Severn River Monitoring Report 2011

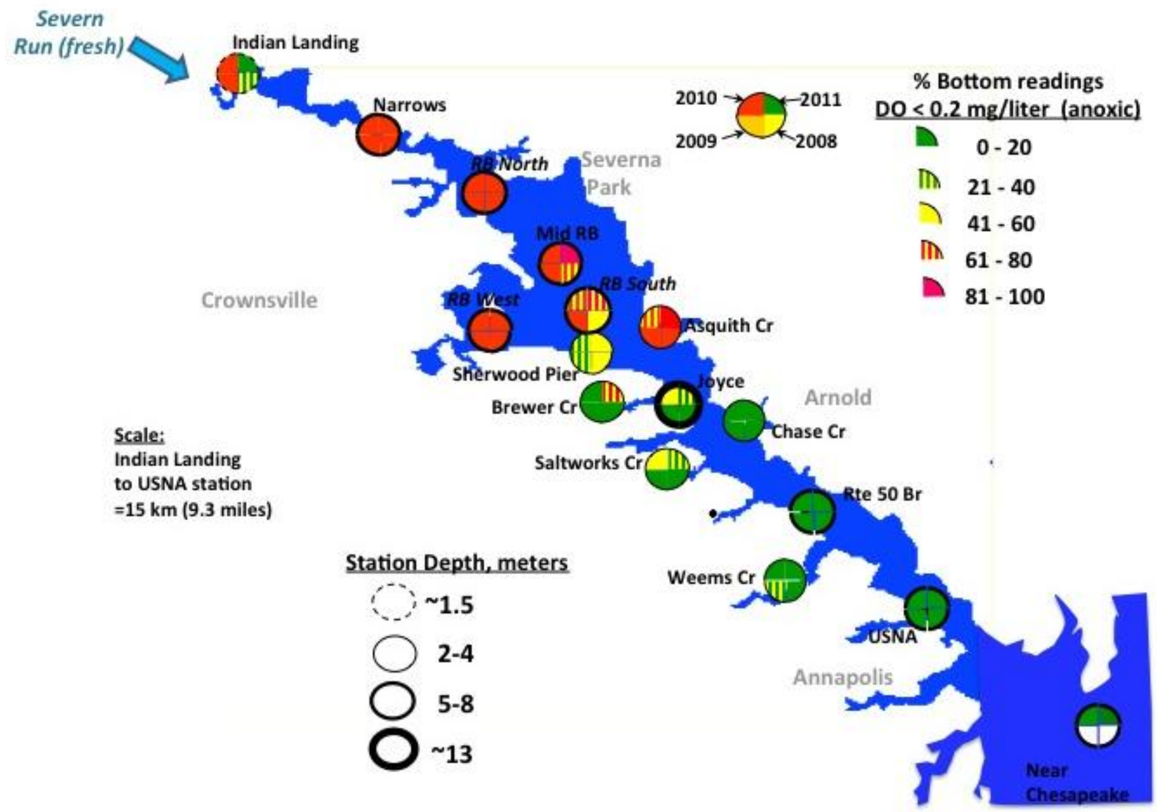
This Severn River Monitoring Report is being issued on the 10th Anniversary of the Severn Riverkeeper Program and 40th Anniversary of the Clean Water Act.

The continuing dead zones in the Severn River documented in this report are due to the continuing failure to provide adequate resources to protect and restore the Bay and its tributaries despite the promises of politicians and the President's Executive Order 13508.

Fred Kelly
The Severn Riverkeeper

Severn Riverkeeper Water Quality Monitoring Program

2011 Report



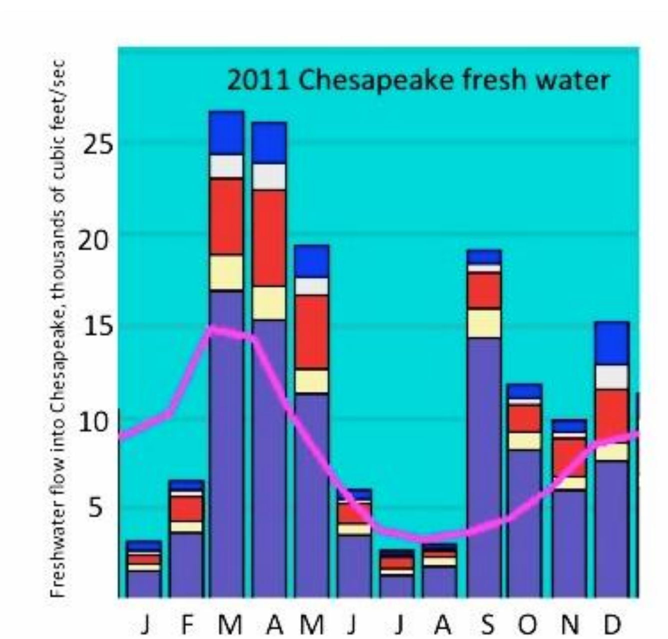
Summary

The Severn Riverkeeper Water Quality Monitoring Program conducted weekly monitoring at 16 stations throughout the tidal Severn during the summer months of 2011. This was an interesting year because of the extraordinary low salinity throughout this period, driven by high Susquehanna flows in both spring and fall. Perhaps as a consequence of these salinity conditions, the summer water column hypoxic squeeze was somewhat milder than previous years. However, 2011 saw the repeated occurrence of the Severn's most dramatic oxygen problem, the prolonged summer bottom anoxia in northern Round Bay and adjacent upper Severn. In spite of much fresher water than we had in any of our 5 previous monitoring seasons, the Severn's summer "dead zone" recurred in 2011 with a very similar pattern to that seen in previous years.

