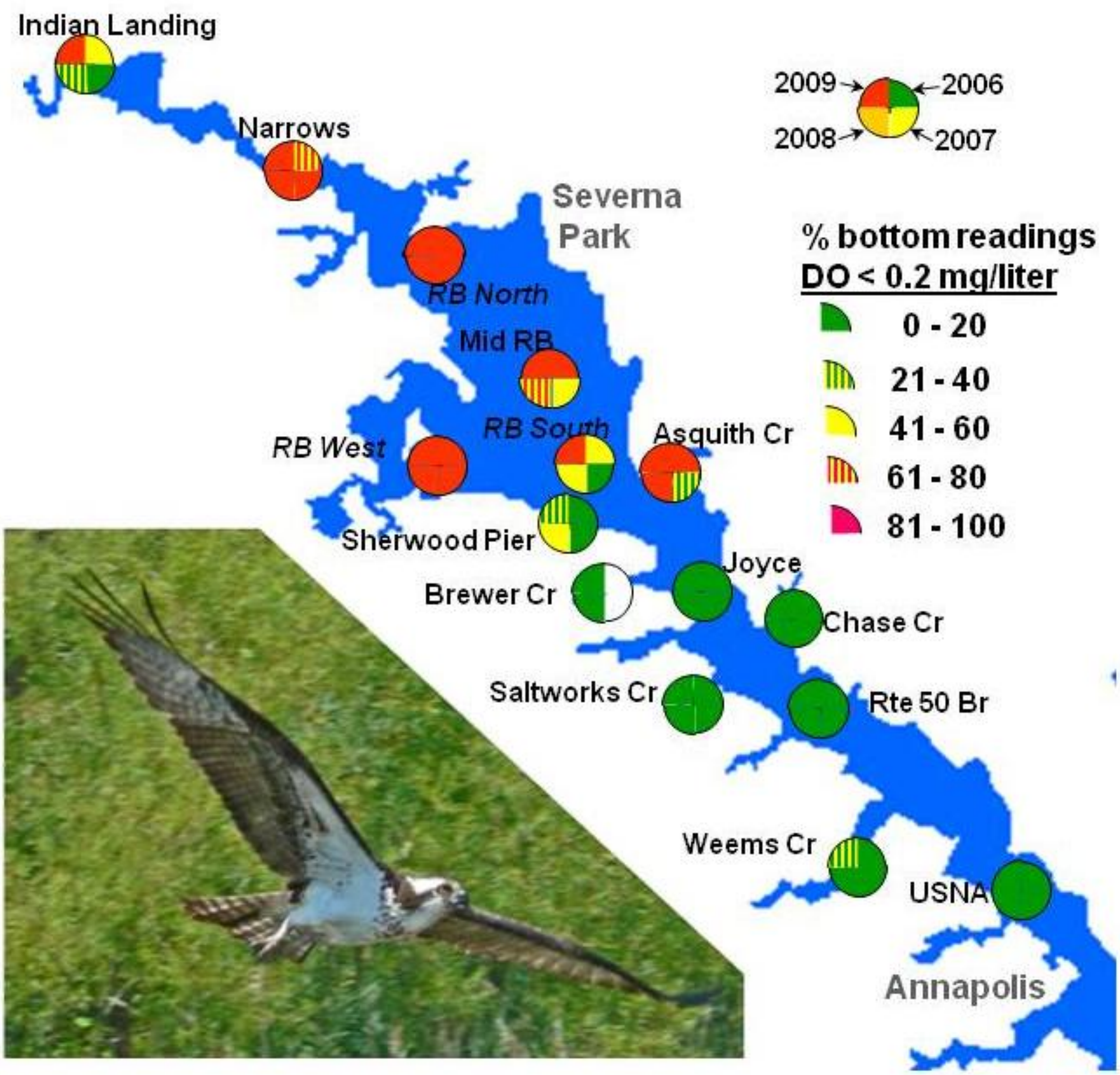
Severn Riverkeeper Monitoring Project

2009 Annual Report

Pierre Henkart



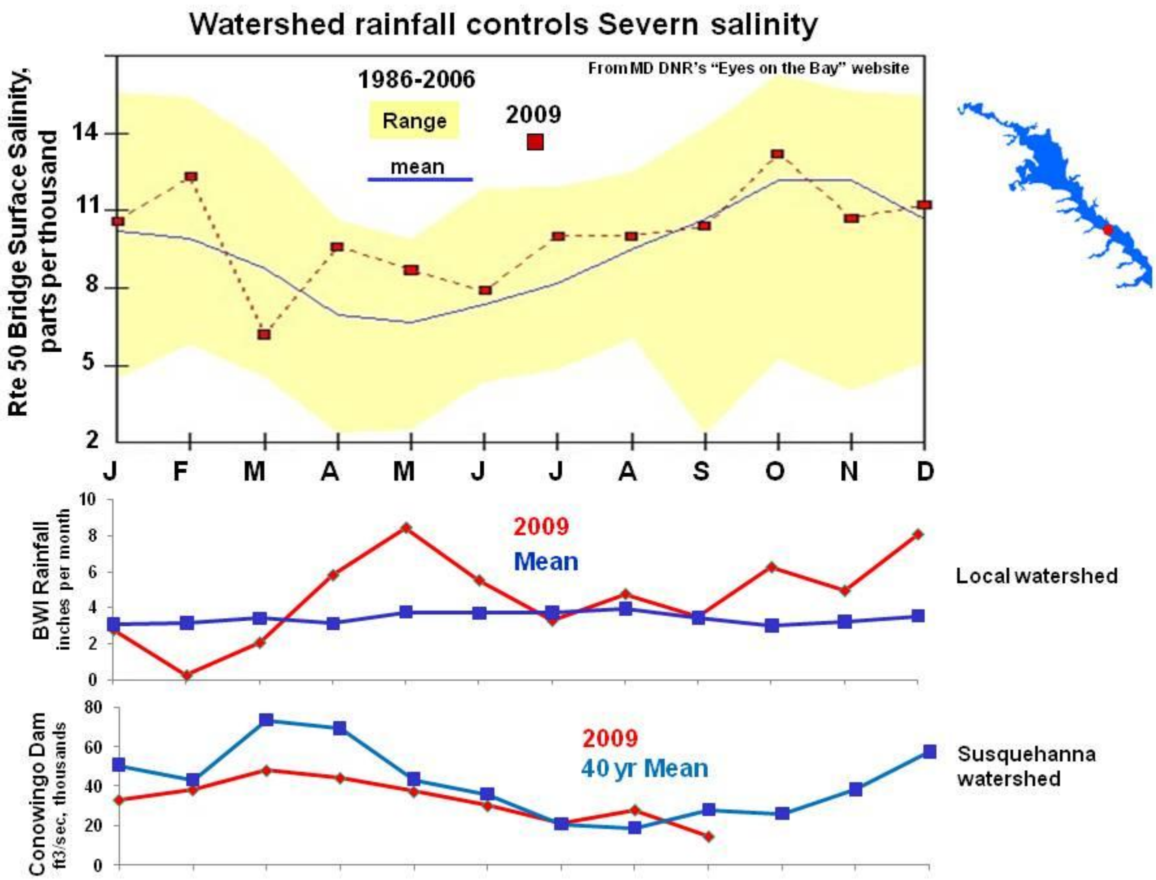
Introduction

The Severn Riverkeeper monitoring project was started in 2006 to characterize basic water quality parameters throughout the tidal Severn River. Because personnel and equipment are available chiefly in the summer months, the chief objective of this program has always been to assess dissolved oxygen levels throughout the Severn and its tidal tributary creeks. By the end of July 2006 we had gotten repeated bottom readings of very low dissolved oxygen levels (<0.2 mg/liter) in the middle of the Severn's Round Bay, much lower than the bottom levels we were finding in the Severn below Round Bay. Since our readings at the Route 50 bridge were similar to those reported by the Maryland Department of Natural Resources monitoring group, it appeared that the Severn from Round Bay and above was suffering from more severe bottom oxygen depletion than other nearby areas. This anoxia continued throughout the summer of 2006, and these unexpected and surprising findings have motivated us to continue our monitoring efforts over the ensuing four summers. Our results have shown that the upper Severn's bottom anoxia is a regular occurrence in the summer, and indeed in 2009 we found it extended to near the tidal head of the Severn in less than 6 feet of water. While short-term anoxia is responsible for occasional fish kills in such shallow areas around the Chesapeake, and the deep areas of the Chesapeake mainstem suffer well-documented summer-long anoxia (often referred to as the "dead zone"), we have not seen data from other areas of the Chesapeake describing persistent anoxia at depths of less than 40 feet. This report will summarize our oxygen findings in the Severn over four summers.

Another surprising finding by our monitoring group in 2006 came from salinity measurements, as described in our 2006 monitoring report. When we began monitoring in May of 2006, the Severn's salinity was higher than normal due to low spring rainfall. However, in June a major rain event dropped over 5 inches of rain throughout the region, and subsequently we found the Severn's salinity became lower as expected. What was eye-opening was that our monitoring data showed that most of the fresher water entered the Severn from the Chesapeake at Annapolis and moved "upwards", contrary to what we had expected (although we did find a brief local drop in salinity at the tidal head of the Severn). This unusual storm event demonstrated the dominant influence of the Chesapeake in controlling the Severn's water, showing how misleading it is to think of the Severn as a "river". Subsequent salinity measurements over four summers have reinforced our thinking about the dominance of the Chesapeake's water in the Severn, as our 2009 data also shows.

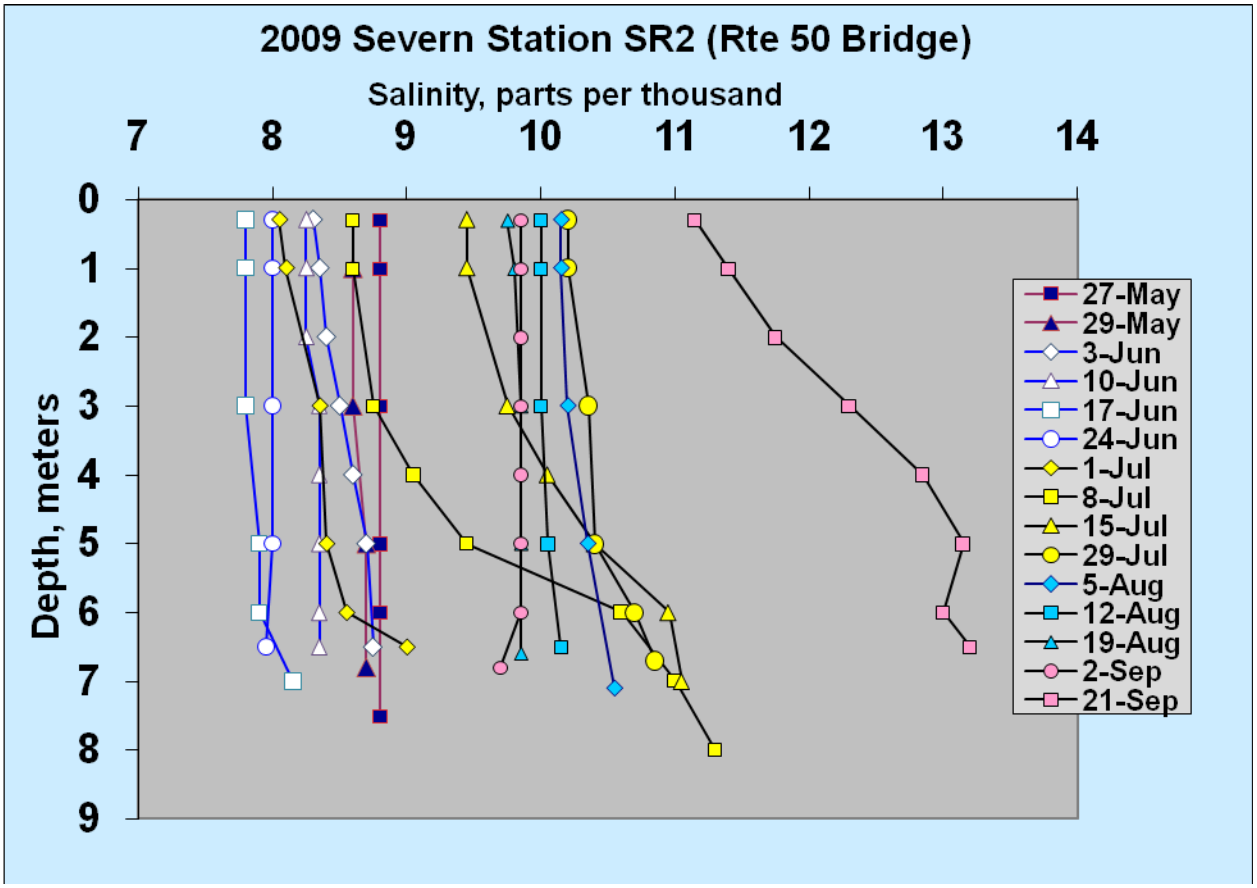
Salinity measurements show the Chesapeake's influence on the Severn

The Severn's salinity in 2009 did not follow the usual pattern of gradually increasing salinity throughout the summer months. The graph below shows the surface salinity data from the MD DNR monitoring program, recorded at the Severn's Rte 50 bridge.



