Water Quality in College Creek, Annapolis, MD, 2003-2010
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Background

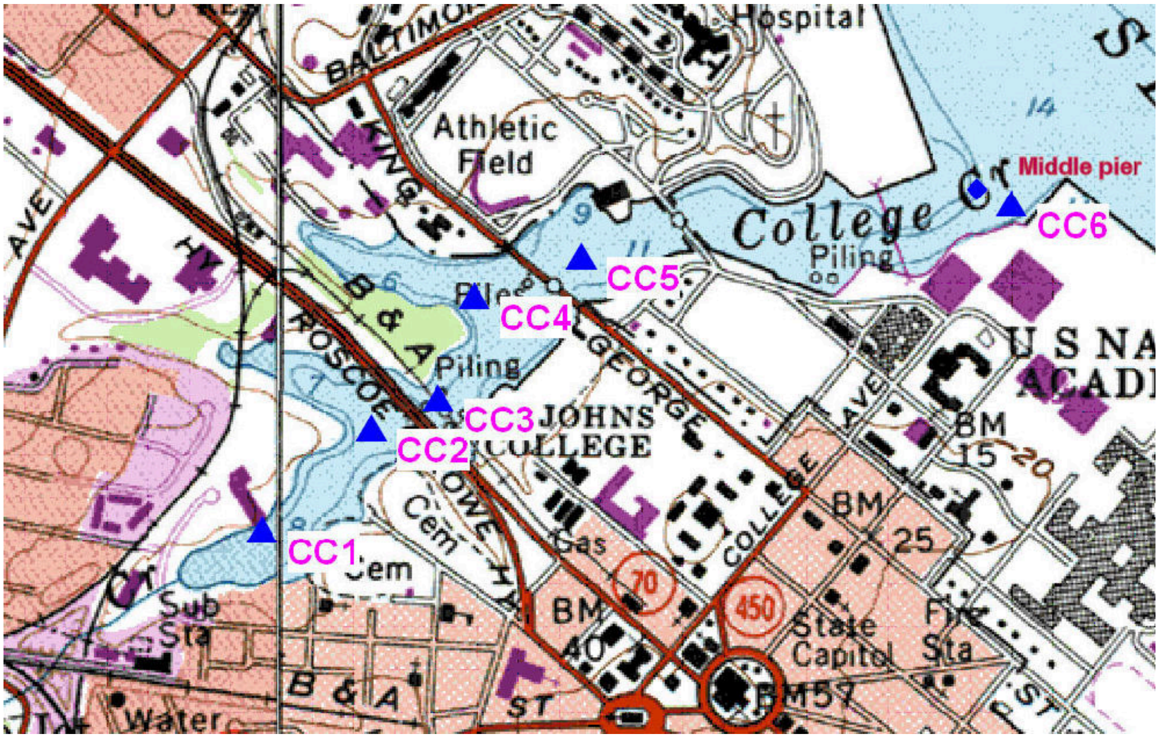
College Creek is a small tidal creek in Annapolis, MD. It is south of Weems Creek and north of Spa Creek. It is an unusual creek because almost all of its tidal shoreline is owned by Federal, state, or county government, a private college, or local churches (mainly for graveyards). Its current name presumably comes from the two colleges on its shores, the US Naval Academy (USNA) and St. Johns College. It was previously called Dorsey Creek after the family who owned land on Hospital Point (on the north shore of the creek) that became part of the US Naval Academy, although USNA maps still label the lower portion as Dorsey Creek. It is crossed by more bridges than any other creek in Annapolis: three automobile bridges, at Rowe Boulevard, King George Street, and within the US Naval Academy connecting Bowyer and Decatur roads, and one foot bridge within USNA. The nontidal portion of the creek is short and extends only to West St. The watershed covers only 732 acres (1.1 square miles), and contains over 57% impervious surface, making it an urban watershed. A map of the watershed is in this 2007 watershed assessment:
http://www.chesapeakeecologycenter.org/vertical/Sites/%7BA7B77D20-B5CC-4703-BAAB-C49A8FAC22DD%7D/uploads/%7BBAF11098-FC0B-48A5-A532-062F88AA1222%7D.PDF

Methods

A State Highway Administration contractor, ESA, sampled water quality in College Creek once a month from 2003-2007 at 5 sites (CC1-CC5) to assess possible Rowe Boulevard bridge construction impacts. (Fig. 1) The bridge was under construction from 2004-2006. Nutrients and total suspended solids were only sampled at the sites just above and below the bridge (CC2 & CC3), due to their costs. All samples were from the surface layer except dissolved oxygen was only sampled 1 m (meter) above the bottom, which was essentially a mid-water sample at sites this shallow (all are 2-3 m deep). Sampling was erratic in 2004, with no sampling in April, May, or July, and two samples from August. In 2006, there was no August data. The contractor stopped sampling after August 2007, so the 2007 medians and status are missing one (for DO) or two (for clarity and salinity) months of data.