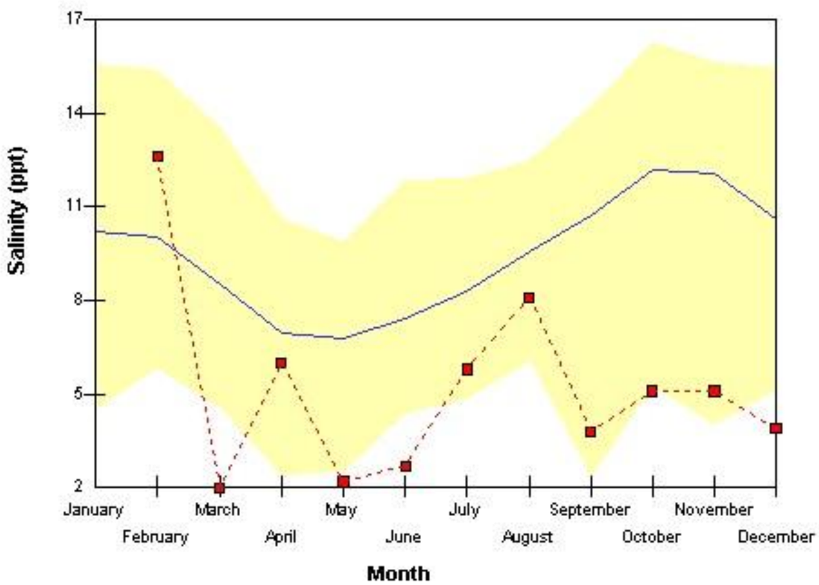
Introduction

The Severn Riverkeeper Water Quality Monitoring Program was established in 2006 to provide a more detailed assessment of the Severn's water quality than was available from existing monitoring efforts. In particular, the Maryland Department of Natural Resources Water Quality Monitoring Program has for over 20 years monitored the Severn throughout the year on a monthly schedule, measuring a number of parameters at a station near the Severn's Route 50 bridge. A major concern in the nearby portion of the Chesapeake has been the depletion of oxygen from deeper waters during the summer, and DNR data has consistently shown that the Severn suffered from a similar summer hypoxia problem. Curious to know whether the Route 50 bridge area was representative of the Severn, we established a preliminary set of monitoring stations throughout the Severn in the summer of 2006, and to our surprise found that most of the mid-upper Severn showed much more severe hypoxia and indeed, bottom anoxia, than we or DNR found at the Route 50 bridge. Our 2006 efforts led to an annual Severn Riverkeeper-sponsored monitoring program operating in the summer months, when problems with low dissolved oxygen levels are maximal, and we have continued to focus our efforts on dissolved oxygen. As shown in the included graphics, we have established 16 monitoring stations throughout the tidal Severn, from beyond the Severn entrance off Greenbury Point northwestward to near the tidal head of the Severn off Indian Landing. We have utilized monitoring instruments with probes for dissolved oxygen, salinity, and temperature, and we also measure surface water clarity. Most weeks during the 2011 summer we monitored full depth profiles at each of our 16 monitoring stations to develop a complete assessment of Severn water volume. As described below, our 2011 dissolved oxygen results were quite similar to those of the previous 5 years. This was particularly interesting in light of the dramatically lower salinity in the Severn throughout 2011, conditions that are expected to influence vertical mixing and consequent reoxygenation of bottom waters.

