SEVERNSTAT REPORT
2006

Introduction

The Severn River is the Capital River of the State of Maryland and was designated as a Maryland Scenic River in 1971. Despite this designation, the **Chesapeake 2000 Agreement**, the Chesapeake Bay Program, the importance of the Severn as the Capital River of the State of Maryland, and the best efforts of concerned citizens, the Severn continues to deteriorate at a rapid pace. Due to unabated pollution, the Severn is now designated as an “impaired” body of water by the Environmental Protection Agency.

On February 14th, Governor Martin O’Malley announced his **BayStat** Program to address the continuing deterioration of the Chesapeake Bay and its tributaries. **BayStat** is designed to monitor the health of the Bay and, most importantly, the effectiveness of the state agencies in protecting and restoring the Bay and its tributaries.

The Governor’s Transition Team on the Environment and Natural Resources reported to the Governor that because state environmental agencies “are currently weakened by structural fiscal deficiencies and difficulties in maintaining an experienced professional workforce”, the state is headed toward an “environmental train wreck”.

To bolster the Governor’s **BayStat** Program and avoid a “train wreck” on the Severn River, the Severn Riverkeeper and concerned citizens have established **SevernStat.** This program monitors the health of the Severn River and provides a report to the Governor with recommendations for protecting and restoring the Severn. The **BayStat Report** is provided in two parts, a summary of the monitoring results and recommendations for action by the Governor.

Part One- Summary of the 2006 Severn River Monitoring Report:

Dissolved Oxygen is the prime indicator of the health of any body of water. The **2006 Severn River Monitoring Report** (attached hereto) contains dissolved oxygen data from 18 monitoring stations collected from June through September of 2006.

The level of professionalism that the Transition Team emphasized is assured in this report by the stature of the author, Dr. Pierre Henkart. Dr. Henkart is the Chief of the Lymphocyte Cytotoxicity Section of the Immunology Branch of the National Cancer Institute at the National Institute of Health. He has a doctorate from Harvard in Biochemistry and Molecular Biology and conducted his post-doctoral research in Marine Biochemistry at the Scripps Institution of Oceanography.

The most striking finding of the report is that the bottom of much of Round Bay in the Severn was either severely hypoxic or anoxic throughout most of the summer. This finding is alarming because "dead zones" have been described in the deep channel of the Chesapeake's mainstem, but not in the Chesapeake tributaries before now.

Neither oysters, crabs, nor fish of any kind can survive or reproduce in "dead zones" or even extremely low oxygen areas such as discovered in our 2006 monitoring of the Severn. Decisive immediate action is imperative and the two most important are listed below in order of importance.

Part Two- Recommendations for Immediate Action:

1. **That the Governor immediately write to County Executive John Leopold and the Anne Arundel County Council to affirm his promise to provide matching funds if Anne Arundel County adopts a Stormwater Utility Ordinance.**

The single most important act to protect the Severn River is the creation of a Stormwater Utility Fund. Without it, the Severn and the other tributaries in Anne Arundel County will continue to deteriorate at an alarming rate.

Every time it rains, large amounts of oxygen robbing stormwater runs into the Severn and other tributaries of Anne Arundel County. The only way to significantly reduce this stormwater will be to retrofit the failing stormwater controls in older communities along the river.

The cost of such retrofitting has been estimated by the Anne Arundel County Chamber of Commerce and others to be between $500 to $750

Million. Such large amounts can only be obtained through a dedicated utility fund. The monies would then be used by the Anne Arundel County Department of Public Works to retrofit the older communities.

A letter to County Executive Leopold and the County Council will simply affirm the Governor's previous promise "to develop a state matching fund program that will match dollar for dollar up to some ceiling any local dedicated funds that are raised for stormwater retrofits".

Such a letter should encourage Anne Arundel County to meet its responsibility to protect its own waterways, particularly when it would stand to lose important state funding by failing to act.

2. That the Governor direct his new Secretary of the Maryland Department of the Environment to change policy to require "living shorelines" for shoreline erosion control unless the applicant can provide proof from a certified engineer that only traditional riprap is feasible for the specific location.

The Severn River and other Maryland tributaries are fast losing their critical land/water edge to shoreline hardening. Traditional destructive riprap is being approved by the Maryland Department of the Environment when it should not.

The shoreline edge, where land meets water, is the incubator and nursery for all life in the Bay and its tributaries. The scientific community has long known and reported that "living shorelines" can both protect the shoreline from erosion and preserve those areas critical to life in the Bay. Traditional destructive riprap is inappropriate and unnecessary in most instances. Inexplicably, the Maryland Department of the Environment continues to approve their use despite the scientific evidence.

Shoreline property owners have an absolute right to protect their shoreline from erosion. MDE has a legislative mandate to regulate such activities, so that they have the least environmental impact. Both can be accommodated, if MDE simply requires that shoreline property owners install "living shorelines" unless site engineering requires otherwise.

The Severn River and the other Maryland tributaries of the Bay cannot afford to lose any more of their critical incubators and nurseries of life. Protective action by MDE is long overdue.

2006 Severn Monitoring Project

Pierre Henkart, PhD

SEVERN RIVERKEEPER PROGRAM

Arlington Echo Outdoor Education Center

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The Severn Riverkeeper Program
Is dedicated to Protecting and
Restoring the Severn River.

The Severn River Monitoring Project
Measures the health of the River
And is sponsored by
<u>The Severn River 1000 Club</u>:

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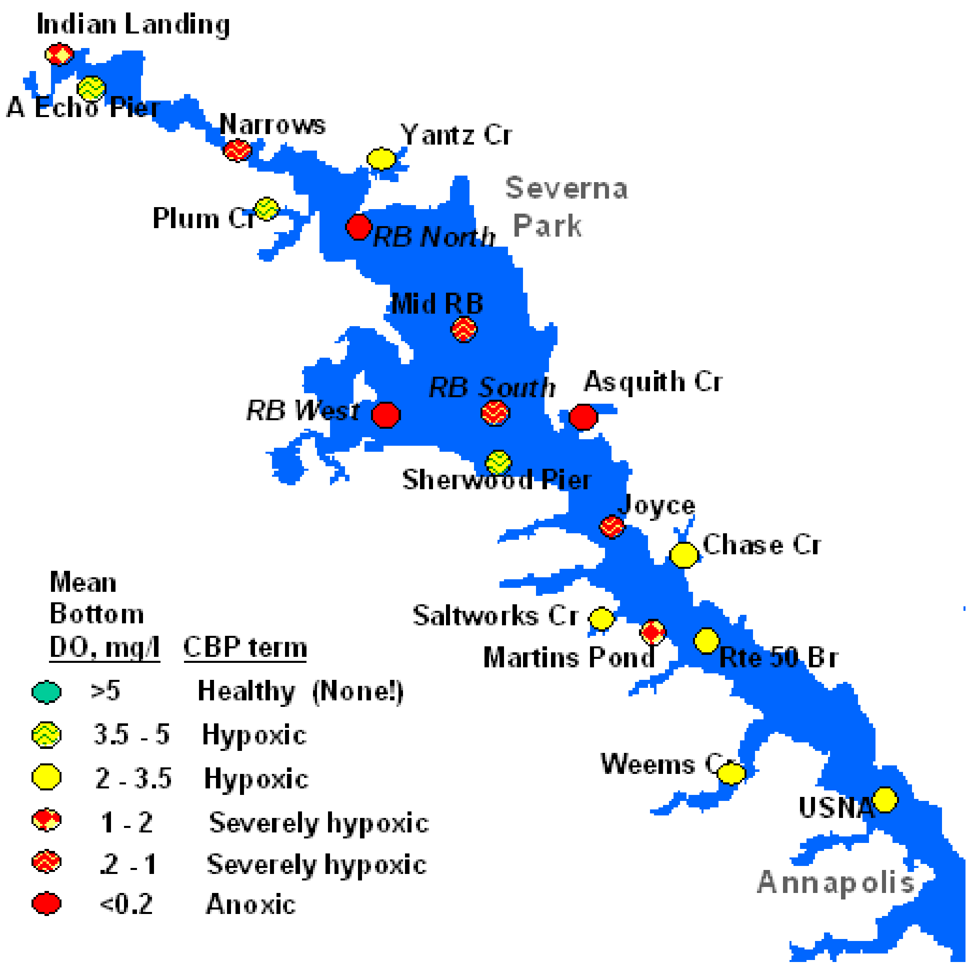
To join the **Severn River 1000 Club** call (410)849-8540
Or write to: The Severn Riverkeeper Program
329 Riverview Trail
Annapolis, MD 21401

