Revised 05-25-12

Analytical Results of Nutrients and Chlorophyll Relative to the 2008 Fertilizer Ordinance in Lee County

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Introduction

During the summer months in southwest Florida, storm water ponds exhibit from time to time frequent algae blooms. It is thought that a major contributor to these algae blooms was the increased amount of nitrogen (N) and phosphorus (P) contained in the fertilizer that enters the ponds, via washed off lawns, storm water runoff from impervious surfaces and water that percolates through predominant sandy soils.

In 2008, Lee County Board of Commissioners enacted a fertilizer ordinance (Ref 1) which became mandatory during the wet months of 2009. Among many best management practices, the ordinance prohibits the application of nitrogen (N) and phosphorus (P) (from fertilizers) during the 4 wet summer months (June through September) with the stated objective of lessening loads (and concentrations) of nutrients in storm water ponds and other waters that runs into major bodies of water.

Lee County Hyacinth Control District has the program Pond Watch, which has been in existence since the early 90s. The program is a citizen volunteer monitoring initiative that involves numerous storm water ponds which are sampled and analyzed monthly to help understand and manage the ponds. This paper examines the Pond Watch data to compare the amount of nitrogen, phosphorus and chlorophyll A regarding the implementation of the fertilizer ordinance.
The specific question addressed by this paper is whether it has been a difference in the amount of nutrients present in the water of storm water ponds in the summer months of 2009, 2010, and 2011 when compared to the prior years, 2004 through 2008.

Data and Methodology

Rain Data

Data was gathered from the Lee County, Natural Resources, Hydrological Monitoring Group website (Ref 3). The averages of 16 sites were tabulated to determine differences between summer rainy months (June through September) and the dry months (October through May). These averages were determined by calculating the cumulative daily average rain for each of the four summer months and the eight dry months in every year between 1992 through 2011.

Water Quality Data and Analysis

Pond Watch receives water samples for analysis every month, from about 20 community ponds in Lee County. In the interest of having an appropriate set of ponds for comparison, we selected ponds with the following basic characteristics.

Ponds range in surface area between 0.5 to 18 acres and a maximum depth of 12 ft. Ponds were surrounded by housing facilities, lawns maintained by private contractors, and sampling data available since 2004 to the present. There were 9 ponds that meet the criteria. These ponds are shown in Table 1.

	Pond Watch ID	Location	Acres	Longitude	Latitude
1	1	Stone Bridge	1	-81.896515	26.506573
2	4	Peppertree Pointe	5.3	-81.949689	26.519921
3	14	South Pointe South	5	-81.909797	26.547372
4	35	Corkscrew Woodland	18.5	-81.777317	26.424099
5	37	Wellington	6.4	-81.900010	26.502472
6	42	Wyldewood Lakes	0.5	-81.888100	26.562310
7	47	South Wind	7.8	-81.897330	26.485810
8	54	Candlewood Lake	15.5	-81.966610	26.509190
9	57	Calosa Creek	10	-81.969470	26.513330

Table 1. Nine ponds selected from the Pond Watch Program to evaluate nutrient contents.

The data used for the comparison was the average of nutrients in the rainy months, because the fertilizer ordinance restricts the application of fertilizers in the months between June and September.

Chemical analyses of the pond water were conducted at the Water Quality Laboratory of the Lee County Hyacinth Control District (DOH Certification # E25945, Florida USEPA ID. FL01214). Total phosphorus (TP) was determined using the ascorbic acid method (Standard Method 4500PE). Total Kjeldahl Nitrogen (TKN) was determined using the block digestion procedure (Standard Method 4500ND) followed by the phenolic method of ammonia determination (Standard Method 4500NH3F). Chlorophyll A (Chl A) analyses were determined by acetone extraction with fluorometric analysis (EPA Method 446.0 and 445.0).
The data 'pre' ordinance years were from 2004 through 2008 because TKN analysis was introduced in 2004. 'Post' ordinance years were from 2009 through 2011.

Statistical analysis

The comparison of the data was done by grouping parameters independently (Total Phosphorus, Total Kjeldahl Nitrogen, and Chlorophyll A) for the wet months (June, July, August, and September) in the years before (pre) the ordinance went into effect with the same wet months the years after (post) the ordinance was in effect.
The consolidated tabulation for all 9 ponds and their parameters were performed using MS-Excel (version 2007). The parametric statistic technique used for the comparison was t test since the 2 groups of data (pre and post) are independent and have a normal distribution.

