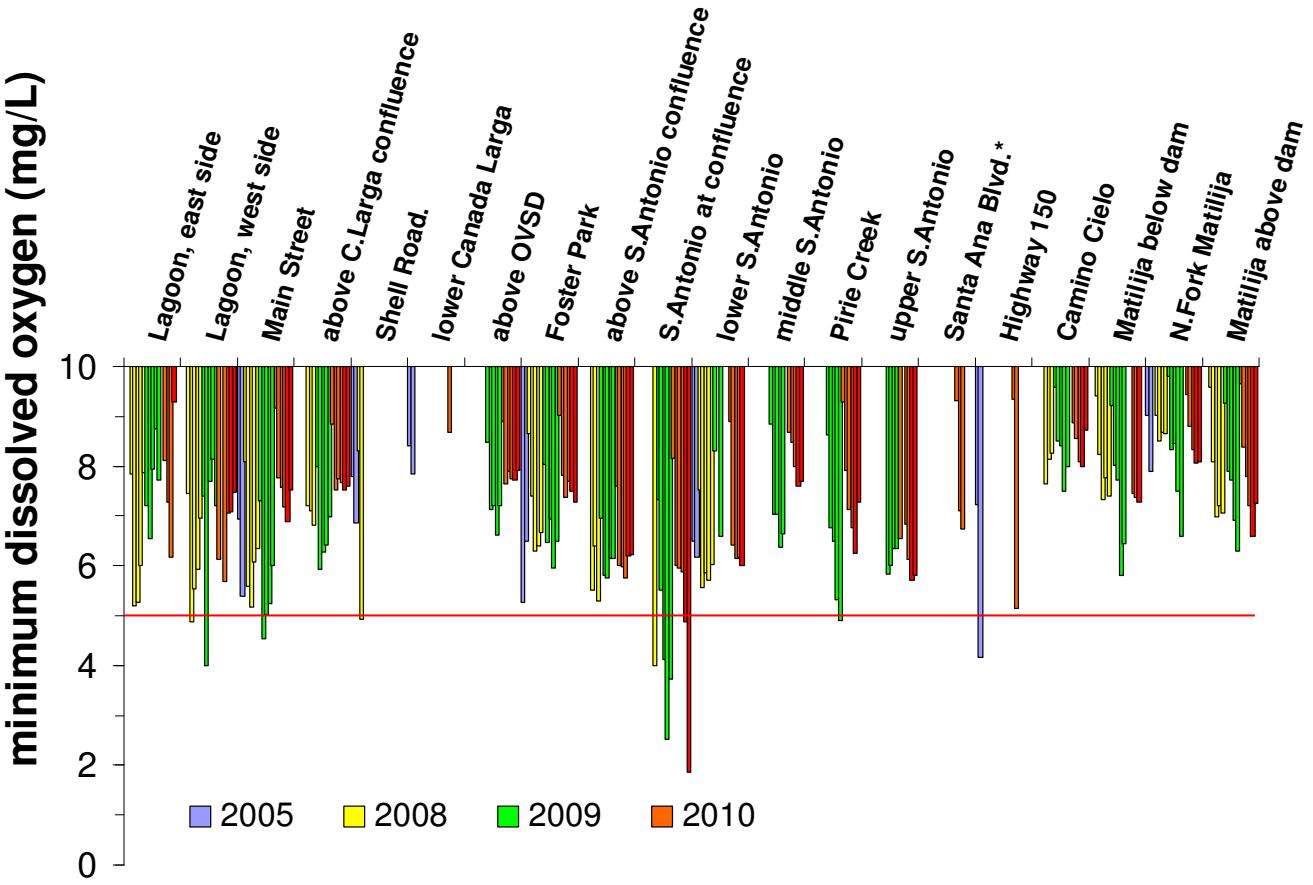


The above graph summarizes all measurements of pre-dawn dissolved oxygen (DO) made by Santa Barbara Channelkeeper (SBCK) from 2005 through 2010. Although DO appreciably varies over a 24 hour period during the algal season (sometime after mid-March until the end of September) it generally reaches a minimum during the early morning hours before sunrise. Considered by itself, algal respiration (the uptake of oxygen by algae) would gradually decrease DO throughout the nighttime hours until sunlight reversed the process to one of oxygen production and carbon dioxide uptake (i.e., the start of photosynthesis).