2006 Severn Monitoring Project

Summary

This report describes a water quality study showing that during the summer of 2006, persistent severe oxygen depletion occurred near the bottom in a substantial section of the Severn River. The occurrence of such "dead zones" has not previously been described in relatively shallow Chesapeake tributaries. In order to assess summer dissolved oxygen levels in the Severn River, a collaborative monitoring project was carried out by teams from the Severn Riverkeeper and Arlington Echo Outdoor Education Center, beginning in June 2006 and extending into the fall of 2006. Every 1-2 weeks, monitoring was carried out at a series of 18 fixed stations, from near the Chesapeake off the US Naval Academy, throughout the Severn, to the head of the tidal Severn at Indian Landing. These stations were located throughout the Severn mainstem, Round Bay, and in representative creeks on both shores of the Severn. Using electronic meters with cable-suspended probes measuring dissolved oxygen, salinity, and temperature, values for these parameters were obtained from the surface to the bottom, every 1-2 meters, providing multiple depth profiles for each station visit. Over the course of the summer, significant results were obtained for both salinity and dissolved oxygen measurements.

Salinity measurements from monitoring after the 5-10" rain storm of June 25-27 showed the expected decrease in salinity throughout the Severn. However, although fresh water was detected at Indian Landing right after the storm, the major source of fresh water entered the Severn from the Chesapeake Bay rather than from the Severn watershed. This was shown by data from a week after the storm, when the Severn's salinity decreased progressively from its mouth at Annapolis through our station in the Narrows above Round Bay. Measurements over the next week showed the replacement of all of the older saltier water with fresher water from the Bay. As the dry summer continued into August, saltier water entered the Severn along the bottom from the Chesapeake. These results show that water flows in the Severn as a whole are dominated by density-driven exchange from the adjoining Chesapeake. Thus, from the point of water flow, the Severn should be regarded more as a long narrow bay of the Chesapeake than as a river.



Dissolved oxygen (DO) levels near the Severn's surface generally showed healthy, near-atmosphere saturated levels as expected. However, throughout the summer, DO levels near the bottom all averaged below the "healthy" water threshold of 5 mg/l, from "moderately hypoxic" (2-5 mg/l) down to the anoxic levels (<0.2 mg/l) characteristic of "dead zones". These results are depicted by the color coded circles on the map above. Stations in Asquith Creek and throughout most of Round Bay showed the lowest levels, which were at or close to anoxic. Anoxia at these stations was confirmed by easily detectable levels of hydrogen sulfide, a product of anaerobic bacterial metabolism. Stations nearer the Severn's mouth, and those in most Severn creeks, showed milder bottom hypoxia (2-5 mg/l). Our dissolved oxygen results explain previous studies documenting degradation of the benthic habitat in the Severn, which is most pronounced in and above Round Bay.

Monitoring Program Description

Background

In recent years, hypoxia (low levels of dissolved oxygen) has become recognized as the major water quality problem for the Chesapeake Bay, and has negatively impacted other fresh and marine water bodies world-wide. Hypoxia is known to develop as a result of nutrient-fueled overgrowth of phytoplankton, which end up sinking to the bottom and being consumed by oxygen-depleting decay bacteria. Estuaries are particularly vulnerable to hypoxia because of the restricted vertical mixing of bottom salty water with fresher, oxygen-rich surface water.

Extensive monitoring by the Chesapeake Bay Program has shown the development of large volumes of hypoxic water in the deep portions of the Chesapeake every summer, with the levels of hypoxia correlating with the annual input of nutrients. Efforts to monitor dissolved oxygen in tributaries such as the Severn have been limited, and it is generally assumed that hypoxia is much less likely in these shallower waters with greater contact with atmospheric oxygen. However, data from the DNR Severn monitoring station at the Rte 50 Bridge shows consistent summer hypoxia near the bottom (25-foot deep).

Additional DNR monitoring at the head of the tidal Severn for two summers showed hypoxia even in shallow water, at a one meter depth. Another reason for concern is that the Severn's traditionally good yellow perch population has declined in recent years in spite of stocking efforts by the DNR Fisheries Division, and a detailed study of this problem has laid much of the blame to hypoxia in the fresher Severn creeks.

Finally, preliminary monitoring of the Severn's Saltworks Creek by Pierre Henkart in the summer of 2004 revealed bottom hypoxia in depths as shallow as 6 feet. Taken together, there was clear evidence of summer hypoxia in the Severn, but without a more complete and wide-ranging monitoring program, the extent of the problem was difficult to assess. In the spring of 2006, the Severn Riverkeeper Program and the Arlington Echo Outdoor Education Center collaboratively developed this Monitoring Project to provide a more detailed picture of the Severn's water quality, with a major focus on dissolved oxygen levels.

Strategy and Resources

In order to characterize the Severn's hypoxia during the summer of 2006, the Monitoring Project monitored the Severn at multiple stations from Annapolis to its tidal head at Indian Landing every 1-2 weeks. This Project was headed by Pierre Henkart, a semi-retired NIH scientist with a bachelor's degree in chemistry, a PhD in biochemistry and molecular biology, postdoctoral research in marine biochemistry, and many years of activity on the Chesapeake.

The Project was based on a collaboration between the Severn Riverkeeper Program and Arlington Echo Outdoor Education Center, allowing the full length of the river to be monitored using the Riverkeeper's boat and personnel based in Saltworks Creek, and boats and personnel based at Arlington Echo on the upper Severn near Indian Landing.

Allison Albert lowers the YSI 85 probe

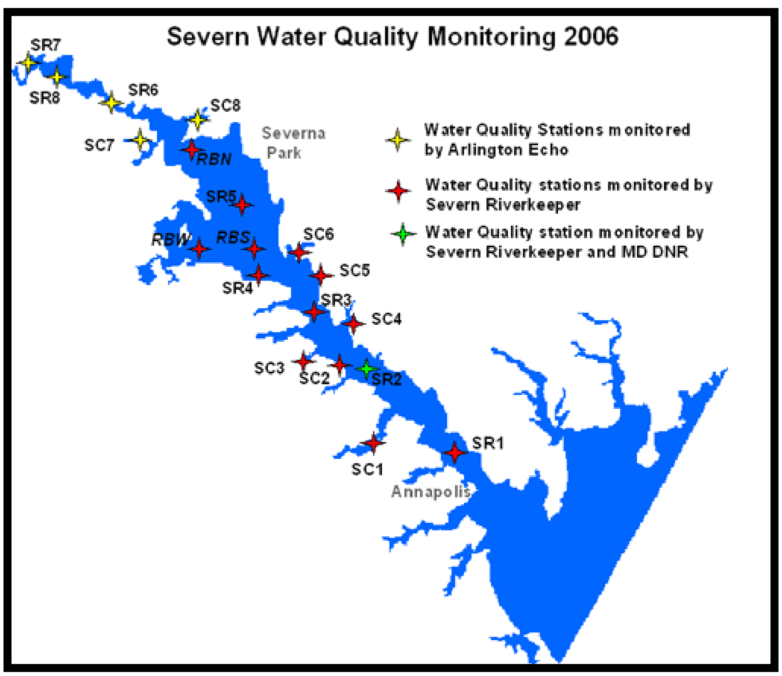
The Riverkeeper purchased two YSI 85 meters capable of measuring dissolved oxygen (DO), salinity, and temperature, and Arlington Echo purchased one identical instrument. The Riverkeeper Program assigned intern Allison Albert to work on this project along with Dr. Henkart, Riverkeeper Fred Kelly and various volunteers.