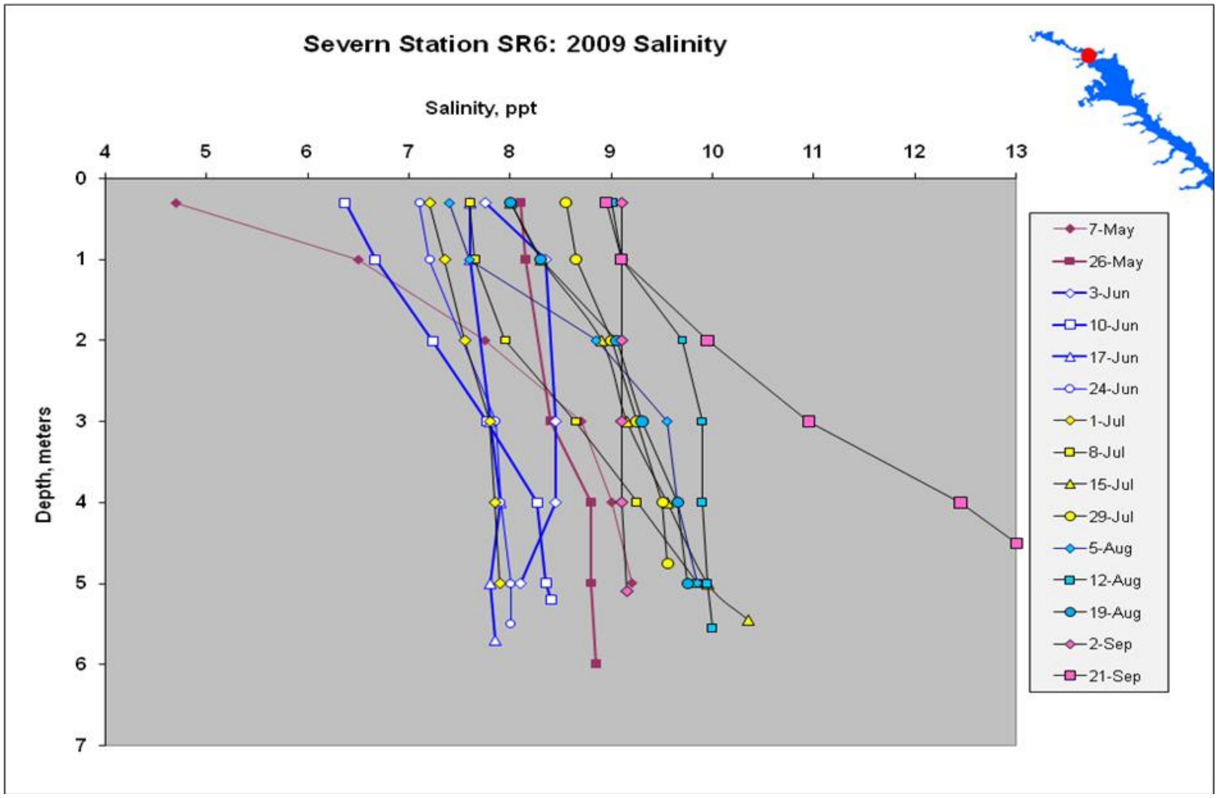
Also shown is rainfall data from BWI airport (close to the Severn watershed), and the freshwater flowing into the head of the Chesapeake from the Susquehanna River. While the local Severn area had a dry winter and wet spring, the Susquehanna watershed had a drier-than-normal winter and spring. The Severn's salinity was higher than normal throughout most of the spring and summer, reflecting the dominant influence of the nearby Chesapeake, which is in turn largely controlled by the strength of the Susquehanna's freshwater input.

Our salinity measurements (as well as dissolved oxygen and temperature measurements) were done at a range of depths to provide a standard water column profile used by oceanographers. The 2009 data for this same Rte 50 bridge station is shown in the next figure. On most occasions throughout the summer, the salinity was quite uniform from top to bottom (indicated by the vertical profiles), indicating the estuary was vertically well mixed. The

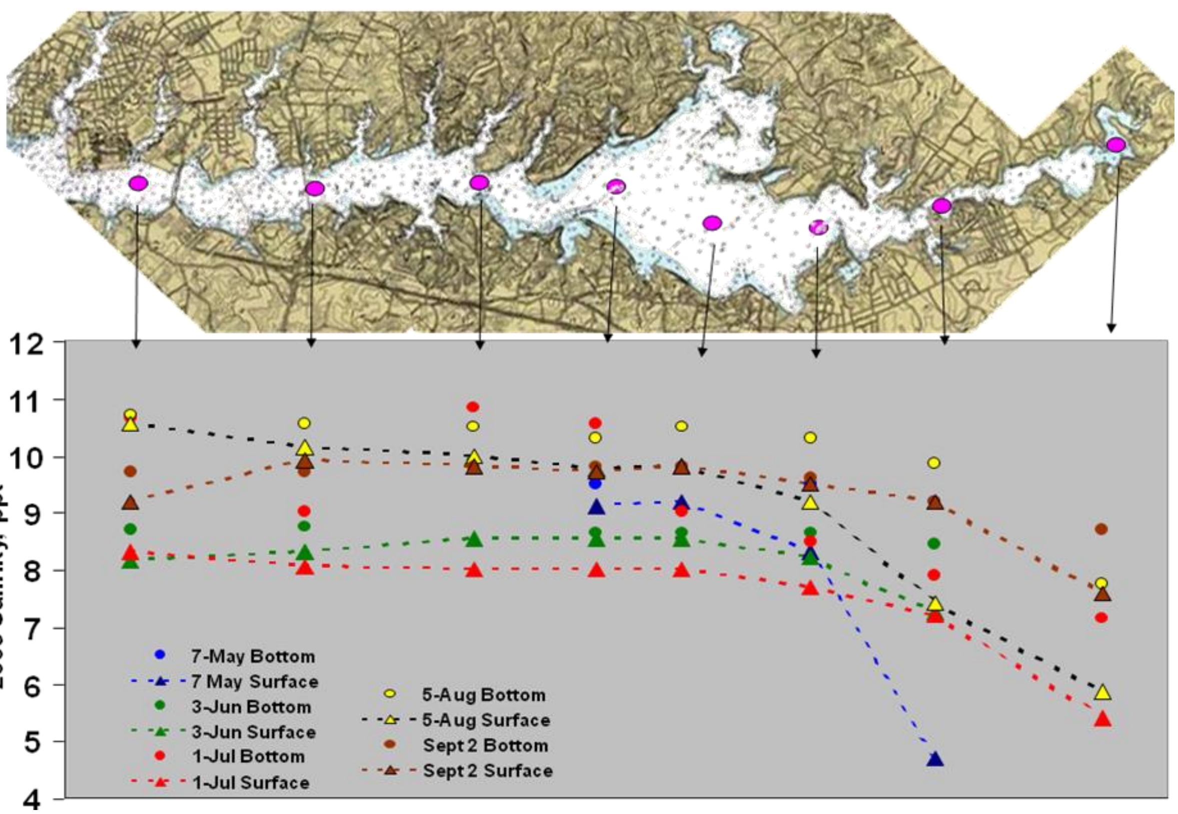


profiles of September 21, July 8 and July 15 show saltier water at the bottom. Looking back at the previous figure, these are periods when the Severn's salinity was increasing, which occurs when the Chesapeake's dense salty water enters the Severn along the bottom. At this station, there is no indication of fresher water from runoff near the surface after rain events. In contrast to this station in the lower Severn, the next page shows profiles at our monitoring station in the upper Severn (Narrows), with clear fresher water entry near the surface at many of our monitoring dates. In is interesting that on September 21 as well as in July, the saltier water coming in from the Chesapeake near the bottom is also seen here, over 6 miles above the Rte 50 bridge.

Overall, a comparison of salinity data between these two stations near the top and bottom of the tidal Severn reveal many similarities. The freshwater influence from Severn Run can be readily detected at our SR6 station, but it is mainly near the surface and mainly seen after rainstorms. Salinity comparisons between our Severn mainstem stations are shown in the following figure, reinforcing the dominant influence of the Chesapeake's water throughout the tidal Severn, with a Severn "sub-estuary" operating mainly above Round Bay where fresh water impacts from Severn Run are significant.



Salinity measurements show most of the water in the tidal Severn comes from the Bay



