Martin O'Malley, Governor
John R. Griffin, Secretary

Lower Eastern Shore Water Quality and Habitat Assessment

Maryland Department of Natural Resources
Tidewater Ecosystem Assessment

Tawes Building, D-2, 580 Taylor Avenue
Annapolis, MD 21401
http://dnr.maryland.gov

Toll Free in Maryland:
1-877-620-8DNR, ext: 8630
Out of state call: 410-260-8630
TTY users call via the MD Relay:
711 (within MD)
Out of state call: 1-800-735-2258

Martin O'Malley, Governor

Anthony G. Brown, Lt. Governor

Primary Author:

Renee Karrh rkarrh@dnr.state.md.us
Diana Domotor

Contributors:

Diana Domotor, Rebecca Golden, Lee Karrh, Brooke Landry, William Romano, Brian Smith, Ben Cole, Sherm Garrison, Thomas Parham, Mark Trice

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Acknowledgements:

Information on the water and habitat quality of Maryland's rivers and bays is available due to the hard work of many dedicated staff including:

- staff who are in the field collecting the samples year-round, sometimes under less than desirable weather conditions
- laboratory staff who perform the chemical tests to determine what exactly is in those water samples
- data management staff who collect the resulting information, confirm the accuracy and quality of the data, and organize and maintain the databases and
- analytical staff who interpret the data to answer the question 'how is the river/Bay doing?'

There are too many individuals to directly name from more than 25 years of monitoring, so we simply wish to commend all of them for their commitment to collecting high quality information and making it available and useful to the citizens of Maryland.

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Overall Condition

Healthy rivers and bays support a diverse population of aquatic life as well as recreational uses, such as swimming and fishing. To be healthy, rivers and bays need to have good water and habitat quality. High levels of nutrients and sediments lead to poor water quality. Poor water quality reduces habitat quality, including water clarity (how much light can get to the bottom) and the amount of dissolved oxygen in the water. In turn, habitat quality affects where plants and animals can live. The Maryland Department of Natural Resources (DNR) is responsible for monitoring water and habitat quality in the Chesapeake Bay and rivers, as well as the health of aquatic plants and animals. DNR staff use this information to answer common questions like "How healthy is my river?", "How does my river compare to other rivers?", "What needs to be done to make my river healthy?" and "What has already been done to improve water and habitat quality in my river?"

The Lower Eastern Shore basin includes five major rivers and four embayments. Overall, this basin is dominated by agricultural land use and has a low to medium human population density in most areas. Negative impacts from urban land use, percent impervious surface and waste-water treatment plants are much lower than in the Western Shore rivers. Despite the similarities overall among the Lower Eastern Shore rivers, there are differences in water and habitat quality conditions due to localized land use and human impacts.

How healthy are the Lower Eastern Shore Rivers?
How do the Lower Eastern Shore Rivers compare to other Maryland rivers?

Chicamacomico River and Transquaking River Water quality is fair because sediment levels are too high and getting worse (Table 1). Habitat for underwater grasses is poor because algal densities are too high and water clarity is poor. Habitat for bottom dwelling animals is good.

The Transquaking River is a 'Low Urban, High Agriculture' river (Figure 1). Nitrogen and phosphorus levels are higher than in most other similar rivers in Maryland (Figure 2). Algal densities are the highest in this land use category and only lower than one other Maryland River (Back River). Sediment levels are moderate but water clarity is very low compared to other rivers. Chicamacomico River is considered part of the Transquaking river system for land use assessments so is not compared separately.

Fishing Bay Water quality is good, with moderate nitrogen and sediment levels and low phosphorus levels. Habitat quality for underwater grasses is fair but water clarity is poor. Underwater grass beds covered approximately 70% of the restoration goal area in 2010, though half of the habitat for bottom animal populations is degraded.

Fishing Bay is in the 'Low Urban, Low Agriculture' category. Nitrogen, phosphorus and sediments levels are moderate compared to similar systems, and low compared to other rivers in

Maryland. Algal densities are moderate. Secchi depths are the lowest in this land use category, but moderate compared to all rivers in Maryland. Bottom dissolved oxygen levels are good.

Table 1. Summary of tidal water quality and habitat parameters.
Algal densities, water clarity, inorganic phosphorus and sediments either ‘Meet’ or ‘Fail’ SAV habitat requirements (Appendix 5). Dissolved nitrogen levels below the level for nitrogen limitation ‘Meet’ criteria, otherwise ‘Fail’ criteria. Summer bottom dissolved oxygen levels above 3 mg/l ‘Meet’ criteria, otherwise ‘Fail’ criteria. Annual trends for 2003-2010 either ‘Increase’ or ‘Decrease’ if significant at $p \leq 0.01$ or ‘Maybe Inc’ or ‘Maybe Dec’ at $0.01 < p < 0.05$; blanks indicate no significant trend. Improving trends are in green, degrading trends are in red. Nitrogen trends are for total nitrogen, phosphorus trends are for total phosphorus, water clarity trends are for Secchi depth. Depth ‘Shallow’ is from the shallow water monitoring program, ‘Open’ is from the long-term monitoring program.

			Water Quality			Habitat Quality		
	Water body	Depth	Nitrogen	Phosphorus	Sediments	Algal densities	Water Clarity	Summer Bottom Diss. Oxygen
Fishing Bay	Chicamacomico	Open	Meet	Meet	Fail Increase	Fail Maybe Inc	Fail	Meet
Fishing Bay	Transquaking	Open	Meet	Meet	Fail	Fail	Fail	Meet
Fishing Bay	FishingBay	Shallow	Meet	Meet	Meet	Meet	Fail	Meet
Fishing Bay	FishingBay	Open	Meet Maybe Dec	Meet Maybe Dec	Meet Decrease	Meet Decrease	Fail	Meet Inc
Nanticoke	Upper	Open	Fail Decrease	Meet Maybe Dec	Fail Decrease	Meet Increase	Fail	Meet
Nanticoke	Middle	Open	Meet	Meet Decrease	Fail Decrease	Meet	Fail	Meet
Wicomico	Upper	Shallow	Fail	Meet	Fail	Fail	Fail	Meet
Wicomico	Upper	Open	Fail Decrease	Meet	Fail	Fail Increase	Fail	Meet
Wicomico	Middle	Shallow	Fail	Meet	Fail	Meet	Fail	Meet
Wicomico	Middle	Open	Meet Decrease	Meet Decrease	Fail	Meet	Fail Inc	Meet
Wicomico	Lower	Shallow	Meet	Meet	Meet	Meet	Fail	Meet
Wicomico	Lower	Open	Meet Decrease	Meet Maybe Dec	Meet Maybe Dec	Meet Maybe Dec	Fail	Meet
Manokin	Upper	Open	Meet	Fail	Fail	Meet	Fail	Meet
Manokin	Lower	Open	Meet Maybe Dec	Meet	Meet Maybe Dec	Meet	Fail Inc	Meet Inc
	Big Annemessex	Open	Meet Decrease	Meet	Meet	Meet	Fail	Meet
Pocomoke River	Upper	Open	Fail Decrease	Fail Maybe Dec	Meet	Meet Maybe Inc	Fail	Meet
Pocomoke River	Middle	Open	Fail	Fail Decrease	Fail	Meet Maybe Inc	Fail	Meet
Pocomoke River	Lower	Open	Meet Decrease	Fail	Fail Increase	Meet	Fail	Meet
	Pocomoke Sound	Open	Meet Maybe Dec	Meet	Meet	Meet Decrease	Fail Maybe Inc	Meet
	North Tangier Sound	Open	Meet Decrease	Meet	Meet	Meet Maybe Dec	Fail	Meet
	South Tangier Sound	Open	Meet Decrease	Meet	Meet	Meet	Meet Maybe Inc	Fail

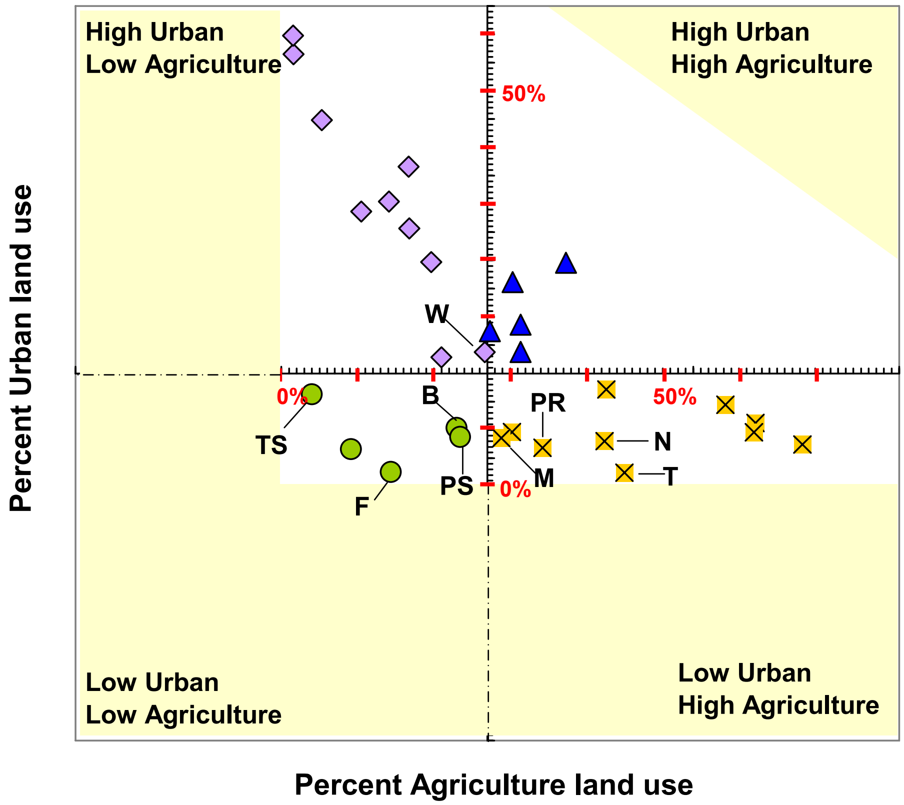

Figure 1. Classification of Maryland rivers and bays by land use.
The medians of all systems percent agriculture and percent urban land use are used to create a grid with four categories. Systems with percent urban less than the median are considered low urban. Systems with percent agriculture less than the median are considered low agriculture. Each system was categorized based on placement on the grid. Note that yellow areas are not mathematically possible (i.e. there is not a negative percent agriculture land use, and it is not possible for percent agriculture + percent urban to be greater than 100%). These groupings were used to evaluate each system relative to other rivers with similar land use characteristics. Abbreviations are: T (Transquaking), N (Nanticoke), W (Wicomico), M (Manokin), B (Big Annemessex), PR (Pocomoke River), F (Fishing Bay), TS (Tangier Sound) and PS (Pocomoke Sound). Chicamacomico River is considered part of Transquaking River for land use assessments and is not compared separately.

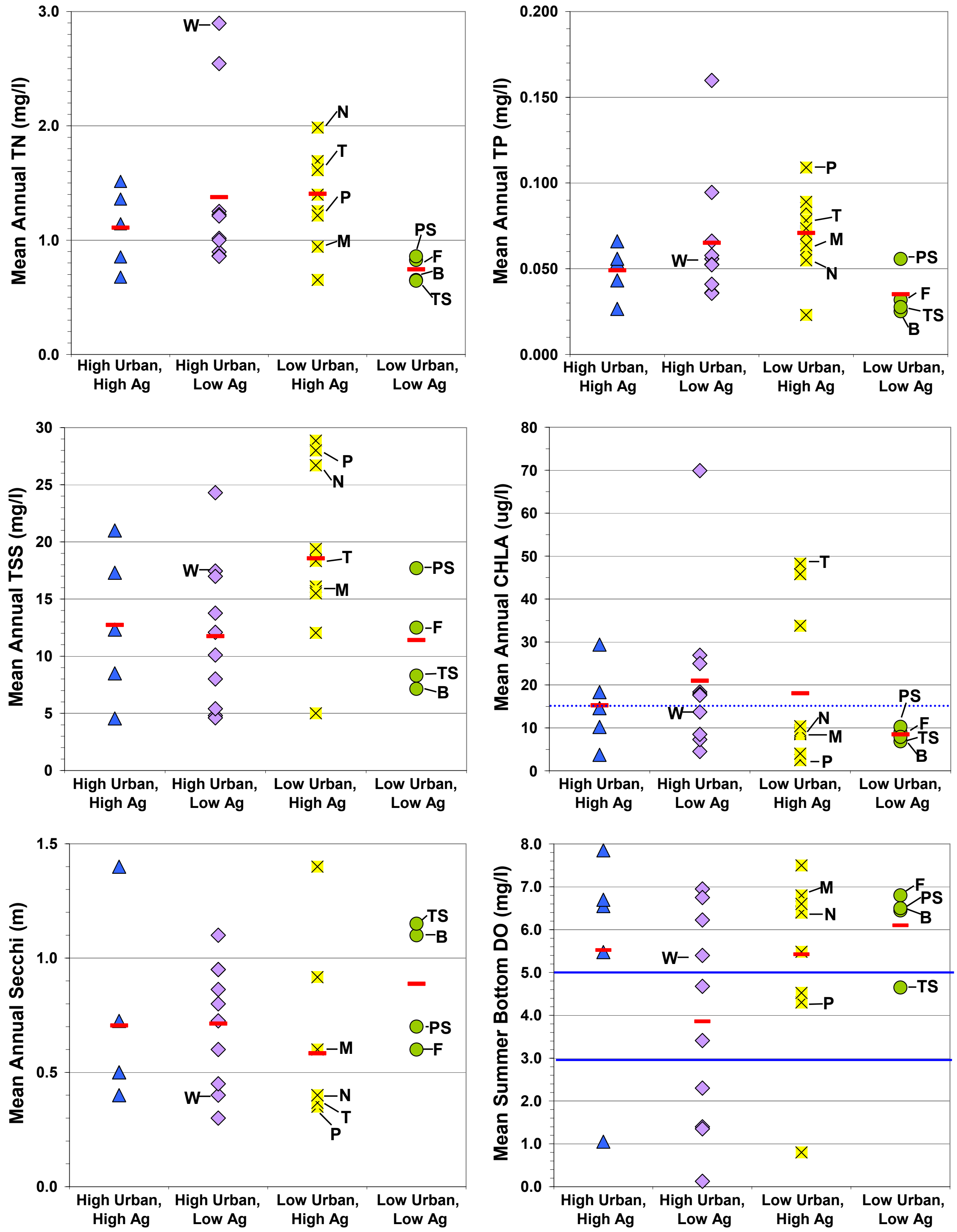

Figure 2. Comparison of the Lower Eastern Shore Rivers to similar systems.
The mean annual level or depth (bottom dissolved oxygen, BDO, is only summer) for 2008-2010 data. Red bars indicate the mean of all systems within a category. Algal densities are measured by chlorophyll a (CHLA) levels. Water clarity is measured by Secchi depths. Reference lines are included on the CHLA and BDO graphs. Abbreviations are: T (Transquaking), N (Nanticoke), W (Wicomico), M (Manokin), B (Big Annemessex), PR (Pocomoke River), F (Fishing Bay), TS (Tangier Sound) and PS (Pocomoke Sound).

Nanticoke River Water quality is poor in the upper river due to high nitrogen and sediments levels. Water quality is fair in the middle river but sediments levels are too high. Water quality has improved due to decreases in nitrogen, phosphorus and sediment levels. Habitat quality for underwater grasses is poor because water clarity is poor and algal densities increased. Habitat quality for bottom dwelling animals is degraded and has gotten worse. No underwater grasses have been found in the Nanticoke.

Nanticoke River is a 'Low Urban, High Agriculture' river. Nitrogen and sediments levels are very high in comparison to the other rivers in Maryland and phosphorus levels are moderate. Algal densities are low, but so is water clarity. Bottom dissolved oxygen levels are good.

Wicomico River Water quality is poor in the upper river due to very high nitrogen and high sediment levels. Conditions are better in the middle river but sediment levels are still too high. Water quality in the lower river is good. Nitrogen levels improved throughout the river and phosphorus levels improved in the middle river. Habitat quality for underwater grasses is poor in the upper and middle river due to high algal densities and poor water clarity. Habitat quality for underwater grasses in the lower river is fair but water clarity is poor. No underwater grasses are found in the Wicomico River, and about half of the areas sampled had unhealthy habitat for bottom dwelling animals.

Wicomico River is the only 'High Urban, Low Agriculture' river in the Lower Eastern Shore Basin. Nitrogen levels are the highest among all other Maryland rivers. Phosphorus levels and algal densities are low within this category and moderate compared to other rivers, but sediments levels are high and water clarity is very low compared to similar rivers. Bottom dissolved oxygen levels are good.

Manokin River Water quality is poor in the upper river but good in the lower river. Phosphorus levels are extremely high in the creeks, and sediment levels are also too high. Water quality improved due to decreases in nitrogen throughout the river and sediments in the lower river. Habitat quality for underwater grasses is poor in the upper river and fair in the lower river because water clarity is low but has improved. Underwater grass beds covered approximately 45% of the restoration goal in 2010, and bottom dwelling organisms are healthy.

Manokin River is in the 'Low Urban, High Agriculture' category. Nitrogen, phosphorus and sediments levels and algal densities are low compared to similar systems and moderate compared to all Maryland rivers. Water clarity is moderate compared to similar rivers, and bottom dissolved oxygen levels are good.

Big Annemessex River Water quality is good and improving due to improvements in nitrogen levels. Habitat quality for underwater grasses is fair because water clarity is low. Underwater grass beds only covered 20% of the restoration goal in 2010, but bottom dwelling animals are healthy.

Big Annemessex is a 'Low Urban, Low Agriculture' river. Nitrogen, phosphorus and sediments levels are low or very low compared to other Maryland rivers and water clarity is high. Bottom dissolved oxygen levels are good.

Pocomoke River Water quality is poor due to high nitrogen, phosphorus and sediments levels, especially in the upper and middle river. Nitrogen levels improved in the entire river and phosphorus levels improved in the upper river. Sediments levels have degraded in the middle river and in the lower river over the longer term. Habitat quality for underwater grasses is poor because water clarity is poor and algal densities have increased. Underwater grass beds are almost never seen in the river.

Pocomoke River is in the 'Low Urban, High Agriculture' category. Nitrogen levels are moderate but phosphorus and sediments levels are among the highest. Algal densities are very low as is water clarity. Bottom dissolved oxygen levels are fair but low compared to other Maryland rivers.

Tangier Sound Water and habitat quality is good and nitrogen levels improved. Habitat quality for underwater grasses is fair in North Tangier Sound but water clarity is poor. Habitat quality in South Tangier Sound is good for underwater grasses but fair for bottom dwelling animals because dissolved oxygen level are sometimes too low. Underwater grasses covered less than 20% of the restoration goal in the Maryland portions of Tangier Sound but the amount of area covered with grass beds has been increasing since 2003. Bottom dwelling animals are healthy in Tangier Sound.

Tangier Sound is in the 'Low Urban, Low Agriculture' category. In all measures, Tangier Sound is better than most of the rivers and bays in Maryland. Algal densities in Tangier Sound are low and water clarity is very high in comparison to all of Maryland's rivers and bays. Bottom dissolved oxygen levels are good.

Pocomoke Sound Water and habitat quality is good. Habitat quality for underwater grasses is fair but water clarity is poor. Underwater grasses covered less than 20% of the restoration goal in the Maryland portions of Pocomoke Sound but the amount of area covered with grass beds has been increasing since 2003. Bottom dwelling animals are healthy in about half of Pocomoke Sound.

Pocomoke Sound is in the 'Low Urban, Low Agriculture' category. Pocomoke Sound has low nitrogen levels but moderate phosphorus and sediments levels compared to all rivers and bays in Maryland, but has the highest levels within this land use category. Algal densities are low. Water clarity is moderate compared to all other rivers but low within this land use category. Bottom dissolved oxygen levels are good.

What needs to be done to make the Lower Eastern Shore Rivers healthy?

The biggest water quality issue, shared by almost all the rivers, is poor water clarity. By lowering nutrients and sediments, water clarity should improve which will improve habitat quality for underwater grasses. Reductions in nutrients will also lead to lower algal densities and further improve habitat quality. Dissolved oxygen levels on average were adequate for healthy habitat for bottom dwelling animals, but on shorter time periods very low oxygen levels can and do occur. Reducing algal densities by reducing nutrients will improve dissolved oxygen conditions, especially in shallow water areas.

In most of the rivers, nitrogen levels and/or sediment levels are too high (Wicomico, Nanticoke, Transquaking, Manokin, Pocomoke River). Reductions in nitrogen, phosphorus and sediments loadings from agricultural lands should be the priority in these rivers, and septic system upgrades to reduce nitrogen should also be considered. Upgrades to wastewater treatment plants will reduce nitrogen loadings in the Wicomico and Nanticoke rivers and these improvements are already in place or planned.

Wicomico River is the most impacted by urban land use. Reducing nutrients and sediments that enter the river with urban runoff are needed. Urban runoff of sediments should also be a priority in the Manokin River. As more areas of the Lower Eastern Shore Basin are developed, alternatives to conventional methods should be used to reduce the amount of impervious surfaces and prevent additional degradation of water quality in the other rivers.

In Tangier Sound and Pocomoke Sound, most of the needed improvements will be due to reducing the nutrient and sediment levels in the rivers. Direct inputs to these water bodies are relatively very small.

What has already been done to improve water and habitat quality in the Lower Eastern Shore Rivers?

A variety of actions have already been taken to lower nitrogen, phosphorus and sediment loadings from agricultural lands. While specific goals have not been set for this basin, improvements are being made. In 2010 there were almost 38,000 acres of cover crops planted in between growing seasons to absorb excess nutrients and prevent sediment erosion. Fencing on 70 acres of farmland was used to keep livestock out of streams and prevent streambank erosion. More than 1,000 containment structures had been built to store animal wastes to allow these nutrients to be applied to the land in the most effective manner at the appropriate time. More than 30,200 acres of stream buffers were also in place, allowing areas next to streams to remain in a natural state with grasses, trees and wetlands.

To reduce nutrient inputs from urban lands, additional actions have been taken. These actions include upgrades to wastewater treatment plants, managing stormwater runoff and retrofitting septic systems. Upgrades to the largest wastewater treatment plants in the basin have been implemented or are under construction. A total of 780 septic system retrofits were completed between 2008-2010, amd stormwater retrofits have reduced nitrogen loadings and prevented 2,500 pounds of nitrogen from entering the rivers since 2003.

Maryland also has a number of programs in place to reduce the impacts of continued development and increasing amounts of impervious surfaces. Program Open Space projects have conserved about 16,000 acres of land for outdoor recreation opportunities. Rural Legacy Program projects have protected more than 12,200 acres, with special focus on areas with important cultural sites and natural resources and to ensure large areas of habitat. Maryland Environmental Trust projects have helped individual land owners protect more than 9,300 acres. Maryland Agricultural Land Preservation Program projects have preserved more than 4,000 acres of agricultural land from development.

The electronic version of the full report is available at
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Introduction

Water quality is measured as the level of nutrients and sediments in the water. Habitat quality is determined by how nutrients and sediments impact water clarity, algal populations and bottom dissolved oxygen levels. Habitat quality is also determined by salinity and water temperatures, but these measures are not changed by nutrients and sediments. Habitat quality determines if and where underwater grasses, fish and bottom dwelling animals can live. Reducing the levels of nutrients and sediments is a major focus of restoration efforts. The goal is to reduce nutrient and sediment levels so that habitat quality is improved and high quality habitat is expanded. Assessing water and habitat quality is an important first step in making decisions on what needs to be done to improve water and habitat quality.

Habitat quality can be assessed by looking at the health of the aquatic plants and animals that remain in the same location, such as underwater grasses and bottom dwelling animals. The health of these organisms depends on habitat that is suitable for growth and survival, so healthy organisms indicate healthy habitats. Changes in the populations of these plants and animals can often be linked to specific parts of habitat quality that are poor, such as water clarity or bottom dissolved oxygen. This additional information helps managers better pinpoint what needs to be changed to improve water and habitat quality.

Land use in a watershed is linked to the human population density. Rivers with high urban land uses have higher population densities and more impervious surfaces. Rivers with high agricultural land uses in rural areas have lower population densities and less impervious surfaces. Higher population densities are often linked to management of human wastes through wastewater treatment plants, while septic systems are more prevalent in areas with lower population density. Pollutant loadings from undeveloped lands such as forests are different from loadings from more developed areas. Information on human population and land use help managers decide the best methods for reducing nutrients and sediments going from the land into the water.

The Lower Eastern Shore Basin Water Quality and Habitat Assessment includes a variety of information. Land use data and census data are examined to understand how the watersheds are impacted by human uses. Loadings data is examined to identify how much nutrient and sediment is entering the non-tidal streams from the watershed. Data from the long-term tidal water quality monitoring program are examined for current water and habitat quality and changes over time. Data from monitoring in shallow water habitats are examined to determine water and habitat quality in the areas most important for underwater grasses and the organisms that live there. Data from monitoring of algal populations, underwater grasses and bottom dwelling organisms are examined to determine how well the resulting habitat quality supports healthy plant and animal populations.

Land use and Human population

The Maryland Lower Eastern Shore Basin includes all of Wicomico County and portions of Caroline, Dorchester, Somerset, and Worcester Counties as well as areas in Delaware and Virginia (Figure 3). The basin drains approximately 1,400 square miles in 16 sub-watersheds. The basin lies in the Coastal Plain province.

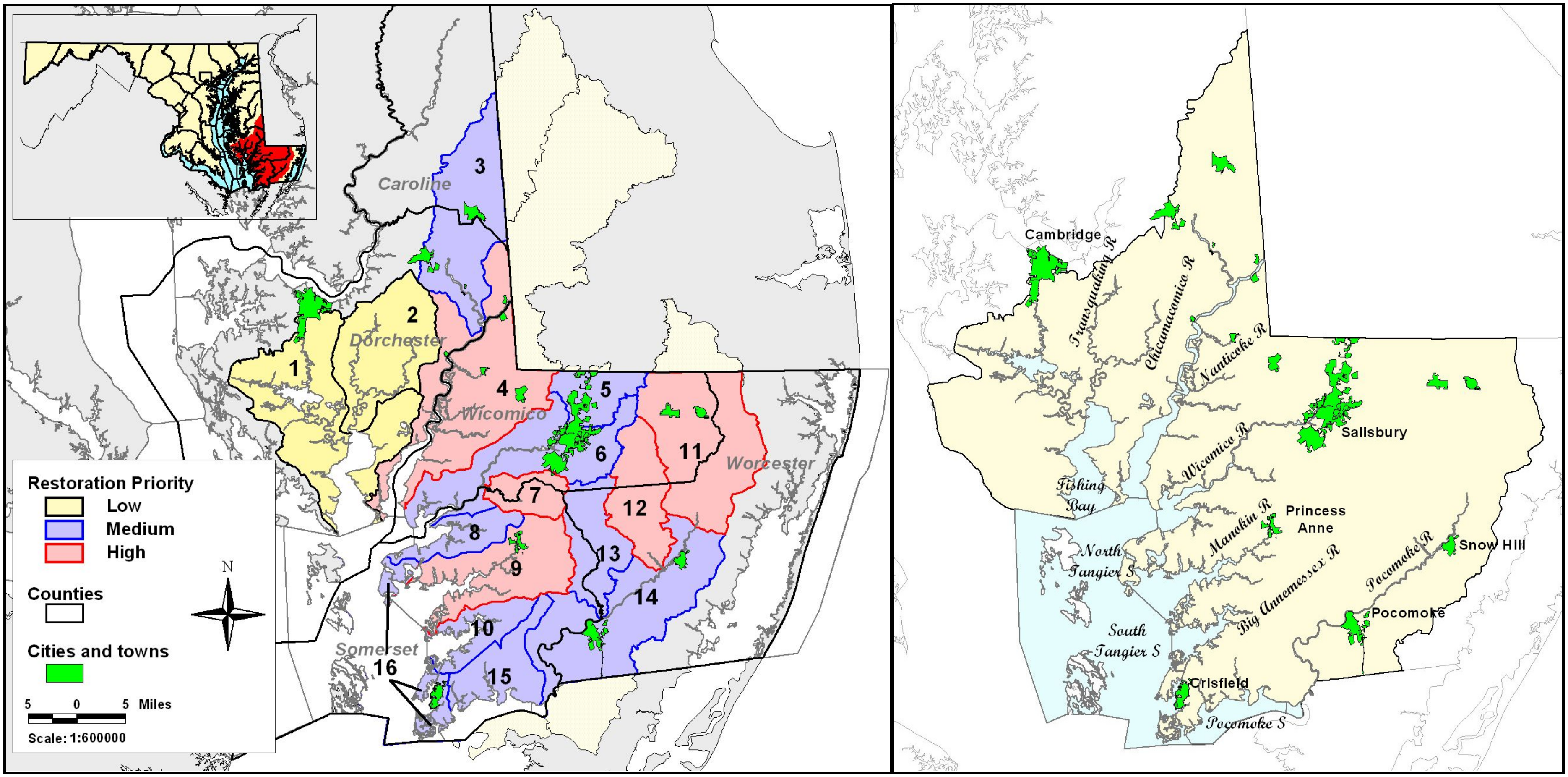

Figure 3. **Lower Eastern Shore basin.**
Left Panel- Trust Fund Priority Watershed Restoration Priority designation (high, medium, low), county lines and cities/towns are shown. Sub-watersheds (8-digit) are: 1: Fishing Bay, 2: Transquaking River, 3: Marshyhope Creek, 4: Monie Bay, 5: Wicomico River Head, 6: Lower Wicomico River, 7: Wicomico Creek, 8: Lower Wicomico, 9: Manokin River, 10: Big Annemessex River, 11: Upper Pocomoke River, 12: Nassawango Creek, 13: Dividing Creek, 14: Lower Pocomoke River, 15: Pocomoke Sound, 16: Tangier Sound. Delaware and Virginia watersheds from http://datamil.delaware.gov/geonetwork/srv/en/main.home. Right Panel- Rivers, bays and cities/towns are shown.

This basin includes the Nanticoke, Wicomico, Manokin, Big Annemessex and Pocomoke rivers. The basin also includes Fishing Bay, Tangier Sound, and Pocomoke Sound. Major population centers include Salisbury, Princess Anne, Pocomoke City, Snow Hill and Crisfield in Maryland and Laurel and Seaford in Delaware.

As of 2010, there were approximately 160,000 people living in the basin in Maryland, 80,000 people in Delaware and 14,000 people in Virginia (Figure 4).[1] Population density was mostly low (between 10-100 people per square mile), with some areas with moderate (100-1,000 people mi^2) and a few areas with high (1,000-10,000 people mi^2) population densities.

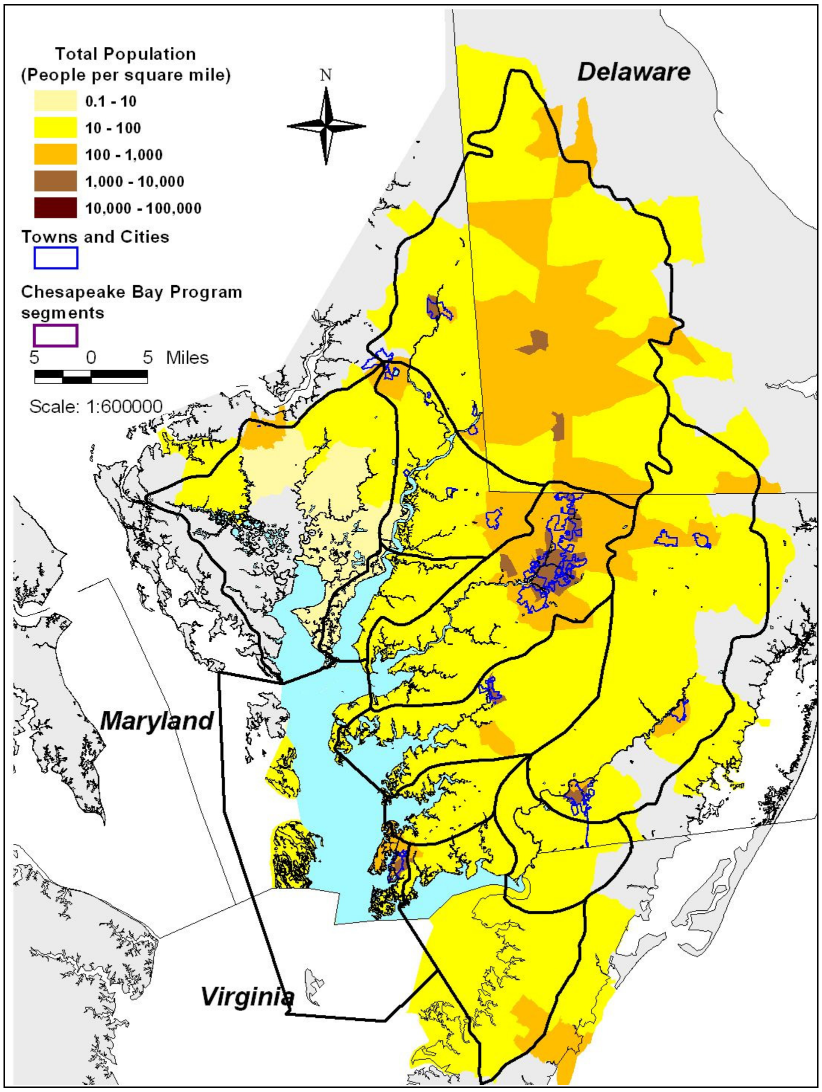

Figure 4. 2010 Census data for total population by block group.
Total population per square mile is shown using a log scale. Delaware and Virginia data is included for the corresponding watersheds that also drain to the Lower Eastern Shore basin (based on the Chesapeake Bay Program segment watersheds). Differences between the watershed boundaries and the Census bureau block group boundaries result in non-exact matching of the population data to the given watershed.

[1] 2010 data from the U.S. Census Bureau available online at http://www2.census.gov/census_2010/04-Summary_File_1/

In the northern portion of the basin is the Chicamacomico/Transquaking/Fishing Bay watershed. Wetlands are a prominent feature of the Chicamacomico/Transquaking/Fishing Bay watershed, covering 32% of the total area. Some of this wetland area is protected within the Blackwater National Wildlife Refuge, a critical stopping point along the Atlantic flyway for migrating birds.[2] The watershed is 40% forest and 27% agricultural (Figure 5, Appendix 1).[3] Urban land use and impervious surfaces are very limited in this watershed. Stream health is classified as Poor.[4] All of the sub-watersheds are low priority watersheds for Trust Fund Restoration activities (Figure 3).[5]

The Nanticoke River system includes the Marshyhope Creek and Nanticoke River sub-watersheds. Most of the Marshyhope Creek watershed and more than half of the Nanticoke River watershed is within Delaware. Within Maryland, forest and agricultural land use is roughly equal (approximately 40% each). Urban land use and impervious surfaces are limited. Stream health in Marshyhope Creek subwatershed is Fair, but steam health is Poor in the Nanticoke River sub-watershed. The Nanticoke River sub-watershed is a high priority watershed and the Marshyhope Creek sub-watershed is a medium priority watershed for Trust Fund Restoration activities.

The Wicomico River system includes four sub-watersheds, also with a small amount of watershed area in Delaware. In Maryland, 38% of the total area is forested, 28% is urban and 26% is agricultural. The city of Salisbury accounts from most of the urban areas. From 2000 to 2010, urban land use increased by 5% (Figure 6). Impervious surfaces cover 6% of the area. Stream health is Fair in the Maryland portion of the Wicomico River Head sub-watershed but Poor in the other three sub-watersheds. Three of the sub-watersheds are medium priority watersheds for Trust Fund Restoration activities; Wicomico Creek is a high priority watershed.

The Manokin River and the Big Annemessex River each have a single sub-watershed. Land use in the Manokin watershed is 43% forest, 28% agriculture and 19% wetlands. In the Big Annemessex, land use is 40% forest, 27% wetlands and 23% agriculture. Urban land use is approximately 10% and impervious surfaces are 1% or less in these watersheds. The health of streams in the Manokin watershed is Poor, and in the Big Annemessex stream health is Fair. The Manokin watershed is a high priority and the Big Annemessex is a medium priority watershed for Trust Fund Restoration.

The Pocomoke River system includes four sub-watersheds: Dividing Creek, Nassawango Creek, Upper Pocomoke River and Lower Pocomoke River. A small portion of this watershed is in Delaware and another small portion is in Virginia. In Maryland, land use in the system as a whole is 50% forest and 34% agriculture. Stream health is Fair in the upper three sub-watersheds, and Poor in the lower Pocomoke sub-watershed. The Upper Pocomoke River and the Nassawango Creek sub-watersheds are high priority for Trust Fund Restoration and the other two sub-watersheds are medium priority.