Arlington Echo assigned staffer Suzanne Kilby and two college student interns, Jessica Childs and Ashley Fussell, to obtain water quality data from the upper Severn. All monitoring personnel were trained in the use of the meter and data handling by Pierre Henkart, who was present on all but one Riverkeeper monitoring trips.

Helpful advice in many areas was provided by NOAA's Dr. Peter Bergstrom, who accompanied one monitoring trip to provide quality control for the DO measurements. A detailed list of monitoring personnel is included in the monitoring results spreadsheet.

Monitoring

A series of monitoring stations in the Severn mainstem and selected Creeks was established, and a guide using both GPS and visual line-ups was developed to allow monitors to make repeated measurements at the same position. The creek stations were selected as representative of others based on the character of their entrance channels (shallow versus deep, straight versus curved), and included several from each side of the Severn. The stations are shown on the map below.



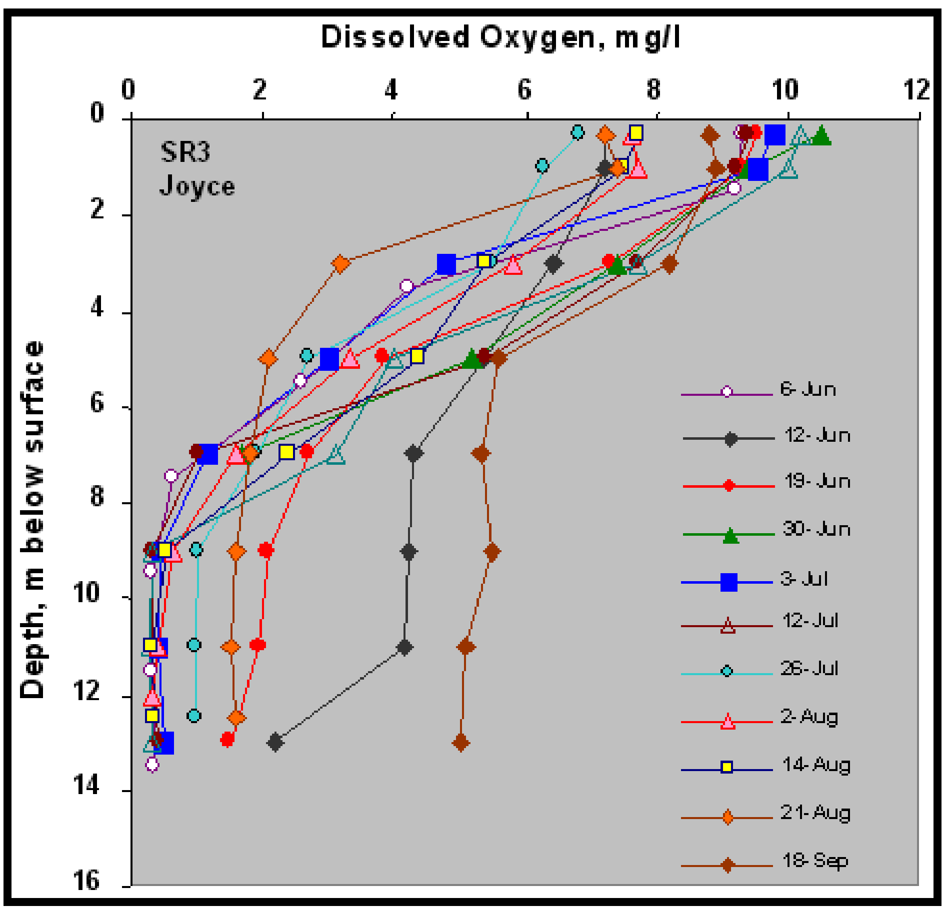
Monitoring each station consisted of anchoring the boat using established line-ups, and lowering the YSI probe to ~0.5 meter off the bottom as determined by feeling the weight suspended below the probe contact the bottom. Monitoring personnel then recorded dissolved oxygen levels (both percent saturation and concentration in mg/liter), salinity and temperature. Numbers from the meter screen were recorded on a paper datasheet mounted on a clipboard. The probe was then raised 1-2 meters and the readings repeated to provide a profile of the entire water column, with 4-5 points taken at most stations. The Riverkeeper boat typically used both meters at each station to provide duplicate values.

By August, it became clear that some monitoring stations were consistently showing bottom dissolved oxygen levels below 1 mg/l, and the accuracy of our meters at these low levels was open to question. A water sampling device (LaMotte, JT-1) was then used to obtain near-bottom water samples at these stations to allow olfactory assessment of the presence of hydrogen sulfide (H_2S), a product of anaerobic bacterial metabolism. The presence of H_2S confirmed that these stations were truly anoxic, i.e., DO levels <0.2 mg/l. No H_2S-positive samples were obtained when metered bottom DO levels were >0.2mg/l.

Dissolved Oxygen Results

A series of depth profiles for dissolved oxygen was obtained for each monitoring station, and plots constructed of dissolved oxygen concentration versus depth, as is standard for oceanographic data. As an example, data for our 40-foot-deep mid-Severn station at Joyce below Round Bay is shown.

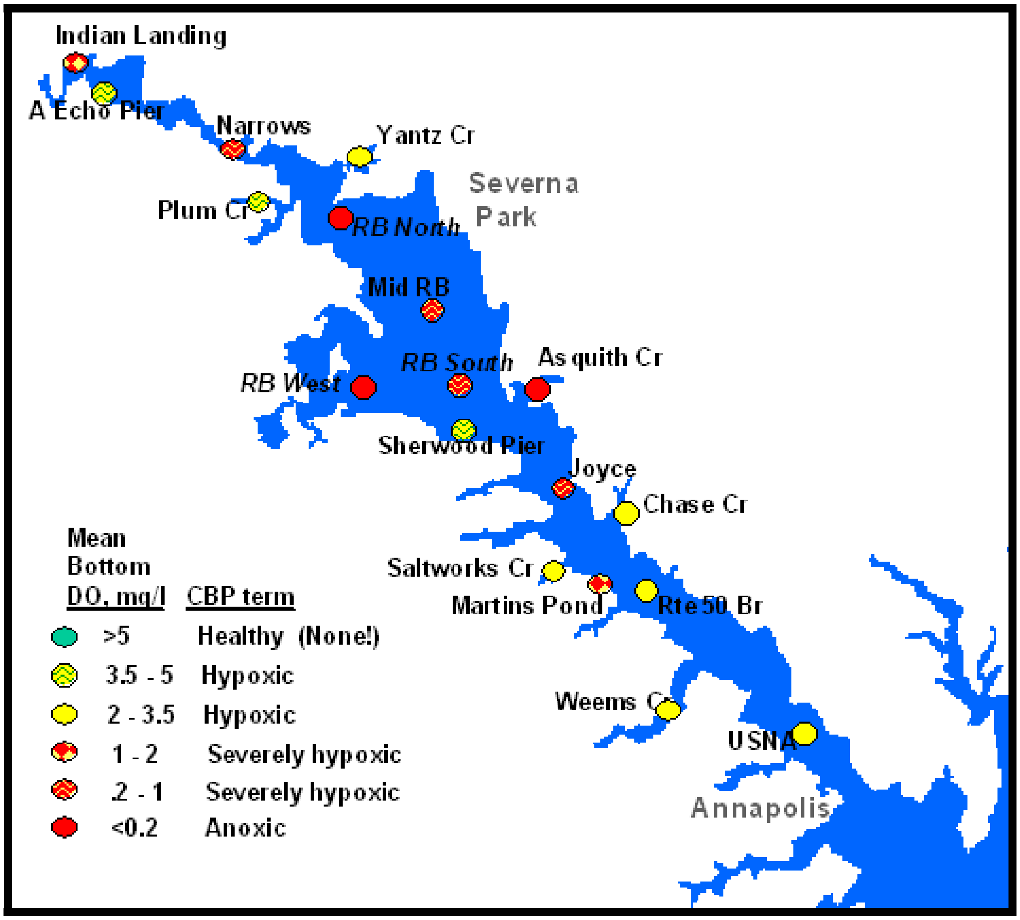
The Y-axis in these graphs is unusual in that it starts with zero at the top and goes down, but this should be thought of as depicting the water being measured. The depth is given in meters, so that the ~40 foot bottom is show at ~13 meters. The depth of deepest point varies according to the tide at the time of measurement. The dissolved oxygen concentration is shown in milligrams per liter (mg/l), plotted on the X-axis. Each colored line is a profile at this station obtained from a monitoring trip whose date is shown in the legend in the lower right.



