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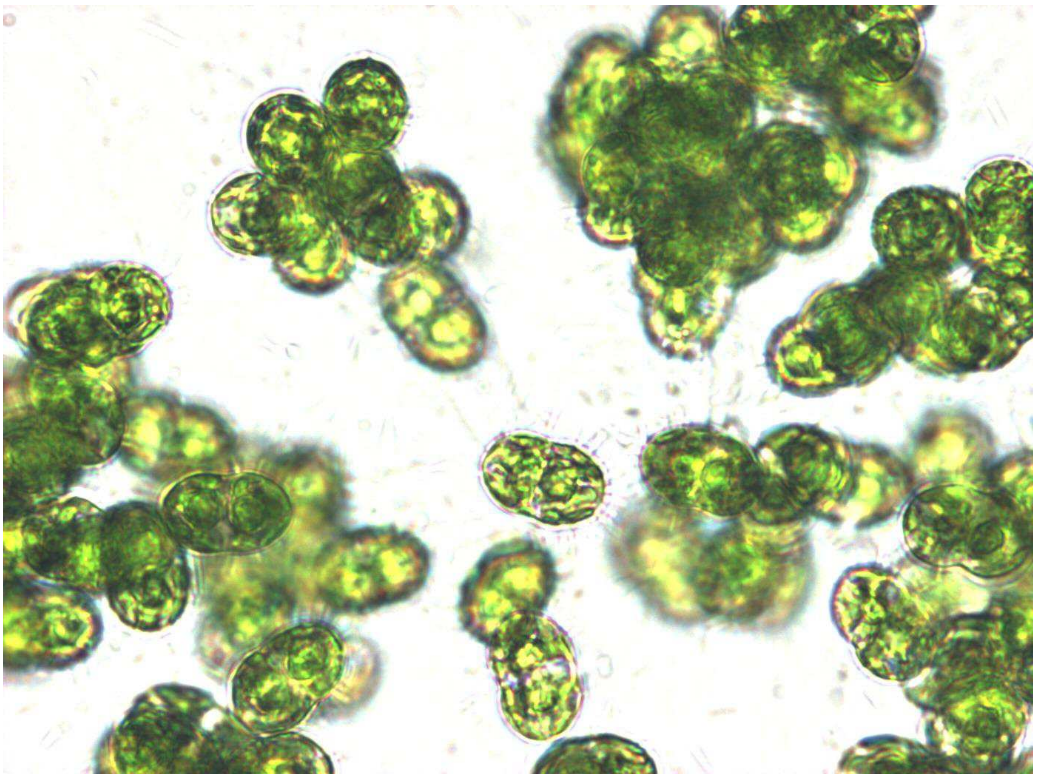

Relationship between Drinking Water Treatment Chemical Usage and Lake Whatcom Water Quality and Algal Data

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October 4, 2004

Background Information

This assessment is based on daily City water treatment data provided by Peg Wendling and a composite data file containing monthly averages[1] for City water treatment chemical data and IWS water quality and algal data collected at the Intake site. The monthly averages were calculated using all available depths and dates from September 1992 through May 2004. (Note that the 2004 data only include January through May.)

The City data contained an entry of “11” for alum gallons on May 17 2004. Although this value is unlikely, it was not omitted from the file. Even if incorrect, the single point will have little influence on the outcome of these analyses.

The variables included in this analysis are indicated below.

Abbr.	Description	Abbr.	Description
month	Month	chl	Chlorophyll (mg/m^3)
day	Day	temp	Lake temperature at Intake (°C)
year	Year	ph	Lake pH at Intake
zoop	Zooplankton (#/m^3)	cond	Lake conductivity at Intake (μS)
chry	Chrysophyta (#/m^3)	do	Lake dissolved oxygen at Intake (mg/L)
cyan	Cyanophyta (#/m^3)	secchi	Lake Secchi depth at Intake (m)
chlo	Chlorophyta (#/m^3)	inflow	Influent flow (mgd)
pyrr	Pyrrophyta (#/m^3)	rawturb	Raw water turbidity (NTU)
alk	Alkalinity (mg/L as $CaCO_3$)	rawpH	Raw water pH
turb	Turbidity (NTU)	alumdose	Alum dose (mg/L)
nh3	Ammonia (μg-N/L)	alumgal	Alum gallons
tn	Total nitrogen (μg-N/L)	ashdose	Soda ash dose (mg/L)
nos	Nitrate/nitrite (μg-N/L)	ashpounds	Soda ash pounds
srp	Soluble phosphate (μg-P/L)	cldose	Chlorine dose (mg/L)
tp	Total phosphorus (μg-P/L)	clres	Chlorine residual (mg/L)