Results and Discussion

Rain Data Analysis

Certainly, rainfall is much greater in the 4 wet months of summer, June through September, compared to the other dry months. The cumulative distribution of average rain for each of the 12 months of the last 20 years (1992 to 2011) is plotted in Fig. 2. The 4 wet months (June through September) have an average monthly rainfall of 9.8 inches. The 8 'other' months have an average of 2.6 inches.

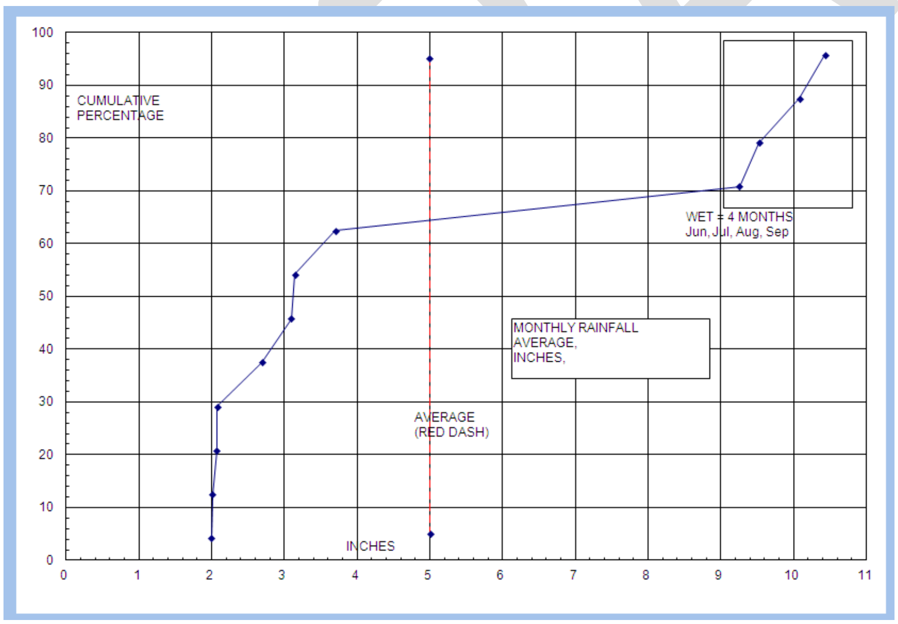

Fig. 2 Cumulative distribution of average rain from 1991 to 2011 in Southwest Florida

We have gathered data on the amount of rainfall in the summer months. When we first compiled the results for 2009, we received a comment that the rainfall had been unusually low for this year. We plotted the total rainfall for the summer months per year to show the cumulative distribution (Fig.3). The smooth red line shows the normal distribution based on the average and standard deviation for the data. Utilizing the one-tail comparison for 19 points of data (degree of freedom, n-1), the 2009 summer value was at the 10% probability and the 2010 summer was at 15 % probability. It is true that the rainfall was on the low side, but not the extreme of 2 sigma or more, meaning that there were no significant difference (p<.10) between the amount of rain on 2009, 2010 and 2011, vs. the years 1992 through 2011.