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[2] For more information, please see http://www.fws.gov/blackwater/.
[3] Maryland Department of Planning data for 2010 available at http://www.planning.maryland.gov/OurWork/landUse.shtml
[4] Maryland Department of Natural Resources data available at www.streamhealth.maryland.gov/stream_health.asp
[5] Information on Maryland's Trust Fund is available at http://www.dnr.maryland.gov/ccp/funding/pdfs/TrustFundPriorities.pdf

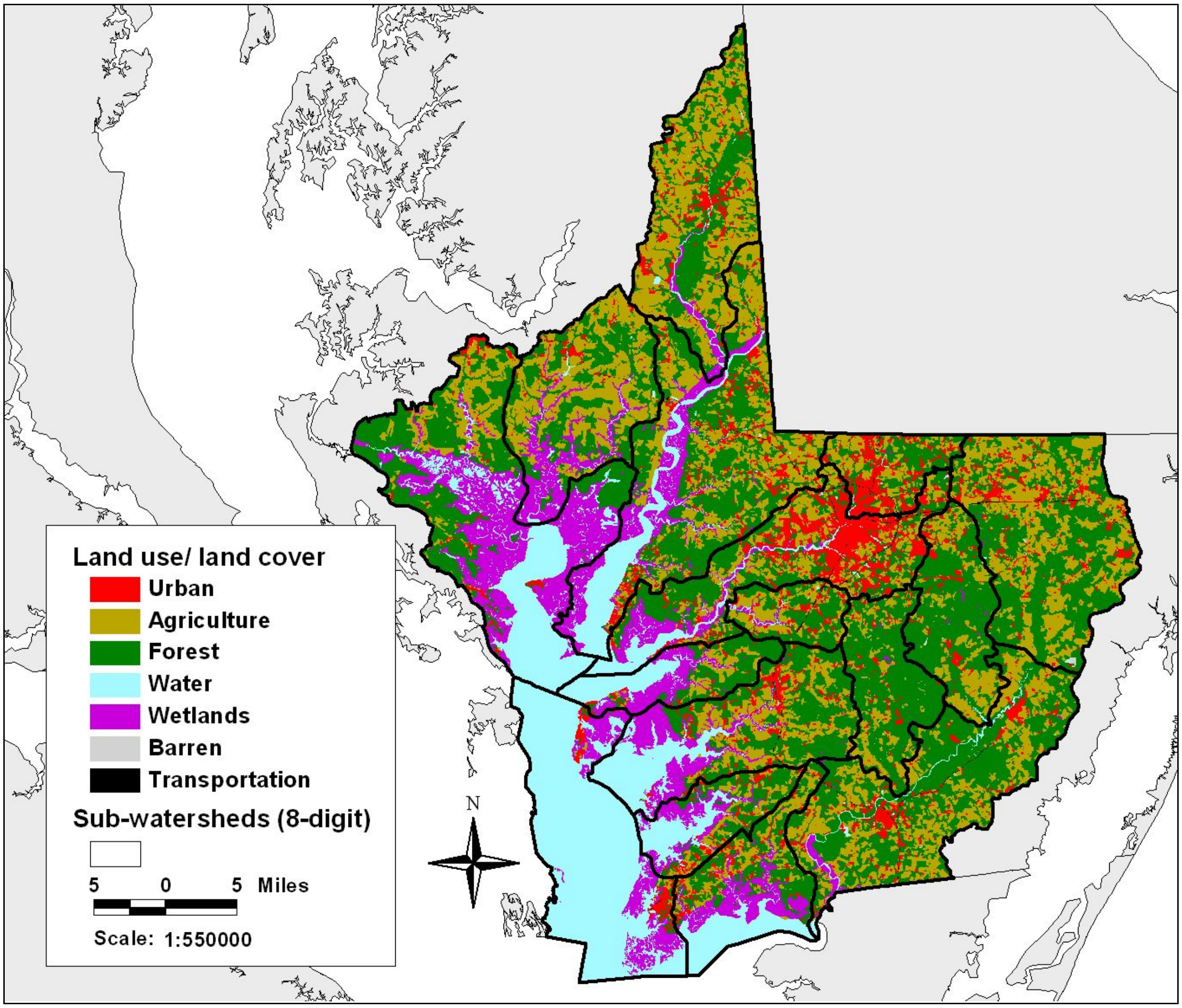

Figure 5. Lower Eastern Shore basin land use/land cover data for 2010.
See Appendix 1 for detailed land use/land cover information.

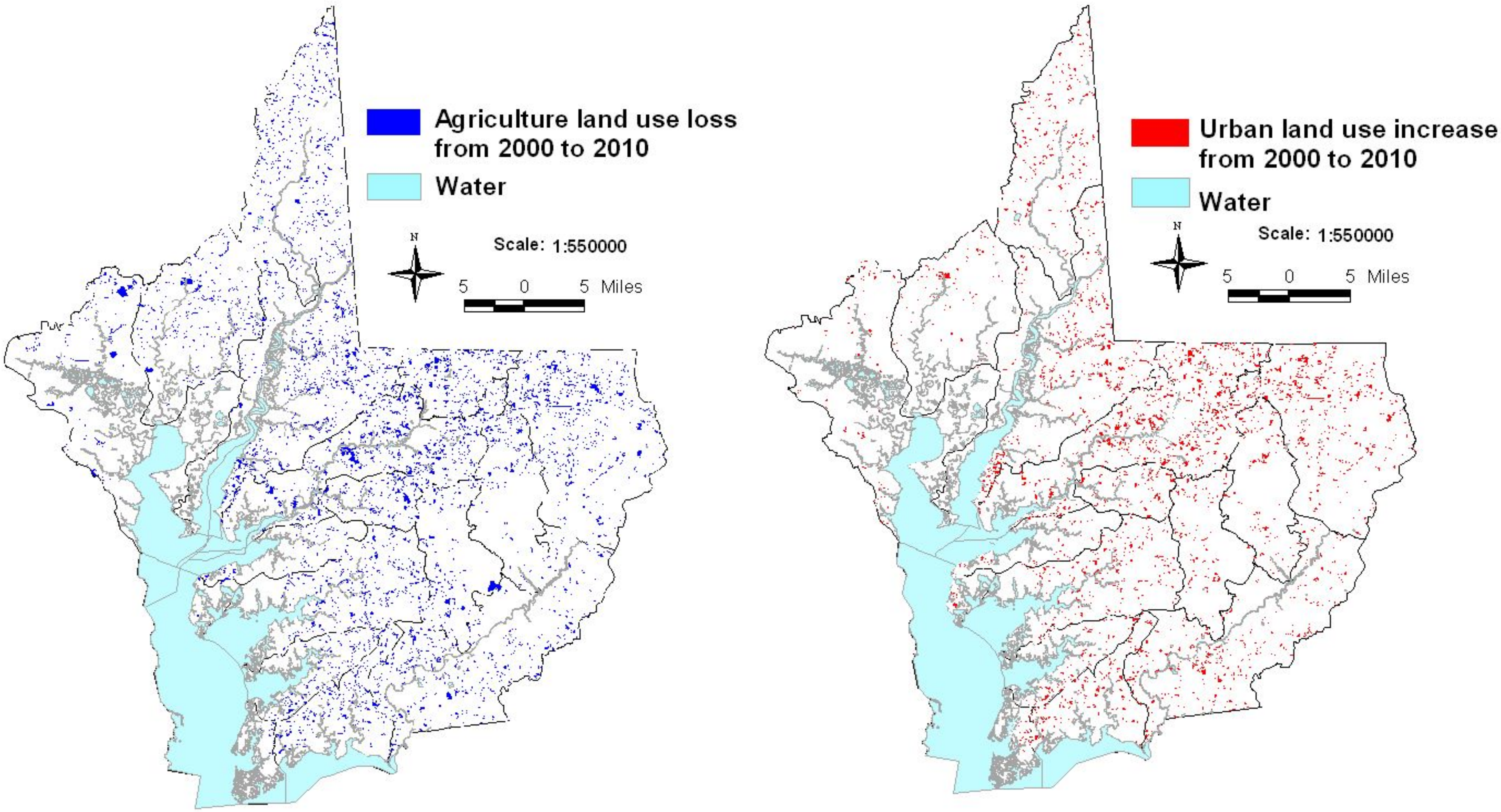

Figure 6. Change in land use from 2000 to 2010.
Left panel shows change in agricultural land use in blue. Right panel shows change in urban land use in red.

Maryland has a number of programs in place to reduce the impacts of continued development and increasing amounts of impervious surfaces. Program Open Space projects have conserved about 16,000 acres of land for outdoor recreation opportunities. Rural Legacy Program projects have protected more than 12,200 acres, with special focus on areas with important cultural sites and natural resources and to ensure large areas of habitat. Maryland Environmental Trust projects have helped individual land owners protect more than 9,300 acres. Maryland Agricultural Land Preservation Program projects have preserved more than 4,000 acres of agricultural land from development.

Nutrient and Sediment Loadings

In accordance with the Chesapeake Bay Total Maximum Daily Load (TMDL), Maryland has developed a Watershed Implementation Plan (WIP) for making reductions in nitrogen, phosphorus and sediment loads to the Chesapeake Bay.[6] Maryland is required to reduce loads to Final Target loads by 2025. Maryland's Interim Target loads are set at 60% of the Final Target loads by 2017. Progress toward these Interim and Final Target loads is further broken into 2-year milestone loads. The first of these 2-year milestones is set for July 1, 2011- June 30, 2013.[7]

The rivers in the Lower Eastern Shore basin are combined with the other eastern shore rivers into a single category- the Eastern Shore Basin. Final Target Loads for the Eastern Shore Basin are 11.82 million pounds per year of nitrogen, 1.02 million pounds per year of phosphorus and 189 million pounds per year of sediments. The information below is for loadings in 2009.

The Lower Eastern Shore overall received approximately 4.4 million lbs/yr nitrogen, 0.40 lbs/yr phosphorus and 38 million lbs/yr of sediments (Appendix 2). Agriculture was the largest contributor of nitrogen, phosphorus and sediments to Nanticoke, Manokin, Big Annemessex and Pocomoke rivers and Fishing Bay (Figure 7). In the Wicomico River, both agriculture and point sources contributed nitrogen and phosphorus, and urban runoff was the largest contributor of sediments. Point sources were an important contributor of phosphorus in the upper Nanticoke (within Delaware).

Urban runoff was a contributor of phosphorus to the Wicomico and the middle Pocomoke rivers and the largest source of sediments to Wicomico River. Forest sources were also important to loadings of nitrogen, phosphorus and sediments to the lower Nanticoke, Manokin, Big Annemessex, upper and lower Pocomoke, Fishing Bay and Tangier Sound.

[6] Maryland's Phase II Watershed Implementation Plan is online at www.mde.state.md.us/programs/Water/TMDL/TMDLImplementation/Pages/FINAL_PhaseII_WIPDocument_Main.aspx

[7] Progress toward meeting the 2011-2013 milestones is available on BayStat at www.baystat.maryland.gov/milestone_information.html

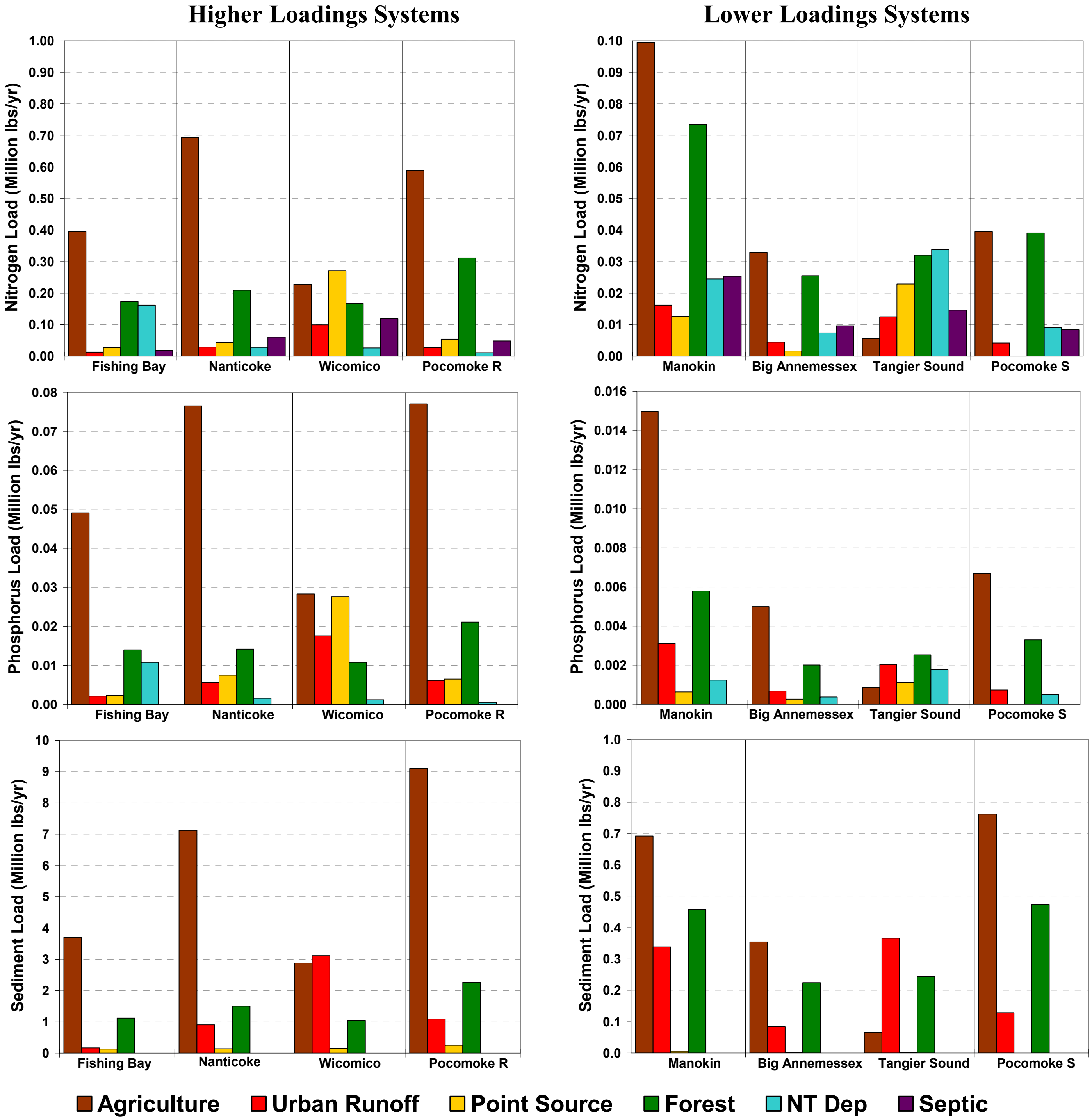

Figure 7. Nitrogen, phosphorus and sediment loadings per year.
Delivered loadings by category in million lbs/yr (see Appendix 2). Septic is not a source of phosphorus or sediment loadings and atmospheric deposition (NT Dep) is not a source of sediment loadings. Left-hand graphs show the higher loadings rivers/bays; right-hand graphs show lower loadings systems. In the left-hand graphs, nitrogen load and sediments load scales are 10 times and phosphorus load scale is 5 times the right-hand graphs scale.

Point Source Loads

Nutrient loadings from point sources (including wastewater treatment plants, WWTPs) are the easiest to measure. Point source loads are often the most cost-effective to manage. A major focus of management actions to reduce nutrient loads has been upgrades to WWTPs. In 2004, Maryland passed legislation creating the Chesapeake Bay Restoration Fund specifically to fund WWTP upgrades to enhanced nutrient removal (ENR).[8] The program is working to complete ENR upgrades to 67 major WWTPs, including nine facilities in the Lower Eastern Shore basin.[9] Upgrades to three Lower Eastern Shore basin facilities were complete by the end of 2010: Hurlock WWTP and Federalsburg WWTP which discharge to Marshyhope Creek and then to the Nanticoke River and Crisfield WWTP which discharges to the Little Annemessex River and then to Tangier Sound.

Point sources were an important source of loadings to the Wicomico and upper Nanticoke rivers and less important in the other rivers. The Wicomico River receives discharges from three major WWTPs: Salisbury, Delmar and Fruitland. Salisbury WWTP, with a design flow of 8.5 million gallons per day (MGD) accounts for approximately 90% of the nitrogen and phosphorus loads from WWTPs to the Wicomico River. Salisbury WWTP was upgraded to biological nutrient removal (BNR) at the end of 2008 but is not scheduled for upgrades to ENR until 2014.[10] Nitrogen loads generally follow the same pattern as the total facility flow, while phosphorus loads are more independent of flow. Nitrogen loads are still three to four times higher than the loading cap for this facility (Figure 8).[11] Phosphorus loads are more than five times lower than in the past due to bans on phosphorus in detergents, and are relatively stable, though still about double the loading cap.

The Fruitland WWTP (0.8 MGD) contributes approximately 1% of the nitrogen and 8% of the phosphorus loads from WWTPs to Wicomico River. Fruitland WWTP upgraded to BNR in 2003 and is scheduled to begin upgrades to ENR in 2013. Delmar WWTP (0.85 MGD) contributes approximately 6% of the nitrogen and 4% of the phosphorus loads from WWTPs to the Wicomico River. Delmar WWTP upgraded to BNR at the end of 2008 and ENR upgrades are scheduled to be complete by the end of 2011.

The upper Nanticoke River receives discharge from five major WWTPs, two in Maryland and three in Delaware (Figure 9). Delaware facilities contribute most of the nitrogen and phosphorus loads from WWTPs to the Nanticoke River. Hurlock WWTP was upgraded to ENR in 2006. Federalsburg WWTP was upgraded to ENR in 2010.

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[8] The Chesapeake Bay Restoration Fund collects fees from wastewater treatment plant users to pay for the upgrades. A similar fee is paid by septic system users to upgrade onsite systems and implement cover crops to reduce nitrogen loading to the Bay. For more information on the Chesapeake Bay Restoration Fund see http://www.mde.state.md.us/programs/Water/BayRestorationFund/Pages/index.aspx.

[9] Major wastewater treatment plants (WWTP) are those with greater than 0.5 million gallons per day (MGD) design flow.

[10] Biological nutrient removal (BNR) technology removes additional nitrogen than traditional methods, bringing nitrogen levels in effluent to below 8 mg/l. Enhanced nutrient removal (ENR) reduces nitrogen levels to below 3 mg/l and phosphorus levels to below 0.3 mg/l in effluent.

[11] Data for Maryland facilities is from the Maryland Department of the Environment (MDE).

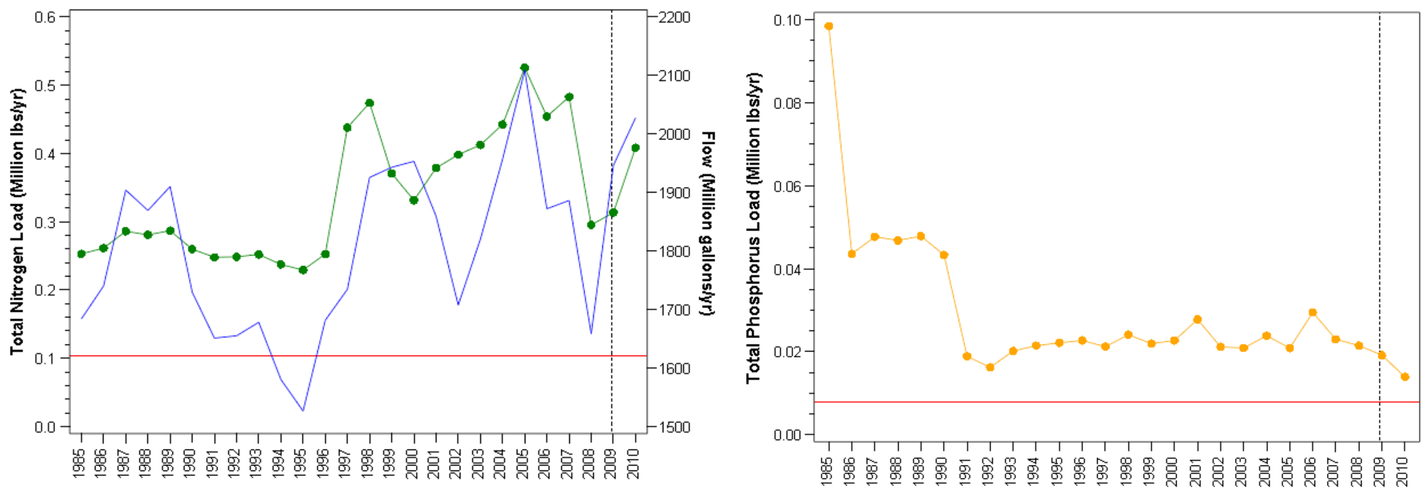

Figure 8. Annual total nitrogen and total phosphorus loadings from Salisbury WWTP to the Wicomico River.
Blue line on nitrogen graph shows total annual effluent flow. Red horizontal line indicates the loading cap for the facility following implementation of ENR. The dotted vertical line indicates when BNR was implemented.

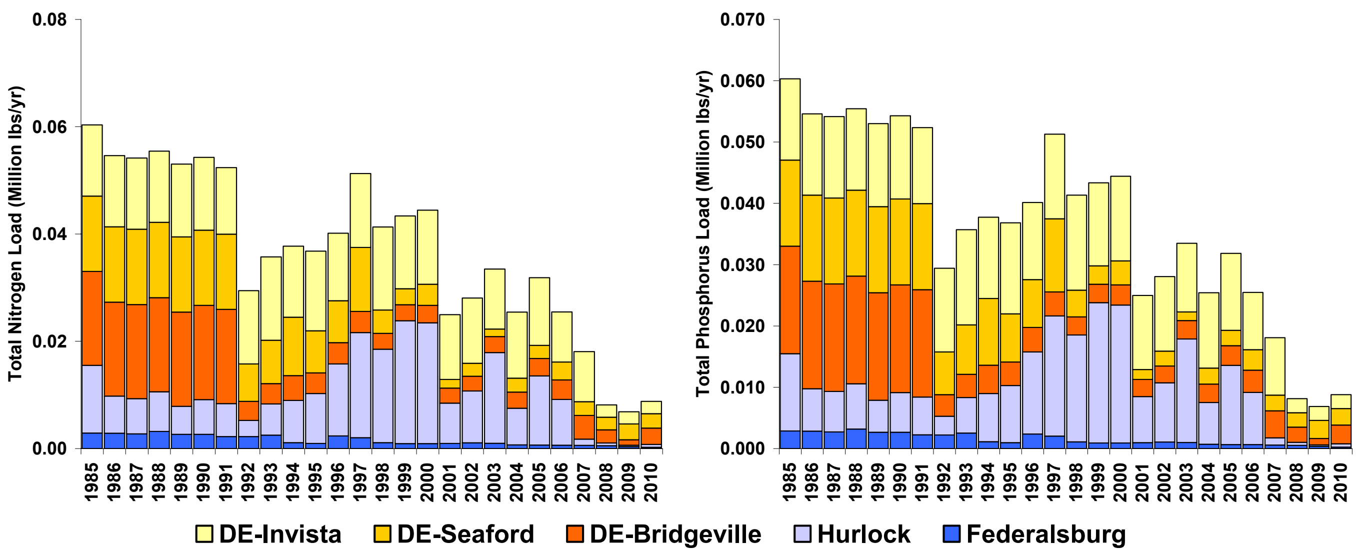

Figure 9. Annual total nitrogen and total phosphorus loadings from WWTPs to the Nanticoke River.
Three of the major facilities are in Delaware: Invista, Seaford and Bridgeville. [12] Note that the Invista facility, which is commercial, dramatically reduced production in mid-2007, likely in response to the economy. Reporting requirements for this facility changed from the early to the later period, causing a drop in the reported load that was not due to changes in operation of the facility.[12]

[12] Data for Delaware facilities for 1985-2005 is from http://www.chesapeakebay.net/data/downloads/bay_program_nutrient_point_source_database. Where data was missing, the best available time period data was used for multiple years. Data for 2006-2010 for Delaware facilities is from the Delaware Department of Natural Resources and Environmental Control (DNREC). Prior to 2008, data for Invista show discharge and intake values. Data for 2008-2010 just show "Net" levels (i.e., discharge – intake). In addition, with the U.S. economy in recent years, Invista is running at a fraction of their production capacity. Their numbers may increase if/when their production rate goes up. (John DeFriece, DNREC, personal communication).

Non Point Source Loads

In 1998, Maryland passed the Water Quality Improvement Act, which requires farmers to reduce nitrogen and phosphorus loadings from agricultural lands.[13] Soil Conservation and Water Quality Plans (SCWQPs) are developed to determine what the appropriate actions, or best management plans (BMPs), are for a given area.[14] Each of Maryland's counties has a Soil Conservation District Office with staff to help farmers develop and implement SCWQPs. The total number of BMPs in place in the basin as a whole (not by individual farm) is used to measure progress.[15] In 2010 there were almost 38,000 acres of cover crops planted in between growing seasons to absorb excess nutrients and prevent sediment erosion. Fencing on 70 acres of farmland was used to keep livestock out of streams and prevent streambank erosion. More than 1,000 containment structures had been built to store animal wastes to allow these nutrients to be applied to the land in the most effective manner at the appropriate time. More than 30,200 acres of stream buffers were also in place, allowing areas next to streams to remain in a natural state with grasses, trees and wetlands.

Water and Habitat Quality

Tidal Rivers

Tidal water quality monitoring is done year-round at ten stations that have been monitored since 1985 (Figure 10). Year-round tidal water-quality monitoring was started in 2003 at ten additional stations.

The following parameters were evaluated to assess water and habitat quality: total nitrogen (TN), total phosphorus (TP) , total suspended solids (TSS), dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (PO_4), algal abundance (as measured by chlorophyll *a*, CHLA), water clarity (as measured with a Secchi disc and by calculating the percent light through water, PLW), summer bottom dissolved oxygen (BDO), salinity and water temperature.

Assessment methods are described in Appendix 4. Selected graphical results are included with the text. Trends results discussed in the text refer to the 2003-2010 period so that all stations are assessed for the same time period. Seasons for 1999-2010 trends are: spring (March-May), summer (July-September)[16] and SAV growing season (Apr-October). Significant trends for 1985-2010 and 1999-2010 are noted in the footnotes. Figure and Appendix references apply to all rivers and are given only the first time referenced. Summary results are presented in Table 1 in the 'Overall Assessment' section. Detailed tabular results are included in Appendices 7 and 8.

[13] For more information, please see the Maryland Department of Agriculture website http://mda2.maryland.gov/resource_conservation/Pages/nutrient_management.aspx

[14] For more information see http://mda.maryland.gov/pdf/scwqplan.pdf

[15] Progress on different BMPs is available at http://www.baystat.maryland.gov/milestone_information.html

[16] For summer bottom dissolved oxygen analysis, the months used are June-September.

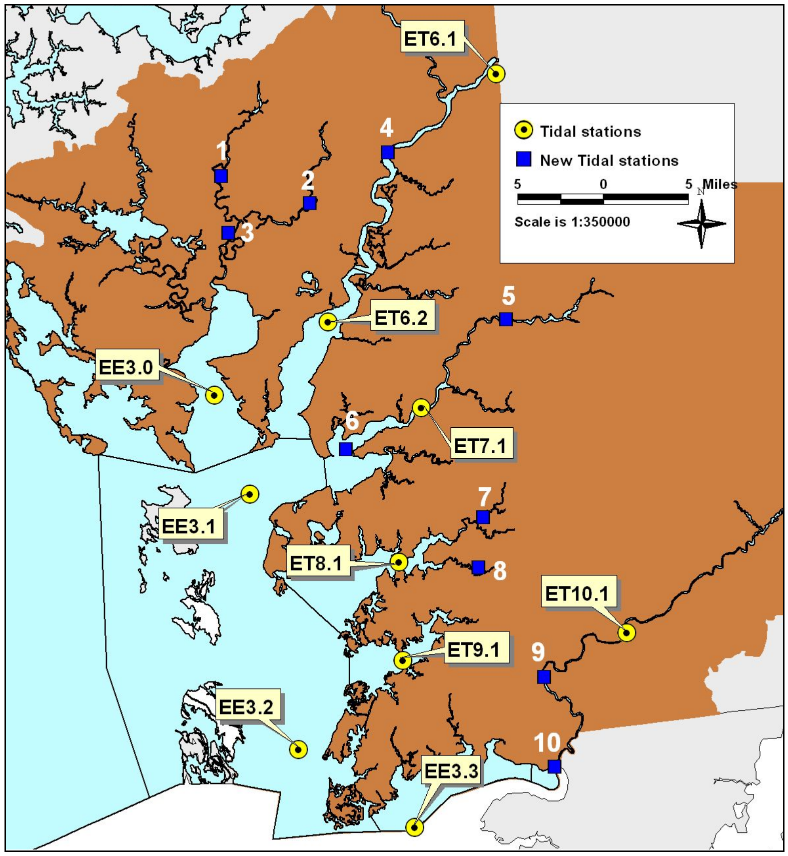

Figure 10. **Long-term tidal water quality monitoring stations.**
Stations monitored from 1985-2010 are shown with a yellow circle and labeled with station name. Stations monitored from 2003-2010 are shown with a blue square and labeled numerically: 1 TRQ0146, 2. CCM0069, 3. TRQ0088, 4.XDJ9007, 5. WIW0141, 6. XCI4078, 7. MNK0146, 8. BXK0031, 9. POK0087, 10. XAK7810. Station descriptions are provided in Appendix 3.

Chicamacomico River/ Transquaking River/ Fishing Bay

Water Quality

TN levels in the Chicamacomico and Transquaking Rivers and Fishing Bay were high and relatively poor and DIN levels were relatively good. TN levels were highest in the upper Transquaking River (Figure 11). TN may have decreased in Fishing Bay annually and in the spring.[17] TN may have increased in summer in the Chicamacomico but DIN levels may have improved annually. In summer, DIN levels were low enough that nitrogen limitation of algal growth likely occurred in Fishing Bay, Chicamacomico and upper Transquaking, and occasionally in the lower Transquaking (Figure 12).[18] Nitrogen limitation may have also occurred in the fall in some years.

[17] TN:TP ratio decreased from 1999-2010 in Fishing Bay but was still 58:1 in 2010
[18] Yet, despite very low DIN in summer, algal blooms still occurred in the upper Transquaking. TRQ0146 average summer CHLA for 2006 is extremely high due to a bloom event August 17, 2006 with CHLA measurement of 236 µg/l despite DIN level of 0.014 mg/l (well below the 0.07 mg/l DIN nitrogen limitation threshold). The low DIN level likely was the result of the algae depleting any available DIN in the process of blooming. CHLA samples for the other summer months in 2006 ranged from 58-62 µg/l and DIN ranged from 0.01-0.03 mg/l. A similar situation occurred in July and August 2005.

TP was relatively poor in the Transquaking, relatively fair in the Chicamacomico, and relatively good in Fishing Bay. PO_4 was relatively poor in both the Transquaking and Chicamacomico and good in Fishing Bay. TP levels may have improved in Fishing Bay annually and in the spring.[19] PO_4 levels improved annually in the upper Transquaking and in the SAV growing season in the Chicamacomico. PO_4 levels may also have improved annually in the Chicamacomico and lower Transquaking, in summer in Chicamacomico and upper Transquaking, and in the SAV growing season in the upper and lower Transquaking and Fishing Bay. PO_4 levels were low enough to meet the SAV habitat requirement in Fishing Bay, Chicamacomico and the lower Transquaking, and were low enough in 2010 to meet the requirement in the upper Transquaking (Figure 13).

TSS levels were relatively good in the Chicamacomico but degraded annually and in the summer and maybe in the SAV growing season. TSS levels were relatively poor in the Transquaking and Fishing Bay, but improved in Fishing Bay in the summer and SAV growing season and may have improved annually.[20] TSS levels were much higher in the lower Transquaking than elsewhere. Only Fishing Bay met the requirement for TSS.

Habitat Quality

Algal abundance was relatively poor in the rivers and relatively fair in Fishing Bay. Annual mean CHLA was highest in the upper Transquaking, above 50 µg/l in 2009 and 2010. CHLA levels improved in Fishing Bay annually and in the SAV growing season, but may have degraded in the Chicamacomico annually and in the SAV growing season.[21] Only Fishing Bay CHLA levels met the SAV Habitat requirement.

Water clarity was relatively poor in the rivers and Fishing Bay. Secchi depth may have improved in the SAV growing season in Fishing Bay and may have degraded in the spring in the Chicamacomico.[22] Water clarity failed to meet the requirement in all three systems. Summer BDO levels were good in Fishing Bay (not measured at the shallow river sites) and monthly average BDO were always above 5 mg/l (Figure 14).[23]

[19] TP levels in Fishing Bay may have improved annually and in the SAV growing season from 1999-2010.
[20] TSS levels in Fishing Bay improved annually and in the SAV growing season and may have improved in spring and summer from 1999-2010.
[21] CHLA levels degraded in Fishing Bay from 1985-2010.
[22] Secchi depth in Fishing Bay may have degraded from 1985-1997 but improved starting in the early 2000s.
[23] Summer BDO in Fishing Bay improved from 1999-2010.

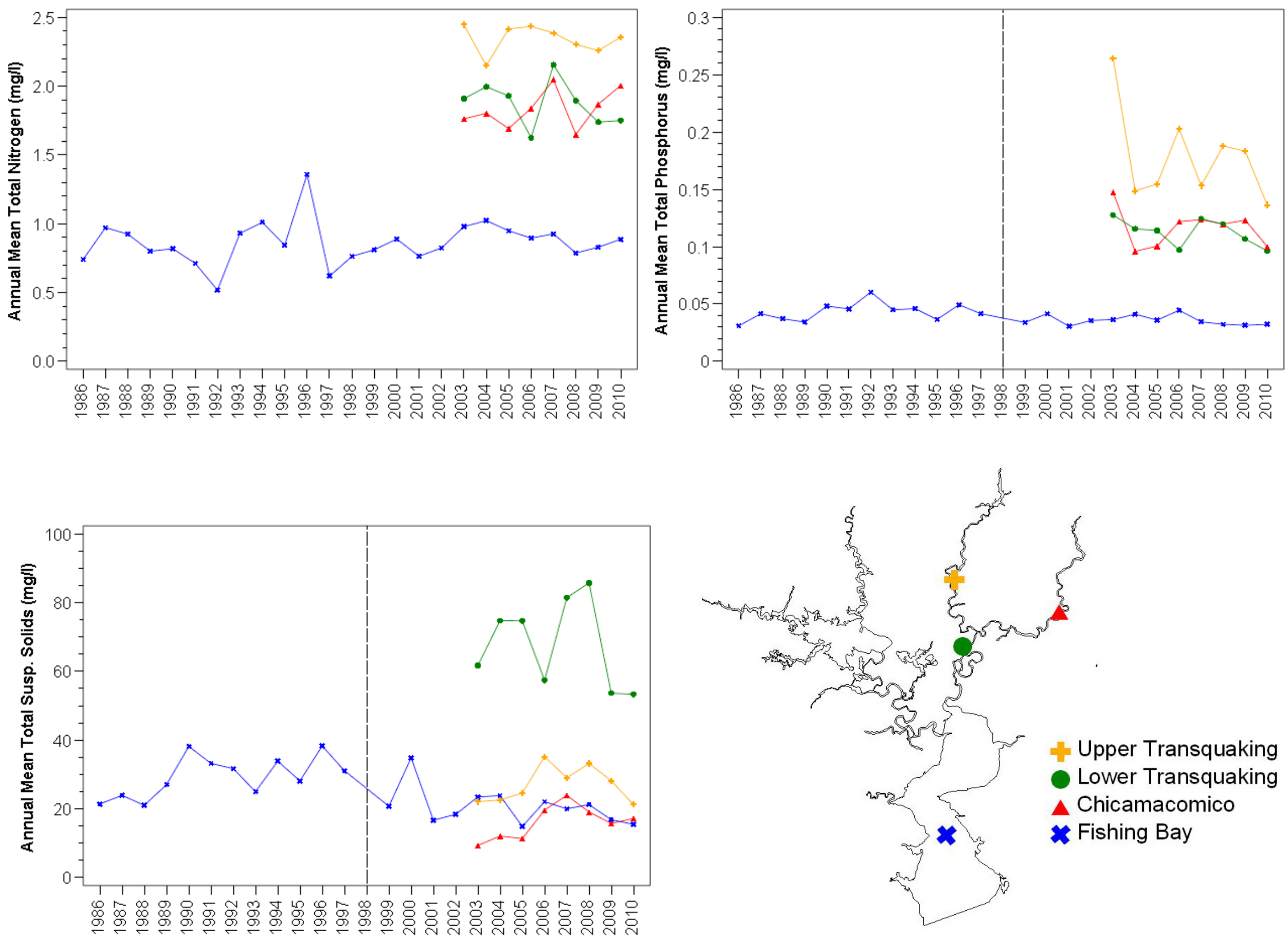

Figure 11. Annual means for total nitrogen, total phosphorus and total suspended solids in the Chicamacomico and Transquaking rivers and Fishing Bay.
Dotted line (1998) indicates when the lab change occurred that may have impacted TP and TSS. Caution should be used in making comparisons for TP and TSS from before to after the lab change.