[1]Monthly averages were compared to monthly medians, and found to be similar.

Summary

1. All of the City's water treatment variables were significantly correlated.[2] with year. This indicates that the amount of chemicals and doses have increased with time. The only exception was chlorine residual, which has not changed significantly over time (Figure 1).

   The amounts and doses of chemicals used to treat drinking water have increased with time.

2. Alum dose had the best linear relationship with time (Figure 2), especially during the months of May, August, October, and November (Figure 3). May, August, October, and November are month often associated with diatom or cyanobacteria blooms in the lake.

   Alum dose can be predicted using a simple linear regression vs. time.

3. Several groups of Lake Whatcom plankton were correlation with time, particularly the Chrysophyta (yellow-green algae, consisting primarily of diatoms, *Dynobryon*, and *Mallomonas*) and Cyanophyta (Figure 4). These two groups are often associated with water treatment problems.

   Algae that can cause drinking water taste and odor problems have increased with time.

4. Although chlorophyll concentrations were significantly correlated with all water treatment variables, the correlations were weak (Figure 5, alum vs. chlorophyll). This is because high chlorophyll concentrations are not necessarily caused by high plankton counts. (Figure 5, chlorophyll vs. total plankton count). Diatoms, for example, may be very abundant, but because they are tiny cells, they contribute relatively little to the chlorophyll concentration. Cyanophyta, on the other hand, are often counted as colonies rather than individual cells, so they are underrepresented in the numerical counts, but may contribute substantially to the chlorophyll concentration.

   Chlorophyll concentration and total plankton counts are not the best indicator of alum dose.

[2]Correlation analysis was based on Kendall's tau rank-sum correlation; linear models were based on least-squares linear regression.

5. The best predictor of alum dose was Cyanophyta (Figure 6). Cyanophyta (bluegreen "algae" or cyanobacteria) are increasingly abundant in Lake Whatcom (Figure 4), with peak densities in late summer or early fall, just prior to turnover. Many Cyanophyta species cause taste and odor problems in water treatment.

   Cyanobacteria counts have increased in Lake Whatcom and are closely related to alum dose.

6. Overlay plots of alum dose and scaled Cyanophyta counts[3] show the increase in both variables over time (Figure 7). In addition, Figure 7 reveals the seasonal relationship between alum dose and Cyanophyta populations. Peak alum doses occur in September or October (mean alum dose = 10.6 and 10.5 mg/L, respectively); these months are preceeded by increasing populations of Cyanophyta in the lake.

   Alum dose and cyanobacteria counts increase in late summer and early fall.

7. During 2003–2004 there was a closer relationship between Chlorophyta (green algae) and peak alum doses (Figure 8) than in previous years. As in previous years, Chrysophyta and alum dose did not appear to be related except, perhaps, in May 2004, where the combined effects of high Chrysophyta, Chlorophyta, and Cyanophyta counts may have contributed to the unusually high alum dose required during that month.

   During the past year, cyanobacteria **and** *green algae peaks preceeded late summer alum dose peaks*

8. Despite the close correlation between alum dose and Cyanophyta, it is important to note that *correlation* is not the same as *causation*. Both variables might be responding in the same manner to other environmental factors. Many of the lake's water quality measurements are showing changes over time.[4]

   Cyanobacteria are not the only factor affecting drinking water treatment.

[3]Scaling does not change the basic pattern in the Cyanophyta counts.
[4]See Tables 12–13 in the 2002/2003 Lake Whatcom Monitoring Project Final Report.