Salinity

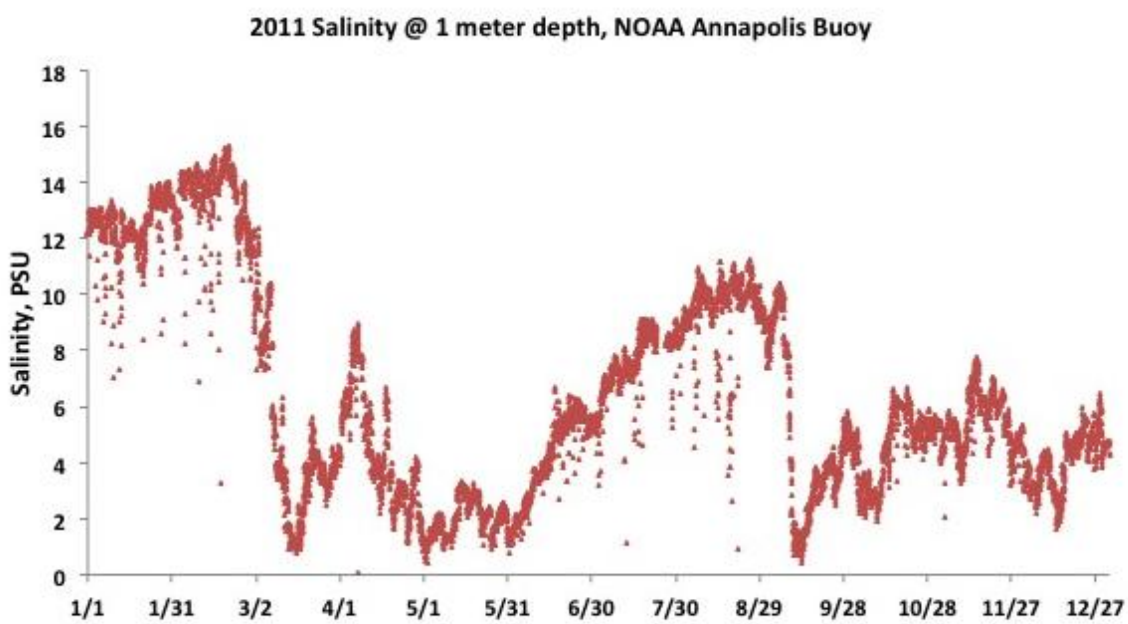


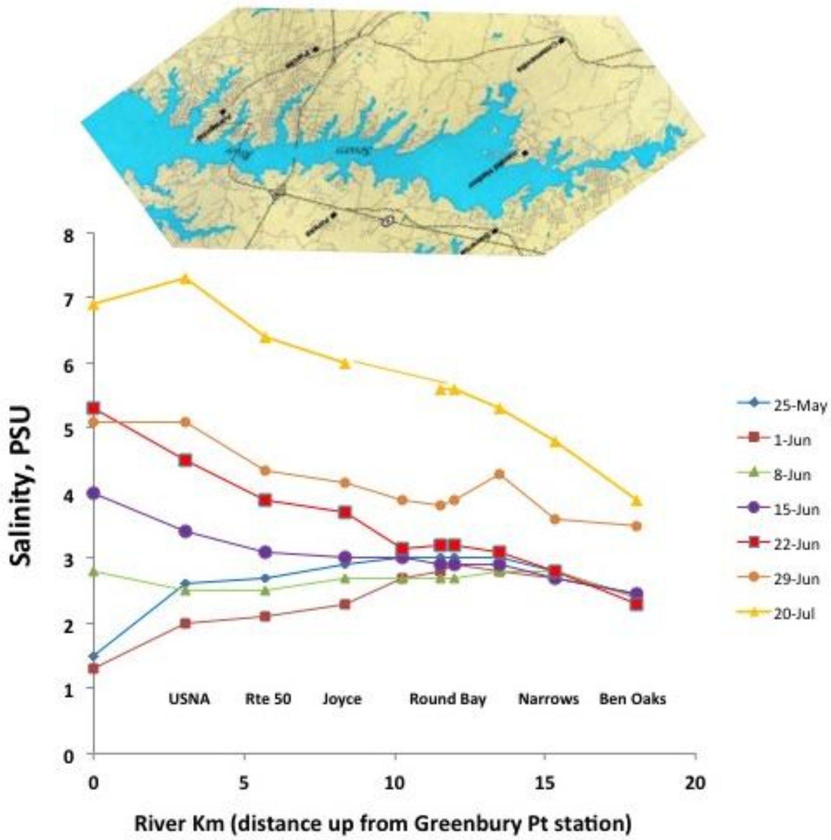
The salinity levels of estuaries reflect the mixing of fresh water from input rivers and the density-driven influx of seawater from the ocean. For a tidal tributary such as the Severn, we typically have a salinity of about 1/4 of seawater, consistent with our location in the Chesapeake about 1/4 of the way between the Susquehanna River mouth and the ocean. However there is a normal strong seasonal variation in the Chesapeake’s fresh water input, as shown in the pink line in the figure, which is the long-term average freshwater input. This USGS graph shows what an exceptional year we had in 2011, with extremely high flows in both the spring and fall. The lower blue-gray portion of the bars shows the Susquehanna contribution, with other colors representing other inputs down the bay. The mouth of the Severn exchanges water with the adjacent portion of the Chesapeake, whose dominant fresh water input is the Susquehanna.



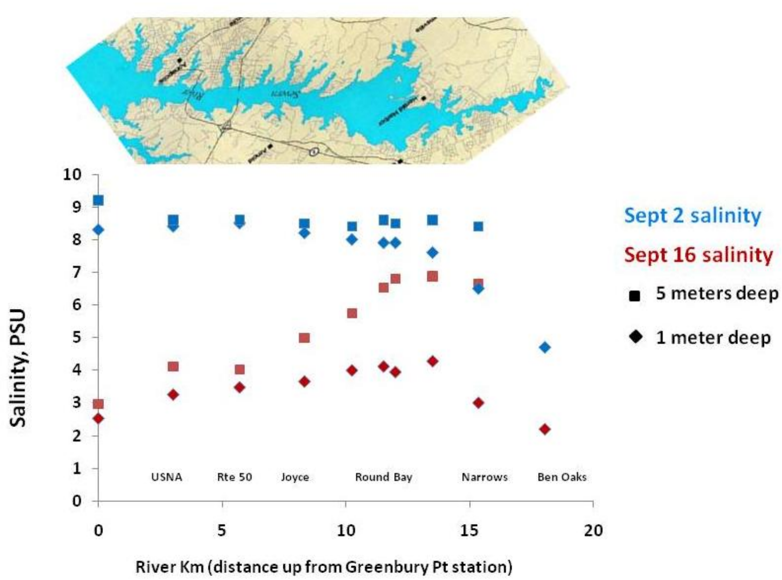
The Maryland Department of Natural Resources monitors the Severn once a month throughout the year at a single station at the Rte 50 bridge. Their 2011 surface salinity data is shown in red in the figure at the left, which also shows the 20 year average in blue, with the 20 year range in yellow. Consistent with the Susquehanna flows, the Severn in 2011 showed exceptionally low salinity starting in March and continuing through the year. Four of the 10 monthly readings starting in March are below previously recorded salinity levels.

A more detailed picture of the variation in surface salinity is available from the NOAA buoy anchored at the mouth of the Severn off Greenbury Point. Measurements are recorded every hour, with data available from a NOAA website. Individual dots below the line show rain events that are quickly neutralized by mixing with underlying saltier water. There is an obvious correlation between this data and the Route 50 bridge DNR data above.





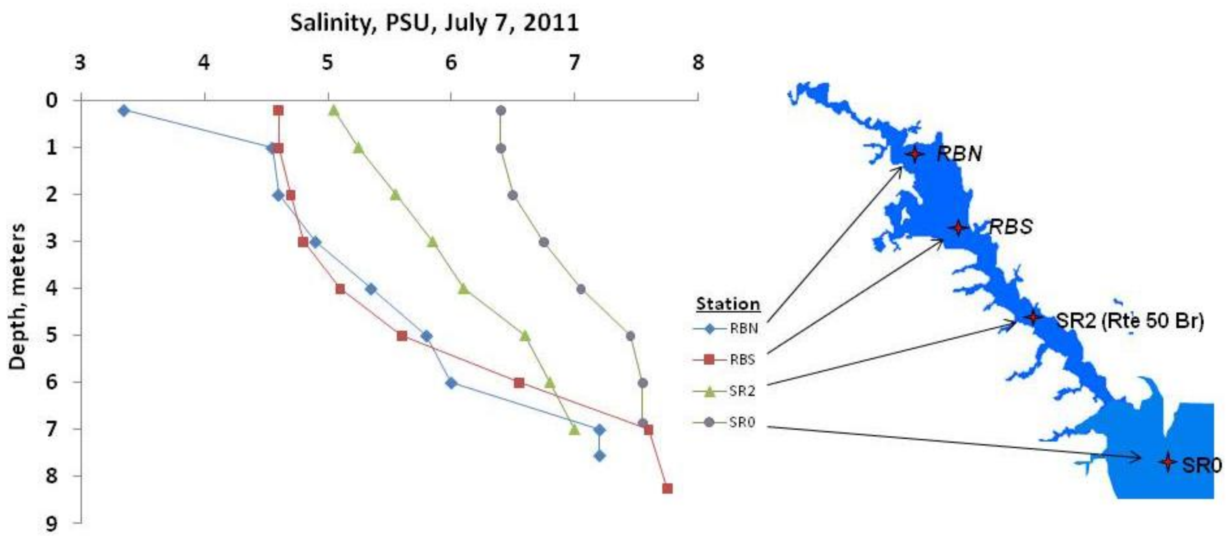
This figure shows the surface salinity distribution within the Severn, based on Riverkeeper monitoring data for the first half of the summer. Our data from May 25 and June 1 show the lowest salinity at the mouth of the Severn, gradually increasing to Round Bay, and then falling again due to local fresh water input from Severn Run. This pattern tends to be seen every spring. As the Susquehanna flows subside, the Severn's salinity increases as the nearby portion of the Bay gets saltier. At the end of July, Severn Run's fresh water entering the head of the Severn gave rise to a relatively smooth salinity gradient down to Annapolis where saltier Chesapeake water dominated.



