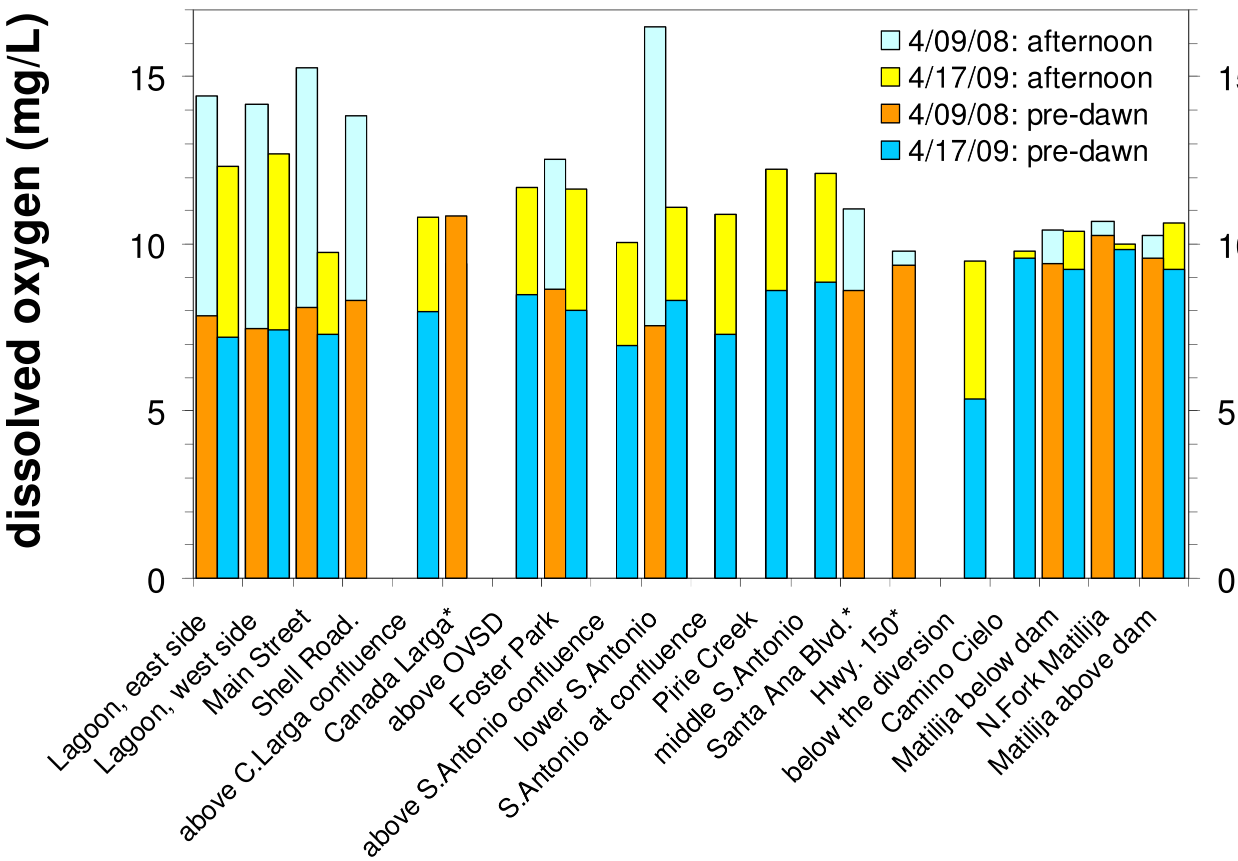


On April 17, 2009, Santa Barbara Channelkeeper began its first round of 2009 diel measurements of dissolved oxygen (DO), water temperature and *p*H on the Ventura River. Pre-dawn measurements are typically made between 4:30 to 6:30 AM, afternoon measurements between 1:30 and 3:30 PM. The dissolved oxygen values recorded, displayed to emphasize differences between pre-dawn and mid-afternoon concentrations, are shown on the graph (in mg/L, i.e., ppm). Fifteen locations were sampled, including 2 in the lagoon. Also included in the graph are results from just below the Lake Casitas (Robles) diversion, sampled on April 22 (by Scott Lewis and the other fisheries guys from Casitas Municipal Water District). And, for comparison, diel results from last year's sampling on April 9, 2008, shown in contrasting colors to help them stand out.

The lowest DO values recorded on April 22 were 6.95 mg/L just above the San Antonio confluence and 5.37 below the diversion; both were above the 5 mg/L basin plan limit.

Since its original conception sites included in the diel monitoring program have been considerably revised. This year Channelkeeper has made an effort to include more of the locations referenced in the UCSB-TMDL Report (recently completed and now available) and additional San Antonio Creek sites. Sites shown on the graph with missing data for either April 2008 or 2009 give an indication as to what changes were made. In the program we endeavor to monitor as many locations (locations relatively accessible in the dark) as three teams can accomplish in approximately two hours. Sampling locations labeled with an asterisk were dry on April 17th.

Ordinarily Channelkeeper has not concerned itself with algae in a dry-year (i.e., one with below average winter rainfall and no significant flood-flows). We've only measured algal impacts on pre-dawn DO in years like 2005 and 2008 – big rainfall years, years with lots of rain, major storms and significant flood-flows. The reason lies in the presence or absence of aquatic plants and fine sediment.