Dissolved oxygen in the Severn

Dissolved oxygen measurements in the summer of 2009 were made using the same monitoring protocol as was used in the summers of 2006 through 2008, so that we are able to directly compare our results with previous summers. Each data point in our dissolved oxygen depth profiles is the average of two independent YSI 85 meter readings at each depth, and examples of these profiles from one of our 14 Severn stations is shown here.
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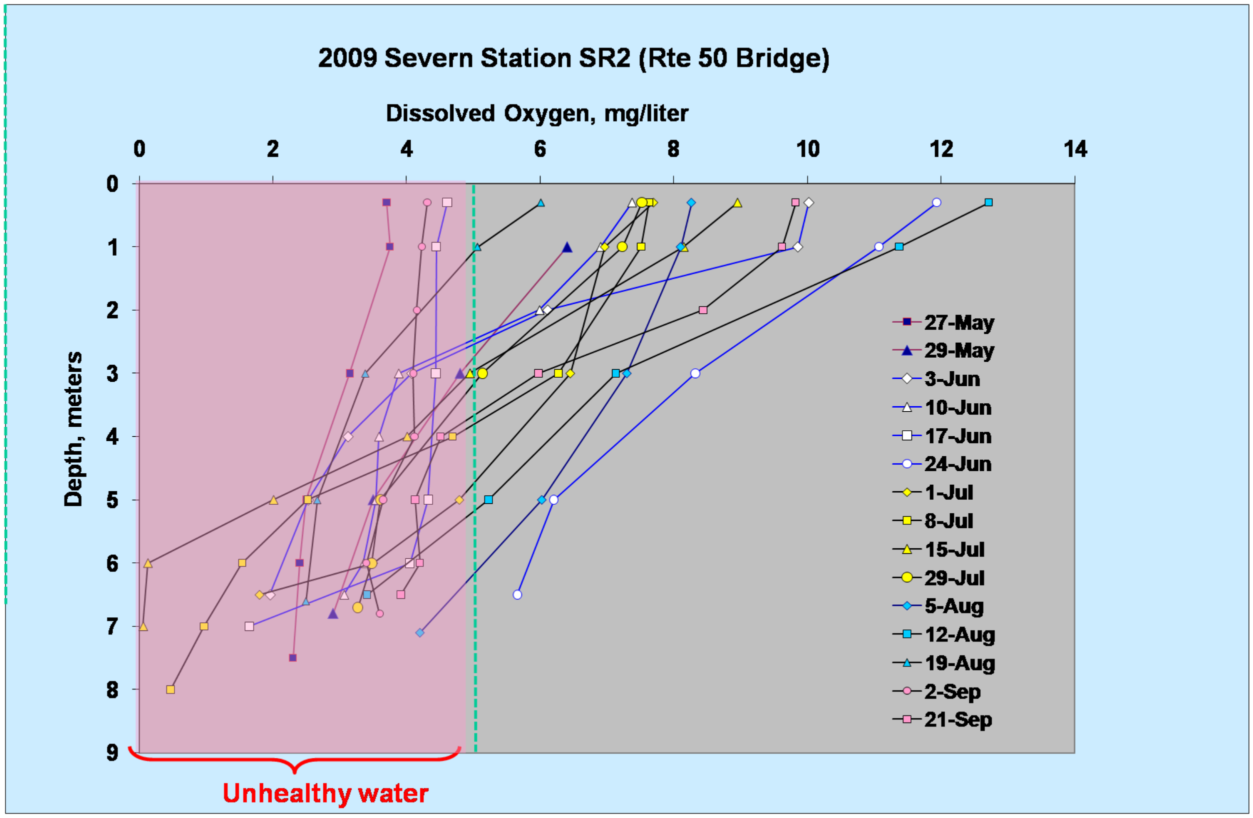
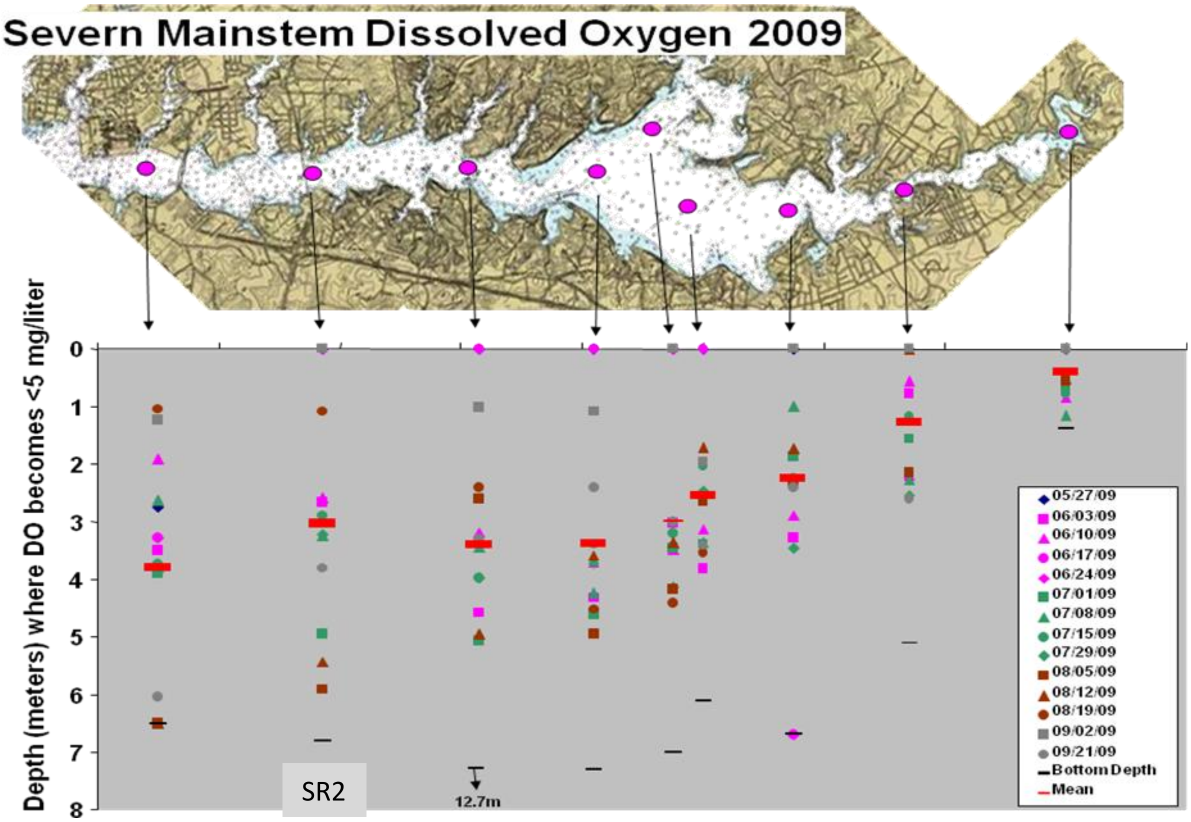


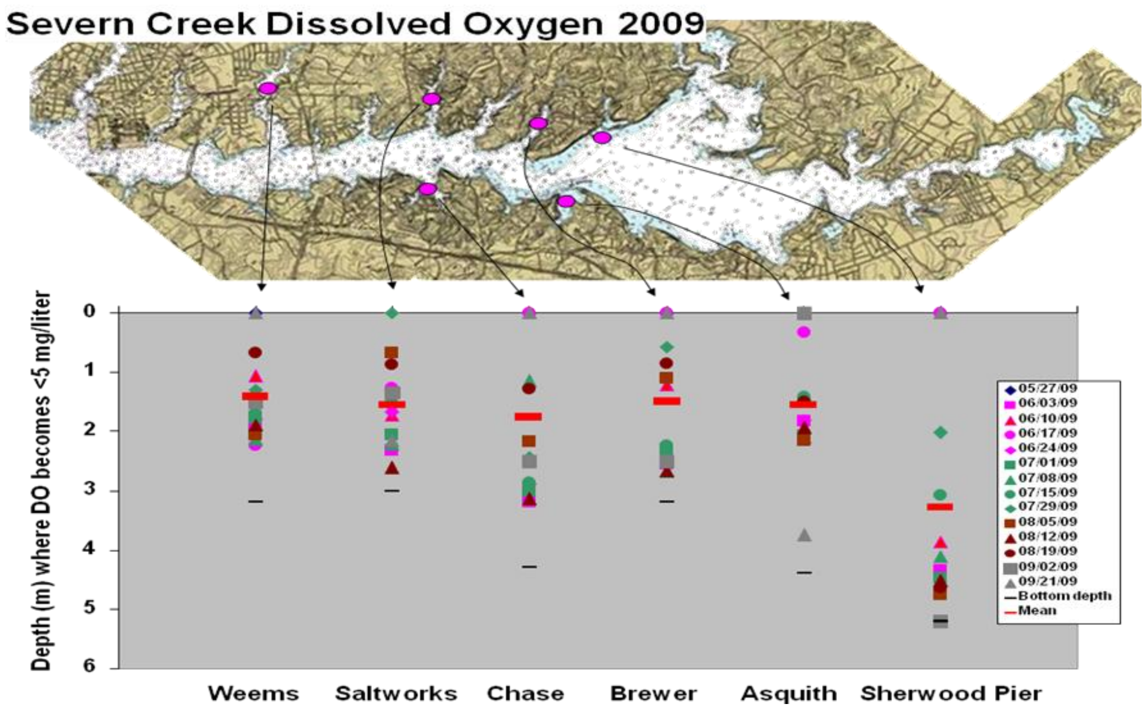
As expected, dissolved oxygen concentrations are highest near the surface (right end of the profiles above) because this water receives oxygen from the air. Oxygen concentrations decline with depth because oxygen is consumed by organisms at the bottom, and vertical mixing is often limited in the summer. While there are various ways of summarizing data like that shown above, we have used a measure of water "health" based on the Chesapeake Bay Program's dissolved oxygen standard of 5 mg/liter or greater. This oxygen level is shown by the dashed blue vertical line in the above figure, and actively swimming fish such as striped bass and bluefish become stressed at dissolved oxygen levels below this level (pink). Looking at the figure above, it can be seen that on some days oxygen levels even near the surface are unhealthy, but on June 3 we had healthy water all the way from the surface to the bottom. Using this approach, we have calculated the depth where the water column becomes "unhealthy" for each station on each monitoring day.

The results of this approach to quantitating the "health" of the Severn's water are shown below for our Severn mainstem stations.

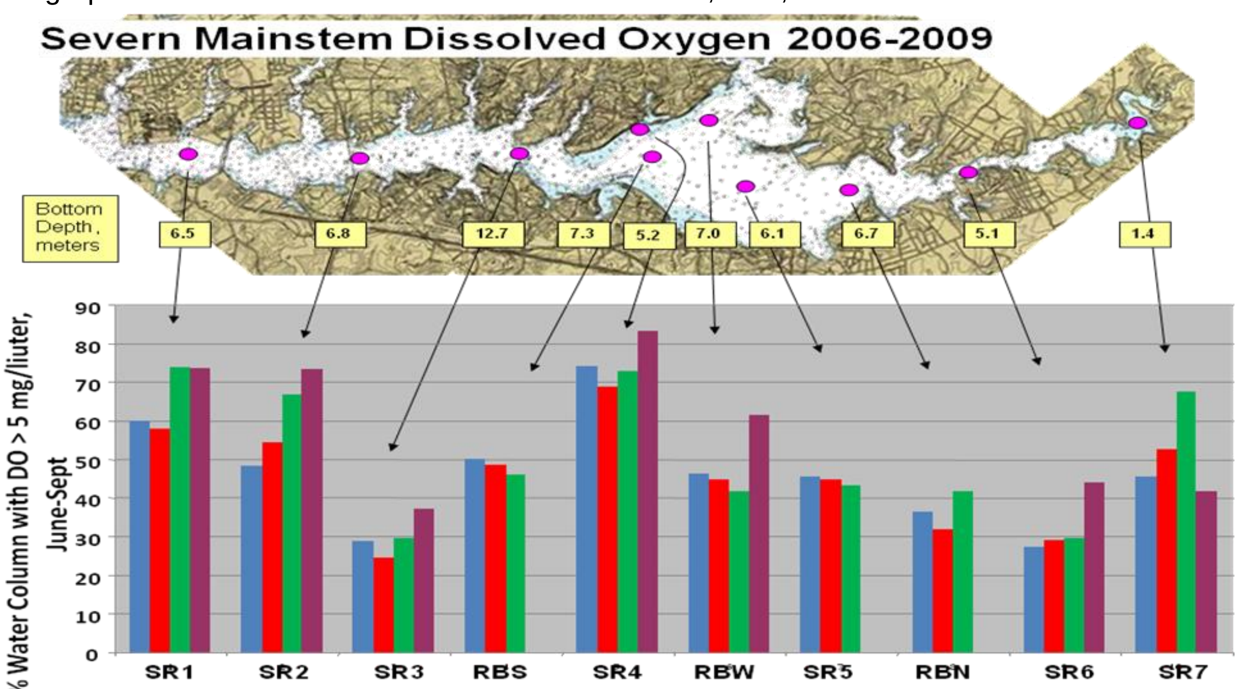


The plot above allows comparison of the depth where dissolved oxygen levels become unhealthy and also the bottom depth at each station. Stations are plotted on a horizontal axis showing their distance "up" the Severn from the Annapolis outer harbor. At any one station we find considerable variation in the depth at which dissolved oxygen levels go below healthy levels, as could also be seen from the SR2 station data on the previous page. The mean levels over the May-September period are shown by the red bars, and these depths tend to be a bit less than half the overall water depth at that station. Careful inspection of this graph shows that, for all stations except the one off the US Naval Academy, there were times when the entire water column was unhealthy (symbols at the top of the graph). In general, stations closer to the Chesapeake showed better mixing than stations in Round Bay and above.