The Severn's fall 2011 fresh-water surge was attributable to hurricane Irene (BWI recorded 4.7 inches rainfall Aug 27-28) and tropical storm Lee (BWI recorded 8.5 inches Sept 5-9). Hurricane Irene led to minor increases in Susquehanna flow, but tropical storm Lee caused a huge boost in that flow. The former led to minor changes in the Severn's salinity, while the latter dramatically lowered salinity levels, as shown in the figure. Within two weeks, the salinity at the mouth of the

Severn dropped by a factor of three at both depths shown, and the surface salinity in Round Bay dropped by a factor of two. However, the deeper portion of Round Bay retained most of the saltier water from before the storm influx. On September 30, the 5m salinity throughout Round Bay was around 4 psu, indicating that salty water flowed out into the Chesapeake during those two weeks. These data demonstrate the influence of the Susquehanna in controlling Severn salinity up to and including Round Bay. This extraordinary rain event resulted in fresh water (<0.5 psu) near the surface at our uppermost tidal station at Indian Landing, but the this fresh water input did not appear to drive the salinity change in most of the Severn.

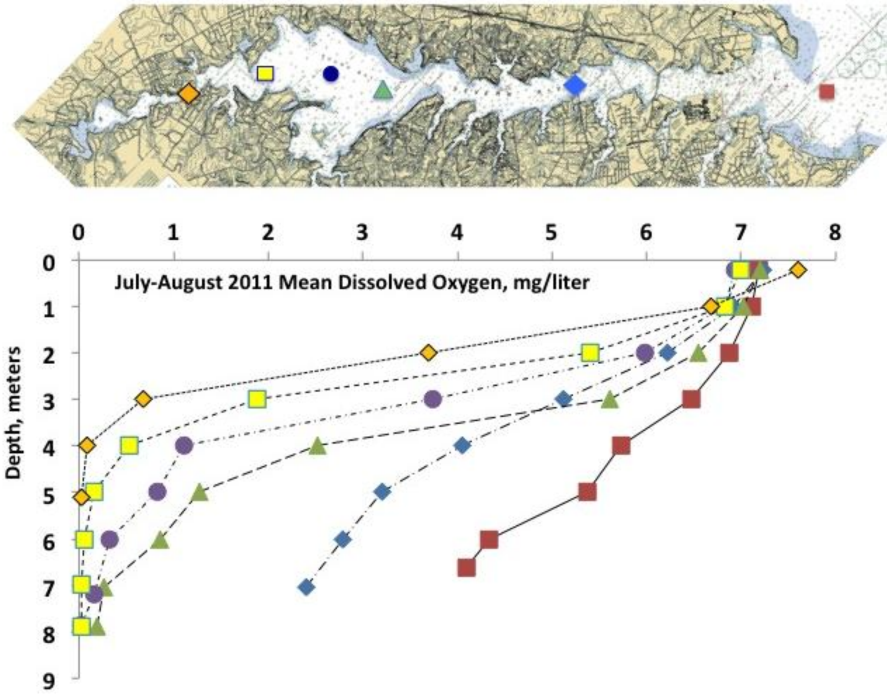
Vertical salinity profiles are important because salinity is a dominant factor determining density, and density layering in turn retards vertical mixing that is required to provide oxygen throughout the water column. As described in the next section and consistent with our previous years of Severn monitoring, by July the bottom of Round Bay had become anoxic, i.e., devoid of oxygen. This reflects a lack of vertical mixing due to a combination of density layering that resists mixing, and weak local forces