However, once dissolved oxygen levels fall below saturation a growing oxygen deficit along with decreasing nighttime water temperatures accelerate the transfer of oxygen from atmosphere to the stream. Water depth, wind conditions and reach topography also play a role and continuous measurement is needed to determine the exact point when DO is at its minimum. For all intents and purposes, however, the difference between the exact minimum and the pre-dawn value is almost always quite small and the measurements shown in the graph can be considered minimum values.

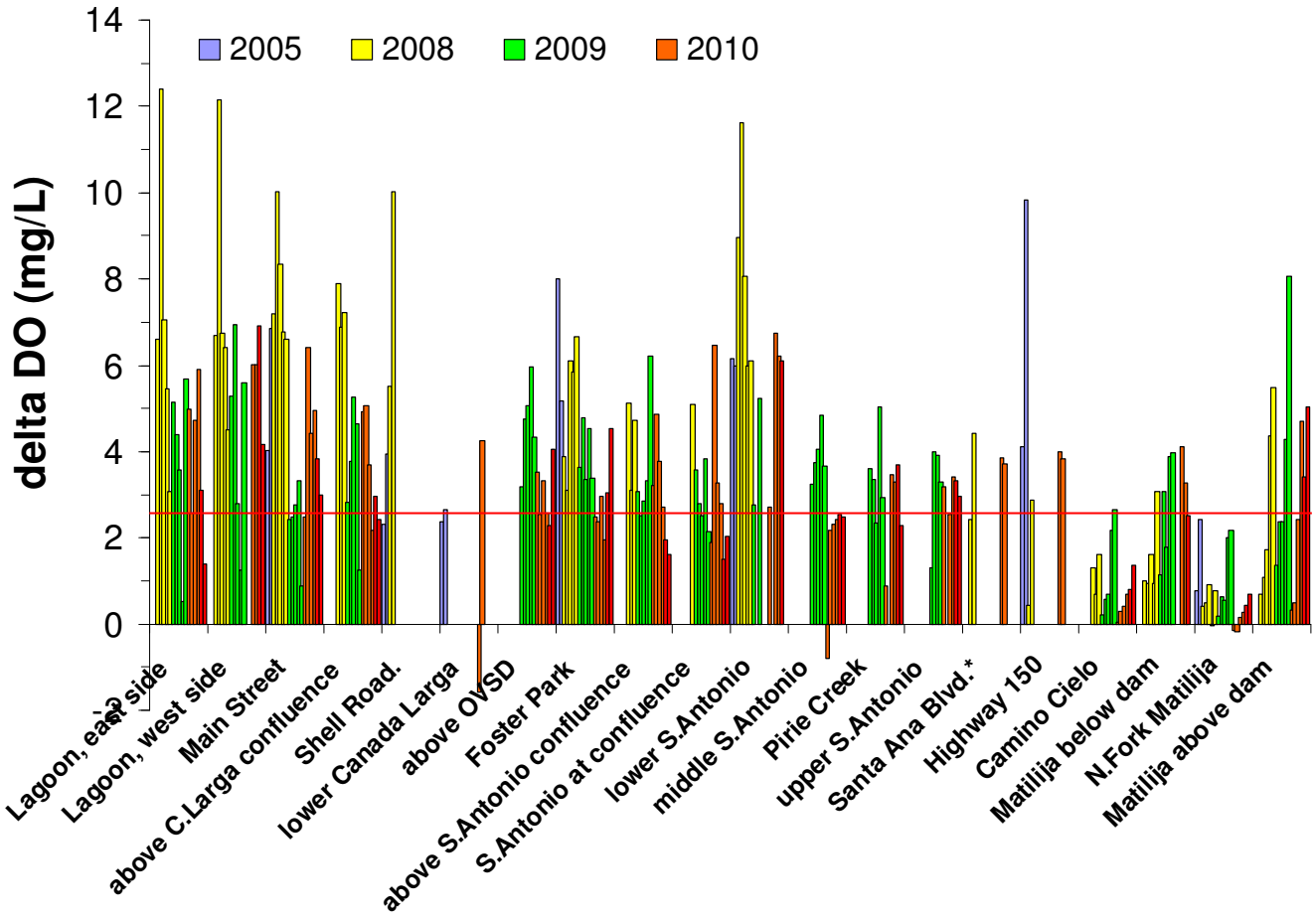
The red line on the graph marks the Basin Plan limit of 5 mg/L, the point below which lower oxygen levels begin to affect aerobic biological life in the stream. SBCK results (usually measured once a month during the algal season) are arranged chronologically by site and a separate color is used to indicate each year. Bars extending below the red line indicate a measured violation of the 5 mg/L limit.

