Summary

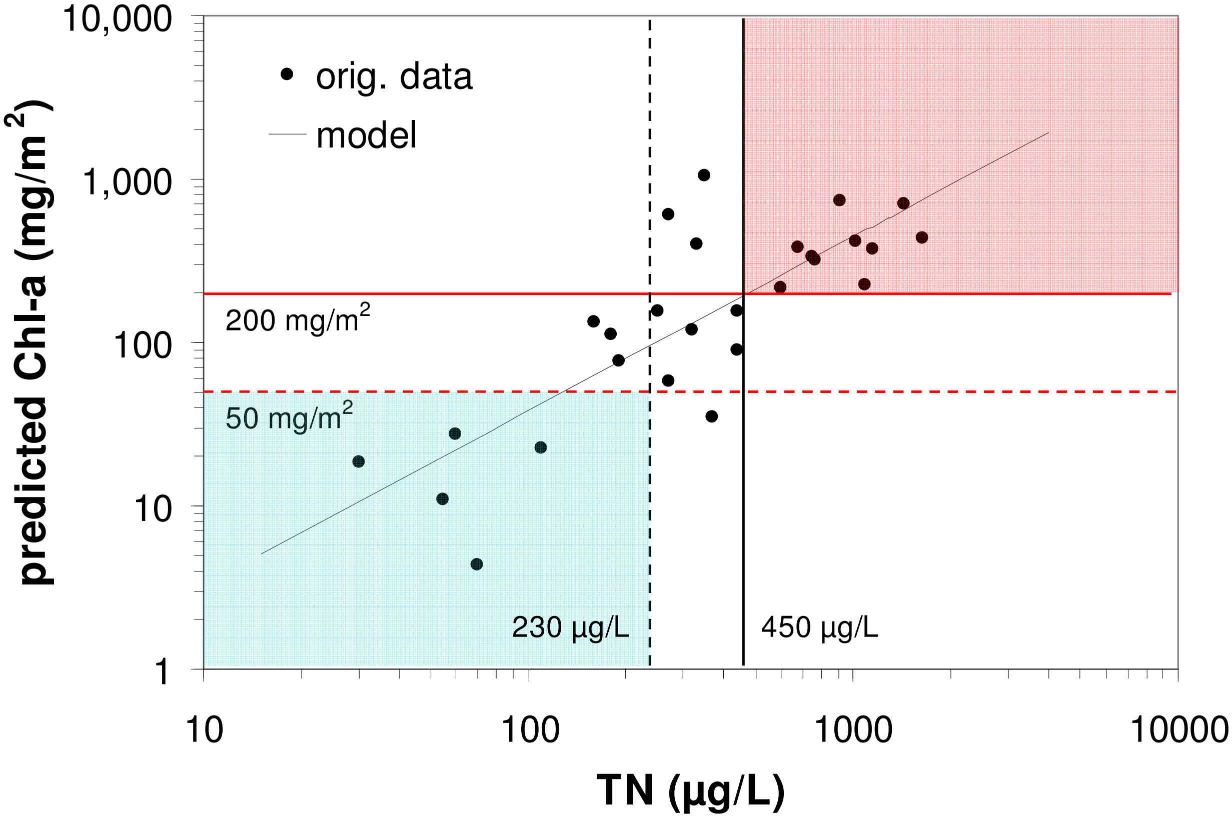
- Algal biomass is primarily determined by N supply
- Recommended impairment thresholds.

Response	Not impaired	Requires study	Impaired	Endpoint
Chlorophyll a (mg/m^2)	< 50	50 - 200	> 200	150
TN (mg/L)	< 0.23	0.23 – 0.45	> 0.45	0.40
TP (mg/L)	< 0.02	0.02 -0.03	> 0.03	0.025

- Dissolved oxygen directly related to flow rate and inversely related to algal biomass. Recommended thresholds will protect aquatic life.
- Nutrient concentrations related to human land uses and wastewater treatment plant effluent.

