February 16, 2011

Governor Martin O'Malley — Hand Delivered

2010 SevernStat Report – Millions Lost to Maryland

Dear Governor O'Malley:

The State of Maryland is losing millions in federal restoration funds for the Chesapeake Bay and its tributaries due to EPA's failure to comply with their own **Supplemental Environmental Projects Policy** (SEP Policy) in enforcement actions.

EPA issued their **Final Supplemental Environmental Projects Policy** on April 10, 1998. Their Enforcement Department still refuses to implement this policy at the cost of millions to Maryland. The Severn River alone just lost $600,000 in SEP funds for a restoration project that would have stopped significant stormwater pollution from the Annapolis Mall.

A simple letter from you would secure these funds for Maryland. A letter formally requesting Lisa Jackson, Administrator of EPA, to instruct her Enforcement Department to comply with their own SEP Policy would provide millions for Bay restoration. The best part is that these funds come from polluters.

The loss of these funds is inexplicable given the state of the economy and the President's Executive Order. You could remind Lisa Jackson that the President not only declared the Bay a National Treasure, but ordered immediate action to protect the Bay. EPA's failure to implement its own SEP Policy could be interpreted as a direct violation of that Executive Order.

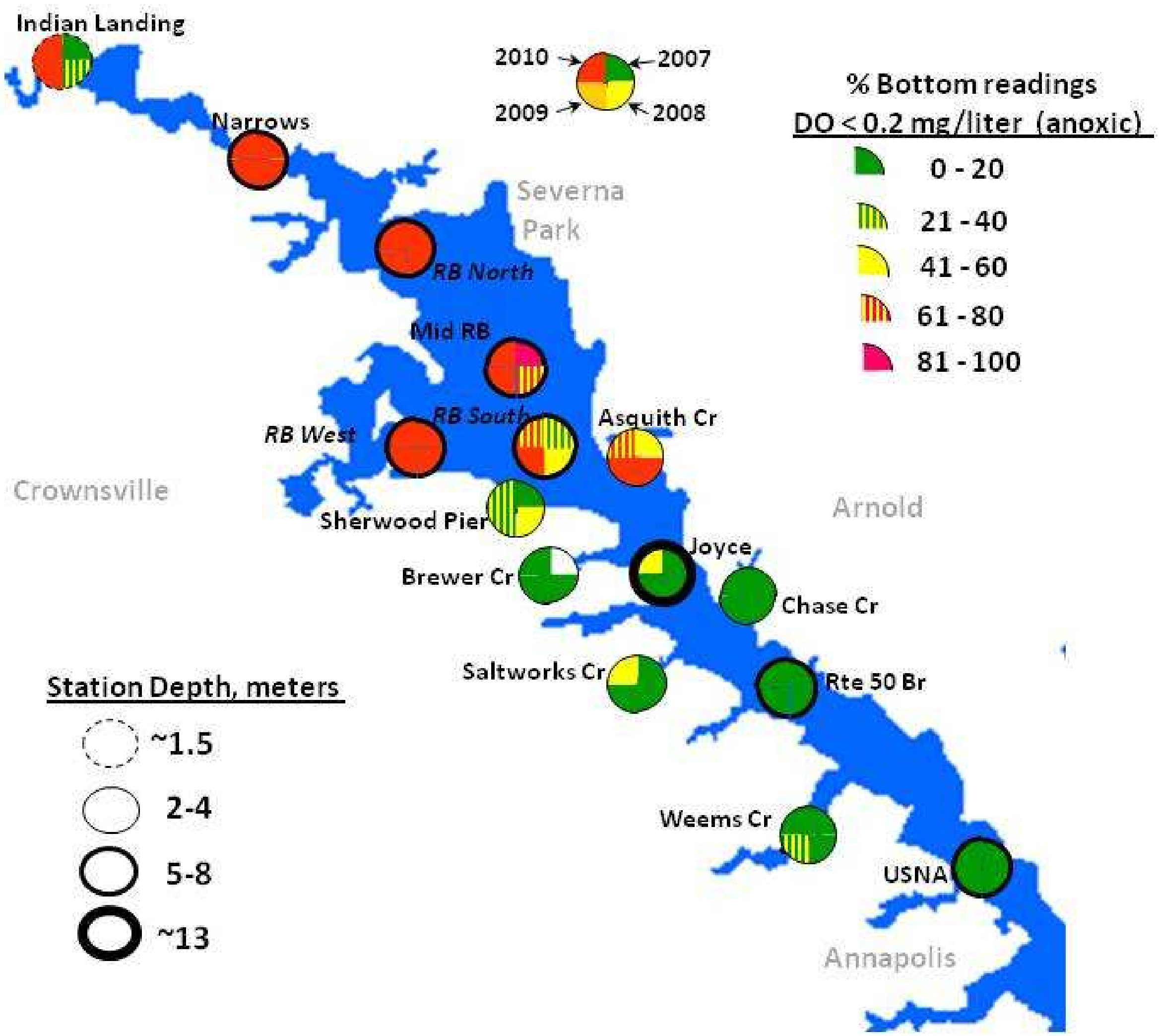
The enclosed **2010 SevernStat Report** on the health of the Severn River highlights the critical need for these SEP funds. We appreciate your dedication to protecting and restoring the Chesapeake Bay and urgently request your help in securing these funds for Bay restoration.

Sincerely,

Fred Kelly
Severn Riverkeeper

2010 Severn Riverkeeper Monitoring Project Report

Pierre Henkart



Summary

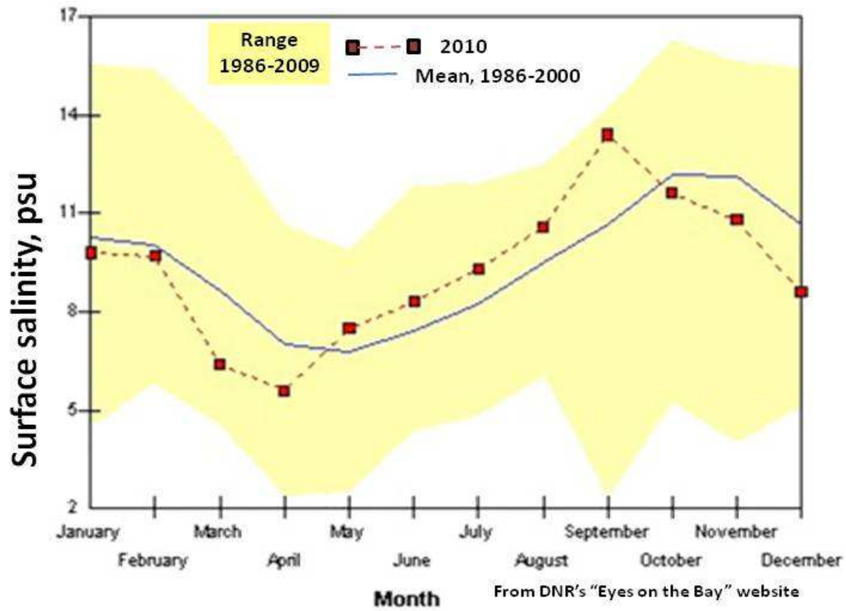
The Severn Riverkeeper Monitoring Project operated in the summer of 2010 as a continuation of its monitoring efforts that started in 2006. Water quality measurements (dissolved oxygen, salinity and temperature) as depth profiles at 1 meter intervals were made at each of 15 stations, located from near the tidal head of the Severn down to Annapolis and into 5 of the Severn's tidal creeks. Surface water clarity (Secchi depth) was also measured at each station. In 2010 as in previous years, hypoxia/anoxia (low levels of dissolved oxygen) developed during June, became persistent throughout the Severn during July and August, and began moderating in September. Hypoxia was more pronounced in northern Round Bay and the upper Severn; both this spatial pattern and the intensity of the hypoxic habitat squeeze were similar to that observed in 2009 . Also repeating the pattern of previous years, bottom anoxia was persistent in the northern half of Round Bay extending to the upper Severn throughout July and August. Surface water clarity throughout the Severn was slightly better in 2010 than in 2009, but was less than was found in 2008.