A similar plot for our monitoring stations in creeks and at the edge of Round Bay is shown on the next page. Again, there was considerable variation over the course of the summer, with DO values of 5 mg/liter and above generally found to about half the overall depth. Our station near the Sherwood Forest pier near the edge of Round Bay shows the effect of wave-induced mixing, as nearby deeper stations in the middle of Round Bay have less healthy water.

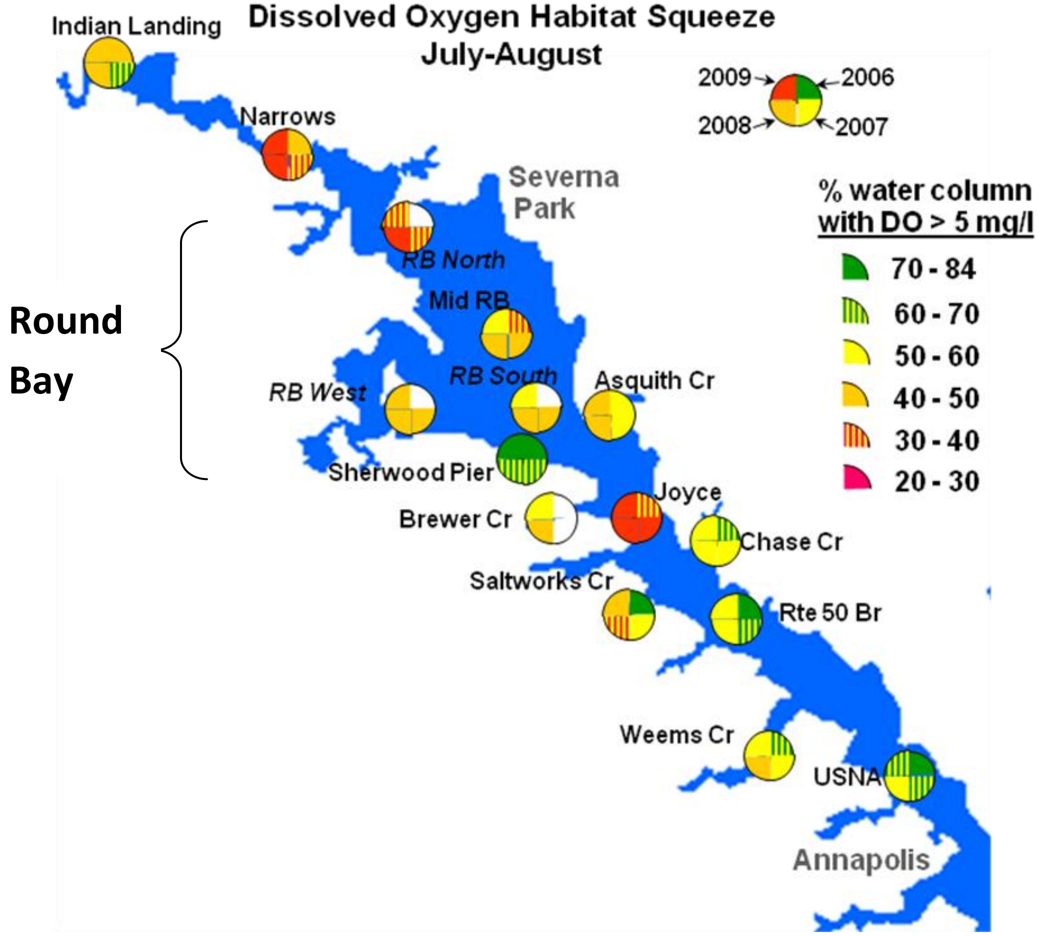


Because we have used the same monitoring protocol and monitored the same stations over four summers, we can ask whether significant changes are occurring over this time span. The graph below shows that lower Severn stations SR1, SR2, and SR3 seem to show a



worsening trend over this time, while for the rest of the Severn changes over these four years are not clear. Another way of showing our water column dissolved oxygen data over these four years is shown by the following map.

2006-2009 Severn Monitoring: Water Column Dissolved Oxygen

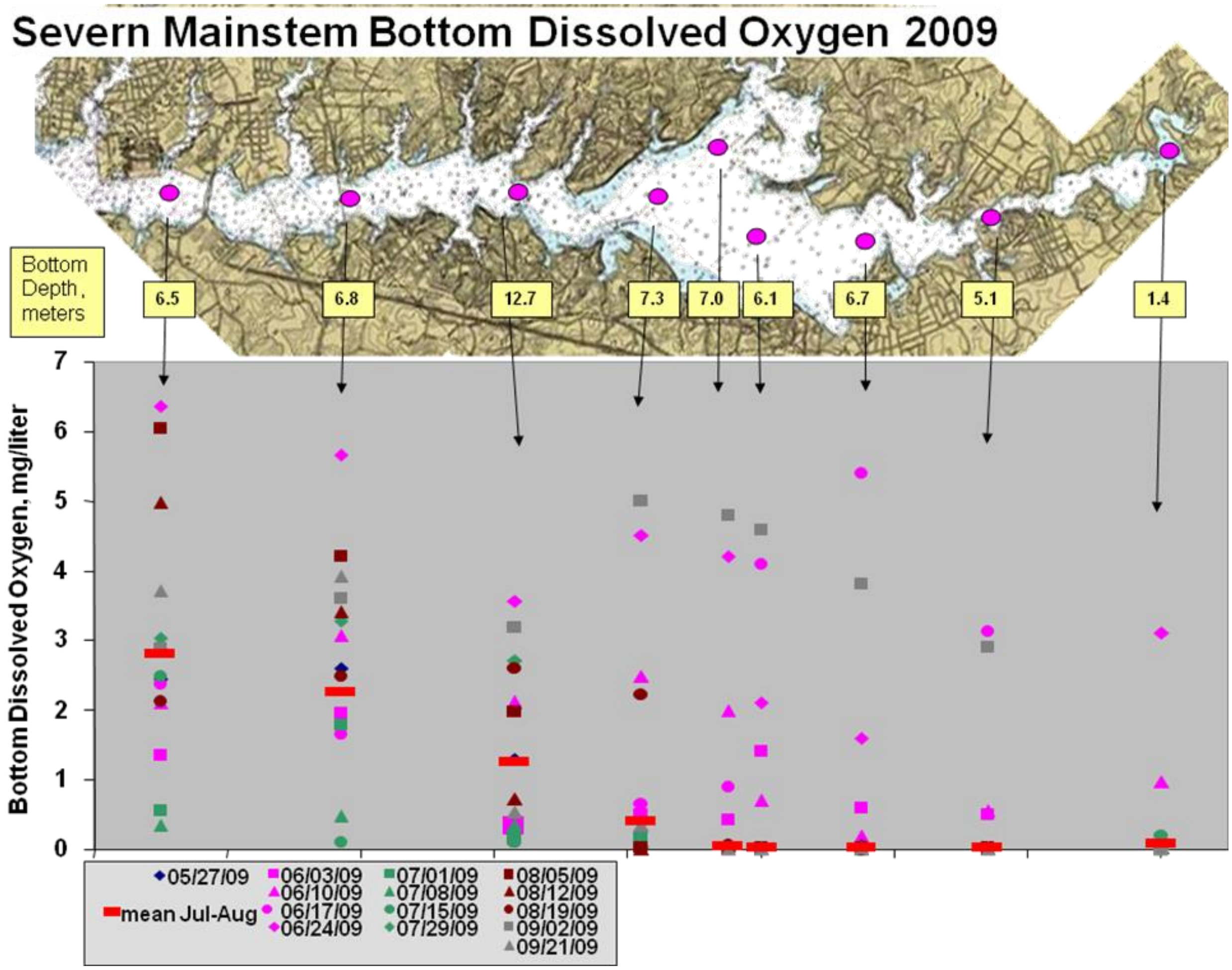


This shows the general tendency for better dissolved oxygen in the "lower" Severn than in Round Bay and above. The Joyce station midway up the Severn (SR3) is our deepest one, with a depth of almost 40 feet, while most of the other mainstem stations are 20-25 feet deep. The uppermost station at Indian landing is only about 5 feet deep, but the density layering effect of incoming surface fresh water retards vertical mixing.

Dissolved oxygen at the bottom

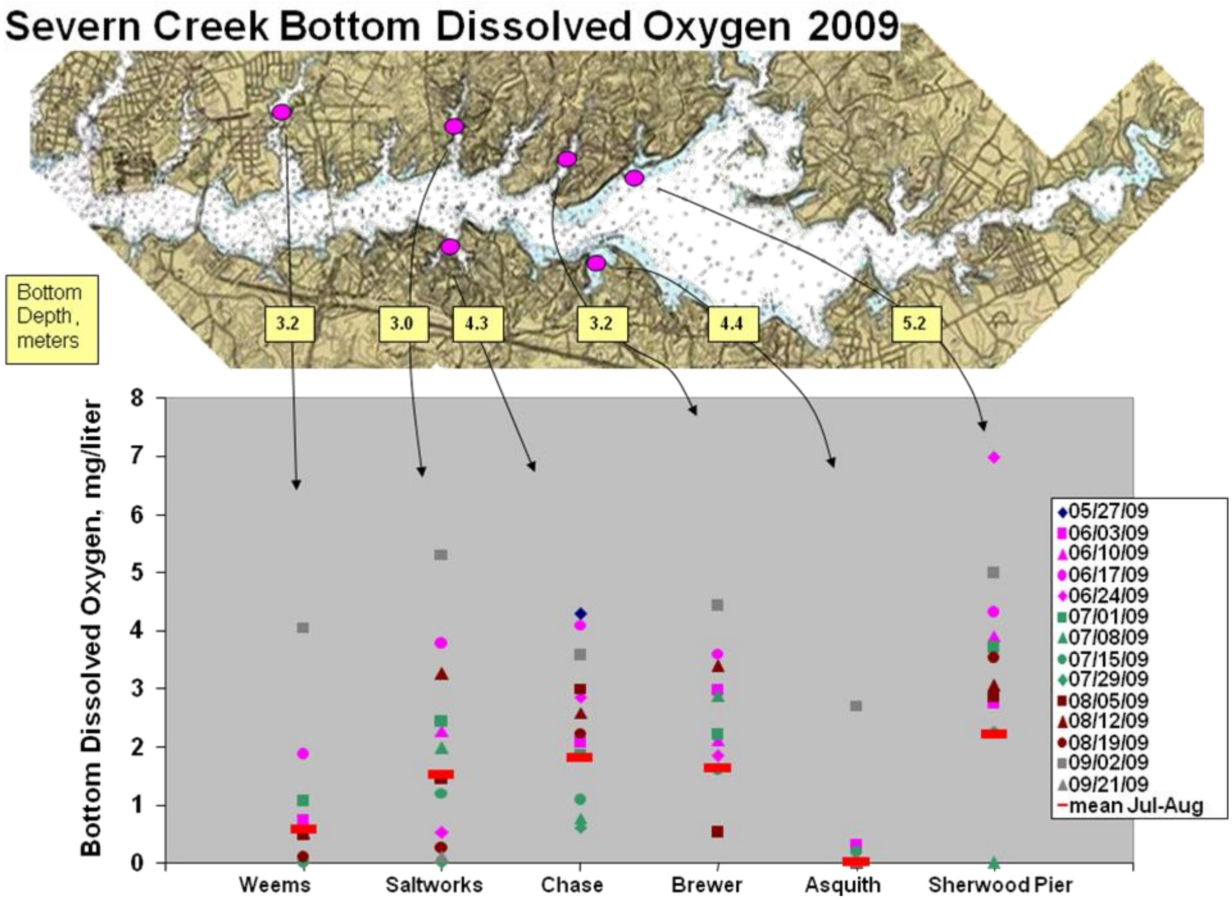
The oxygen concentrations discussed in the last section reflect the habitat of most of the Severn's fish, which can swim freely from the top to the bottom of the water column. Another community of invertebrate organisms inhabits the bottom of the Severn, including oysters and their associates on top of shelly bottom areas, and also those organisms like worms, clams and burrowing amphipods that live in tunnels in the bottom itself. Unlike fish or crabs that can swim up towards higher oxygen when they are stressed by hypoxia, these bottom-dwellers lack the ability to escape when low oxygen levels become stressful. They have evolved to adapt to lower dissolved oxygen levels than fish like striped bass, but when dissolved oxygen levels get down to 1-2 mg/liter, they also become stressed, and will die if these conditions persist over several days. Another biological community residing at the bottom is microbial--bacteria that feed on the abundant phytoplankton that have settled to the bottom after dying off higher in the water column. This abundant carbon source drives bacterial growth that depletes oxygen from the water near the bottom. After oxygen levels decline to near zero, these bacteria switch to anaerobic metabolic pathways including one that converts the sulfate that is a normal component of seawater into hydrogen sulfide, a toxic gas that we associate with rotten eggs. This occurs only after prolonged periods of oxygen deprivation, also known as anoxia.