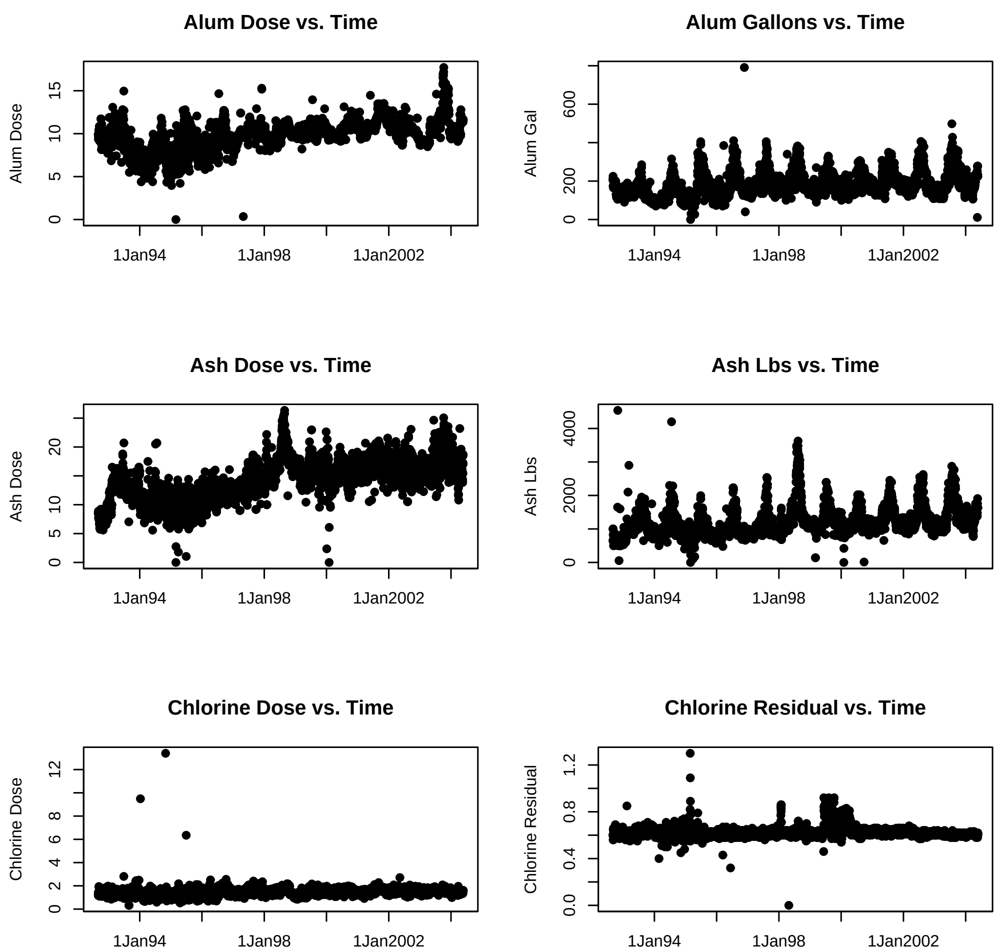

Figure 1: Changes in water treatment chemical use over time. (Daily water treatment data provided by City. All variables except chlorine residual were significantly correlated with time ($p \leq 0.05$)