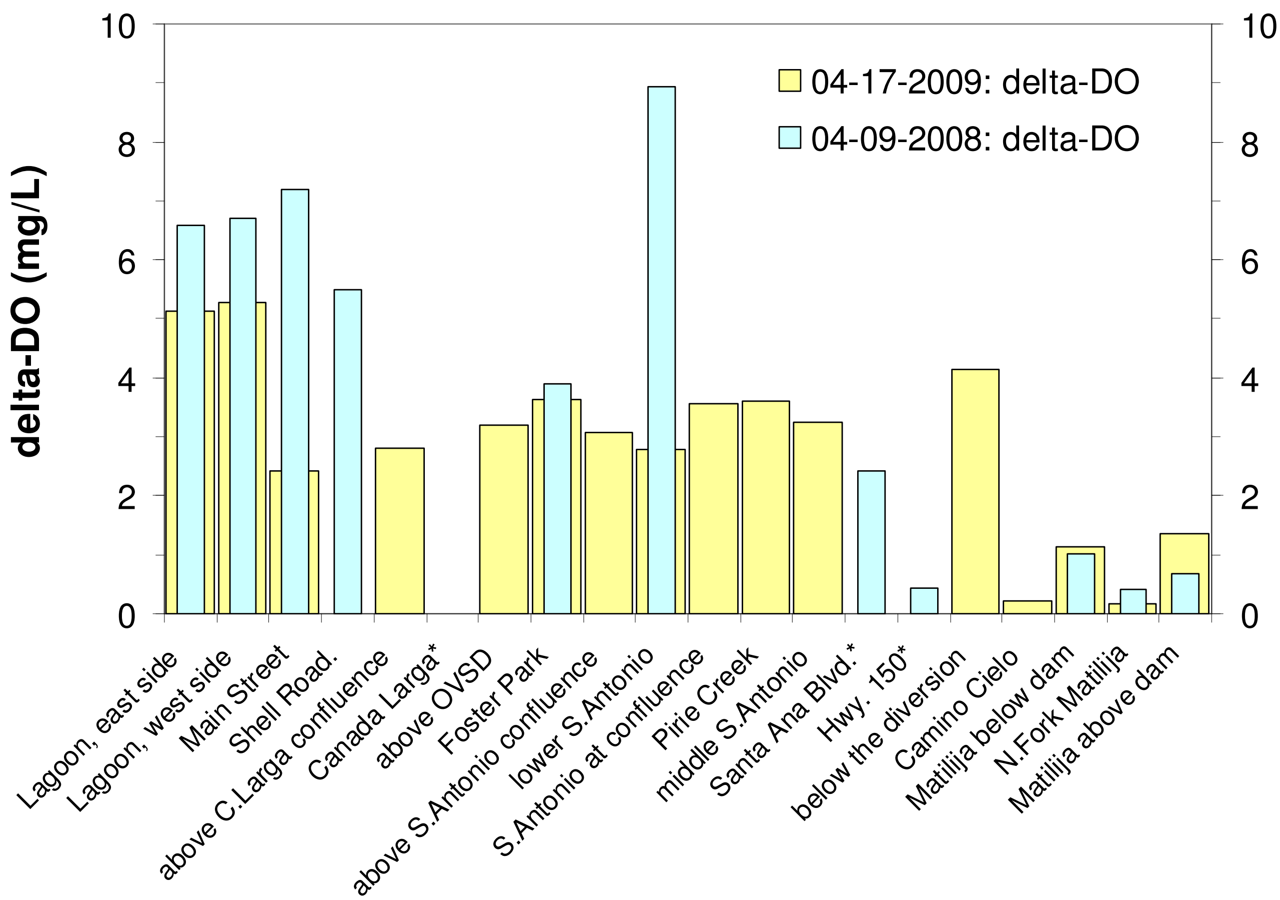
Aquatic plants out-compete algae by over-shadowing the water surface and hogging sunlight, and fine sediment covers bottom gravels and cobbles that provide preferred habitat for the algal species that usually dominate the Ventura watershed. In a dry year, the lack of big, riverbed-clearing, storms, leaves plants and sediment from the previous fall in place, depriving algae of its usual head start at the end of winter. It's a mutually-reinforcing process: increasing amounts of sediment on the bottom allow aquatic plants to expand across the riverbed which, in turn, increases the efficiency of sediment capture. Low flows also shrink river widths, intensifying competition between plants and algae, and in that competition algae loses. Observing this process in the past, we've never worried about algal problems in years like 2009.

However, we are continuing last year's program of diel measurements into 2009 for a number of reasons. One being that our claim of no, or greatly lessened, algal problems in a dry-year may not be taken seriously during the developing algal TMDL process. After all, it's logical that algal problems should be greater when flows are lower. The impact of algae on DO and *p*H (algal growth produces a daily cycle in both DO and *p*H: daylight photosynthesis adds oxygen while removing carbon dioxide; nighttime respiration reverses the process) is a product of (1) the amount of algae *and* (2) the volume of flow they exert their effect on. Lower flows will experience a greater algal effect. The UCSB-TMDL Report makes this very point. And if the only year the Regional Board chose to actually study algae on the Ventura happened to follow a wet winter, why would they think differently? After all, the Board's view of the problem is centered around nutrients and algae – high nutrients causing lots of algae – and no one has ever mentioned aquatic plants. Much less that over-enrichment of the river by nutrients has produced periodic explosions of aquatic plant growth as well as algal blooms. The fact that Channelkeeper has never bothered to measure the diel DO cycle in a dry-year, because it never appeared that algae might be a problem, may just bite us in the ass.

