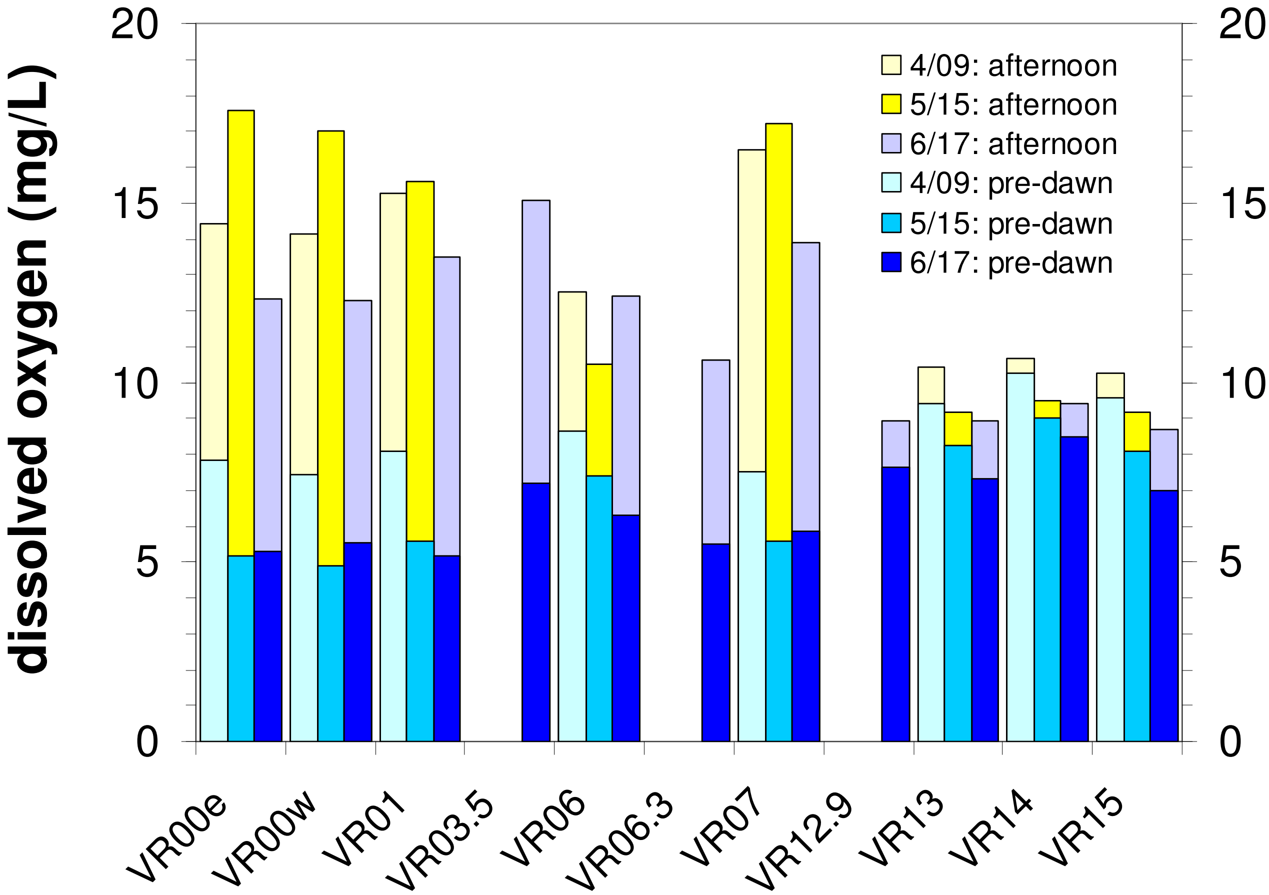



On June 17, 2008, Santa Barbara Channelkeeper measured diel variations in dissolved oxygen (DO) and *p*H at 11 locations on the Ventura River. Measurements were made either in the stream or from samples collected by bucket tossed from a bridge into the center of flow (bucket samples allow faster and easier measurement, especially at night). Pre-dawn measurements were made from 4:30 to 6:15 AM, afternoon measurements between 2:10 and 3:35 PM. The dissolved oxygen values recorded, along with differences between the two readings, are shown on the graph (in mg/L, i.e., ppm). They are shown with results from similar earlier samplings (April 9 & May 15) to illustrate change as the algal season progresses. Sites with whole numbers indicate the regular Channelkeeper monitoring locations at which measurements were made; those shown with a decimal identifier are new locations substituted for previously monitored sites that have since gone dry (Canada Larga, VR04; the middle Ventura sites, VR11 & 12). The new locations, VR03.5 (just above the C. Large confluence, 0.5 km below the treatment plant outfall), VR06.3 (just above the San Antonio confluence, 3.4 km above Foster Park) and VR12.9 (at the Camino Cielo ford, 0.3 km below the confluence of the main and N.F. branches of the Matilija) are all sites surveyed this summer by the UCSB-TMDL project. VR00 indicates samples collected along the east (e) and west (w) sides of the railroad causeway over the Ventura estuary.