The graph below shows the Severn mainstem's bottom dissolved oxygen levels over the summer of 2009. There is a dramatic decline in these levels going up the Severn, such that true anoxia is found starting at mid-Round Bay throughout the months of July and August.



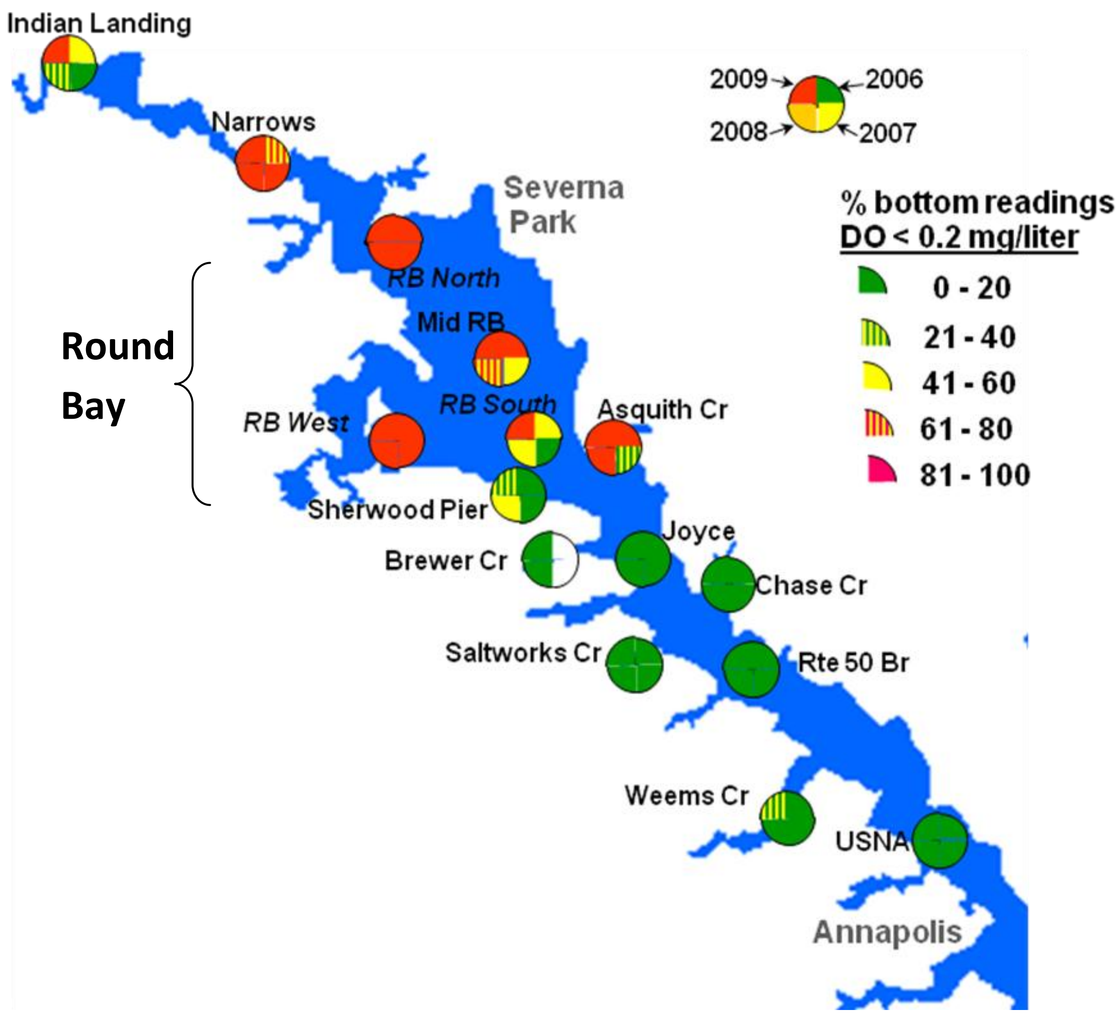
This bottom anoxia in the summer of 2009 is generally quite similar to our observations of the previous three summers. As found previously, when our YSI 85 meters indicated anoxia, water samples retrieved from the same depth usually smelled of hydrogen sulfide. The most surprising 2009 results are the extremely low dissolved oxygen levels found in the uppermost station, off the Ben Oaks community pier. Even at a mean depth of only 1.4 meters, true anoxia (DO < 0.2 mg/liter) was found near the bottom on most of our summer visits to this station. The high freshwater inflows during this period caused the formation of readily detectable pycnoclines at this station, as can be inferred from our salinity and temperature data. Pycnoclines are sharp vertical changes in water density, and are well known for their ability to prevent vertical mixing in estuaries. Nevertheless, persistent bottom anoxia at depths of less than 5 feet is unusual, and previous years of our monitoring did not show such pronounced anoxia at this station. Overall, our results in 2009 confirm our results of the previous three years showing large areas of anoxic bottom persist throughout July and August in the upper Severn.

The Severn creeks we monitored generally showed bottom dissolved oxygen levels of 0.5-3 mg/liter, indicative of hypoxia but not anoxia. Our station at the edge of Round Bay near the Sherwood Forest pier showed moderate hypoxia as well.



However, as we found in the past 3 years, Asquith Creek was unusual for a Severn creek in that it had a strongly anoxic bottom water layer for most of the summer of 2009. This water also smelled strongly of hydrogen sulfide, confirming anoxia. These results are depicted in the figure above, and are generally similar to our findings of the previous three years, as shown on the following map.

2006-2009 Severn Monitoring: July-August Bottom Anoxia



These results show that the "lower" Severn and its creeks rarely suffer from bottom anoxia, but much of Round Bay and the "upper" Severn is severely impacted on an annual basis during July and August. Our monitoring project has provided the first documentation of this extensive area of bottom anoxia, which has not been described in neighboring Chesapeake tributaries.

Severn Dissolved Oxygen—Discussion

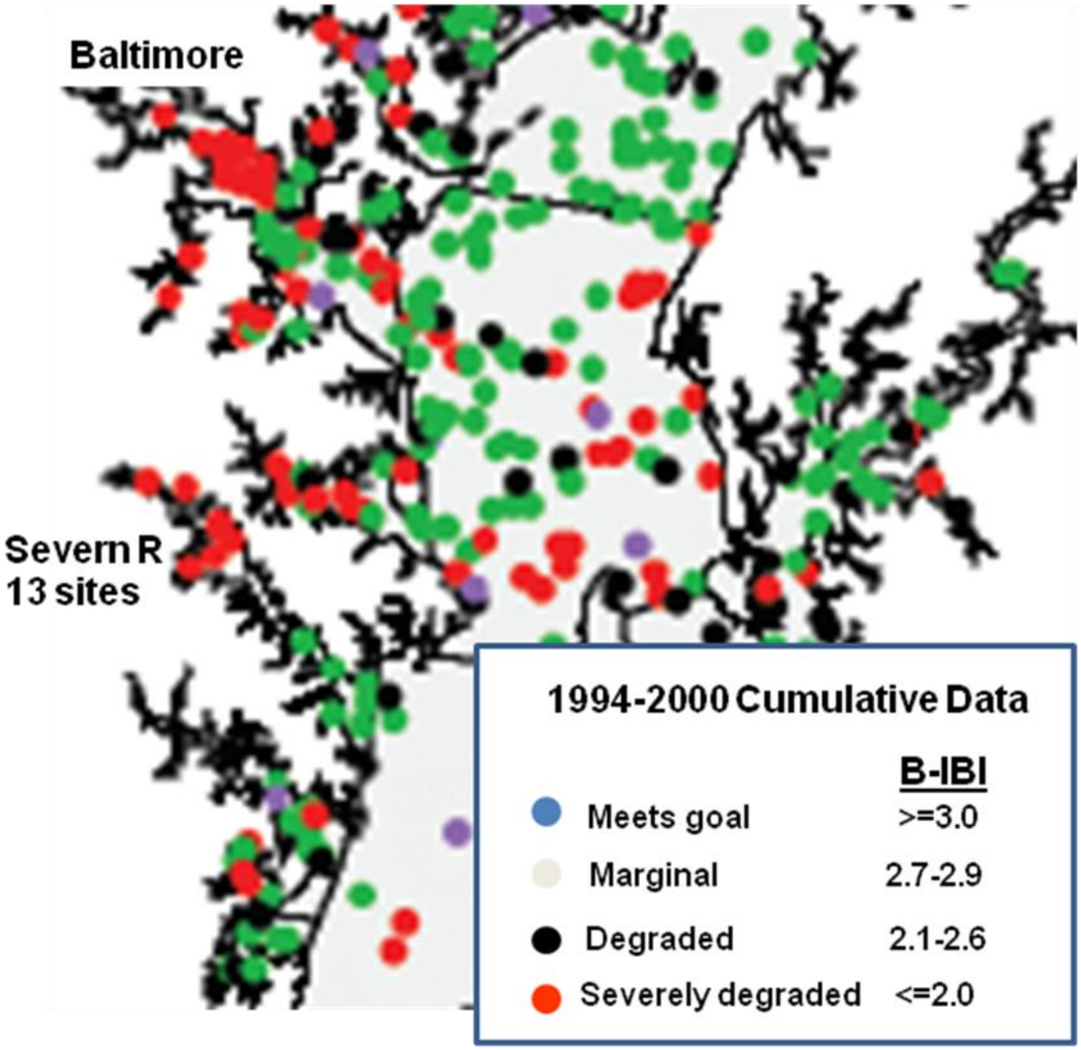
Dissolved oxygen has been the principal focus of the Severn Riverkeeper Monitoring Project since it began in 2006. This priority was chosen because of preliminary data pointing to severe bottom hypoxia in the summer, and the availability of both personnel and reliable monitoring instruments for measuring dissolved oxygen levels. We now have 4 years of data that reveal a rather consistent pattern, and as more data become available from neighboring tributaries, it appears that most of the upper Severn has a regular pattern of anoxia--severely depressed bottom dissolved oxygen levels. Such bottom anoxia is not seen regularly in the lower Severn, nor has it been found in such a consistent pattern in neighboring Chesapeake tidal tributaries. At the same time, the overall pattern of dissolved oxygen in the mid-upper levels of the water column do not appear to be significantly worse in the upper Severn than in the lower Severn. In as much as comparable data are available, these mid-upper water column dissolved oxygen levels seem similar in the Severn's and its neighboring tributaries.