Another reason is that we've never really searched out possible problems in locations other than those regularly sampled. We focused on places with major wet-year problems, and since these same locations didn't have dry-year problems we never bothered to look further. And perhaps we should have. Since 2005 we've become aware of the serious algal situation above the San Antonio confluence and there are probably other potential problem areas we've never thought of. We've been jumping to conclusions by assuming that no dry-year algae problems on the lower river means their absence elsewhere. And if sites elsewhere on the river do not have a serious algae problem in a big algae year (a wet year like 2005 or 2008), they will not have one in a dry-year either. Helping us along was the simple fact that a number of sites with wet-year algae problems, like lower San Antonio Creek, Lion Canyon and Canada Larga, often go dry in years like 2009 (by definition: no water = no algae) or may never have water at all (like the middle Ventura reaches circa Highway 150 and Santa Ana Blvd.).

We'd forgotten that low flows, by themselves, might enhance the impact of even low amounts of algae. Perhaps even at sites in shady locations (e.g., San Antonio Creek, the N.F. Matilija) which generally don't present problems with dense algae.

Delta-DO is the difference between the maximum and minimum daily dissolved oxygen concentrations, or in Channelkeeper's case, the difference between mid-afternoon and pre-dawn concentrations (the approximate times when these extremes normally occur).



The above graph contrasts delta-DO values for the April 2008 and 2009 data shown in the opening chart. The highest values this April were found in the lagoon (dominated by planktonic algae, Figure 1), but elsewhere on the lower river (i.e., below the Ojai Sewage Treatment Plant) concentrations were much lower than last year and lower than in reaches further upstream (above the plant, at Foster Park and on San Antonio Creek). Delta-DO was relatively high at Foster Park (Figures 2 and 3) and on the lower San Antonio (Figure 4), but lower than last April. The oxygen variation was appreciable all along San Antonio even though sites like Pirie Creek are in well-shaded locations. As usual, the lowest amount of variation was found in the upper basin, but, in contrast with everywhere else, the diel cycle here was greater than in April 2008.

Since filamentous algae were much less in evidence during April 2009 than in 2008 (e.g., Figures 8 and 9), reduced flows are causing a surprisingly strong cycle almost everywhere; the exception being below the treatment plant, where increased dominance by aquatic plants explains a reduced diel cycle (Figures 5, 6 and 7). It appears that whatever filamentous algae were present, along with crustal alga colonies occupying cobles at most sites and diatoms, were enough to produce appreciable diel variations. Figure 10 shows close-up views of what the river-bed looked like at two locations; neither is what we usually think of when contemplating adverse algal impacts.

The location with the highest April ’09 freshwater delta-DO (see the above graph) was below the diversion. Data at this location were collected on April 22 (and again on May 11) by the Casitas fisheries guys using an automatic recording meter. Since this was the first opportunity (since 2003) to see hourly data from the Ventura I’ll discuss it in greater detail later. The diversion would not

Figure 1. The Ventura lagoon, looking upstream from the RR bridge: upper photo April 9, 2008, lower April 17, 2009. Not much has changed (delta-DO of 6.6 mg/L in '08, 5.2 in '09). The lagoon was open to the ocean in April of both years although greater flows in 2008 produced a less brackish environment and more filamentous algae. Both photos exhibit the greenish tinge given water by planktonic algae which dominated the lagoon on these dates.

Figure 2. Looking upstream from the Foster Park bridge: upper photo April 9, 2008, lower May 2, 2009. In spite of appreciably changed conditions, the April diel cycle was roughly the same for both years. While there is noticeably less algae this year, there is also only ¼ of the flow (10 vs. 40 cfs).

Figure 3. Looking downstream from the Foster Park bridge: upper photo April 9, 2008, lower April 17, 2009. Again, less algae and lower flows are evident. I'm curious as to why the foliage appears so different in both photos: Different cameras? A trick of the light? A later Spring? Although I have the impression of a colder winter and spring this year the Ojai temperature record does not bear this out.

Figure 4. Lower San Antonio Creek on Old Creek Rd., looking downstream: upper photo April 10, 2008, lower April 17, 2009. Aquatic plants, low flows and a relative absence of algae in '09 explain a much oxygen variation (delta-DO = 2.8 mg/L) than in '08 (8.9 mg/L).

Figure 5. Looking upstream from the Main Street bridge: upper photo April 9, 2008, lower April 17, 2009. Lower flows and dominance by aquatic plants (bright green = watercress, reddish tinge = Ludwigia) says it all, but healthy cladophora can also be seen in the open water of the lower photo.

Figure 6. At the Canada Larga confluence (just below the treatment plant), looking upstream: upper photo April 10, 2008, lower April 17, 2009. Algae (cladophora) were present this April, but the major difference is the almost overwhelming growth of watercress since last October.

Figure 7. At the Canada Larga confluence (just below the treatment plant), looking downstream: upper photo April 10, 2008, lower April 4, 2009. Appreciable encroachment by plants occurred along the river edge and in slack water areas in the absence of a significant flood last winter.