Introduction

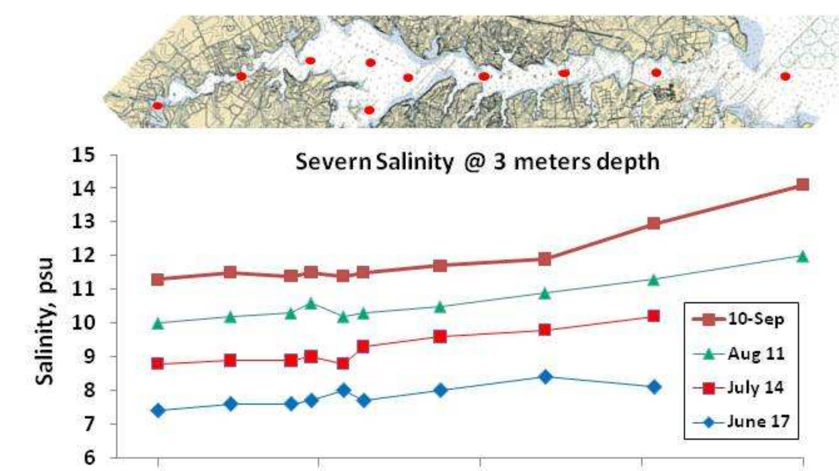
The Severn Riverkeeper monitoring project was started in 2006 to characterize basic water quality parameters throughout the tidal Severn River. The chief objective of this project has been to assess dissolved oxygen levels throughout the Severn and its tidal tributary creeks. From the outset all our data has been collected using YSI 85 meters to obtain oxygen, salinity and temperature levels, recorded at 1 meter depth intervals throughout the water column. All reported data are the result of the average of two independent measurements with different meters from opposite ends of the anchored monitoring boat. From our first months of operation it became clear that the Severn suffered from very low bottom dissolved oxygen levels (<0.2 mg/liter) in northern Round Bay, much lower than the bottom oxygen levels found below Round Bay including those at the Route 50 bridge where the Maryland Department of Natural Resources has monitored the Severn's water quality for 20 years. Subsequent years of monitoring by our project have shown that the upper Severn's persistent summer bottom anoxia is a regular occurrence. This anoxia is distinct from the short term anoxia responsible for occasional fish kills in shallow areas around the Chesapeake, and is more similar to that found in the deep areas of the Chesapeake mainstem, where it has been referred to as the "dead zone". Monitoring data from other Chesapeake tributaries has not documented the type of persistent bottom anoxia we have described, and that has motivated us to continue our monitoring program to document its year-to-year consistency. This report will summarize our oxygen findings in the Severn over five summers, along with our observations of water clarity. I will also discuss how our salinity and temperature data allow us to assess the role of water density layering in retarding vertical mixing, which allows re-oxygenation of water throughout the water column.

Salinity

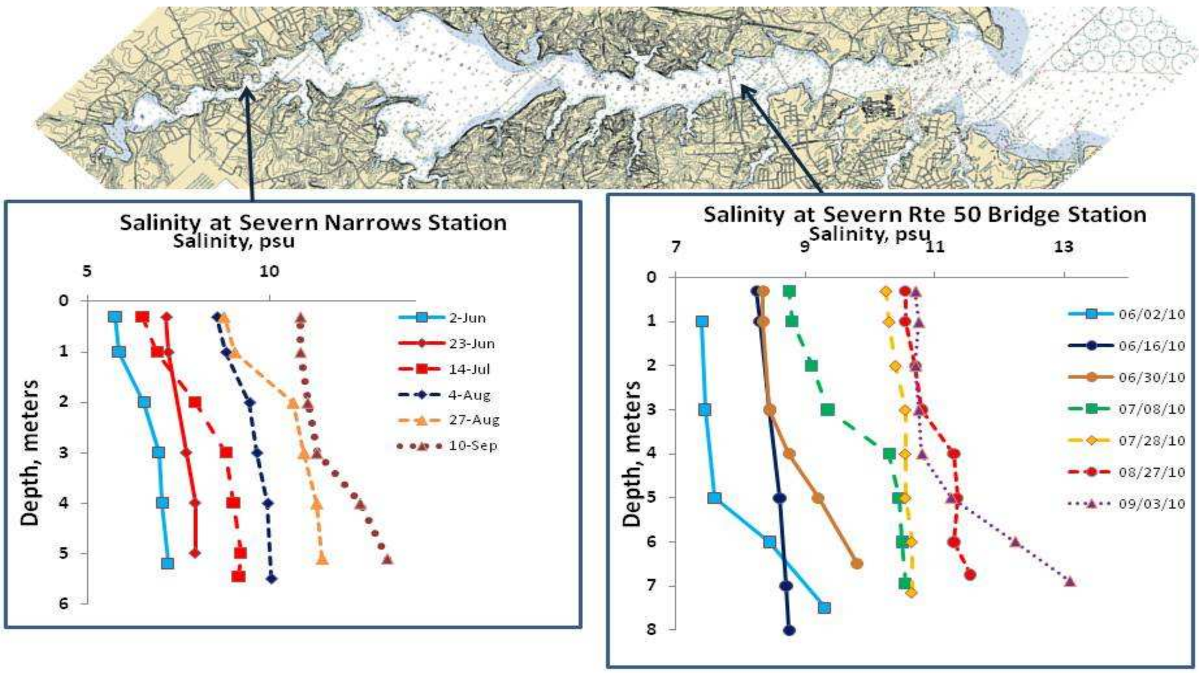
As estuaries are by definition water bodies where fresh and seawater mix, their water quality is greatly affected by the quantity and quality of freshwater input. Salinity levels are readily measured, and provide a quantitative measurement of seawater's influence. The figure below shows the Maryland DNR's 2010 data from the Severn's Route 50 bridge, located about a mile above the US Naval academy. It can be seen that in 2010, the Severn's normal seasonal salinity cycle was altered by fresher-than-normal water in March-April, followed by saltier-than-normal water from May-September. Rainfall patterns explain these salinity changes from the normal pattern, but during the course of our monitoring season from May-September, the Severn was experiencing a gradual increasing salinity. While this DNR data nicely shows the annual pattern in the Severn's salinity, our monitoring program's data shows more detail, both up and down the Severn and as a function of water depth.



The following figure shows the salinity variation starting at the tidal head of the Severn, close to Severn Run, which is the Severn's major fresh water input, draining by far the largest land area of any of the Severn's local fresh water sources. At the right side of this figure is a station which is basically in the Chesapeake, off the mouth of the Severn beyond Greenbury Point.



Our monitoring procedures have always been directed at providing a full depth profile at each station, which allows us to look at how much the heavier salty water is layering below the lighter fresh water. Examples of these salinity depth profiles are shown in the figure below.

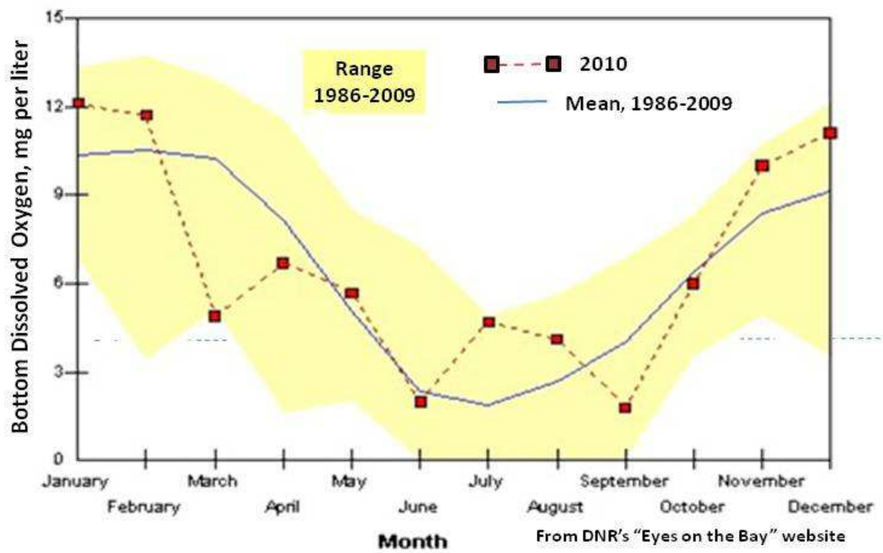


These salinity depth profiles at Severn Narrows show the effect of fresh water input near the surface on July 14 and August 27, while on dates such as June 23 the water column was well mixed. On the other hand, at the Rte 50 bridge, the intrusion of saltier water from the Chesapeake along the bottom can be seen on June 2 and September 3, while at other times the water column tends to be well mixed. Overall, our salinity data indicates that the major source of water in the tidal Severn is the Chesapeake Bay, with a significant but minor contribution originating from Severn Run and other local freshwater inuts, especially locally after rainfall.

Because salinity is the major determinant of water density, in a later section I will show how density depth profiles reflect these salinity profiles, and discuss the implications of the importance of these density profiles for proposed regulations based on dissolved oxygen levels.

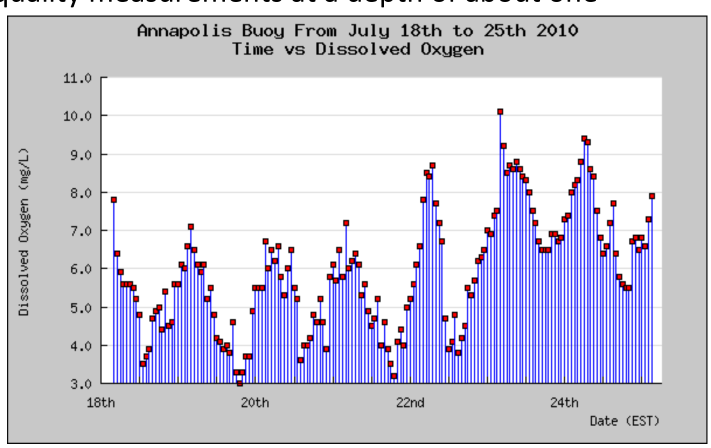
Severn Dissolved Oxygen Levels

Dissolved oxygen has been the focus of our monitoring program because much of the Chesapeake suffers from summer oxygen levels that fall below to low levels that are stressful to fish and crabs. This problem is more pronounced in deeper water near the bottom, where oxygen from the air cannot penetrate readily, and even organisms like oysters and worms living on the bottom become stressed when oxygen is depleted.



