EVALUATION OF "ALGAE BLOOM ACTION LEVEL" WITH REGARDS TO COUNTING METHODOLOGY AND HISTORICAL DATA.

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ABSTRACT

Historical City of Austin Water and Wastewater Department phytoplankton data was used to look at phytoplankton community structure in Town Lake and Lake Austin. The data were reviewed and statistically analyzed to examine past trends and evaluate current needs for monitoring. Several methods were investigated to compare phytoplankton groups and better understand the dynamics of the phytoplankton community in Town Lake. In addition, suggestions for revising the "algae bloom" action level are proposed.

INTRODUCTION

Phytoplankton, as the base of the food chain, most readily integrate chemical and physical conditions, in addition to influencing other lake biota (Wehr and Sheath, 2003; Wetzel 2001; Reynolds 1984). Under adverse conditions, algae 'blooms' can produce unpleasant consequences for the recreational and aesthetic uses of the lake. A better understanding of these communities will enable a more resolved view of the influence of nutrients and other factors on the relative health of this aquatic system. In addition, refinements can be made to the methods currently used to assess phytoplankton abundance and 'nuisance' levels.

Currently, City of Austin Water and Wastewater (COA WWW) staff collect phytoplankton grab samples from the Green, Davis, and Ullrich water treatment plants on a near daily basis (Figure 1). These counts have been performed in Town Lake since 1987, and since 1991 in Lake Austin. Until approximately one year ago, species level counts were recorded into the WWW SLIM database. In addition, while the resolution of the Green data is very high temporally, data is only collected from one location in Town Lake. The data have been used previously, along with chlorophyll a data to set an action level for algal bloom monitoring by the Watershed Protection and Development Review Department (WPDRD). Historically, when counts exceeded 10,000 units/mL, algae bloom sampling was undertaken to collect data on oxygen dynamics in Town Lake.

A closer look at this data set could answer questions about the conditions in Town Lake and Lake Austin, and may suggest revisions of protocols or additional sampling concerns. Some of the questions currently being investigated include:

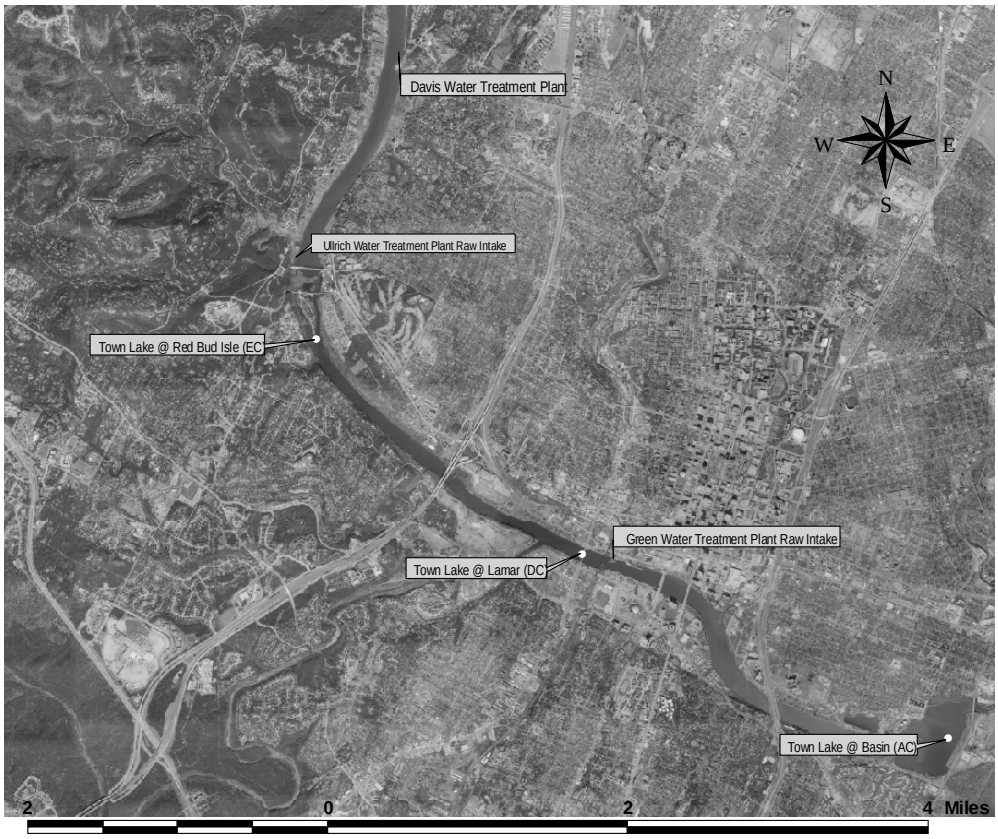

Figure 1. Aerial photograph of Town Lake sampling sites. The surface water sampling sites are represented by the white points, and the WWW sites at treatment plants are labeled with callouts.

- Are phytoplankton populations in Town Lake significantly different spatially?
    - How do the Green WWW counts extrapolate to the rest of the lake?
    - What effect does the City of Austin (urban tributaries) have on Town Lake?
- How are release and non-release algal communities different?
    - Are release populations worth measuring, given residence time?
    - What is the succession of the algal community when 'blooms' develop during non-release periods?
- What should be considered a 'bloom' in the context of Town Lake?

Data available at this time cannot answer all of these questions, but various techniques to better define an "algae bloom event" on Town Lake are have been investigated. The remainder of these questions may be answered through a special short term Town Lake phytoplankton study at a later date.

METHODS

Collection Methodology

Whole water grab samples were collected from the shoreline at the green, Davis, and Ullrich water treatment plants in Austin, TX. An aliquot was taken from a mixed sample and identified to species in a Sedgewick-Rafter chamber (SM 10200F) at 200x magnification. The counts were performed on natural

units, where colonies and filaments are counted as one organism, and extrapolated to organisms/mL. The division level information is recorded into the WWW database and is available to ERM for analysis.

Analysis Methodology

City of Austin WWW phytoplankton data were queried from the COA Watershed Protection and Development Review (WPDRD) database. Data was imported into Statistica 6.0 (Statsoft, 2003). Descriptive statistics and graphs were analyzed to provide summary information about the data set. Statistical analysis was performed on all sites, including tests of normality and homogeneity of variances to determine whether parametric ANOVA assumptions were met. Despite the abundance of data, only the total count numbers approached normality. Biological data rarely meets normality assumptions, and data were also examined using a lognormal transformation (lnx+0.1) Storm and baseflow samples were not analyzed separately in the data, after reviewing group summary information. Data were grouped by month, year, and site to distinguish trends and differences in the algal divisions. Data were standardized by mean and standard deviation (X=(x-M)/SD) to reduce the bias of counting by natural units. In addition, data was analyzed in time series to better comprehend the community dynamics between algal groups. Medians of plankton concentrations using 7 and 14 point-prior smoothing were calculated from the standardized data set and compared in graphic form to simulate the build-up in bloom dynamics.

RESULTS

A total of 5,795 data points collected between January 1987 and September 2003 (Table 1). Town Lake collections started in 1987, and Lake Austin collections began in 1991. A total of 2,953 data points were collected on Town Lake. Flagellate counts appear to contribute most of the total phytoplankton numbers, based on a mean that is an order of magnitude higher than the other categories. This occurrence; however, is an artifact of the "natural unit" counting methodology employed by WWW. This method considers filaments, colonies, and unicells equally in phytoplankton counts, and therefore does not allow direct comparisons between numbers of organisms that have different organizations. The green and blue-green algae in Town Lake are largely colonial or filamentous, and are seriously underrepresented by this counting method (Figure 2). Diatoms are often present in unicells and in colonies, while flagellates are most often unicells. This accounts for the enormous differences in mean concentrations between these plankton groups (Table 1).