The overall impression given by the data is probably more meaningful than any site by site

examination. Pre-dawn DO concentrations below 5 mg/L were found on only a few occasions: 12 out of a total of 239 measurements, i.e., 5 % of the time. Considering that SBCK may not have captured the actual daily minimum, we can include an added factor of safety and use 5.5 mg/L as an empirical red flag: 9 % of measured minimum DO values (22 out of 239) were below 5.5.

Note that half of the below 5 mg/L events (6 out of 12) occurred at a single location: lower San Antonio Creek just above its Ventura confluence. These were also the most dramatic oxygen depletion events, and occurred during the latter part of the summer; they were associated with low flow conditions long after the peak of the algal growth had passed. At a majority of locations the lowest seasonal dissolved oxygen values occurred at this time of lowest flow.

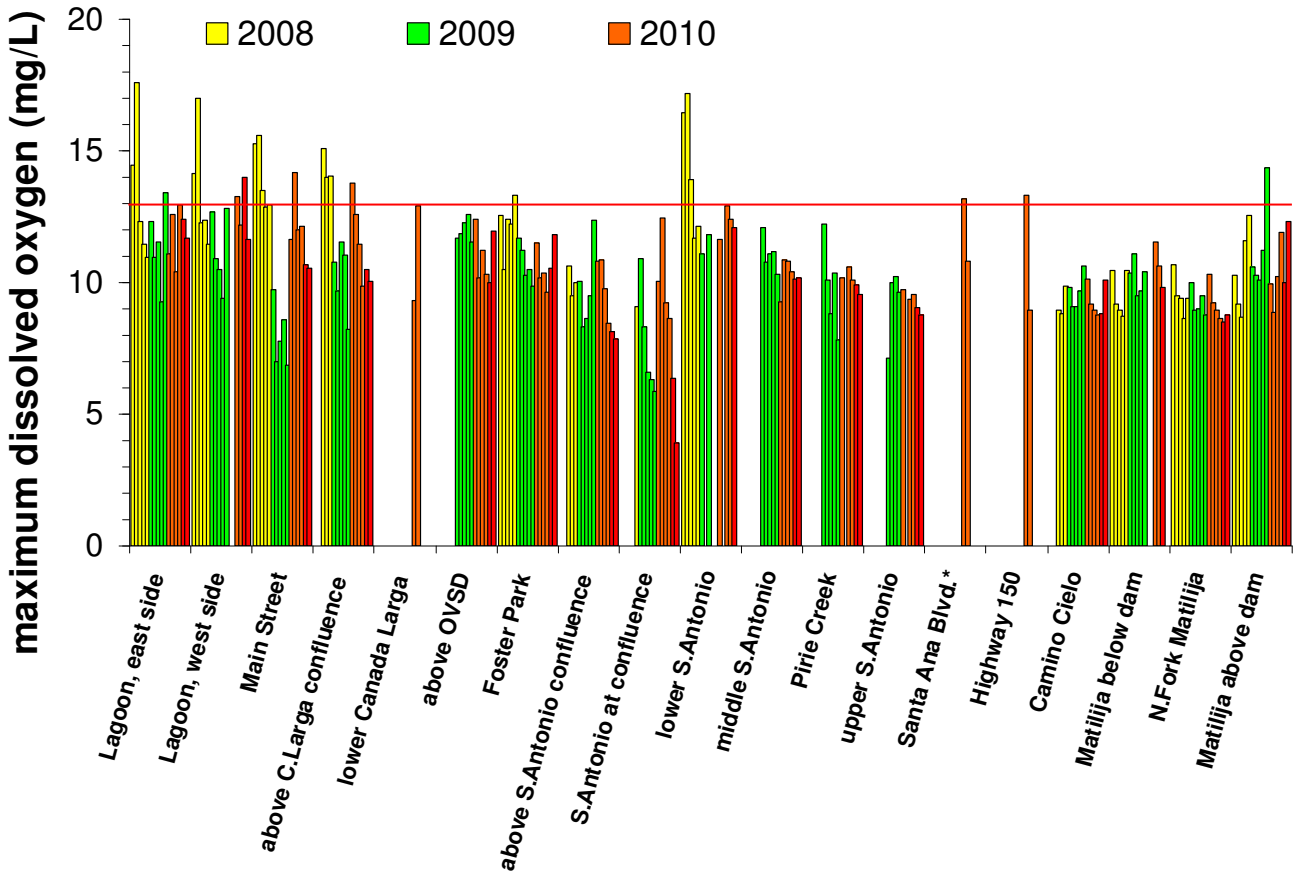
This rather contradictory result is a product of the relationship between algal mass, DO and flow: yes, the minimum oxygen value is directly proportional to the amount of algae present (the more algae, the greater the amount of nighttime oxygen removed from the stream), but it is also inversely proportional to the amount of flow (the greater the flow, the lower the impact of algae on DO – simply because it's far more difficult, and takes far more algae, to modify a larger mass of moving water). Only on the lower river and in the lagoon (when it's dominated by freshwater inputs) do we see the lowest values of DO near the beginning of the algal season; only in very heavy algal-growth years are these values likely to fall below 5 mg/L.