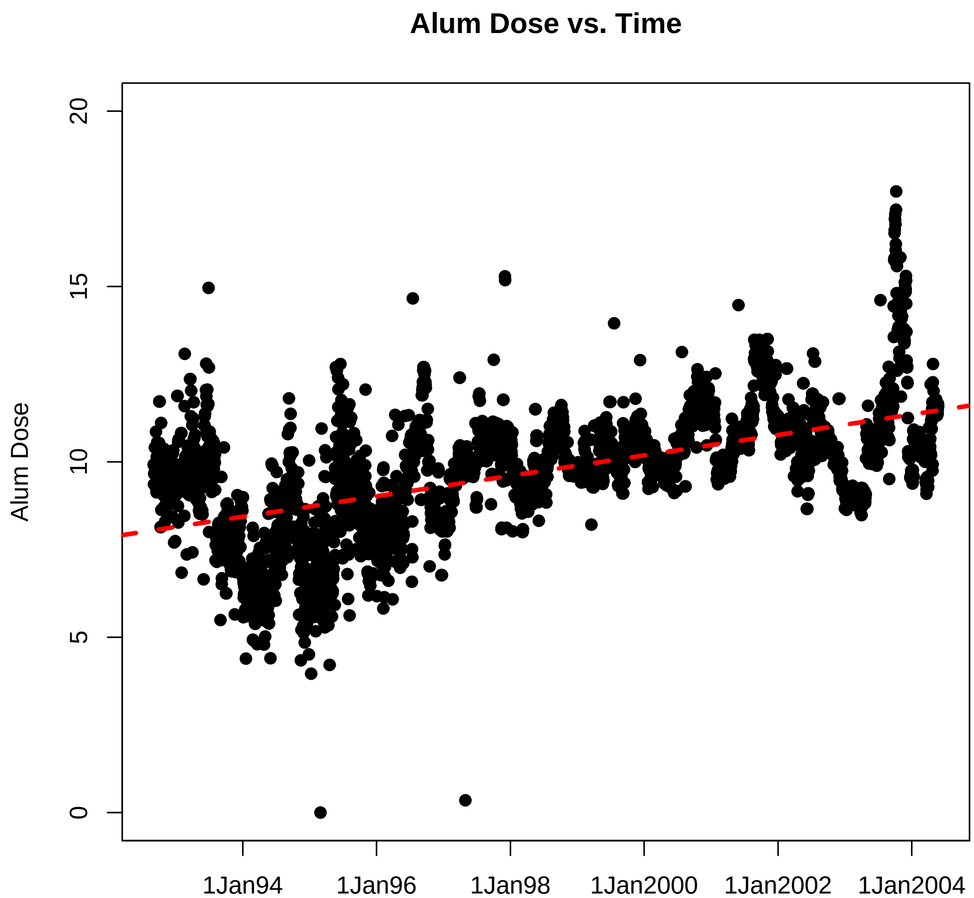

Figure 2: Changes in alum dose over time. The dashed red line shows the linear regression with time (r^2 = 0.335; $p < 2.2e - 16$).