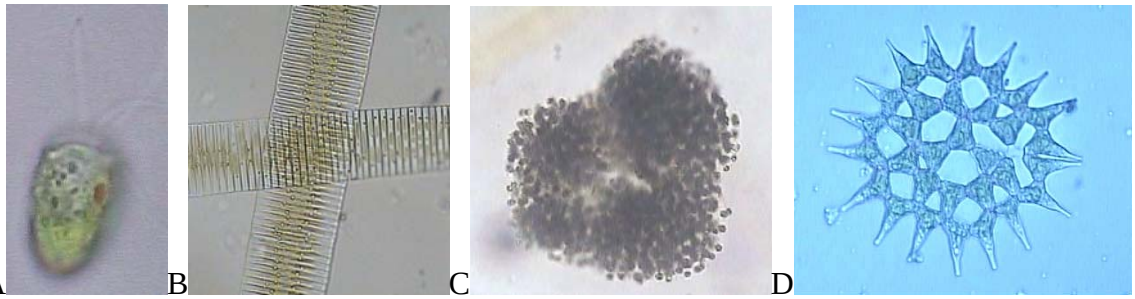

Figure 2. All of the above organizations of algal growth are counted as one using the natural unit method. A. single flagellate B. (Two) *Fragillaria* chains (diatom) C. *Microcystis* colony (blue green) D. *Pediastrum* colony (green)

Table 1. Descriptive statistics for WWW Town Lake and Lake Austin phytoplankton samples.

Variable	Descriptive Statistics (all WWW algae data in TL algae.stw)							
	Valid N	Mean	Median	Minimum	Maximum	Variance	Std.Dev.	Standard Error
blue green	2916	132.62	100.00	0.00	5251	56522	237.74	4.40
flagellate	2951	2469.87	1652.00	20.00	306162	41127938	6413.11	118.05
green	2917	57.34	20.00	0.00	1800	14955	122.29	2.26
diatom	2912	126.15	100.00	0.00	2305	19525	139.73	2.59
plankton	2953	2791.14	1900.00	120.00	306812	42025078	6482.68	119.30

Biological data often exhibit high variability, which can obscure trends. Due to the size of this data set (almost 3000 points), monthly median values were examined to illustrate overall trends. The central areas of these box-plots (including the 25%-75% values) were enlarged to compare phytoplankton category dynamics over annual time between Town Lake and Lake Austin (Figures 2,3,4).

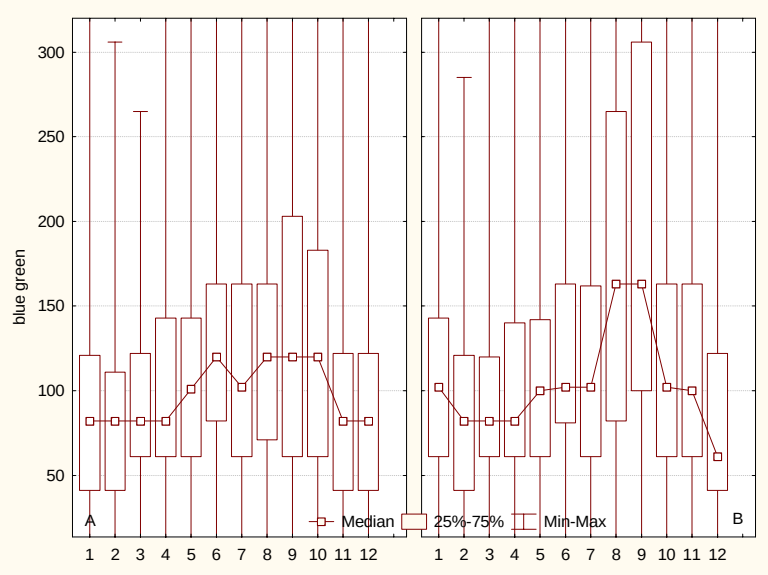

Figure 3. Median blue-green algal counts by month in Town Lake (A) and Lake Austin (B).