In this piece (I never quite know what to call these exercises, are they essays, reports, clarifications, presentations . . . or simply the ramblings of a disordered mind?) I'm going to look at the impairment thresholds recommended by Dr. Cooper in his recent slide show presentation and as documented in the UCSB Report that will, almost certainly, form the basis of the developing Ventura River TMDL. I've reproduced his summary slide here. The recommendations are clear: impairment exists if algal density is above 200 mg Chl-a/square-meter; *or* if the concentration of total nitrogen in the water column is above 450 µg/L; *or* if total phosphorus is above 25 µg/L. Whenever a single criterion – not any two, nor all three – is exceeded the reach is to be considered impaired. Similarly, any reach with an algal density below 50 mg Chl-a/square meter *and* total nitrogen below 230 µg/L *and* total phosphorus below 20 µg/L is, by definition, unimpaired. Sites falling in-between the stated standards for *any* of the three parameters require further study.

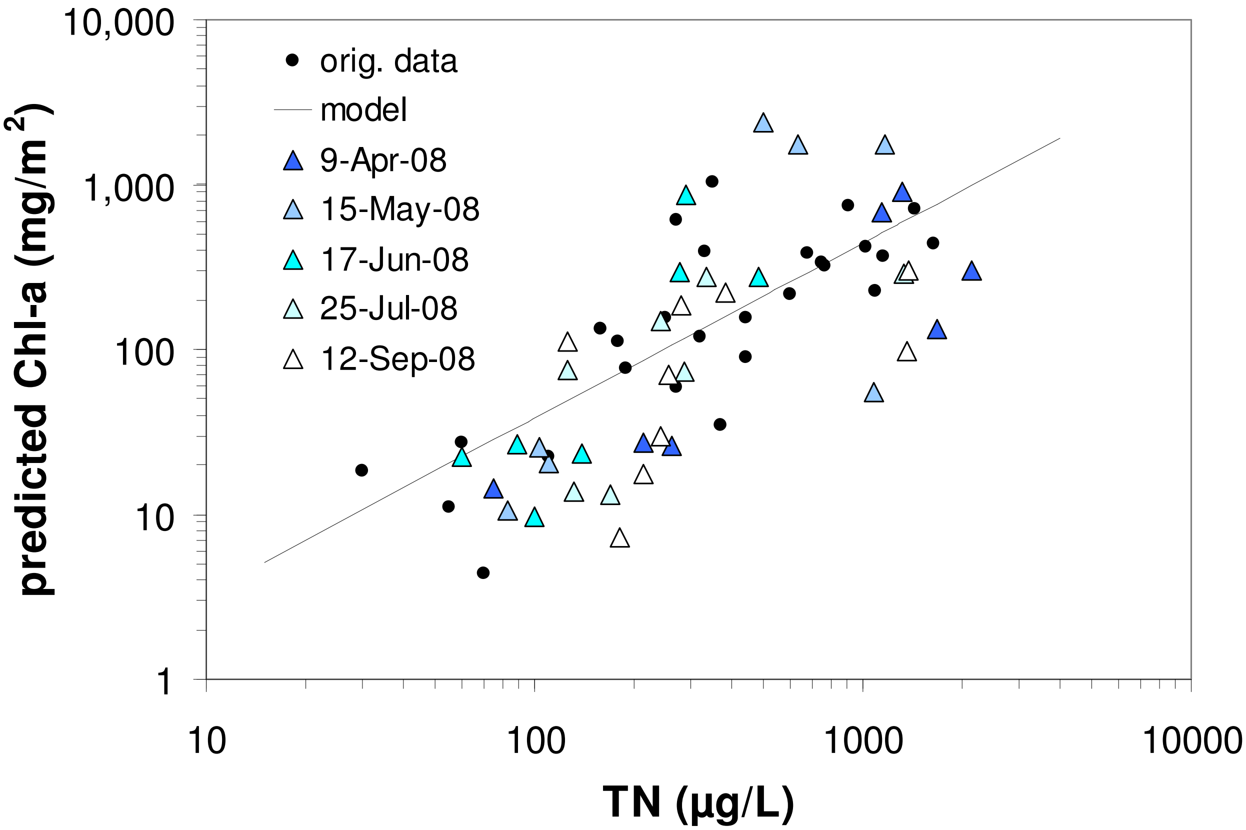
My purpose here is neither to affirm nor criticize these recommendations, but rather to add a note of caution. The UCSB study, and therefore its conclusions, was the product of but a single summer of research on the river. Perhaps that research accurately represents the situation as it existed in 2008. Perhaps not. But a more important question might be whether or not it accurately represents other years as well. Since throughout my Ventura studies I've stressed the extreme inter-annual variability that takes place in the watershed and on the river, my initial supposition is *no*, results from 2008 do not adequately cover what happened, or will happen, in other years.