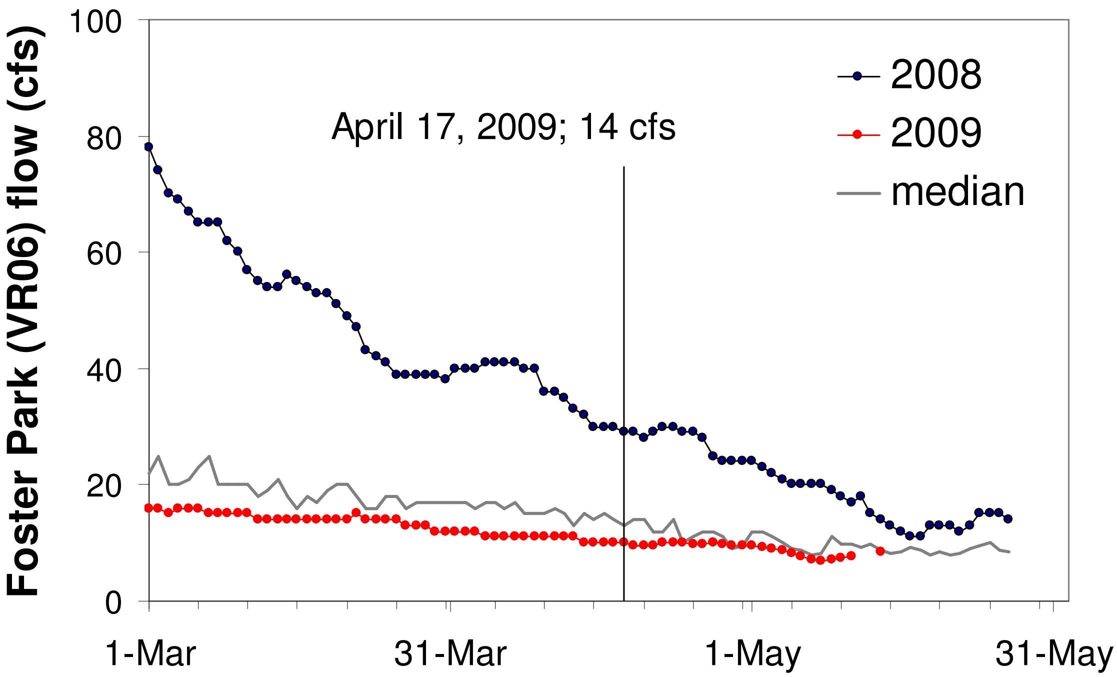
Figure 8. Looking upstream just above the sewage treatment plant: upper photo April 10, 2008, lower April 17, 2009. The April '09 oxygen variation was surprisingly greater here than below the treatment plant, in spite of a relative paucity of filamentous algae.

Figure 9. Matilija Creek above the dam: upper photo April 9,2008, lower April 17,2009. Much lower flows have more than made up for the relative absence of algae in 2009, compared with 2008, producing a deeper oxygen depression and stronger diel cycle in April. The same situation holds throughout much of the upper Ventura watershed.

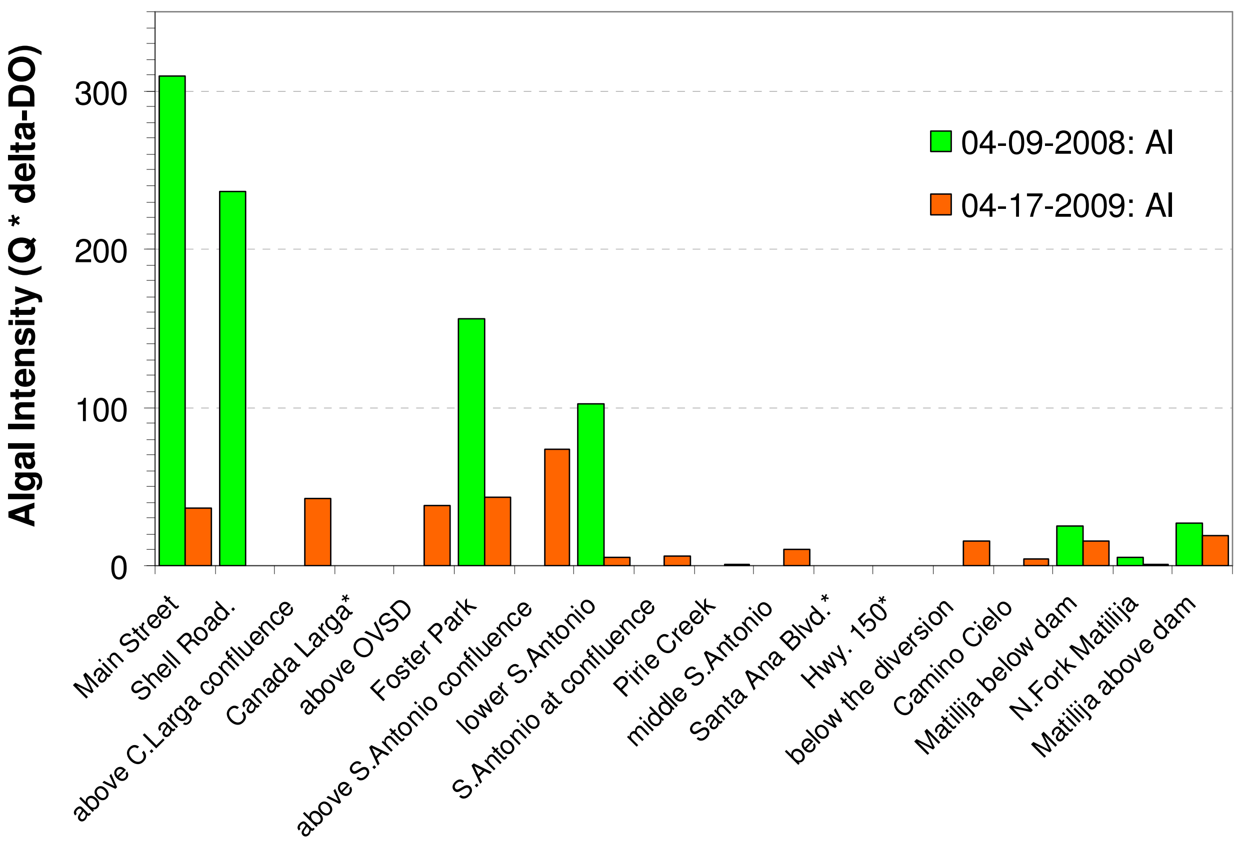
Figure 10. Some algal close-ups on April 17, 2009: The upper photo at Foster Park shows entromorpha and some relatively unhealthy looking caldophora along with the greenish tinge of crustal algae on rocks. The lower, from just above the treatment plant, indicates mostly diatoms and crustal algae. These relatively low amounts of algae were still producing appreciable oxygen variations in the low flows we are seeing this year.