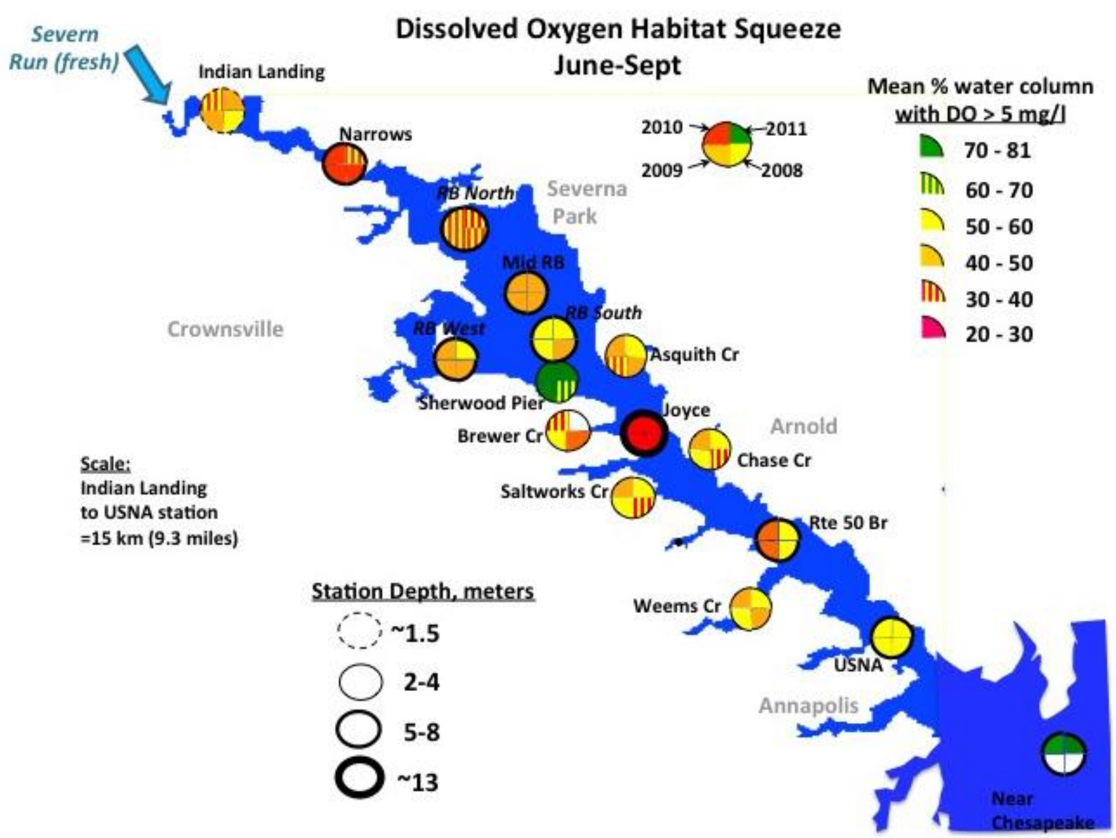
promoting mixing. The figure above shows that the Round Bay stations have steeper July vertical salinity profiles than the better oxygenated lower Severn stations. Much of this is attributable to Severn Run's fresh water depressing near-surface salinity.

Dissolved oxygen

In 2006, the first year of our monitoring program, we were surprised to find that the Severn suffered from summer low oxygen problems that were more severe than previously reported, and also more severe than other Chesapeake tributaries. In succeeding years including 2011, our monitoring program has focussed on dissolved oxygen measurements to see whether 2006 was an unusual year. The results show that the Severn suffers from summertime oxygen depletion in two different habitats: 1) the general estuarine water column utilized by free swimming fish; 2) the benthic habitat at the bottom, utilized by worms, clams, and amphipods that provide an important food source for fish and crabs.



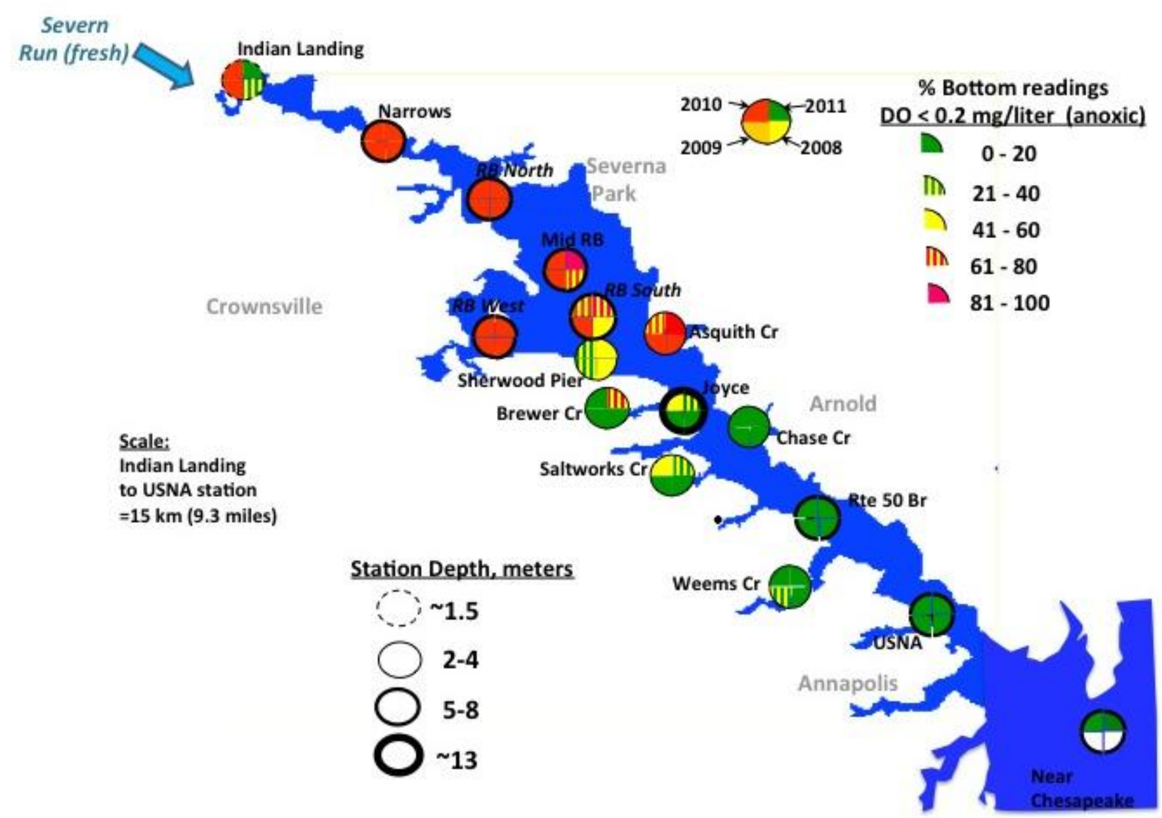
Hypoxia in the water column creates a habitat squeeze for fish, depriving them of the use of the lower part of the water column that is most impacted. A common dissolved oxygen threshold for fish is 5 mg/liter, which means that such fish will not normally venture into water with lower oxygen levels. Since the main source of oxygen is the atmosphere, this means that these fish will be restricted to the upper portion of the water column. The extent of this hypoxic habit squeeze can be calculated from the oxygen depth profiles seen in the above figure, which plots the mean dissolved oxygen concentrations for July and August vs depth at each of six stations. It clearly shows dramatic differences between the upper Severn/Round Bay profiles and those at stations close to or in the Chesapeake. A simple calculation of the percent of the water column with DO>5mg/liter provides a quantitative measure of the hypoxic



habitat squeeze at each station, and our results for the past four summers are summarized in the figure on the previous page.