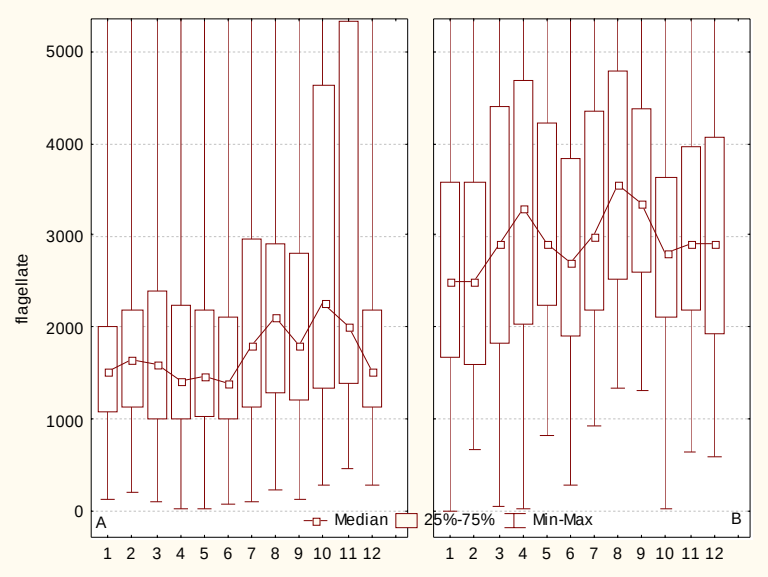

Figure 4. Median flagellate algal counts by month in Town Lake (A) and Lake Austin (B).

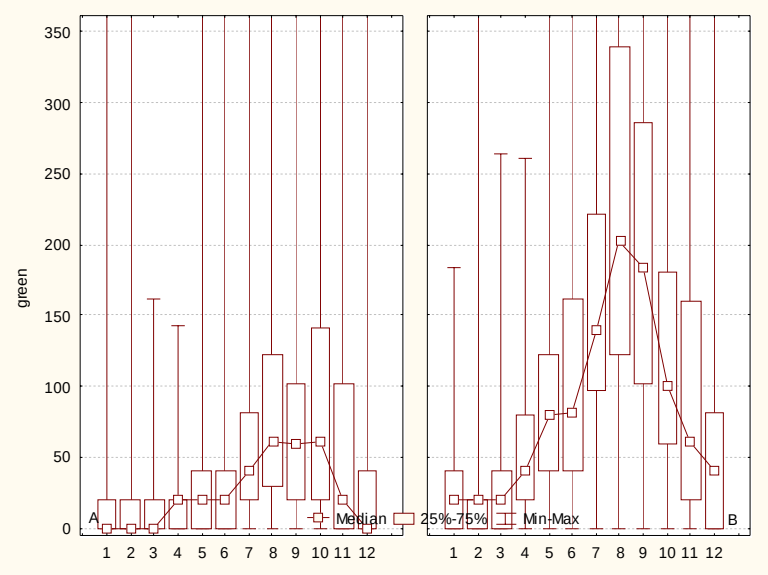

Figure 5. Median green algal counts by month in Town Lake (A) and Lake Austin (B).

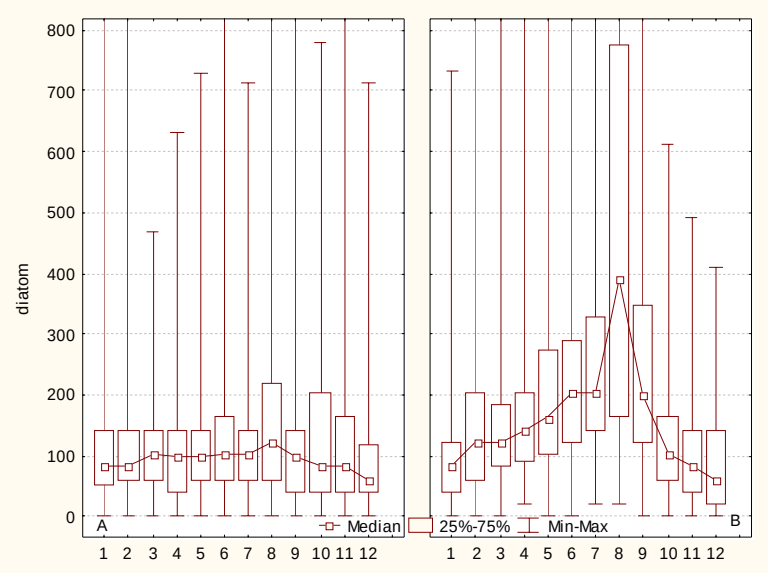

Figure 6. Median diatom algal counts by month in Town Lake (A) and Lake Austin (B).