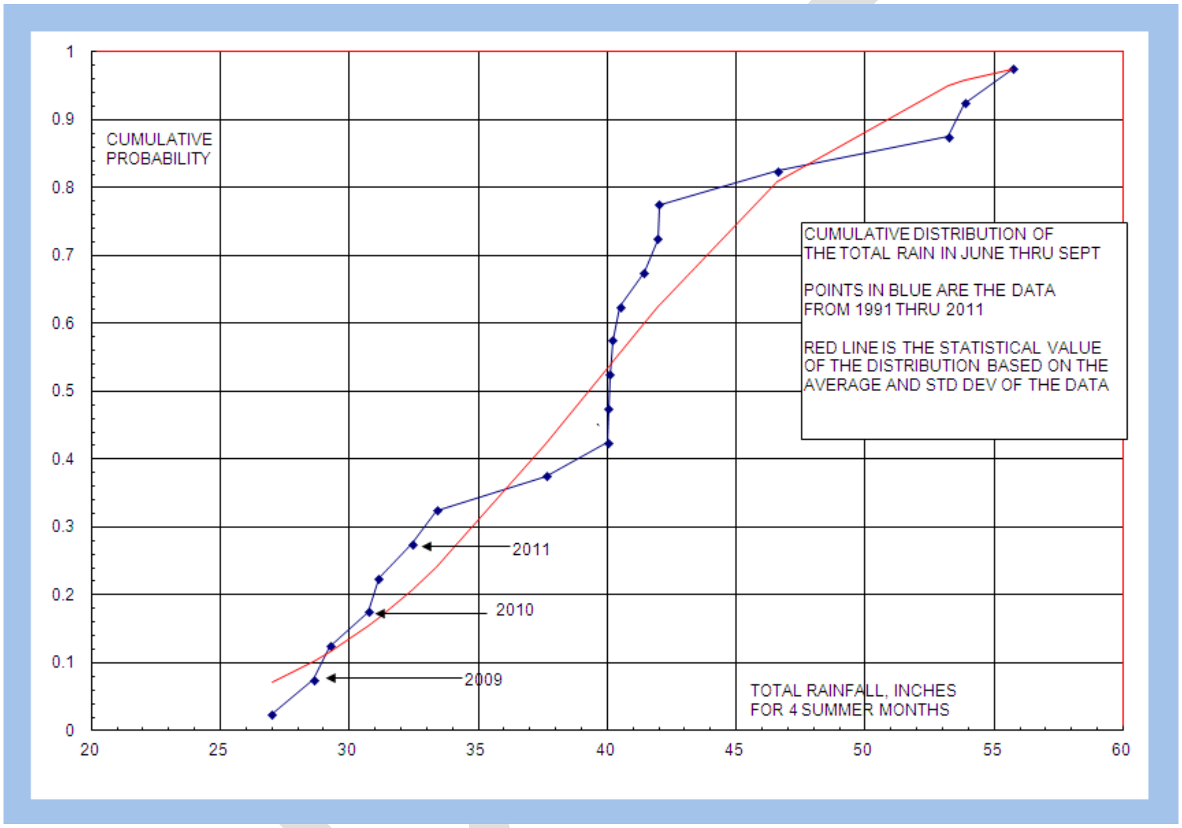

Fig. 3 Cumulative distribution of total rain in wet months from 1991 to 2011 in SW Florida

Analysis of all Parameters

All monthly data for the 9 ponds are presented in tables in Appendix A. The tables have been grouped as Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN) and Chlorophyll A (ChlA) per pond, presenting the average for the 'pre' and 'post' ordinance years. All concentrations for TP and TKN are in mg/L, and concentrations for ChlA are expressed in ug/L. An example for TP for Pond 1 is presented in Table 2 bellow.

TABLE P-1

PHOSPHORUS (total P) DATA FOR 9 PONDS, MONTHLY AND YEARLY

(mo)				seq nbr 1	**Pond 1**	**Stone Bridge**			pre	post	pre	post	post/pre
TP	2004	2005	2006	2007	2008	2009	2010	2011	avg 2004	avg 09	avg 2004	avg 09	% (09 to 11)
mg/L	------------------------ years pre ordinance				--------------------	<----------- years post ord		---------	to 2008	10 & 11	to 2008	10 & 11	gt (04 to 08)
1	0.055	0.072	0.043	0.065	0.089	0.030	0.048	0.076	0.065	0.051	mo 1 to 5	mo 1 to 5	mo 1 to 5
2	0.085	0.048	0.064	0.072	0.085	0.057	0.080	0.071	0.071	0.069	0.079	0.059	-25.5
3	0.097	0.135	0.098	0.061	0.092	0.081	0.054	0.066	0.097	0.067			
4	0.067	0.127	0.109	0.100	0.099	0.058	0.060	0.062	0.100	0.060	**all dry mo**	**all dry mo**	**all dry mo**
5	0.055	0.091	0.071	0.031	0.070	0.052	0.044	0.047	0.064	0.048	**0.072**	**0.055**	**-23.8**
6	0.050	0.257	0.158	0.064	0.053	0.010	0.041	0.043	0.116	0.031			
7	0.206		0.124	0.138	0.394	0.032	0.054	0.058	0.216	0.048	**wet mo**	**wet mo**	**wet mo**
8	0.172	0.077	0.083	0.093	0.106	0.042	0.057	0.052	0.106	0.050	**0.118**	**0.056**	**-52.3**
9	0.073	0.038	0.064	0.049	0.044	0.105	0.121	0.060	0.054	0.095			
10		0.059	0.065	0.076	0.046	0.040	0.041	0.068	0.061	0.050	mo 10 to 12	mo 10 to 12	
11		0.064	0.060	0.017		0.034	0.048	0.060	0.047	0.047	0.057	0.048	-15.9
12		0.065	0.068	0.051	0.054		0.049	0.041	0.059	0.045			
all dry, avg	0.072	0.083	0.072	0.059	0.076	0.050	0.053	0.061	0.072	0.055			
all wet, avg	0.125	0.124	0.122	0.086	0.149	0.048	0.068	0.053	0.118	0.056			
% wet gt dr	74.4	50.2	69.4	45.9	94.8	-5.3	28.3	-13.2	63.1	2.2			

Table 2. Example of Excel™ spreadsheet presenting Total Phosphorus data for Pond 1.