The Friends of College Creek started sampling at the same 5 sites (CC1-CC5) in 2008, sampling once a month from April-October, and continued this through 2010. Parameters were the same as those sampled by the SHA contractor except we did not measure nutrients, turbidity, total dissolved solids, or total suspended solids. We changed the sampling depths to surface & bottom for all parameters at all sites, with surface samples collected about 0.3 m below the surface, and bottom samples about 0.3 m above the bottom. Thus, sample size for DO rose from 3-4 samples per site per year in 2004-2007 (mid-water sampling only), which is not really enough to assess DO status (but I included this in Fig. 4 to compare to later data), to 8 per site per year in 2008-2010 (surface & bottom, June-September), which is adequate for assessing DO status.

Figure 1. Map of samplings sites used, 2003-2010. A few data from CC6 are included.



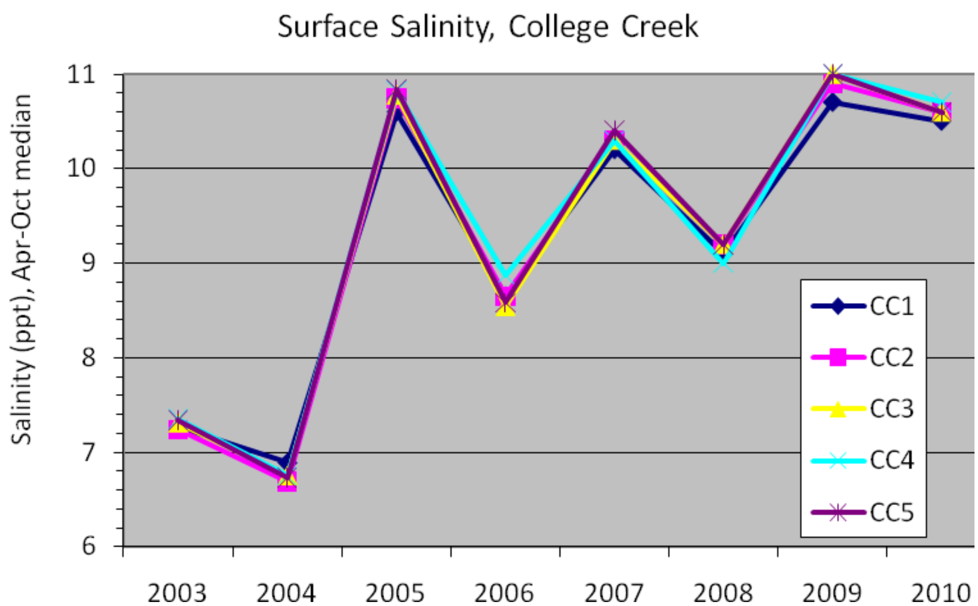
USNA staff & students sampled at one pier near the mouth of the creek (CC6) starting in 2007, and via short-term deployments of continuous water quality monitors, but the sampling was not regular enough to calculate annual status. Some of their 2010 data are summarized below.

I calculated water clarity and DO status by site and year over the appropriate months (the status measures and months used were those used in Chesapeake Bay Program and local river keeper analyses for tidal waters). For water clarity (Secchi depth) this was April-October (the SAV growing season), and for dissolved oxygen (DO) it was June-September (the period when most low DO occurs). Water clarity status was the percent of measurement above the habitat requirement for SAV growth in mesohaline waters, 0.97 m (also the state standard), while the DO status was the percent of measurements (including both surface and bottom from 2008 onward with no averaging) above the 5 m/l habitat requirement for finfish, which is also the state standard for tidal waters. I also calculated DO & clarity status by month over all sites for 2008-2010 to show how this changed through the year and among years. I also calculated surface salinity medians over April-October since they respond to rainfall. I graphed the medians or status by site and year with years on the x-axis (to show any changes over time) and the sites as 5 different lines. Two figures also show the mean status over all sites by month for 2008-2010, and another figure shows a continuous record of bottom DO from a site in the lower creek in Sept. 2010.