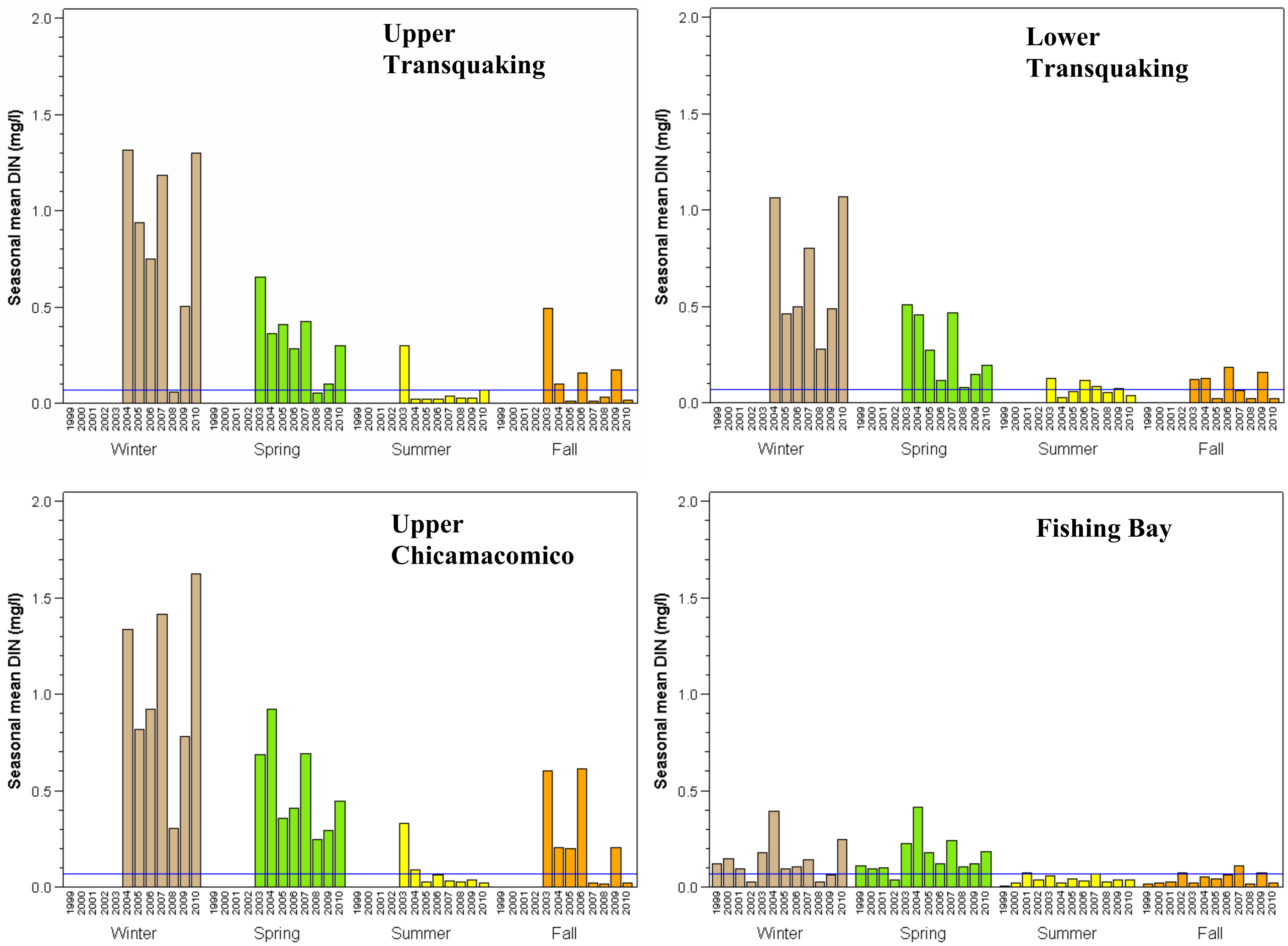

Figure 12. Mean dissolved inorganic nitrogen by season for the Chicamacomico and Transquaking rivers and Fishing Bay.
The blue line at 0.07 mg/l indicates the DIN level below which nitrogen limitation likely occurs. Winter season includes December (of the previous year), January and February. Spring season includes March-May. Summer season includes July-August (June is a transition month and not included). Fall season includes October and November. Biological nutrient removal of nitrogen at WWTPs is most effective in warmer months, and seasonal changes in phytoplankton populations (blooms in spring and fall) reduce DIN.

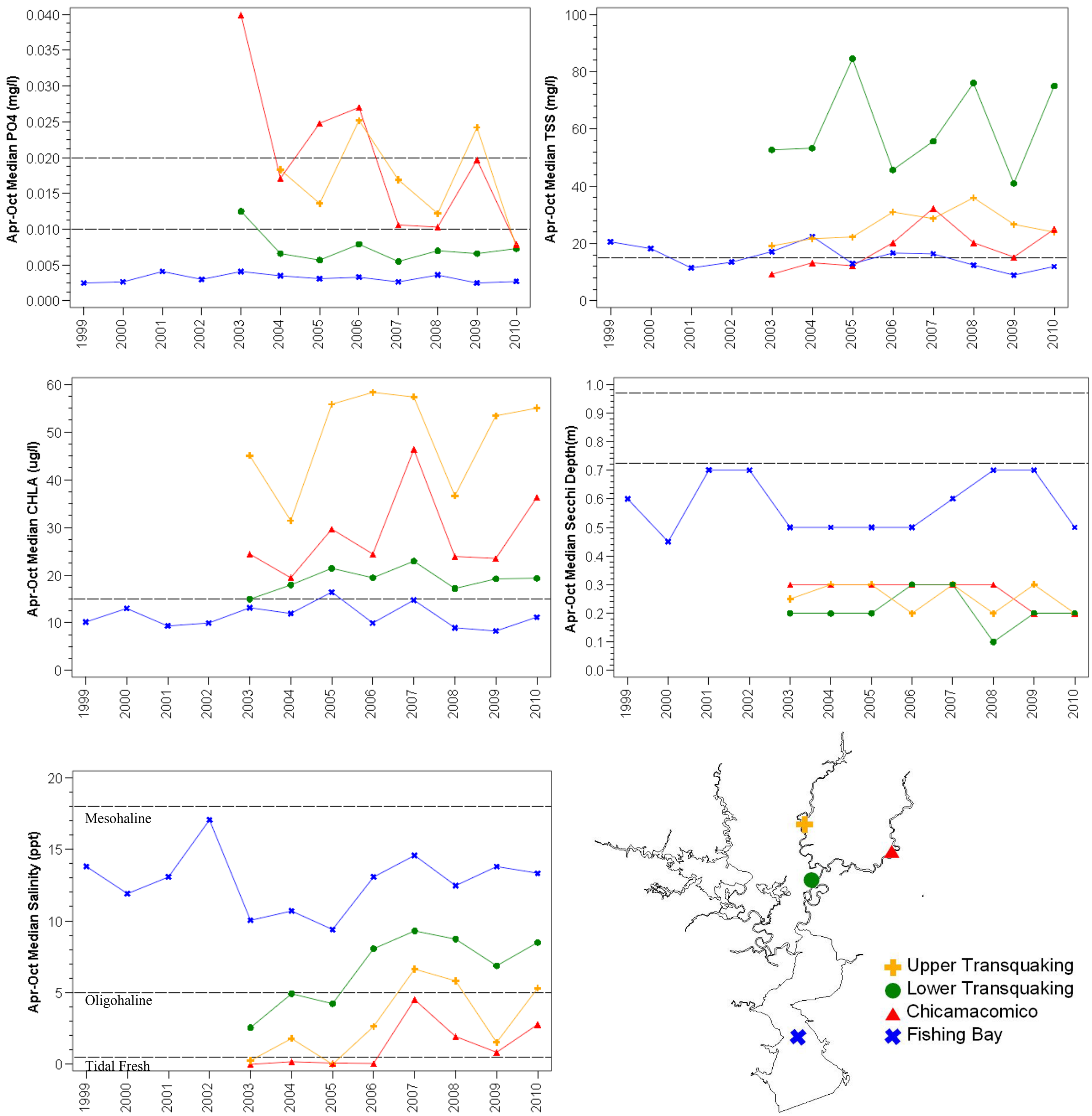

Figure 13. SAV habitat requirement parameters in the Chicamacomico and Transquaking rivers and Fishing Bay.
SAV growing season (April-October) median values for PO_4, TSS, CHLA, Secchi depth and salinity. Threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of PO_4, TSS and CHLA need to be lower than the threshold and Secchi depth needs to be above the threshold. Chicamacomico data and upper Transquaking data for 2009 need to meet the tidal fresh/oligohaline thresholds and the remaining Transquaking data and Fishing Bay data need to meet to mesohaline thresholds.

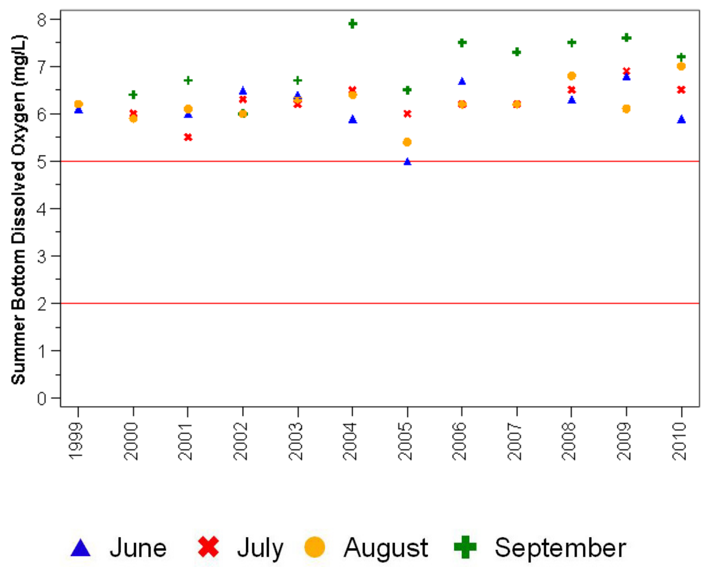

Figure 14. Summer bottom dissolved oxygen levels in Fishing Bay.
Bottom dissolved oxygen levels with threshold values of 5 mg/l and 3 mg/l shown with red reference lines.

Salinity increased in the rivers and Fishing Bay annually and in the summer. SAV growing season salinity increased in the lower Transquaking and Fishing Bay, and may have increased in the Chicamacomico and Transquaking.[24] In the upper Transquaking, SAV growing season salinities varied from tidal fresh (2003 and 2005) to oligohaline (2004, 2006 and 2009) to mesohaline (2007, 2008, 2010). In the lower Transquaking SAV growing season salinity in 2003 and 2005 was in the oligohaline regime and in the mesohaline regime in 2006-2010. Chicamacomico SAV growing season salinities changed from tidal fresh in 2003-2006 to oligohaline in 2007-2010. Fishing Bay salinities remained in the mesohaline regime. There were no trends in water temperature.

Nanticoke

Water Quality

Nitrogen levels in the Nanticoke River were high and relatively poor but also decreased annually, in summer and in the SAV growing season throughout the river (Figure 15).[25] DIN levels at both upper river stations were too high for nitrogen limitation of phytoplankton to occur (Figure 16). Lower DIN levels in the mid-river likely limited algal growth in summer months and in the fall in some years.[26]

Phosphorus levels were similar throughout the Nanticoke. However, the current relative status varies depending on the salinity zone. At the station farthest upstream, levels were relatively good for both TP and PO_4. At the downstream upper river station, TP and PO_4 levels were the

[24] Salinity may have decreased in Fishing Bay in the spring from 1999-2010 and in annually from 1985-2010.
[25] TN increased in the upstream upper Nanticoke river from 1985-1997, but a non-linear trend indicates that levels decreased after the early 2000s.
[26] DIN levels in the middle Nanticoke river may have decreased in the summer from 1999-2010. DIN: PO_4 ratio decreased for 1999-2010 in the middle river but was 359:1 in 2010, well above the Redfield ratio of 16:1

highest but salinity was also higher, so the current status was relatively good for TP and relatively poor for PO_4. In the middle river, TP and PO_4 were both relatively poor despite being the lowest levels of both components.[27] PO_4 levels improved in the upstream upper river annually, in summer and in the SAV growing season. PO_4 levels also improved at the downstream upper river station annually and may have improved in the summer and SAV growing season. PO_4 levels were close to or below the habitat requirement for SAV growth and survival (Figure 17).[28]

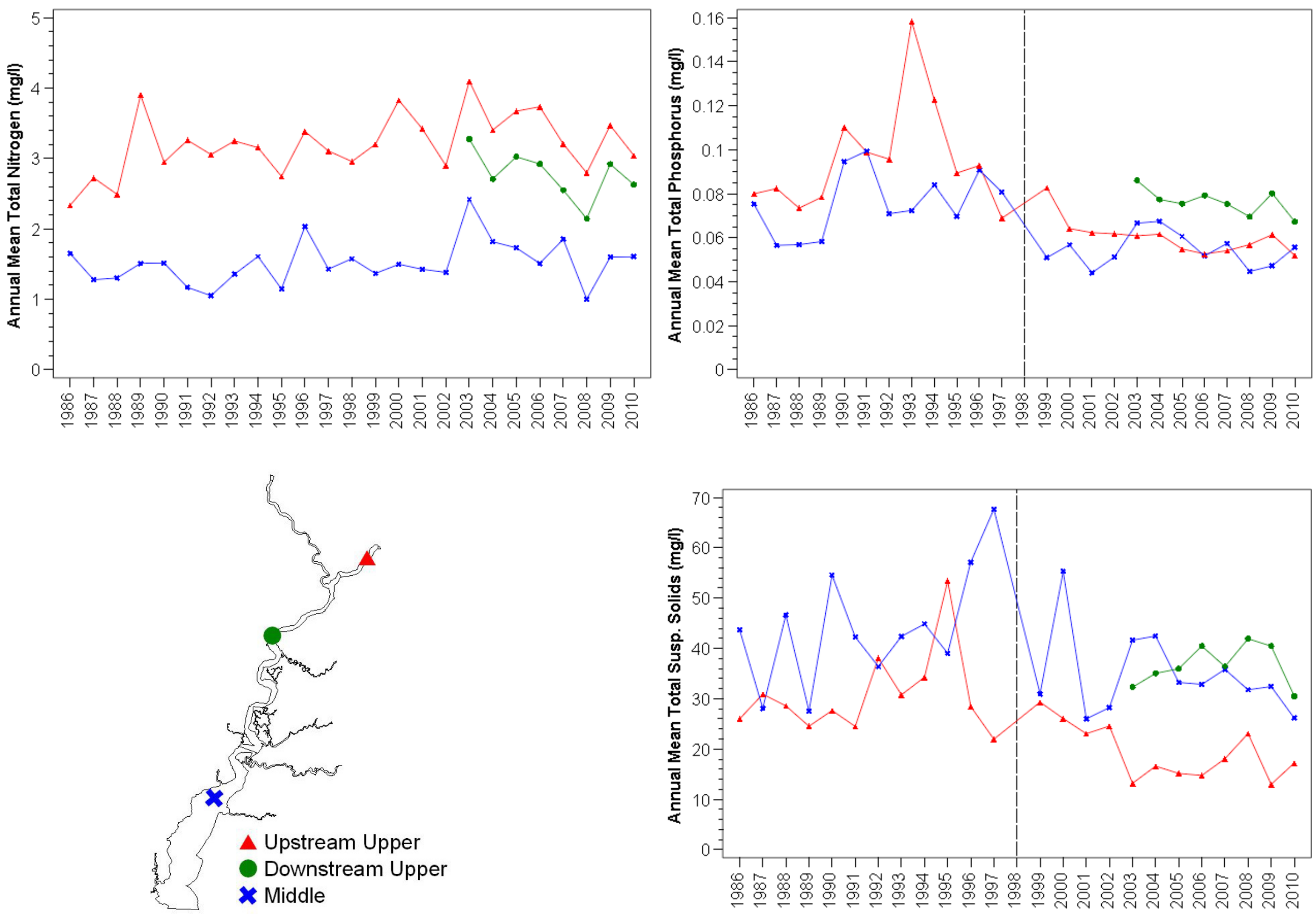

Figure 15. Annual means for total nitrogen, total phosphorus and total suspended solids in the Nanticoke River.
Dotted line (1998) indicates when the lab change occurred that may have impacted TP and TSS. Caution should be used in making comparisons for TP and TSS from before to after the lab change.

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[27] TP levels improved annually, in the summer and in the SAV growing season in the upstream upper Nanticoke from 1999-2010. PO_4 levels may have also decreased annually from 1999-2010.

[28] Middle Nanticoke river PO_4 levels were above the SAV habitat requirement for 2010.

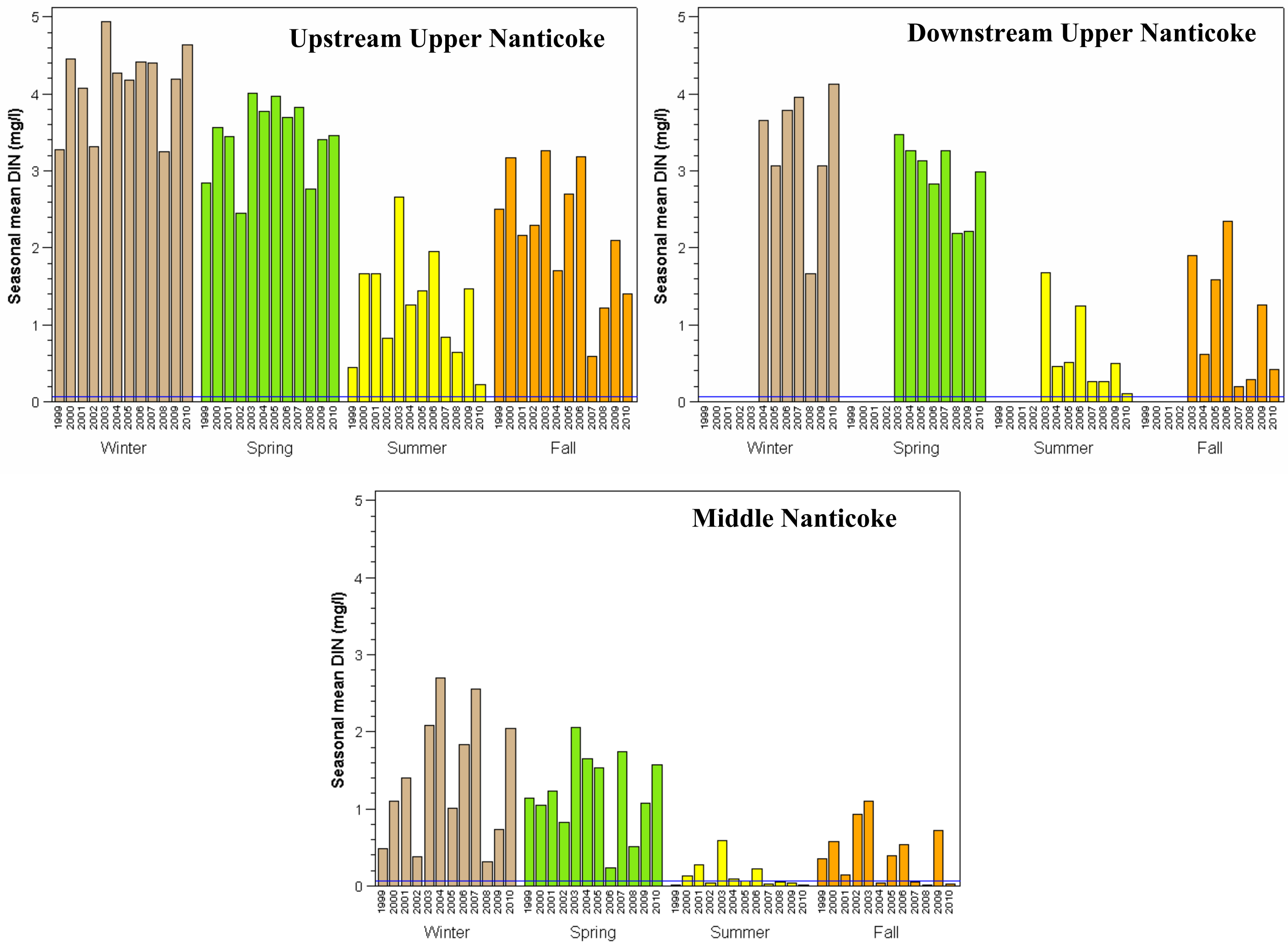

Figure 16. Mean dissolved inorganic nitrogen by season in the Nanticoke River.
The blue line at 0.07 mg/l indicates the DIN level below which nitrogen limitation likely occurs. Winter season includes December (of the previous year), January and February. Spring season includes March-May. Summer season includes July-August (June is a transition month and not included). Fall season includes October and November. Biological nutrient removal of nitrogen at WWTPs is most effective in warmer months, and seasonal changes in phytoplankton populations (blooms in spring and fall) reduce DIN.

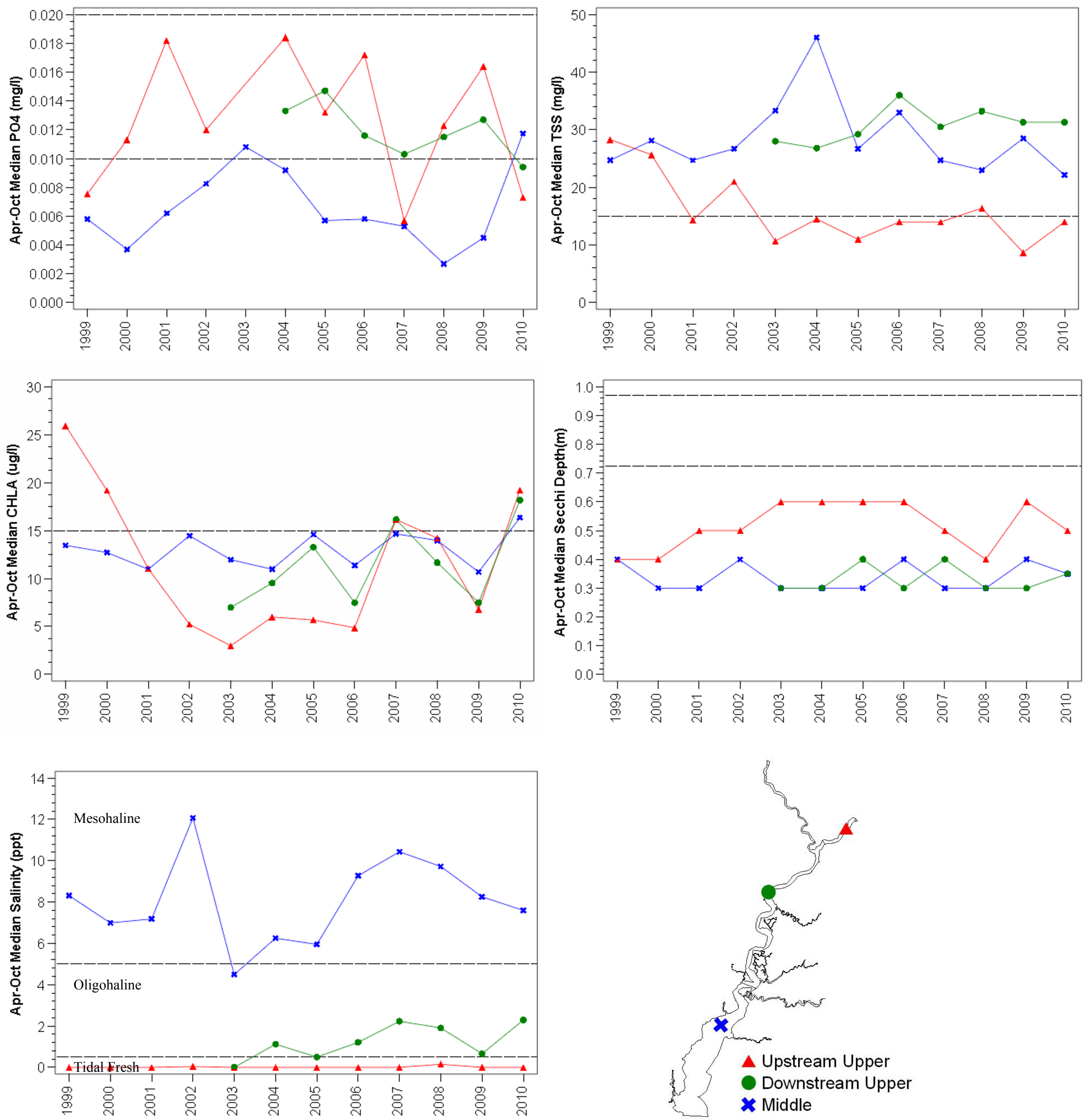

Figure 17. SAV Habitat Requirement parameters in the Nanticoke River.
SAV growing season (April-October) median values for PO_4, TSS, CHLA, Secchi depth and salinity. Threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of PO_4, TSS and CHLA need to be lower than the threshold and Secchi depth needs to be above the threshold. Upper river stations need to meet the tidal fresh/oligohaline thresholds and middle river needs to meet the mesohaline thresholds.

Habitat Quality

TSS levels improved in the summer and SAV growing season in the middle river.[29] TSS was still high and relatively poor throughout the river. TSS levels were close to or below the SAV habitat requirement in the upstream upper river but failed to meet the requirement at the downstream upper river and the middle river stations.

Algal abundance was relatively fair at the upstream upper river station, relatively good at the downstream upper river station and relatively poor in the middle river even though levels were similar. CHLA increased at the upper most station annually, in the summer and the SAV growing season.[30] CHLA levels met the requirement throughout the river in most years, but were above the threshold in 2010 at all three locations.

Water clarity was relatively poor throughout the river and failed to meet the requirement.[31] Summer BDO levels were good in both the upstream upper and middle river (not measured at the downstream upper river site) and monthly averages rarely dropped below 5 mg/l indicating good habitat quality (Figure 18).[32]

Salinity increased at the downstream upper and middle river stations annually, in summer and in the SAV growing season. SAV growing season salinities at the downstream upper station were predominantly oligohaline, while middle Nanticoke salinities were predominately mesohaline. Upstream upper river salinities were tidal fresh. There were no trends in water temperature.

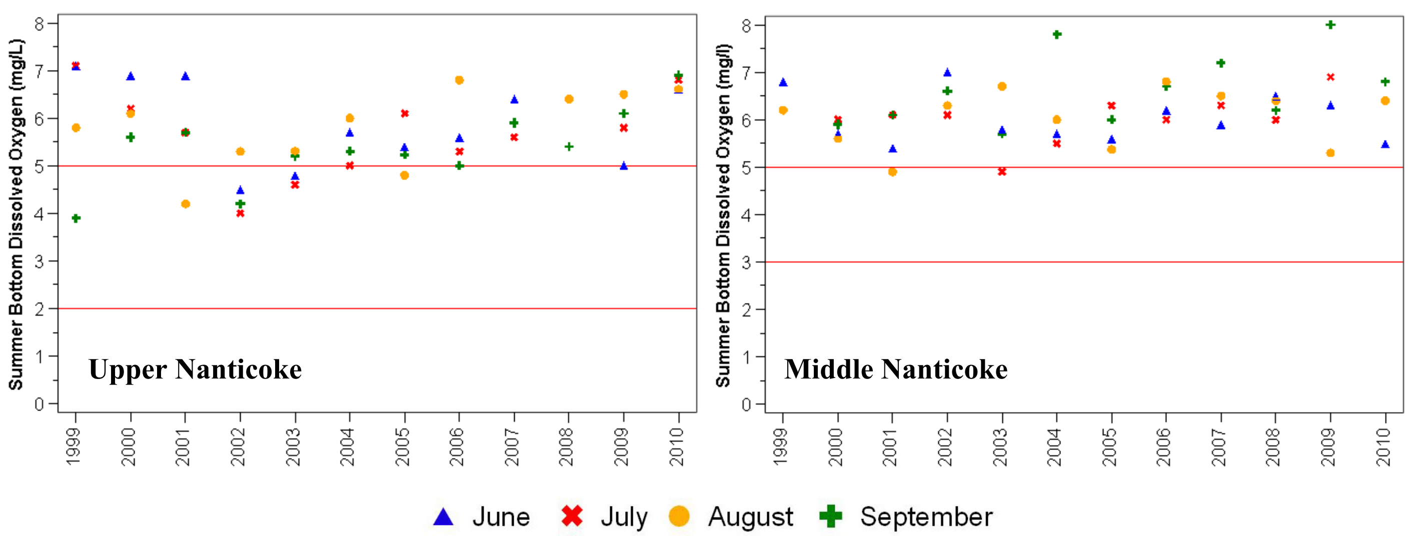

Figure 18. Summer bottom dissolved oxygen in the Nanticoke River.
Monthly bottom dissolved oxygen levels with threshold values of 5 mg/l and 3 mg/l shown with red reference lines.

[29] TSS improved in the upstream upper river annually, in summer and SAV growing seasons and may have improved in the spring from 1999-2010.

[30] Upriver algal levels decreased for 1985-2010 and during the spring and maybe annually for 1999-2010, which is in contrast to the 2003-2010 trend.

[31] Secchi depth improved for 1985-2010 in the upstream upper river.

[32] However, summer BDO levels decreased in the upstream upper river from 1985-2010.

Wicomico River

Water Quality
Nitrogen levels in the Wicomico River were high and relatively poor in the upper and middle river. TN was relatively poor and DIN was relatively good in the lower river. TN decreased throughout the river annually, in the summer and the SAV growing season. TN levels in the upper river are twice as high as in the middle and lower river (Figure 19). DIN levels in the upper river were extremely high and no nitrogen limitation occurred (Figure 20). DIN levels were low enough in the middle river for nitrogen limitation in the summer in most years and occasionally in the fall. DIN levels were also low enough in the lower river for nitrogen limitation in the summer and fall in most years.

Phosphorus levels were higher in the upper river than in the middle or lower river. In the upper river, TP levels were relatively poor and PO_4 levels were relatively fair. TP and PO_4 levels were both relatively poor mid- river. The lower river TP and PO_4 levels were both relatively good. PO_4 levels were lower than the SAV habitat requirement throughout the river (Figure 21). TP levels improved in the middle river annually, in the summer and SAV growing season and may have improved in the lower river annually. PO_4 levels improved annually and in the SAV growing season in the middle and lower river and may have improved in the upper river as well. PO_4 levels in the summer may also have improved throughout the river in the summer.

TSS levels were high and relatively poor throughout the river. TSS improved in the lower river in the SAV growing season and may have improved annually. Middle river TSS levels may have improved in the summer, but upper river TSS levels may have degraded in the SAV growing season.[33] Upper river TSS levels failed to meet the requirement. TSS levels in the lower river met the requirement in 2008-2010 and in the middle river in 2010.

Habitat Quality
Algal abundance was highest in the upper river and relatively poor throughout the river. Upper river algal levels degraded annually and in the SAV growing season, while lower river CHLA levels may have improved annually and in the SAV growing season. The middle and lower river CHLA levels met the habitat requirement for the SAV growing season.[34]

Water clarity was relatively poor throughout the river. Secchi depth improved in the middle river in the SAV growing season and may have improved in the summer, but water clarity still failed to meet the habitat requirement. Summer BDO levels were good mid-river (not measured at the upper and lower river sites), though monthly averages occasionally dropped below 5 mg/l (Figure 22).

Salinity increased in the middle and lower Wicomico annually, in summer and in SAV growing season. Upper river SAV growing season salinities were tidal fresh except for in 2008 when they were oligohaline. Mid-river salinities were oligohaline in 2003 and 2005 and mesohaline in other years. Lower river salinities remained in the mesohaline regime. There were no trends in water temperature.

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[33] Middle Wicomico River TSS levels may have improved in the summer from 1999-2010.
[34] CHLA levels in the middle Wicomico River were only slightly above the habitat requirement in 2010.

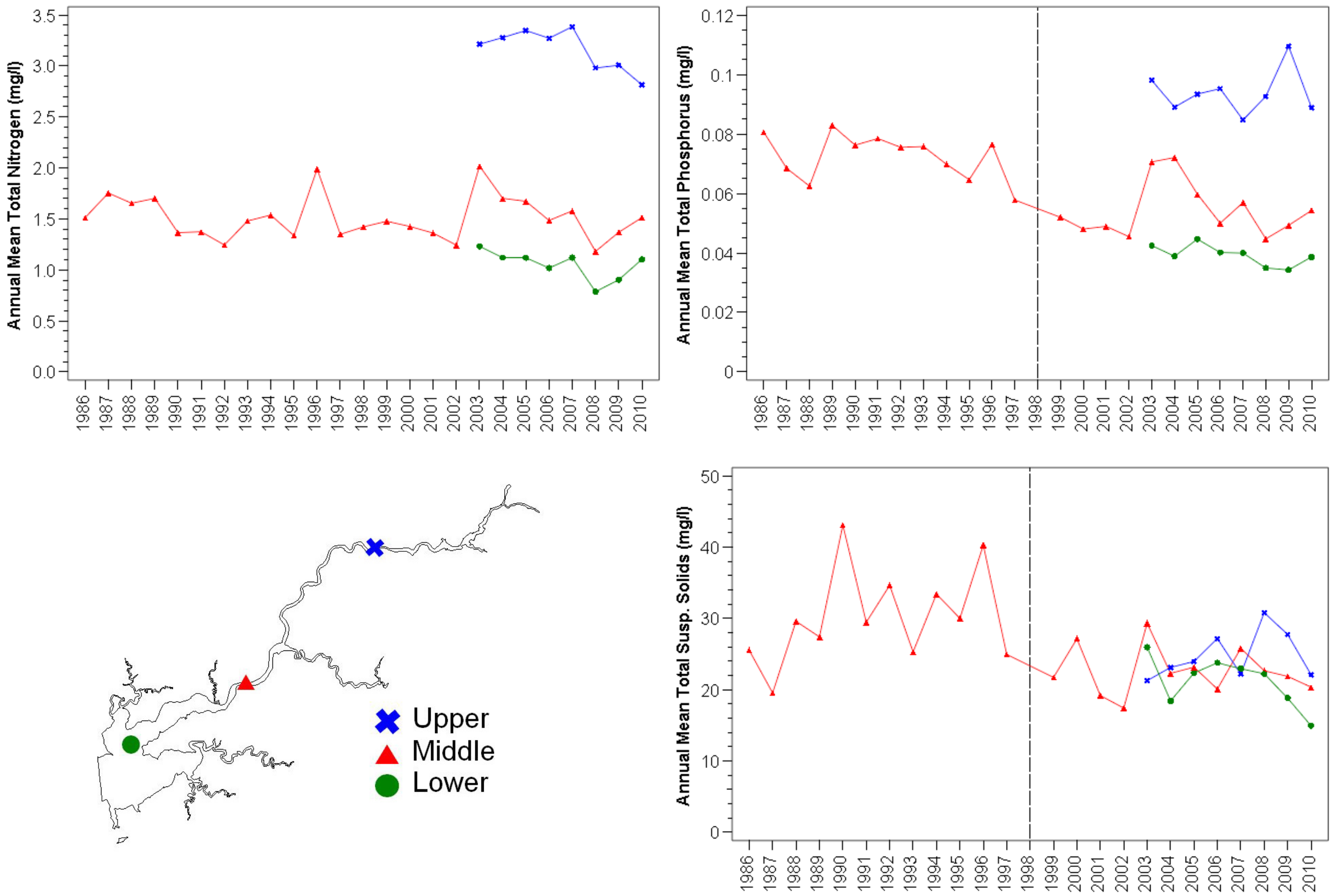

Figure 19. Annual means for total nitrogen, total phosphorus and total suspended solids in the Wicomico River.
Dotted line (1998) indicates when the lab change occurred that may have impacted TP and TSS. Caution should be used in making comparisons for TP and TSS from before to after the lab change.