It is my considered opinion that a direct correlation between algal biomass and nitrogen is too simplistic a model to adequately describe the variability seen on the Ventura. I intend to test this supposition by considering data from 2003 and 2009, combining it with data from 2008 and seeing if the center still holds. I suspect, along with Hamlet, that "there are more things in heaven and earth, Horatio, than are dreamt of in your philosophy."

The key finding presented in the UCSB report, the basis behind the statement in the list of recommendations that "algal biomass is primarily determined by nitrogen supply," is graphically represented in the above chart. In it Kristie's Chl-a data is plotted against total nitrogen concentrations from samples collected during each survey on a log-log graph. The black dots represent individual data points. And the relationship of best fit between Chl-a and TN is shown as a straight line – this line represents a power relationship given the log-log plot. I've added the recommended impairment thresholds for Chl-a (50 and 200 mg/square-m) and total nitrogen (230 and 450 µg/L) as red and black lines – dashed for the lower threshold below which no impairment exists, solid for the upper threshold above which a reach is definitely impaired. I've also colored in the region representing *both* algal and nitrogen impairment in red and the region of no impairment in blue. The sites that fit into either of these categories are obvious; others fall within the white areas that define "further study" for possibly excessive amounts of either nitrogen or algae (Chl-a), or both. Note that no data points fall within the upper left or lower right regions – areas that represent either high Chl-a/low nitrogen or low Chl-a/high nitrogen. Convenient that, but whether or not it will remain true is the question I'm examining here.

Aside from the points shown in the graph there are two additional sources of data available to test the conclusions of the UCSB report. The first source is straight-forward. As I've mentioned elsewhere, in 2003 Julie Simpson and myself measured Chl-a and nutrient concentrations at four locations on