Results

Surface salinity (Fig. 2) responded inversely to rainfall, as it usually does. It was lowest in 2003-2004 (wet years), highest in 2005, 2007, 2009 & 2010 (dry years), and intermediate in 2006 and 2008. Note that the scale only goes from 6-11 ppt to show the very slight differences among sites more clearly. This puts College Creek, like the Severn, in the low mesohaline zone; mesohaline is applied to areas with salinity from 5-18 ppt. Note that 2009 had the highest median salinity values at all sites, but salinity by month was highest in September-October 2008, when the values were all near 15 and 19 ppt respectively. Total river flow into Chesapeake Bay was much higher than normal in 2003-2004 (causing the lower salinity then), slightly lower than normal in 2009 (highest median salinity), but it was normal in 2005-2008 and 2010 (see http://md.water.usgs.gov/waterdata/chesinflow/ and scroll down to the annual graph).

Figure 2. Surface salinity medians in College Creek by site and year, April-October.

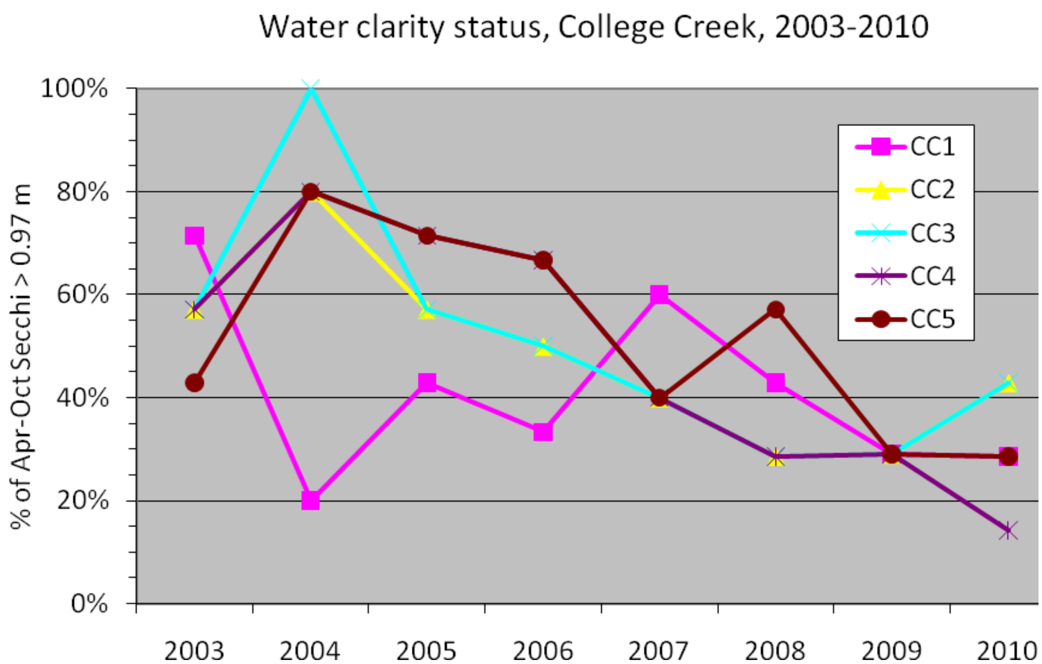


For the next two parameters, water clarity and bottom DO status, there were much larger differences among sites than those seen for salinity. Status of water clarity (Fig. 3) and Dissolved Oxygen (DO, Fig. 4) were sometimes worst at CC1, farthest up the creek (3/7 years for clarity, 2/7 years for DO) and best at CC4 or CC5, farthest down the creek (3/7 years for clarity, 2/7 years for DO). For both parameters, more is better.

Looking at annual changes in clarity (Fig. 3), 2009 had the worst clarity status over 2003-2009 (29%) for four of the five sites in College Creek (all but CC1), or was tied with 2008 for the worst status. In 2010, mean clarity status went up slightly to 31%. Looking at each site, clarity status got slightly worse at one site (CC4), slightly better at two sites (CC2 and CC3), and stayed the same at the two other sites (CC1 and CC5). Clarity was better in 2004 at all sites except CC1. This increased clarity in 2004 was probably due to filtration by dark false mussels, which were common elsewhere in the Severn and in the Magothy in 2004, and were common in Peters Cove in College Creek in 2008. It's possible that clarity got worse at CC1 in 2004 because the mussels were all located down the creek from that site; there were no surveys of mussels in the creek until 2008.