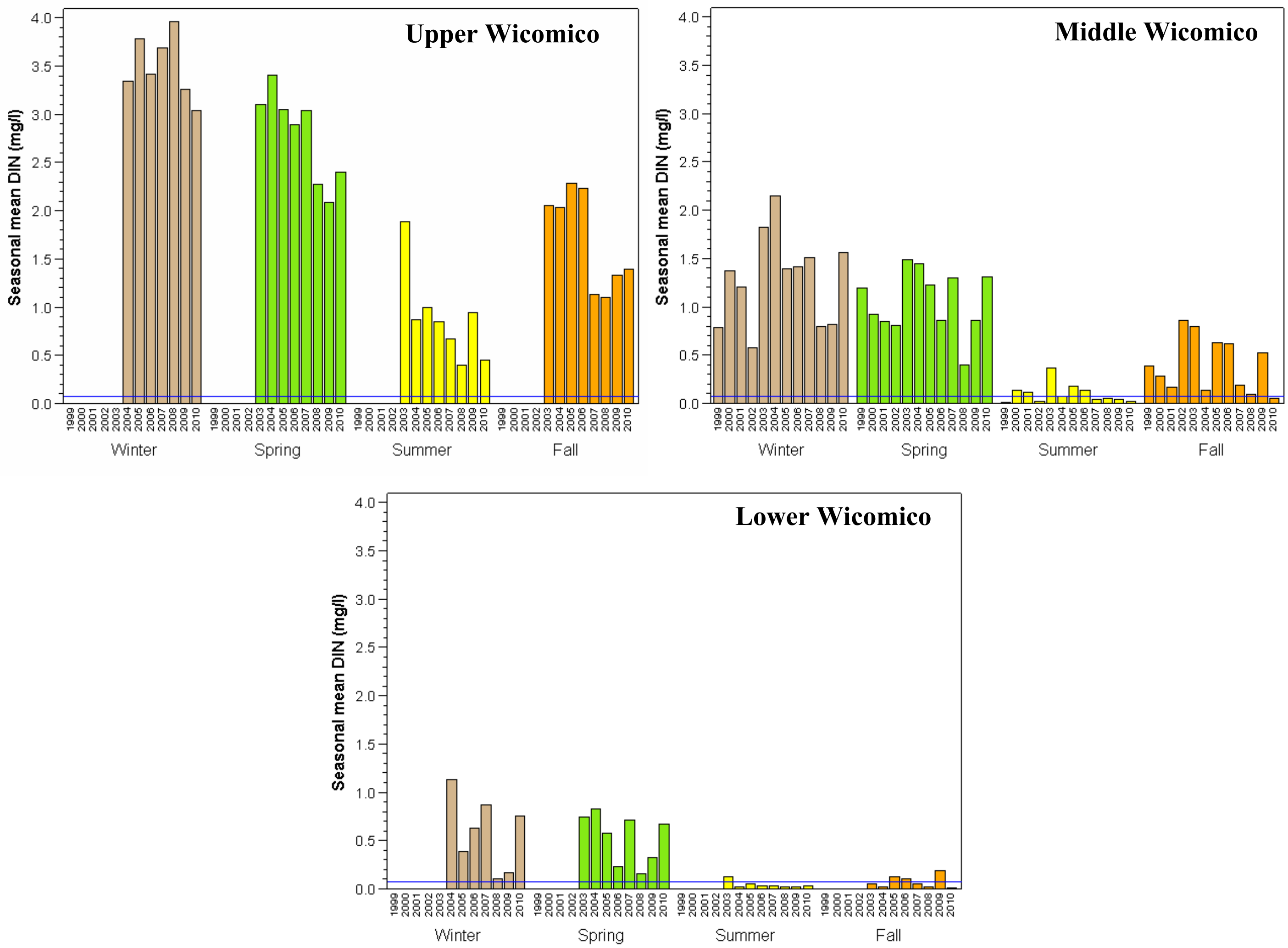

Figure 20. Mean dissolved inorganic nitrogen by season in the Wicomico River.
The blue line at 0.07 mg/l indicates the DIN level below which nitrogen limitation likely occurs. Winter season includes December (of the previous year), January and February. Spring season includes March-May. Summer season includes July-August (June is a transition month and not included). Fall season includes October and November. Biological nutrient removal of nitrogen at WWTPs is most effective in warmer months, and seasonal changes in phytoplankton populations (blooms in spring and fall) reduce DIN.

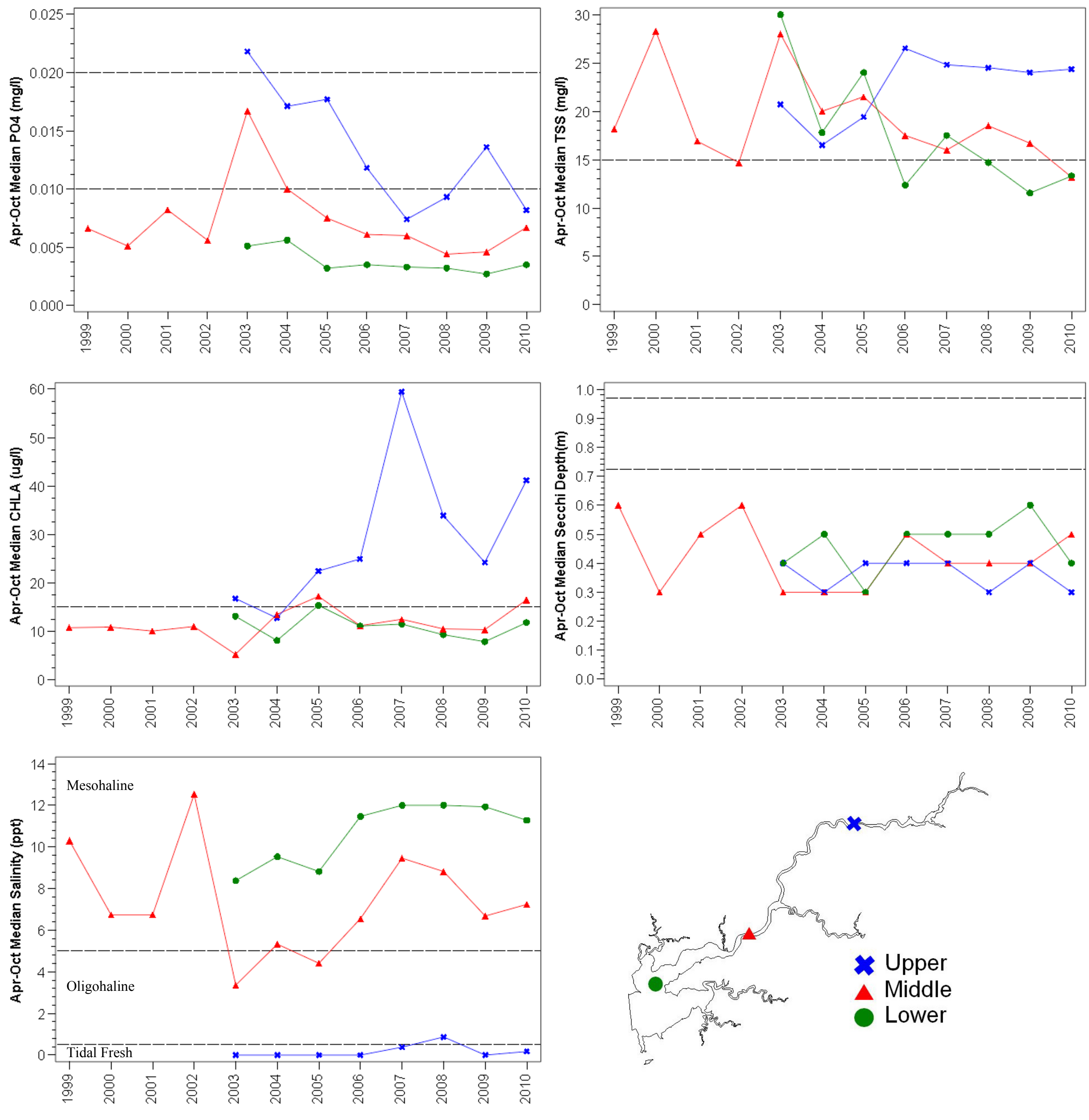

Figure 21. SAV habitat requirement parameters in the Wicomico River.
SAV growing season (April-October) median values for PO_4, TSS, CHLA, Secchi depth and salinity. Threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of PO_4, TSS and CHLA need to be lower than the threshold and Secchi depth needs to be above the threshold. Upper river and middle river need to meet the tidal fresh/oligohaline thresholds and lower river needs to meet the mesohaline thresholds.

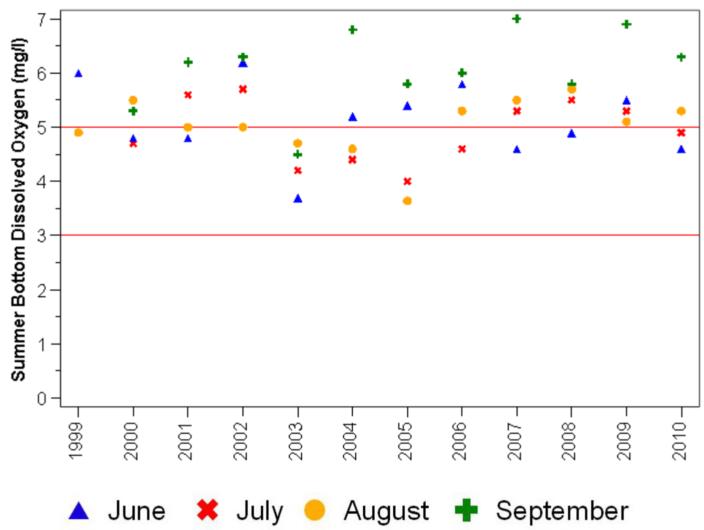

Figure 22. Summer bottom dissolved oxygen in the Wicomico River.
Monthly bottom dissolved oxygen levels with threshold values of 5 mg/l and 3 mg/l shown with red reference lines.

Manokin River

Water Quality
TN levels were relatively fair and DIN levels were relatively good in the Manokin River (Figure 23). TN in the Manokin may have improved annually. DIN levels in the upper Manokin decreased annually, in the summer and may have decreased in the SAV growing season. Lower Manokin DIN levels may have decreased annually. DIN levels in the upper Manokin were low enough for nitrogen limitation to occur in some years in the summer and fall (Figure 24). Nitrogen limitation likely occurred in the lower Manokin in the summer and fall and also in the winter and spring in some years.

Phosphorus levels were much higher in the upper Manokin than in the lower Manokin. TP was relatively poor throughout the Manokin. PO_4 levels were relatively poor in the upper Manokin and relatively good in the lower. Upper Manokin PO_4 levels in the SAV growing season were above the habitat requirement, but lower Manokin PO_4 levels met the requirement (Figure 25).

TSS may have improved in the lower Manokin annually, in summer and in the SAV growing season.[35] TSS was still high and relatively poor in the lower Manokin. Upper Manokin had relatively fair TSS levels for the salinity regime (though actual levels were higher than down river). Upper Manokin TSS levels were higher than the SAV habitat requirement, but lower Manokin TSS levels met the SAV habitat requirement.

[35] TSS may have improved in the SAV growing season in the lower Manokin from 1999-2010.

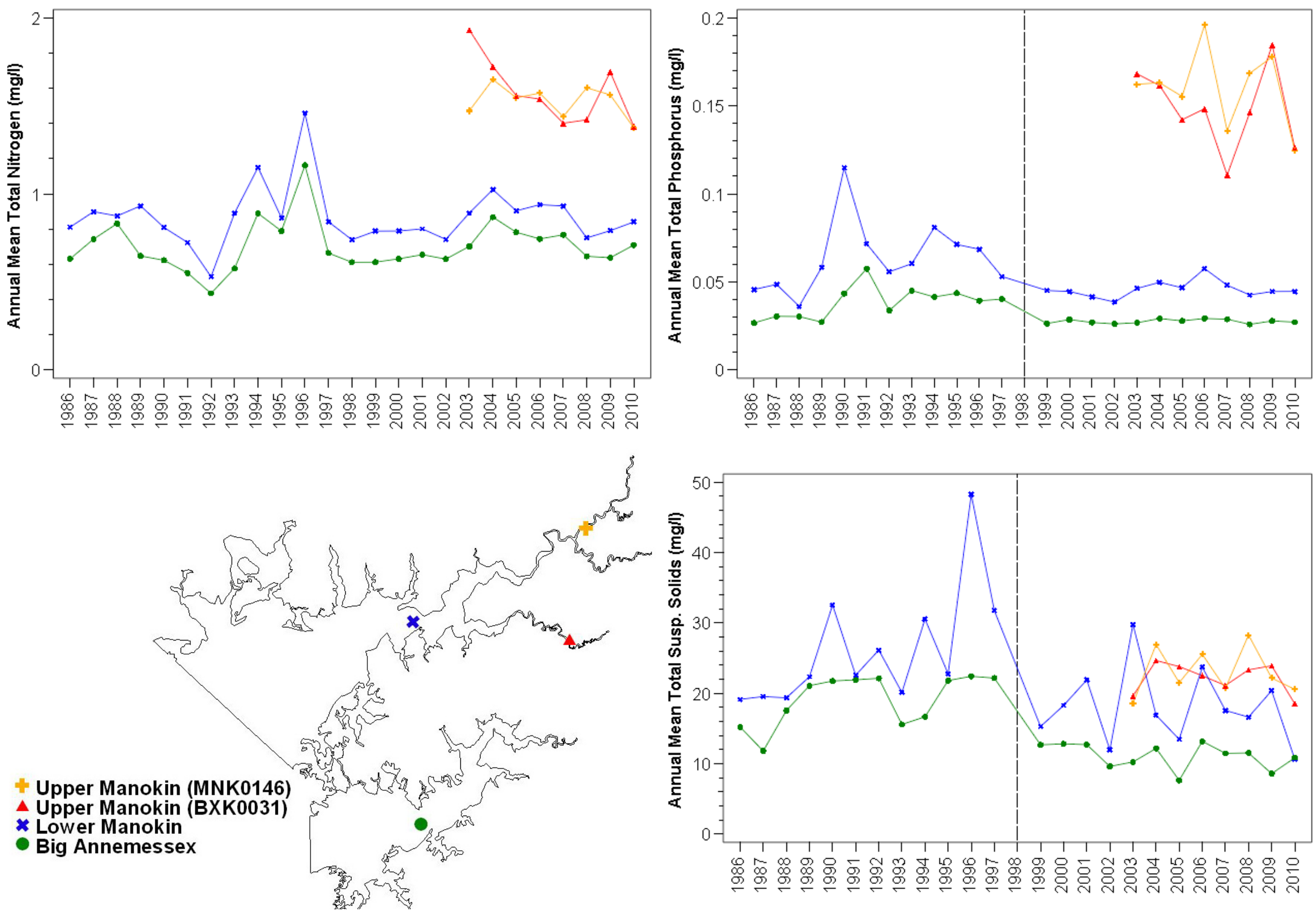

Figure 23. Annual means for total nitrogen, total phosphorus and total suspended solids in the Manokin and Big Annemessex rivers.
Dotted line (1998) indicates when the lab change occurred that may have impacted TP and TSS. Caution should be used in making comparisons for TP and TSS from before to after the lab change.

Habitat Quality

Algal abundance was highest and relatively poor in the upper Manokin, especially at MNK0146. Lower Manokin levels were relatively good. At the upper Manokin station MNK0146, CHLA levels have both met the SAV habitat requirement and were as much a 3 times higher than the requirement in different years. The other upper Manokin station met or was very close to the habitat requirement. The lower Manokin met the CHLA habitat requirement.

Water clarity was relatively poor. Lower Manokin Secchi depth improved annually, in the summer and in the SAV growing season.[36] Water clarity did not meet the habitat requirement. Summer BDO levels were good in the lower Manokin (not measured at the upper Manokin sites) indicating good habitat quality (Figure 26).

Salinity increased in the lower Manokin annually, in summer and in SAV growing season. Upper Manokin salinities increased in summer and SAV growing season and may have increased annually. SAV growing season salinities at MNK0146 changed from tidal fresh in 2003 and

[36] Secchi depth in the lower Manokin may have improved in the SAV growing season from 1999-2010.

2004 to oligohaline in 2005 to mesohaline in 2006-2008. MNK0146 salinity dropped back to oligohaline in 2009 but was mesohaline again in 2010. At BXK0031, salinities were mesohaline except in 2005 and 2009 when they were oligohaline. Lower Manokin salinities remained in the mesohaline regime except in 2002 when salinity was polyhaline. There were no trends in water temperature.

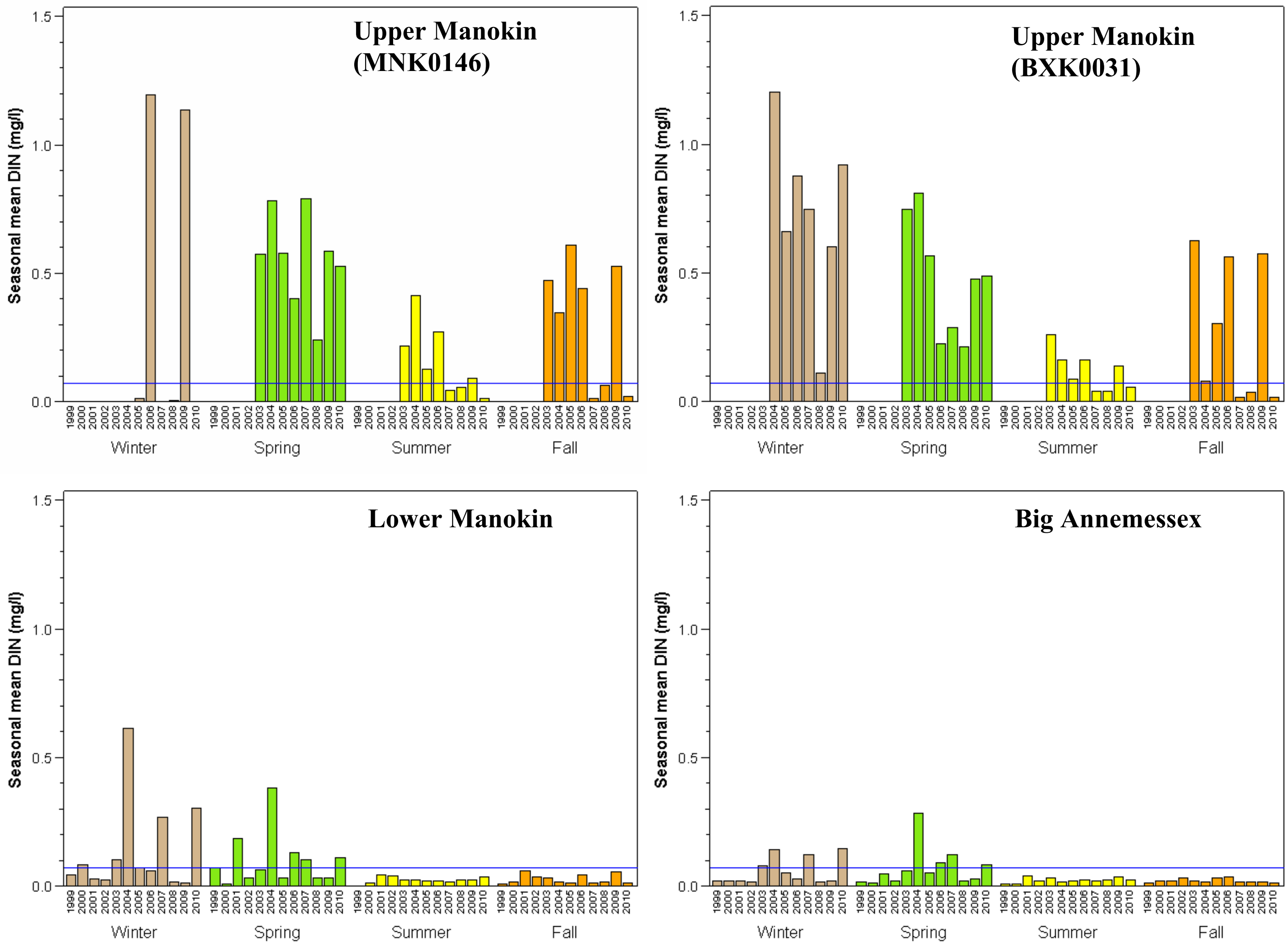

Figure 24. Mean dissolved inorganic nitrogen by season in the Manokin and Big Annemessex rivers.

The blue line at 0.07 mg/l indicates the DIN level below which nitrogen limitation likely occurs. Winter season includes December (of the previous year), January and February. Spring season includes March-May. Summer season includes July-August (June is a transition month and not included). Fall season includes October and November. Biological nutrient removal of nitrogen at WWTPs is most effective in warmer months, and seasonal changes in phytoplankton populations (blooms in spring and fall) reduce DIN. Note that the upper Manokin (MNK0146) is often not measured in the winter due to weather.

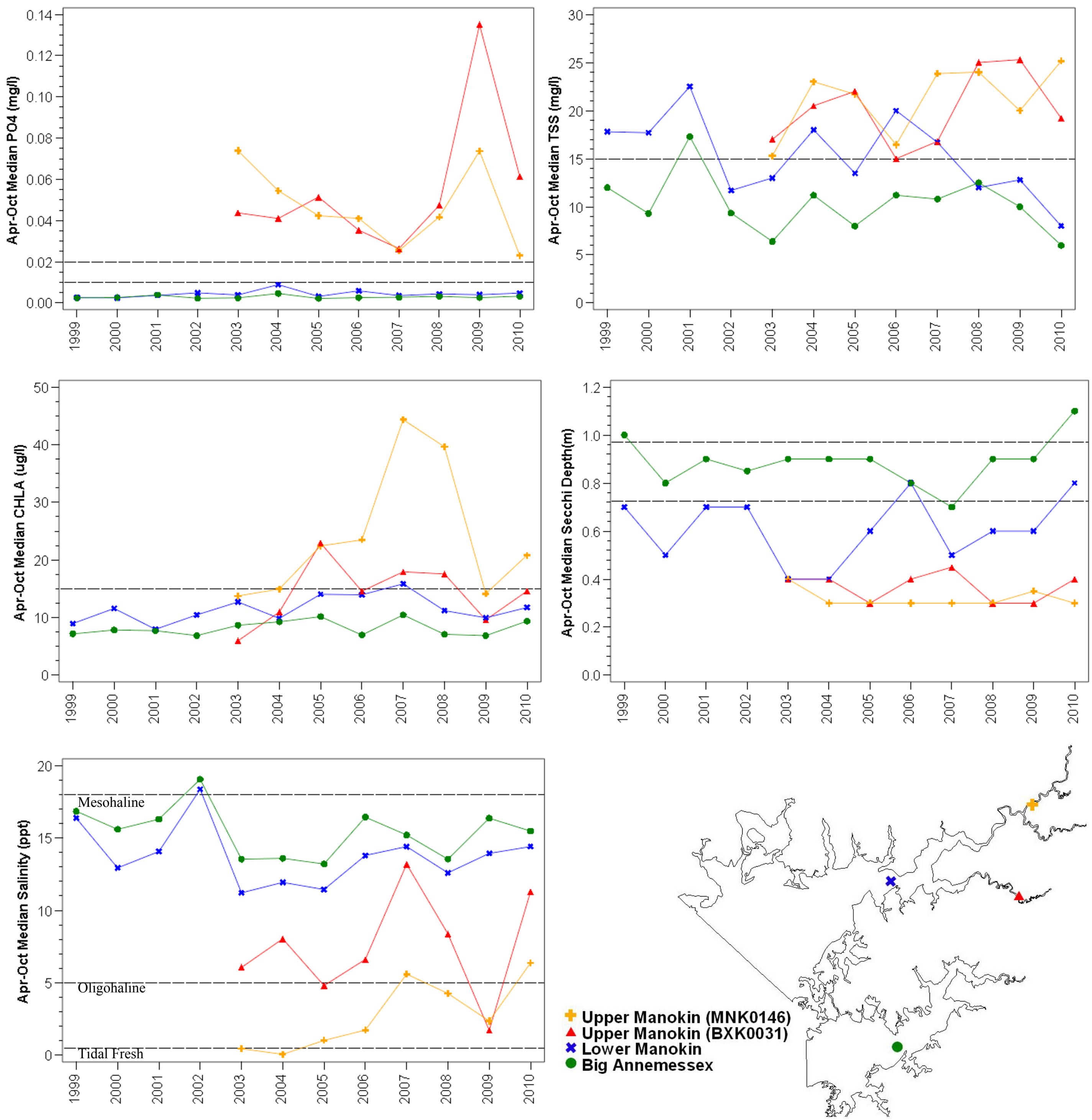

Figure 25. SAV habitat requirement parameters in the Manokin and Big Annemessex rivers. SAV growing season (April-October) median values for PO_4, TSS, CHLA, Secchi depth and salinity. Threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of PO_4, TSS and CHLA need to be lower than the threshold and Secchi depth needs to be above the threshold. Upper Manokin stations fluctuate between the oligohaline and the mesohaline salinity zone. Lower Manokin and Big Annemessex are in the mesohaline salinity zone.

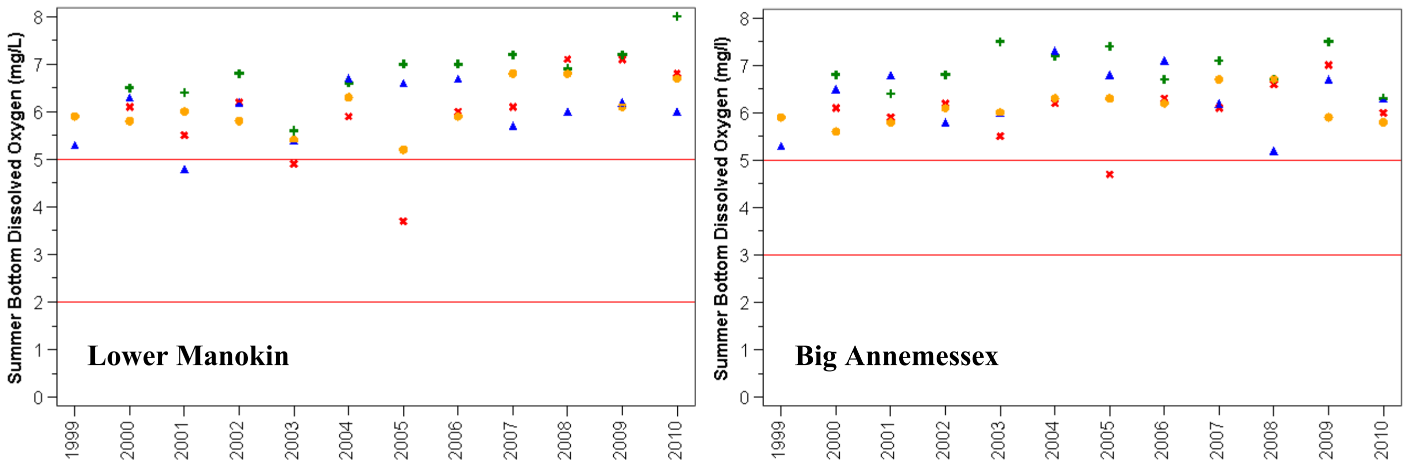

Figure 26. Summer bottom dissolved oxygen in the Manokin and Big Annemessex rivers. Monthly bottom dissolved oxygen levels with threshold values of 5 mg/l and 3 mg/l shown with red reference lines.

Big Annemessex River

Water Quality

Both TN and DIN levels were relatively good in the Big Annemessex (Figure 23). TN improved in the Big Annemessex annually and may have improved in the spring. Nitrogen limitation likely occurred in the Big Annemessex Rivers in the summer and fall and also in the winter and spring in some years (Figure 24). TP, PO_4 and TSS levels were relatively good in the Big Annemessex River and PO_4 and TSS levels met the requirements (Figure 25).

Habitat Quality

Algal abundance was relatively good in the Big Annemessex and met the habitat requirement. Water clarity was relatively poor, but did meet the requirement in 2010. Summer BDO levels were good, indicating good habitat quality (Figure 26).

Salinity increased in Big Annemessex annually, in summer and in SAV growing season. Big Annemessex salinities remained in the mesohaline regime except in 2002 when salinity was polyhaline. There were no trends in water temperature.

Pocomoke River

Water Quality
The Pocomoke River is a blackwater river.[37] The water is naturally darkened by tannins which reduces water clarity and algal densities. In addition, sediments in the Pocomoke watershed are naturally high in iron, which binds to phosphorus.[38] When these sediments are washed into the water, they carry a higher amount of phosphorus than sediments in other rivers would carry. In addition, the iron-rich sediments contribute to decreased water clarity. For these reasons, phosphorus levels are higher and water clarity is lower due to natural conditions and not only human activities.

TN levels in the Pocomoke were high and relatively poor in the middle and lower river (Figure 27). TN levels were relatively good in the upper river despite actual levels similar to the rest of the river. DIN levels were low and relatively good throughout the river. TN decreased in the upper and middle river annually and in the summer and SAV growing season.[39] TN decreased in the lower river in spring and may have decreased annually. DIN decreased annually, in the summer and the SAV growing season throughout the river.[40] DIN levels in the upper and middle river were high enough that nitrogen limitation of algal growth rarely occurred, but may have occurred in the lower river in some years (Figure 28).

Phosphorus levels were high and relatively poor throughout the river. TP and PO_4 may have improved annually and in the SAV growing season in the upper river, and PO_4 may have improved in the summer in the upper and middle river.[41] PO_4 levels were still too high in the upper and middle river to meet the SAV habitat requirement (Figure 29). The lower river met the habitat requirement for PO_4 in 2008.

TSS levels degraded annually and may have degraded in the SAV growing season in the middle river.[42] TSS was relatively good in the upper river and relatively poor in the middle and lower river. TSS levels in the SAV growing season met the habitat requirement in the upper river but not in the middle or lower river.

Habitat Quality
Algal density was relatively good upriver and mid-river and relatively poor in the lower river. CHLA levels degraded in the upper river in the summer and may have degraded annually and in the SAV growing season. CHLA levels in the middle river may have degraded annually and in

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[37] A blackwater river is one that is deep and slow-moving through a forested area. Tannins created by decaying plants stain the water.
[38] Bricker, O.P., Newell, W.L., Simon, N.S, 2003, Bog iron formation in the Nassawango Watershed, Maryland: U.S. Geological Survey Open-File Report 03-0346. http://pubs.usgs.gov/of/2003/of03-346/
[39] TN decreased in the upper Pocomoke River from 1985-2010; upper river TN decreased from 1999-2010 annually and in the SAV growing season, and may have decreased in spring and summer as well.
[40] The summer and SAV growing season DIN trends from 2003-2010 in the lower Pocomoke were significant at $p = 0.011$ and $p = 0.013$ respectively. DIN levels also decreased upriver from 1999-2010 annually, in the summer and in the SAV growing season, and may have decreased in the spring. The DIN:PO_4 ratio decreased from 1999-2010 annually in the mid and lower river, and in the summer and SAV growing season in the lower river. Mean annual DIN: PO_4 ratio was 15:1 in the middle river and 33:1 in the lower river, close to the Redfield ratio of 16:1
[41] Upper Pocomoke River PO_4 levels may have improved annually from 1999-2010.
[42] TSS levels improved in the upper Pocomoke River annually and may have improved in the SAV growing season from 1999-2010.

the summer.[43] CHLA levels met the SAV habitat requirement in the upper and middle river, and in the lower river in 2009.

Water clarity was poor throughout the river and failed to meet the habitat requirement. BDO levels in the summer were relatively fair in the upper river (not measured at the mid-river or lower river site) but monthly averages from June-August almost always fell below 5 mg/l and occasionally below 3 mg/l (Figure 30).[44]

Salinity increased in the lower Pocomoke annually and in summer and may have increased in the SAV growing season. Middle river salinity also increased in the summer. SAV growing season salinities in the upper Pocomoke were tidal fresh. Middle river salinities were tidal fresh except in 2007 and 2010 when they were oligohaline. Lower Pocomoke salinities were mesohaline except for oligohaline in 2003, 2005 and 2009.

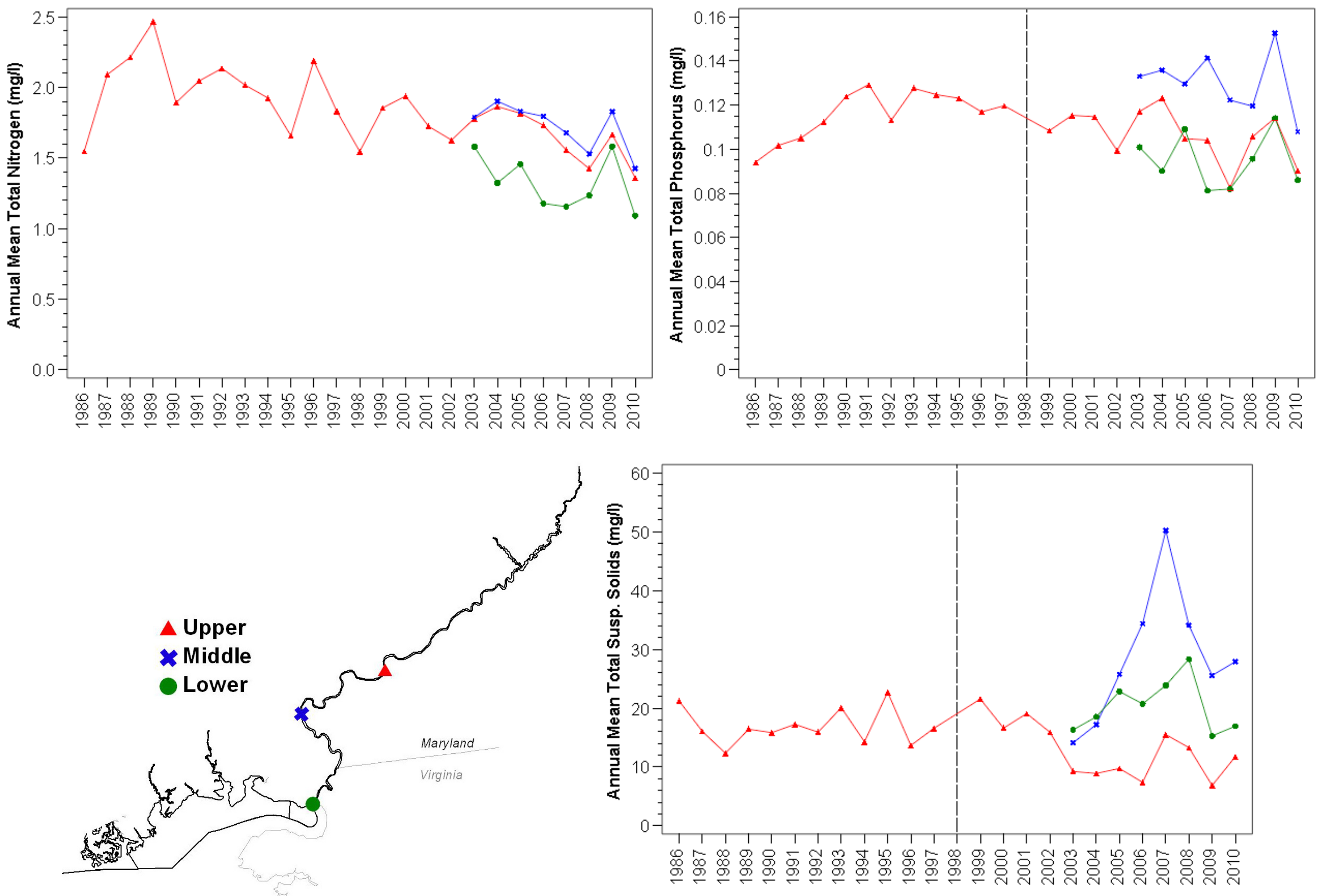

Figure 27. **Annual means for total nitrogen, total phosphorus and total suspended solids in the Pocomoke River.**
Dotted line (1998) indicates when the lab change occurred that may have impacted TP and TSS. Caution should be used in making comparisons for TP and TSS from before to after the lab change.

[43] Upper Pocomoke River algal levels decreased from 1985-2010 and during the spring from 1999-2010 and may have decreased annually from 1999-2010.
[44] BDO levels decreased in the upper river from 1985-2010.