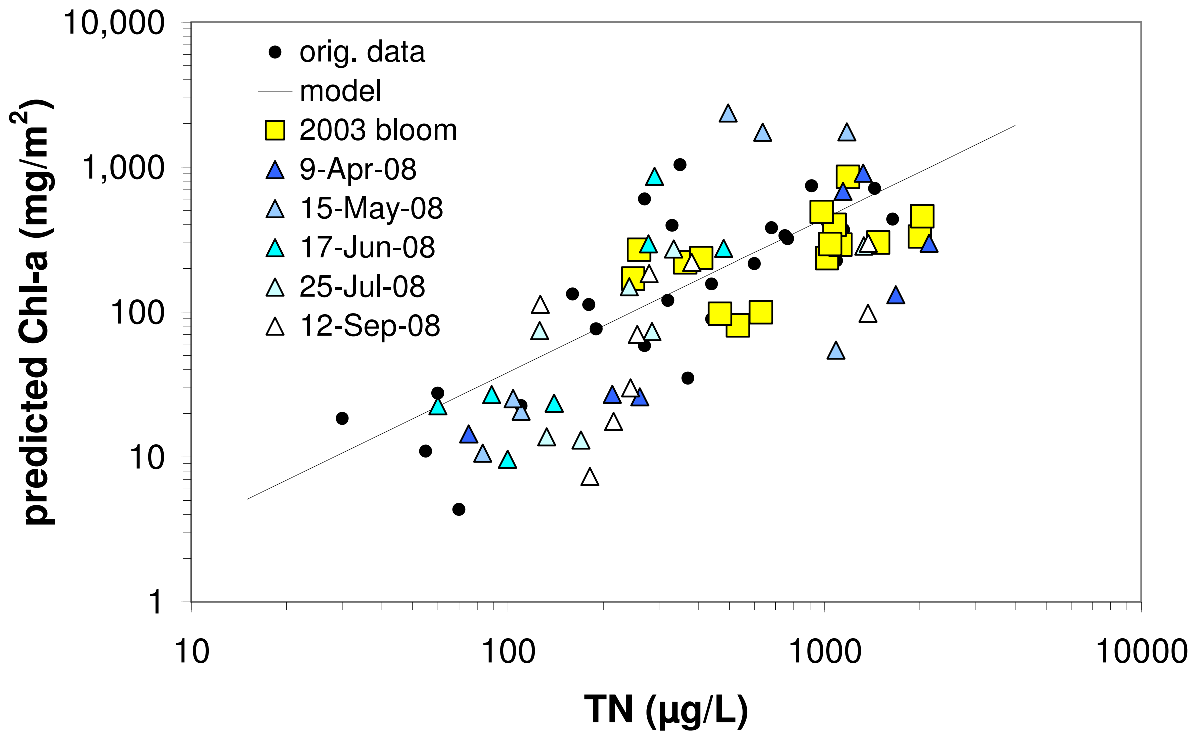


the lower Ventura River at approximately 2 week intervals from mid-April into the beginning of October. The four locations were at (1) Main Street, (2) adjacent to Stanley Drain, at (3) Shell Road and at (4) Foster Park – f our locations that fell within the "red zone," signifying impairment, in 2008.

The second set of data are more problematic. The 2008 UCSB data has allowed us to construct a model that estimates Chl-a from delta-DO and flow, delta-DO being the difference between mid-afternoon and pre-dawn concentrations of dissolved oxygen. The daily fluctuation in dissolved oxygen is a measure of the effect of photosynthesis (primarily from algae) on a river reach. Combined with flow, it allows an estimate of the amount of chlorophyll present (and is the basis for the statement in the summary slide that "dissolved oxygen is directly related to flow rate and inversely related to algal biomass). I've been using these estimates since May of this year in my reports on results from Channelkeeper's monthly diel measurement program. Since total nitrogen concentrations are available for these same locations, from either water samples collected at the same time or by interpolation from Channelkeeper's regular monthly sampling program, it is an easy exercise to plot these values (estimated Chl-a and TN) for the 2008 diel sampling dates, along with UCSB data, on the same graph. This is the graph shown above.

If anything, the 2008 diel data reinforce the impression of a strong correlation between Chl-a and total nitrogen; were they to be included in a revised regression an even steeper slope to the regression line would be the probable result. The only worrying note being the now wider spread in estimated Chl-a values at high concentrations of total nitrogen.

In Figure 1 I continue the process of adding data, first adding data from 2003 that I characterize as "2003 bloom" (shown in the upper panel), and then the remaining 2003 data along with April 2009