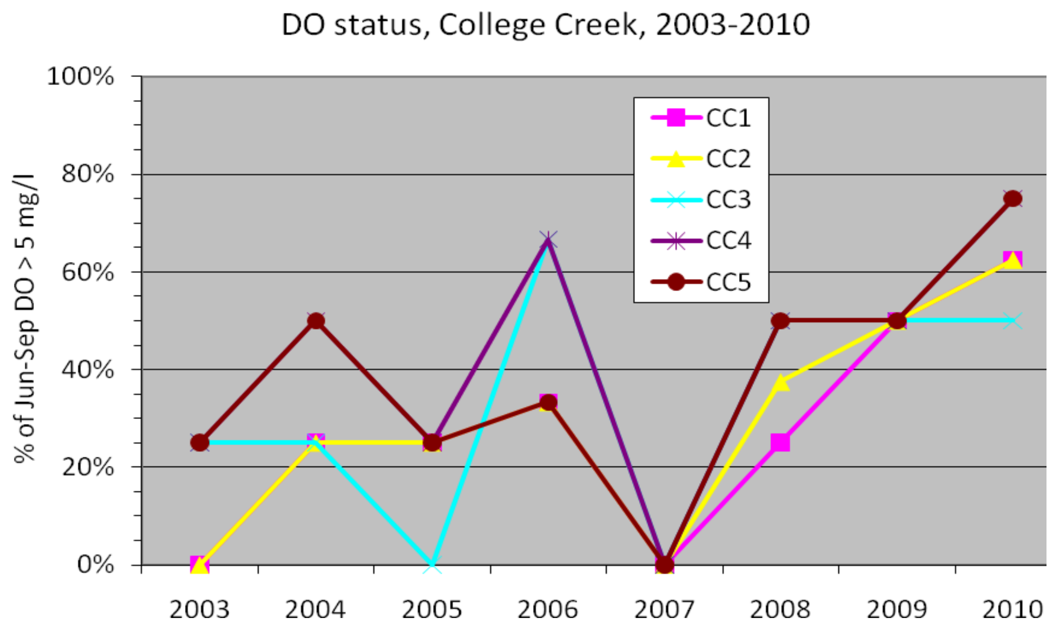
Reasons for the general decline in water clarity status from 2005-2009 are not known, except that it follows the general baywide decline in clarity status that started in 2003. That was a wet year following four dry years, and baywide clarity has shown some improvement since 2006, especially in 2009 (see http://www.chesapeakebay.net/status_clarity.aspx?menuitem=19838). The recent clarity decline in College Creek probably led to the loss of persistent SAV from the creek in 2010.

Figure 3. Secchi depth (water clarity) status in College Creek by site and year.



Looking at annual changes in DO status (Fig. 4), 2010 had the best mean status over all sites (65%, up from 50% last year). There were three years (2003, 2005, and 2007) with one or more sites that had no measurements above 5 mg/l (0% status). All five sites had 0% status in 2007, but as noted above in Methods, sampling was erratic that year, and was skewed towards the summer months when DO is usually the lowest. Thus, the 2007 status was probably not as bad as this graph suggests. As noted above, status in 2008-2010 included twice as many measurements as the earlier years (N=8 vs. 3-4), with surface & bottom data rather than a single sample 1 m above the bottom, which probably explains the lower variability in the 2008-2010 DO status, both among sites and among years. Most sites had improving DO status over 2008-2010, except in a few cases where the status stayed the same for two years.

Figure 4. Dissolved oxygen (DO) status in College Creek by site and year. Sample sizes were inadequate for 2004-2007 (only 3-4 samples per site per year).