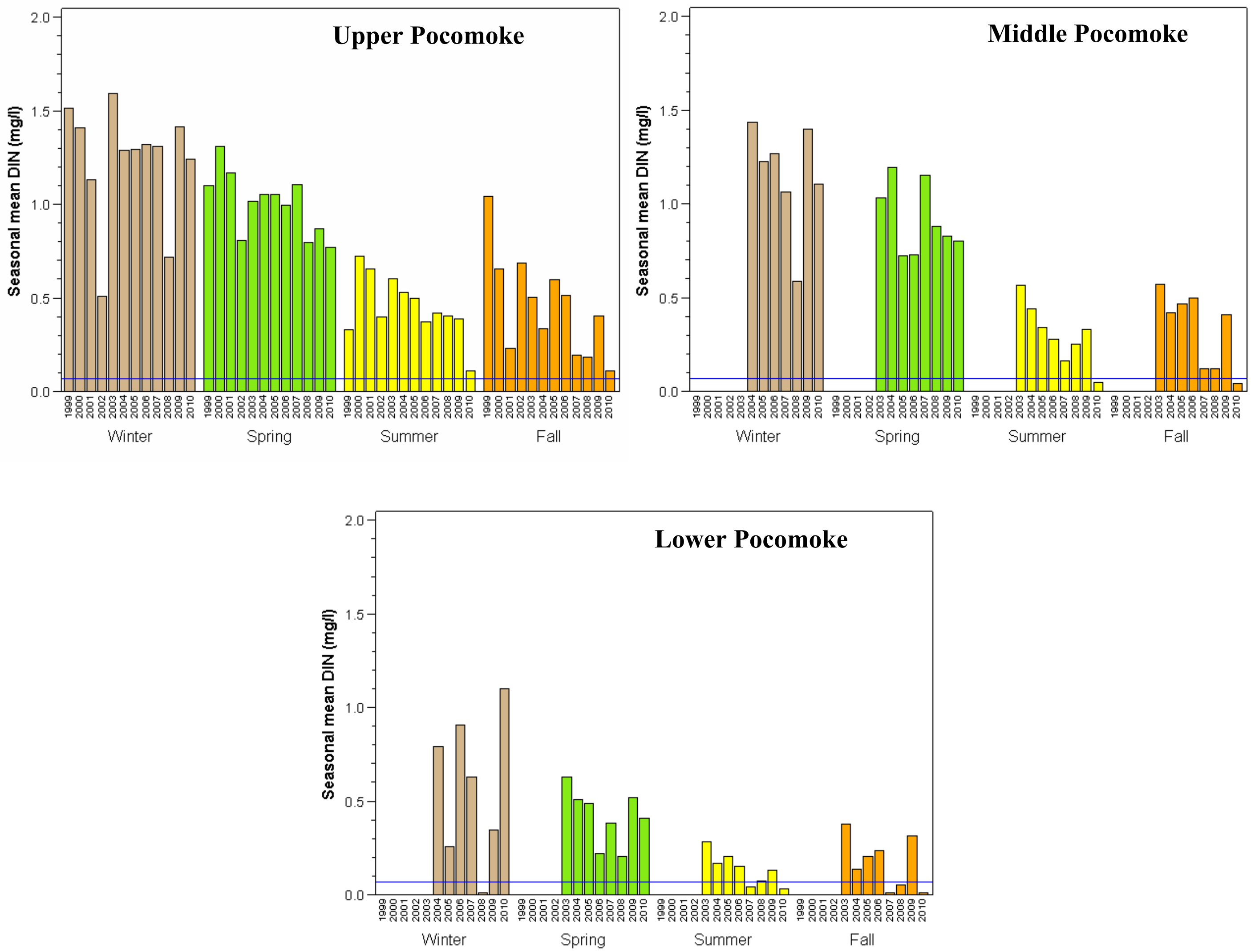

Figure 28. Mean dissolved inorganic nitrogen by season in the Pocomoke river.
The blue line at 0.07 mg/l indicates the DIN level below which nitrogen limitation likely occurs. Winter season includes December (of the previous year), January and February. Spring season includes March-May. Summer season includes July-August (June is a transition month and not included). Fall season includes October and November. Biological nutrient removal of nitrogen at WWTPs is most effective in warmer months, and seasonal changes in phytoplankton populations (blooms in spring and fall) reduce DIN.

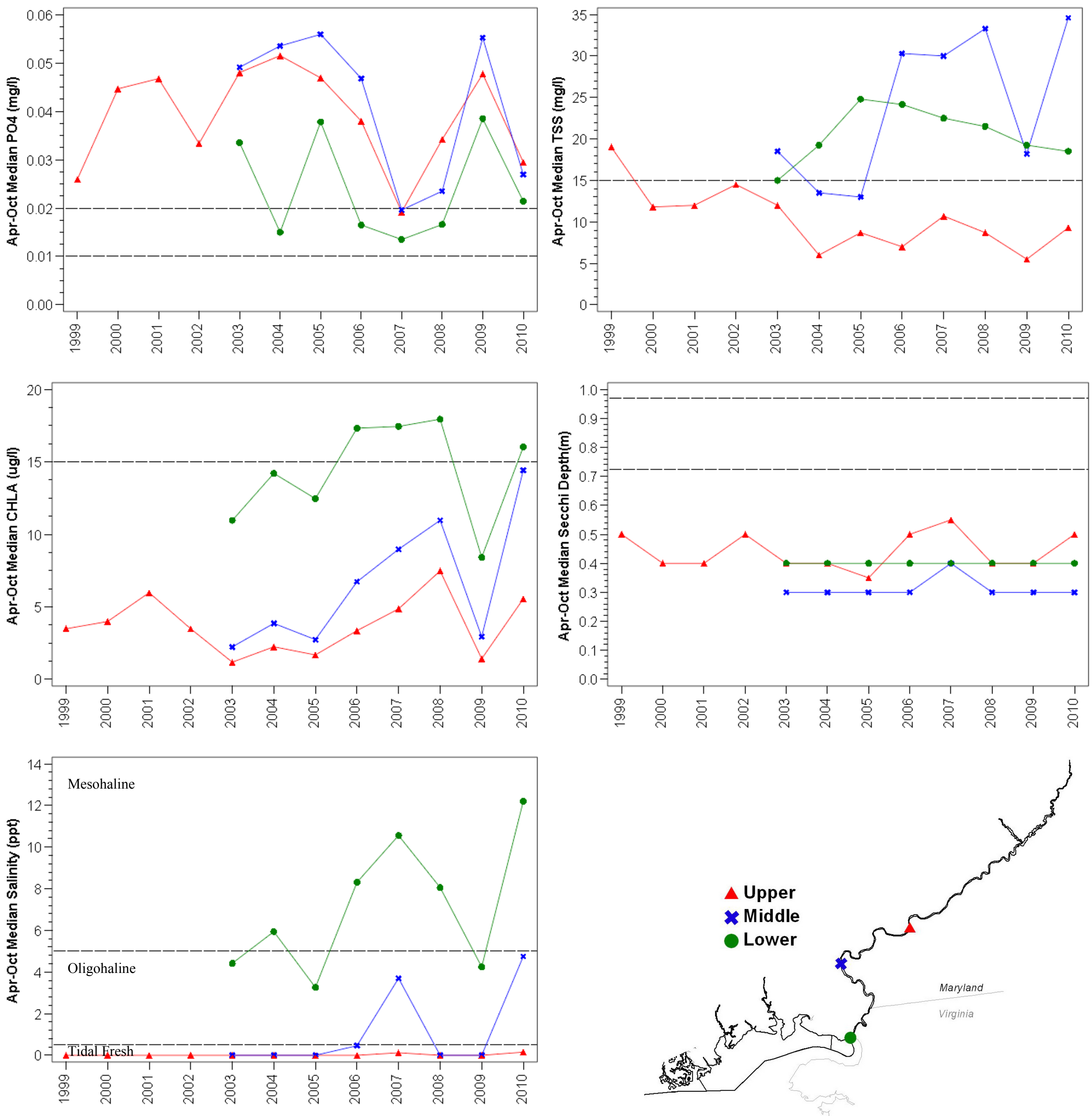

Figure 29. SAV habitat requirement parameters in the Pocomoke River.
SAV growing season (April-October) median values for PO_4, TSS, CHLA and Secchi depth. Threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of PO_4, TSS and CHLA need to be lower than the threshold and Secchi depth needs to be above the threshold. Upper river needs to meet the tidal fresh/oligohaline thresholds. Middle Rivers needed to meet the tidal fresh/oligohaline thresholds in 2008 and 2009 and the mesohaline thresholds in 2010. Lower river needs to meet the mesohaline thresholds in 2008 and 2010 and the oligohaline thresholds in 2009.

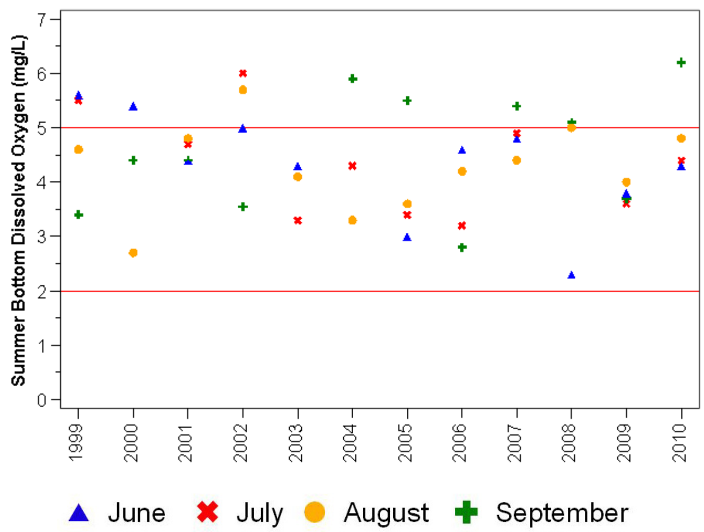

Figure 30. Summer bottom dissolved oxygen in the upper Pocomoke River.
Monthly bottom dissolved oxygen levels with threshold values of 5 mg/l and 3 mg/l shown with red reference lines.

North Tangier Sound/ South Tangier Sound

Water Quality
Nitrogen levels were low and relatively good in the North and South Tangier Sounds (Figure 31).[45] TN levels improved annually and in the SAV growing season in North and South Tangier Sound and may have improved in the summer. TN levels also may have improved in the spring in South Tangier Sound. DIN levels improved annually and may have improved in both in the SAV growing season and in summer in North Tangier Sound. DIN levels were low enough to allow nitrogen limitation of algal growth in the summer and fall in most years and winter and spring in some years (Figure 32).

Phosphorus levels were low and relatively good. PO_4 met the habitat requirement (Figure 33). TSS levels were relatively good and improved in the SAV growing season in North Tangier Sound and may have improved in the summer.[46] TSS levels in the Sounds met the SAV habitat requirement.

Habitat Quality
Algal abundance was relatively fair in North Tangier and relatively good in South Tangier Sound. CHLA may have improved in North Tangier Sound annually and in SAV growing season.[47]

Water clarity was relatively poor in North Tangier and relatively good in South Tangier Sound. Secchi depth may have improved in South Tangier annually, in the SAV growing season, and the

[45] TN levels may have increased in the South Tangier Sound annually from 1999-2010.
[46] From 1999-2010, TSS improved in South Tangier Sound in the SAV growing season and in North Tangier Sound in summer. TSS may have improved in North Tangier from 1999-2010 annually and in summer.
[47] CHLA degraded in both North and South Tangier Sound from 1985-2010.

summer.[48] North Tangier Sound failed to meet the SAV habitat requirement for water clarity but South Tangier Sound met the habitat requirement in 2008-2010.

BDO levels in the summer were fair in North and South Tangier. However, monthly average BDO often falls below 5 mg/l and sometimes falls below 3 mg/l (Figure 34).[49] Salinity increased in the Sounds annually, in summer and in the SAV growing season.[50] There are no trends in water temperature.

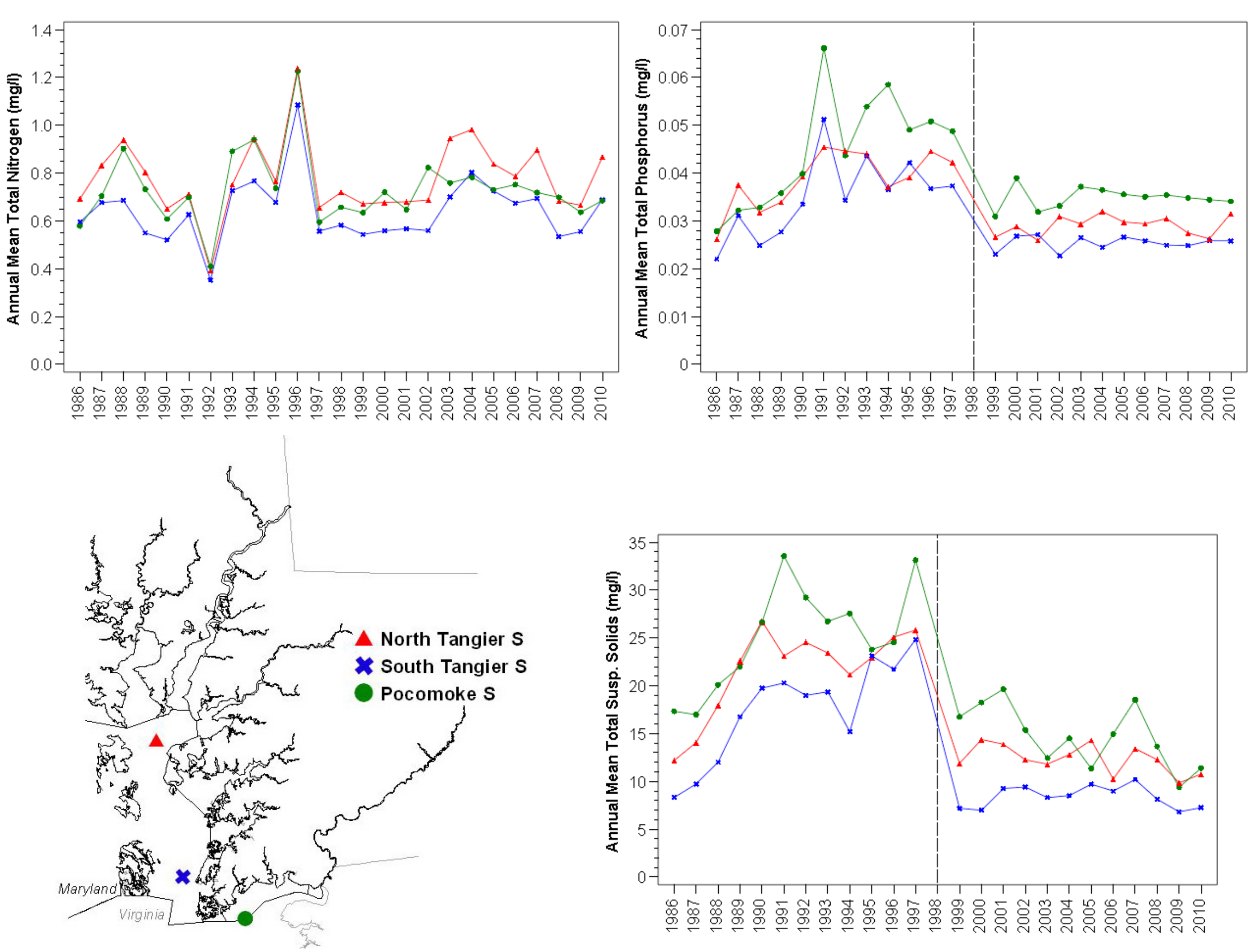

Figure 31. Annual means for total nitrogen, total phosphorus and total suspended solids in Tangier and Pocomoke sounds.
Dotted line (1998) indicates when the lab change occurred that may have impacted TP and TSS. Caution should be used in making comparisons for TP and TSS from before to after the lab change.

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[48] Secchi depth degraded from 1985-2010 in North and South Tangier Sounds but a non-linear trend indicates improvement since the early 2000s.
[49] From 1985-2010 summer BDO levels decreased in South Tangier Sound and may have decreased in North Tangier Sound.
[50] Salinity decreased in the Sounds in the spring from 1999-2010 and may have degraded annually in South Tangier Sound.

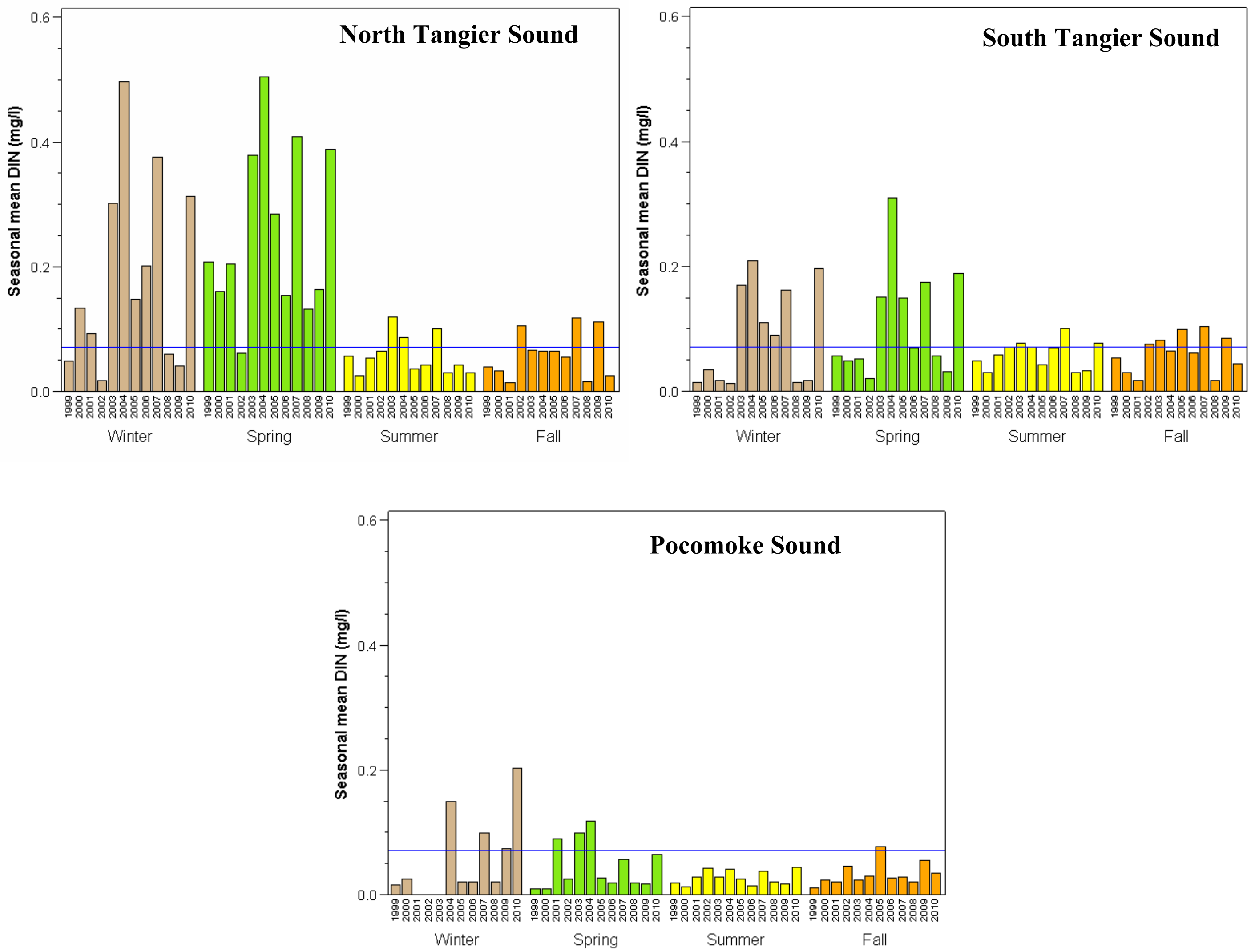

Figure 32. Mean dissolved inorganic nitrogen by season in Tangier and Pocomoke sounds. The blue line at 0.07 mg/l indicates the DIN level below which nitrogen limitation likely occurs. Winter season includes December (of the previous year), January and February. Spring season includes March-May. Summer season includes July-August (June is a transition month and not included). Fall season includes October and November. Biological nutrient removal of nitrogen at WWTPs is most effective in warmer months, and seasonal changes in phytoplankton populations (blooms in spring and fall) reduce DIN.

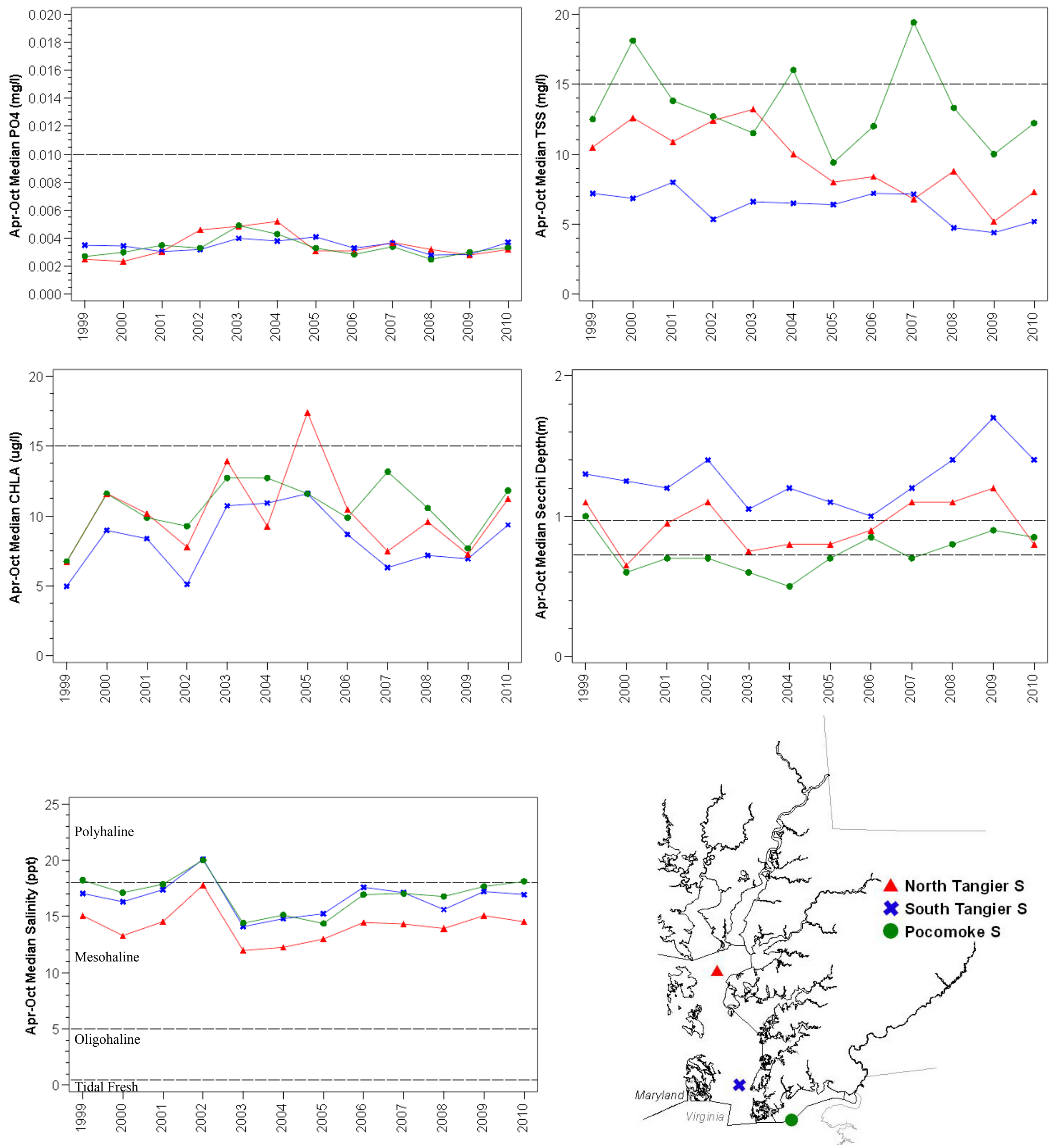

Figure 33. SAV habitat requirement parameters in Tangier and Pocomoke sounds.
SAV growing season (April-October) median values for PO_4, TSS, CHLA, Secchi depth and salinity. Threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of PO_4, TSS and CHLA need to be lower than the threshold and Secchi depth needs to be above the threshold. All three stations need to meet the mesohaline thresholds.

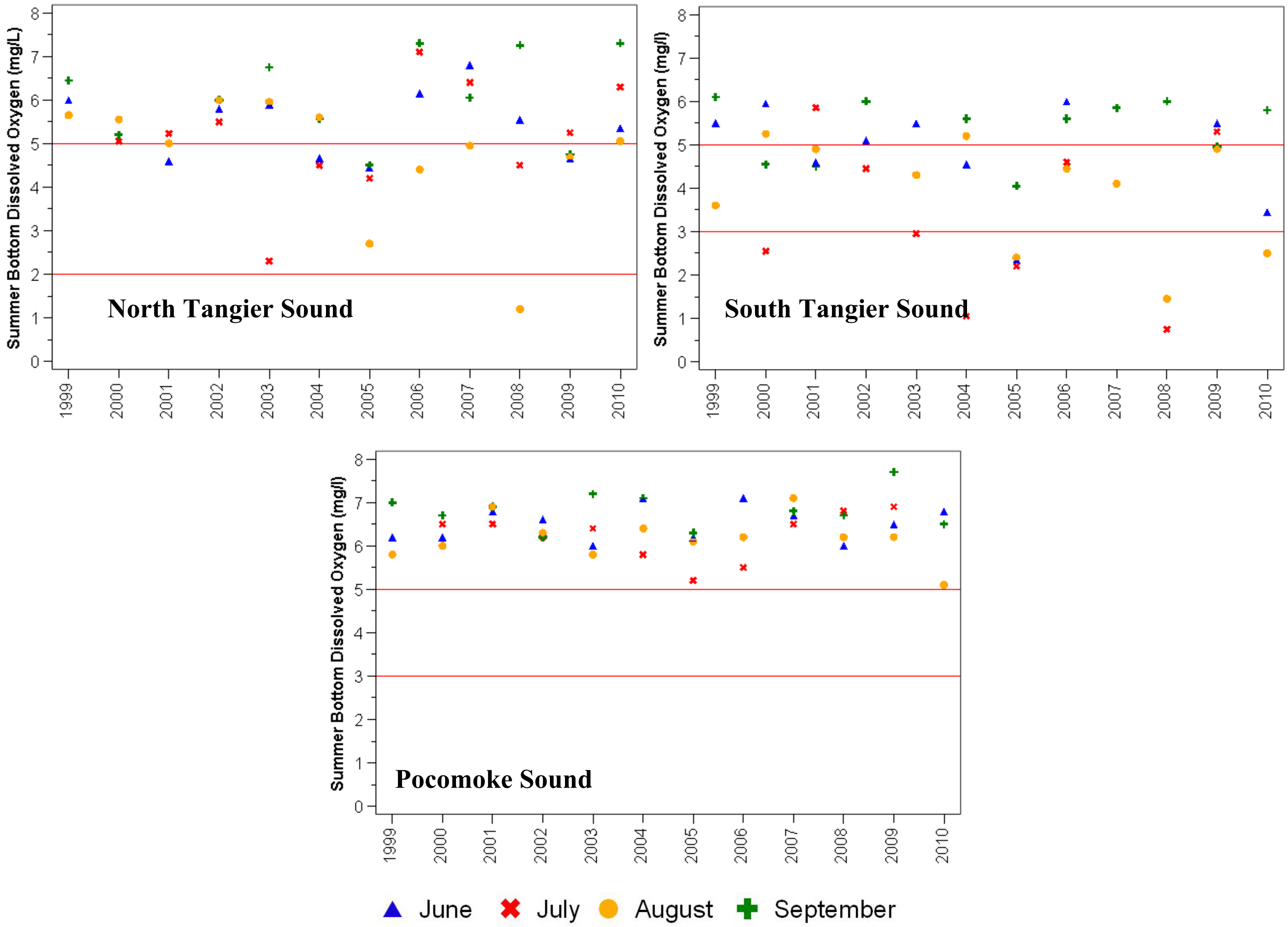

Figure 34. Summer bottom dissolved oxygen in the Tangier and Pocomoke sounds. Monthly bottom dissolved oxygen levels with threshold values of 5 mg/l and 3 mg/l shown with red reference lines.

Pocomoke Sound

Water Quality

Nitrogen levels were low and relatively good in Pocomoke Sound (Figure 31).[51] TN levels may have improved annually. DIN levels were low enough to allow nitrogen limitation of algal growth almost always in Pocomoke Sound (Figure 32). Phosphorus levels were low and relatively good and PO_4 levels met the habitat requirement (Figure 33). TSS levels were relatively poor but met the SAV habitat requirement.[52]

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[51] TN levels may have increased in Pocomoke Sound annually from 1999-2010.

[52] TSS may have improved in Pocomoke Sound from 1999-2010 annually.

Habitat Quality
Algal abundance was relatively poor in Pocomoke Sound. CHLA improved in annually and may have improved in SAV growing season.[53] Water clarity was relatively poor but Secchi depth may have improved annually and in the SAV growing season.[54] Pocomoke Sound failed to meet the SAV habitat requirement for water clarity.

BDO levels in the summer were good and always above 5 mg/l. Salinity increased annually, in summer and in the SAV growing season.[55] There are no trends in water temperature.

Shallow water

The tidal long-term monitoring program samples at a fixed point that is generally in the center channel and deeper waters of a river. Sampling is usually done once or twice a month. The strength of this type of monitoring is that the repetition of sampling over many years (more than two decades) measures how water quality has changed over time and in response to management actions, land use changes, etc. However, conditions at the long-term monitoring station may not adequately capture water quality conditions in shallow waters, the river as a whole or on short time scales. The shallow water monitoring program is designed to measure conditions in the areas closest to land that are critical habitat areas, especially in the areas with underwater grass beds. Sampling in a river is done for a 3-year period to determine short-term changes in water quality that occur due to weather, such as between a year with very high rainfall and a year with low rainfall. Some shallow water stations have been monitored for longer periods.

The first part of the shallow water monitoring program uses instruments that stay in the water for extended periods (usually April-October) and collect information every 15 minutes; this is called the continuous monitoring program. Instead of the one or two samples a month typical of the long-term monitoring program, the continuous monitoring program can collect more than 2,800 samples a month.[56] This type of monitoring 1) measures water quality changes that occur between night and day, between days and at longer times spans; 2) determines how long water quality problems persist, such as algal blooms or low oxygen water; and 3) measures water quality changes that occur related to weather events such as storms.

The second part of the monitoring program samples all of the shallow waters of a river (or river segment in larger rivers) once a month from April-October; this is the water quality mapping program. Data is collected nearly constantly as a boat moves along the entire shoreline, so changes in water quality can be measured from one part of the river to another. This data captures water quality in very localized areas and can identify places with better or worse water quality than the river overall. This monitoring is also able to capture changes in water quality related to events that occur in only part of the river such as algal blooms or in response to localized nutrient sources.

The Maryland DNR shallow water monitoring originated in the Pocomoke River in response to the *Pfiesteria piscicida* outbreak in 1998. Continuous monitoring stations were established at

[53] CHLA degraded in Pocomoke Sound from 1985-2010.
[54] Secchi depth degraded from 1985-2010 in Pocomoke Sound but a non-linear trend indicates improvement since the early 2000s.
[55] Salinity decreased in the Pocomoke Sound in the spring from 1999-2010 and may have degraded annually.
[56] Nutrient samples are collected twice a month instead of continuously.

three locations in the Pocomoke River: Rehobeth, Cedar Hall Wharf, and Shelltown. Additional stations were added in 2000 in the Chicamacomico and Transquaking Rivers. Building on the success of these early monitoring efforts, the DNR shallow water monitoring program conducted three-year intensive monitoring assessments in Fishing Bay (2003-2005) and the Wicomico River (2006-2008) (Figure 35, Appendix 9).[57]

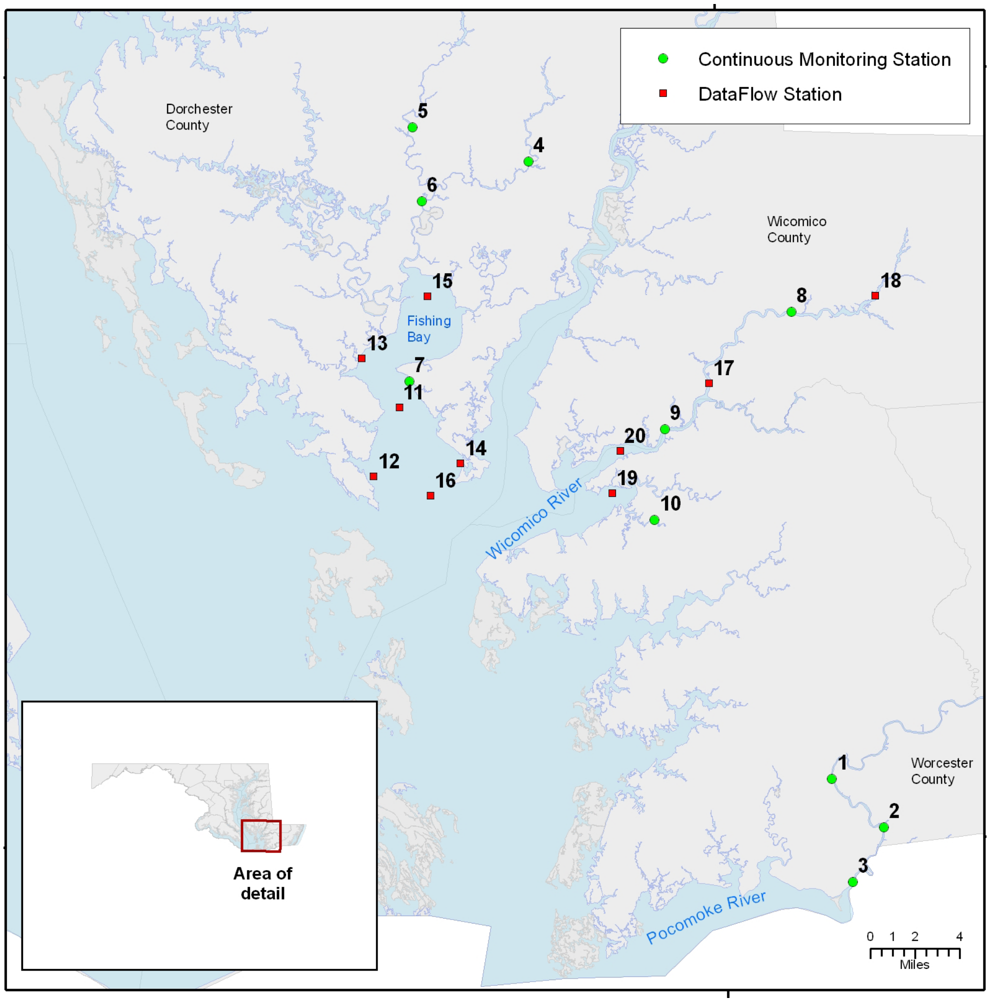

Figure 35. Shallow water calibration stations in the Lower Eastern Shore Basin. Green circles show the continuous monitoring locations: Pocomoke River-1. POK0087 Rehobeth 2. POK0043 Beverly / Cedar Hall Warf, 3. POK0009 Shelltown; Chicamacomico River – 4. **CCM0069** Drawbridge; Transquaking River- 5. **TRQ0146** Decoursey Bridge, 6. **TRQ0088** Bestpitch; Fishing Bay- 7. XCH8097; Wicomico River- 8. WIW0144 Upper Ferry, 9. XCJ6023 Whitehaven Ferry, 10. LMN0028 Little Monie Creek. Red squares show water quality mapping calibration stations: Fishing Bay- 11. **EE3.0**, 12. XCH4378, 13. XCH8973, 14. XCI4821, 15. XDI1306, 16. XCI5506 (2003 only); Wicomico River -17. WIW0089, 18. WIW0198, 19. XCI3696, 20. XCJ5200. Stations listed in **bold** are also long-term monitoring program stations.

[57] An interactive map of all continuous monitoring stations and complete archived data are available at http://mddnr.chesapeakebay.net/newmontech/contmon/archived_results.cfm. Interpolated maps for all water quality mapping cruises are available on the Maryland Department of Natural Resources "Eyes on the Bay" website http://mddnr.chesapeakebay.net/sim/dataflow_data.cfm

Current conditions

Wicomico River
In 2010, one continuous monitoring station was active in the Little Monie Creek, a tributary of the Wicomico River. The continuous monitoring data for Little Monie Creek (Figure 35) show a drop in temperature and salinity values in early October due to Tropical Storm Nicole. In 2010, dissolved oxygen concentrations less than 5 mg/l appeared in May and persisted into October. Several algal blooms are evident in the chlorophyll graphs, with one particularly large bloom (>300 µg/l chlorophyll) appearing in mid-July and lasting several weeks. Large spikes in turbidity also occurred, often in conjunction with the algal blooms. The largest turbidity spike of approximately 600 NTU occurred in late June.