All profiles show the expected high levels of dissolved oxygen near the surface, which is in contact with abundant atmospheric oxygen. These near-surface DO levels can be elevated, especially on sunny days, due to oxygen generated by microscopic phytoplankton during photosynthesis.

Going down from the surface, DO levels diminished within 2-3 meters. At this station a constant DO level was generally observed at about 6-8 meters, and throughout most of July-August these bottom DO levels were below 1 mg/l. This station is representative of the deepest areas in the Severn. Much of the Severn mainstem bottom is 6-9 meters (20-30 feet) deep, including our lower Severn monitoring stations SR1 off the USNA, and SR2 near the Rte 50 Bridge. These shallower stations gave profiles that looked generally like the top portion of this graph, without the bottom plateau. Complete profiles for all Severn stations monitored are presented in groups on the following pages: Severn mainstem stations; lower Severn creek stations; Round Bay stations; Upper Severn creek stations.

All our DO profiles showed the lowest DO levels near the bottom. This is expected as this water is generally saltier and thus more dense than surface water, and is the least able to mix with the abundant atmospheric oxygen. Because the bottom water bathes the bottom-dwelling (benthic) organisms such as oysters, clams, worms, and amphipods, low DO levels will limit the survival of these organisms, which form an important part of the food chain for fish and crabs. A DO level of 2 mg/l, termed severe hypoxia, is generally recognized as a minimal level for a healthy benthic habitat. A map showing the average summer (July and August) bottom DO levels at each Severn monitoring station is shown on the next page.



As can be seen from the map, all our Severn mainstem stations above the Rte 50 bridge, and two creek stations showed average summer DO levels near the bottom that were severely hypoxic. These creeks, Asquith Creek and Martin's Pond, have compromised circulation with the Severn mainstem due to shallow bars blocking their entrance. The four Round Bay stations that were more than 1/4 mile for shore all showed mean bottom DO levels less than 1 mg/l, while the station near shore at the Sherwood Forest pier was only slightly hypoxic. Further up the Severn, our Narrows station also showed a mean bottom DO level of less than 1mg/l. At the head of the Severn, the Indian Landing station showed severe hypoxia in spite of its shallow (6-8 foot) depth.

Sites showing consistently low bottom DO levels were additionally tested with a water sampling device, providing an opportunity to test for the presence of hydrogen sulfide by its pronounced rotten egg odor. Hydrogen sulfide was readily detectable in near-bottom water samples at the Asquith Creek, RB West, Mid RB, and RB North stations, but was not present in samples taken from higher in the water column at these stations, nor in near-bottom samples taken from other stations.

Monitors Allison Albert, Jessica Childs, Suzanne Kilby, and Ashley Fussell reacting to the rotten egg smell from a water sample near the bottom of Asquith Creek

No station showed an average bottom DO greater than 5 mg/l, a level considered "healthy" by the Chesapeake Bay Program and Maryland Department of the Environment. In some cases such as the SR3 station pictured above, that level was not achieved even half way between the bottom and the surface. However, the dissolved oxygen profiles of different monitoring stations varied considerably over the course of the summer, and the detailed graphs of the different station should be examined to get a feel for this. In general it appears that the lower Severn stations closer to the Chesapeake had higher DO levels than those above the Rte. 2 Bridge.

Detailed dissolved oxygen profiles for each of our stations are presented In the appendix.

Dissolved Oxygen Discussion

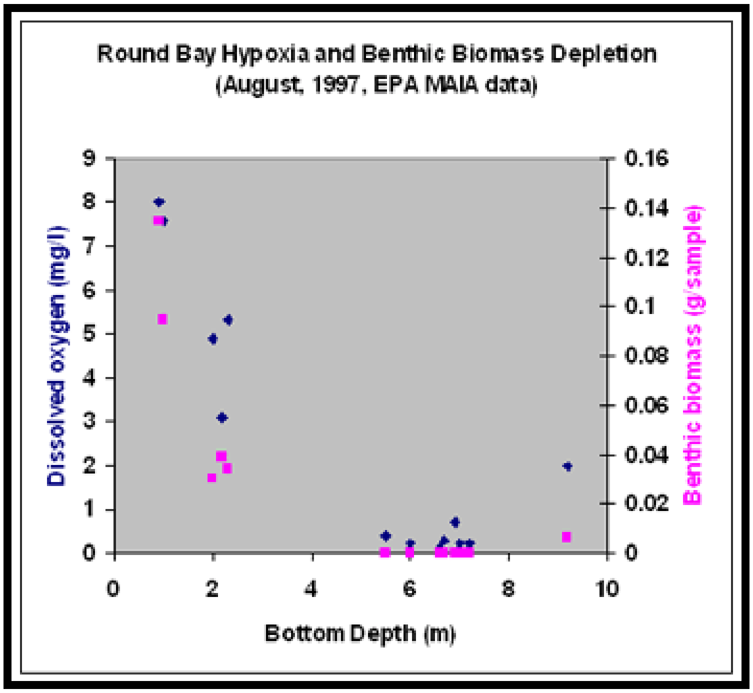
The most striking finding of our 2006 monitoring project was that, near the bottom, much of Round Bay was either severely hypoxic or anoxic throughout most of the summer, and this condition also existed in Asquith Creek. These findings are surprising because "dead zones" have been described in the deep channel of the Chesapeake's mainstem, but not in Chesapeake tributaries.

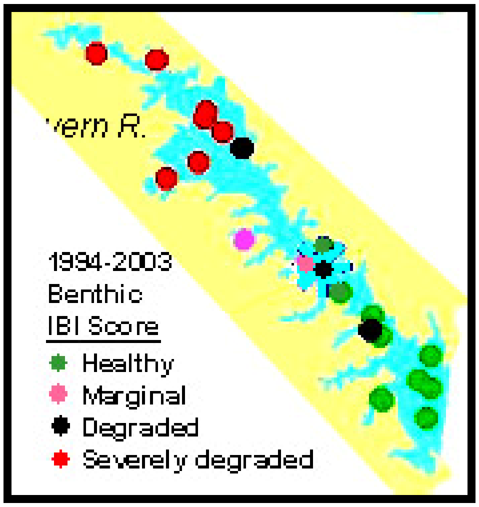
Whether or not our monitoring results lead to "dead zone" labels could be debated, as we did not have any stations with average metered DO levels of less than 0.2 mg/l, generally considered anoxic. However, at oxygen levels below 2 mg/l our two meters showed inconsistent low readings and did not agree with each other very well, so we cannot make a strong claim for strictly-defined anoxia based on our DO numbers.

Additional observations with a water sampling device lend strong support to the "dead zone" label. While the great majority of our measurements at each monitoring station were done with the YSI 85 meters, in August we began to sample stations showing consistently low bottom DO levels with a bottle-type water sampler. Samples brought up from close to the bottom at the Asquith Creek station and three Round Bay stations (SR5, RBW, and RBN) gave a pronounced rotten-egg smell of hydrogen sulfide. This toxic gas is produced by anaerobic bacteria only in the absence of oxygen, and hydrogen sulfide itself is unstable in the presence of oxygen. Based on these observations we characterize most of Round Bay and at least part of Asquith Creek as "dead zones" for at least part of the summer. This seems surprising because both Round Bay and Asquith Creek are aesthetically very pleasant water bodies, with relatively low levels of shoreline development visible (relative to other parts of the Severn), and both have seen recent remarkable increases in submerged aquatic vegetation in their shallows. However, the hypoxia we observed was only near the bottom (about 25 feet down), and could only have occurred if vertical mixing was minimal.