It is apparent from the above figure that during the summer, for most of the Severn, fish requiring 5 mg/liter oxygen will be restricted to the top half or third of the water column. This hypoxic squeeze generally becomes more severe as one moves up the Severn, and is found in both the Severn mainstem and in the creeks. It is less pronounced in the near Chesapeake, and near the shore of Round Bay, where better vertical mixing is expected. The deep Severn “holes” such as our station at Joyce show oxygenated water only in the first few meters under the surface, with their greater depth giving them a low percentage of acceptable oxygenation. Close inspection of this figure reveals that the hypoxic squeeze was generally more moderate in 2011 than in 2010. A plausible explanation for this is that the fresher water in 2011 did not allow the stable density layering seen in 2010, when the Severn experienced greater overall salinity and hence steeper density gradients due to local fresh water inputs.

As discussed above, oxygen often limits life in the benthic habitat, the bottom mud inhabited by clams and worms. These invertebrate organisms are adapted to live with lower oxygen levels than free-swimming fish, and 1 mg/liter is sometimes considered as a threshold acceptable oxygen level for these organisms. True biological anoxia is considered to begin at 0.2 mg/liter, where multicellular organisms cannot survive for long. Our previous 5 years of Severn monitoring revealed the regular formation of a truly anoxic “dead zone” (dissolved oxygen < 0.2 mg/liter) at the bottom of the northern Severn and northern Round Bay by the beginning of July. As shown in the figure below, our 2011 results show that such anoxia formed again by July in the same Severn region where it had previously occurred.

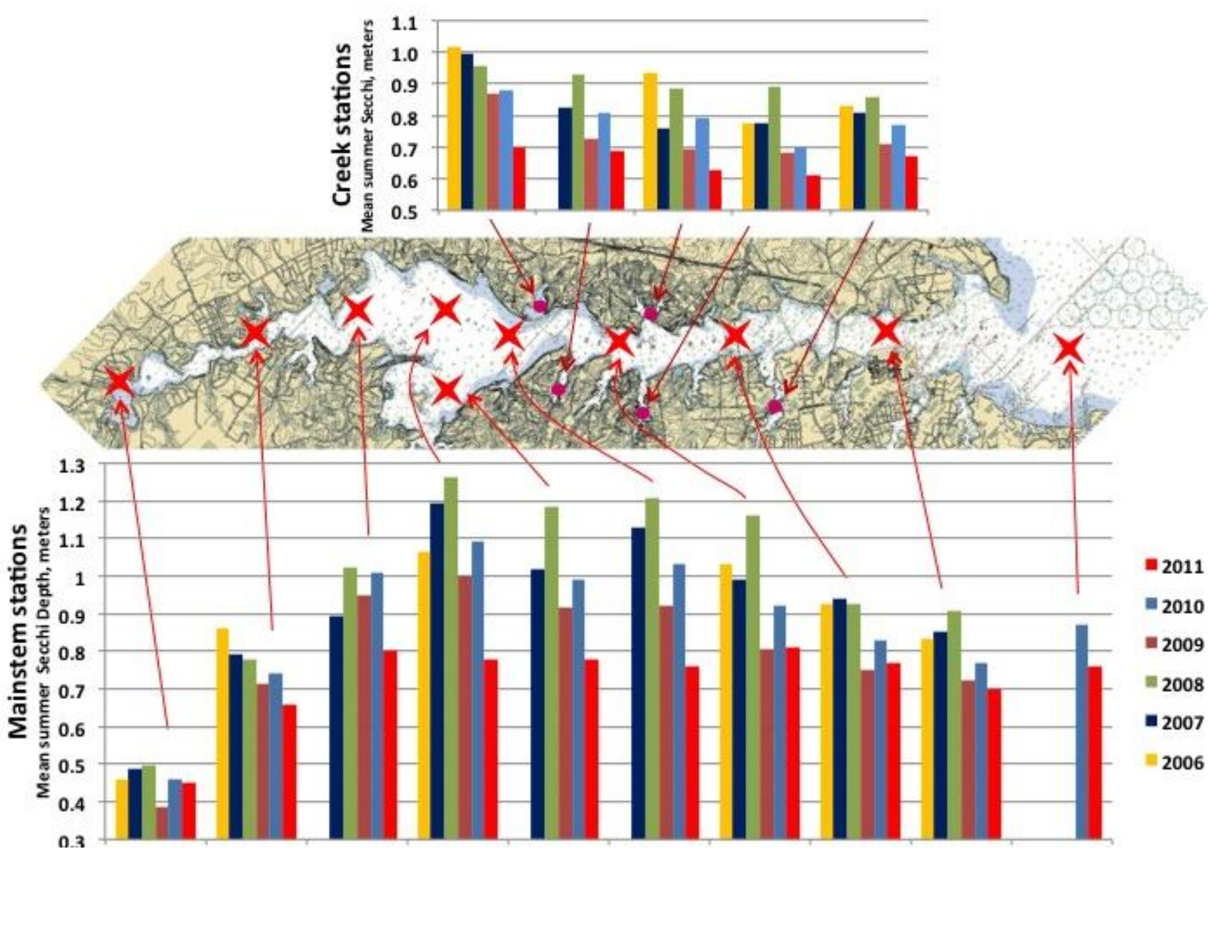


The fresher water that may have produced less hypoxic squeeze in the overall water column did not seem to lessen the tendency towards bottom anoxia.

Our 2011 monitoring again confirmed the presence of hydrogen sulfide in near-bottom water samples brought up from stations when our meters showed anoxia. Hydrogen sulfide is a product of anaerobic bacterial metabolism and this odoriferous gas is unstable in the presence of oxygen. Thus its presence indicates a long term anoxic condition. In 2011 we were also able to deploy a new monitoring instrument with an oxygen sensor based on oxygen's ability to quench luminescence as opposed to the traditional Clark electrode in our regularly used meters. The new meter confirmed anoxia in dozens of side-by-side trials with our old meters, as well as giving excellent correlations with oxygen levels generally. In summary, 2011 gave us further confidence in our previous findings of regular Severn summer bottom anoxia, confirming its formation even in a year when the hypoxic squeeze in the overall water column was somewhat more moderate than previous years.