Temporal and Spatial conditions

Water and habitat quality in the shallow water was evaluated in two ways. The first was a temporal assessment. High temporal frequency data from the continuous monitoring program were used to determine how often water quality met conditions needed for healthy habitats. Percent failures are defined as the percent of values in each year that did not meet the water quality thresholds (see Appendix 4 for methods). Data for the years 2003-2010 were used. Chlorophyll and turbidity measurements collected during the SAV growing season (April through October) and summer dissolved oxygen values (June through September) were included in the analysis. The percent failures for all stations are shown in Appendix 10.

The second method was a spatial assessment. The nutrient data collected at continuous monitoring and water quality mapping calibration stations for April-October were compared to the SAV habitat requirements (Appendix 10). Water quality and habitat conditions were also compared between the shallow water stations and the long-term station.

Chlorophyll concentrations greater than the 15µg/l threshold were common in the Lower Eastern Shore basin, with most stations having more than 50% of values exceed the chlorophyll threshold. Shelltown (Pocomoke River), Drawbridge (Chicamacomico River), and Decoursey (Transquaking River) all had a failure rate greater than 70% for chlorophyll during the years 2000-2002. Fishing Bay and the downstream stations of the Wicomico River (Whitehaven and Little Monie Creek) had the least percent failures for chlorophyll, with values greater than 15 µg/l occurring less than 15% of the time All stations had greater than 70 % (and often more than 90%) failure of the 7 NTU turbidity threshold.

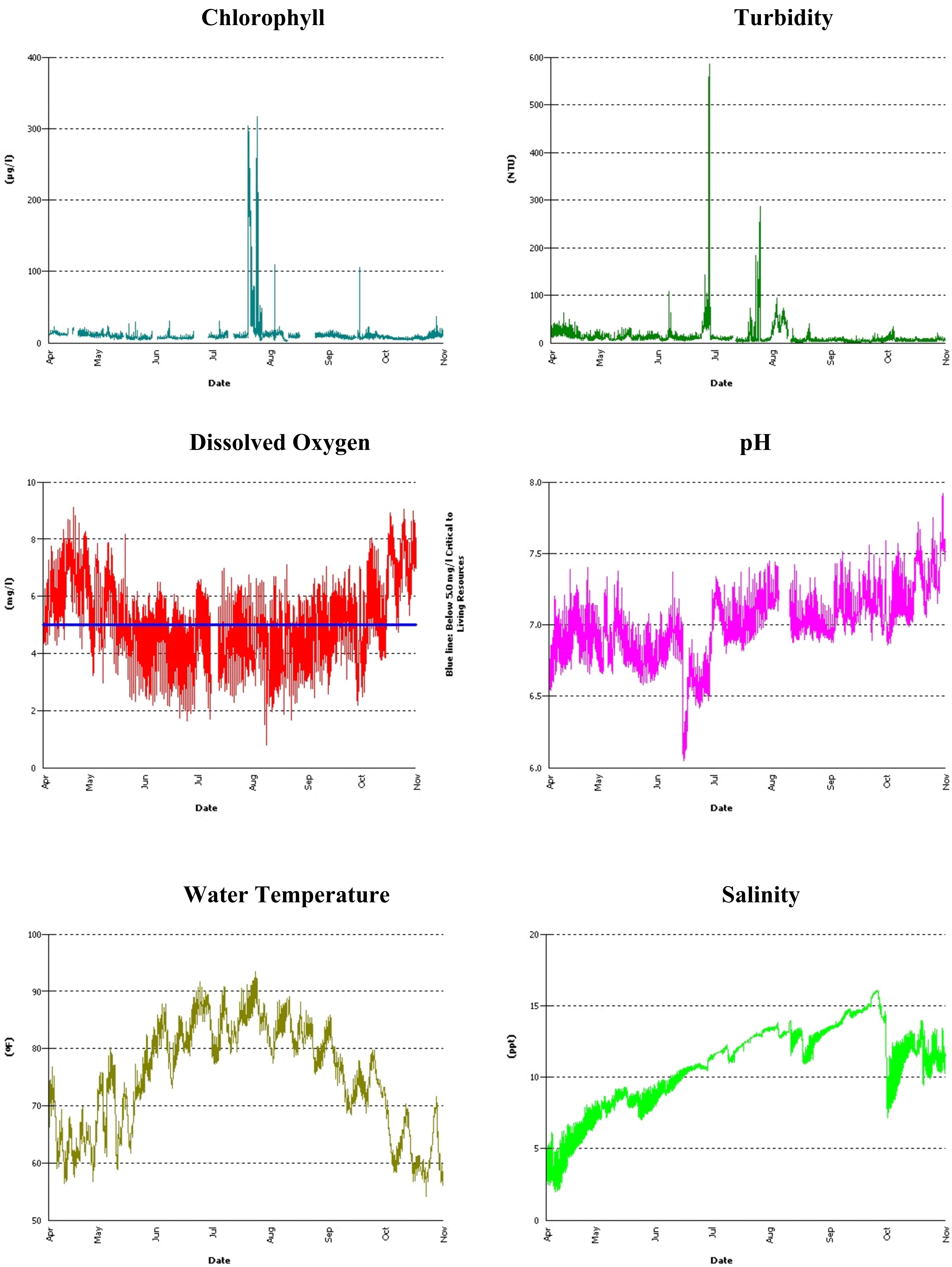

Figure 36. Continuous monitoring results at Little Monie Creek in 2010.

Wicomico River
Little Monie Creek had some of the lowest dissolved oxygen concentrations in the Lower Eastern Shore basin. Dissolved oxygen values <3.2 mg/l were generally observed over 10% of the time for the years 2006-2010 in Little Monie Creek. By comparison, most other locations had less than 5% failure of the 3.2 mg/l dissolved oxygen threshold.

The shallow waters at the upper Wicomico River stations (WIW0198, WIW0144, WIW0141) had the worst water quality, only meeting the SAV habitat requirement for PO_4 (Appendix 10). The middle Wicomico River stations (ET7.1, XCJ6023, and XCG5200) met the habitat requirements for PO_4 and CHLA, and the lower Wicomico River stations (XCI4078, XCI3696) met all of the habitat requirements. The shallow waters of Little Monie Creek failed to meet the TSS habitat requirement, and also failed to meet the summer bottom dissolved oxygen threshold in 2006 and 2007. CHLA and DIN levels were significantly higher at the uppermost station (WIW0198), and CHLA and DIN at the other two upper stations were significantly higher than the middle Wicomico stations.[58] Secchi depths were significantly better in the lower river. TSS and PO_4 levels were similar throughout the river. The three long-term stations were not different from the other stations in the same portion of the river.

Chicamacomico River/Transquaking River /Fishing Bay
During 2003-2005, Transquaking River, Chicamacomico River and Fishing Bay were monitored as part of both the long-term and the shallow water monitoring programs at the same locations. These locations were monitored in 2008-2010 only in the long-term monitoring program, so the data for 2008-2010 is not at a frequency to allow for the percent failure assessment.

For the 2008-2010 period, the Transquaking and Chicamacomico stations failed to meet the SAV habitat criteria for CHLA, TSS and water clarity (Appendix 10). All three stations met the requirements for DIN and PO_4. The lower Transquaking River station (TRQ0088) failed to meet the summer dissolved oxygen threshold. See the 'Tidal Rivers' section above for more information.

The shallow waters of Fishing Bay were monitored in 2003-2005 at four stations in addition to the long-term monitoring station.[59] The stations in the upper bay (XCH8973, XCH8097, and EE3.0) failed to meet the SAV habitat requirement for TSS but met the other requirements. The lower bay stations (XCH4378, XCI4821) met all four habitat requirements. Secchi depths were significantly lower at one upper bay station (XCH8973) than at the other shallow water locations though not different from the long-term station. CHLA, TSS, PO_4 and DIN levels were similar throughout the bay.[60]

Water quality patterns

The water quality mapping program data provides information on the patterns of water quality throughout the river. Water quality mapping results in Fishing Bay are shown for July 31, 2003 and September 1, 2004 (Figure 36). Although these two surveys were conducted over a year apart, they both show a similar distribution of turbidity. Higher turbidity values appear

[58] Comparisons of 2006-2008 data. TN and TP were significantly higher at the two uppermost stations in the Wicomico River.
[59] Two additional stations (XDI1306, XCI5506) were monitored in 2003 only so are not included in the analyses.
[60] TN and TP levels at station XCH8973 were significantly higher than at station XCH4378 but neither station was different from the remaining shallow water stations or the long-term station.

concentrated along the southern shoreline at the bend in the river. This area of higher turbidity is a regular feature in the water quality mapping results for Fishing Bay and may be due to the water circulation patterns in the bay.

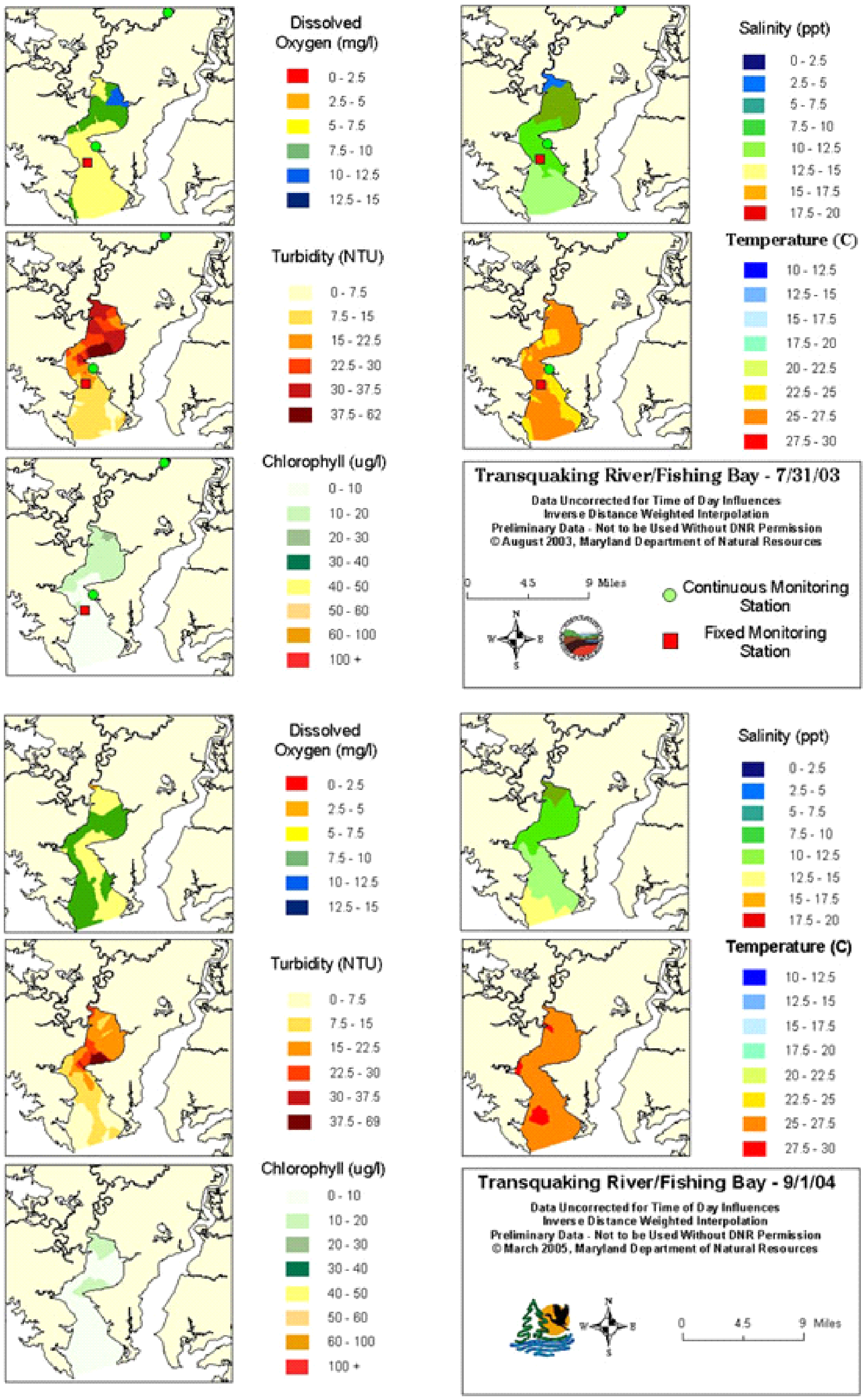

Figure 37. Water quality mapping survey results for Fishing Bay in July 2003 and September 2004.

The Wicomico River survey results for September 6, 2007 (Figure 38) illustrate the advantage of spatially intensive monitoring. The data maps show bands of alternating higher and lower values of dissolved oxygen, chlorophyll, and temperature in the upper reaches of the Wicomico River. This spatial pattern of parameter values would not be detected by monitoring at a single location.

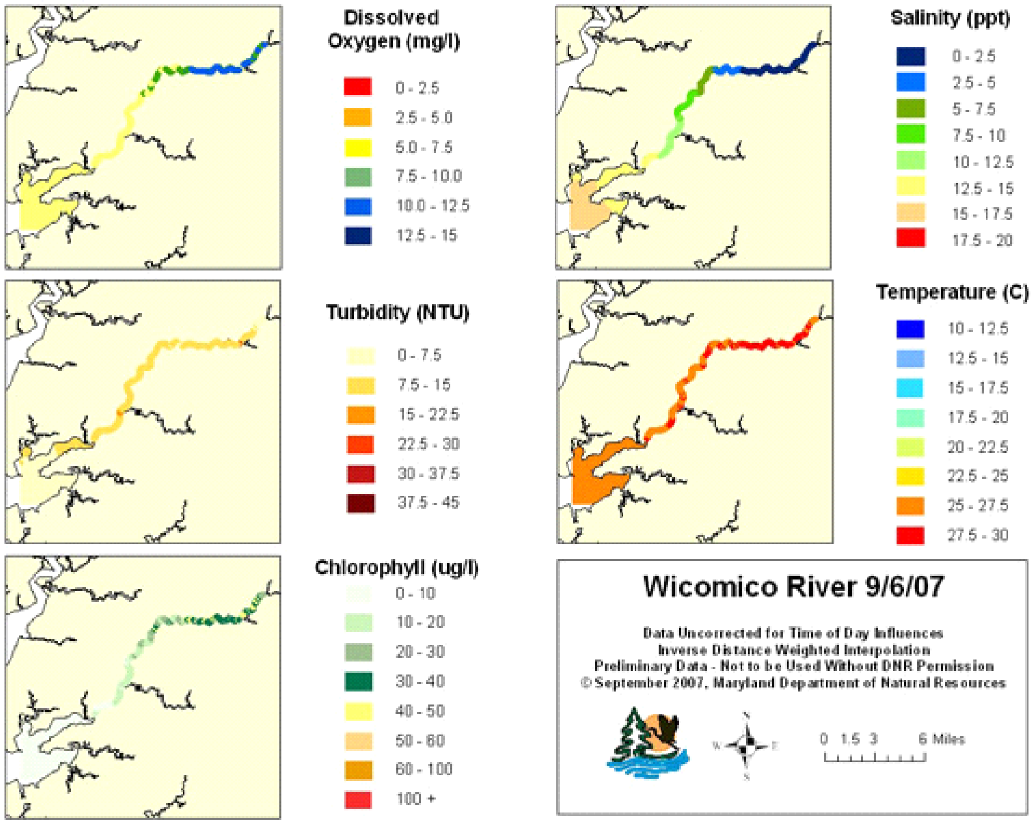

Figure 38. Water quality mapping survey results for Wicomico River, September 2007.

Health of Key Plants and Animals

Phytoplankton

Phytoplankton (generally algae) are the primary producers in the Chesapeake Bay and rivers and the base of the food chain. Routine samples collected in the long-term tidal and shallow water monitoring programs estimate the abundance of algae but can not determine the health of the population overall. As part of a supplemental program, the overall phytoplankton community is sampled at a sub-set of the long-term tidal water quality stations; very limited phytoplankton data has been collected from the Lower Eastern Shore waters. Samples were collected in 2010 from the North Tangier Sound in spring (March, April, May) and summer (August and September). The phytoplankton index of biotic integrity (PIBI) assesses the health of the community. [61] A PIBI score of greater than 3 is considered meeting the goal for phytoplankton community health criteria. In North Tangier Sound, spring and summer PIBI scores both failed to meet the restoration criteria (scores of 2.37 and 2.50 respectively).[62]

Harmful Algal Blooms (HABs)

High algal density (algal blooms) can degrade habitat quality. Blooms of certain species of phytoplankton (harmful algae) can also degrade habitat quality. Routine samples collected in the long-term tidal and shallow water monitoring programs can not distinguish between good and harmful algae. Additional samples are taken at some locations to determine what algal species are present and in what densities. When a bloom occurs, samples are taken to test for the presence and levels of toxins, which can be released by some types of harmful algae. Fortunately, of the more than 700 species of algae in Chesapeake Bay, less than 2% of them are believed to have the ability to produce toxic substances.[63]

Blue-green algae are generally smaller cells and not as nutritious and edible to small animals (zooplankton). Blooms of blue-green algae look like blue-green paint floating at or near the water surface (Figure 39). Blue-green algae can only live in low salinity waters. Some species of blue-green algae (*Microcystis* and *Anabaena*) can produce a toxin that is released into the water. Contact with or ingestion of water containing high toxin levels can cause human health impacts (skin irritation, gastrointestinal discomfort), and can be harmful or even fatal to livestock and pets.

Blooms of some species of dinoflagellates are known as 'mahogany tides' because the color of the algae and the density of algae in the bloom make the water appear brown or reddish-brown (Figure 39). These conditions are most often caused by blooms of *Prorocentrum minimum*. While *Prorocentrum* frequently blooms in the spring, blooms have been observed in Maryland waters in all seasons. These algae do not produce a toxin, but the magnitude of the bloom can harm fish and shellfish by replacing more nutritious algae, depleting oxygen in the water column or clogging gills. The darkened waters can also reduce the light reaching underwater grasses.

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[61] Methods for calculation of the PIBI are available at www.chesapeakebay.net/.../indicator_survey_phyto_ibi_2011_final.docx

[62] PIBI scores calculated by J. Johnson, Interstate Commission on the Potomac River Basin/Chesapeake Bay Program.

[63] Information on Harmful Algal Blooms is available at http://mddnr.chesapeakebay.net/eyesonthebay/habs.cfm

Other harmful algal species can lead to fish kills. *Karlodinium venificum* can release a toxin that harms fish, and densities above 20,000 cells/milliliter can be acutely toxic to fish. Extremely low dissolved oxygen is often the result of the abrupt die off of a bloom, when the process of decomposing the large amount of plant material uses up the oxygen in the water. The combination of the toxin and low dissolved oxygen can lead to fish kills.

Figure 39. Harmful algal blooms.
Left panel: Blue-green algae bloom. Right panel: 'Mahogany tide' bloom.

HABs have occurred in several of the Lower Eastern Shore rivers. Blooms of blue-green algae occur in most summers in the Chicamacomico River and Transquaking River, except in years where salinities are elevated due to drought conditions. Blue-green algal blooms in these two rivers have been smaller than in the Upper Eastern Shore rivers (primarily the Sassafras River). The primary species of blue-green algae found in the Chicamacomico and Transquaking river are *Microcystis* and *Anabaena*, but several other species have also been identified in these rivers. Once of these other species (*Cylindrospermopsis raciborskii)* had not been seen in Maryland waters since 1977; this species is of concern worldwide due to its expanding distribution, preference for nutrient-enriched waters and a varied ability to produce toxins (different strains may or may not produce toxins) that have been known to harm insects, fish, pets, livestock and humans. In recent years, this species has begun replacing other bloom-forming algae as the dominant alga following the nutrient enrichment of lakes, reservoirs, and rivers around the world.

Another recurring type of HAB in the Lower Eastern Shore rivers are 'mahogany tides' caused by the dinoflagellate *Prorocentrum minimum*. Mahogany tides are widespread within the Chesapeake Bay and rivers, including blooms in the lower Pocomoke River.

In 1999, blooms of *Pfiesteria piscicida* included the release of toxins into the water that caused human health and fish health impacts. Blooms were reported in the Pocomoke, Chicamacomico and Transquaking Rivers. In June 2001, two samples from the Manokin contained *Pfiesteria. Pfiesteria* was also found in the next several years in the Chicamacomico and Transquaking rivers and in September 2002 and 2003 *Pfiesteria* blooms were associated with unhealthy fish, primarily menhaden with lesions.

Underwater grasses

Water quality determines the distribution and abundance of underwater grasses (submerged aquatic vegetation, SAV). For this reason, SAV communities are good barometers of the health of the tidal rivers and bays. SAV is also a critical nursery habitat for many bay animals. Similarly, several species of waterfowl are dependant on SAV as food when they over-winter in the Chesapeake region. SAV distribution is determined through the compilation of aerial photography directed by the Virginia Institute of Marine Science (VIMS).[64]

Fishing Bay
Fishing Bay had impressive gains in SAV coverage in recent years. SAV coverage soared in 2002 to 109 acres (55% of the goal), but then declined to 7 acres in 2005 (Figure 40). SAV coverage increased to 13 acres in 2006, but SAV was absent from Fishing Bay in 2007. Coverage increased from 22 acres in 2008 to 147 acres in 2009, then decreased slightly to 138 acres, or 70% of the restoration goal, in 2010 (Figure 41). There is no ground-truthing information from Fishing Bay.

Nanticoke River
In the Nanticoke River, SAV has never been mapped by the VIMS aerial survey and there is not a goal in this area. In 1996, a citizen ground-truthing the upper part of the river did find wild celery, coontail, hydrilla, slender pondweed, an unidentified naiad, and other unidentified species of SAV in Gales Creek, near the Maryland/Delaware state line. Also, staff from EPA did find horned pondweed in Shiles Creek in 1996. A wild celery *(Vallisneria americana)* transplant was tested on Marshyhope Creek in 2001 and 2002, a tributary of the Nanticoke, near the town of Federalsburg. This transplant failed, due to grazing and borderline water quality conditions.

Wicomico River
In the Wicomico River, SAV has never been mapped by the VIMS aerial survey and there is not a goal in this area. Ground-truthing by staff from EPA did find horned pondweed in Wetipquin Creek.

Manokin River
The Manokin River has had highly variable SAV, particularly in recent years. SAV abundance has ranged from a low of 20 acres in 1999 to a high of 883 acres in 2010, or 20% of the goal of 4,353 acres. These SAV beds have been mapped on the southern shore from St. Pierre Marsh to Mine Creek near the mouth of the Manokin River and from St. Peters Creek to the Lower Thorofare on the northern shore. Currently, there is no ground-truthing in this area.

Big Annemessex River
The Big Annemessex River has had fairly consistent SAV coverage of approximately 400 acres for the last 15 years, with some fluctuations. In 2010, SAV coverage was 949 acres, the largest ever recorded by VIMS, representing approximately 46% of the restoration goal (2,043 acres). Ground-truthing by the DNR found widgeon grass and eelgrass. SAV beds generally fringe the shoreline from the mouth to Persimmon Point on the north shore and to Charles Point on the south shore.

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[64] Reports detailing methodology and annual SAV coverage are available at www.vims.edu/bio/sav . Details on species of SAV discussed in this report can be found at www.dnr.maryland.gov/bay/sav/key

Pocomoke River
In the Pocomoke River, upstream of Williams Point, VIMS has never mapped SAV in the annual aerial survey. In addition, there are no ground-truthing sites in this area.

Pocomoke Sound
The Maryland portion of Pocomoke Sound has had fairly consistent SAV coverage, with abundance peaking in 2002 at 98 acres or 11% of the revised goal (877 acres). SAV coverage has increased since 2007 to 151 acres in 2010, the highest acreage recorded. Most of Maryland's SAV beds are located around Oystershell Point. Ground-truthing by VIMS staff in the area has found widgeon grass and eelgrass

Tangier Sound
The Maryland portion of Tangier Sound had a good resurgence of SAV, hitting a high of 9,143 acres in 1992, 37% of the revised goal of 24,757 acres. Since then, SAV suffered massive declines to a low of 1,947 acres in 1998. SAV coverage increased to 5,801 acres in 2005; however, high water temperatures and low winds, which occurred in late summer 2005, led to large declines in eelgrass coverage throughout the lower Chesapeake Bay. SAV has increased steadily since then, reaching 7,913 acres in 2010. SAV was dense and abundant in a number of locations, notably the coves of Bloodsworth, South Marsh and Smith Islands. Much of this area is covered by eelgrass in the deeper portions and widgeon grass in the shallows.

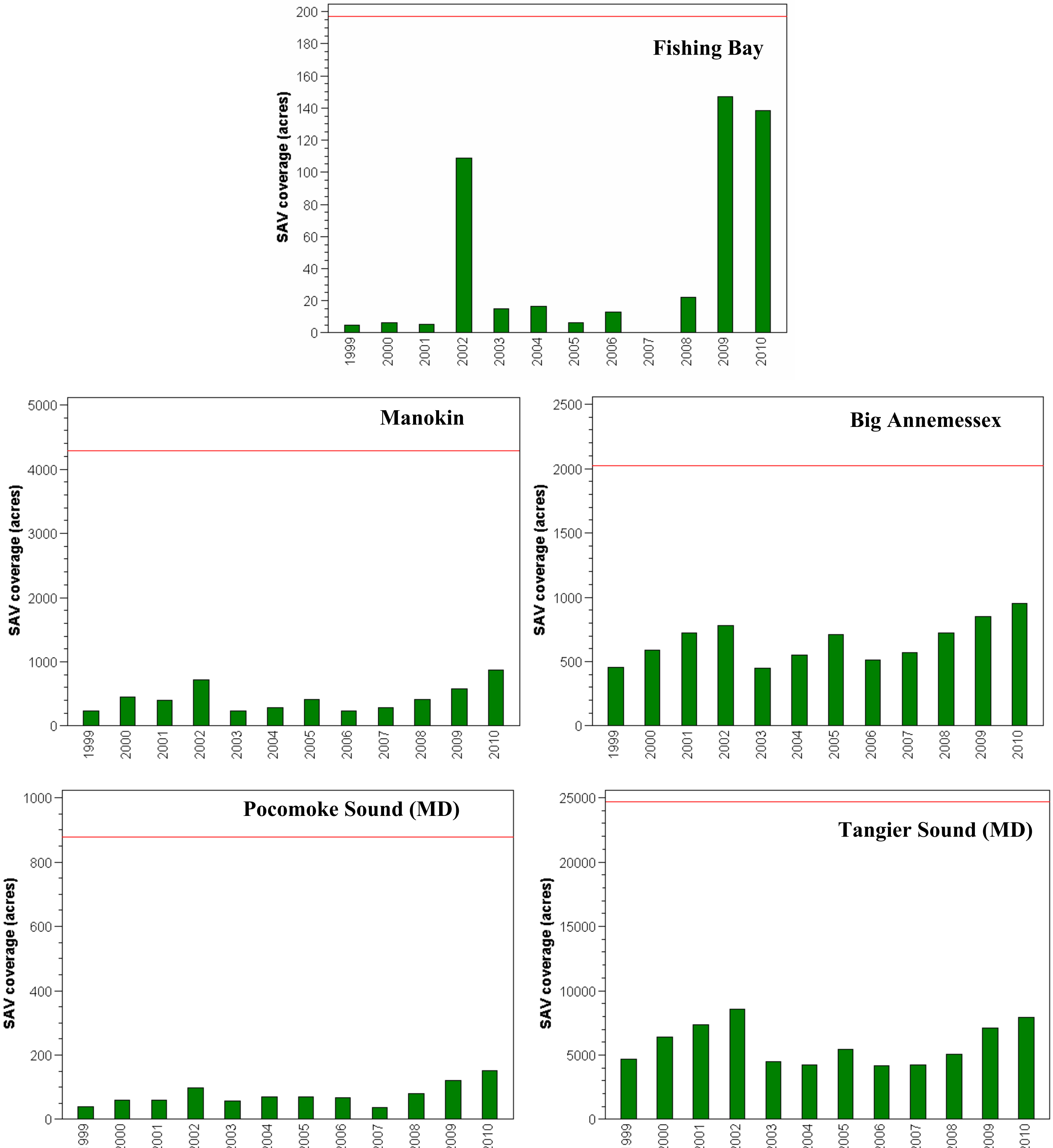

Figure 40. SAV coverages from in the Lower Eastern Shore basin 1999-2010.
SAV data provided by the Virginia Institute of Marine Science. Red line shows the restoration goal for each river.

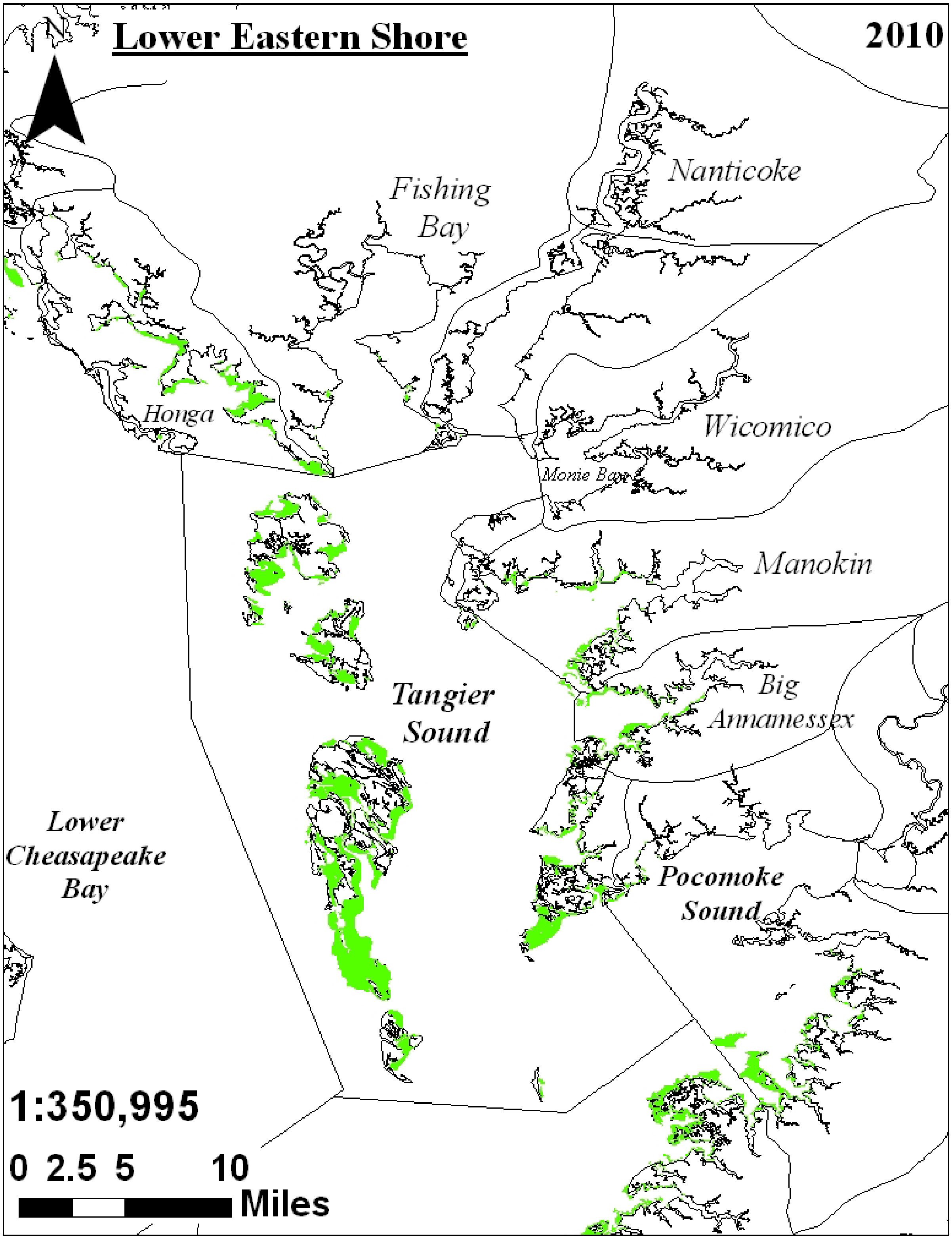

Figure 41. SAV beds (in green) in the Lower Eastern Shore Basin in 2010.

Benthic animals

Benthic animals are the animals that live in or on the bottom of the bay. To determine the health of benthic communities, samples are collected at one long-term benthic monitoring station in the Nanticoke River. This station has been monitored since 1984 and trends are calculated for this station. Starting in 1994, samples were also collected from all of the rivers and mainstem Bay each year from randomly selected locations. Within the eastern shore rivers, there are not a fixed number of samples each year in any particular river and each river is not sampled in every year. Larger rivers end up with more samples collected over time. The benthic index of biotic integrity (BIBI) assesses the health of the benthic community.[65] A BIBI score of greater than 3 is considered meeting the goal for benthic community health.

In 2008-2010, benthic animal community health was degraded at the long-term station in the Nanticoke and has degraded since 1985. During this time period, 51 random samples were collected in the Lower Eastern Shore basin (Figure 42). Samples in the Big Annemessex, Manokin and Tangier Sound generally passed the BIBI goal. Samples in the Nanticoke, Wicomico and Pocomoke Sound were split about half pass/half fail. Fishing Bay was only sampled once (degraded) and the Pocomoke River was not sampled. By year, 2008 sample locations generally failed to meet the goal, 2009 sample locations were split about half pass/half fail, and 2010 sample locations generally passed. The results indicated that about 50% of the total benthic habitat was degraded in 2008-2010.[66] Poor benthic community health in the eastern shore rivers results from low dissolved oxygen levels and high nutrient and sediment loadings.[67] Severely degraded conditions are likely due to prolonged low oxygen conditions that decrease the number of benthic animals. Degraded conditions are more often due to high nutrients, high levels of organic matter in the sediments and the absence of low dissolved oxygen conditions.

[65] Methods for calculation of the BIBI are available at http://www.baybenthos.versar.com/DsgnMeth/Analysis.htm#BIBI.
[66] Annual reports for 2008, 2009 and 2010 are available online at http://www.baybenthos.versar.com/referenc.htm.
[67] See Annual reports, section 4.

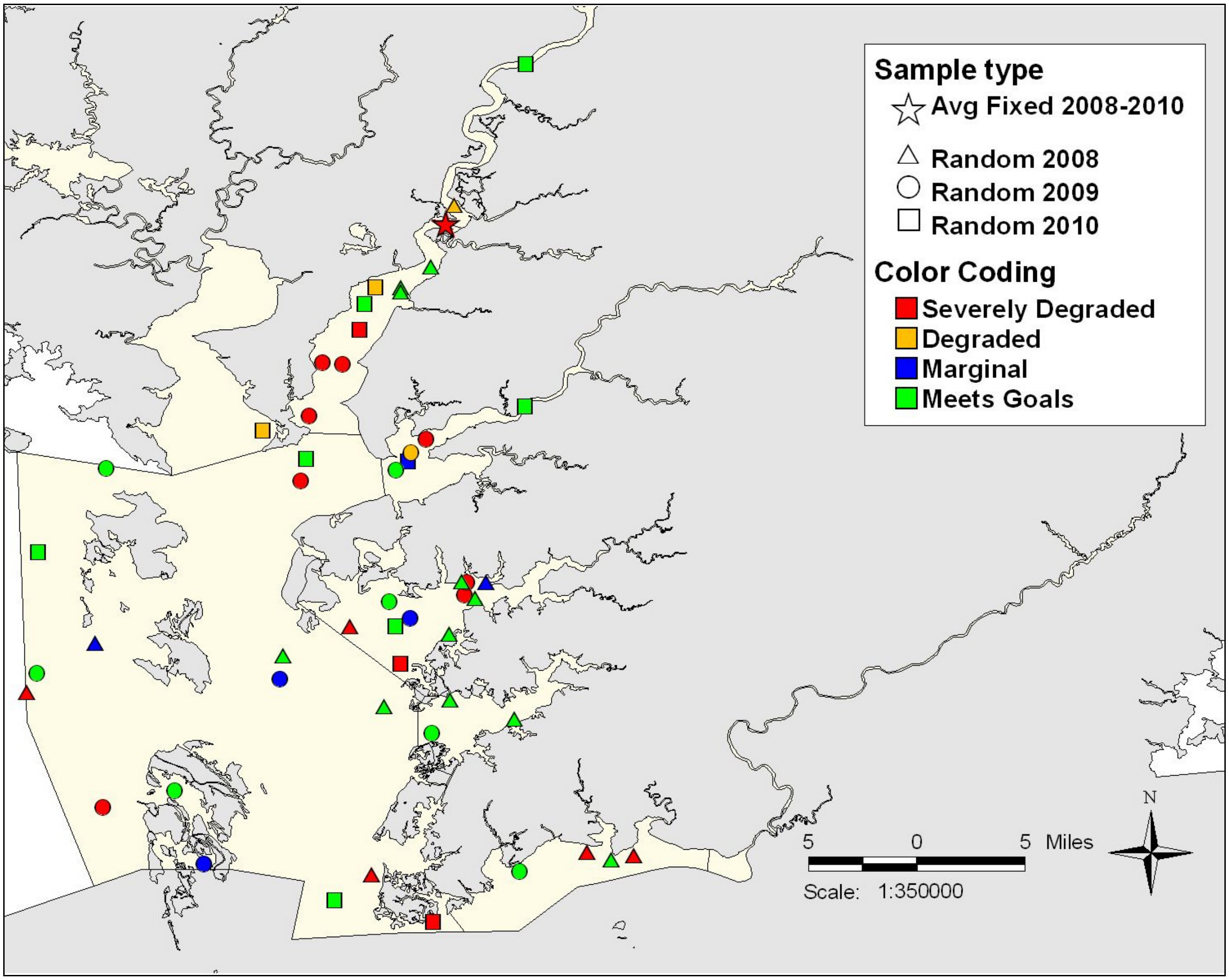

Figure 42. Benthic Index of Biotic Integrity results.
Random samples were collected in 51 locations in 2008-2010. A BIBI score of 3 or greater Meets Goals. BIBI scores of 2.7-2.9 are Marginal, 2.1-2.6 are Degraded and less than 2.1 are Severely Degraded.