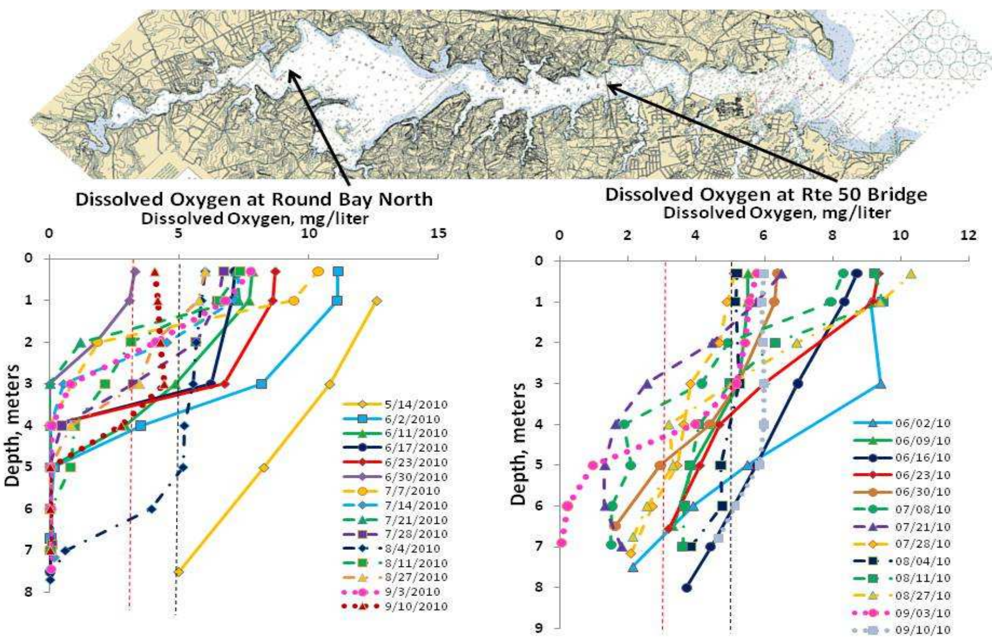
The Severn's dissolved oxygen levels have been measured at the Route 50 bridge by the DNR for many years, and their 2010 measurements are shown here, compared to historical records. It can be clearly seen that bottom dissolved oxygen is minimal in the summer, when levels routinely get below 3 mg/liter, a level decidedly stressful to most Severn fish. In 2010 we can see the usual variations from average bottom dissolved oxygen levels at this monitoring station, with the July-August readings higher than the long-term average.

In 2010, a new NOAA-installed buoy off Greenbury Point near the mouth of the Severn provided virtuously continuous water quality measurements at a depth of about one meter. Data from this buoy show the daily dissolved oxygen cycles driven by phytoplankton. These microscopic organisms grow in response to the plant nutrients nitrogen and phosphorous, and they derive most of their energy from photosynthesis. Thus during daylight hours they give off oxygen, so that surface oxygen levels often exceed those expected from equilibration with the overlying air. After sunset, phytoplankton consume oxygen as they metabolize sugar produced during daylight

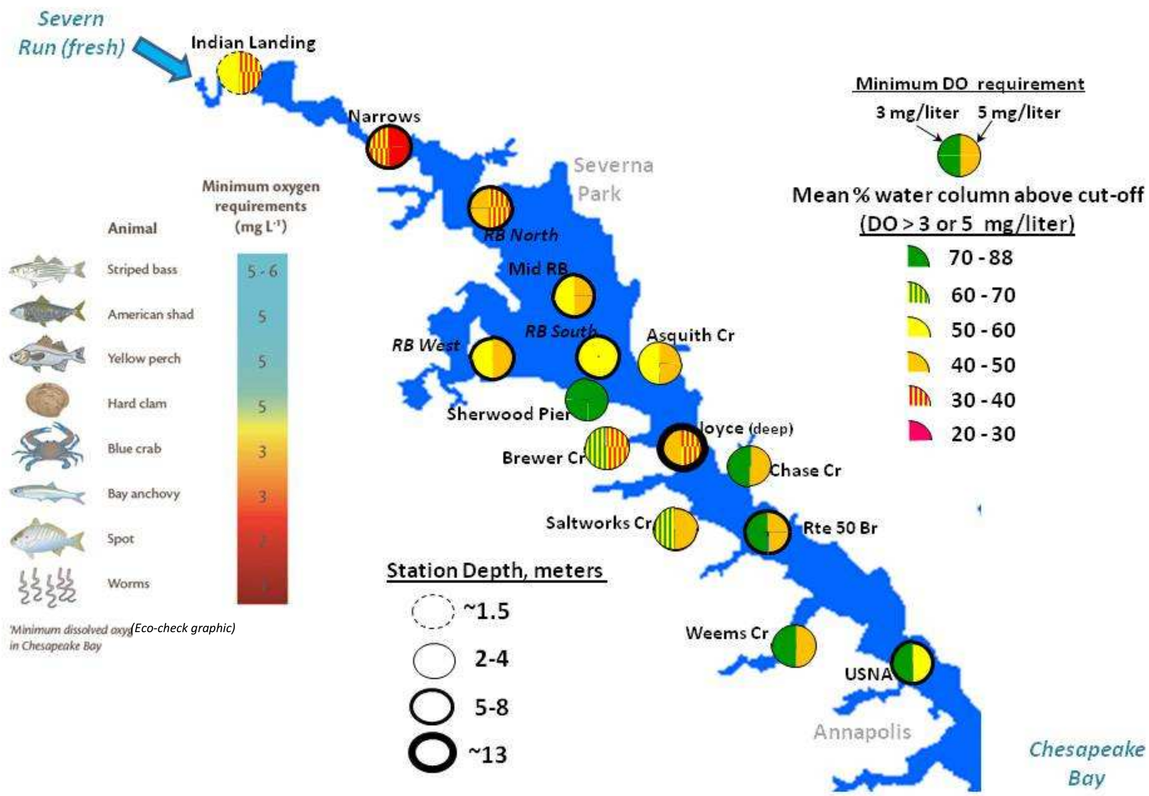


hours. An example of such cycling typical of Chesapeake surface waters in the summer is shown in this figure. On cloudy days when the sunlight is less intense, phytoplankton produce less oxygen, so that the daily highs and subsequent lows are not all equal. However, these near-surface oxygen levels do not drop to stressful levels for long.

In parallel with the salinity measurements discussed above, our monitoring program obtains profiles of dissolved oxygen concentrations with depth at each of 15 Severn stations. This figure shows examples of our 2010 data at the Route 50 station (where the DNR monitors the Severn), and also our station in upper Round Bay. The two “acceptable” DO criteria levels of 3 and 5 mg/liter used by the CBP are shown by the vertical blue and red dashed lines, and one can define lower oxygen levels as “hypoxic”. As discussed later in this report, it is not presently clear which of these will be applied to the Severn. These DO profiles show that for both stations, the upper portion of the water column is generally above either possible “acceptable” oxygen level, while in most cases some or most of the lower portion is below these levels. The percentage of the water column that is above the acceptable level provides a measure of the hypoxia-induced “habitat squeeze” for fish, since they can avoid stress by swimming nearer the surface.