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.

**Figure 1**. Ventura Lagoon (VR00): (top) The green color indicates the return of planktonic micro-algae as the dominant player since the berm break; (bottom) the sand berm is now re-established but does not, as yet, provide a substantial barrier; birds (mostly pelicans, up to 300 at times) may be the major vector of nutrients to the lagoon.

DO concentrations in the surrounding water typically peak around mid-afternoon and decline to a minimum just before sunrise. The magnitude of the change in DO reflects both the abundance of algae, the extent of their biological productivity, i.e., how hard they are working, and the amount of water in which this change in DO is reflected. A fixed amount of algae will produce increasingly greater changes in DO as the volume (or flow) of water decreases. And since the dominant alga at all these sites is still cladophora, which usually grows outward from a rock substrate, water depth is also a factor: the shallower the flow, the easier it is for algae to change its characteristics.

The location with the greatest diel variation was Main Street (VR01; from ~5 to 13 mg/L, from 50-60 % saturation to over 160). This represents a change from the previous month when the largest variations occurred in the lagoon. However, as reported previously (*The Ventura Lagoon Breaches on June 4.pdf*), the lagoon experienced a catastrophic failure of the sand berm blocking its mouth on June 4th and the macro-algae that dominated lagoon dynamics in May either died or were swept into the channel. Since then, the lagoon has returned to the state it was in in April: dominated by micro-algae suspended in the water column (Figure 1). This probably accounts for the similarity in lagoon DO cycles during April and June. By June 17th the sand berm had just been re-established (barely) and lagoon water was again totally fresh (1200 to 2000 µS/cm standard conductivity; after the break lagoon waters were decidedly brackish, varying, depending on location, from 1400 to 11,000 µS/cm).

All sites on the lower river (VR06.3 and below) continued to have appreciable day-night DO differences as did lower San Antonio Creek. However, at locations with multiple monthly measurements, these differences decreased over those of May. With one exception: Foster Park (VR06). Here the change in DO (delta-DO, i.e., mid-afternoon - pre-dawn DO concentrations) had gone from 3.9 mg/L in April to 3.1 in May to 6.1 mg/L on June 17th. I ascribed the May decrease to senescence and early decay of benthic algae at this location so a June increase comes as a surprise. The most obvious explanation would be an error in the May data, or in this month's (the possibility of errors in April and June are lowered somewhat since two sets of separate measurements were made on those occasions, on both the upstream and downstream sides of the bridge). However, re-examinating all the photos taken at VR06 since April indicates that something much stranger may be going on – there appears to have been a resurgence of algal health and productivity since mid-May.

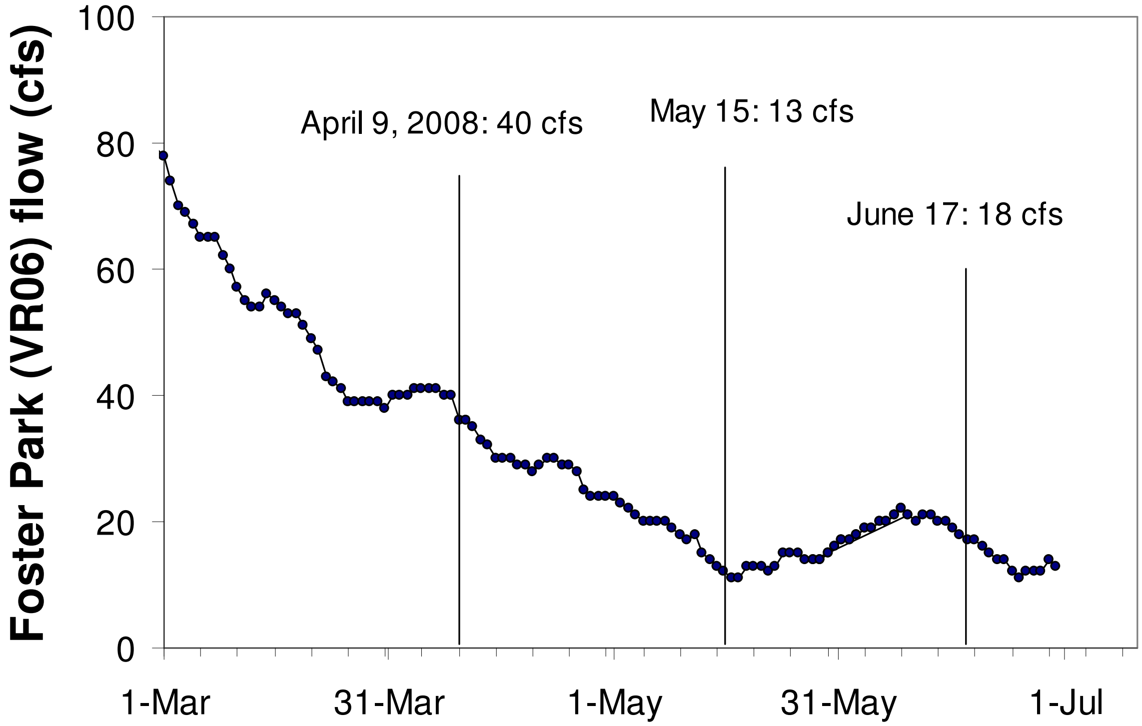
I find this bordering on the miraculous, so much so that I've included three sets of photos showing the transformation (Figures 4, 5 and 6). When Kristi and I were at Foster Park on June 4th, I recall thinking the algae looked so much healthier than I remembered from my May visits, but I put this down to creeping senility. However, the measurements and photos support my initial impression. I am, however, somewhat at a loss to account for why this might be so. While complete nutrient data for June is, as yet, unavailable, nitrate and phosphate concentrations on June 4th show a continued decline from the decreasing trends of previous months (see *The Ventura Nutrient Story_June 2008.pdf* and *The Nutrient Story_June 2008_addendum.pdf*). I can not recall this kind of algal resurgence ever happening in the past.