ordinarily have been considered a location requiring diel monitoring, but photos taken there on April 7 showed an extraordinary amount of algae – extraordinary because nothing like it was seen elsewhere during regular Channelkeeper monitoring on April 4th. I've included one taken just above the diversion here:

Channelkeeper was unable to get permission for pre-dawn access to the diversion, but the fisheries guys generously offered to monitor it for us; they plan to take hourly measurements over a 24 hr period every other week until the site goes dry. Their data will be an extremely valuable, and much appreciated, addition to the diel monitoring program.



It appears that flow will be the critical factor in determining the severity of algal impacts in the watershed during the current year. The previous graph indicates the current situation at Foster Park, showing this year's and last year's average daily flow, as well as the median daily flow (for 49 years of record; half of recorded daily flows were above the median, half were below it). If we consider median flow the "average" flow (the real average, or *daily mean flow*, is higher than the median because the occasional "big" year, like 2005, exerts an exaggerated influence and biases this measure), we are currently below average but not too far below. (For comparison purposes: this year is looking very much like 2007, but flows in 2002 and 2004 were much lower.)



Last year I introduced the concept of *Algal Intensity* as a measure of algal impact or algal effect. Algal Intensity (AI) is calculated by multiplying delta-DO by flow; if delta-DO is measured in mg/L and flow in cubic feet per sec (cfs), the resulting unit for Algal Intensity is mg/L*cfs, but the actual units are of no practical importance. What is important is that AI can serve as an indirect measure of overall algal productivity since it combines the effect algae are having on oxygen concentrations and the amount of water they are having this effect on. Expressed differently AI/Q = delta-DO: when algal productivity increases – an increase in biomass or photosynthetic activity or both – delta-DO increases; when flow increases, delta–DO decreases.

It is, of course, an imperfect measure. Other processes add or subtract dissolved oxygen from the water column (and I'll be happy to go into this with anyone who cares enough to email me), but if algae are the dominant process doing this the concept is useful (and I would point out that not many other processes do both over a 24 hr period) – and, more importantly, it's an easy value to calculate. The above graph compares last April's AI values with this year's.

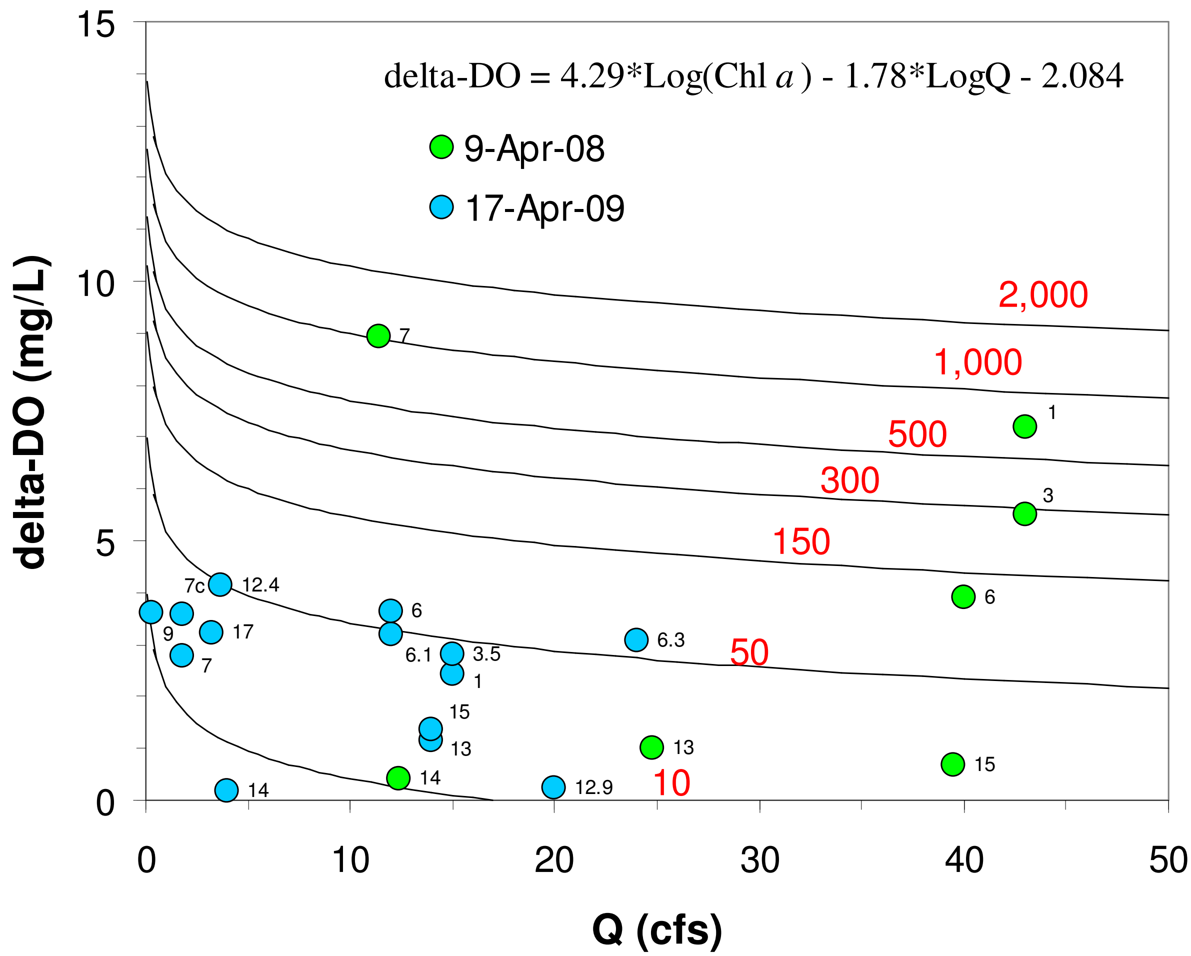
The UCSB-TMDL report and the Regional Board use another measure: chlorophyll a (Chl-a, the active ingredient, so to speak, of photosynthesis). Chl-a differs from AI in two substantial ways: first it's very difficult to accurately determine and, second, it's a measure of the *amount* of algae and not it's *impact* on a river or stream reach. In one of last year's reports I looked at possible ways to relate the two. It turns out that what I proposed back then was wrong. So here's the current version: Algal impact or the effect algae will have on a river reach will be directly proportional to the amount of Chl-a and inversely proportional to the flow (Chl-a/Q): the more algae the greater the impact or effect; the more water, the less impact or effect a given amount of algae will have, and visa versa. Therefore AI is proportional to Chl-a/Q, or stated another way AI times Q ($AI \times Q$) is proportional to Chl-a. Since AI equals delta-DO times Q, delta-DO times Q squared ($AI \times Q^2$), is proportional to Chl-a. Rearranging terms:

$$\text{delta-DO} \propto \text{Chl-a}/Q^2$$

In other words, a reduction in flow will have an exponentially greater impact on the diel oxygen variation than a similar reduction in the amount of algae. As an example, flows this year are presently about ¼ of last year's implying a 16-fold increase in delta-DO had Chl-a densities been similar; considering locations where this April's delta-DO is roughly the same as last year's, Chl-a densities will have to have decreased by a factor of 16 to produce the same effect. This accounts for the appreciable variations in DO seen this April in spite of what appears to be rather sparse algal cover (see Figure 10). (Still confused? Think of it this way. Delta-DO measures the *impact* of algae on the river at a given location; multiplying it by flow quantifies the magnitude of this impact. Chl-a measures the *amount* of algae; dividing it by flow determines the likely impact of this amount of algae – more flow, less impact; less flow, more impact.)

Be that as it may, the Chl-a density data collected in last year's UCSB-TMDL algal study and Channelkeeper's near contemporaneous delta-DO measurements along with Ventura County, USGS and Channelkeeper flow records allowed the development of a model derived by regressing delta-DO on Chl-a and Q (shown on the next page). The model, featuring lines of equal Chl-a densities (red numbers represent density in mg/m^2), allows an estimate of Chl-a derived by entering values of flow (in cfs on the x-axis) and delta-DO (in mg/L on the y-axis). To demonstrate how it works I've entered flow and delta-DO values from the April measurements of 2008 (green) and 2009 (blue). Channelkeeper site numbers are shown along side each point (identified below).