It may also seem surprising that hypoxia/anoxia was not previously described in an area as large and well known as the Severn's Round Bay. Part of the answer is that monitoring programs are always faced with limited resources, and it is never possible to monitor more than a small fraction of desirable sites. As discussed previously, the Maryland DNR has excellent long-term data from the Rte 50 Bridge station, and in the summers of 2002 and 2003 carried out technically demanding continuous and mapping measurements of DO in the Severn. These monitoring programs very likely failed to detect the low DO levels we found in Round Bay because they only made measurements at a depth of 1 meter, where severe hypoxia is unexpected (and where we did not find it). Other monitoring programs examining DO levels in the Severn were undertaken by the DNR Fisheries division to assess potential yellow perch habitat, and while considerable hypoxia was found in creeks in the upper Severn, Round Bay was apparently not monitored. However, one existing dataset from an extensive Bay-wide monitoring program shows results entirely compatible with ours.

In August 1997, the EPA's MAIA program conducted extensive monitoring of the Severn and other Chesapeake tributaries. Data were obtained from multiple stations throughout the Severn, and included dissolved oxygen measurements and measurements of benthic organisms. The left hand graph below shows their Round Bay data.



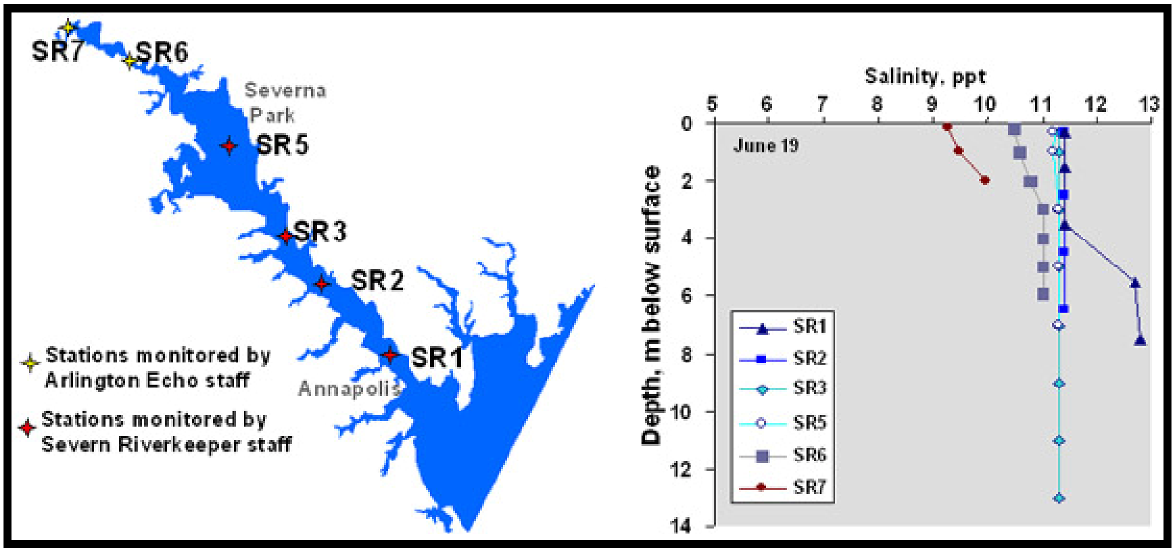


This graph shows a strong dependence of DO readings on the depth of the station, such that, with one exception, all stations below 5 m in depth showed severe hypoxia (the exception was a station near our RBS station, where we also found milder hypoxia). This MAIA dataset also includes data for benthic biomass, a measure of total living organisms in the top layer of bottom (Pink symbols, right hand scale). These numbers are strongly correlated with the DO levels, and indicate that the deeper parts of Round Bay were indeed "dead", i.e., devoid of benthic organisms. The correlation supports the obvious hypothesis that hypoxia caused the depletion of this important component of the estuarine food chain, making it a "dead zone". Further evidence for degraded benthic habitat in the upper Severn including Round Bay comes from measurements of the "benthic index of biological integrity" by Versar, Inc for the Chesapeake Bay Program (right chart above). These data show that the benthic habitat in the top half of the Severn including Round Bay is not healthy, and in some cases, devoid of life. While in principal this could be caused by toxic chemicals, there is no strong evidence to support this, and oxygen depletion is a much more compelling explanation. Looking over our dissolved oxygen results for the Severn as a whole, all of the mainstem and the Creek stations showed some hypoxia

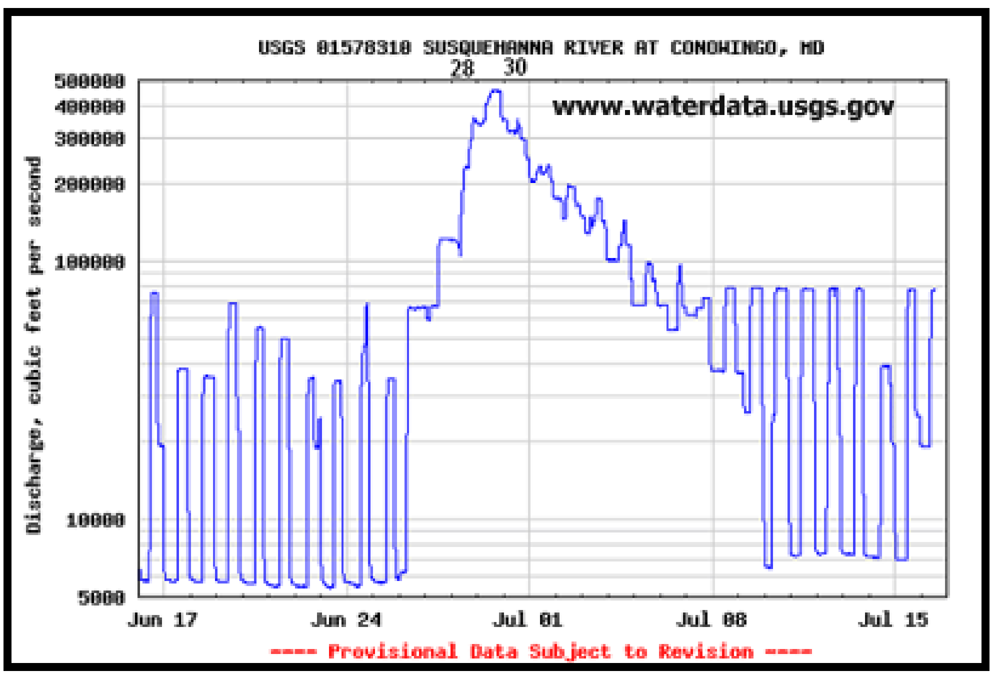
(DO < 5mg/l) near the bottom, and most showed healthy oxygen levels near the surface. It appears that episodes of severe bottom hypoxia at most stations did not persist as they largely did in Round Bay and Asquith Creek. Although the criterion of 5 mg/l for "healthy" DO levels applies to fish, benthic organisms such as worms, clams, and oysters are adapted to low oxygen conditions and can tolerate DO levels down to 2 mg/l for substantial periods. However, even looking at this less stringent criterion, one can see that the benthic habitat is stressed in much of the Severn and its creeks over the summer months.