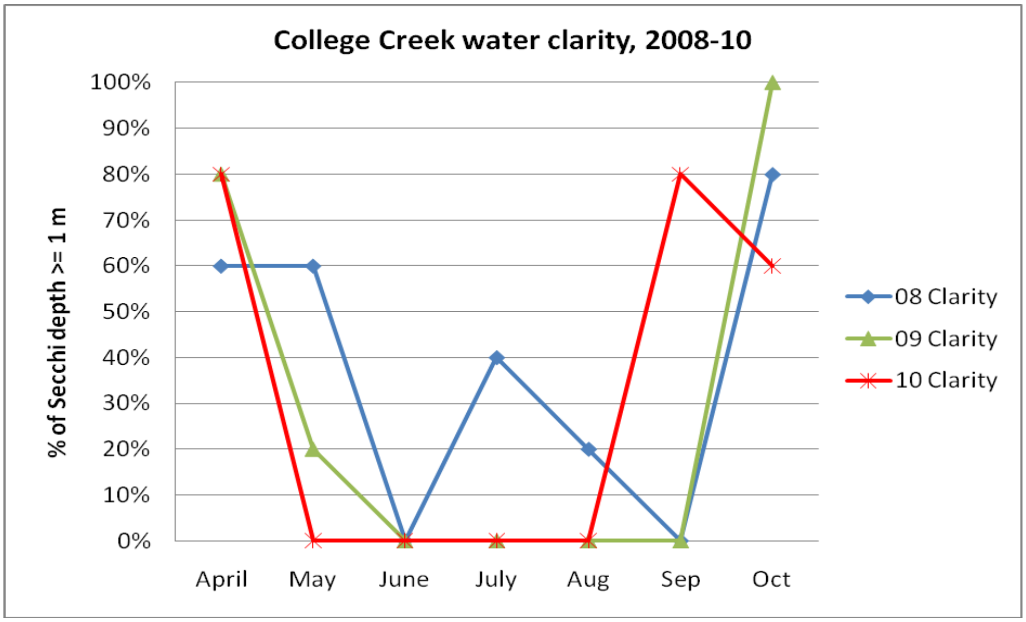


After collecting three years of water quality data in College Creek with consistent methods (2008-2010), I also compared the mean DO and clarity status by month as well as comparing them by site. As in the data reported above by site, DO status is the percent of surface & bottom measurements at that site that were 5 mg/l or more, while clarity status is the percent of Secchi depths that were 1 m or more. The values graphed are mean status over the 5 sites.

As expected, both status measures got worse in the summer each year and better again in the fall. Mean water clarity status by month (Fig. 5) started at 60-80% in April and fell to 0% each summer, starting in May or June, and then rose again in October. This year (2010) followed the same pattern, except the status rose in September. The exception was the summer of 2008 when status rose in July-August and fell again in September. That was the year that dark false mussels (Mytilopsis leucophaeata) made a brief comeback in July in parts of the creek, especially in Peters Cove, a reminder of the high mussel populations in the Severn, Magothy, Patapsco, and nearby rivers in 2004. Rather than being eaten by ducks, which appeared to be the fate of most of the mussels in 2004, the mussels in 2008 were smothered by encrusting animals called bryozoans. To see photos of the mussels in College Creek in 2008 and other years, see http://picasaweb.google.com/pbergstrom37/2008DarkFalseMussels# . The first photos in the album are from July 2008 when the mussels were abundant, and there are two from Sept. 2008 after they had been covered by bryozoans and killed.
It’s interesting to note that July-August 2008, when the mussels were abundant and water clarity improved in College Creek (Fig. 2), was also the period with the worst DO status in the creek (Fig. 1), when three of the surface DO values fell below 5 mg/l. In contrast, when dark false mussels were extremely abundant in Magothy creeks in summer 2004, and water clarity got much better, the DO status got better, not worse.