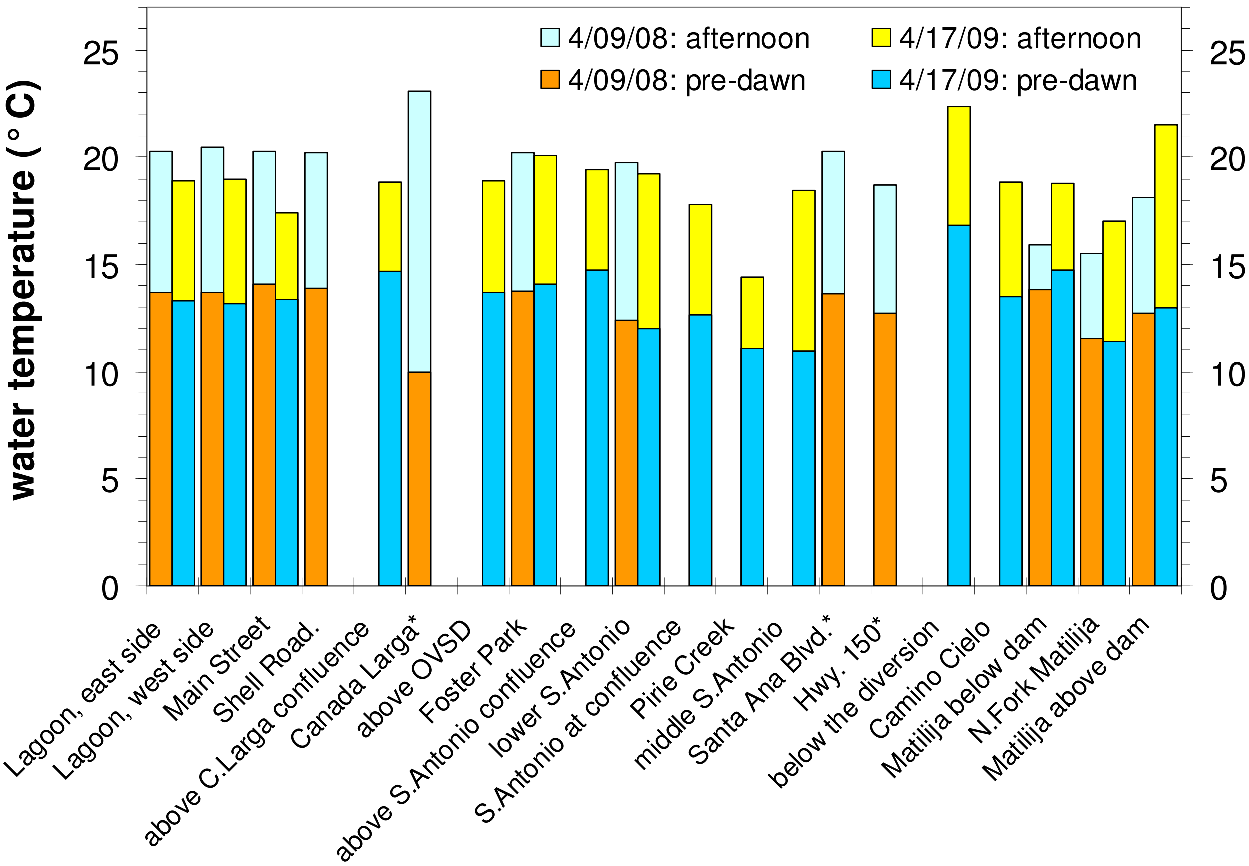
location name	no.	location name	no.
Lagoon, east side	0e	Lion Canyon	8
Lagoon, west side	0w	Pirie Creek	9
Main Street	1	upper S.Antonio	10
Stanley Drain	2	Santa Ana Blvd.	11
Shell Road.	3	Hwy. 150	12
above C.Larga confluence	3.5	below the diversion	12.4
Canada Larga	4	above the diversion	12.4
Upper C. Larga	5	Camino Cielo	12.9
Foster Park	6	Matilija below dam	13
above OVSD	6.1	N.Fork Matilija	14
above S.Antonio confluence	6.3	Matilija above dam	15
S.Antonio at confluence	7c	middle S.Antonio	17
lower S.Antonio	7		



The graph is a good visual representation of how data from this year varies from last. Note that 2009 flow and delta-DO data are clustered in the lower left-hand corner, whereas flow and delta-DO were considerably higher in 2008. Since the TMDL standards will almost assuredly be in Chl-a concentrations (less than 50 mg/m^2 defining "unimpaired" reaches, greater than 150 or 200 mg/m^2 "impaired" reaches; anything falling in-between requiring further study or monitoring), we need some method to convert from some easily measured parameter, like delta-DO, to one (Chl-a) that seems designed to provide job opportunities for unemployed aquatic biologists. In my, admittedly highly biased, opinion it's the difference between measuring a well-defined impact on the river vs. counting the number of angels on the head of a pin (OK, so I'm exaggerating a little). (I'll be happy to provide more information on this model, and the data used to derive it, to those requesting it.)

Those who have managed to read this far will be pleased to learn that I'll not be discussing *p*H at this time. Last year pH required ever more convoluted story-telling to present a reasonable narrative explaining numerous seemingly contradictory changes as the months went by. Until, finally, even I gave up. This year I plan on waiting until the end of the season and reviewing the available Channelkeeper data, along with the hourly sonde measurements made last September by OVSD. If, at that time I can think of anything intelligent to say, I'll present it all in a single report.