The above distinction between mid/upper and bottom DO levels is biologically important because they reflect the "health" of two different biological habitats: a) the overall water column which can be thought of as the habitat of most finfish; and b) the bottom of the water column which is the habitat of benthic (and epibenthic) invertebrates like clams, worms and oysters, as well as the demersal fish that spend most of their time there. We have chosen to summarize our DO profiles by reporting the depth at which DO concentrations become less than 5 mg/liter, which is the level that fast swimming fish such as striped bass and bluefish require to avoid stress. When compared to the depth of the bottom, this DO_5 depth represents the degree of "habitat squeeze" inflicted on such fish by hypoxia. Thus if the water is 10 meters deep and the DO_5 depth is 5 meters, striped bass will utilize only (the top) half the water column without stress.

As shown by the data presented above, over the past four summers our data reveal a fairly consistent Severn DO pattern. For the overall water column DO, our data show that in the summer, anywhere from less than 30% to slightly more than 70% of the water column is suitable for striped bass in the Severn, with ~50% being a common result. The lower Severn tends to have less DO-induced habitat squeeze than the upper Severn, and the Severn creeks are quite variable within the 30-70% range. In almost all cases our monitoring stations were located in the deepest portion of the Severn or one of its creeks, and we expect that higher oxygen levels will be found at shallower depths.

Our finding of consistent summer bottom anoxia in the mid/upper Severn was surprising to us when we first observed it in 2006, but this pattern has been repeated over 4 years. Such anoxia has not been reported by other Severn monitoring efforts. This is explainable by considering that the MD DNR monitoring program has excellent long term data with depth profiles for only one station in the Severn, and it is in the lower Severn (our SR2, their WT7.1). They also carried out DO monitoring up and down the Severn for two years (2002 and 2003), but these efforts only obtained data at a depth of one meter where DO levels are generally high.

The Chesapeake Bay Program has funded a monitoring program to assess the health of the benthic habitat. This program samples the benthic invertebrates living in the bottom mud and analyzes their number and composition to produce a Benthic Index of Biotic Integrity (BIBI). This index has been used to assess benthic community health throughout the mid-Atlantic coastal region, and local results are summarized in the figure below.



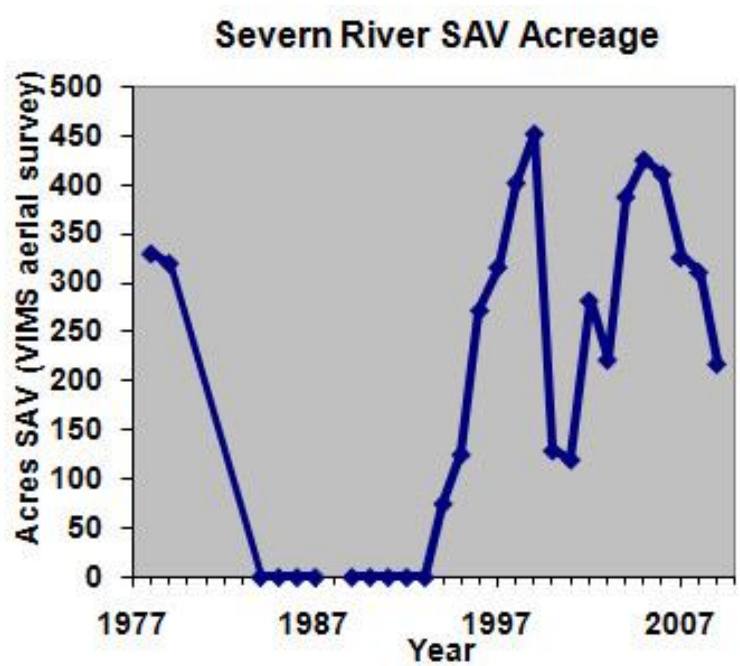
RJ Llanso et al,
Environmental Monitoring and Assessment,
81: 163 (2003)

These results show that the upper Severn (and also the upper Magothy and upper Patapsco as well as the Chesapeake deep channel) had severely degraded benthic habitats. Such degradation can occur as a result of long term anoxia or due to toxic chemical contamination. The latter insult may explain the Patapsco benthic degradation, but it seems highly unlikely in the Severn and Magothy. Although the Severn has not been consistently sampled every year in this monitoring program, in 2009 two sites were sampled, with both giving B-IBI scores of "severely degraded". One of these sites was close to our mid-Round Bay station SR5, in 20-25 feet of water, and the other was close to Cedar Point at the northwestern end of Round Bay. Thus, our findings of anoxia in the upper Severn are clearly correlated with the results of this benthic monitoring program, although more benthic sampling data would be desirable. These results suggest that the pattern of anoxia we have observed in the upper Severn in the last 4 years has been in place for decades. Because benthic monitoring to calculate B-IBI values is expensive, a more thorough look at the relation between Severn anoxia and degraded benthic habitat seems unlikely.

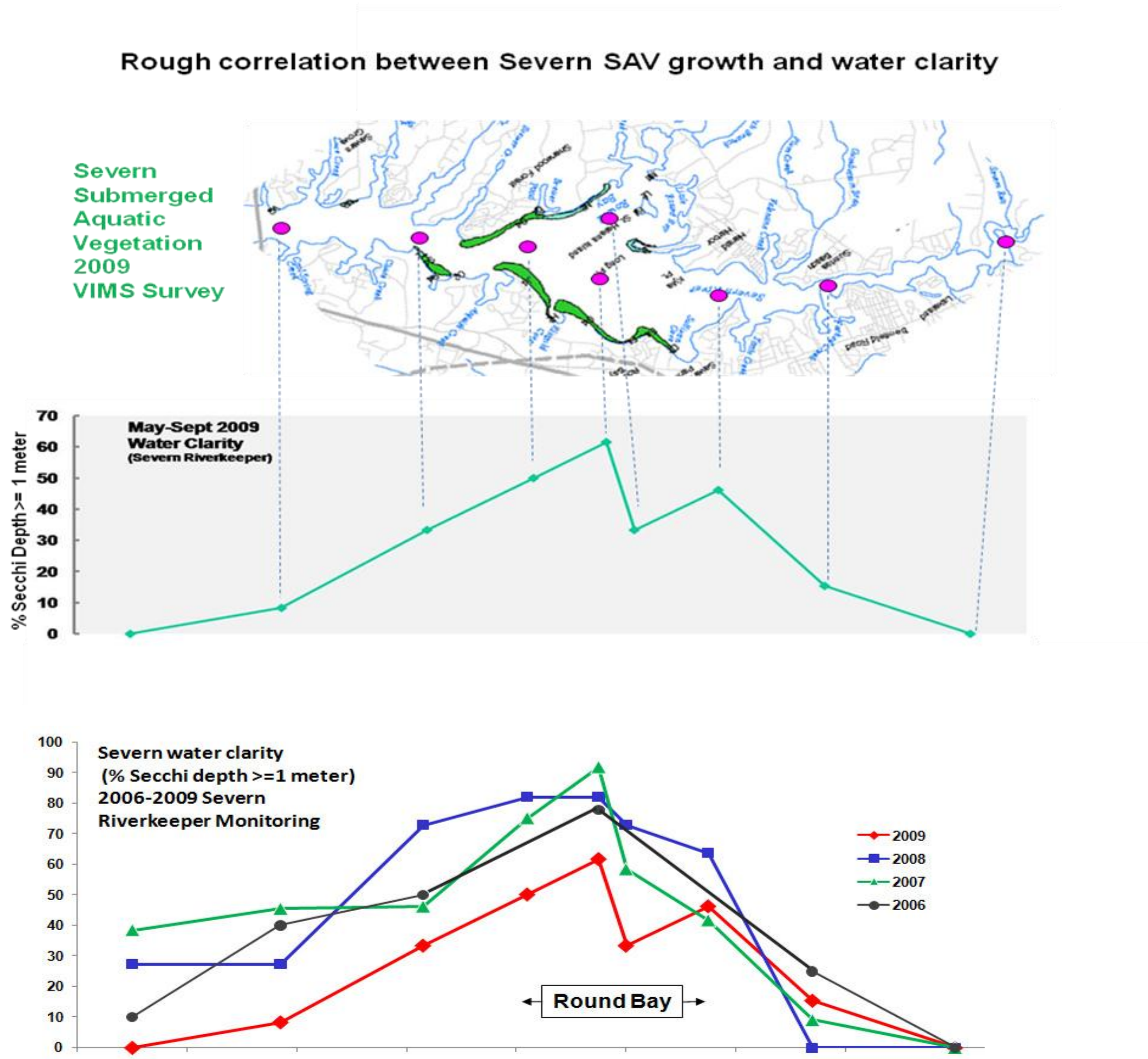
Severn Water Clarity

Our monitoring routinely measures surface water clarity by the crude but widely used approach of lowering a standard white-and-black Secchi disk over the side and recording the depth to which it is visible. Both sediment and plankton cloud the Severn's water, and distinguishing between these is not simple. While the Chesapeake has never had the superb water clarity of some lakes or tropical coral areas, both sediment and plankton have increased in recent years to the point where the submerged aquatic vegetation traditionally dominating its shallow edges has been depleted. The Severn has traditionally had extensive beds of this SAV along the shores of its mid-section, providing excellent habitat for fish and crabs.

The Virginia Institute of Marine Science has conducted an aerial surveillance-based monitoring program for SAV throughout the Chesapeake and nearby coastal bays for over 20 years. This program documented the absence of SAV in the Severn from the mid-1980s to the mid-1990s, followed by its spontaneous regrowth to peak levels in 1999. Since then the Severn's SAV acreage has varied dramatically, with the sharp drop in 2000 due to phytoplankton growth that spring.



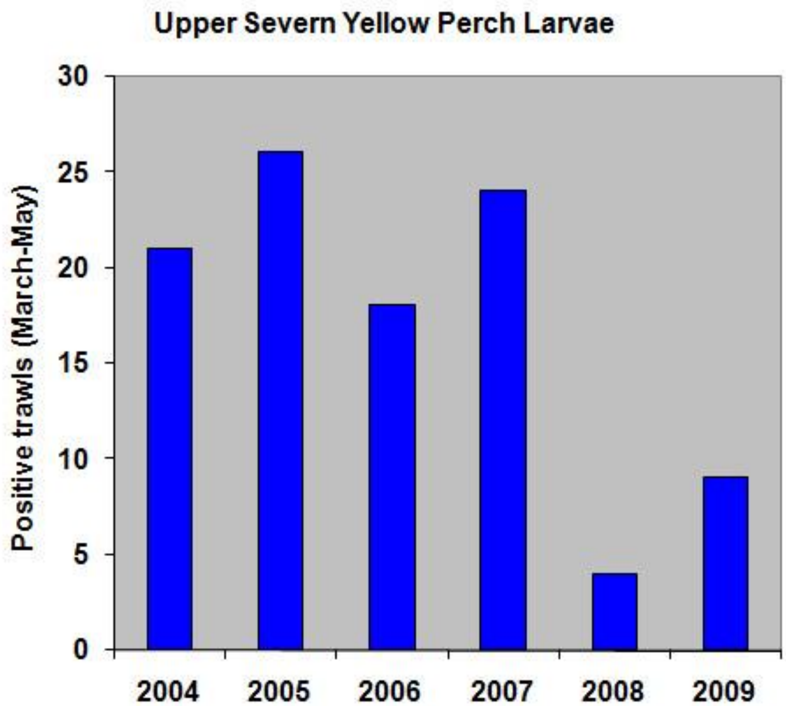
Our water clarity monitoring has revealed an interesting correlation between the Severn's water clarity and the areas where SAV grows along its shallows. Data from 2009 is shown in the figure on the next page, in which we have plotted the percentage of our Secchi depths that are at or above the Chesapeake Bay Program's standard of one meter for SAV in our area. In the lower Severn up to the Rte 50 bridge and above Round Bay, this level was rarely achieved in the summer (when SAV grows). However, in the mid-Severn the water clarity often was above the 1 meter criterion, and this corresponds to the area where SAV was found. The upper part of Round Bay had about the same water clarity as the well vegetated lower part of Round Bay, but in 2009 there was no SAV above Sullivan's Cove, so the correlation is imperfect.