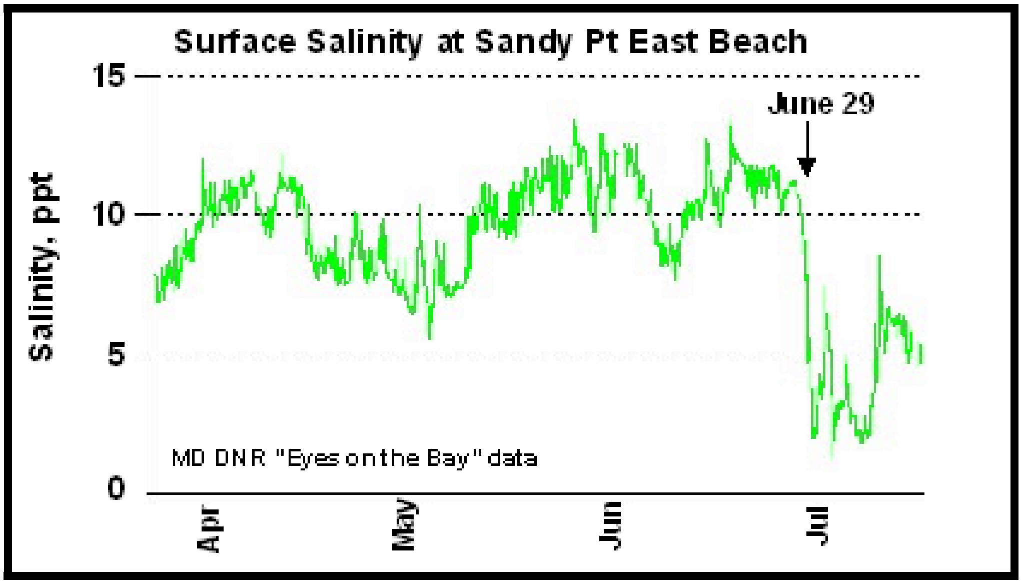
Salinity Results

Although the primary objective of the 2006 Severn Monitoring Project was to characterize summer hypoxia, monitoring personnel also recorded salinity and temperature from the YSI 85 meters along with the DO readings. The Severn is located about 4/5 of the way up the Chesapeake estuary, and its salinity is roughly 1/5 of that of sea water, which is 35 parts per thousand salt. Actually, the salinity in both the Severn and the Chesapeake varies seasonally, with lows in the spring and highs in the winter, as shown by DNR monitoring data. Because rainfall was unusually low during the spring of 2006, the normal seasonal high fresh water inflow from the Susquehanna and other rivers did not occur. By early June, the salinity in most of the Severn was about 11 parts per thousand (ppt) rather than the seasonally normal 5-7 ppt. As seen on the next page, our monitoring on June 19 showed a rather even salinity distribution throughout the Severn, with fresh water inflow from Severn Run apparent at the head of the Severn, and some saltier, denser water entering the Severn along the bottom near its mouth. This pattern was representative of what we found in early June, as our monitoring project was gearing up.

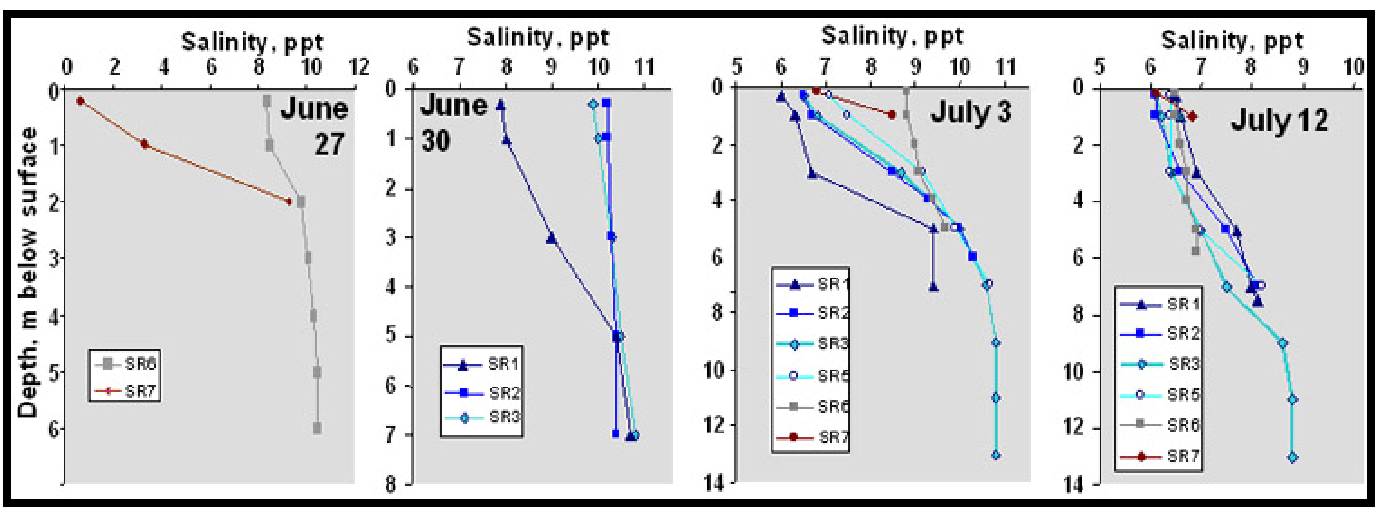


What was most unusual in 2006 was a major rainstorm June 25-27, which dropped 5-12 inches of rain on the local area and most of the Susquehanna watershed. This led to a marked decrease in salinity in the Severn and northern Chesapeake. Data from the Susquehanna's Conowingo Dam shows a ~20 fold increase in water flow from June 24 to June 30 (see image below), which was followed by a dramatic decrease in surface salinity on June 29 in the Chesapeake at Sandy Point near the Bay Bridge (see graph on the next page).



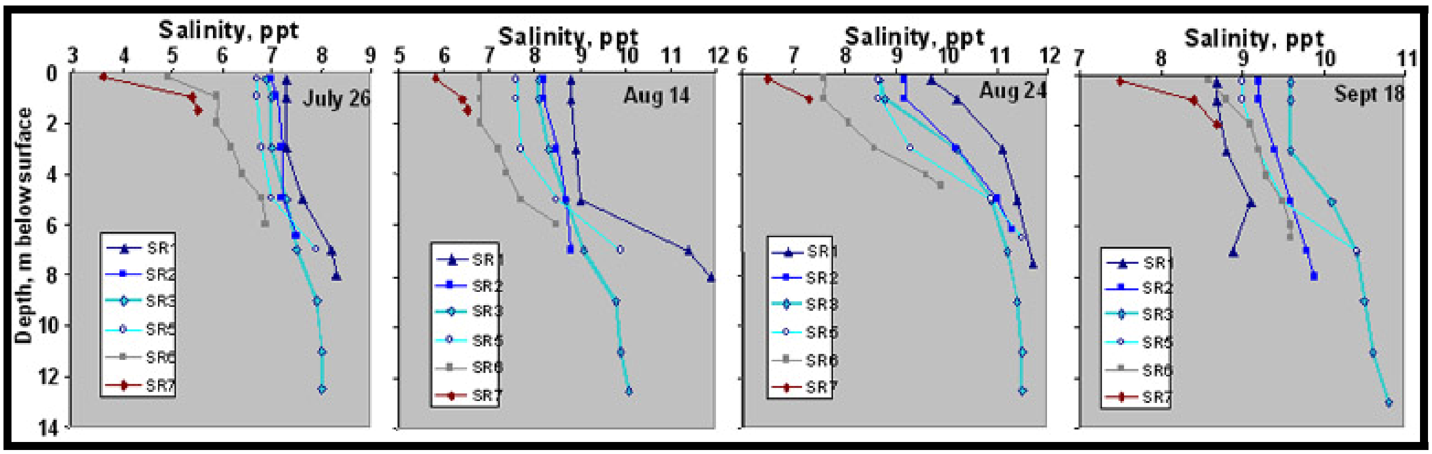


Because our monitoring program was in place at this time, we were able to follow the subsequent salinity changes up and down the Severn, as shown by our data below. On June 27, the Arlington Echo team found fresh water at the surface near the head of the Severn (Station SR7), although the nearby deeper station SR6 showed a salinity profile quite to that of June 19. Several days later on June 30, the Riverkeeper team found the mid-Severn stations SR2 and SR3 to show similar salinity profiles to those of June 19, while station SR1 near the Severn's mouth showed fresher water entering at the surface.



