter of 2006, approximately 18,467 kg of $NO_3 + NO_2$ was discharged off the island between January and March compared to 7,530 kg over the same period in 2007. Differences in loads between the 2 winters was NOT due to changes in pumping (in fact pumping was lower in the winter of 2006 than 2007), but due to the increased mobilization of labile N from increased precipitation.

Total $NO_3 + NO_2$ discharged in 2006 WY = 25,289 kg



Due to only 1 pump station on-line, maximum pumping rates in the winter of 2006 were half those of the winter of 2007. NH_3 concentrations were similar between the 2 winters, but much higher loads were observed in the winter of 2007 compared to winter 2006. This suggests that unlike $NO_3 + NO_2$, the volume of water pumped, not precipitation was a better predictor of NH_3 winter loading.

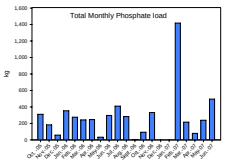
Total NH_3 discharged in 2006 WY = 3,525 kg



TKN monthly load patterns appeared similar to NH_3 patterns above.

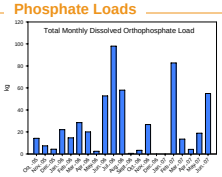
Total TKN discharged in 2006 WY = 27,379 kg.

Phosphate Loads



Total P discharged in the 2006 calendar year represented approx. 5% of the phosphorus fertilizer applied to the island.

Total P discharged in 2006 WY = 2,701 kg



Unlike other nutrients, the greatest dissolved orthophosphate loads occurred during the summer irrigation season. This also corresponded to the analytes' highest concentrations.

Total Orthophosphate discharged in 2006 WY = 325 kg

7 Load Comparisons

Nutrient loads from a Delta peat island have never been directly quantified. Measured inorganic N loads (and rates) from Staten Island were compared to estimates of loads and rates from another high peat island (Twitchell Island). As shown in the table below, inorganic N loads from Staten Island were substantially lower than those calculated for Twitchell, however nutrient loads for Twitchell Island were estimated using average pumping rates in 1994 and 1995 combined with values collected between 1995 and 2000. Additionally, Staten Island's yearly loading rates were higher for both N & P than those of other local agricultural areas (CBD or Mud Slough).

Staten Island's N loading numbers were extrapolated to the area encompassed by the 35 Delta islands and tracts classified as high carbon peat islands. Comparing this value to estimates of Delta agricultural contributions of inorganic N loading (TetraTech, 2006) suggested that high peat islands may contribute up to 40% of the inorganic N load attributed to agricultural drainage in the Delta. Similarly, extrapolated calculations for total P loads suggested that either estimates of total Delta ag drainages were low or that extrapolating results from this study to the rest of high carbon peat islands was not feasible.

Nitrogen

	Year Type	Inorganic N Load (kg)	Inorganic N Loading Rate ($g/m^2/yr$)	Organic N Load (kg)	Organic N Loading Rate ($g/m^2/yr$)	Total N Load (kg)	Total N Loading rate ($g/m^2/yr$)
Staten Island (2006 Calendar Year)	W	28,527 ($NO_3 + NO_2 + NH_3$)	0.85	24,564	0.72	53,091	1.57
Twitchell Island*	Mostly W year types. Flows and samples collected in different years & by different agencies.	76,903 ($NO_3 + NO_2 + NH_3$)	4.02	--	--	--	--
Mokelumne River†	W					180,903	0.06
CBD-Sac river ag drainage†	W	‡1.05×10^6	--	--	--	--	0.25
Mud Slough-SJ river ag drainage†	W	--	--	--	--	--	0.74
Extrapolation to high C islands		7.00×10^5 ($NO_3 + NO_2 + NH_3$)	0.84	6.03×10^5	0.72	1.30×10^6	1.56
All Delta ag drainage†		1.63×10^6 (NO_3 only)	0.86	--	--	--	--

* Brown & Caldwell, 2005 † TetraTech, 2006, ‡ used area provided by Saleh, 2003 -- data not available

Phosphate

	Year Type	Total P Load (kg)	Total P Loading rate ($g/m^2/yr$)
Staten Island (2006 Calendar Year)	W	2,575	0.08
Twitchell Island	--	--	--
Mokelumne River†	W	32,891	0.01
CBD-Sac river ag drainage†	W	‡2.01×10^5	0.05
Mud Slough-SJ river ag drainage†	W	--	0.02
Extrapolation to high C islands		63,197	0.08
All Delta ag drainage†		51,030	0.03

* Brown & Caldwell, 2005 † TetraTech, 2006 ‡ Used area provided by Saleh, 2003 -- data not available

8 Conclusions

1. Nutrient concentrations were generally higher in the winter than in the summer.
2. With the exception of dissolved orthophosphate, nutrient concentrations immediately fell as soon as the summer irrigation season began. Concentrations immediately increased following the cessation of irrigation water (NH3, TKN, Total P) or were mobilized later in the season due to winter rains ($NO_3 + NO_2$).
3. Organic N seasonal patterns were similar to those of organic carbon, especially where peat soils predominated.
4. There was no general pattern with respect to changes in nutrient concentrations with year type. Year type did not affect NH_3 or total P concentrations at any site.
5. In the 2006 calendar year the total loads discharged from Staten Island were 53,091kg and 2,575 kg for total nitrogen and phosphorous, respectively.
6. Loading rates for both nutrient groups were greater than other agricultural areas draining to the Delta.
7. Extrapolating the results from Staten island to other high peat islands in the Delta suggested that approximately 1.3 x 10^6 kg of nitrogen and 63,197 kg of phosphorus might be discharged into the delta during a predominantly wet year.

Literature Cited

Brown and Caldwell. 2005. Joint study to identify projects of mutual benefit to SRCSD and water agencies. http://www.sacriver.org/documents/2006/JointStudy/SRCSDWaterAgencies.pdf.

Saleh, D. K., J. L. Domagalski, C. R. Kratzer, and D. L. Knifong. 2003. Organic carbon trends, loads, and yields to the Sacramento-San Joaquin Delta, California, Water Years 1980-2000. U.S. Geological Survey Water-Resources Investigation Report 03-4070. 77 pages.

Tetra Tech Inc. 2006. Conceptual model for nutrients in the Central Valley and Sacramento-San Joaquin Delta. Final Report, September 20, 2006. http://www.swrcb.ca.gov/rwqcb5/available_documents/dw-policy/Cover_TOC_ES.pdf.