The figure showed that the Severn's SAV declined significantly in 2009 compared to the previous few years, and it is interesting that our Secchi water clarity readings also declined in 2009, as shown in the lower panel. It is also clear that water clarity was lower in 2009 than previous years in the stations below Round Bay but not in upper Round Bay and stations above that. This finding suggests that the source of impaired water clarity came from the Chesapeake and not from the Severn watershed.

Yellow Perch Spawning in the Severn

The Severn has traditionally been regarded as a fisherman's favorite for catching yellow perch, a freshwater fish that makes its way into the upper tidal Chesapeake and associated tributary rivers. In recent years yellow perch have become scarce in the Severn, leading to a ban on the taking of this species in the Severn. Since 2006 the Severn Riverkeeper Monitoring Project has collaborated with the Arlington Echo Outdoor Education Center and the Maryland DNR Fisheries Division to monitor the presence of larval yellow perch in the tidal upper Severn. This protocol, carried out each spring since 2004, calls for two minute plankton tows conducted twice a week in each of 10 locations during the annual spawning season. The results are presented as the total number of trawls that were positive for yellow perch larvae, as shown in the figure at the right. While the 2009 results were better than the all-time low 2008 results, we found relatively few yellow perch larvae compared to the 2004-2007 results. These years were already greatly diminished compared to the Severn's historic yellow perch reproduction before monitoring was begun.



DNR studies of the Severn's yellow perch decline have not clearly revealed the cause of this problem, which is likely to be attributable to the local watershed as opposed to a Chesapeake Bay influence. A major suspect is increased development-associated imperviousness in the watershed of Severn Run and its numerous tributaries which causes greater runoff after rain events and reduces the freshwater base flow in the spawning areas.

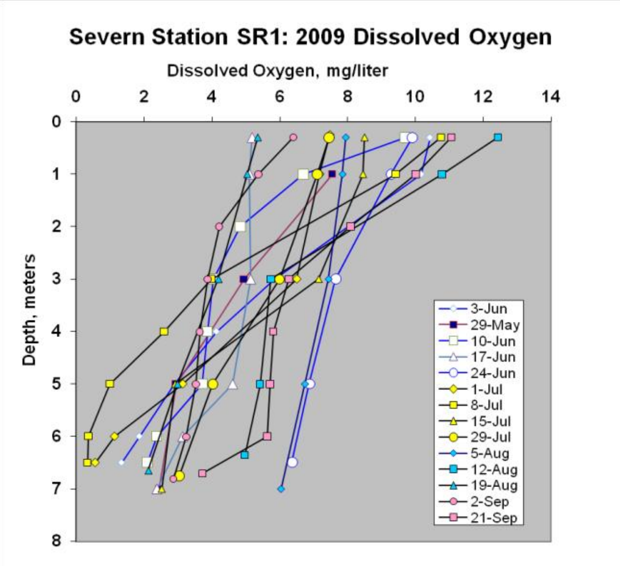
Acknowledgements:

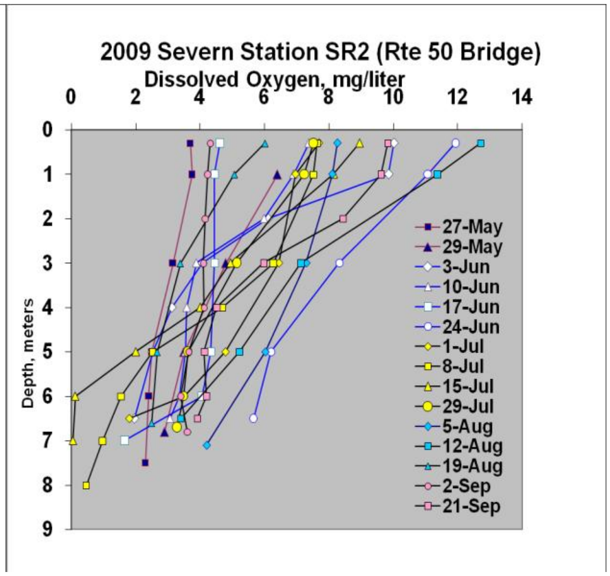
The 2009 Severn Riverkeeper Monitoring Project was a combined effort of a number of people, without whom this project would not exist. Firstly, I thank Riverkeeper Fred Kelly for constant support over four years of this project, supplying and maintaining the Riverkeeper boat, providing monitoring meters and other equipment, and supporting monitoring personnel. In 2009 our regular monitoring crew included 4 year veterans Nate Frankoff and Aaron Canale, as well as Riverkeeper interns Wiley Laufman and Brooke Warrington. In addition to these regulars, our monitoring efforts were greatly enhanced by volunteers. In particular, I thank several who made multiple monitoring trips with us in 2009: Jerry Smith, Mike Robinson, Dave Wilkinson, and Charlotte Lubbert.

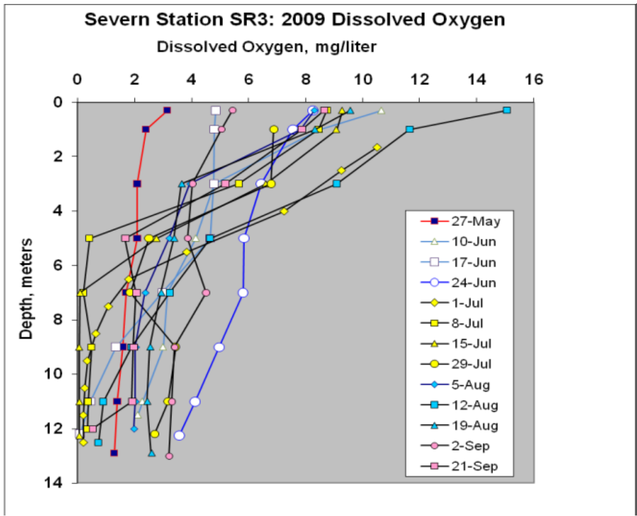
The Severn's early spring larval yellow perch monitoring effort has been possible thanks to a shared monitoring schedule with Steve Barry and staff from the Arlington Echo Outdoor Education Program.

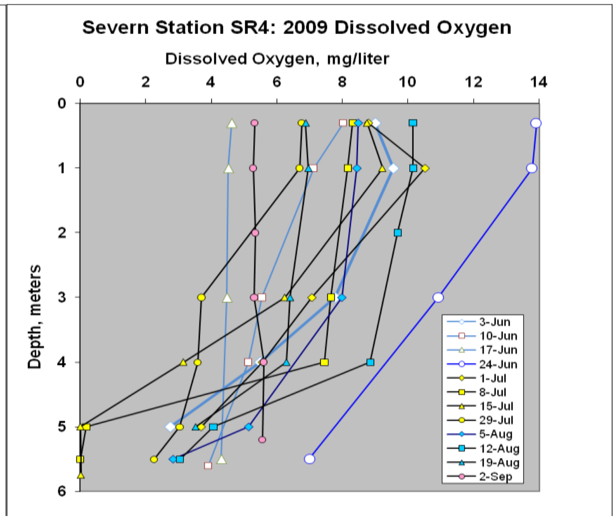
University of Maryland's Center for Environmental Science and Dr. Bill Dennison have organized an effort to foster water quality monitoring by local watershed groups. Meetings with this group have helped improve our analysis of our Severn monitoring data. Our program also thanks Dr. Peter Bergstrom of NOAA's Chesapeake Bay office, as well as Dr. Andrew Muller of the Oceanography Department of the US Naval Academy and South Riverkeeper Diana Muller for helpful advice.

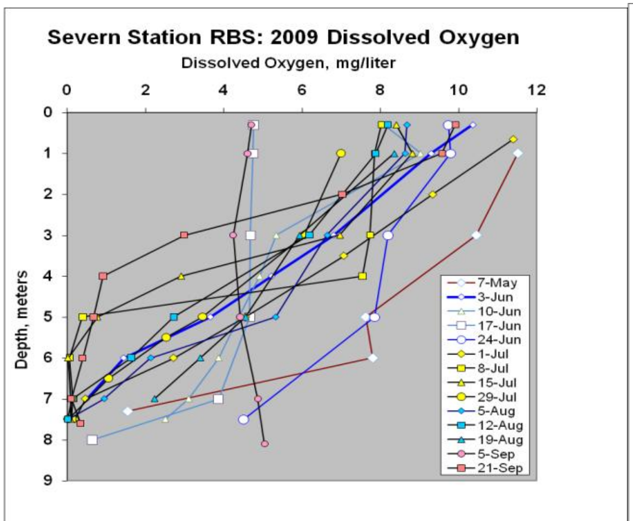
2009 Severn Riverkeeper Monitoring Program Dissolved Oxygen Profiles