On July 3, a striking "reversed salinity" picture was found, with the salinity decreasing progressively from station SR1 near the Chesapeake through station SR6 near the head of the Severn. The shallow top station SR 7 had increased its salinity compared to June 17, but was fresher than nearby station SR6. On July 12, we found that even the saltier water in the deeper stations had been replaced with fresher water, and at depths shallower than 6 m, the Severn's salinity had almost halved compared to pre-storm levels. These data clearly show that the major influx of fresh water throughout the tidal Severn came from the top layer of the adjacent Chesapeake, which in turn is derived from the Susquehanna.

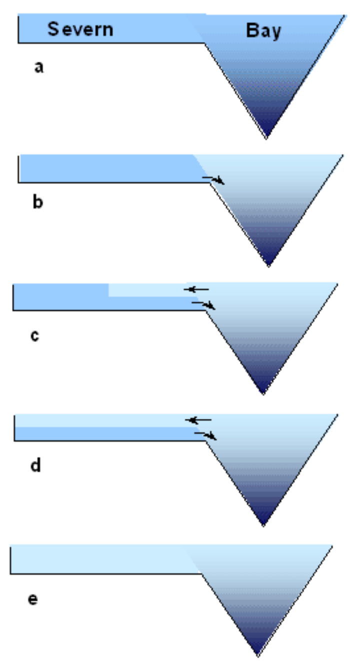
July and August 2006 were very dry months in this region, and the salinity rose steadily throughout this period. As expected, our monitoring showed that this heavier saltier water came in from the Chesapeake along the bottom (e.g., station SR1 on August 14) displacing the lighter, fresher water from the Severn. During the first week of September, hurricane Ernesto and associated storms dropped over 5 inches of water locally, and a smaller scale influx of fresh water occurred, again from the Chesapeake as seen in late June. On September 18, our lowest station SR1 was again fresher than other Severn stations except for SR7 at the mouth of Severn Run, with salinity increasing through mid-Severn station SR3.



Salinity Discussion

Our 2006 monitoring project was fortunate to be able to document the salinity changes following the unusual rain event at the end of June, as similar large influxes of fresh water normally occur earlier in the spring. Over the course of the next few weeks, this rainfall caused the Severn's salinity to drop by a factor of two. While many would have envisioned the fresh water source for this as the Severn watershed, especially Severn Run, our results show clearly that the great majority of new fresh water entered the Severn from the Chesapeake, spreading up past Round Bay and into the upper Severn within a week. At our SR7 (Indian Landing) station, at the head of the tidal Severn, fresh water from Severn Run is seen immediately after the rain ended, but within a week it is replaced by the saltier water that came in from the Bay, similar to that dominating the rest of the Severn. This "salinity reversal" is a regular occurrence in the Severn and neighboring Chesapeake tributaries during the spring months, when large volumes of fresh water normally enter the head of the Chesapeake from the Susquehanna (USGS data). This spring salinity reversal in the Severn has been nicely mapped by the MD DNR's surface monitoring program, although our data provided depth profiles showing additional features during the June rain event.

After this rain in late June, minimal rain fell during the summer until hurricane Ernesto at the end of August. As a result, the Severn's salinity increased slowly due to the denser saltier water intruding along the bottom from the Chesapeake, which was itself getting saltier due to the decreased fresh water influx from the Susquehanna. The Severn's salinity changes are caused density-driven water exchanges from the top layer of the Chesapeake, whose salinity in turn reflects a balance between fresh water coming from the Susquehanna and the intruding denser saltier water coming from the Atlantic.



The model above schematically depicts the Severn's rapid salinity decrease after the rain event in June, with dense salty water shown in dark blue and fresher water in light blue. The diagram shows a simplified east-west vertical section of the Severn and adjacent Bay as seen from the south. Panel **a** shows the pre-storm situation, when the Severn was well-mixed and had a moderate salinity level. Panel **b** shows the effect of the storm-induced fresh water flow making the surface of the Bay fresher, while the Severn still contains denser, saltier water from before. Panel **c** shows the density-driven flow of this saltier water out of the Severn into the adjoining bay. This flow continues, resulting in the layering of incoming fresher water on top of outgoing saltier water, as shown in panel **d**. When this dense older, saltier water has emptied out into the Bay, the Severn becomes filled with well-mixed fresher water with the same salinity as the adjacent Bay (panel **e**). This model does not depict the detectable "sub-estuary" which exists at the tidal head of the Severn and undoubtedly also at the tidal heads of other Severn Creeks that have significant fresh water streams feeding them. However, our salinity measurements showed that these are only minor influences, and the great majority of the Severn's fresh water is derived from the Susquehanna via density driven exchanges with the adjacent Chesapeake. These exchanges were described for the Severn and neighboring tributaries in a 1982 paper in the journal Estuaries by Schubel and Pritchard (vol 9, p. 236).

Because the Severn is named a river and looks like a river on a map, most people assume that fresh water flowing in from its watershed makes it a sub-estuary of the Chesapeake. For the great majority of the tidal Severn, our data do not show a salinity profile compatible with a sub-estuary, and it is more realistic to think of the Severn as an elongated bay off the Chesapeake. Except for density-driven exchanges of the kind described above, water movement into and out of the Severn is limited. The Severn has the lowest lunar tide (about 1 foot) of any place on the Chesapeake, and this twice daily flow sloshes existing water back and forth more than mediating significant water exchange between the mid-upper Severn and the Bay. Wind driven changes in water height cause more water movement than tides, but strong winds driving these are rare during the summer. Thus nutrients entering the Severn from the adjacent Bay and from the local watershed are expected to be trapped in the Severn, where they promote phytoplankton growth, driving the summer hypoxia we observed. Tide-driven water exchanges with the Chesapeake probably account for the better condition of the benthic habitat in the lower Severn, as described in our discussion of the dissolved oxygen results.

Our salinity and temperature measurements show that in the summer, the Severn's water shows the expected layering, with saltier and colder water near the bottom, and fresher and warmer water near the top. Both these temperature and salinity differences create a density gradient, with lighter water near the surface and denser water on the bottom. However, this density gradient is much less pronounced than that found in the Chesapeake, where a sharp density change known as the pycnocline occurs in the deeper parts of the Bay. The pycnocline is a strong barrier to vertical mixing, cutting off the supply of atmospheric oxygen to deeper water layers, and it has been associated with formation of the Bay's "dead zone". The milder density gradient we found in the Severn is less of a barrier to vertical mixing, but the forces promoting such mixing may be much less in its relatively protected waters with little horizontal water flow.

Supporting Staff and Volunteers

Pierre Henkart is Chief of the Lymphocyte Cytotoxicity Section, Experimental Immunology Branch of the National Cancer Institute. After earning his PhD in Biochemistry and Molecular Biology from Harvard and conducting post-doctoral research in marine biochemistry, Pierre came to NIH and Annapolis in the 1970s. He is a life-long sailor, served on the Severn River Commission, and designed and supervised the Severn Riverkeeper water quality monitoring program in 2006.