Water Clarity

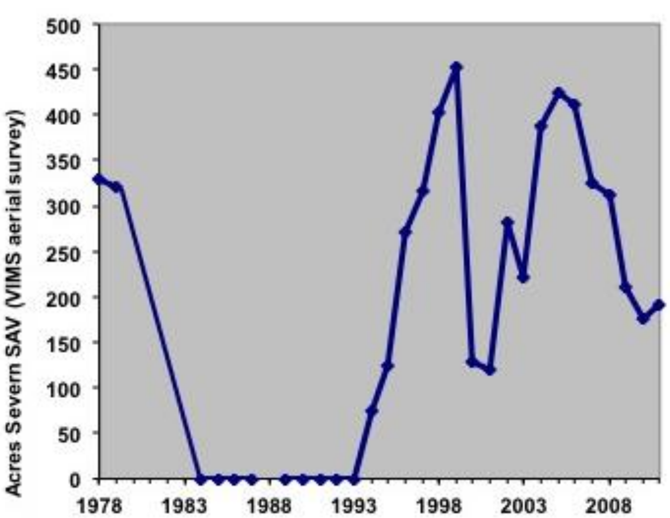
Water clarity in estuaries is compromised by two largely independent factors: 1) Sediment entering from the watershed or resuspended from the bottom; 2) phytoplankton, which are free-swimming photosynthetic microscopic organisms whose growth is fostered by nitrogen- and phosphorous-based nutrients. Unfortunately, using readily-available instruments it is not easy to separate these two factors, and most Chesapeake monitoring groups including ours use the centuries-old simple Secchi disk to assess surface water clarity. In 2011, our measurements showed significantly lower Severn summer



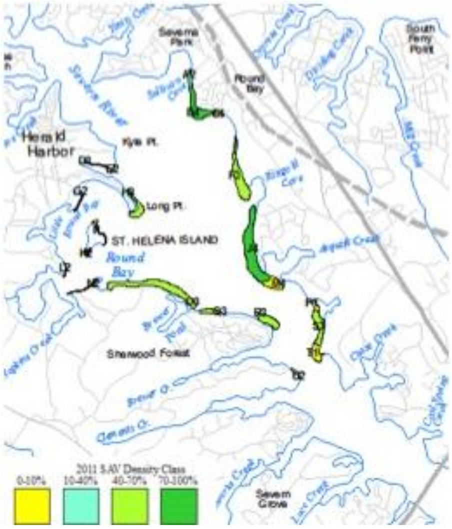
water clarity than in the previous years of our monitoring program. This result is not surprising in light of the increased fresh water input carrying both sediment and nutrients. It is tempting to speculate that the major cause of lower Severn water clarity in 2011 was increased nutrients, because the local watershed did not experience higher-than-normal rainfall until August, while (as shown in the first section) the Susquehanna flows were extraordinarily high in the spring. While most Susquehanna sediment settles before reaching the mouth of the Severn, the spring nutrients from the Susquehanna enter the Severn with the fresh water during and the early season. With the acquisition of our new monitoring meter with chlorophyll sensors, we will be able to obtain relative phytoplankton densities in 2012, and we hope to gain some insights into the sediment vs nutrients issue.

Two major east coast rain events in 2011 were hurricane Irene, dropping 4.7 inches of rain at BWI on August 27-28, and the more significant tropical storm Lee, dropping 8.5 inches from September 5-9. The latter event unleashed a massive influx of fresh water and sediment from the Susquehanna as well as smaller impacts from local watersheds. The NASA satellite image from September 11 shows Susquehanna sediment covering the Chesapeake mainstem down to the Patuxent, but close inspection shows sediment only in the Annapolis section of the Severn with local intrusion in the upper Severn. This image is consistent with our Severn observations, where on September 16 we found a Secchi reading of 0.3 meters at our near Chesapeake station (SR0), but normal Secchi readings of ~0.8 at our lower Severn stations. Two weeks later the water clarity was at typical levels at all stations, consistent with the settling of the storm-related sediment so that it was not observed from the surface. Thus, even though tropical storm Lee had a major impact on Severn salinity, its sediment impact was largely restricted to local events, particularly Severn Run's loading of the upper Severn.

Submerged aquatic vegetation



Submerged aquatic grasses grow in shallow water at the edges of the Chesapeake, and they provide an important habitat for juvenile fish of several species. Their growth and survival is impacted not only by water clarity, but also by excess nutrients that foster the growth of epiphytic algae blocking light penetration to the leaves of the grasses. The Virginia Institute of Marine Science has conducted excellent bay-wide SAV monitoring



by aerial surveillance, with their estimate of Severn SAV acreage over the last 33 years shown above. It is clear that the growth of these grasses is variable, but the most striking feature of the Severn's SAV is that it recovered substantially from zero starting in 1994, and the Severn has the best SAV of any the western shore Chesapeake tributaries. Although Severn SAV declined from 2005 through 2010, 2011 saw a slight increase in acreage. The figure at the left is the 2011 VIMS mapping of Severn SAV beds, showing that Round Bay is the heart of local SAV growth. Much of the SAV loss over the last six years has occurred along the shores below Round Bay down to the Route 50 Bridge, although the Round Bay beds have also become thinner. Given the Severn's decidedly lower water clarity in 2011, a decline in SAV acreage might have expected. One interpretation of the observed slight increase in 2011 SAV might be that water clarity is not limiting SAV growth in the Severn. Unfortunately, it has proven difficult to identify the critical factors controlling Chesapeake SAV growth, and there is no clear reason why the Severn has so much better SAV than other neighboring tributaries.