Summary of Water Quality and Habitat Conditions

Information on current water and habitat quality and the changes through time is needed to assess the health of a river. Many types of information are needed to most completely understand the current conditions. In some instances the assessment is straight forward and all of the information indicates both good water quality and healthy habitats. Most often, some aspects of the overall picture indicate good conditions and other aspects indicate poor conditions. The summary presented here is intended to best represent an overall condition. This is a simplified version and can not capture all the detail presented in the previous sections of this report. Informing the public about the overall health of a river is often best done with a summary of all of the data. Management decisions can benefit from both the summarized and the detailed information.

Overall, the Lower Eastern Shore basin is dominated by agricultural land use and has a low to medium human population density in most areas. Urban land use and percent impervious surface is much lower than in the Western shore basins, though there is a greater impact of human population density/urban land around the town Salisbury. Point sources are important source of nitrogen and phosphorus to some of the rivers. Forest sources are also important to nitrogen (N), phosphorus (P) and sediment (S) loadings to the Manokin, Big Annemessex and Pocomoke rivers. Despite the similarities overall among the Lower Eastern Shore rivers, there are differences in water and habitat quality conditions due to localized land use and human impacts.

Chicamacomico River/Transquaking River/Fishing Bay
Wetlands are a prominent feature of the Chicamacomico/Transquaking/Fishing Bay watershed, covering about 30% of the total area. Some of this wetland area is protected within the Blackwater National Wildlife Refuge, a critical stopping point along the Atlantic flyway for migrating birds. Forest covers approximately 40% and agricultural uses cover about 25% of the watershed. Stream health is poor.

Water quality in the Chicamacomico River was fair but S levels are too high and getting worse. P levels improved and met the habitat requirement for underwater grasses. Habitat for underwater grasses was poor because algal densities were too high and water clarity was poor.

Water quality in the Transquaking River was fair but S levels are too high. S levels were very high in the lower river. P levels improved and were low enough to meet the habitat requirement for underwater grasses. Habitat quality for underwater grasses was poor due to high algal densities, especially in the upper river, and poor water clarity.

Water quality in Fishing Bay was good, with moderate N and S levels and low P levels. Habitat quality was fair for underwater grasses but water clarity was too low. Algal densities improved and N, P and S levels and may have improved. Underwater grass beds covered approximately 70% of the restoration goal area in 2010, though approximately 50% of the habitat for bottom animals was degraded.

Nanticoke River
Forests cover approximately 40% of the area of the Nanticoke River watershed. Agricultural uses cover an additional 40% of the area. Much of the watershed is in Delaware. Stream health is

fair in the Marshyhope Creek sub-watershed but is poor in the Nanticoke River sub-watershed. The Nanticoke River sub-watershed is a high priority for restoration efforts.

Water quality in the upper Nanticoke was poor due to high N and S levels but improved due to decreases in N, P and S levels. Water quality in the middle river was fair due to high S levels but improved due to decreases in P and S levels. P levels met the habitat requirement for underwater grasses but S levels did not.

Habitat quality was poor because water clarity was poor throughout the river, but water clarity improved in the upper river over the longer term. Algal densities in the upper river increased. Summer dissolved oxygen levels decreased in the upper river over the long-term but are still above 5 mg/l. No underwater grasses have been found in the Nanticoke, and habitat quality for bottom dwelling animals was degraded and had gotten worse over the longer term.

Wicomico River

The Wicomico River watershed has the highest amount of urban lands in the Lower Eastern Shore Basin (28% of the entire area), mostly within the City of Salisbury. Urban land use increased five percent since 2000, and six percent of the basin is covered by impervious surfaces. The rest of the watershed is forest (38% of the total area) or used for agriculture (26% of the total area). Stream health is fair in the upper sub-watersheds but poor in lower sub-watersheds. Wicomico Creek sub-watershed is a high priority for Trust Fund restoration efforts, and the other three sub-watersheds are medium priority.

Water quality in the Wicomico River was poor in the upper river due to very high N and high S levels. Conditions were better in the middle river but S levels were still too high. Water quality in the lower river was good and was fair in the Little Monie Creek. N levels improved throughout the river, and P levels improved in the middle river. P levels in the whole river met the habitat requirement for underwater grasses. S levels improved in the lower river but may have degraded in the upper river. Water and habitat quality in shallow water areas was not different from the long-term site within each segment.

Habitat quality was poor in the upper river due to high algal densities. Algal densities degraded in the upper river but may have improved in the lower river. Water clarity in the middle river improved but still failed to meet the habitat requirement for underwater grasses. Algal densities degraded in the upper river and may have degraded in the lower river. No underwater grasses were found in the Wicomico River, and about half of the areas sampled had unhealthy habitat for bottom dwelling animals.

Manokin River

Wetlands cover approximately 20% of the Manokin River watershed. Forest covers approximately 45% and agricultural uses cover approximately 30% of the total area. Stream health is poor and the watershed is a high priority for restoration efforts.

Water quality in the upper Manokin River was poor, but good in the lower river. P levels were extremely high in the creeks, and S levels were too high. Water quality improved in the lower river due to improvements in N and S levels. N levels improved in the upper river as well.

Habitat quality was poor in the upper river and fair in the lower river. Algal densities were too high in the upper river in some years, and water clarity was too low in the entire river. Water clarity improved in the lower river. Underwater grass beds covered approximately 45% of the restoration goal in 2010, and bottom dwelling animals were healthy.

Big Annemessex River

Wetlands cover more than 25% of the Big Annemessex River watershed. Forest covers 40% and agricultural uses cover approximately 20% of the total area. Stream health is fair and the watershed is a medium priority for restoration efforts.

Water and habitat quality in the lower Big Annemessex river was good with the exception of water clarity. N levels improved. Underwater grass beds only covered 20% of the restoration goal in 2010, but bottom dwelling animals were healthy.

Pocomoke River

Forest covers almost 50% of the Pocomoke River watershed, and agriculture covers approximately 35% of the total area. Of the four sub-watersheds, two are high priority and two are medium priority for Trust Fund restoration efforts. Stream health is fair except in the Lower Pocomoke sub-watershed where stream health is poor.

The Pocomoke River is a blackwater river so the water is naturally darkened by tannins. This feature reduces water clarity and algal densities. Watershed sediments are also high in iron, which binds to P and, once washed into the water, can reduce water clarity. These sediments also carry more P into the water than sediments in other watersheds. P levels were high, especially in the upper and middle river. N levels were also high in the upper and middle river, while S levels were high in the middle and lower river. N levels improved in the entire river and P levels may have improved in the upper river. S levels degraded in the middle. Algal densities improved over the long-term but degraded in the upper and middle river from 2003-2010. Water clarity failed to meet the habitat requirement for underwater grasses. Summer dissolved oxygen deceased in the upper river on the long-term. Underwater grass beds are almost never seen in the river.

Tangier Sound/Pocomoke Sound

The rivers of the Lower Eastern Shore Basin drain to North Tangier Sound (Fishing Bay, Nanticoke, Wicomico), South Tangier Sound (Big Annemessex, Manokin) or Pocomoke Sound (Pocomoke River). In addition to inputs from the rivers, Tangier Sound and Pocomoke Sound receive some direct runoff from small watershed areas.

Water and habitat quality in the Sounds was good. South Tangier Sound met all of the habitat requirements for underwater grasses, and North Tangier Sound and Pocomoke Sound met all but the water clarity requirement. N levels improved in North and South Tangier Sound, and may have improved in Pocomoke Sound.

Algal densities improved in Pocomoke Sound and maybe North Tangier Sound. Water clarity may have improved in South Tangier Sound and Pocomoke Sound. However, dissolved oxygen levels in North Tangier Sound were often below 5 mg/l and sometimes below 3 mg/l. Underwater grasses covered less than 20% of the restoration goal in the Maryland portions of Tangier and Pocomoke Sounds but the amount of area covered with grass beds has been increasing since 2003. Bottom dwelling animals were healthy in Tangier Sound, but about 50% of Pocomoke Sound had degraded bottom habitat.

Appendix 1

Land use/Land cover for 2000 and 2010 and Amount of Impervious Surface

Land-use/Land-cover 2000 and 2010 from the Maryland Department of Planning. 2010 data available at www.planning.maryland.gov/OurWork/landUse.shtml. 2000 data available from Maryland Department of Planning, Planning Data Services, (410) 767-4450. Use codes from the Maryland Department of Planning Land Use/ Land Cover Classification Definitions (http://www.planning.maryland.gov/PDF/OurWork/LandUse/AppendixA_LandUseCategories.pdf). Impervious surface calculated from definitions in Cappiella and Brown, Urban Cover and Land Use in the Chesapeake Bay watershed, Center for Watershed Protection, 2001, as referenced in Table 4.1 of a User's Guide to Watershed Planning in Maryland, http://dnr.maryland.gov/watersheds/pubs/userguide.html

Sub-watershed	Land use/ Land cover	Area in 2000 (sqr miles)	%Total in 2000	Area in 2010 (sqr miles)	%Total in 2010	Area Change (sqr miles)	%Total Area change
Chicamacomico/ Transquaking/ Fishing Bay	AGRICULTURE	71.53	**27%**	70.03	**27%**	1.50	1%
	BARREN LAND	0.17	0%	0.05	0%	0.13	0%
	FOREST	101.85	**39%**	101.49	**39%**	0.35	0%
	TRANSPORTATION	0.00	0%	0.15	0%	-0.15	0%
	URBAN	5.16	2%	7.23	3%	-2.07	-1%
	WETLANDS	83.55	**32%**	83.39	**32%**	0.16	0%
	IMPERVIOUS SURFACE	1.34	1%	1.57	1%	-0.23	0%
Nanticoke River/ Marshy Hope Creek	AGRICULTURE	128.23	**43%**	124.18	**42%**	4.05	1%
	BARREN LAND	0.22	0%	0.05	0%	0.17	0%
	FOREST	119.08	**40%**	114.32	**39%**	4.76	2%
	TRANSPORTATION	7.11	2%	10.27	3%	-3.17	-1%
	URBAN	13.21	4%	18.56	6%	-5.35	-2%
	WETLANDS	27.78	9%	28.06	9%	-0.28	0%
	IMPERVIOUS SURFACE	3.79	1%	4.43	1%	-0.64	0%
Wicomico River Head, Lower Wicomico, Wicomico Creek, Monie Bay	AGRICULTURE	66.80	**31%**	57.16	**26%**	9.64	4%
	BARREN LAND	0.29	0%	0.35	0%	0.02	0%
	FOREST	87.88	**40%**	83.11	**38%**	4.76	2%
	TRANSPORTATION	1.26	1%	2.99	1%	-0.59	0%
	URBAN	49.91	**23%**	61.27	**28%**	-11.36	-5%
	WETLANDS	11.33	5%	11.15	5%	0.18	0%
	IMPERVIOUS SURFACE	11.01	5%	13.19	6%	-2.18	-1%
Manokin River	AGRICULTURE	27.44	**29%**	26.54	**28%**	0.90	1%
	BARREN LAND	0.01	0%	0.01	0%	0.00	0%
	FOREST	42.38	**46%**	40.25	**43%**	2.13	2%
	TRANSPORTATION	0.01	0%	0.29	0%	-0.28	0%
	URBAN	5.37	6%	8.21	9%	-2.84	-3%
	WETLANDS	17.93	19%	17.84	19%	0.09	0%
	IMPERVIOUS SURFACE	1.44	1%	1.72	1%	-0.28	0%
Big Annemessex River	AGRICULTURE	8.86	**25%**	7.88	**23%**	0.97	3%
	BARREN LAND	0.00	0%	0.00	0%	0.00	0%
	FOREST	14.18	**41%**	13.93	**40%**	0.25	1%
	TRANSPORTATION	0.00	0%	0.03	0%	0.00	0%
	URBAN	2.46	7%	3.69	11%	-1.24	-4%
	WETLANDS	9.27	**27%**	9.30	**27%**	-0.03	0%
	IMPERVIOUS SURFACE	0.48	0%	0.61	0%	-0.13	0%
Pocomoke River, Nasawango, Dividing Creek	AGRICULTURE	148.91	**34%**	147.72	**34%**	1.19	0%
	BARREN LAND	48.50	11%	47.33	11%	1.51	0%
	FOREST	219.51	**50%**	208.32	**48%**	11.19	2%
	TRANSPORTATION	0.41	0%	1.20	0%	0.14	0%
	URBAN	15.80	4%	28.08	6%	-12.28	-3%
	WETLANDS	20.35	5%	21.67	5%	-1.32	0%
	IMPERVIOUS SURFACE	4.06	1%	6.08	1%	-2.02	0%
Pocomoke Sound	AGRICULTURE	13.94	**26%**	12.39	**23%**	1.55	3%
	BARREN LAND	0.00	0%	0.00	0%	0.00	0%
	FOREST	22.53	**42%**	21.77	**41%**	0.77	1%
	TRANSPORTATION	0.00	0%	0.04	0%	0.00	0%
	URBAN	2.65	5%	4.82	9%	-2.18	-4%
	WETLANDS	14.51	**27%**	14.62	**27%**	-0.11	0%
	IMPERVIOUS SURFACE	0.51	0%	0.60	0%	-0.09	0%
Tangier Sound	AGRICULTURE	1.13	5%	0.87	4%	0.25	1%
	BARREN LAND	0.14	1%	0.12	1%	0.02	0%
	FOREST	1.72	7%	1.65	7%	0.07	0%
	TRANSPORTATION		0%	0.03	0%	0.00	0%
	URBAN	3.49	15%	3.95	17%	-0.46	-2%
	WETLANDS	17.37	**73%**	17.24	**72%**	0.13	1%
	IMPERVIOUS SURFACE	0.92	0%	0.90	0%	0.02	0%

Appendix 2

Delivered Loads to the Lower Eastern Shore

Phase 5.3 2009 Progress Run 8/25/2010

Chesapeake Bay Program. Accessed January 10, 2012 from
http://www.chesapeakebay.net/watershedimplementationplantools.aspx?menuitem=52044
File
(ftp://ftp.chesapeakebay.net/Modeling/phase5/Phase53_Loads-Acres-BMPs/MD/
Load_Acres_MDWIP_08252010.xls)

Loads by Land Use Type and Segment

Loads > 20% are highlighted in bold

River	CBP segment	Category	N load (Million lbs per yr)	% Total N Load	P load (Million lbs per yr)	% Total P Load	Sed load (Million lbs per yr)	% Total Sed Load
Upper Nanticoke DE	NANTF_DE	Agriculture	0.015	**58%**	0.0016	**56%**	0.09	**75%**
Upper Nanticoke DE	NANTF_DE	Point Source	0.004	17%	0.0009	**30%**	0.01	6%
Upper Nanticoke DE	NANTF_DE	Septic	0.002	6%				
Upper Nanticoke DE	NANTF_DE	Urban Runoff	0.001	2%	0.0001	4%	0.01	8%
Upper Nanticoke DE	NANTF_DE	Forest	0.004	16%	0.0003	9%	0.01	11%
Upper Nanticoke DE	NANTF_DE	Non-tidal Water Deposition	0.000	**<1%**	0.0000	<1%		
Upper Nanticoke DE	NANTF_DE	**Total Load**	**0.026**		**0.0029**		**0.13**	
Upper Nanticoke MD	NANTF_MD	Agriculture	0.053	**78%**	0.0060	**86%**	0.45	**80%**
Upper Nanticoke MD	NANTF_MD	Point Source	0.000	0%	0.0000	0%	0.00	0%
Upper Nanticoke MD	NANTF_MD	Septic	0.004	6%				
Upper Nanticoke MD	NANTF_MD	Urban Runoff	0.002	2%	0.0003	4%	0.05	8%
Upper Nanticoke MD	NANTF_MD	Forest	0.009	13%	0.0007	10%	0.06	11%
Upper Nanticoke MD	NANTF_MD	Non-tidal Water Deposition	0.000	1%	0.0000	<1%		
Upper Nanticoke MD	NANTF_MD	**Total Load**	**0.068**		**0.0070**		**0.56**	
Middle Nanticoke	NANOH	Agriculture	0.576	**69%**	0.0632	**75%**	6.17	**76%**
Middle Nanticoke	NANOH	Point Source	0.035	4%	0.0059	7%	0.13	2%
Middle Nanticoke	NANOH	Septic	0.045	5%				
Middle Nanticoke	NANOH	Urban Runoff	0.021	2%	0.0042	5%	0.74	9%
Middle Nanticoke	NANOH	Forest	0.144	17%	0.0100	12%	1.13	14%
Middle Nanticoke	NANOH	Non-tidal Water Deposition	0.018	2%	0.0010	1%		
Middle Nanticoke	NANOH	**Total Load**	**0.839**		**0.0842**		**8.16**	
Lower Nanticoke	NANMH	Agriculture	0.049	**38%**	0.0057	**51%**	0.42	**51%**
Lower Nanticoke	NANMH	Point Source	0.003	3%	0.0007	7%	0.00	
Lower Nanticoke	NANMH	Septic	0.009	7%				
Lower Nanticoke	NANMH	Urban Runoff	0.006	5%	0.0009	8%	0.11	13%
Lower Nanticoke	NANMH	Forest	0.052	**40%**	0.0033	**29%**	0.30	**36%**
Lower Nanticoke	NANMH	Non-tidal Water Deposition	0.010	8%	0.0006	5%		
Lower Nanticoke	NANMH	**Total Load**	**0.130**		**0.0112**		**0.82**	
Entire Nanticoke	Overall total	Agriculture	0.693	**65%**	0.0765	**73%**	7.13	**74%**
Entire Nanticoke	Overall total	Point Source	0.043	4%	0.0075	7%	0.14	1%
Entire Nanticoke	Overall total	Septic	0.060	6%				
Entire Nanticoke	Overall total	Urban Runoff	0.029	3%	0.0055	5%	0.90	9%
Entire Nanticoke	Overall total	Forest	0.209	**20%**	0.0142	13%	1.50	16%
Entire Nanticoke	Overall total	Non-tidal Water Deposition	0.028	3%	0.0015	1%		
Entire Nanticoke	Overall total	Total Load	**1.062**		**0.1053**		**9.67**	

River	CBP segment	Category	N load (Million lbs per yr)	% Total N Load	P load (Million lbs per yr)	% Total P Load	Sed load (Million lbs per yr)	% Total Sed Load
Fishing Bay	FSBMH	Agriculture	0.395	**50%**	0.0491	**63%**	3.70	**72%**
		Point Source	0.027	3%	0.0023	3%	0.13	3%
		Septic	0.019	2%				
		Urban Runoff	0.012	2%	0.0021	3%	0.17	3%
		Forest	0.173	**22%**	0.0140	18%	1.12	**22%**
		Non-tidal Water Deposition	0.161	**21%**	0.0107	14%		
		Total Load	**0.787**		**0.0782**		**5.12**	
Wicomico	WICMH	Agriculture	0.228	**25%**	0.0283	**33%**	2.88	**40%**
		Point Source	0.271	**30%**	0.0276	**32%**	0.15	2%
		Septic	0.119	13%				
		Urban Runoff	0.099	11%	0.0176	**21%**	3.11	**43%**
		Forest	0.167	18%	0.0108	13%	1.04	14%
		Non-tidal Water Deposition	0.026	3%	0.0012	1%		
		Total Load	**0.910**		**0.0855**		**7.18**	
Manokin	MANMH	Agriculture	0.099	**40%**	0.0150	**58%**	0.69	**46%**
		Point Source	0.013	5%	0.0006	2%	0.01	<1%
		Septic	0.025	10%				
		Urban Runoff	0.016	6%	0.0031	12%	0.34	**23%**
		Forest	0.074	**29%**	0.0058	**22%**	0.46	**31%**
		Non-tidal Water Deposition	0.024	10%	0.0012	5%		
		Total Load	**0.252**		**0.0257**		**1.49**	
Big Annemessex	BIGMH	Agriculture	0.033	**40%**	0.0050	**60%**	0.35	**53%**
		Point Source	0.002	2%	0.0003	3%	0.00	<1%
		Septic	0.010	12%				
		Urban Runoff	0.004	5%	0.0007	8%	0.08	13%
		Forest	0.025	**31%**	0.0020	**24%**	0.22	**34%**
		Non-tidal Water Deposition	0.007	9%	0.0004	4%		
		Total Load	**0.081**		**0.0083**		**0.66**	
Tangier Sound	TANMH_MD	Agriculture	0.006	5%	0.0008	10%	0.07	10%
		Point Source	0.023	19%	0.0011	13%	0.00	<1%
		Septic	0.015	12%				
		Urban Runoff	0.012	10%	0.0020	**25%**	0.37	**54%**
		Forest	0.032	**26%**	0.0025	**30%**	0.24	**36%**
		Non-tidal Water Deposition	0.034	**28%**	0.0018	**22%**		
		Total Load	**0.121**		**0.0083**		**0.68**	

River	CBP segment	Category	N load (Million lbs per yr)	% Total N Load	P load (Million lbs per yr)	% Total P Load	Sed load (Million lbs per yr)	% Total Sed Load
Upper Pocomoke	POCTF	Agriculture	0.495	**55%**	0.0652	**68%**	8.09	**72%**
		Point Source	0.053	6%	0.0065	7%	0.25	2%
		Septic	0.042	5%				
		Urban Runoff	0.023	3%	0.0046	5%	0.79	7%
		Forest	0.275	**31%**	0.0186	**20%**	2.06	18%
		Non-tidal Water Deposition	0.008	1%	0.0004	<1%		
		Total Load	**0.897**		**0.0954**		**11.19**	
Middle Pocomoke VA	POCOH_VA	Agriculture	0.049	**70%**	0.0062	**81%**	0.55	**77%**
		Point Source	0.000		0.0000		0.00	
		Septic	0.002	4%				
		Urban Runoff	0.002	2%	0.0005	6%	0.09	12%
		Forest	0.017	**24%**	0.0010	13%	0.07	10%
		Non-tidal Water Deposition	0.000	**<1%**	0.0000	<1%		
		Total Load	**0.069**		**0.0077**		**0.71**	
Middle Pocomoke MD	POCOH_MD	Agriculture	0.045	**62%**	0.0056	**68%**	0.45	**57%**
		Point Source	0.000		0.0000		0.00	
		Septic	0.003	4%				
		Urban Runoff	0.003	3%	0.0011	13%	0.21	**27%**
		Forest	0.020	**27%**	0.0014	17%	0.13	17%
		Non-tidal Water Deposition	0.003	4%	0.0001	2%		
		Total Load	**0.073**		**0.0082**		**0.80**	
Entire Pocomoke River	Overall Total	Agriculture	0.589	**57%**	0.077	**69%**	9.096	**72%**
		Point Source	0.053	5%	0.006	6%	0.250	2%
		Septic	0.048	5%				
		Urban Runoff	0.027	3%	0.006	6%	1.092	9%
		Forest	0.311	**30%**	0.021	19%	2.264	18%
		Non-tidal Water Deposition	0.011	1%	0.001	0%		
		Total Load	**1.039**		**0.1113**		**12.70**	
Pocomoke Sound	POCMH_MD	Agriculture	0.039	**39%**	0.0067	**60%**	0.76	**56%**
		Point Source	0.000		0.0000		0.00	
		Septic	0.008	8%				
		Urban Runoff	0.004	4%	0.0007	6%	0.13	9%
		Forest	0.039	**39%**	0.0033	**29%**	0.47	**35%**
		Non-tidal Water Deposition	0.009	9%	0.0005	4%		
		Total Load	**0.100**		**0.0112**		**1.36**	

Appendix 3

Station locations and descriptions

Long-term Tidal Water Quality Monitoring Stations

Stations monitored from 1985-2010 are labeled in **bold**. Stations monitored from 1999-2010 are labeled *italics*.

System	Station Name	Location/Depth	Latitude/ Longitude (NAD83 DMS)	Characterizes
Chicamacomico/ Transquaking/ Fishing Bay	*CCM0069*	Chicamacomico River at Drawbridge road crossing. 2.4 m.	38° 26.537’ N 75° 54.285’ W	Tidal fresh
	TRQ0088	Transquaking River at bridge on Bestpitch Ferry Rd; 2.7 m.	38° 25.036’ N 75° 59.607’ W	Tidal fresh
	TRQ0146	Transquaking River at Decoursey Rd. bridge crossing; 2.2 m.	38° 27.939’ N 76° 00.006’ W	Lower Estuarine
	EE3.0	Fishing Bay at daymarker 3, W of Roasting Ear Pt; 7.0 m.	38° 16.856’ N 76° 00.620’ W	Embayment
Nanticoke	**ET6.1**	Upper Nanticoke River at old Rt. 313 bridge (fishing pier,1987) in Sharptown; 5.0 m.	38° 32.904’ N 75° 42.187’ W	Tidal fresh
	XDJ9007	Nanticoke River at old Rt 50 bridge in Vienna; 1.8 m.	38° 29.025’ N 75° 49.259’ W	Tidal fresh
	ET6.2	Lower Nanticoke River mid-channel near Fl G 11; 3.5 m.	38° 20.496’ N 75° 53.248’ W	Lower Estuarine
Wicomico	*WIW0141*	Wicomico River at upper ferry crossing on Upper Ferry Road; 3.9 m.	38° 20.492’ N 75° 41.741’ W	Tidal Fresh
	ET7.1	Lower Wicomico River at Whitehaven, 150 yds downriver of Ferry Road, mid-channel; 7.0 m.	38° 16.070’ N 75° 47.276’ W	Lower Estuarine
	XCI4078	Wicomico River at Island Pt. in channel at buoy Fl14; 4.4 m.	38° 14.027’ N 75° 52.178’ W	Lower Estuarine
Manokin	*MNK0146*	Manokin River on unnamed Rd. Off Stewart Neck Rd. below unnamed tributary; 4.7 m.	38° 10.508’ N 75° 43.341’ W	Lower Estuarine
	BXK0031	Back Creek (tributary to Manokin) at Milliard Long Rd; 2.6 m.	38° 08.138’ N 75° 45.094’ W	Lower Estuarine
	ET8.1	Manokin River at upper extent of channel; approx 100 yds NNE of buoy R 8, mid-channel; 6.0 m.	38° 08.276’ N 75° 48.847’ W	Lower Estuarine
Big Annemessex	**ET9.1**	Big Annemessex River, NW of Long Pt in channel S of daymarker G5; 5.0 m.	38° 03.299’ N 75° 48.678’ W	Lower Estuarine

System	Station Name	Location/Depth	Latitude/ Longitude (NAD83 DMS)	Characterizes
Pocomoke River	**ET10.1**	Pocomoke River on Alt US Rt. 13 (Market Street) on old drawbridge in Pocomoke City; 5.0 m.	38° 04.569' N 75° 34.275' W	Tidal Fresh
	POK0087	Pocomoke River off Rehobeth Rd in town of Rehobeth 1.3 m.	38° 02.310' N 75° 39.674' W	Tidal Fresh
	XAK7810	Pocomoke Sound at middle of mouth of river; 3.4 m.	37° 57.837' N 75° 39.028' W	Lower Estuarine
Pocomoke Sound	**EE3.3**	Pocomoke Sound, near buoy W "A" Pa, state line; 4.0 m.	37° 54.873' N 75° 48.089' W	Embayment
Tangier Sound	**EE3.1**	North Tangier Sound, NW of Haines Pt, 100 yds N of buoy R16; 13.0 m.	38° 11.811' N 75° 58.393' W	Embayment
	EE3.2	South Tangier Sound, mid-channel East of Smith Island, 500 yds NNW of buoy R8; 28.0 m.	37° 58.883' N 75° 55.454' W	Embayment

Shallow water monitoring locations and dates

Waterbody	Segment	Station Name	Station	Years deployed	LAT (NAD83)	LONG (NAD83)
Pocomoke River	POCOH	Rehobeth	POK0087	1999 – 2002	38° 02.326' N	75° 39.707' W
		Cedar Hall Wharf	POK0043	1998 – 2002	38° 00.388' N	75° 37.173' W
		Shelltown	POK0009	1998 – 2002	37° 58.293' N	75° 38.733' W
Chicamacomico River	FSBMH	Drawbridge	CCM0069	2000 – 2003	38° 26.525' N	75° 54.304' W
Transquaking River	FSBMH	Decoursey Bridge	TRQ0146	2000 – 2001	38° 27.917' N	76° 00.045' W
		Bestpitch	TRQ0088	2003 – 2005	38° 25.036' N	75° 59.607' W
Fishing Bay	FSBMH	Fishing Bay	XCH8097	2003 – 2005	38° 18.002' N	76° 00.334' W
		Additional water quality mapping calibration stations	EE3.0	2003 – 2005	38° 17.004' N	76° 00.846' W
			XCH4378	2003 – 2005	38° 14.316' N	76° 02.160' W
			XCH8973	2003 – 2005	38° 18.936' N	76° 02.682' W
			XCI4821	2003 – 2005	38° 14.808' N	75° 57.846' W
			XDI1306	2003	38° 21.330' N	75° 59.406' W
	TANMH		XCI5506	2003	38° 13.552' N	75° 59.352' W
Wicomico River	WICMH	Upper Ferry	WIW0144	2006 – 2008	38° 20.533' N	75° 41.353' W
		Whitehaven	XCJ6023	2006 – 2008	38° 16.028' N	75° 47.707' W
		Little Monie Creek	LMN0028	2006 – present	38° 12.513' N	75° 48.275' W
		Additional water quality mapping calibration stations	WIW0089	2006 – 2008	38° 17.796' N	75° 45.510' W
			WIW0198	2006 – 2008	38° 21.114' N	75° 37.188' W
			XCI3696	2006 – 2008	38° 13.566' N	75° 50.370' W
			XCJ5200	2006 – 2008	38° 15.210' N	75° 49.944' W

Appendix 4

Water and Habitat Quality Data Assessment Methods

Loadings
For USGS methods see http://md.water.usgs.gov/publications/sir-2006-5178/index.html

Current condition- Status
Tidal station nutrient levels and physical properties were evaluated to determine the current health of the rivers (status). Relative status was determined for total nitrogen (TN), dissolved inorganic nitrogen (DIN), total phosphorus (TP), dissolved inorganic phosphorus (PO_4), total suspended solids (TSS), algal abundance (as measured by chlorophyll *a*, CHLA) and water clarity (as measured with a Secchi disc) for the 2008-2010 period. For status calculation methods see
http://mddnr.chesapeakebay.net/eyesonthebay/documents/ICPRB09-4_StatusMethodPaperMolson2009.pdf.

Results for some parameters are compared with established threshold values to evaluate habitat quality. Summer bottom dissolved oxygen (BDO) is compared to US EPA Chesapeake Bay dissolved oxygen criteria for deep-water seasonal (June- September). Summer dissolved oxygen is considered healthy if levels are 5 mg/l or greater and impaired if levels are less than 3 mg/l. For more details see www.chesapeakebay.net/content/publications/cbp_13142.pdf. DIN is compared to a nitrogen limitation threshold value of less than 0.07 mg/l (Fisher and Gustafson 2002, available online at http://www.hpl.umces.edu/gis_group/Resource%20Limitation/2002_report_27Oct03.htm#es). Submerged aquatic vegetation (SAV) growing season median levels for 2008-2010 for PO_4, TSS, CHLA and Secchi depth are compared to SAV habitat requirements (Appendix 5) using the methods of Kemp et al. (2004) available online at http://archive.chesapeakebay.net/pubs/sav/savreport.pdf).

Change over time- Trends
Nutrient levels and physical properties were evaluated to determine progress toward improved water quality (trends). For trends calculation methods see http://mddnr.chesapeakebay.net/eyesonthebay/documents/stat_trend_hist.pdf. The following parameters were evaluated: TN, DIN, TP, PO_4, TSS, algal abundance (as measured by chlorophyll *a*, CHLA), water clarity (as measured with a Secchi disc), summer BDO, salinity and water temperature. In order to understand results in the primary parameters, additional parameters were examined including nitrate-nitrite (NO_{23}), ammonium (NH_4) and ratios of nutrient levels (TN:TP, DIN:PO_4) that may explain more about nutrient use by aquatic plants and limitations of available nutrients.

Water quality data were tested for linear trends for 1985-1997, 1999-2010, 2003-2010 and 1985-2010. Tests for non-linear trends were also done for 1985-2010. Trends are significant if $p \leq 0.01$; also included in the discussion are trends that 'may be' significant when $0.01 < p < 0.05$. Due to a laboratory change in 1998 that affects the tidal water quality data, a step trend may occur for TP, PO_4, DIN and TSS. For these parameters, trends are determined for 1985-1997 and 1999-2010 only.

In addition to annual trends for the various time ranges above, tidal water quality data was tested for seasonal trends for 1999-2010 and 2003-2010. Seasons tested were spring (March-May), summer (July-September) and SAV growing season (April-October).

Shallow water Temporal Assessment (Percent failure analysis)

Continuous monitoring data were compared to water quality thresholds. Measurements of dissolved oxygen taken during the months of June through September were compared to the US EPA threshold value of 3.2 mg/l for shallow water bay grass use (instantaneous minimum). This time period was used because the summer months typically experience the lowest dissolved oxygen levels and are the most critical for living resources. Chlorophyll and turbidity measurements collected during the SAV growing season of April through October were compared to threshold levels of 15 µg/l and 7 NTU, respectively. Values above these levels can inhibit light penetration through the water column and impact growth of underwater grasses. Percent failures are defined as the percent of values in each year that did not meet the water quality thresholds.

Shallow water Spatial Assessment

Algal density, sediment and nutrient samples were collected from calibration sites on water quality mapping cruises, some of which were also at continuous monitoring sites. In addition, samples were collected at the continuous monitoring sites when the equipment was serviced (approximately every two weeks). All data for a station (water quality mapping calibration and continuous monitoring calibration) were used to calculate a monthly median. Monthly medians for April-October were used to calculate the SAV growing season median. Note that the long-term stations include data from long-term and water quality mapping sampling. The median CHLA, TSS, PO_4 and DIN levels and Secchi depth for the April-October SAV growing season were compared to the habitat requirements in the same manner as the long-term tidal data (Appendix 5).

Non-parametric one-way ANOVAs were used to determine if there were differences between stations (SAS Institute software). Where a significant difference was present, a Tukey's Studentized Range (HSD) test was performed to determine which stations were different from each other. Tests were considered significant at $p < 0.05$.

Appendix 5

Submerged Aquatic Vegetation Habitat Requirements

Submerged Aquatic Vegetation (SAV) habitat requirements by salinity regime (from Habitat Requirements for Submerged Aquatic Vegetation in Chesapeake Bay: Water Quality, Light Regime, and Physical-Chemical Factors. W. M. Kemp, R. Batiuk, R. Bartleson, P. Bergstrom, V. Carter, C. L. Gallegos, W. Hunley, L. Karrh, E. W. Koch, J. M. Landwehr, K. A. Moore, L. Murray, M. Naylor, N. B. Rybicki, J. C. Stevenson and D. J. Wilcox. Estuaries. 2004. 27:363–377 available online at http://archive.chesapeakebay.net/pubs/sav/savreport.pdf.).

SAV growing season for all three regimes in Maryland is from April-October. Median seasonal values are compared to the listed habitat requirement to determine if water quality is suitable for SAV growth and survival. Note that the dissolved inorganic nitrogen (DIN) requirement for mesohaline waters exceeds the 0.07 mg/l level where nitrogen limitation of algal growth likely occurs. The more stringent nitrogen limitation DIN level is used for interpretation of habitat quality instead. Due to issues with the model calibration, instead of Percent light at leaf (PLL) water clarity is assessed with percent light through water (PLW) at 1.0 meter depth (L. Karrh, personal communication). PLW can be calculated for the long-term stations that were sampled from 1985-2010. For all stations, Secchi depth can also be used to estimate PLW (L. Karrh, personal communication).