It is apparent that phytoplankton category data is similar in Town Lake and Lake Austin when examined by month. However, the actual count values are often higher in Lake Austin, and the peaks more exaggerated. It is also important to note that each group has a different series of values on the y-axis, indicating that the natural counts are very different between categories of phytoplankton.

Standardizing the variables is one method of making the data unit-free, and thus comparable. A comparison of the standardized data to the current bloom action level showed potential differences in the number of events considered "blooms". With all phytoplankton data standardized, an action level would have to be set by best professional judgment, at a certain number of standard deviations from the mean. It would be possible to set different action levels for groups of particular importance or concern, such as blue green algae. This standardized value could also be compared to the original data in order to set a natural unit value that is more representative of a bloom condition. In the following frequency tables, manipulation of the data into categories simplified the frequency tables. At the current action level of 10,000 units/mL, 74 total counts were flagged at the current "bloom" action level by ERM methodology (Table 2). Ninety-seven percent of the Town Lake data fell within one standard deviation of the mean (Table 3). Choosing an action level of greater than 1 standard deviation from the mean value would flag 84 total plankton counts at the "bloom" action level. Counting anything greater than 2 standard deviations would flag only 33 counts. In addition, this method shows four sampling events with extremely high counts (Table 3). These numbers represent the total number of points, with the understanding that a bloom event comprises several adjacent daily points in duration. A graphical representation of the data would show individual blooms as peaks, similar to a hydrological discharge graph. Graphical representation would therefore better illustrate both the intensity *and* the duration of these bloom events.

Table 2. Frequency table representing the number of values currently classified at the current "bloom" level of 10,000. All other values were converted to zero.

Category	Count	Cumulative Count	Percent	Cumulative Percent
0	2879	2879	97.36219	97.3622
>=10000	74	2953	2.50254	99.8647

Table 3. Frequency table representing the number of standardized values falling within a certain distance from the mean. Data was grouped for ease of interpretation.

Category	Count	Cumulative Count	Percent	Cumulative Percent
0	2164	2164	73.18228	73.1823
1	705	2869	23.84173	97.0240
2	51	2920	1.72472	98.7487
5	29	2949	0.98072	99.7295
5.0978744802	1	2950	0.03382	99.7633
6.0866637974	1	2951	0.03382	99.7971
11.363806160	1	2952	0.03382	99.8309
46.897438857	1	2953	0.03382	99.8647
Missing	4	2957	0.13527	100.0000

To examine group composition standardized data was compared in a time series analysis (Figure 7,8). These analyses were performed with different transformations, and with varying moving median prior-point moving averages in an attempt to capture the most descriptive pattern of phytoplankton community structure. The differences in these graphs are illustrated in the amount of noise associated with each line, and the height of each peak. These graphs give valuable information as to the temporal build-up of phytoplankton communities. It is however, important to note that any temporal data gaps were not addressed before applying the smoothing transformations, and therefore the effect of weekends (no collections) particularly, have not been accounted for.