The second graph shows "delta-DO," the difference between maximum and minimum dissolved oxygen over a 24 hour period; more accurately, describing the SBCK data used here, the difference between pre-dawn measurements and a second measurement made in mid-afternoon of the same day. As with minimum DO, mid-afternoon DO is a good approximation of the actual maximum. And as in the first graph results are arranged chronologically by site with a separate color indicating each year.

The red line is my interpretation of one of the screening criteria developed by the Central Coast RWQCB to identify reaches undergoing excessive nutrient enrichment or, as they call it, "biostimulation." These markers were identified using Central Coast data on DO and nitrate along with a TetraTech model. Without going into further detail (various reports are available on the CC RWQCB website) they identified sites having a maximum algal oxygen depletion of 1.5 mg/L or less as not being endangered by excessive nutrient enrichment. I've simply doubled that value and applied it to the delta-DO values shown on the chart. The implication of the red line is that locations with a delta-DO greater than 2.5 mg/L may be undergoing excessive biostimulation.

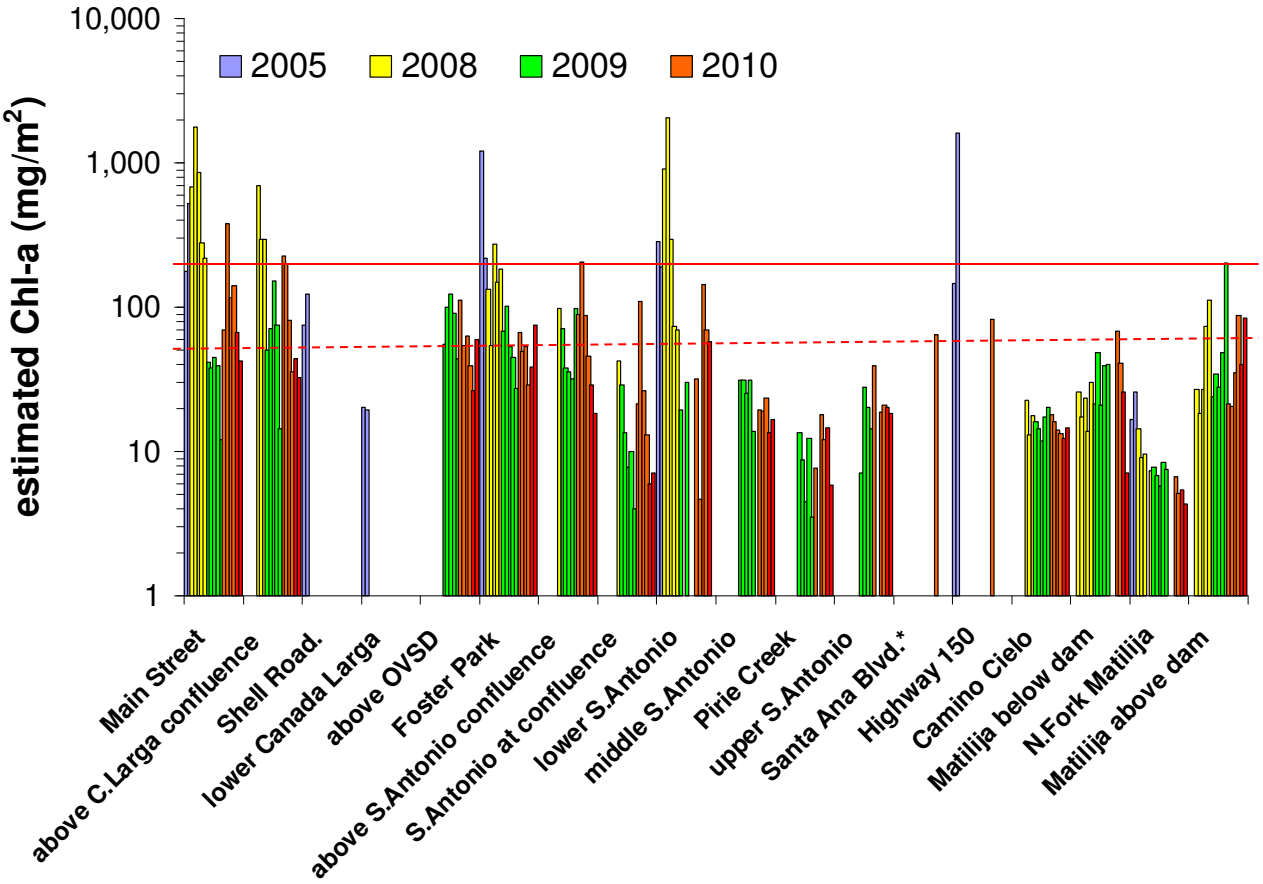
As a standard it does a pretty good job of identifying sites with significant algal problems, and the particular months and years when these problems occurred (you'll have to take my word for it). (Negative delta-DO values appearing in the graph were caused by the combination of negligible algae and a large day/night temperature differential which caused mid-afternoon DO concentrations to be lower than those measured at pre-dawn.)