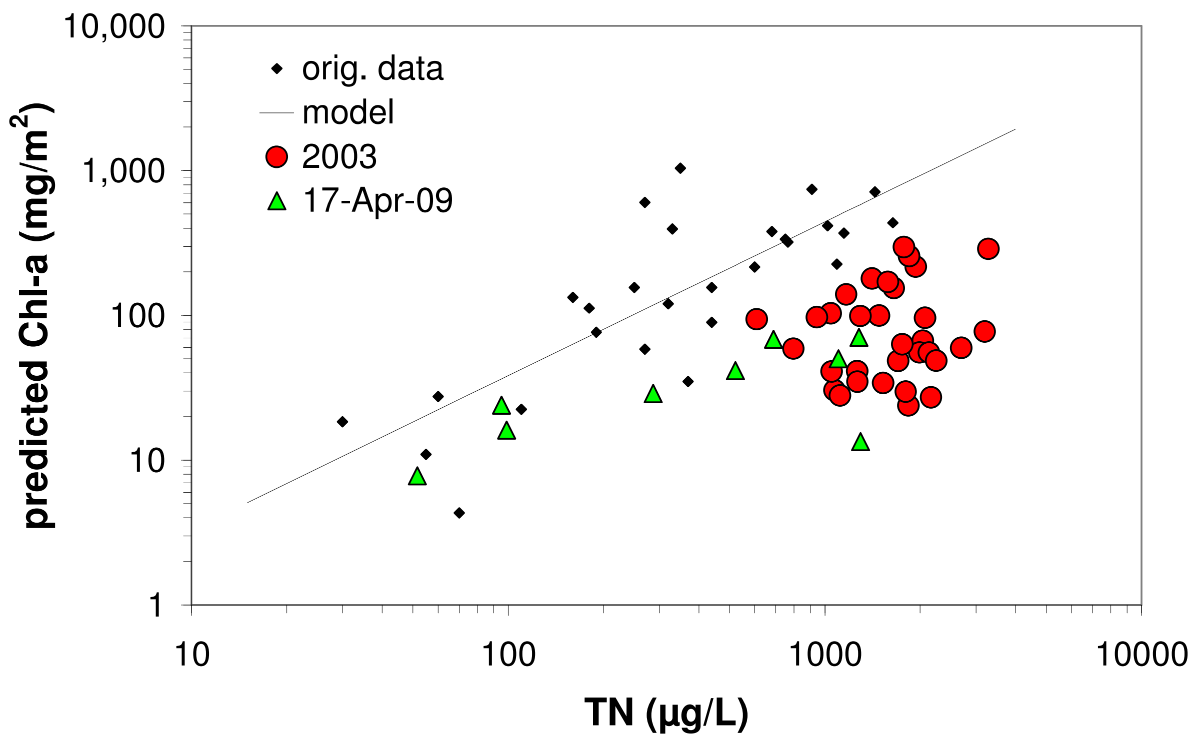
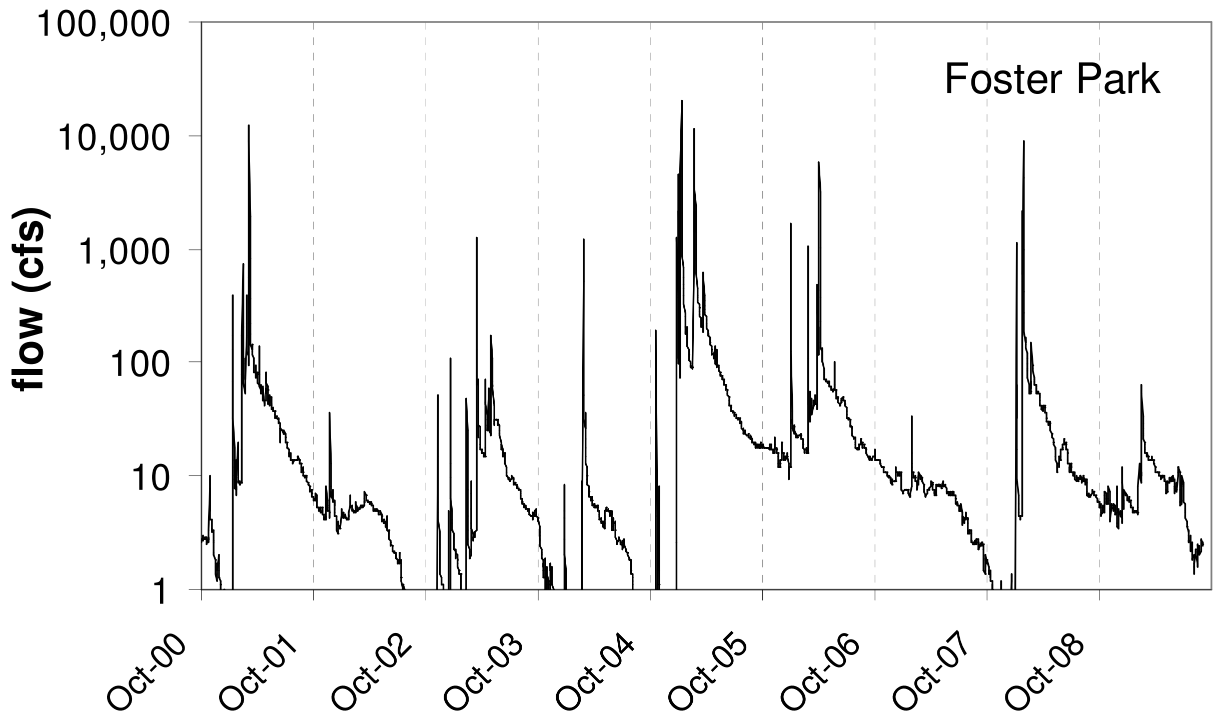