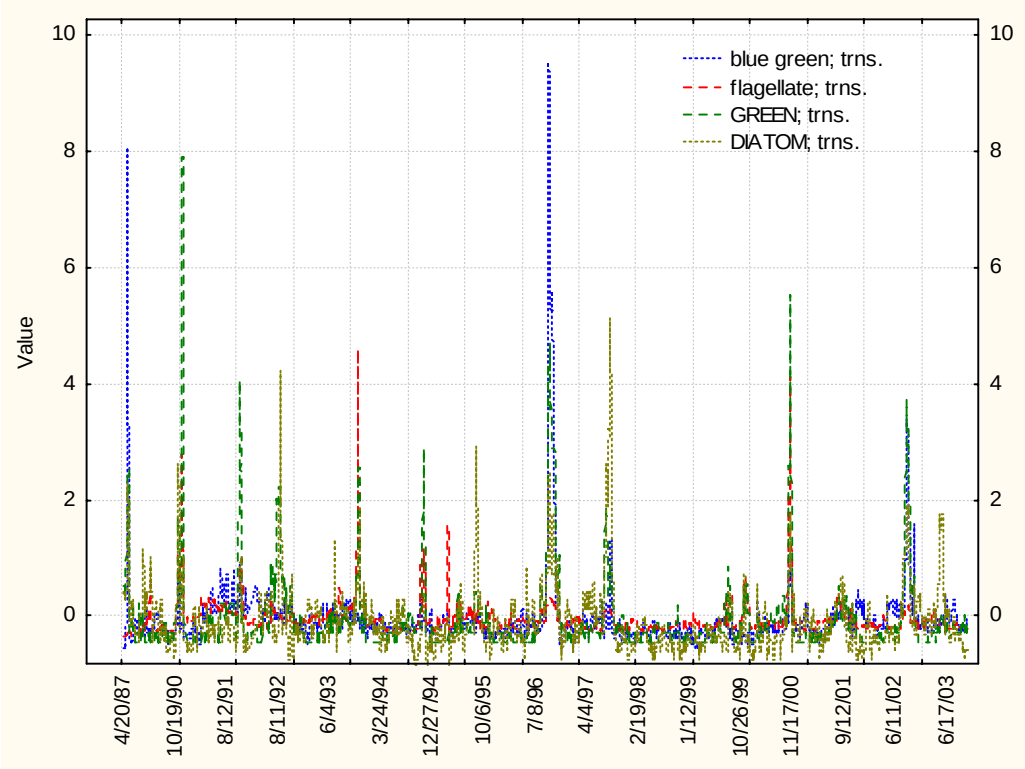

Figure 7. Time series of Town Lake phytoplankton data with standardized data and seven point prior smoothing.

Using a seven-point prior smoothing transformation (Figure 7), eleven events were above 2 standard deviations in the dataset. Most of these events were a combination of elevated levels of all four algal groups, with one providing the bulk of the peak. Two events were mainly blue green events, three were mainly green algal events, three were predominantly diatoms, and one was predominantly a flagellate bloom event. The remaining event was almost equally blue green and green algae. Eight of these eleven events were above four deviations, though three were just barely above. Two of the blue green peaks and one green algal peak were above 6 deviations from the mean counts, all of these events occurring before 1997. The data is very similar using the fourteen-point prior smoothing transformation. The event compositions were the same; however, the peaks were reduced when considering more prior data in the average. Using this transformation, only 6 events were above two deviations, and only one event (blue green) was above four. The actual smoothing transformation used should reflect a time period reflective of the temporal dynamics of an algal event.