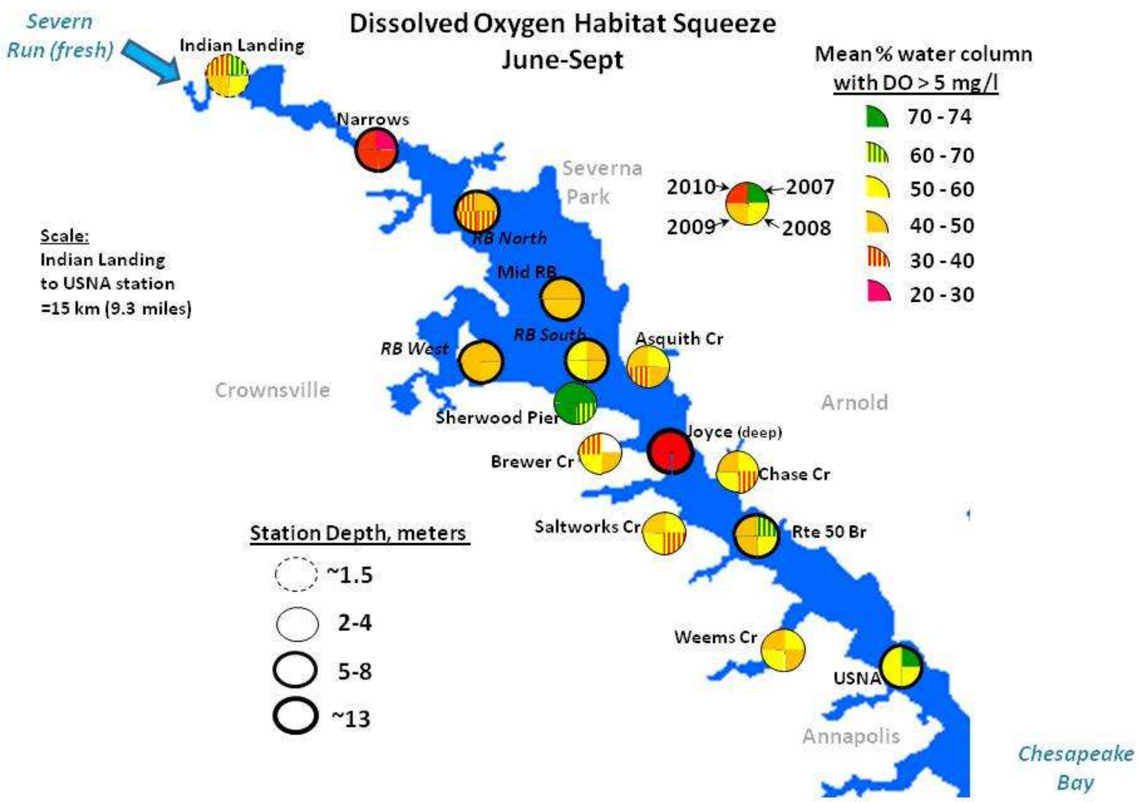


The figure below shows the hypoxic habitat squeeze from our 2010 dissolved oxygen monitoring, using data averaged from May through September and either 3 or 5 mg/liter criteria for "acceptable" DO levels.



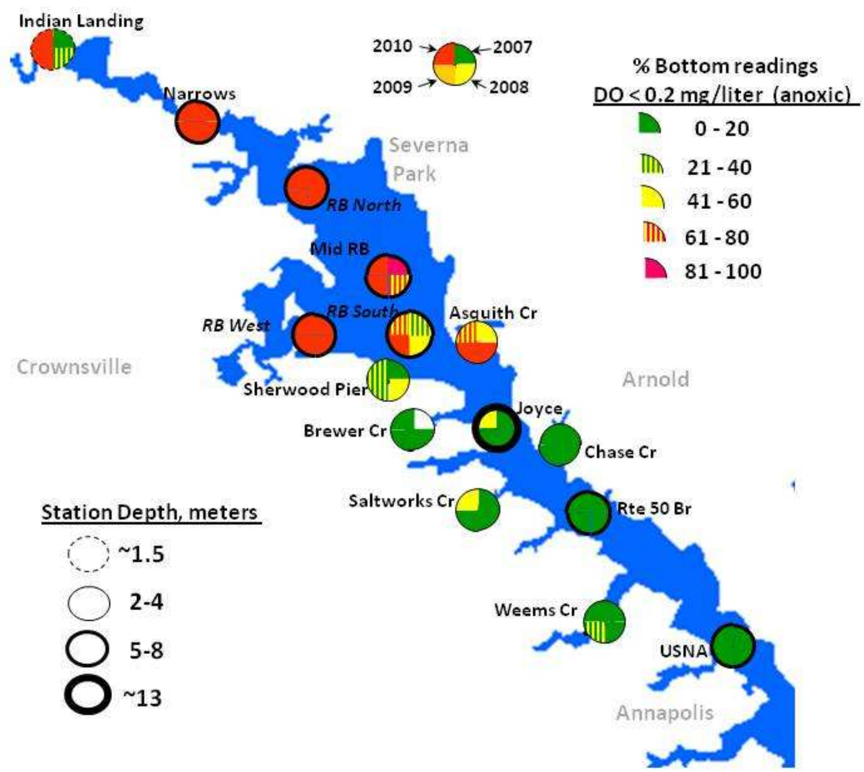
With either criterion, the hypoxic habitat squeeze is more pronounced in the upper Severn and less severe in the lower Severn. Stations in the creeks, in spite of their shallower depth, are not better than nearby stations in the mainstem. The most severe hypoxia is found above Round Bay, at the Severn Narrows station, where the water depth is about 16 feet. In contrast, our mid-Severn station near Joyce Point has a depth of about 40 feet, but shows a higher percentage of acceptable dissolved oxygen. Our shallowest station, at Indian Landing near the tidal head of the Severn, was only 4-5 feet deep, but less than half of this depth showed acceptable oxygen levels by either the 3 or 5 mg/liter acceptable criterion.

Since we have been monitoring the same stations by the same protocol for the previous five summers, it is reasonable to ask whether any changes in the hypoxic habitat squeeze are apparent in the Severn over this period. Since we find considerable variation



from week to week, the June-September seasonal averages are used with the 5 mg/liter criterion. The figure below summarizes our data over the last 4 years. It is clear that there is substantial year-to-year variability in the hypoxic habitat squeeze, but some patterns are apparent. The upper Severn suffers from greater water column hypoxia than the lower Severn, and while the creeks are variable from year-to-year, they are quite hypoxic considering they are not as deep as the Severn mainstem stations. Our station off the Sherwood Forest pier in Round Bay shows the lowest levels of hypoxia, presumably because of the wave action at this shallower depth (compare to deeper Round Bay stations). While 2007 was a year of “good” Severn oxygen compared to the following three years, a detailed quantitative look at the dissolved oxygen numbers does not allow us to conclude any trend is apparent. Overall, no general trend of increasing or decreasing water column hypoxia can be seen from 2007 through 2010, the most recent four years of Severn monitoring data.

The above analysis of the Severn's dissolved oxygen problems was designed to reflect the hypoxic habitat squeeze experience by fish that can freely move within the water column. However there are benthic organisms such as worms and clams that are confined to the bottom, lacking the ability to move upwards in search of more oxygenated water near the surface. Our monitoring procedure includes measurement of water quality parameters at half a meter above the bottom at each station, and our data starting in 2005 has shown that some Severn bottom areas are dramatically impacted by extremely low oxygen levels that are incompatible with survival of any multicellular animals. Dissolved oxygen levels lower that 0.2 mg/liter are considered anoxic, conditions that occur every summer in the deep portions of the mid-Chesapeake and are referred to as the "dead zone". Our results for Severn bottom dissolved oxygen in 2010 were quite similar to those in previous years, as shown in this figure summarizing our July-August bottom dissolved oxygen data data over the past four years. A striking difference is seen between the lower Severn stations, which only occasionally show oxygen depletion to the level of anoxia, and the upper Severn, where anoxia is routinely found throughout July and August. The southern portion of Round Bay and the shallow Asquith Creek station show year-to-year variability in the consistency of bottom anoxia, but the Round Bay West, Round Bay North, and Severn Narrows show remarkably consistent bottom anoxia throughout July and August. Bottom water samples retrieved from these stations contained readily detectable hydrogen sulfide, which is produced by anaerobic bacteria when no oxygen is available for weeks and is unstable in the presence of oxygen. Our data show that the lower Severn (where the DNR monitors the Severn at the Route 50 bridge) rarely shows bottom anoxia, while the upper Severn is dramatically impacted. It is fair to say that our monitoring efforts have described a



new Severn dead zone that is separate from the Chesapeake's deeper anoxia. Monitoring efforts in the neighboring Magothy River have not revealed similar persistent summer bottom anoxia, and 2010 data from South River Keeper Diana Muller show some bottom anoxia there, but not as persistent or extensive as we find in the Severn (D. Muller, personal communication).