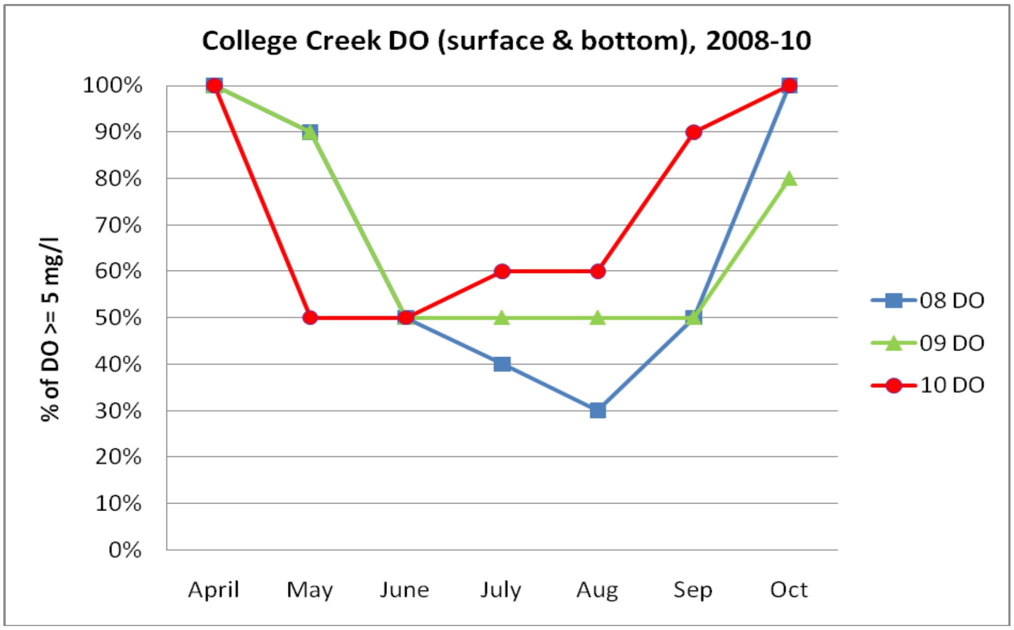
Those three low surface DO values were the only ones we recorded in all three years of sampling; in some Magothy creeks, low surface DO occurs in 30-70% of samples.

Figure 5. Mean water clarity status by month in College Creek, 2008-2010.



DO status also got worse each summer, which is why only summer data (June-September) are used to calculate DO status. Figure 6 shows that DO status fell to near 50% for most of each summer, which represents all bottom values less than 5 mg/l, and all surface values about that value. However, in the summer of 2008, there were three surface values less than 5 mg/l (15% of the summer surface measurements), so DO status fell below 50% in July and August (Fig.4). DO status was slightly worse in 2010 than in previous years in May, and by June, it had reached its usually low summer values near 50%. DO status was a bit better in July through September 2010 than it was in the two previous years (Fig. 6).

Figure 6. Mean dissolved oxygen (DO) status by month in College Creek, 2008-2010.



Our sampling had excellent spatial coverage (few creeks this small have 5 monitoring sites over several years), but the temporal coverage was less than ideal. With infrequent sampling (once a month in this case), you don't adequately capture the variability in each parameter. We have an idea of the temporal variability that we missed because Dr. Cecily Steppe at the US Naval Academy has deployed water quality instruments near site CC6 that measured water quality around the clock every 15 minutes for several days. Bottom dissolved oxygen from one of the longest of these records, from late August and early September 2010, is graphed in Fig. 7.

Figure 7. Continuous record of bottom dissolved oxygen (DO) in lower College Creek (near site CC6), early September 2010. Graph from Dr. Cecily Steppe, USNA.

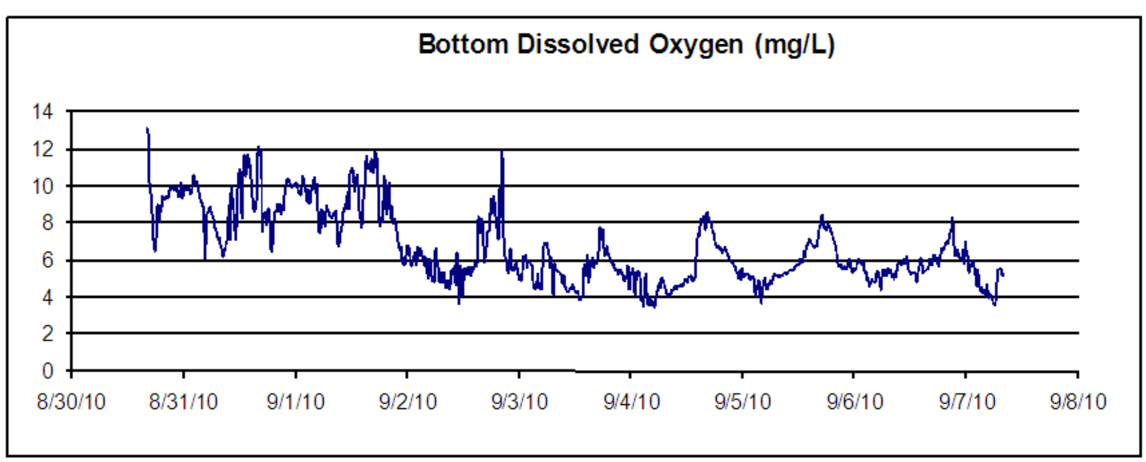


Fig. 7 shows that daily maxima fell from about 12 mg/l (quite high for bottom DO) to about 8 mg/l over several days, while the daily minima fell a bit less (from about 6 to 4 mg/l). Within a 24 hour period, however, bottom DO varied by up to 8 mg/l (from about 4 to 12 mg/l on 9/2; each date is at midnight).