The only possibility that occurs to me is an, equally surprising, increase in Foster Park flow between May 15th and June 9th, from 13 to 22 cfs – at least as measured by the USGS gauging station at the bridge. If this is valid, and off-hand I can think of no reason, given the gauge location, why it wouldn't be (while flow measurements are often in error, stage, or depth, measurements rarely are;

**Figure 2**. VR01: The top photo was taken May 15$^{th}$, the bottom June 17$^{th}$. Note that water levels seem to have decreased and the algal mats on the right are drying out. The aquatic plants are Ludwiga, and are increasingly encroaching on the channel. As an aside, what moved the concrete slab in the lower foreground (it was still in the upper photo position on June 7$^{th}$)?

**Figure 3**. VR03.5: Algae (cladophora) are still doing well at this location just above the confluence of C. Larga (0.5 km below the treatment plant), but the bottom close-up indicates that appreciable decay is finally taking place.

the Foster Park gauge measures stage in a relatively deep pool and little else, other than an increase in flow, is likely to cause increased depth at this location) the near doubling of flow would have expanded algal habitat and increased current speeds (enhancing the nutrient flux, i.e., delivery of nutrients, to the algae). This, and the additional accumulations of floating algae seen in the photos, could have led to the measured increase in the strength of the VR06 DO cycle.




The above graph shows average daily flows at the Foster Park gauge and the increase that occurred from mid-May to early June. As to the reason for the increase, one possibility is reduced groundwater extractions for the communities of Ojai and Ventura from horizontal wells below the river bed, just upstream of the bridge. The dates of the three Channelkeeper pre-dawn/mid-afternoon samplings are shown on the graph. As an aside, the strength of the DO cycle, as mentioned earlier, is dependent on algal density and the extent of photosynthetic activity, and the amount of flow influenced by this activity. The June DO cycle was about twice as strong as in May (6.1 vs. 3.1 mg/L), but there was also 40 % more flow. Therefore the algal recovery was even stronger that the measurements indicate. In contrast, while the April DO cycle was smaller than that of June (3.9 vs. 6.1 mg/L), April flow was more than double, i.e., April algal productivity was stronger than in June (a rough calculation, multiplying April delta-DO by the proportionally greater flow – 40/18 or 2.2 – shows it to have been about 40 % stronger).

DO measurements at VR06.3, just above the San Antonio confluence, were equally strange, albeit in the opposite direction. Pre-dawn concentrations were low, at 5.1 mg/L, lower than anywhere else except at VR01 and VR00e. However, mid-afternoon concentrations were surprisingly lower than expected, lower than at any other site with a substantial algal presence (i.e., only the Matilija sites and VR12.9, locations with very little functioning algae, were lower). Surprising because algae here are currently the densest and healthiest on the river (Figure 7).