The third figure shows SBCK data along with another screening criterion used by the Central Coast Board: maximum DO (SBCK mid-afternoon DO values are shown on the graph). They found that sites that never violated their minimum established oxygen limits (5 mg/L for warm-water aquatic life; 7 mg/L for cold-water) also rarely exceeded a maximum dissolved oxygen concentration of 13 mg/L. The attractiveness of this criterion is obvious. Whereas pre-dawn DO measurements are few and far between (and parameters such as Chl-a density even harder and far more expensive to acquire) measuring DO in the afternoon (in daylight!) is much more easily accomplished.

Maximum DO >13 mg/L may be a better criteria for identifying locations subject to algal-caused DO problems than the actual measurement of minimum DO. The key phrase behind this seemly nonsensical conclusion being "algal-caused." In the end-of-season/low-flow situations in which most of the DO < 5mg/L problems on the Ventura have been found, a significant portion of the lowered DO results not from algal respiration but by decay processes in bottom sediments.

Note that the location with the greatest occurrence of below 5 mg/L DO, San Antonio Creek just above its confluence with the Ventura, shows no incidences of mid-afternoon DO above 13 mg/L, an indication that the largest problem at this site is not so much algae but decay and low, sluggish flows. Conversely, a little further upstream, at the location named "lower San Antonio," maximum DO has often been above 13 mg/L, indicating lots of algal growth and yet, looking at figure 1, SBCK has never measured a DO below 5 mg/L.



Finally, as part of the UCSB study of algae and nutrients a model predicting algal densities from flow and delta-DO was developed from Ventura data collected in 2008. The model was later slightly modified by adding earlier Ventura data from 2003 and additional Calleguas watershed data supplied by Diana Engle. I've applied this model to the delta-DO values shown in the second graph and used flows from various sources (SBCK measurements, USGS and Ventura County Water Protection District gauging data) to estimate algal density (in mg Chl-a per square meter, mg/m^2).

These results are shown in the last graph. The red lines indicate the >200 (solid – undeniably impaired) and < 50 (dashed – non-impaired) mg/m^2 Chl-a criteria recommended in the study. Readers can draw their own conclusions. I think the results look reasonable. Lots of algae in good water years like 2005 and 2008, not so much in drier years like 2009 and 2010. But this is something we already knew without any measurements whatever.

It's no secret that I believe the measurement of algal density to be impractical, absurdly expensive and statistically (and scientifically) flawed, and that it should not be used as a primary compliance criteria in the Ventura TMDL. Which is why I've shown some of the alternative Central Coast screening standards here. The real problem on the Ventura River is not algae but excessive nutrient enrichment, algae are merely a symptom of the problem. And far from the only symptom. A symptom, moreover, only extravagantly present in some years and often only during certain months of those years. In certain areas algae are almost never a visually present because necessary ingredients for their growth – like sunlight – are in short supply. Yet the underlying problem still exists. I have a simple solution. If excessive nutrient enrichment is the problem – as it is – let's simply measure nutrient concentrations and base the TMDL criteria on allowable concentrations of those nutrients.