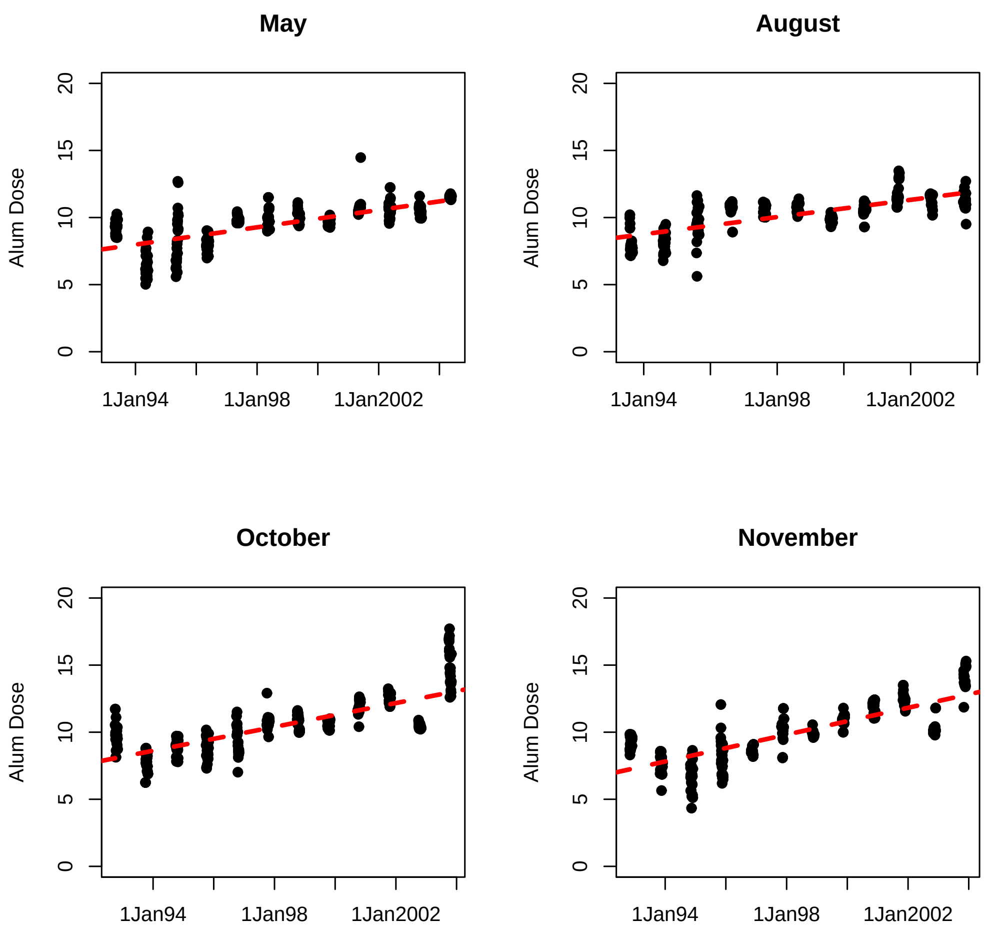

Figure 3: Monthly alum dose vs. time for the four months showing the greatest change (r^2 ranged from 0.50–0.65; $p < 2.2e - 16$).

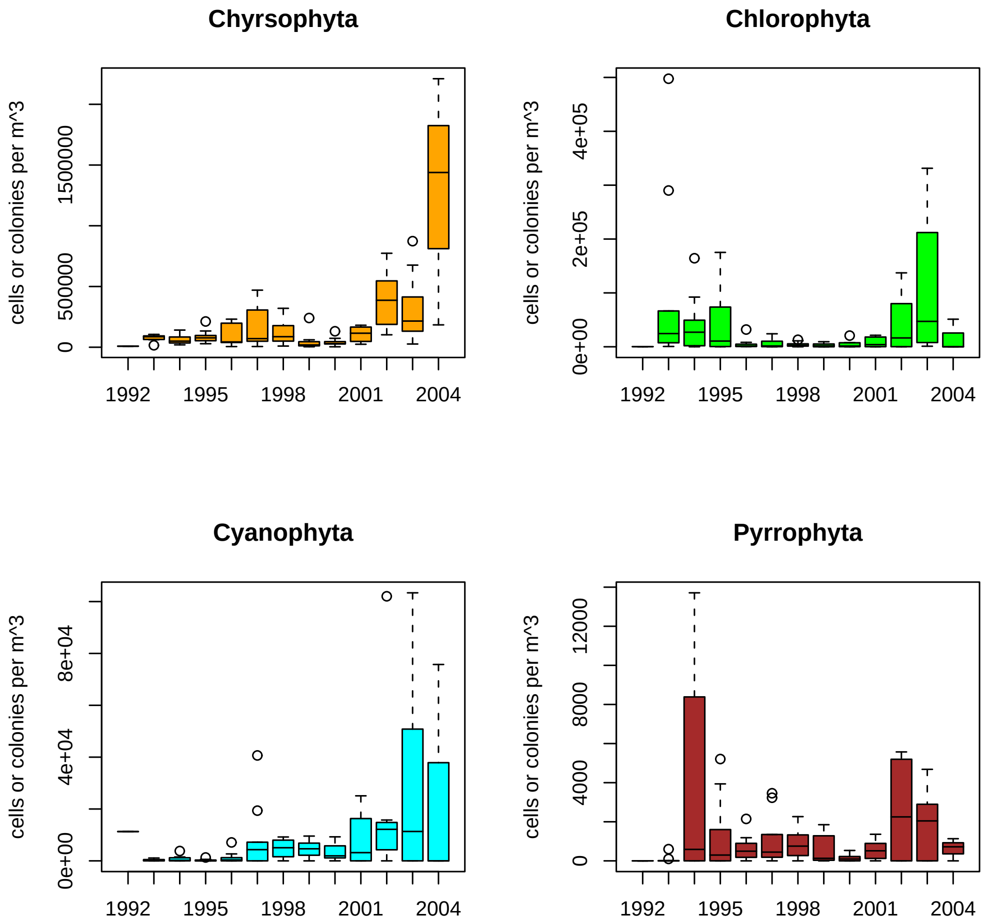

Figure 4: Boxplots showing Lake Whatcom algal patterns over time. Boxplots show median and upper/lower quartiles; whiskers extend 1.5 $\times$ interquartile range or to minimum value; outliers lie outside 1.5 $\times$ IQR.