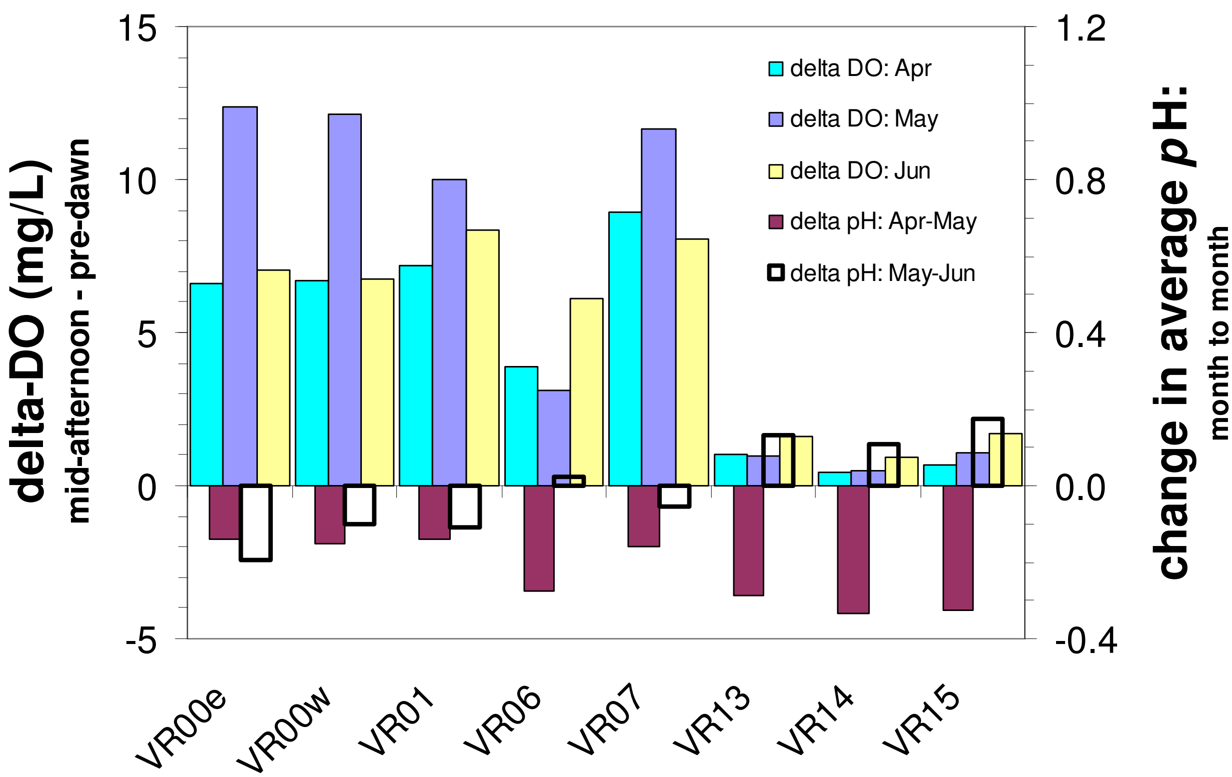
**Figure 4**. VR06 from Foster Park Bridge: It appears as if algae here has gotten a new lease on life. The upper photo was taken on May 15th, the lower on June 17th. Aside from the much greater build-up of algal mats anchored on boulders (mainly cladophora and enteromorpha), the benthic algae seems to have increased in density and exhibits a more vivid hue.

**Figure 5**. VR06 from Foster Park Bridge: upper photo - May 15th; lower - June 17th. The concept of a miraculous June recovery of VR06 algae is rather unbelievable, but I've checked additional photos (including these closer views and others from June 4th & 7th) and it appears to be true.

**Figure 6**. Unfortunately, I don't have good close-up photos of similar locations taken on the correct days, but these looking downstream from the bridge on May 15rd (upper) and June 17th (lower) may (or may not) support the idea of algal revival at Foster Park.

I'm unable to account for the very low reading (10.64 mg/L, at 2:24 PM). (On May 18th DO measurements at this location were ~12 mg/L around 4-4:30 PM.)

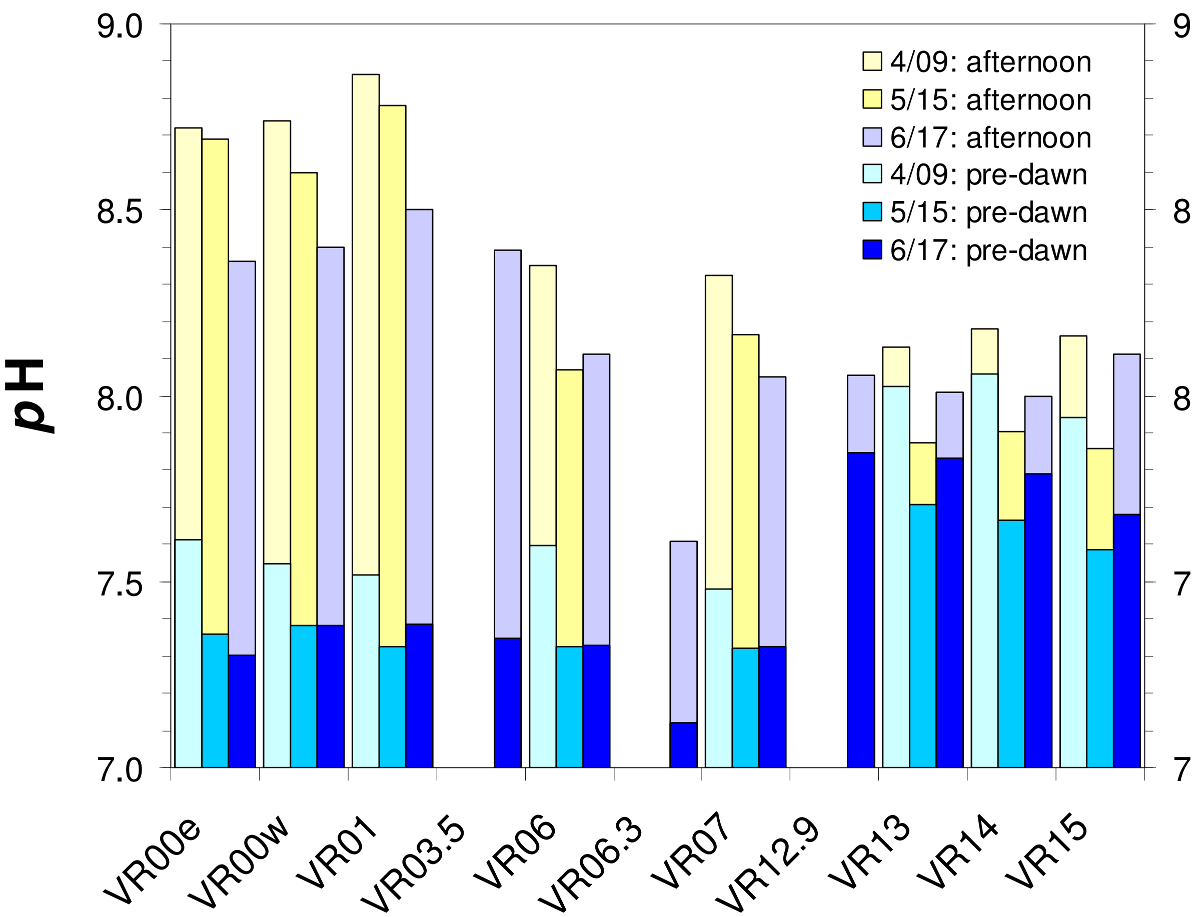
Diana Engle, who has been deploying sondes continually measuring DO and *p*H for periods of about a week at various locations on Calleguas Creek, has results showing that different sites peak at different times: a couple of locations at ~2 PM, one at either 3 or 4 PM and one, for some still undetermined reason, at 11 AM. A previous study, done by Julie and me in 2003, showed peaks between 2 and 3:30 PM at the lower river sites (minimum DO values remained relatively flat from around midnight to 5-6 AM). The time intervals we are currently using in this study are based on these 2003 results, but, in truth, we lack any sure knowledge as to the actual maximum and minimum times – and as to whether or not they might vary by location or with time. It *is* possible that we simply sampled VR06.3 at the wrong time (but I don't really think so).