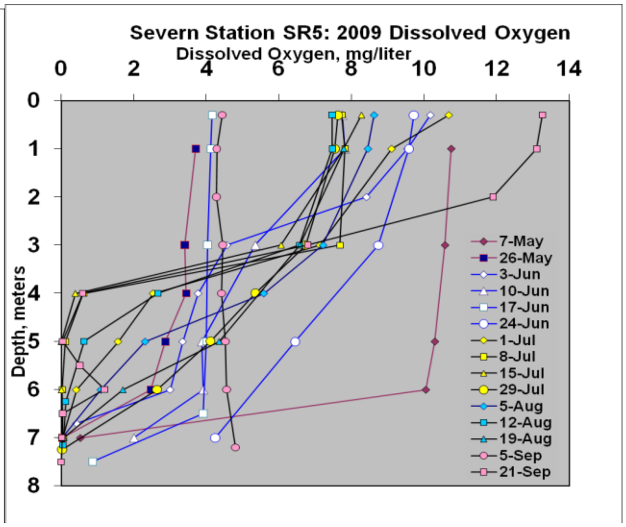


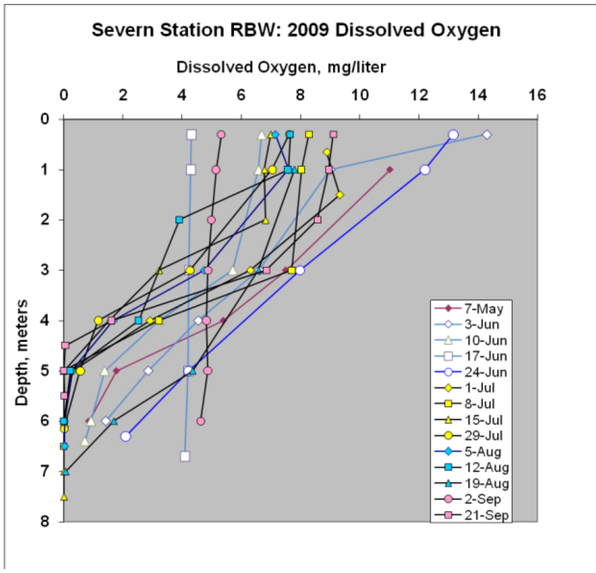


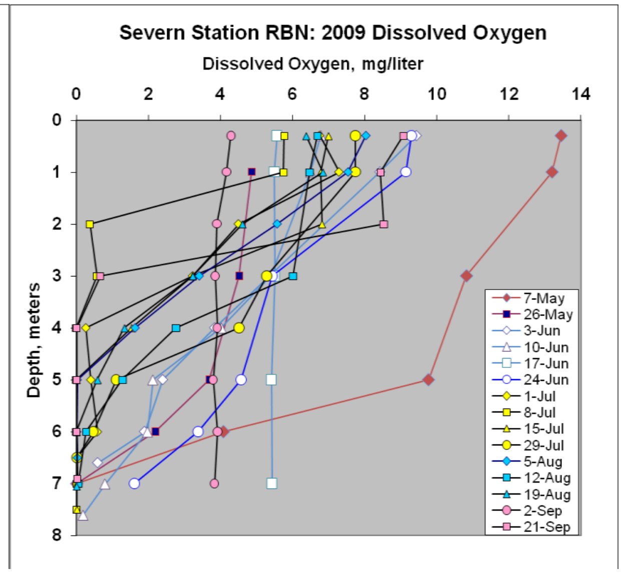


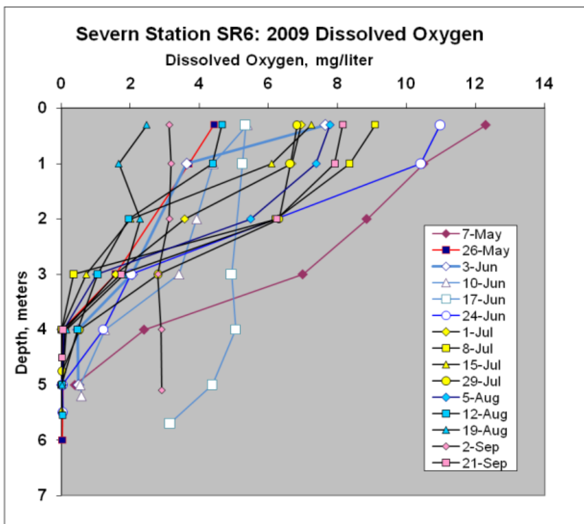


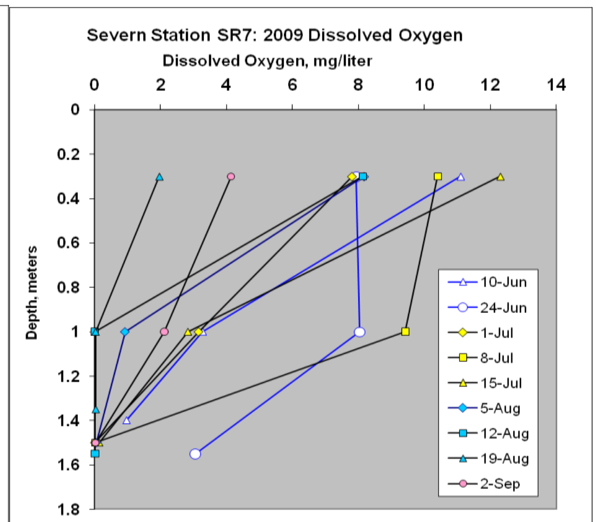


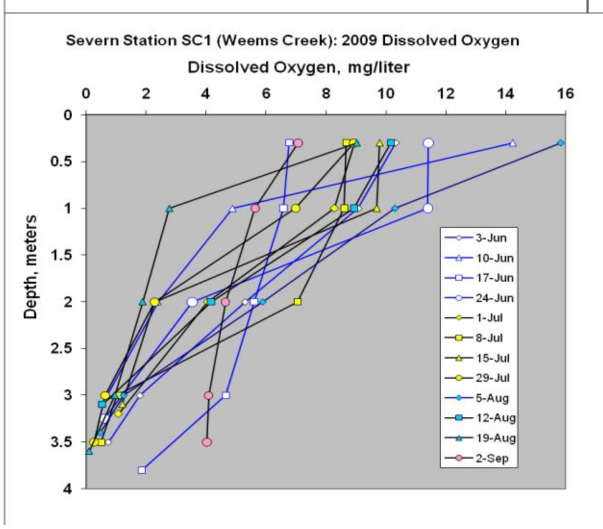


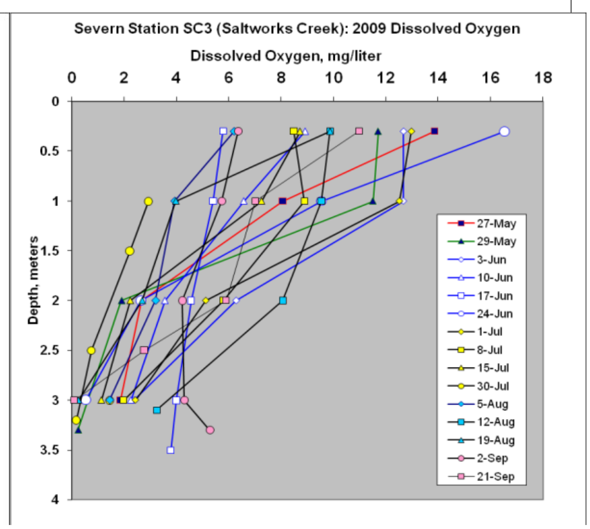

Severn Station RBW: 2009 Dissolved Oxygen
Dissolved Oxygen, mg/liter
Depth, meters
7-May
3-Jun
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
29-Jul
5-Aug
12-Aug
19-Aug
2-Sep
21-Sep

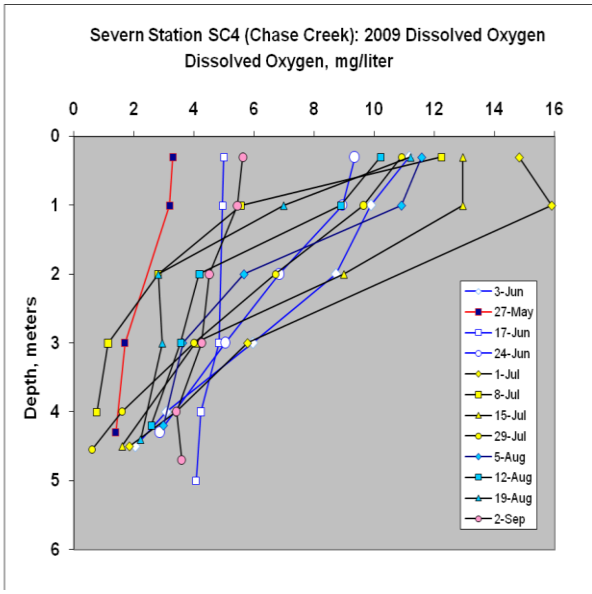

Severn Station RBN: 2009 Dissolved Oxygen
Dissolved Oxygen, mg/liter
Depth, meters
7-May
26-May
3-Jun
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
29-Jul
5-Aug
12-Aug
19-Aug
2-Sep
21-Sep

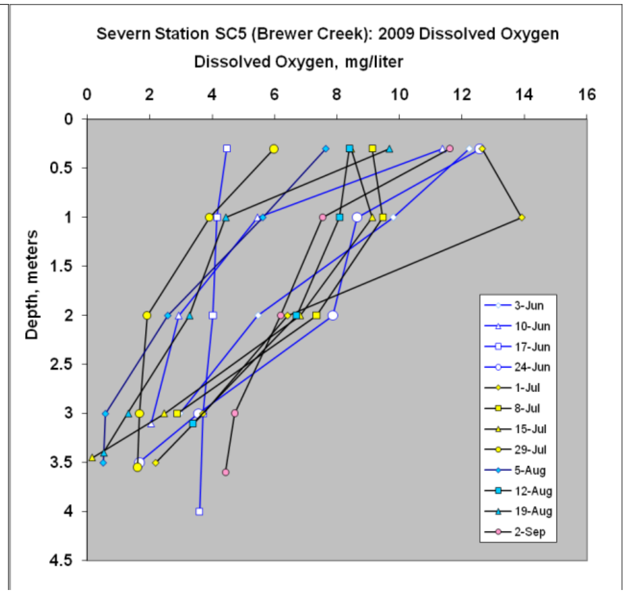

Severn Station SR6: 2009 Dissolved Oxygen
Dissolved Oxygen, mg/liter
Depth, meters
7-May
26-May
3-Jun
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
29-Jul
5-Aug
12-Aug
19-Aug
2-Sep
21-Sep

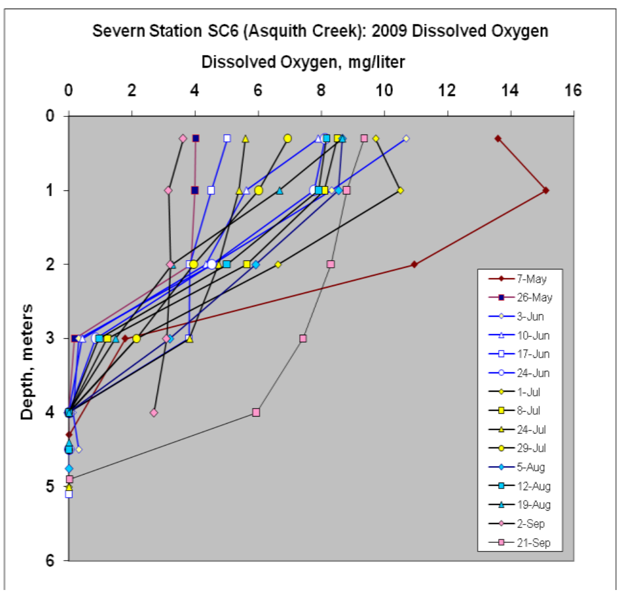

Severn Station SR7: 2009 Dissolved Oxygen
Dissolved Oxygen, mg/liter
Depth, meters
10-Jun
24-Jun
1-Jul
8-Jul
15-Jul
5-Aug
12-Aug
19-Aug
2-Sep


Severn Station SC1 (Weems Creek): 2009 Dissolved Oxygen
Dissolved Oxygen, mg/liter
Depth, meters
3-Jun
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
29-Jul
5-Aug
12-Aug
19-Aug
2-Sep


Severn Station SC3 (Saltworks Creek): 2009 Dissolved Oxygen
Dissolved Oxygen, mg/liter
Depth, meters
27-May
29-May
3-Jun
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
30-Jul
5-Aug
12-Aug
19-Aug
2-Sep
21-Sep


Severn Station SC4 (Chase Creek): 2009 Dissolved Oxygen
Dissolved Oxygen, mg/liter
Depth, meters
3-Jun
27-May
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
29-Jul
5-Aug
12-Aug
19-Aug
2-Sep


Severn Station SC5 (Brewer Creek): 2009 Dissolved Oxygen
Dissolved Oxygen, mg/liter
Depth, meters
3-Jun
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
29-Jul
5-Aug
12-Aug
19-Aug
2-Sep


Severn Station SC6 (Asquith Creek): 2009 Dissolved Oxygen
Dissolved Oxygen, mg/liter
Depth, meters
7-May
26-May
3-Jun
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
24-Jul
29-Jul
5-Aug
12-Aug
19-Aug
2-Sep
21-Sep