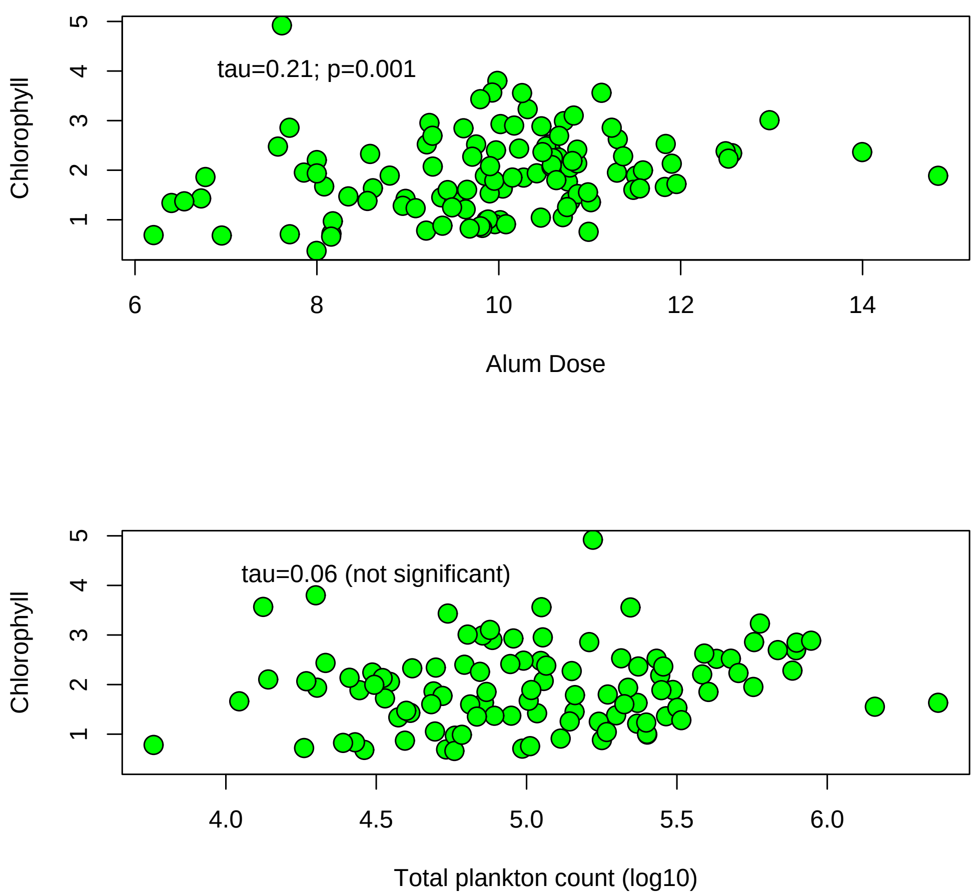

Figure 5: Lake Whatcom chlorophyll concentrations vs. total plankton counts.