The above graph shows monthly delta-DO for all sites with multiple monthly measurements. It also shows the change in average (the average of pre-dawn and mid-afternoon measurements) monthly *p*H from month to month, i.e., the change from April to May, and from May to June. As can be seen in the graph, elsewhere on the lower river (below VR06.3) and at VR07, the magnitude of the diel DO fluctuation had decreased from values measured in May. This is due to increasing senescence of both benthic and floating algae (now almost omnipresent) (Figures 2 and 3). On the Matilija branches, and VR12.9, the magnitude of the June diel cycle had increased slightly (by about 0.6 mg/L) at all three locations. I attribute the this to increasing amounts of spirogyra colonizing these sites, more so at VR15 and VR12.9 then at VR13.

**Figure 7**. Almost as hard to accept were the afternoon DO (and *p*H) values at VR06.3, just above the San Antonio confluence (top photo-looking upstream, bottom-downstream). Although the algae here was the densest and most vibrant seen on the 17$^{th}$, the DO (and *p*H) increase was relatively modest compared with other algal dominated sites – although pre-dawn levels were predictably low. I'm unable to account for this.

New spyrogyra can be seen coming in in Figures 8 and 9, generally on top of, or adjacent to, patches of decaying cladophora. I suspect, given the low nutrient status of these streams, that spirogyra is making a virtue out of necessity; I've observed this phenomena, of spirogyra seemingly colonizing decaying cladophora, at numerous other locations. In Figure 8, I've included photos taken on April 10$^{th}$ to show the transformations that have since taken place; they, and the photo in Figure 9, also show how much flow has decreased from what now appears to have been the peak of the upper-watershed algal bloom (at least the first bloom, we may yet have a spirogyra bloom like the one that occurred last summer). The magnitude of the diel cycle measured in June is actually greater than it was in April; this is not a contradiction, but simply the effect produced by greatly reduced flows in the upper-catchment.




June *p*H values, along with those of previous months, are shown in the above graph. In general, upper-watershed sites show an increase over May values; a rise in average *p*H of approximately 0.15 units. As I attributed a substantial decrease of ~0.3 units between April and May at these locations (see the previous graph) to aerobic decay and the production of increased amounts of carbon dioxide, I believe the present rise is being caused by a reduction in decay at the tail end of that process. At other locations the June *p*H cycle has generally weakened compared with May's, except at Foster Park where it's has strengthened – this is in agreement with the DO results.