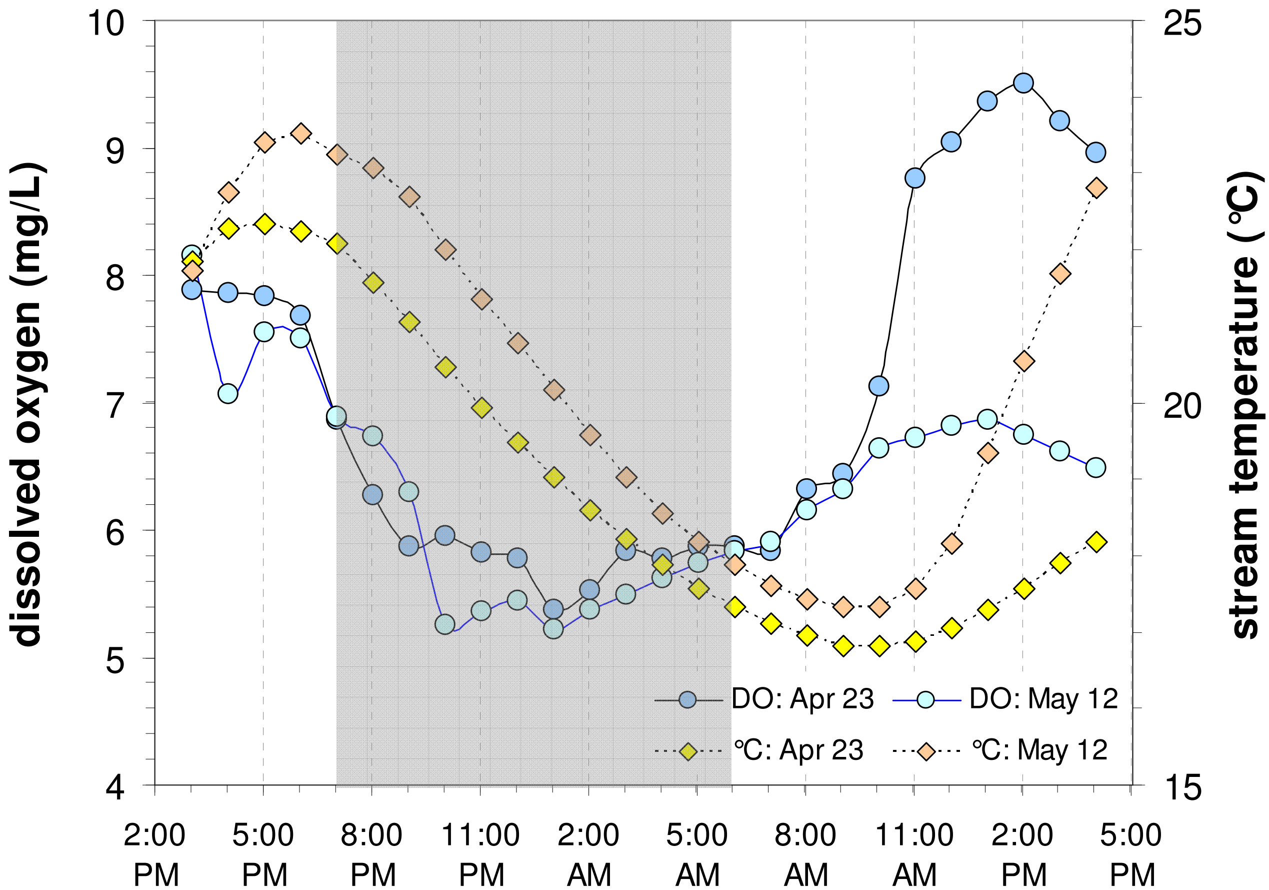
That leaves only stream-temperature. Last year we became concerned about what seemed to be very high water temperatures in the upper basin: reaching almost 30 °C (on Matilija Creek above the dam. that's 86 °F; we're talking bathwater here). This situation was completely unknown to us since Channelkeeper normally samples between 9:30 AM and noon and this was the first time we looked at what might be happening later in the day. The current plan is to place tidbit temperature loggers, recording hourly data, at a number of locations in the upper basin later this month, but until then the diel measurements are all we have available.



The graph shows pre-dawn and mid-afternoon water temperatures for April 2008 and 2009. Generally, in the mid- and lower-basins, temperatures were both slightly lower and showed a diminished range this April. However, an opposite pattern, of higher temperatures and greater variation, was found in the upper basin. Of course, individual daily air temperature variations and the duration and intensity of coastal fog might be responsible for these differences, but the contrast between lower-below/higher-above, on what was a sunny day throughout, is not a good portent for the remainder of the summer.

Last year's primary suspect, at least on Matilija Creek above the dam, was the arundo removal project which opened up the river bed to considerably more sunlight (however measurements elsewhere, on reaches generally in the shade and unaffected by arundo removal, indicate that high water temperatures might be a more regular occurrence). This year's low flows (see Figure 9) are likely to exacerbate the problem.

And the problem is probably worse than previously thought. One of the most valuable uses of the hourly data (DO, water temperature and *p*H) collected at the diversion has been providing a check



on our assumptions that minimum and maximum DO occurs at pre-dawn and mid-afternoon, respectively. The above graph presents some of this data: hourly water temperature and DO concentrations taken on April 23 and May 12, 2009 (the shaded portion represents the approximate hours of darkness). Below the diversion maximum DO occurred between 1 and 2 PM; which is quite reassuring. Minimum DO presented a more complicated picture, but measurements taken before 7 AM would have captured most of the decline in oxygen concentrations. However, with regards to water temperature our assumptions appear to be further off: minimum and maximum temperatures both occurred considerably later than assumed, between 8-9 AM and 5-6 PM, respectively.

This was quite a surprise. Scott Lewis and I have talked this over, and Scott suggests that there could be a lag effect due to retention time in the pools above and below the diversion dam; the volume of water being retained is relatively large compared with the ~ 3 cfs that currently flows below the diversion. I've since been provided with sonde data from Calleguas Creek by Diana which suggests that the diversion may not be a special case: maximum water temperatures at various locations occurred relatively closer to the 5-6 PM diversion time than the 1-3 PM we initially assumed (they varied as follows: 3:15-4:30 PM, 4:45-4:30 PM, 4:00-4:30 PM, 4:30-5:00 PM and 4:30-5:30 PM). Another implication of the diversion data is that Channelkeeper temperatures recorded around 9 AM to noon represent more of a minimum than an average.

Hopefully, installation of those tidbit loggers at some of the problem upper basin locations (and up into the wilderness area for purposes of comparison with more pristine locations) will help us resolve some of these questions.

Photos taken on April 9, 10 and 29, 2008 and on April 17, 2009 (and on other Channelkeeper sampling days in 2008 and 2009) can be downloaded at:
http://sbc.lternet.edu/~leydecke/Al's_stuff/Recent%20Stream-Team%20Photos/

Photos of the initial UCSB-TMDL algal survey conducted in 2008 can be downloaded at:
http://sbc.lternet.edu/~leydecke/Al's_stuff/Ventura%20Nutrient%20TMDL/TMDL%20algal%20survey%20photos/

Posted PDF copies of all my previous Ventura Nutrient TMDL reports can be found at:
http://sbc.lternet.edu/~leydecke/Al's_stuff/Ventura%20Nutrient%20TMDL/My%20PDF%20files%20on%20algae%20&%20nutrients/

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