Fish kill on the upper Severn

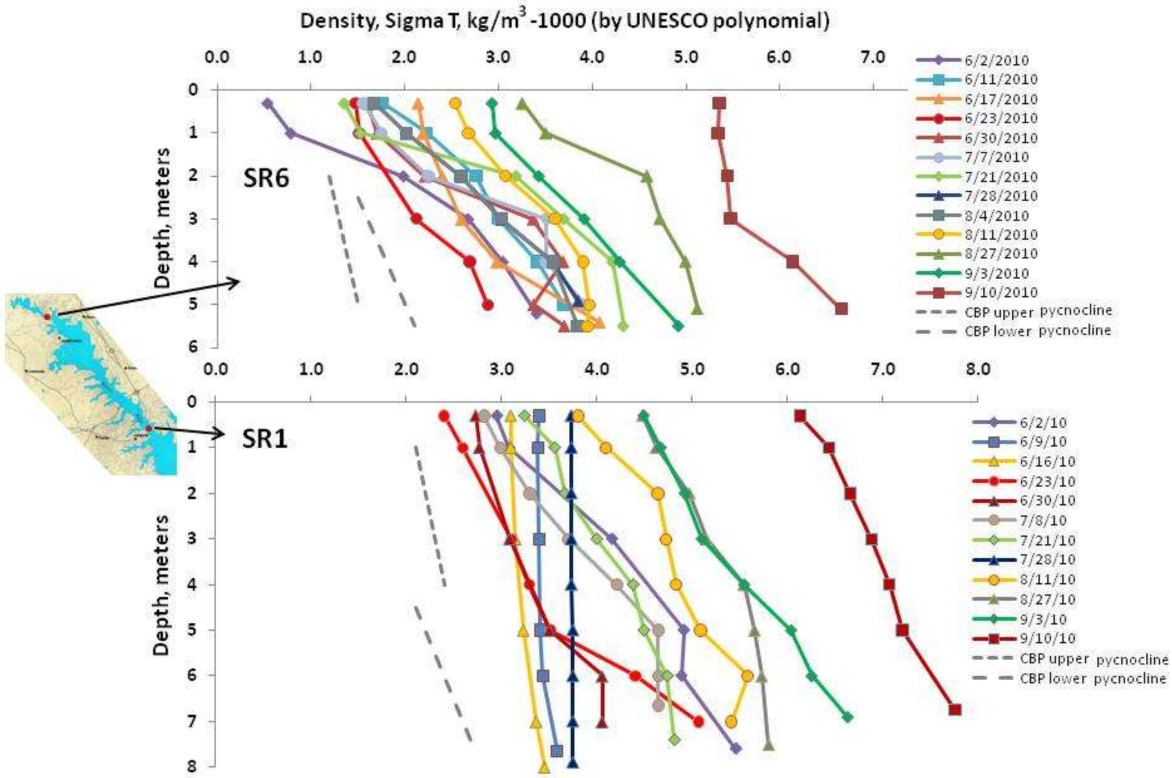
On the morning of July 26, 2010, a fish kill occurred in northern Round Bay and the upper Severn. Responding to a call from Mike Robinson in the Arden community, I went with him to two nearby beaches on the upper Severn, where dead fish were present at the shoreline, as shown in this photo (most of these are juvenile spot). Residents reported that many more dead fish were on the beach earlier in the day, but rising tide had washed most away by the time we arrived after 3 pm. At the end of a pier close to where this photo was taken, we measured dissolved oxygen levels of <0.2 mg/liter at depths from 1.5 meters to the bottom at 2.3 meters, with normal near-saturation levels close to the surface. In response to another resident, the Maryland Department of the Environment sent an investigator to a nearby beach where they estimated over 22,000 anchovy, 5000 menhaden, and other fish had been killed. MDE reported evidence of a modest phytoplankton bloom at the affected beach.

It seems likely that this fish kill resulted from temporary anoxic conditions that precluded escape of these fish. There is no evidence for other known causes of fish kills (toxic phytoplankton, chemical spills, etc), and the following speculation appears to be the best explanation. The affected beaches were within .5 miles of our SR6 monitoring station, where on July 14 and 21 we found anoxic water starting at 2 meters below the surface, down to the bottom at 5.5 meters. This anoxic water mass may have shifted towards the affected beaches. Combined with night-time oxygen depletion by resident phytoplankton near the surface, complete water column anoxia may have developed in local areas, resulting in this fish kill.

The Severn Pycnocline and the Chesapeake Bay Program's "Redesignation"

The US Clean Water Act provides for controlling non-point source nutrient pollution via a "Total Maximal Daily Load" (TMDL) provision that requires affected regions to set water quality standards and carry out monitoring to assess whether local water quality has met these standards. In the case of dissolved oxygen, the Chesapeake Bay Program has recognized that deeper water in the Chesapeake Bay has long suffered from hypoxia because of physical limitations to vertical mixing imposed by pycnoclines. Pycnoclines are common in estuaries, where rapid vertical changes in water density occur due to lighter fresher water layering on top of the saltier water intruding up the estuary from the ocean. Pycnoclines are a physical restraint on the vertical mixing of well-oxygenated surface water that can supply deeper areas with atmospheric oxygen. Wave-induced mixing serves to oxygenate the upper portion of the water column, but its potency diminishes with depth. The Chesapeake Bay Program has defined 5 mg/liter dissolved oxygen as a Clean Water Act goal for most of the Chesapeake except the deeper water below the pycnocline, which they have defined as particular quantitative vertical density changes that can be calculated from salinity and temperature monitoring data. It was initially assumed that relatively shallow Chesapeake tributaries like the Severn would not have pycnoclines, and would be required to restrain watershed nutrients until the 5 mg/liter DO goal was attained. In 2010 the Chesapeake Bay Program proposed to "redesignate" the Severn's dissolved oxygen attainment criterion to a "deep channel" criterion of 3 mg/liter based on newly considered monitoring data suggesting a pycnocline. The CBP appears to assume that the physical forces promoting vertical mixing in tributaries like the Severn are the same as those in the Chesapeake mainstem. There is no generally accepted quantitative criterion for pycnocline density gradients that withstand vertical mixing in the oceanographic literature, and it is not clear that Chesapeake mainstem criteria should be applied to Chesapeake tributaries like the Severn.

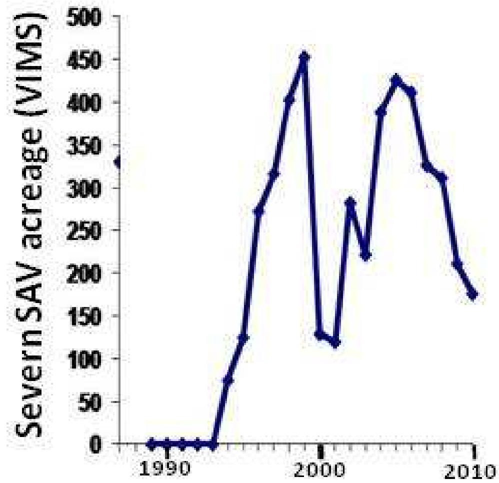
For this reason these two criteria were compared in first dissolved oxygen figure above. The relevant CBP "redesignation" memorandum is included in the Appendix to this report, along with my comments in response to this "redesignation". A number of important aspects of this issue were not clear from the CBP memorandum, and with help from physical oceanographer Dr. Andrew Muller of the US Naval Academy, I have calculated water density based on our 2010 Severn monitoring data. Density/depth profiles are shown on the next page for our monitoring stations near the head of the Severn and off the US Naval Academy.



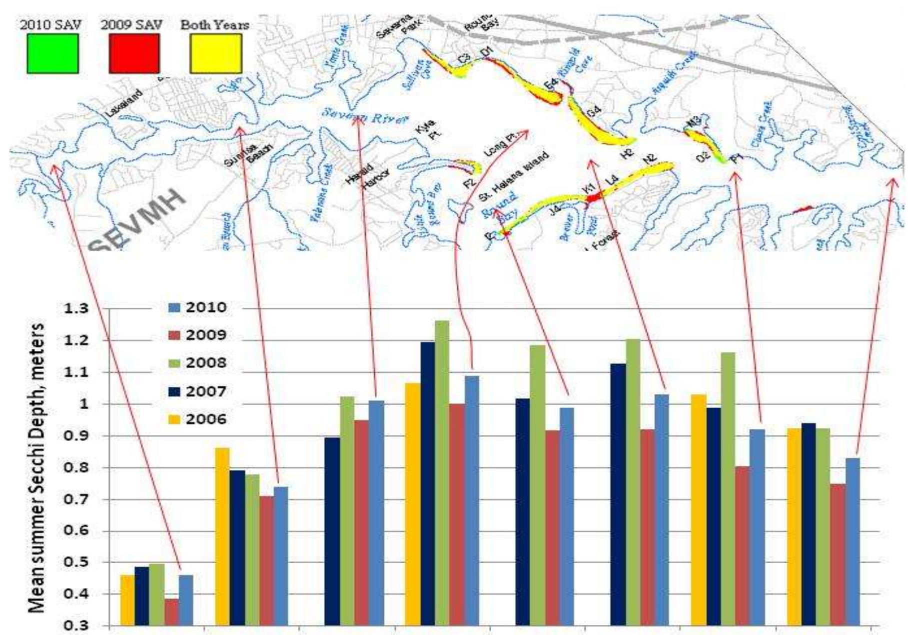
The dashed lines show the density gradients used by the Chesapeake Bay Program to delineate upper and lower pycnocline boundaries in the Chesapeake mainstem. These density profiles show that the Severn does have significant density layering that can retard vertical mixing, and Severn density gradients often exceed those used by the Chesapeake Bay Program to define mainstem pycnoclines. The density profiles at SR6 are on average steeper that those at SR1, compatible with the greater influence of local freshwater lowering surface salinity at this station. At SR1 we found little or no density layering on June 9, 16, and July 28, but most other days showed density gradients greater that the CBP "upper pycnocline" levels for at least some part of the water column. Thus it is reasonable that these density gradients be considered in setting dissolved oxygen attainment goals for the Severn. However, the "redesignation" memo from the Chesapeake Bay Program justifies the proposed 3 mg/liter DO standard on the basis of calculations by their water quality model that achievable nutrient limitations would raise Severn DO levels above this new standard. Unfortunately there is no way the public can access this model to make a judgment as to whether these calculations are reasonable. The CBP water quality model appears to have been constructed largely to account for Chesapeake mainstem monitoring data, and this model does not appear to predict the presence of extensive bottom hypoxia/anoxia we have found over the last five summers in the upper Severn.