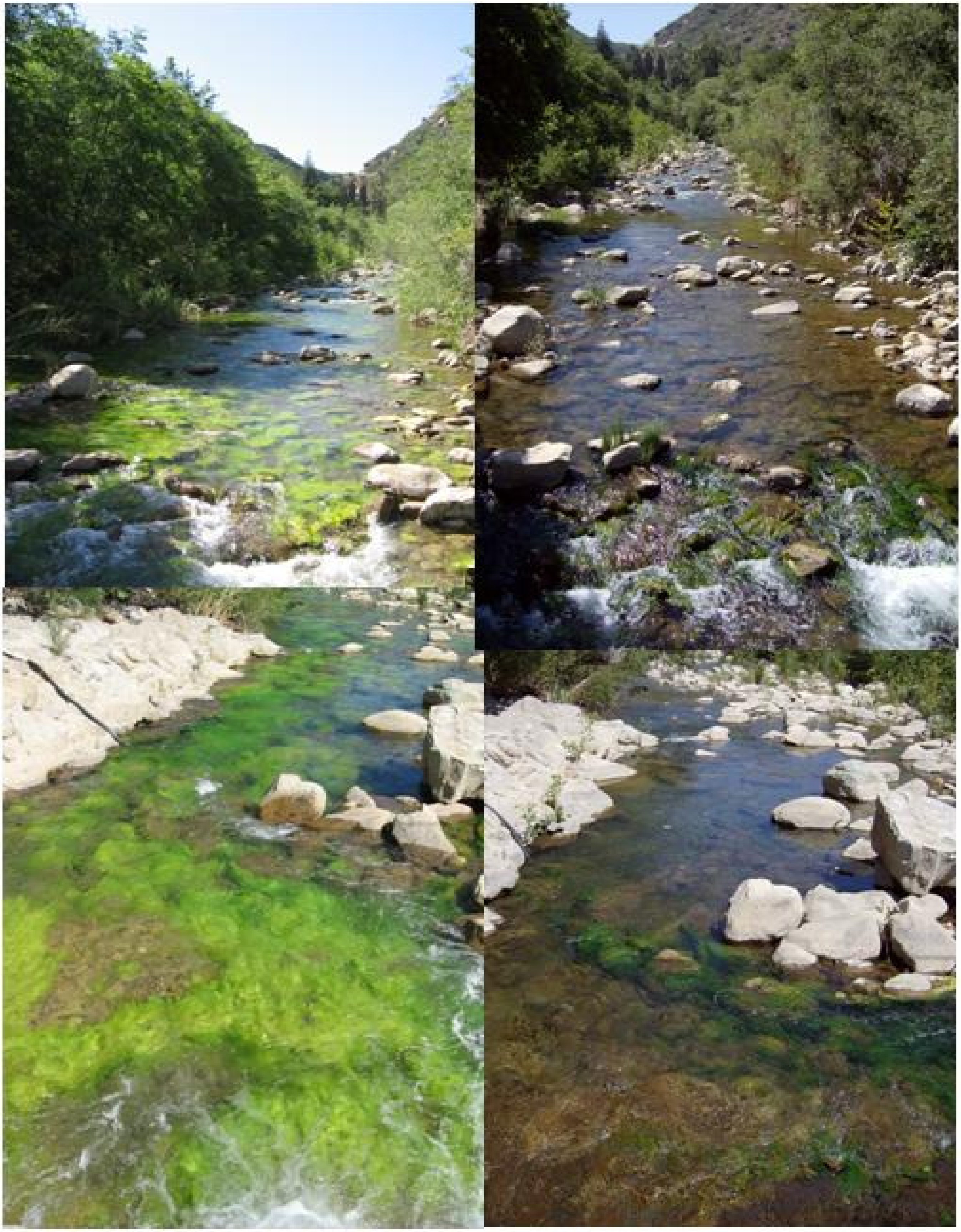


**Figure 8**. VR12.9: From the Camino Cielo ford, April 10th on left, June 17th on right, looking upstream on top, downstream on bottom; cladophora then, spirogyra coming in on top of decaying cladophora now. Note the decrease in water level since April.

We would expect both cycles to roughly follow similar trends: in the presence of algae *p*H changes track those of DO. As photosynthesis removes carbon dioxide from water, i.e., removing acidity, and replaces it with oxygen, pH rises to an afternoon peak; it then declines to a pre-dawn minimum as night-time algal respiration restores carbon dioxide to the flow (making it more acidic).

In contrast with the rise in pH from May to June seen at the upper-watershed locations, VR07 and the lower river sites have shown a steady decrease: from April to May, and from May to June. Again, I'd attribute this decrease to continual decay. I believe the peak of the bloom at these locations occurred in April. If I apply the same kind of rough calculation I did earlier to the respective monthly delta-DO values (the magnitude of the DO cycle multiplied by the relative amount of flow) this assumption appears valid. If so, decay has been an on-going process since that time, gradually decreasing *p*H by providing a steady increase in background carbon dioxide. Throughout this period there has also been a steady accumulation of sediment on the river bottom. This buildup of sediment (only noticeable over time since dry-season flows usually have extremely low turbidity), especially of fines and organic material, also utilizes increasing amounts of dissolved oxygen – these various processes are usually lumped together under the term *sediment oxygen demand*, or SOD. (Other than decay, think of nitrification of ammonium and the chemical oxidation of reduced compounds released from the sediment – especially from anaerobic sediments, e.g., ferrous iron and sulfides.)