Items underlined are data from monthly Pond Watch reports of analysis. Calculated results, such as averages, are not underlined. Data in color red indicate information for the wet months (June through September).

Two different averages have been calculated: 1. in columns, the averages (all dry avg) for the amount of nutrients present in the water column in the 'dry months' (October to May, color black) and the average (all wet avg) of the 'wet months' (June to September, color red) per year; 2. in rows, the average of the amount of nutrients present in the 'pre' vs. 'post' ordinance years per month, and grouped by all dry and wet months.

In the bottom of the table, the averages for the dry and wet months are compared by calculating the percent ratio per year for all wet average months vs. all dry average months. In addition, the comparison of the averages for the pre and post years is presented on the bottom line far right cells.

In the right side of the table, averages are calculated for data per month, pre (2004 to 2008) and post (2009 to 2011). The results are further grouped and summarized in average of all dry months ('all dry mo') and all wet month ('wet mo'). Finally, at the extreme right column of the table, the percent change between pre and post averages is calculated to describe the reduction (a negative value) or an increase (a positive value) of nutrients.

Statistical Analysis

In order to determine the significance for each average generated per pond and per parameter between pre and post fertilizer ordinance, one tail t-test was done independently with a probability of 90%. Appendix B presents tables with individual tables of the results. These analyses were performed for all 9 ponds to determine if there was a significant difference (Probability less than 90%) between the values pre and post ordinance.

The groups of tables bellow (Table 3) present examples of statistical analyses of the three parameters for Pond 1.

Phosphorus			
seq nbr 1	Pond 1	Stone Bridge	
wet mo	pre	post	all
1, N	19	12	31
1, mean	0.1180	0.05631	
1, ss	0.1453	0.009881	
2, s^2			0.005350
3, sd			0.02697
4, diff			-0.06164
4, t			-2.286
5, signf?			yes

Nitrogen			
seq nbr 1	Pond 1	Stone Bridge	
wet mo	pre	post	all
1, N	20	12	32
1, mean	1.577	1.468	
1, ss	5.638	2.377	
2, s^2			0.2672
3, sd			0.1887
4, diff			-0.1088
4, t			-0.5765
5, signf?			no

Chlorophyll-A			
seq nbr 1	Pond 1	Stone Bridge	
wet mo	pre	post	all
1, N	19	12	31
1, mean	27.84	16.53	
1, ss	4116	455.8	
2, s^2			157.7
3, sd			4.630
4, diff			-11.31
4, t			-2.443
5, signf?			yes

Table 3. Example of tables presenting statistical (t-test) analysis for 3 parameters for Pond 1.

In this case, Pond 1 - Phosphorus, is showing that all 31 averages (19 for the pre years and 12 for the post years) present a negative value for the difference (diff: -0.061) indicating that there was a reduction on the concentration of phosphorus present in the water, and this difference is significant (t_{calc}= -2.286) when compared to the t critical value (t_{crit}= -1.320).

The comparison of the change in values between pre and post ordinance were summarized in Table 4. The values presented in the column labeled TP %Change, TKN %Change and Chl A % Change, are the percentage difference of the concentrations of the post values parameters relative to the pre values. These values were calculated with the following formula:

$$\% \text{ Change} = \frac{[(\text{avg } 04\text{-}08) - (\text{avg } 09\text{-}11)]}{(\text{avg } 04\text{-}08)} \times 100$$

pd id	PW id		TP avg 2004 to 2008	TP avg 2009 to 2011	TP % % change	TKN avg 2004 to 2008	TKN avg 2009 to 2011	TKN % change	Chl A avg 2004 to 2008	Chl A avg 2009 to 2011	Chl A % change
1	1	wet mo	0.118	0.056	**-52.3**	1.577	1.468	-6.9	27.84	16.53	**-40.6**
2	4	wet mo	0.193	0.099	**-48.5**	1.289	1.169	-9.3	33.60	26.58	-20.9
4	35	wet mo	0.046	0.022	-52.6	1.013	0.7449	-26.5	18.54	15.45	-16.7
5	37	wet mo	0.140	0.144	2.5	1.489	1.511	1.5	26.11	20.27	**-22.4**
6	42	wet mo	0.160	0.154	-3.5	1.338	1.504	12.3	34.86	19.72	**-43.4**
7	47	wet mo	0.093	0.051	**-45.8**	1.058	1.020	-3.7	11.43	4.654	**-59.3**
8	54	wet mo	0.112	0.069	-38.4	2.522	2.174	**-13.8**	40.26	28.02	**-30.4**
9	57	wet mo	0.160	0.113	-29.5	1.693	1.416	-16.4	32.38	10.21	**-68.5**
		avg of 8	0.128	0.088	-33.5	1.497	1.376	-7.8	28.130	17.679	-37.8
		avg of significant values (bold)			**-48.8**			**-13.8**			**-44.1**
3	14	wet mo	0.223	0.2885	29.2	1.227	0.7364	**-40.0**	24.34	6.866	**-71.8**