Discussion

One could argue from the results in Fig. 7 that point measurements of DO are meaningless, because bottom DO in College Creek varied so much within and among days. However, continuous monitoring devices are still far too expensive to put and maintain 10 of them (surface and bottom) in a small creek from April-October, and the surface sensors would impede boat traffic. We tried to reduce the effects of the diurnal variability on the DO measurements by sampling at about the same time each month, usually staring at about 10 AM. The tidal monitoring protocol document being prepared by the Mid-Atlantic Tributary Assessment Coalition (MTAC) recommends twice monthly sampling as a minimum frequency, with weekly sampling preferred. We sampled monthly because that's what done before, and that was all the time that I could devote to it.

These status percentages and their changes over time are similar to what I've measured at 3-4 sites on the Magothy. Most of the Magothy sites I sample are in creeks (two off the upper river, one off the middle to lower river), while one is in the shallows of the mainstem in the middle to lower river.

The 2010 clarity status at those 4 Magothy sites was only 7-14%, a bit worse than the 31% status in College Creek. In recent years, the clarity at Magothy sites also peaked in 2004 and has generally declined since then, but it declined faster than it did in College Creek. All three of the long-term Magothy sites dropped below 20% clarity status for one or more years in 2005-2009, and all of them were still below 20% in 2010.

The Magothy 2010 DO status depended on the site. The shallow mainstem site had good DO status, 81%, while the DO status at the three creek sites ranged from 31%-63%, slightly less than the 50-75% status found in College Creek in 2010. In contrast to the clarity comparison, the Magothy sites have generally had better DO status than the College Creek sites in previous years, with Magothy DO status never falling below 19%. One might expect better status in College Creek than in the Magothy creeks I sample since it is off the lower Severn, and most of our rivers have better water quality near the mouth than they do farther upriver. However, recall that the SHA contractor did not sample surface DO in College Creek from 2003-2007, skewing those DO status percentages lower, since surface DO is usually better than bottom DO.

College Creek was in better shape than several Magothy creeks in terms of unusual low DO events, defined as surface DO < 5 mg/l, and anoxic bottom DO (<= 0.2 mg/l). Both are indications of severe algae blooms that died and are decomposing, using up DO. Low surface DO was only found 3 times in College Creek, all in July-August 2008, making up 15% of the surface readings that year. In contrast, the three Magothy creeks with long-term data (Cattail, Old Man, and Forked) had low surface DO in 33% of their samples in 2008, with low surface DO in 23-33% of samples every year from 2005-2010. Two Magothy creeks that are sampled by other volunteers, Dividing and Mill creeks, had even higher rates of low surface DO, which was found in 44-71% of samples from 2006-2010. Anoxic bottom DO was only recorded twice in College Creek, both in 2009, making up 10% of the summer bottom samples. In the three Magothy creeks with long-term data, anoxic bottom DO was found in 0-25% of summer bottom samples over 2008-2010, with 25% in 2009, the same year that anoxia was found in College Creek. Anoxia in Mill & Dividing creeks ranged from 4-16% in the same years, and also peaked in 2009.

The 2009-2010 water quality status for the Severn River is not available, but 2008 status is in the report card at
http://www.severnriverkeeper.org/pdf/SevernReportCard2008.pdf . Fig. 3 on page 2 of that report shows that clarity status in the mainstem outside College Creek was below 30% in 2008, in the middle of the range of clarity status at the sites in College Creek that year (Fig. 2). Clarity status was much better upriver in Round Bay, but DO status was generally worse there.

Conclusions

In College Creek in 2010, median surface salinity was near the highest since sampling started in 2003, near 11 ppt, and water clarity status was only slightly better than it was in 2009. There was an increase in water clarity in 2004, probably due to filtration by dark false mussels, and a decline in clarity since 2004 with no known cause. That decline probably led to the loss of persistent SAV from the creek in 2010. DO status had no clear pattern over time; the dip in 2007 may have been related to erratic sampling. In general, water quality and dissolved oxygen in College Creek was similar to what was measured at nearby sites on the Severn and in the Magothy, although it had better conditions for surface DO and bottom anoxia than several Magothy creeks.