Water Clarity

Our monitoring program uses the traditional simple measurement of surface water clarity, the Secchi disk. In the Chesapeake, water clarity is compromised by phytoplankton and by sediment, which comes from the watershed during rain events or is resuspended from bottom deposits. In recent years, substantial beds of submerged aquatic vegetation (SAV) have grown along the shores of Round Bay and adjacent parts of the Mid-Severn. This resurgence of historic Severn SAV growth is striking, given the complete absence of summer SAV from the 1970s until the mid-1990s. The Virginia Institute of Marine Science has conducted aerial surveys of SAV throughout the Chesapeake, and its estimates of SAV acreage in the Severn are shown in this figure. The striking drop in Severn SAV in 2000 was caused by a major spring phytoplankton bloom that clouded the water for weeks, but recovery occurred again with a recent maximum in 2005 followed by a decline continuing in 2010. The Severn SAV growth is particularly interesting because the Severn's southern neighbor tributaries, the South, Rhode, and West Rivers have no summer SAV growth, while the Magothy has some diminishing areas of growth but only a small fraction of the Severn's area.



While our monitoring program was not designed with SAV in mind, over the last 5 years our data have shown a general spatial correlation of Secchi water clarity with regions of SAV growth. This figure shows that the Severn's best water clarity occurs in the mid-Severn and Round Bay, which is where the VIMS



mapping shows SAV growth. However, the declining SAV growth from 2006-2010 does not correlate with our varying annual summer average water clarity measurements, and in particular we observed a slight increase in water clarity from 2009 to 2010 while the SAV acreage declined. However, our monitoring stations are mostly not close to the Severn SAV beds, and it may well be that water clarity is only one of the major factors limiting SAV growth in the Severn. While SAV needs clear water to allow light for photosynthesis, other agents including epiphytic algae and pathogens can compromise SAV viability.

Conclusions

The fifth summer of monitoring the Severn's dissolved oxygen, salinity, temperature and water clarity have yielded data quite similar to those obtained in the previous four years. Our most striking finding of bottom anoxia throughout the northern Severn appears to be a regular summer event, and monitoring by others on neighboring tributaries has not shown similar anoxia that persists throughout the summer months. The bottom anoxia we have found is incompatible with a viable benthic community of clams, worms, etc, which in turn comprises a major resource for crabs and fish. Our bottom anoxia data are supported by the very limited Severn sampling of the Chesapeake Bay Program's benthic monitoring program, which reported that in 2009 the benthic community was "severely degraded" (its worst category) at upper Severn sites near our RBN and SR5 stations, and "acceptable" near our SR2, Route 50 bridge station (2010 results not currently available).

The level of hypoxia/anoxia in water is determined by a balance of bacterial metabolism depleting oxygen and re-oxygenation due to vertical mixing from above. Our calculations of Severn water density profiles provide an insight into the latter re-oxygenation process because vertical mixing is limited by density gradients in the water column. Unfortunately we do not have data that gives insights into the Severn's nutrient-driven growth of phytoplankton, which are the cause of oxygen depletion at the bottom when dead phytoplankton drive bacterial growth. It may be that nutrient loading into the Severn is greater than nutrient loading of neighboring tributaries, either from the local watershed or from the Susquehanna via the Chesapeake. Meaningful nutrient data to address this issue are technically demanding and expensive, and it is hard to envision how such monitoring could be achieved in the Severn.

Acknowledgments

Our monitoring program is sponsored by Severn Riverkeeper Fred Kelly, who over five summers has continued to support this effort by providing the monitoring boat and fuel, monitoring meters, and monitoring personnel in the form of interns and volunteers. During these 5 summers, interns Nathan Frankoff and Aaron Canale accompanied me on most monitoring trips, collecting data, manning the boat, and inputting data into Excel; their skill in maintaining data accuracy is apparent when the raw data is scrutinized. A number of volunteers were also vital to our monitoring efforts, particularly Mike Robinson.

Our efforts have been made possible by the financial support of many individuals to the Severn Riverkeeper program, as well as the following institutional donors: ERM Foundation, Rathman Foundation, Koons Toyota, Baldwin Homes, Reliable Contracting, Constellation Energy. Without their support our monitoring project could not continue.

I also thank Dr. Andrew Muller of the Oceanography Department of the US Naval Academy, and South Riverkeeper Diana Muller for valuable advice on several aspects of the 2010 monitoring effort. In addition to useful discussions, they accompanied one of our monitoring trips in 2010, allowing us to gain confidence in our dissolved oxygen data by comparisons with a more sophisticated meter.

Appendix 1

Application of the Deep-Water Designated Use to the Severn River: Technical Basis and Justification

U.S. EPA Chesapeake Bay Program Office
Annapolis, Maryland

August 27, 2010

Background

In its May 2010 Criteria Addendum, EPA provided technical evidence that application of deep-water and deep-channel designated uses is appropriate under conditions of episodic stratification of the water column, as documented by presence of a pycnocline (U.S. EPA 2010). Within that document, EPA recommended the application of a summer (June-September) deep-water designated use in the South and Magothy rivers at times when a pycnocline is observed.

The following describes conditions under which the deep-water and deep-channel designated use habitats should apply in the lower regions of tidal rivers and the mainstem Chesapeake Bay (U.S. EPA 2003).

The Deep Water designated use applies to regions where density-induced stratification prevents the physical exchange of oxygen between the surface and deeper layers of water, and the deeper layer is also not re-oxygenated by riverine or oceanic sub-surface flow.

The Deep Channel designated use applies to the very deep water-column and adjacent bottom surficial sediment habitats located principally in the river channel at the lower reaches of the major rivers and along the spine of the middle mainstem of the bay. This use is intended for depths below the Deep Water designated use (i.e. below the lower boundary of the pycnocline), at which seasonal anoxic to severe hypoxic conditions routinely set in and persist for extended periods of time under current conditions.

These designated use categories were originally applied to a small number of segments located in the mesohaline (>5-18 ppt salinity) and polyhaline (>18 ppt salinity) regions of the mainstem and the lower regions of some of the larger tidal tributaries.

In the Fall of 2009, a question arose regarding the applicability of the deep-water and deep-channel designated use habitat categories to additional regions of the Chesapeake Bay and its tidal tributaries (U.S. EPA 2010). While conducting simulations of various nutrient load reduction scenarios in order to identify target nutrient load reductions for the Chesapeake Bay TMDL, Chesapeake Bay Program Office modelers and analysts identified regions where simulated nutrient load reductions did not generate improved dissolved oxygen (DO) concentrations. In some of these regions, it was postulated that a physical constraint – stratification of waters in the summer months – provides a physical barrier that prevents the lower water column from reaching sufficient DO concentrations to attain the open-water dissolved oxygen criteria, even when nutrient loads are reduced dramatically from existing levels.

In response, the EPA Chesapeake Bay Program Office's monitoring and analysis team was asked by the Bay Program's Water Quality Goal Implementation Team to conduct a review of summer stratification and persistent hypoxia in the tidally influenced portions of the Chesapeake Bay and its tributaries. Given that a thorough review of all tidal segments would require several months, the monitoring and analysis team proposed to conduct the review in two phases. Phase 1 would focus on only those "high priority" mesohaline and polyhaline segments (in keeping with the aforementioned "lower reaches") demonstrating both evidence of stratification using a preliminary automated, standardized screening method and persistent hypoxia under nutrient reduction scenarios (U.S. EPA 2010). Phase 2 would comprise a more thorough review of the presence of stratification-induced hypoxia in all tidally influenced segments of the Chesapeake Bay and its tributaries. The mesohaline and polyhaline segments listed in Table 1 showed preliminary evidence of episodic stratification and hypoxic conditions.

Table 1. Mesohaline and polyhaline segments which showed preliminary evidence of episodic stratification and hypoxic conditions.

River	Segment
Elizabeth River	EBEMH
Elizabeth River	WBEMH
Rappahannock River	CRRMH
Fishing Bay	FSBMH
Wicomico River	WICMH
Magothy River	MAGMH
Severn River	SEVMH
South River	SOUMH
West River	WSTMH
York River	YRKMH

Using the results from load reduction scenarios conducted in the Fall of 2009, it was determined that in 8 out of these 10 segments, DO concentrations were responding to nutrient load reductions, resulting in attainment of the dissolved oxygen water quality standards at or before draft "Target Load" nutrient reduction levels. These 8 segments were thus relegated to "Phase 2" review, to commence sometime after July 1, 2010. At the time, only two segments—Magothy (MAGMH) and South River (SOUMH)—showed persistent non-attainment with reduced loads and were thus considered for "Phase 1" (i.e. immediate) review (U.S. EPA 2010). Note that the mesohaline Severn River (SEVMH) showed attainment of the open-water designated use for the critical period being used at the time (1996-1998) at draft "Target Load" nutrient reduction levels of 198 million pounds per year (mpy) TN and 14.8 mpy TP (see Figure 1).