The exception, of course, is Foster Park where the April to May decrease in average *p*H turned into a May to June increase. This somewhat substantiates the concept of a June algal resurrection: the June increase results from an increase in mid-afternoon *p*H, pre-dawn *p*H stayed roughly the same as it was in May, and both were much lower than they were in April – signifying continual decay since that time. Another exception is VR06.3 where both pre-dawn (7.12) and mid-afternoon (7.61) *p*H values were very low – lower than at any other site.

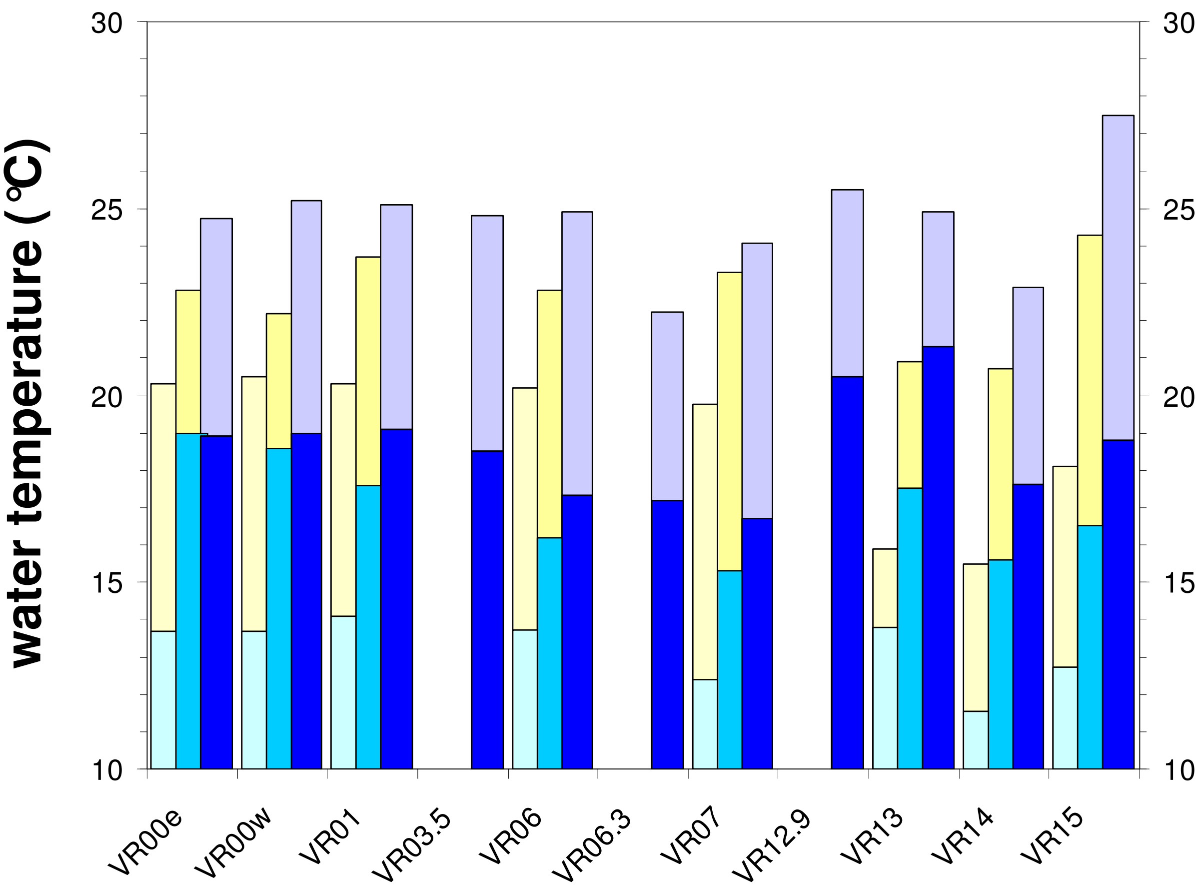
It *is* conceivable that beneath all that green and vibrant VR06.3 algae a hell of a lot of decay is going on – depressing, if you will, the daily *p*H range via the production of excessive amounts of carbon dioxide. However, decay is no respecter of night and day, and with the amount of algae present at this site we could expect both pre-dawn and mid-afternoon values to be equally depressed, i.e., the delta-*p*H or the magnitude of the diel *p*H cycle should remain relatively unchanged. (This is not strictly true, decay rates *are* dependent on temperature and we might expect to see a doubling of the rate for every 10 °C increase, this might somewhat lower mid-afternoon *p*H, but since every site is experiencing more-or-less the same temperature changes the point still holds.) Unfortunately, delta-*p*H at VR06.3, as with delta-DO, was quite small – about the same magnitude as at VR15, a site with relatively little algal activity. VR06.3 remains a puzzlement.