Conclusions

The Severn's year 2011 was unusual for its low salinity, driven by high fresh water inputs in both spring and early fall. As a result, the Severn experienced the expected lowering of its water clarity, due to increased sediment and nutrient-driven phytoplankton growth. Our monitoring has principally focused on dissolved oxygen levels, both in the overall water column where we have found a pronounced hypoxic habitat squeeze in the past, and at the bottom, where it impacts benthic organisms. We found the hypoxic habitat squeeze to be somewhat less severe than in recent years, presumably due to weaker stabilization of the water column by density gradients. What was most interesting about 2011 was that in spite of the diminished hypoxic squeeze, the extent and pattern of bottom anoxia we had described in the previous 5 years of monitoring was not significantly altered by the lower salinity. Our anoxic oxygen measurements were confirmed by a new independent oxygen sensor, and we confirmed our previous observations of hydrogen sulfide in bottom waters with anoxic meter readings. Thus we are ever more confident of our earlier reports of an annual Severn summer "dead zone", which appear to be among the shallowest estuarine dead zones reported anywhere.

Acknowledgements

Once again, Severn Riverkeeper Fred Kelly has made this monitoring program possible by providing the boat, monitoring instruments, supplies, summer interns, and continual encouragement. Once again in 2011 we had the assistance of our two veteran interns, Nate Frankoff and Aaron Canale, whose dedication and skills were vital to our weekly monitoring trips. In addition, we had the regular assistance of Anna and Bethany Baldwin, who have become skilled at carrying out our rigorous quantitative water quality monitoring approach. Our monitoring program has greatly benefited from the regular participation of Mike Robinson and Dr. Bill Boettinger, both of whom provided scientific

insights into our understanding of the Severn's degraded habitats. As in previous years, I thank Dr. Andrew Muller of the Oceanography Department of the US Naval Academy, and South Riverkeeper Diana Muller for numerous helpful discussions.

In addition to data from our Severn Riverkeeper Monitoring Program, this report has utilized relevant data gathered by other monitoring programs. We thank the Maryland DNR for continuing excellent monitoring data at the Severn Route 50 Bridge station, NOAA for its intensive buoy data at the mouth of the Severn, and the Virginia Institute of Marine Science for mapping the Severn SAV beds by aerial surveillance.

Water quality monitoring has always had to struggle in the continuing budget battles endured by government agencies, and has generally been ignored by private funders. Our program is possible due to the generous support from the following donors: Reliable Contracting, Rathmann Family Foundation, Campbell Foundation, Severn 1000, Elm Street Developers, ERM Foundation, Monticello Group, Racoosin Family Foundation, BB&T, Morrell Family, John Bruno, Doug Burkhardt, Baldwin Builders, M&T Bank, Severn Savings Bank, Decker Family, Port Tack Liquors, Sandy Spring Bank, and Bonnell Cove Foundation. We thank these donors for their continuing support.

Appendix

Why no Severn Report Card?

In recent years several Chesapeake organizations have adopted the traditional school report card format for summarizing the Chesapeake's water quality data for public presentation. Given major public and private campaigns to restore the Bay to its former environmental health, interested citizens demand an accounting of whether progress is being made, and how their local waters compare to others . Because there are a number of measures of the health of an estuary like the Chesapeake, and because different interests have different goals, a report card giving individual grades to different health criteria was agreed to be one means of keeping the public informed of year-to-year progress. Several groups currently issue such annual Chesapeake report cards, which have succeeded in attracting press coverage in recent years, especially the overall average grade.

In addition to Bay-wide annual health report cards, various regional groups focused on individual Chesapeake tributaries have adopted the report card format for public presentation of local monitoring data. In some cases these groups have sponsored local monitoring efforts to provide data in addition to that available from state and Chesapeake Bay Program monitoring programs. There has been some effort to compare the health of tributaries based on available monitoring data.

The Severn Riverkeeper Monitoring Program has not adopted the report card format because the limited available data are not adequate for meaningful comparisons beyond what has been discussed in this report. Our monitoring program has been focused on dissolved oxygen from its outset because we felt we had the resources to develop a meaningful picture of summer hypoxia issues throughout the

Severn. We found in our first year of monitoring that different regions of the Severn were dramatically different with regard to bottom anoxia, and specifically that conditions in the lower Severn near Annapolis were not representative of the Severn as a whole. Unfortunately, the excellent recent Severn water quality monitoring data gathered by the Maryland Department of Natural Resources has been exclusively gathered from its station at the Route 50 Bridge near Annapolis. We also monitor this station, and our results are entirely compatible with theirs. However, based on our dissolved oxygen results, we are reluctant to accept Route 50 Bridge DNR data on other parameters such as nutrients as representative of the Severn as a whole. We are particularly skeptical of modeling approaches used by some groups that use the Route 50 water quality data to extrapolate "up" the Severn into areas like Round Bay.

Interestingly, our most surprising finding over the six years of Severn monitoring has been the regular summer bottom anoxia in Round Bay and upper Severn. This "dead zone" is incompatible with survival of benthic life that is an important base of the estuarine food chain. The Chesapeake Bay Program's benthic monitoring program uses a "benthic index of biotic integrity" (BIBI) to assess benthic habitat health by gathering bottom samples and quantitating all organisms greater than .5 mm in size. These labor-intensive measurements result in a quantitative benthic health index reflecting the species composition and abundance of these organisms. Sampling locations are chosen by a statistical model, and have recently included several Severn locations each summer. Not surprisingly, bottom samples from Severn locations where our program has found summer anoxia have shown no living organisms greater than .5mm. However the limited sampling of the Severn by this program has not flagged the Severn as being unusual among Chesapeake tributaries.

Based on the above examples and others, we do not believe we have enough data to make meaningful statements about the Severn's biological health beyond what is discussed in this report. The one Severn biological health parameter that can be meaningfully assessed for temporal trends and compared to other tributaries is SAV abundance. In comparison to neighboring tributaries, the Severn's SAV is healthy (in spite of recent declines, high grades on a report card using Bay Program criteria). It is ironic that not far from these surviving SAV beds along the shallows of Round Bay, the Severn's bottom appears to be unusually unhealthy (off scale low on any grading scheme). Should these findings be averaged into some kind of headline-grabbing report card grade? We think the public deserves a more meaningful account of Severn monitoring results.