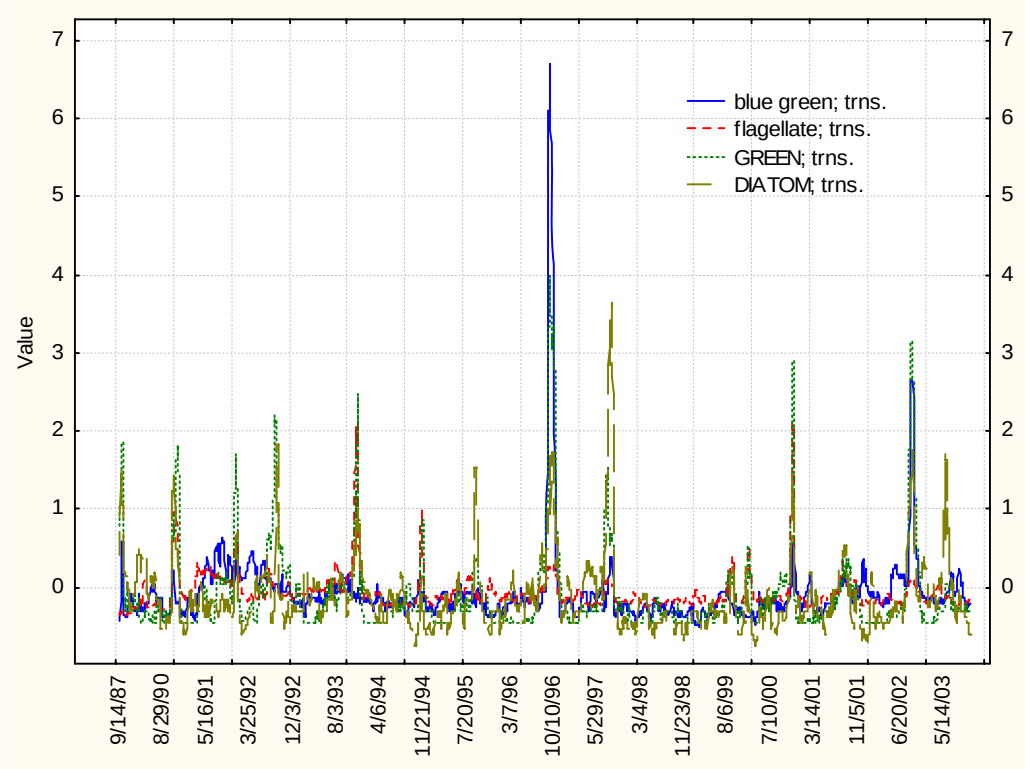

Figure 8. Time series of Town Lake phytoplankton data with standardized data and fourteen point prior smoothing.

DISCUSSION

Because of the counting methodology, the count values of different phytoplankton categories were not directly comparable. This explains the orders of magnitude differences between the flagellate counts and the other groups. In addition, if the 'bloom' trigger is 10,000 organisms per mL, most often flagellates will be the identified cause because they are unicellular. In essence, this target number and counting method are only targeting flagellate blooms. This problem is further compounded by the fact that ERM has not detected an algal bloom using this method for several years. The question then must be asked, are the number of algal blooms decreasing, *OR* are the number of *flagellate* algal blooms decreasing? A completely hypothetical possibility is that the number other bloom types could be increasing, and not being caught by the current methodology. Small algal flagellates have different growth rates and nutrient uptake dynamics than larger colonies/filaments in different algal groups – and would not bloom under the same conditions (Reynolds 1984). Therefore, a shift in the type of algal bloom could indicate changes in the water quality of Town Lake. For instance, an increase in colonial greens and blue green filaments could indicate increasing eutrophication of the water body, which would not be observed if only the flagellate algal community is observed.

If time-series graphs and variable standardizing techniques made "peak' concentrations more readily observable, a more appropriate action number could be selected for each category. The peaks in these graphs however, depend on the averaging method used in the analysis, which should represent the appropriate time period for the build-up of an algal bloom. The standardization method can also be applied to the raw data, to produce frequency tables of distributions. A standardized value can be set using best professional judgment, and this number would be more reliable across all categories of

phytoplankton based on the current counting methodology. However, the practicality of receiving notice when a count is "greater than three standard deviations from the historical mean" is questionable. This deviation number could be back-correlated with actual data points from algal events to produce a more applicable number using the natural units method. Overall, 10,000 cells/mL may not be an unreasonable bloom estimate; however it is misleading in comparisons using the current data set. At the very least, the vast historical data set could be used to evaluate what a reasonable organism number (using the natural units method) would be for each category of phytoplankton, based on a particular standard deviation. This method would at least provide a sound measure as to what is an "excessive" amount of algae that needs to be monitored. In addition, this method needs to be compared to the visibility of certain concentrations of algae as a potential guide for citizen concerns in order to be useful in identifying nuisance conditions.

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