Table 4. TP, TKN, ChlA averages concentrations "post" relative to "pre" in percentage.

Values in red represent an increase (positive values) in the amount of the parameter after the ordinance was put in effect. The values in **bold** are statistically significant based on a 1tail t-test at 90% probability level.
The values for Pond 14, listed separate from the group, were eliminated from the overall computation because there were fewer samples for the periods of 2004 to 2008 compared to all the

other ponds. In addition, this pond was treated with a special dye (AQUASHADE™) to minimize light penetration to control underwater submerged plants. This dye increases the amount of phosphorus present in the water therefore a bias could be added by including this pond.

Two averages are presented, the average for 8 ponds and the average of significant values (in bold). In all accounts, a reduction on the amount of the parameters has been established for all ponds (except Pond 14, previously explained); however, significant results were manifested in 3 out of 9 ponds for Phosphorus, 2 out of 9 for TKN, and 7 out of 9 for Chl A.

The overall analysis is presented in Table 5. Every pond is listed and the decrease (in black) or increase (in red) change has been assigned per parameter. If the change was statistically significant, the font is in bold lettering. A column labeled "Overall" is presented to explain whether the overall condition is "OK", meaning that the decrease was determined, or "Treat with caution" meaning that the condition is uncertain due to other circumstances.

	ID	Location	Overall	TP	TKN	Chl-A	Comment
1	1	Stone Bridge	OK	**Decrease**	Decrease	**Decrease**	
2	4	Peppertree Pointe	OK	**Decrease**	Decrease	Decrease	
3	14	South Pointe S	Treat with caution	Increase	Decrease	**Decrease**	Only pre-ord data are 4 points, interf. with treatment
4	35	Corkscrew	OK	Decrease	Decrease	Decrease	
5	37	Wellington	Treat with caution	Increase	Increase	**Decrease**	small not sig. increase
6	42	Wyldewood Lakes	Treat with caution	Decrease	Increase	**Decrease**	small not sig. increase
7	47	South Wind	OK	**Decrease**	Decrease	**Decrease**	
8	54	Candlewood Lake	OK	Decrease	**Decrease**	**Decrease**	
9	57	Caloosa Creek	Treat with caution	Decrease	Decrease	**Decrease**	Only since Aug 2007

Table 5. Summary of the effect of the Fertilizer Ordinance per pond.

Conclusions

The Lee County Ordinance forbidding the application of N and P in fertilizer during June through September came into effect in May of 2009. The Pond Watch Program of the Lee County Hyacinth Control District has collected data in storm water ponds from summer of 2004 to the present for Total Phosphorus, TKN and Chlorophyll A.

Rainfall has been demonstrated to be different between the wet months of June through September as compared to the dry months of October through May. Thus the comparison of "pre-ordinance" and "post-ordinance" reflects only the wet months.

Total phosphorus (TP) was reduced 48.8% and Chlorophyll-A was reduced 44.1 %, where as Total Kjeldahl Nitrogen (TKN) was reduced 13.8 %. These statistical significant values show that the reduction was considerable, but clearly the magnitude for TKN is small.

Five out of nine storm water ponds demonstrated an overall decrease for the nutrient levels as well as the decrease on the effect associated in the concentration of Chlorophyll A.

We are pleased to inform in this study that the Ordinance has had a positive effect in some of the urban ponds that serve as nutrient filtering and holding units for the improvement of water quality discharges to larger bodies of water.

About the authors

Dr. James Ryan is a retired chemical engineer, having specialized in industrial membrane separations, CO_2 separation and recovery from CO_2 EOR oilfields, gas processing plant technology and refining processes. He is a graduate of MIT and U of Michigan. Presently he is a volunteer with the Pond Watch Program involved with storm water ponds and erosion.

Dr. Ernesto Lasso de la Vega is a biologist working at the Lee County Hyacinth Control District in Fort Myers, FL. He is the Pond Watch Coordinator and water quality analyst of the Water Quality Laboratory of the District.

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