Figure 1. (upper panel) To the graph on page 3 (original + Channelkeeper 2008 data) I've now added a selection of data points from a 2003 study of Chl-a and nutrients at 4 locations on the lower Ventura River. These points, labeled "2003 bloom," represent data collected during a Cladophora bloom. (lower panel) Similarly, to the basic original data graph (page 2) I've added the only 2009 diel data currently available along with the remaining 2003 data from the 4 lower Ventura sites – these 2003 data represent developments after the peak of the bloom when aquatic plants dominated the 3 locations below the Ojai Sewage Treatment Plant.

diel estimates (shown in the lower panel). These last data are shown on a graph with only Kristie's original data as background to emphasize differences from the upper panel. Note that the added data in the bottom panel all fall considerably below the regression line, with most of the points falling below (i.e., lower Chl-a for any given value of TN) any of Kristie's 2008 data.

Before getting into why the 2009 and some of the 2003 data do not fit the 2008 pattern, I need to more fully explain how and, probably more importantly, why I've divided the 2003 data into two separate classes.



As you can see from the Foster Park hydrograph, 2003 was a year that looked like . . . well, an average between 2008 and 2009. It had a big storm, on March 15th, which cleaned out the river and got the algal season off to a rousing start. But then another sizable storm, on May 4th, forced everything start over again. Moreover, total seasonal rainfall was low and flows rapidly decreased – helped along by the fact that 2002 had been an extreme drought year – and aquatic plants soon became dominant below the sewage treatment plant. It turned out that the big 2003 storm was really not big enough, and lots of *Ludwigia* roots remained behind to give it a head start once the rains stopped. Figure 2 documents this transformation at Main Street.

In classifying 2003 data for locations below the treatment plant, Chl-a values from the first part of the dry-season – when the *Cladophora* bloom was active – were placed in the "2003 bloom" category and are shown in the upper panel of Figure 1; data from when aquatic plants dominated were simply designated "2003" and plotted in the lower panel. Alternately we might simply consider data from the initial 2003 algal bloom as fitting in with 2008, while data from later in the season resembles 2009. Above the treatment plant, at Foster Park, *Cladophora* were dominant all season long (see Figure 3) and these data were all placed within "2003 bloom."

Let's assume that what I'm saying is valid, that there is a different relationship between algal

Figure 2. Looking just upstream of the Main Street Bridge in 2003: May 14 above, September 6, below. In May a significant Cladophora bloom was taking place at this location. By mid-June the bloom was over and the reach became dominated by Ludwigia and diatoms. In my differentiation of the 2003 Chl-a data, only the May and early June data at this location was considered "bloom."

Figure 3. Looking upstream from the bridge at Foster Park in 2003: May 14 above, September 10, below. In May the same significant Cladophora bloom taking place lower down was even more pronounced here. Cladophora dominated at Foster Park throughout the dry-season, peaking in early June and again in late August; all Foster Park Chl-a data was considered "bloom."

density and total nitrogen in a year like 2009 than there was in 2008. What might be possible explanations? Off hand I can offer two, perhaps three, suggestions. The first being the presence of aquatic vegetation. Displacement of algae by aquatic plants (via physical exclusion, sunlight competition, etc.) would reduce Chl-a while leaving the availability of nitrogen relatively unaffected (plant chlorophyll is not measured in algal surveys, and as most aquatic plant photosynthesis takes place above the water surface it has little direct impact on diel oxygen variations). The narrowing of the waterway in dry or drought years, along with the growth of riparian vegetation could further reduce the amount of available light.

Second, changes in algal species may also fundamentally modify the relationship between Chl-a and nitrogen availability. *Cladophora*, which dominates following big rainfall winters, appears to have a competitive advantage in faster flows and nutrient enriched environments, while other species, like *Spirogyra*, *Mougeotia*, *Chara* and diatoms, displace it in lower nutrient/low flow circumstances. These changes are most pronounced in the upper basin where we see *Cladophora* only at the beginning of the season in very wet years, and rarely in dryer years when other species dominate, but this transformation also takes place during the late season at Foster Park.

Playing a role in all this is a third possible factor: flow. Flow of course, or rather the intensity of flow, sets the stage during the rainy season for whatever follows. But besides being a critical environmental factor in and of itself, it also determines the flux, i.e., how much, nitrogen is delivered to any developing algal bloom. Amount (flux) is the product of concentration multiplied by flow. We often tend to forget that concentration is only a measure of how much is in the water, whereas the critical factor is how much is being delivered to a relatively fixed-in-place algal mass. High flux is the reason we can still find Cladophora during low nutrient conditions in the upper basin – but usually only in high velocity, cascade situations.