Figure 1: Plot showing attainment of all but the Magothy River (MAGMH) and South River (SOUMH) open water DO designated uses at the “Target Load” scenario given methods and allocations in use in Ocotober 2009.

Cbseg	1985 Scenario 420TN 28.4TP '96-'98 DO Open Water Summer Monthly	91 -'00 Base Scenario 340TN 24.1TP '96-'98 DO Open Water Summer Monthly	Intermed iate B Scenario 279TN 17.2TP '96-'98 DO Open Water Summer Monthly	Loading Scenario 236TN 21.1TP '96-'98 DO Open Water Summer Monthly	Intermed iate A-C Scenario 222TN 17.4TP '96-'98 DO Open Water Summer Monthly	Intermed iate A Scenario 209TN 13.7TP '96-'98 DO Open Water Summer Monthly	Target Load Scenario Option 3 198TN 14.8TP '96-'98 DO Open Water Summer Monthly
EBEMH	32.5%	16.6%	0.0%	0.0%	0.0%	0.0%	0.0%
WBEMH	6.1%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%
CRRMH	10.8%	9.6%	1.5%	0.0%	0.0%	0.0%	0.0%
FSBMH	4.6%	4.6%	0.0%	0.0%	0.0%	0.0%	0.0%
WICMH	33.8%	32.3%	0.0%	0.0%	0.0%	0.0%	0.0%
MAGMH	10.0%	1.3%	5.1%	5.1%	5.1%	1.5%	2.6%
SEVMH	8.9%	0.5%	2.3%	0.0%	0.0%	0.0%	0.0%
SOUMH	15.9%	0.0%	13.5%	9.8%	9.8%	9.8%	8.4%
WSTMH	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
YRKMH	34.9%	25.7%	1.6%	0.4%	0.0%	0.0%	0.0%

The Chesapeake Bay Program Office monitoring and assessment team therefore focused their analyses on MAGMH and SOUMH, the two segments showing persistent non-attainment at the draft “Target Load” level of load reductions. As described in the 2010 EPA Bay criteria addendum (U.S. EPA 2010), frequent episodic occurrence of stratification was found in these regions over the 10-year period investigated (1991-2000). Specifically, in the South River an upper pycnocline boundary was observed for 39 out of 43 sampling events (91%) between 1991-2000, and in the Magothy River an upper pycnocline boundary was observed for 16 out of 40 sampling events (40%).

After reviewing the combined findings of the monitoring and assessment team regarding episodic stratification coincident with hypoxic conditions, the Chesapeake Bay Program’s Criteria Assessment Protocol (CAP) workgroup recommended to the Water Quality Goal Implementation Team that a “summer deep-water” designated use be added to the MAGMH and SOUMH segments for application in the presence of episodic pycnoclines.

Application of the Deep Water Designated Use To SEVMH

In the time between Fall 2009 and the publication of the 2010 EPA Bay criteria addendum in May, the EPA Chesapeake Bay Program’s Water Quality Goal

Implementation Team started applying the recommended revised dissolved oxygen criteria assessment procedures described in the Bay criteria addendum. In addition, the Water Quality Goal Implementation Team changed the “critical period” for standards attainment from 1996-1998 to 1993-1995 based on new information and recommendations. A new set of nutrient load reduction scenarios and results were generated. When these modifications were implemented, the assessment results for the Severn River segment (SEVMH) changed, showing persistent non-attainment at the newly identified draft target load nutrient reduction level of 190 mpy TN and 12.7 mpy TP (see Figure 2).

Figure 2. Plot showing non-attainment of some open water segments with updated models and revision of the “critical period” from 1996-8 to 1993-5. SEVMH now shows persistent non-attainment at the new draft global target load of 190 TN, 12.7TP.

Cbseg	1985 Scenario 342TN, 24.1TP, 9790TSS '93-'95 DO Open Water Summer Monthly	"91 -'00 Base Scenario 309TN, 19.5TP, 8950TSS '93-'95 DO Open Water Summer Monthly	2007 Scenario 254TN, 17.1TP, 6498TSS '93-'95 DO Open Water Summer Monthly	Tributary Stategy 191TN 14.4TP, 6462 TSS '93-'95 DO Open Water Summer Monthly	190 Loading Scenario 190TN 12.6TP, 6030TSS '93-'95 DO Open Water Summer Monthly
EBEMH	23%	23%	21%	0%	0%
WBEMH	15%	11%	15%	8%	8%
CRRMH	40%	25%	0%	0%	0%
FSBMH	0%	0%	0%	0%	0%
WICMH	11%	11%	11%	5%	5%
MAGMH	1%	1%	1%	0%	0%
SEVMH	20%	16%	9%	6%	6%
SOUMH	0%	0%	0%	0%	0%
WSTMH	9%	0%	0%	0%	0%
YRKMH	18%	24%	7%	1%	1%

As a result of these changes, the Severn River (SEVMH) segment now met the criteria for the “Phase 1” group of segments – demonstrating both preliminary evidence of stratification and lack of sufficient response to nutrient load reductions – and was moved from the “Phase 2” review category to “Phase 1.” A more thorough review of stratification in SEVMH showed persistent dissolved oxygen concentrations less than 5 mg/L coincident with episodes of stratification between the surface and deeper waters (i.e. presence of an upper pycnocline boundary). Specifically, stratification was observed in 6 out of the 7 summer months from 1993-1995 during which dissolved oxygen concentrations failed to achieve the monthly average of 5 mg/L necessary for full attainment of the open-water dissolved oxygen criteria (Table 2). Note that insufficient DO concentrations persisted at dramatically reduced TN and TP loads, as far as 170 mpy TN and 11.3 mpy TP.

Table 2. Open-water dissolved oxygen criteria non-attainment for observed and model simulated (170 million pounds TN, 11.3 TP scenario) for 1993-1995 under episodic presence of a pycnocline.

Severn River Year	Month	Observed Percent Non-attainment	170 TN/11.3 TP Scenario Percent Non-attainment	Pycnocline observed
1993	6	25.9%	0.0%	yes
1993	7	25.4%	25.4%	yes
1993	8	14.0%	0.0%	yes
1993	9	0.0%	0.0%	no
1994	6	25.4%	25.4%	yes
1994	7	14.0%	1.8%	no
1994	8	14.0%	0.0%	yes
1994	9	24.6%	3.6%	yes
1995	6	40.0%	4.8%	yes
1995	7	14.0%	0.0%	yes
1995	8	57.5%	57.5%	yes
1995	9	40.0%	40.0%	yes

Further review revealed that over the course of 75 summer monitoring cruises during the 1991-2000 Bay TMDL hydrological period, an upper pycnocline boundary was observed 44 times, or for 58% of observations.

As a result of this review, EPA now recommends application of the deep-water designated use to the Severn River (SEVMH) segment when an upper pycnocline boundary is present (as determined by the standardized method for locating pycnocline boundaries described in U.S. EPA 2008).

Literature Cited

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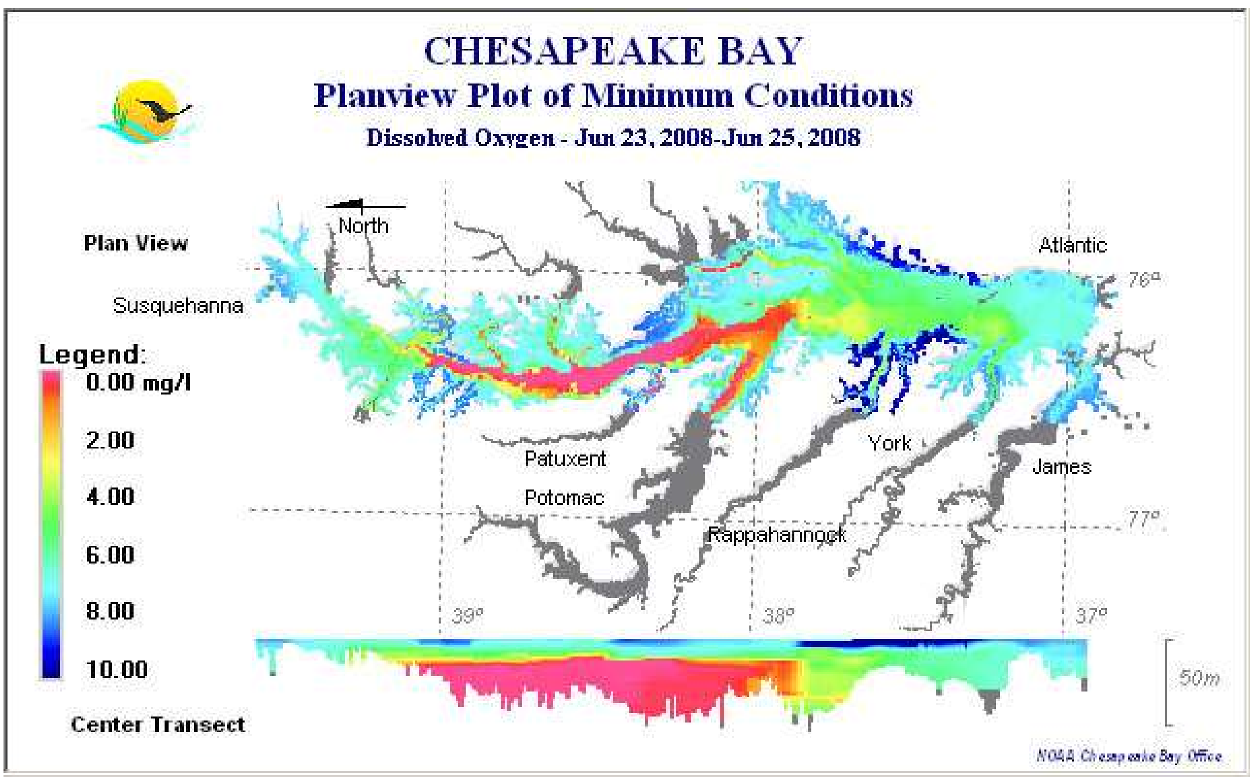
Issues regarding the 8/27/2010 EPA "re-designation" of the Severn River from "open water" to "deep water"
Comments from Pierre Henkart, 10/8/2010