Switching now to the regulatory aspects of the June results, the Basin Plan covering the Ventura River calls for a minimum mean dissolved oxygen concentration of 7 mg/L, although single measurements can go as low as 5 mg/L. Unlike May, when pre-dawn concentrations below this minimum were found at VR00w and VR03 (~ 4.9 mg/L), no concentrations below 5 mg/L were seen (5.17 mg/L at VR01 was the lowest). VR07 and all lower river locations, with the exception of VR03.5 just below the treatment plant, did have pre-dawn concentrations below 7 mg/L.

While in violation of the Plan, these concentrations are still above 4 mg/L, the point below which serious problems with oxygen deficiency could be expected to occur.

Large variations in *p*H are considered dangerous, a change of more than two points on the *p*H scale can kill many species of fish. The EPA and the LA Regional Water Quality Control Board regard a *p*H change of more than 0.5 as harmful: VR07 and 6 of the 7 lower river sites had June *p*H variations greater than this (VR06.3 with delta-*p*H of 0.49 was the exception). A half a unit of *p*H is not a small thing, the scale is logarithmic and half a unit represents a 500 percent change.

In April, on the lower river (VR11-VR01) a 1 unit change in *p*H was roughly accompanied by a DO increase of 5 mg/L. The May ratio was slightly greater, but similar: 1 pH unit for every 6 mg/L DO increase. In June there has been a further increase in the ratio: 1 *p*H unit for every 7.5 mg/L change in DO. In earlier reports I attributed this relationship to the amount of buffering in the stream – and that the modest May increase was caused by increased buffering (i.e., increased ANC or *acid neutralizing capacity*) due to increased evapo-concentration (lower flows and higher water temperatures leading to an increased concentrations of solutes). Frankly, I'm no longer sure and would like to hear from anyone with other ideas (I keep thinking about temperature and decay, but I can't, as yet, see a connection).




Finally, let's consider water temperature. Water temperatures continued to increase at all locations but the increase has slowed, from about 3-4 °C from April to May, to 1-3 °C from May to June; day-night differences have remained about the same, at roughly 6 °C.

**Figure 9**. VR15 (Jun 3rd photos): (top) spirogyra (the dark-green & slimy stuff) coming in on top of dead cladophora; (bottom) close-up of spirogyra on cladophora. Note, from the position of the drying cladophora mat, how far the water level has dropped since the peak of the bloom.

As in last month's report, month-to-month or day/night temperature differences between or among sites can be used to tease out unusual change. For example, the reduction in lagoon day/night differences in May indicated greatly increased storage of river water behind the sand berm. Similarly, the June increase in this same parameter, back to roughly the same difference measured in April, was caused by the breach of the berm and the lowering of water levels. Colder pre-dawn water temperatures at VR06 and VR06.3 result from a cold groundwater source of flow at these two sites. However, a similarly cool pre-dawn flow at VR07 simply indicates the reduced thermal inertia of low flow.

It's interesting that VR06.3 (again, that strange site), with a pre-dawn water temperature similar to that at Foster Park, was noticeably cooler in mid-afternoon (VR06.3 was measured at 2:30 PM, VR06 at 3 PM). This probably indicates that the origin of upwelling groundwater providing flow at this site may not be located too far upstream (something it would be nice to check out). Mid-afternoon water temperature here was the coolest measured in the catchment – even cooler than at VR14, a narrow, generally shaded, mountain stream.
VR15 had the greatest day/night difference in water temperature (8.7 °C) and the highest mid-afternoon value (27.5 °C). This is above the limit generally considered to produce mortality in steelhead (25 °C) and we should probably give that some thought. The absence of riparian shade in this reach is the primary cause, but the decrease in summer-time flows (Figure 9) also plays a role. In contrast, VR15, shaded and narrow as mentioned above, always has cooler water; flows on the North Fork also appear to be less diminished. VR13 is a special case. Temperatures here are usually measured in, or at the exit from, a relatively deep pool where greater thermal inertia usually insures reduced day/night fluctuations. The increase in average temperatures as the season progresses is probably more a function of changes in the reservoir above than in the short reach of creek upstream of this location – most summer flow originates as reservoir seepage. Finally, the combination of low day/night differences in VR13 water and cooler VR14 flows determine the characteristics at VR12.9, located just 0.3 km below the junction of these two streams.

Given the appreciable changes in water temperatures, percent saturation is a poor measure for comparing dissolved oxygen levels between day and night, between locations, and from one dry-season point in time to another. Accordingly, I'm no longer showing that data in these reports.

Photos taken on June 17 (and on other Channelkeeper sampling days) can be downloaded at:

http://sbc.lternet.edu/~leydecke/Al's_stuff/Recent%20Stream-Team%20Photos/

Photos of the UCSB-TMDL algal survey at:

http://sbc.lternet.edu/~leydecke/Al's_stuff/Ventura%20Nutrient%20TMDL/TMDL%20algal%20survey%20photos/

And I've now posted PDF copies of all my previous Ventura Nutrient TMDL reports at:

http://sbc.lternet.edu/~leydecke/Al's_stuff/Ventura%20Nutrient%20TMDL/My%20PDF%20files%20on%20algae%20&%20nutrients/