I don't regard this analysis as yet complete. The lower panel of Figure 1 shows estimated Chl-a from diel data only for April in 2009. Diel data from May, June and August are also available, but, unfortunately, nutrient analyses for these months have not been finished. The UCSB lab. relies heavily on under-graduate student help and, this being the summer break, these samples await the beginning of the new school year. As soon as I have the analysis results I will add them to the graphs and send out a revision. But I must say that I don't expect the overall picture to change.

So what might it all mean? I go back to my original point that extreme inter-annual variability in the Ventura system should preclude thinking that any one year exemplifies the 'Ventura" situation. And that includes any relationship between nitrogen and algae. If I'm correct, and there is a fundamental difference between 2008 and 2009, a look at the Foster Park hydrograph (page 5) will show that "2009 conditions' will apply about half the time (2002, 2004, 2007 and 2009 were similar years) with those of 2008 being somewhat less frequent; and there will also be half-and-half years similar to 2003 where conditions change rapidly between these two extremes.

To summarize, I've placed all the data on one final graph (Figure 4). It's a mess – which is exactly the impression I want to convey. Few data fit into those nicely defined red and blue quadrants: definitely impaired or definitely unimpaired. Most now fall into the no-man's-land of "need-further-investigation." That some fall into the lower right quadrant – of low Chla and high nitrogen – should be no surprise; anyone looking at the lower river this summer would see at a glance that algae were not a pressing problem, even though these are exactly the conditions (very low dry-year flows where high nutrient treatment plant effluent becomes the dominant contributor to flow) that produce very high concentrations of nitrate and total nitrogen. This is also the reason why the spread of data is so