I have been interested in dissolved oxygen in the Severn as a result of the Severn Riverkeeper Monitoring Project that I began 5 years ago. Each year from May through September, we have used YSI-85 meters to measure depth profiles of dissolved oxygen, salinity, and temperature at 15 stations up and down the Severn on a weekly or biweekly schedule. An unexpected and dramatic finding has been persistent summer bottom anoxia (DO<0.2 mg/liter) throughout northern Severn every year. This anoxia was first described by EPA's 1997 MAIA-E project, and subsequently supported by sporadic random CBP-sponsored BIBI monitoring since then. Our program has found this anoxia to be an annual persistent summer event, readily confirmed in the late summer by the presence of hydrogen sulfide in water samples over a meter from the bottom.

While I recognize that regular DNR and CBP monitoring programs do not sample the Severn above the Route 50 bridge, it was a particular surprise to find the following CBP graphic published in the Annapolis Capital. It



appeared that the CBP had determined that the upper Severn had >5 mg/liter bottom dissolved oxygen when our own readings at five stations in this area on June 27, 2008 each showed OVER TWO ORDERS OF MAGNITUDE lower dissolved oxygen concentrations near the bottom (http://www.severnriverkeeper.org/data/08MonitoringCumulative.xls). My efforts to resolve this issue were met with the response that this was what the CBP model showed and maybe the CBP should have grayed out tributaries such as the Severn. It appears that the model designers extrapolated data from CBP mainstem stations into the Severn. CBP's failure to follow up this failure of their obviously flawed water quality model leads to the strong suspicion that current CBP models continue to extrapolate Chesapeake mainstem and lower tributary data up into the tributaries, ignoring both basic estuary science and available data that conflicts with their model. This background may help you understand the skeptical attitude towards CBP models reflected in my specific comments on the Severn re-designation issue which follow.

The goal of the Severn re-designation is to provide dissolved oxygen standards that are attainable with achievable modeled nutrient load reductions. I support this goal but am concerned that some aspects of this decision are not based on good science.

1. The basis for the model's calculation of the Severn's nutrient loads is not clear. In light of the persistent summer bottom anoxia in the northern Severn, the role of benthic nutrient recycling needs to be addressed. Kemp et al (Mar Ecol Prog Ser 303:1) have shown that both phosphate and nitrogen recycling increase as bottom DO approaches anoxia. The Severn may experience a greater impact from benthic nutrient recycling than other tributaries because of its more pronounced hypoxia/anoxia. This source of nutrients needs to be considered in modeling the Severn's nutrient inputs. Diminished watershed-derived nutrients in response to increased local regulations may not be a dominant influence on measured DO levels at Severn station WT7.1.

2. I have wondered for years how much of the nutrients that drive phytoplankton growth in the Severn are derived from the local watershed and how much are derived from the Susquehanna. I have little doubt that most of the nutrients in the tidal creeks and the very uppermost Severn come from local freshwater inputs. However the WT7.1 monitoring station where relevant monitoring data is being considered seems to be another matter. This station is 3 miles from the Bay and 7 miles from the Severn's major freshwater source (Severn Run). Salinity data make it clear that most of the water at WT7.1 comes from the Bay. My chief concern is with the complete annual replacement of the Severn's waters in the late winter/spring with fresher water largely derived from the Susquehanna, as described by Schubel and Pritchard in 1986 (Estuaries 9:236). This phenomenon has been confirmed in the Severn by Maryland DNR monitoring (http://mddnr.chesapeakebay.net/eyesonthebay/april_salinities.html) as well as by our Severn Riverkeeper monitoring project. The question then becomes to what extent this freshet contributes nutrients for phytoplankton growth leading to hypoxia at monitoring station WT7.1. The nutrient contributions from the mainstem to the Severn during the remaining spring/summer months when saltier Bay water gradually displaces fresher Severn waters may also be significant, but seem likely to be less of an issue. I do not have answers to these questions, but am concerned that the model used in the redesignation decision did not address mainstem nutrient contributions to the Severn. Analysis of the limited available nutrient monitoring data by established experts in this area should provide estimates of the extent of mainstem nutrient contributions to all tributaries in the northern Chesapeake. Failure to do so leaves us imagining that local burdensome regulations might eventually lower nutrients from the local watershed without a commensurate response in the Severn monitoring data because Susquehanna nutrients continue unabated.

3. The CBP has defined "deep water" and "deep channel" designated use zones in the Chesapeake mainstem on the basis of vertical density gradients that resist vertical mixing, with the consequent

assignment of lower dissolved oxygen restoration thresholds (Batiuk, et al, J.Exp.Mar Biol. Ecol. 381: S204). Although this policy makes scientific sense and appears to have been generally accepted by the Chesapeake scientific community, the pycnocline definitions used by the CBP (EPA 903-R-08-001; CBP/TRS 290-08) are based on experience with the Chesapeake mainstem. This is reasonable since there is no universally recognized quantitative pycnocline definition in oceanography. However, re-designation of the Severn River from “open water” to “deep water” raises the general question of whether the same vertical density gradient thresholds that have been used in the Chesapeake mainstem are applicable to Chesapeake tributaries, and specifically the Severn. The ability of pycnoclines to resist re-oxygenation from the surface depends on the forces promoting vertical mixing, and the critical question becomes whether those forces are equivalent in the Chesapeake mainstem and the relevant tributaries. For the Severn, we need to consider at least three factors: a) The mean tidal difference in the Severn is close to the lowest of all Chesapeake tributaries, so that turbulence induced by low horizontal tidal flows is expected to be lower than in the mainstem; b) On the other hand, the shallow depth of the Severn may cause more shearing of those low flows than would occur in deeper waters of the mainstem; c)The Severn’s narrow width gives its waters shelter from the winds found in the mainstem. Any sailor will tell you that winds at the Route 50 bridge (WT7.1) are less than those in the Bay east of Annapolis. Studies by Malcolm Scully (Estuaries 28:321) suggest that the locally predominant southerly summer winds in the Chesapeake are important factors in promoting vertical mixing. These effects would be expected to be less in calmer Severn waters than in nearby Chesapeake mainstem locations. Such factors as these need to be considered before applying mainstem criteria for the strength and character of pyncoclines needed to resist vertical mixing to Chesapeake tributaries. Other (non-pycnocline) methods of characterizing stratification of the water column might well give more meaningful measures of its ability to resist vertical mixing. I see no indication that such considerations have been made in re-designating the Severn from “open water” to “deep water”, where mainstem-based criteria have been applied without considering the Severn’s very different physical characteristics. Indeed the “deep water” term itself is indicative of the lack of consideration being paid to the unique attributes of tributaries such as the Severn. The professional opinion of physical oceanographers who have studied estuarine dynamics and published in peer-reviewed journals should be considered before applying Chesapeake mainstem criteria to tributaries such as the Severn.

4. It is not clear from your document whether the Severn’s deep water 3 mg/liter DO threshold will be applied to the whole water column whenever a pycnocline is deemed to be present, or only to measurements below the “upper pycnocline”. Needless to say, the former possibility makes no scientific sense, while the latter brings back the pycnocline issue discussed above.

5. The magnitude of modeled target nutrient load reductions that are deemed reasonable is obviously a judgment call by the CBP, but is central to the justification of the proposed re-designation. I agree with the need to set attainable nutrient reduction goals that would be reflected in improved water quality monitoring data, but the August 27 document does not provide enough information for outsiders to make an informed judgment as to whether the modeled nutrient reduction numbers chosen by the CBP are reasonable in their own view. This is another facet of the general problem that pervades the August 28 re-designation document: we are being asked to accept conclusions derived from a complex model

whose basic inputs and assumptions are not clearly described. While I agree that a modeling approach is needed to formulate regulations designed to moderate nutrient inputs, I question the model being used is appropriate for the Severn River, and can't help wondering if meaningful scientific peer review has been applied to the August 27 document.

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