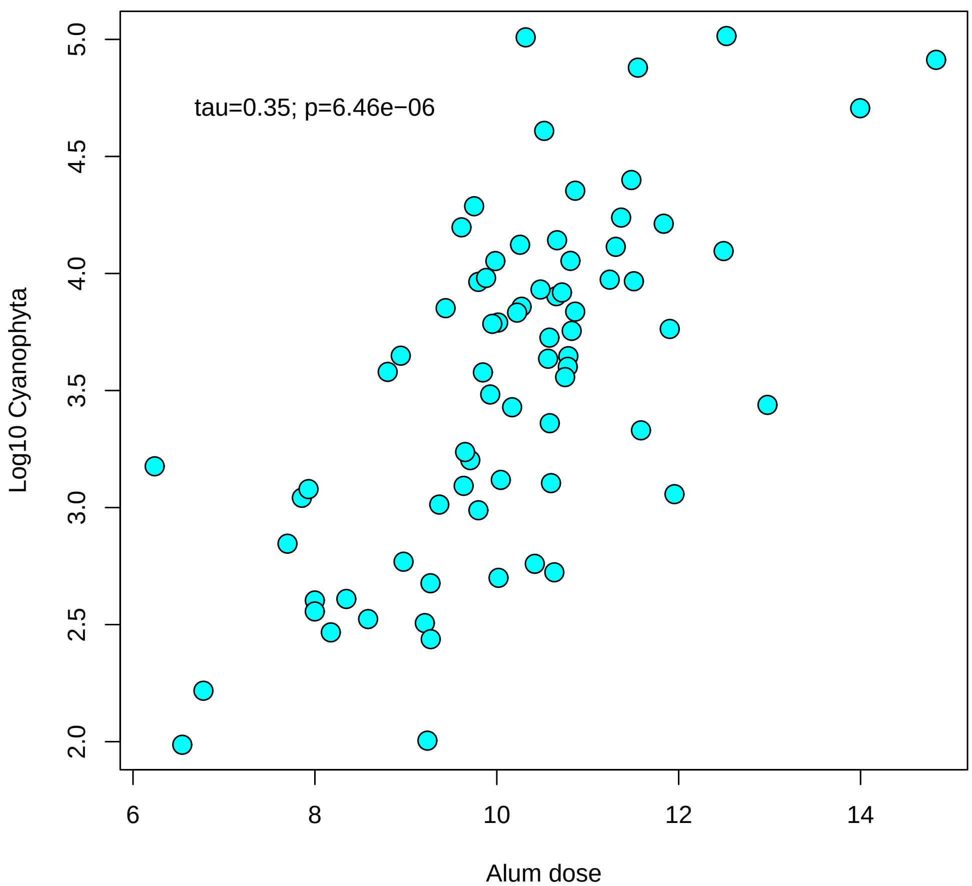

Figure 6: Lake Whatcom Cyanophyta counts vs. alum dose.