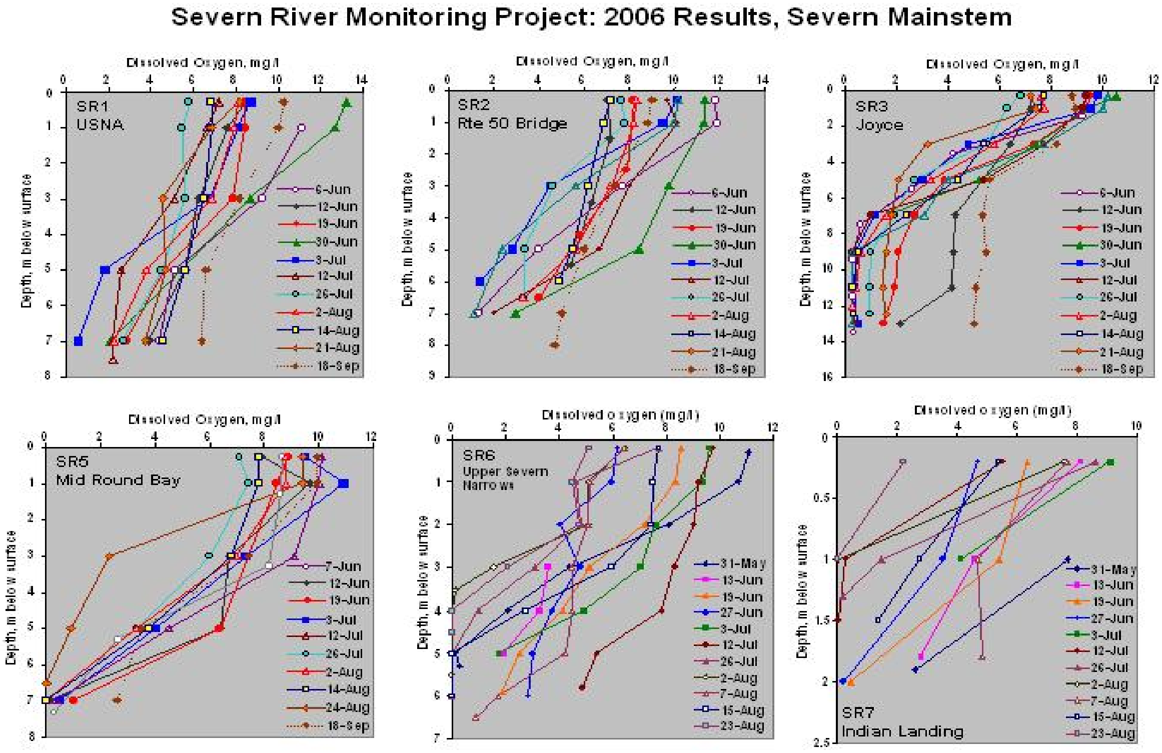
Allison Albert, an intern for the Severn Riverkeeper Program, organized the Program’s monitoring efforts. Allison has a bachelor's degree in Geography from the University of South Carolina and recently completed her Masters in Environmental Policy from the University of Maryland. She now works full time for the Severn Riverkeeper Program.

Crucial volunteers who assisted the Riverkeeper monitoring team were: Sara Caldes, Nate Frankoff, Aaron Canale, and John Clauson. They donated many hours of their time that were vital to the success of this project.

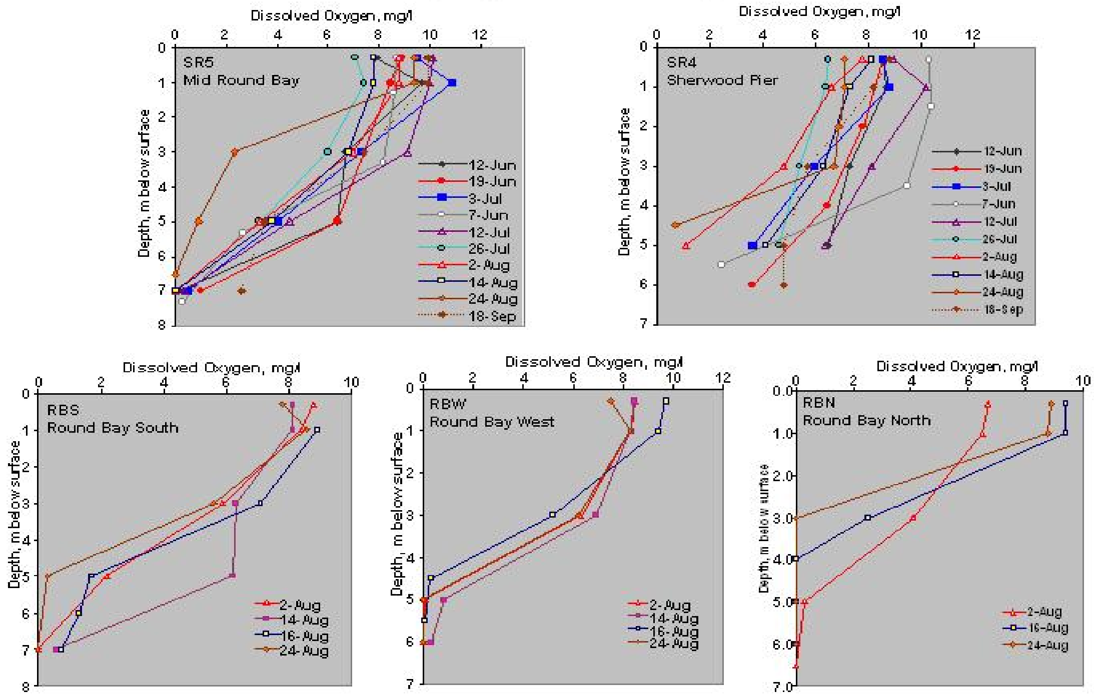
The Arlington Echo monitoring team was headed by Suzanne Kilby, Outdoor Educator at Arlington Echo, and Director Steve Barry made many resources available to the monitoring effort. Major credit for its success goes to two interns, UMBC student Jessica Childs and St Mary’s College student Ashley Fussell, who took great care in providing reliable data.

David Wallace provided the spectacular cover aerial photo of the Severn.

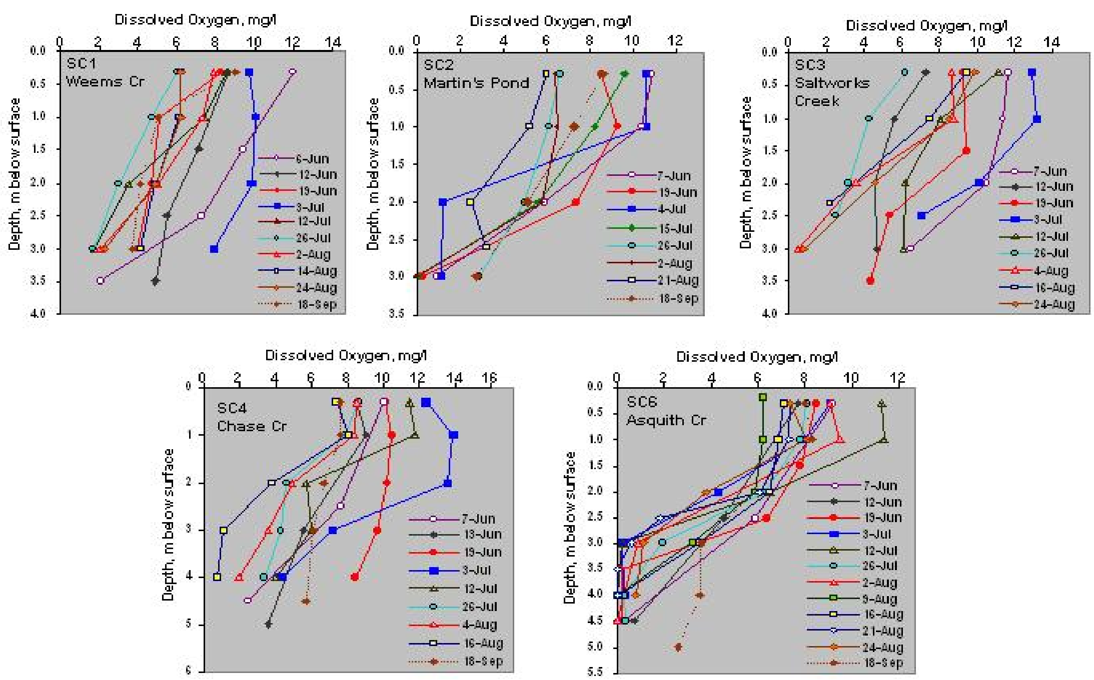
Appendix—Complete 2006 Severn dissolved oxygen data



Severn River Monitoring Project: 2006 Results, Round Bay Stations



Severn River Monitoring Project: 2006 Results, Lower/Mid Severn Creeks



Severn River Monitoring Project: 2006 Results, Upper Severn Creeks