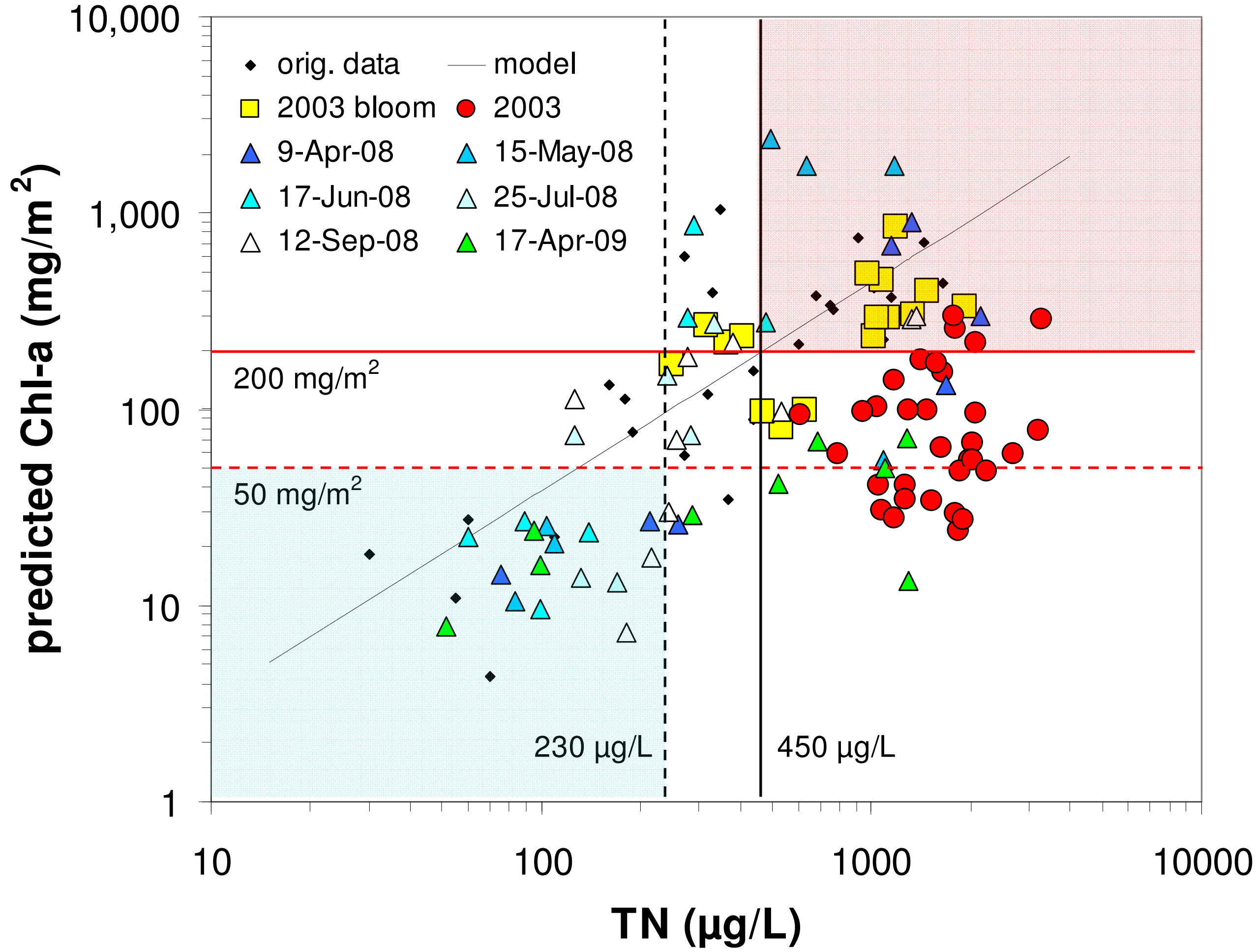


Figure 4. Estimated and measured chlorophyll-a densities (Chl-a) are plotted against total nitrogen concentrations (TN). The black dots and line represent Kristie's original 2008 data and the regression model derived from that data. Measured Chl-a values from 2003 were sub-divided as explained in the text: "bloom" signifying Cladophora as the dominant species, with the remaining data collected from aquatic plant dominated environments. Chl-a estimated from diel measurements of delta-DO and flow are shown as triangles identified by the date of data collection. The graph also shows the recommended impairment thresholds for Chl-a (50 and 200 mg/square-m) and total nitrogen (230 and 450 µg/L) as red and black lines – dashed for the lower threshold below which no impairment exists, solid for the upper threshold above which a reach is definitely impaired. Colored areas delineate the region of *both* algal and nitrogen impairment in red and the region of no impairment in blue. The majority of data now fall within the white areas that define "further study" for possibly excessive amounts of either nitrogen or algae (Chl-a), or both. Note the wide range of Chl-a values that have been found in locations where total nitrogen concentrations exceed 1000 µg/L: Chl-a varying between 10 and 2000 mg/m^2. It should be emphasized that all these points represent the same handful of locations. Indeed the range would be even greater were data from an unbiased selection of high-nitrogen locations included. Sites in narrow, shade-dominated reaches were excluded from the 2008 dataset – the emphasis being placed on surveying algae where they were and not where they weren't. Ironically, the only shade dominated or partially shaded locations included in the UCSB survey were low-nitrogen reference sites, which may have further biased the initial Chl-a vs. TN results.

much greater at the upper end than at the lower: nitrogen concentrations above 450 mg/L yielding Chl-a estimates from as low as 10 to as high as 5000 mg/square-meter. It's only fair to point out that no data falls, either now or initially, within the quadrant representing low nitrogen and high Chl-a. So the relationship between nitrogen availability and algal density is not without value.

I'm not questioning the proposition that nutrient over-enrichment can result in dense algal blooms that pose serious problems. Nor am I proposing that the exuberant aquatic plant growth that we see taking place on the lower Ventura River in 2009, or mid-way through 2003, or even near the end of 2008, are not part and parcel of the very same over-enrichment problem. It definitely is. Indeed, it has bothered me from the beginning that the TMDL appears to be only considering half the problem – the algal half – and seemingly is not even concerned with the aquatic plant half.

The philosopher Karl Popper once defined science as "the art of systematic oversimplification." I'm trying, and have been trying throughout the past year and a half, to prevent oversimplification of the excessive nutrient/algal problem on the Ventura. It may well turn out that the more complex picture I'm presenting is also an oversimplification. It wouldn't surprise me in the least.