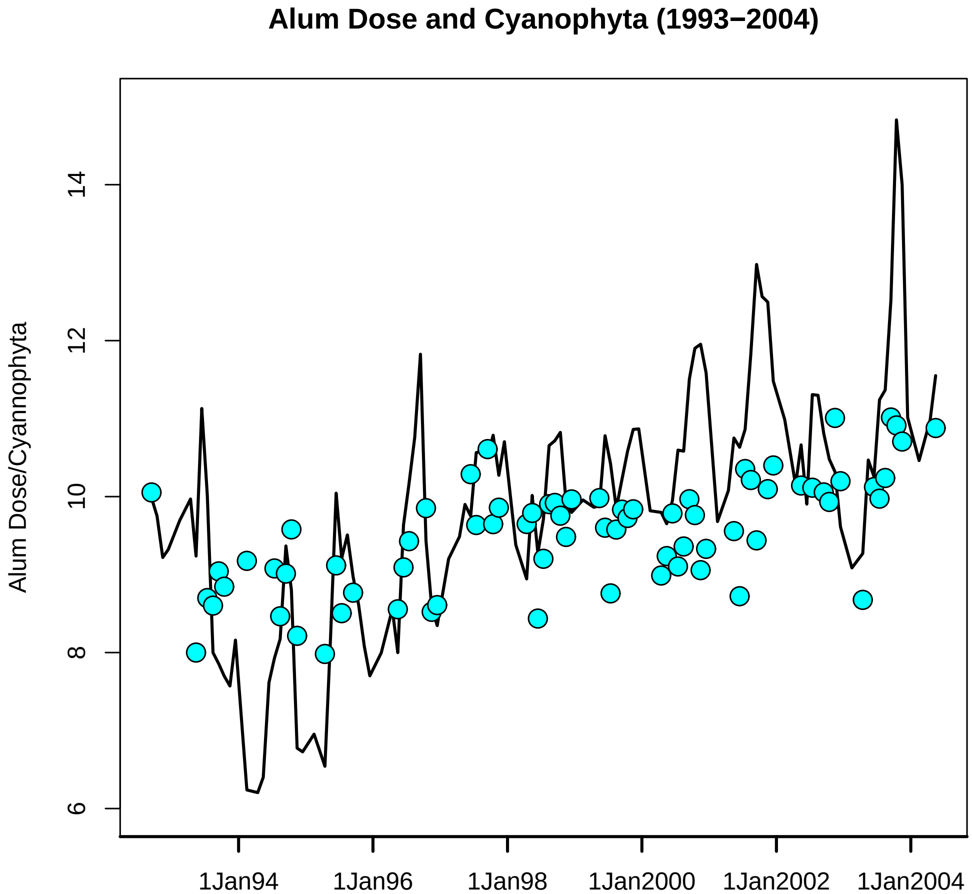

Figure 7: Scaled Cyanophyta counts (○) vs. alum dose (—). Plankton counts were scaled to allow overlay plotting (log10(cyan) + 6).

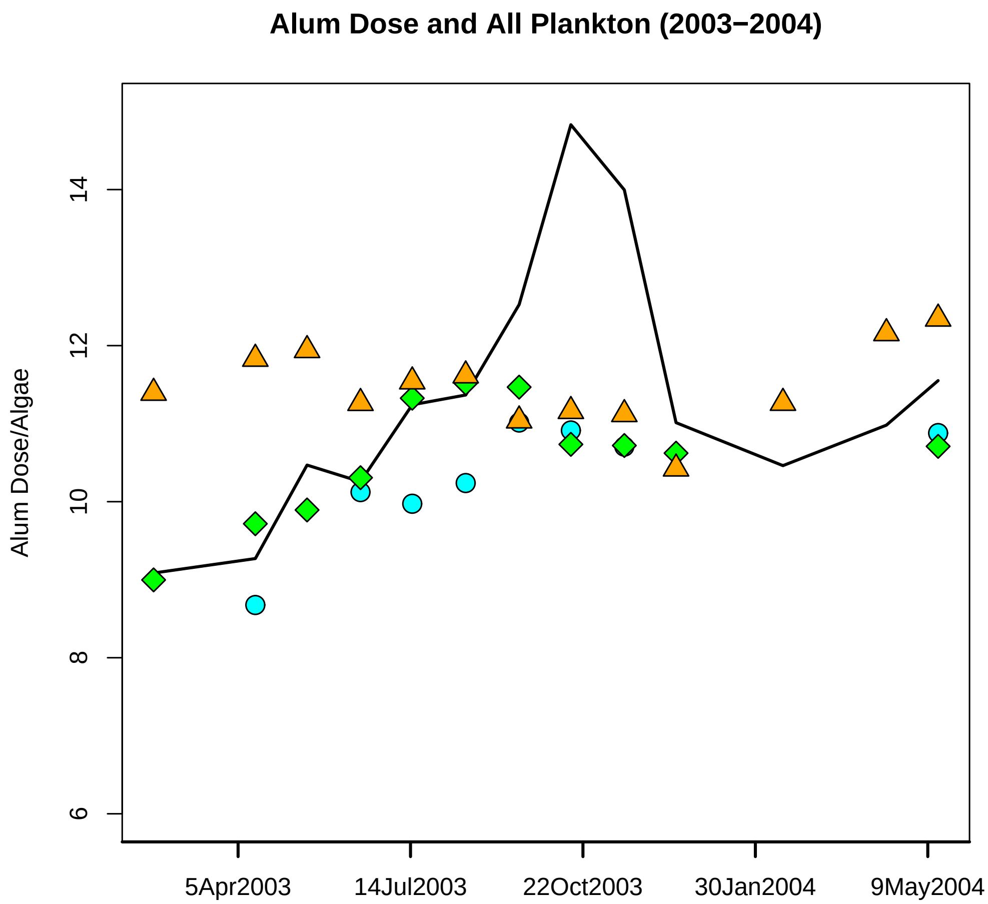

Figure 8: Scaled Cyanophyta (○), Chlorophyta (◇), and Chrysophyta (△) counts vs. alum dose (—). Plankton counts were scaled to allow overlay plotting (log10(count) + 6).