Salinity Regime (ppt)	**Water Column Light Requirement (PLW) (%) or Secchi Depth (m)**	**Total Suspended Solids (mg/l)**	**Plankton Chlorophyll-*a* (µg/l)**	**Dissolved Inorganic Nitrogen (mg/l)**	**Dissolved Inorganic Phosphorus (mg/l)**
Tidal Fresh <0.5 ppt	>13% or 0.725 m	< 15	< 15	Not applicable	< 0.02
Oligohaline 0.5-5 ppt	>13% or 0.725 m	< 15	< 15	Not applicable	< 0.02
Mesohaline 5-18 ppt	>22% or 0.97 m	< 15	< 15	< 0.15 (Nitrogen Limitation < 0.07)	< 0.01

Appendix 6

Long-term tidal water quality trends
1985-1997, 1999-2010 and 1985-2010

Data is from the surface layer with the exception of dissolved oxygen, which is from the bottom. Trends for dissolved oxygen are for summer only (June-September). Red colored results indicate degrading conditions. Green colored results indicate improving conditions. Blue colored results indicate decreasing trends where a qualitative assessment (improving or degrading) is not applicable; purple colored results indicate increasing trends in the same parameters. Grey shading of the 1985-2010 Linear Trend results indicates the non-linear trend is significant and the linear trend results should not be reported. For trends significant at $p \leq 0.01$, results are abbreviated as IMP (improving), DEG (degrading), INC (increasing), DEC (decreasing), U (u-shaped non-linear trend) and INV-U (inverse u-shaped non-linear trend). For trends significant at $0.01 < p < 0.05$, NT (no trend) precedes the abbreviation. NT alone indicates trend is not significant at $p < 0.05$. * indicates too much data was below detection limit to perform the trend analysis for this period.

Param	System	Station	1985-1997 Linear Trend	1999-2010 Linear Trend	1985-2010 Linear Trend	1985-2010 Non-Lin Trend	Non-linear inflection
TN	FISHING BAY	EE3.0	NTDEG	NT	NT		
	UPPER NANTICOKE	ET6.1	DEG	NT	DEG	INV-U	Dec-02
	MIDDLE NANTICOKE	ET6.2	NT	NT	NT		
	MIDDLE WICOMICO	ET7.1	NT	NT	NT		
	LOWER MANOKIN	ET8.1	NTDEG	NT	NT		
	BIG ANNEMESSEX	ET9.1	NTDEG	NT	NT		
	UPPER POCOMOKE R	ET10.1	NT	IMP	IMP		
	POCOMOKE S	EE3.3	DEG	NTDEG	NT		
	N TANGIER S	EE3.1	NT	NT	NT		
	S TANGIER S	EE3.2	NTDEG	NTDEG	NT		
DIN	FISHING BAY	EE3.0	NT	NT	Not evaluated due to lab change		
	UPPER NANTICOKE	ET6.1	DEG	NT			
	MIDDLE NANTICOKE	ET6.2	NT	NT			
	MIDDLE WICOMICO	ET7.1	NT	NT			
	LOWER MANOKIN	ET8.1	DEG	NT			
	BIG ANNEMESSEX	ET9.1	DEG	NT			
	UPPER POCOMOKE R	ET10.1	NT	IMP			
	POCOMOKE S	EE3.3	NT	NT			
	N TANGIER S	EE3.1	NT	NT			
	S TANGIER S	EE3.2	DEG	NT			
TP	FISHING BAY	EE3.0	NTDEG	NTIMP	Not evaluated due to lab change		
	UPPER NANTICOKE	ET6.1	NT	IMP			
	MIDDLE NANTICOKE	ET6.2	DEG	NT			
	MIDDLE WICOMICO	ET7.1	NT	NT			
	LOWER MANOKIN	ET8.1	DEG	NT			
	BIG ANNEMESSEX	ET9.1	DEG	NT			
	UPPER POCOMOKE R	ET10.1	DEG	NT			
	POCOMOKE S	EE3.3	DEG	NT			
	N TANGIER S	EE3.1	NT	NT			
	S TANGIER S	EE3.2	DEG	NT			
PO4	FISHING BAY	EE3.0	*	NT	Not evaluated due to lab change		
	UPPER NANTICOKE	ET6.1	DEG	NTIMP			
	MIDDLE NANTICOKE	ET6.2	*	NT			
	MIDDLE WICOMICO	ET7.1	*	NT			
	LOWER MANOKIN	ET8.1	*	NT			
	BIG ANNEMESSEX	ET9.1	*	NT			
	UPPER POCOMOKE R	ET10.1	NTDEG	NTIMP			
	POCOMOKE S	EE3.3	*	NT			
	N TANGIER S	EE3.1	*	NT			
	S TANGIER S	EE3.2	*	NT			
TSS	FISHING BAY	EE3.0	DEG	IMP	Not evaluated due to lab change		
	UPPER NANTICOKE	ET6.1	NT	IMP			
	MIDDLE NANTICOKE	ET6.2	DEG	NT			
	MIDDLE WICOMICO	ET7.1	NTDEG	NT			
	LOWER MANOKIN	ET8.1	DEG	NT			
	BIG ANNEMESSEX	ET9.1	DEG	NT			
	UPPER POCOMOKE R	ET10.1	NT	IMP			
	POCOMOKE S	EE3.3	DEG	NTIMP			
	N TANGIER S	EE3.1	DEG	NTIMP			
	S TANGIER S	EE3.2	DEG	NT			

Param	System	Station	1985-1997 Linear Trend	1999-2010 Linear Trend	1985-2010 Linear Trend	1985-2010 Non-Lin Trend	Non-linear inflection
CHLA	FISHING BAY	EE3.0	NTDEG	NT	DEG		
	UPPER NANTICOKE	ET6.1	NT	NTIMP	IMP	INV-U	Oct-90
	MIDDLE NANTICOKE	ET6.2	NT	NT	NT		
	MIDDLE WICOMICO	ET7.1	NT	NT	NT		
	LOWER MANOKIN	ET8.1	NT	NT	NT		
	BIG ANNEMESSEX	ET9.1	DEG	NT	NT		
	UPPER POCOMOKE R	ET10.1	IMP	NTIMP	IMP		
	POCOMOKE S	EE3.3	DEG	NT	DEG		
	N TANGIER S	EE3.1	DEG	NT	DEG		
	S TANGIER S	EE3.2	DEG	NT	DEG		
SECCHI	FISHING BAY	EE3.0	NTDEG	NT	SLOPE=0	U	Mar-03
	UPPER NANTICOKE	ET6.1	NT	NT	IMP		
	MIDDLE NANTICOKE	ET6.2	SLOPE = 0	NT	SLOPE=0	U	Sep-03
	MIDDLE WICOMICO	ET7.1	NT	NT	SLOPE=0		
	LOWER MANOKIN	ET8.1	DEG	NT	DEG	U	May-03
	BIG ANNEMESSEX	ET9.1	DEG	NT	DEG	U	Apr-03
	UPPER POCOMOKE R	ET10.1	NT	NT	NT		
	POCOMOKE S	EE3.3	DEG	NT	DEG	U	May-03
	N TANGIER S	EE3.1	DEG	NT	DEG	U	Jun-02
	S TANGIER S	EE3.2	DEG	NT	DEG	U	Oct-02
DO	FISHING BAY	EE3.0	NT	IMP	NT		
	UPPER NANTICOKE	ET6.1	NT	NT	DEG		
	MIDDLE NANTICOKE	ET6.2	NT	NT	NT		
	MIDDLE WICOMICO	ET7.1	NT	NT	NT		
	LOWER MANOKIN	ET8.1	NT	IMP	NT	U	Nov-98
	BIG ANNEMESSEX	ET9.1	NT	NT	DEG		
	UPPER POCOMOKE R	ET10.1	NT	NT	DEG		
	POCOMOKE S	EE3.3	NT	NT	NT		
	N TANGIER S	EE3.1	NT	NT	NTDEG		
	S TANGIER S	EE3.2	NT	NT	DEG		
WTEMP	FISHING BAY	EE3.0	NT	NT	NT		
	UPPER NANTICOKE	ET6.1	NT	NT	NT		
	MIDDLE NANTICOKE	ET6.2	NT	NT	NT		
	MIDDLE WICOMICO	ET7.1	NT	NT	NT		
	LOWER MANOKIN	ET8.1	NT	NT	NT		
	BIG ANNEMESSEX	ET9.1	NT	NT	NT		
	UPPER POCOMOKE R	ET10.1	NT	NT	NT		
	POCOMOKE S	EE3.3	NT	NT	NT		
	N TANGIER S	EE3.1	NT	NT	NT		
	S TANGIER S	EE3.2	NT	NT	NT		
SALINITY	FISHING BAY	EE3.0	DEC	NT	NTDEC		
	UPPER NANTICOKE	ET6.1	SLOPE = 0	NT	SLOPE=0		
	MIDDLE NANTICOKE	ET6.2	DEC	NT	NT		
	MIDDLE WICOMICO	ET7.1	NT	NT	NT		
	LOWER MANOKIN	ET8.1	DEC	NT	DEC		
	BIG ANNEMESSEX	ET9.1	DEC	NT	NTDEC		
	UPPER POCOMOKE R	ET10.1	NT	NT	NT		
	POCOMOKE S	EE3.3	DEC	NTDEC	NTDEC	U	Jan-01
	N TANGIER S	EE3.1	DEC	NT	DEC	U	Nov-00
	S TANGIER S	EE3.2	DEC	NTDEC	NT	U	Jan-01

Param	System	Station	1985-1997 Linear Trend	1999-2010 Linear Trend	1985-2010 Linear Trend	1985-2010 Non-Lin Trend	Non-linear inflection
NH4	FISHING BAY	EE3.0	NT	NT	Not evaluated due to lab change		
	UPPER NANTICOKE	ET6.1	NT	**IMP**			
	MIDDLE NANTICOKE	ET6.2	NT	NT			
	MIDDLE WICOMICO	ET7.1	NT IMP	NTIMP			
	LOWER MANOKIN	ET8.1	**DEG**	NT			
	BIG ANNEMESSEX	ET9.1	**DEG**	NT			
	UPPER POCOMOKE R	ET10.1	NT	NTIMP			
	POCOMOKE S	EE3.3	NTDEG	NT			
	N TANGIER S	EE3.1	NT	NT			
	S TANGIER S	EE3.2	NTDEG	NT			
NO23	FISHING BAY	EE3.0	NT	NT	Not evaluated due to lab change		
	UPPER NANTICOKE	ET6.1	**DEG**	NT			
	MIDDLE NANTICOKE	ET6.2	NT	NT			
	MIDDLE WICOMICO	ET7.1	NT	NT			
	LOWER MANOKIN	ET8.1	SLOPE = 0	NT			
	BIG ANNEMESSEX	ET9.1		NT			
	UPPER POCOMOKE R	ET10.1	NT	**IMP**			
	POCOMOKE S	EE3.3	NT	NT			
	N TANGIER S	EE3.1	NT	NT			
	S TANGIER S	EE3.2	NT	NT			
TN:TP	FISHING BAY	EE3.0	NT	**INC**	Not evaluated due to lab change		
	UPPER NANTICOKE	ET6.1	NT	NT			
	MIDDLE NANTICOKE	ET6.2	NT DEC	NT			
	MIDDLE WICOMICO	ET7.1	NT	NT			
	LOWER MANOKIN	ET8.1	NT	NT			
	BIG ANNEMESSEX	ET9.1	NT	NT			
	UPPER POCOMOKE R	ET10.1	**DEC**	NT			
	POCOMOKE S	EE3.3	**DEC**	NT			
	N TANGIER S	EE3.1	NT	NT			
	S TANGIER S	EE3.2	NT DEC	NT			
DIN:PO4	FISHING BAY	EE3.0	NT	NT	Not evaluated due to lab change		
	UPPER NANTICOKE	ET6.1	**DEC**	NT			
	MIDDLE NANTICOKE	ET6.2	NT	**DEC**			
	MIDDLE WICOMICO	ET7.1	NT	NT			
	LOWER MANOKIN	ET8.1	NT	NT			
	BIG ANNEMESSEX	ET9.1	**INC**	NT			
	UPPER POCOMOKE R	ET10.1	NT	NTDEC			
	POCOMOKE S	EE3.3	NT	NT			
	N TANGIER S	EE3.1	NT	NT			
	S TANGIER S	EE3.2	**INC**	NT			

Appendix 7

Seasonal trends results for long-term tidal water quality data

Seasonal trends results for surface data from 1999-2010. Color codes and abbreviations are the same as used in Appendix 6.

param	System	station	ANNUAL Jan-Dec	SPRING Mar-May	SUMMER Jun-Sep	SAV Apr-Oct
TN	FISHING BAY	EE3.0	NT	NT	NT	NT
	UPPER NANTICOKE	ET6.1	NT	NT	NT	NT
	MIDDLE NANTICOKE	ET6.2	NT	NT	NT	NT
	MIDDLE WICOMICO	ET7.1	NT	NT	NT	NT
	LOWER MANOKIN	ET8.1	NT	NT	NT	NT
	BIG ANNEMESSEX	ET9.1	NT	NT	NT	NT
	UPPER POCOMOKE R	ET10.1	**IMP**	NTIMP	NTIMP	**IMP**
	POCOMOKE S	EE3.3	NTDEG	NT	NT	NT
	N TANGIER S	EE3.1	NT	NT	NT	NT
	S TANGIER S	EE3.2	NTDEG	NT	NT	NT
DIN	FISHING BAY	EE3.0	NT	NT	NT	NT
	UPPER NANTICOKE	ET6.1	NT	NT	NT	NT
	MIDDLE NANTICOKE	ET6.2	NT	NT	NTIMP	NT
	MIDDLE WICOMICO	ET7.1	NT	NT	NT	NT
	LOWER MANOKIN	ET8.1	NT	NT	NT	NT
	BIG ANNEMESSEX	ET9.1	NT	NT	NT	NT
	UPPER POCOMOKE R	ET10.1	**IMP**	NTIMP	**IMP**	**IMP**
	POCOMOKE S	EE3.3	NT	NT	NT	NT
	N TANGIER S	EE3.1	NT	NT	NT	NT
	S TANGIER S	EE3.2	NT	NT	NT	NT
TP	FISHING BAY	EE3.0	NTIMP	NT	NT	NTIMP
	UPPER NANTICOKE	ET6.1	**IMP**	NT	**IMP**	**IMP**
	MIDDLE NANTICOKE	ET6.2	NT	NT	NT	NT
	MIDDLE WICOMICO	ET7.1	NT	NT	NT	NT
	LOWER MANOKIN	ET8.1	NT	NT	NT	NT
	BIG ANNEMESSEX	ET9.1	NT	NT	NT	NT
	UPPER POCOMOKE R	ET10.1	NT	NT	NT	NT
	POCOMOKE S	EE3.3	NT	NT	NT	NT
	N TANGIER S	EE3.1	NT	NT	NT	NT
	S TANGIER S	EE3.2	NT	NT	NT	NT
PO4	FISHING BAY	EE3.0	NT	NT	NT	NT
	UPPER NANTICOKE	ET6.1	NTIMP	NT	NT	NT
	MIDDLE NANTICOKE	ET6.2	NT	NT	NT	NT
	MIDDLE WICOMICO	ET7.1	NT	NT	NT	NT
	LOWER MANOKIN	ET8.1	NT	NT	NT	NT
	BIG ANNEMESSEX	ET9.1	NT	NT	NT	NT
	UPPER POCOMOKE R	ET10.1	NTIMP	NT	NT	NT
	POCOMOKE S	EE3.3	NT	NT	NT	NT
	N TANGIER S	EE3.1	NT	NT	NT	NT
	S TANGIER S	EE3.2	NT	NT	NT	NT
TSS	FISHING BAY	EE3.0	**IMP**	NTIMP	NTIMP	**IMP**
	UPPER NANTICOKE	ET6.1	**IMP**	NTIMP	**IMP**	**IMP**
	MIDDLE NANTICOKE	ET6.2	NT	NT	NT	NT
	MIDDLE WICOMICO	ET7.1	NT	NT	NTIMP	NT
	LOWER MANOKIN	ET8.1	NT	NT	NT	NTIMP
	BIG ANNEMESSEX	ET9.1	NT	NT	NT	NT
	UPPER POCOMOKE R	ET10.1	**IMP**	NT	NT	NTIMP
	POCOMOKE S	EE3.3	NTIMP	NT	NT	NT
	N TANGIER S	EE3.1	NTIMP	NT	NTIMP	**IMP**
	S TANGIER S	EE3.2	NT	NT	**IMP**	NT

param	System	station	ANNUAL Jan-Dec	SPRING Mar-May	SUMMER Jun-Sep	SAV Apr-Oct
CHLA	FISHING BAY	EE3.0	NT	NT	NT	NT
	UPPER NANTICOKE	ET6.1	NTIMP	**IMP**	NT	NT
	MIDDLE NANTICOKE	ET6.2	NT	NT	NT	NT
	MIDDLE WICOMICO	ET7.1	NT	NT	NT	NT
	LOWER MANOKIN	ET8.1	NT	NT	NT	NT
	BIG ANNEMESSEX	ET9.1	NT	NT	NT	NT
	UPPER POCOMOKE R	ET10.1	NTIMP	**IMP**	NT	NT
	POCOMOKE S	EE3.3	NT	NT	NT	NT
	N TANGIER S	EE3.1	NT	NT	NT	NT
	S TANGIER S	EE3.2	NT	NT	NT	NT
SECCHI	FISHING BAY	EE3.0	NT	NT	NT	NT
	UPPER NANTICOKE	ET6.1	NT	NT	NT	NT
	MIDDLE NANTICOKE	ET6.2	NT	NT	NT	NT
	MIDDLE WICOMICO	ET7.1	NT	NT	NT	NT
	LOWER MANOKIN	ET8.1	NT	NT	NT	NTIMP
	BIG ANNEMESSEX	ET9.1	NT	NT	NT	NT
	UPPER POCOMOKE R	ET10.1	NT	NT	NT	NT
	POCOMOKE S	EE3.3	NT	NT	NT	NT
	N TANGIER S	EE3.1	NT	NT	NT	NT
	S TANGIER S	EE3.2	NT	NT	NT	NT
WTEMP	FISHING BAY	EE3.0	NT	NT	NT	NT
	UPPER NANTICOKE	ET6.1	NT	NT	NT	NT
	MIDDLE NANTICOKE	ET6.2	NT	NT	NT	NT
	MIDDLE WICOMICO	ET7.1	NT	NT	NT	NT
	LOWER MANOKIN	ET8.1	NT	NT	NT	NT
	BIG ANNEMESSEX	ET9.1	NT	NT	NT	NT
	UPPER POCOMOKE R	ET10.1	NT	NT	NT	NT
	POCOMOKE S	EE3.3	NT	NT	NT	NT
	N TANGIER S	EE3.1	NT	NT	NT	NT
	S TANGIER S	EE3.2	NT	NT	NT	NT
SALINITY	FISHING BAY	EE3.0	NT	NTDEC	NT	NT
	UPPER NANTICOKE	ET6.1	NT	NT	NT	NT
	MIDDLE NANTICOKE	ET6.2	NT	NT	NT	NT
	MIDDLE WICOMICO	ET7.1	NT	NT	NT	NT
	LOWER MANOKIN	ET8.1	NT	NTDEC	NT	NT
	BIG ANNEMESSEX	ET9.1	NT	NTDEC	NT	NT
	UPPER POCOMOKE R	ET10.1	NT		NT	NT
	POCOMOKE S	EE3.3	NTDEC	DEC	NT	NT
	N TANGIER S	EE3.1	NT	DEC	NT	NT
	S TANGIER S	EE3.2	NTDEC	DEC	NT	NT

Appendix 8

Annual and seasonal trends from 2003-2010 at long-term tidal water quality monitoring stations.

In addition to the ten long-term tidal water quality stations monitored since 1985, 10 more tidal water quality stations were added to the monitoring program beginning in 1999 (spring and summer only until full year monitoring began in 2003). Bottom samples are not collected at these newer stations, so bottom dissolved oxygen data is not available. In order to evaluate all stations in a river system together, data from 2003-2010 were analyzed for annual and seasonal trends. Color codes and abbreviations are the same as in Appendix 6.

system	STATION	TN ANNUAL Jan-Dec	TN SPRING Mar-May	TN SUMMER Jun-Sep	TN SAV Apr-Oct	DIN ANNUAL Jan-Dec	DIN SPRING Mar-May	DIN SUMMER Jun-Sep	DIN SAV Apr-Oct	TP ANNUAL Jan-Dec	TP SPRING Mar-May	TP SUMMER Jun-Sep	TP SAV Apr-Oct	PO4 ANNUAL Jan-Dec	PO4 SPRING Mar-May	PO4 SUMMER Jun-Sep	PO4 SAV Apr-Oct	TSS ANNUAL Jan-Dec	TSS SPRING Mar-May	TSS SUMMER Jun-Sep	TSS SAV Apr-Oct
Chicamacomico Transquaking Fishing Bay	CCM0069	NT	NT	NTDEG	NT	NTIMP	NT	NT	NT	NT	NT	NT	NT	NTIMP	NT	NTIMP	IMP	DEG	NT	DEG	NTDEG
	TRQ0146	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	IMP	NT	NTIMP	NTIMP	NT	NT	NT	NT
	TRQ0088	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NTIMP	NT	NT	NTIMP	NT	NT	NT	NT
	EE3.0	NTIMP	NTIMP	NT	NT	NT	NT	NT	NT	NTIMP	NTIMP	NT	NT	NT	NT	NT	NTIMP	NTIMP	NT	IMP	IMP
Nanticoke	ET6.1	IMP	NT	IMP	IMP	IMP	NT	IMP	IMP	NTIMP	NT	NT	NTIMP	IMP	NT	IMP	IMP	NT	NT	NT	NT
	XDJ9007	IMP	NT	NTIMP	IMP	IMP	NT	IMP	IMP	NTIMP	NT	NT	NT	IMP	NT	NTIMP	NTIMP	NT	NT	NT	NT
	ET6.2	IMP	NT	NTIMP	IMP	IMP	NT	IMP	IMP	IMP	NTIMP	NTIMP	NTIMP	NT	NT	NT	NT	NT	NT	IMP	IMP
Wicomico	WIW0141	IMP	NT	IMP	IMP	IMP	IMP	IMP	IMP	NT	NT	NT	NT	NTIMP	NT	NTIMP	NTIMP	NT	NT	NT	NTDEG
	XCI4078	IMP	NT	NT	NTIMP	IMP	NT	NTIMP	NTIMP	NTIMP	NT	NT	NT	IMP	NT	NTIMP	IMP	NTIMP	NT	NT	IMP
	ET7.1	IMP	NT	IMP	IMP	IMP	NT	IMP	IMP	IMP	NT	IMP	IMP	IMP	NT	NTIMP	IMP	NT	NT	NTIMP	NT
Manokin	BXK0031	NT	NT	NT	NT	IMP	NT	NTIMP	NTIMP	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
	MNK0146	NT	NT	NT	NT	IMP	NT	IMP	NTIMP	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
	ET8.1	NTIMP	NT	NT	NT	NTIMP	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NTIMP	NT	NTIMP	NTIMP
Big Annemessex	ET9.1	IMP	NTIMP	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
Pocomoke River	ET10.1	IMP	NTIMP	IMP	IMP	IMP	NT	IMP	IMP	NTIMP	NT	NT	NTIMP	NTIMP	NT	NTIMP	NTIMP	NT	NT	NT	NT
	POK0087	IMP	NT	IMP	IMP	IMP	NT	IMP	IMP	NT	NT	NT	NT	NT	NT	NTIMP	NT	DEG	NT	NT	NTDEG
	XAK7810	IMP	NTIMP	NT	NT	IMP	NT	NTIMP	NTIMP	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
Pocomoke Sound	EE3.3	NTIMP	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
Tangier Sound	EE3.1	IMP	NT	NTIMP	IMP	IMP	NT	NTIMP	NTIMP	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NTIMP	IMP
	EE3.2	IMP	NTIMP	NTIMP	IMP	IMP	NT	NT	NTIMP	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT

system	STATION	CHLA				SECCHI				WATER TEMP				SALINITY			
		ANNUAL Jan-Dec	SPRING Mar May	SUMMER Jun-Sep	SAV Apr-Oct	ANNUAL Jan-Dec	SPRING Mar May	SUMMER Jun-Sep	SAV Apr-Oct	ANNUAL Jan-Dec	SPRING Mar May	SUMMER Jun-Sep	SAV Apr-Oct	ANNUAL Jan-Dec	SPRING Mar May	SUMMER Jun-Sep	SAV Apr-Oct
Chicamacomico Transquaking Fishing Bay	CCM0069	NTDEG	NT	NT	NTDEG	NT	NTDEG	NT	NT	NT	NT	NT	NT	**INC**	NT	**INC**	NTINC
	TRQ0146	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	**INC**	NT	**INC**	NTINC
	TRQ0088	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	**INC**	NT	**INC**	**INC**
	EE3.0	**IMP**	NT	NT	**IMP**	NT	NT	NT	NTIMP	NT	NT	NT	NT	**INC**	NT	**INC**	**INC**
Nanticoke	ET6.1	**DEG**	NT	**DEG**	**DEG**	NT	NT	NT	NT	NT	NT	NT	NT	**	NT	NT	NT
	XDJ9007	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	**INC**	NT	**INC**	**INC**
	ET6.2	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	**INC**	NT	**INC**	**INC**
Wicomico	WIW0141	**DEG**	NT	NT	**DEG**	NT	NT	NT	NT	NT	NT	NT	NT	**	NT	NTINC	**
	XCI4078	NTIMP	NT	NT	NTIMP	NT	NT	NT	NT	NT	NT	NT	NT	**INC**	NT	**INC**	**INC**
	ET7.1	NT	NT	NT	NT	**	NT	NTIMP	**IMP**	NT	NT	NT	NT	**INC**	NT	**INC**	**INC**
Manokin	BXK0031	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NTINC	NT	**INC**	NT
	MNK0146	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NTINC	NT	**INC**	**INC**
	ET8.1	NT	NT	NT	NT	**IMP**	NT	**IMP**	**IMP**	NT	NT	NT	NT	**INC**	NT	**INC**	**INC**
Big Annemessex	ET9.1	NT	NTIMP	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	**INC**	NT	**INC**	**INC**
Pocomoke River	ET10.1	NTDEG	NT	**DEG**	NTDEG	NT	NT	NT	NT	NTINC	NTINC	NT	NT	**			**
	POK0087	NTDEG	NT	NTDEG	NT	NT	NT	NT	NT	NT	NT	NT	NT	**	NT	**INC**	**
	XAK7810	NT	NT	NT	NT	**	NT		NT	NT	NT	NT	NT	**INC**	NT	**INC**	NTINC
Pocomoke Sound	EE3.3	**IMP**	NT	NT	NTIMP	NTIMP	NT	NT	NTIMP	NT	NT	NT	NT	**INC**	NT	**INC**	**INC**
Tangier Sound	EE3.1	NTIMP	NT	NT	NTIMP	NT	NT	NT	NT	NT	NT	NT	NT	**INC**	NT	**INC**	**INC**
	EE3.2	NT	NT	NT	NT	NTIMP	NT	NTIMP	NTIMP	NT	NT	NT	NT	**INC**	NT	**INC**	**INC**

Appendix 9

Current (2008-2010) status for long-term tidal water quality stations

Data is from the surface layer with the exception of dissolved oxygen, which is from the bottom and the trends are for summer only (June-September). Red colored results indicate poor conditions. Green colored results indicate good conditions. Blue colored status indicates fair conditions.

		2008-2010 median	2008-2010 Status	2008-2010 median	2008-2010 Status	2008-2010 median	2008-2010 Status	2008-2010 median	2008-2010 Status	2008-2010 median	2008-2010 Status
system	**station**	**TN**		**DIN**		**TP**		**PO4**		**TSS**	
Chicamacomico Transquaking Fishing Bay	CCM0069	1.788	POOR	0.173	GOOD	0.098	FAIR	0.012	POOR	14.7	GOOD
	TRQ0146	2.337	POOR	0.046	GOOD	0.161	POOR	0.010	POOR	25.8	POOR
	TRQ0088	1.724	POOR	0.103	GOOD	0.102	POOR	0.006	POOR	62.4	POOR
	EE3.0	0.826	POOR	0.062	GOOD	0.032	GOOD	0.003	GOOD	12.5	POOR
Nanticoke	ET6.1	2.858	POOR	2.245	POOR	0.052	GOOD	0.010	GOOD	17.0	POOR
	XDJ9007	2.258	POOR	1.346	POOR	0.072	GOOD	0.011	POOR	32.0	POOR
	ET6.2	1.105	POOR	0.290	POOR	0.050	POOR	0.004	POOR	28.5	POOR
Wicomico	WIW0141	2.719	POOR	1.723	POOR	0.097	POOR	0.013	FAIR	22.5	POOR
	XCI4078	0.882	POOR	0.074	GOOD	0.036	GOOD	0.003	GOOD	14.0	POOR
	ET7.1	1.128	POOR	0.310	POOR	0.047	POOR	0.004	POOR	17.4	POOR
Manokin	BXK0031	1.456	FAIR	0.092	GOOD	0.118	POOR	0.041	POOR	23.5	FAIR
	MNK0146	1.491	FAIR	0.101	GOOD	0.148	POOR	0.034	POOR	23.4	FAIR
	ET8.1	0.785	FAIR	0.016	GOOD	0.045	POOR	0.003	GOOD	11.5	POOR
Big Annemessex	ET9.1	0.651	GOOD	0.017	GOOD	0.025	GOOD	0.003	GOOD	8.3	GOOD
Pocomoke River	ET10.1	1.446	GOOD	0.583	GOOD	0.101	POOR	0.030	POOR	8.2	GOOD
	POK0087	1.585	POOR	0.437	GOOD	0.124	POOR	0.027	POOR	33.3	POOR
	XAK7810	1.244	POOR	0.094	GOOD	0.087	POOR	0.021	POOR	18.5	POOR
Pocomoke Sound	EE3.3	0.662	GOOD	0.025	GOOD	0.035	GOOD	0.003	GOOD	10.4	POOR
Tangier Sound	EE3.1	0.718	GOOD	0.055	GOOD	0.028	GOOD	0.003	GOOD	8.0	GOOD
	EE3.2	0.587	GOOD	0.037	GOOD	0.023	GOOD	0.003	GOOD	5.9	GOOD

system	station	CHLA 2008-2010 median	CHLA 2008-2010 Status	SECCHI 2008-2010 median	SECCHI 2008-2010 Status	SUMMER BOTTOM DO 2008-2010 median	SUMMER BOTTOM DO 2008-2010 Status
Chicamacomico Transquaking Fishing Bay	CCM0069	24.2	POOR	0.3	POOR		
	TRQ0146	49.5	POOR	0.2	POOR		
	TRQ0088	19.4	POOR	0.2	POOR		
	EE3.0	9.0	FAIR	0.6	POOR	6.8	GOOD
Nanticoke	ET6.1	6.5	FAIR	0.5	POOR	6.5	GOOD
	XDJ9007	7.2	GOOD	0.3	POOR		
	ET6.2	13.2	POOR	0.4	POOR	6.4	GOOD
Wicomico	WIW0141	20.1	POOR	0.3	POOR		
	XCI4078	10.3	POOR	0.5	POOR		
	ET7.1	11.2	POOR	0.4	POOR	5.4	GOOD
Manokin	BXK0031	12.1	POOR	0.3	POOR		
	MNK0146	20.2	POOR	0.3	POOR		
	ET8.1	8.7	GOOD	0.7	POOR	6.8	GOOD
Big Annemessex	ET9.1	6.9	GOOD	1.1	POOR	6.5	GOOD
Pocomoke River	ET10.1	2.0	GOOD	0.4	POOR	4.3	FAIR
	POK0087	4.3	GOOD	0.3	POOR		
	XAK7810	12.7	POOR	0.4	POOR		
Pocomoke Sound	EE3.3	10.5	POOR	0.9	POOR	6.5	GOOD
Tangier Sound	EE3.1	9.2	FAIR	0.9	POOR	4.7	FAIR
	EE3.2	7.1	GOOD	1.5	GOOD	4.7	FAIR

Appendix 10

Shallow water monitoring water and habitat quality

Temporal Assessment- Percent failures

Continuous monitoring data for the years 1998-2010. Instantaneous measurements of dissolved oxygen taken during June through September were compared to threshold value 3.2 mg/l. Chlorophyll and turbidity measurements collected during the SAV growing were compared to threshold levels of 15 µg/l and 7 NTU, respectively. The percent of values in each year that did not meet the water quality thresholds are presented as "percent failures".

Station	Location	Year	Dissolved Oxygen Thresholds % < 3.2 mg/l	Chlorophyll Thresholds % > 15 ug/l	Turbidity Thresholds % > 7 NTU
POK0087	*Pocomoke River* Rehobeth	1999	9.46	No Data	No Data
		2000	35.11	25.92	98.90
		2001	0.41	50.59	99.78
		2002	2.40	82.32	99.84
POK0043 (surface)	*Pocomoke River* Cedar Hall Wharf	1998	0.04	No Data	No Data
		1999	5.64	No Data	No Data
		2000	30.68	35.55	99.97
		2001	1.52	59.49	99.36
		2002	1.63	91.76	98.52
POK0043 (bottom)	*Pocomoke River* Cedar Hall Wharf	2000	31.40	43.57	100.00
		2001	0.76	55.13	91.44
POK0009	*Pocomoke River* Shelltown	1998	0.04	No Data	No Data
		1999	2.06	No Data	No Data
		2000	5.26	71.90	99.99
		2001	0.62	77.26	99.97
		2002	0.51	96.06	99.22
CCM0069	*Chicamacomico River* Drawbridge	2000	11.46	78.41	53.38
		2001	8.67	91.92	90.31
		2002	4.37	99.90	100.00
		2003	22.25	44.56	99.99
TRQ0146	*Transquaking River* Decoursey	2000	2.97	94.05	98.15
		2001	2.41	99.42	99.17
TRQ0088	*Transquaking River* Bestpitch	2003	27.20	95.55	100.00
		2004	2.59	56.54	99.99
		2005	9.55	47.75	100.00
XCH8097	*Fishing Bay*	2003	1.13	1.46	86.28
		2004	1.22	13.42	78.20
		2005	3.04	10.75	78.87
WIW0144	*Wicomico River* Upper Ferry	2006	2.40	54.35	99.64
		2007	0.33	53.80	99.68
		2008	0.49	61.54	99.20
XCJ6023	*Wicomico River* Whitehaven	2006	0.00	8.27	97.84
		2007	0.30	7.45	97.53
		2008	0.01	3.87	96.44
LMN0028	*Wicomico River* Little Monie Creek	2006	20.31	5.60	67.42
		2007	12.50	23.63	92.53
		2008	17.39	17.10	74.53
		2009	24.86	8.69	72.00
		2010	16.67	9.19	58.55

< 10 % failure

10 - 40 % failure

40 - 70 % failure

> 70 % failure

Spatial Assessment

Shallow water monitoring data for 2008-2010 compared to SAV habitat requirements in the Wicomico.
All data for a station (water quality mapping and continuous monitoring) were used to calculate a monthly median. Monthly medians for April-October were used to calculate the SAV growing season median, which was compared to habitat requirements (Appendix 5). Note that the long-term stations include data from long-term and water quality mapping sampling. In 2010, DIN and PO_4 was not measured at some stations.

WATER BODY	STATION	year	Chla mg/l		TSS mg/l		DIN mg/l		PO4 mg/l		Secchi Depth		Dissolved Oxygen		Salinity		TN	TP	wtemp
WICOMICO RIVER	ET7.1	2008	10.5	MEET	18.5	FAIL	0.081	FAIL	0.0044	MEET	0.40	FAIL	6.2	MEET	8.8	MH	0.89	0.0464	21.2
		2009	10.3	MEET	16.7	FAIL	0.261	FAIL	0.0046	MEET	0.40	FAIL	5.6	MEET	6.7	MH	0.973	0.0463	22.6
		2010	16.5	FAIL	13.2	MEET	0.067	MEET	0.0067	MEET	0.50	FAIL	6.8	MEET	7.2	MH	0.99	0.0591	24
	LMN0028	2008	11.2	MEET	27.7	FAIL	0.028	MEET	0.0083	MEET	0.50	FAIL	5.1	MEET	10.2	MH	0.9945	0.0675	22.6
		2009	9.6	MEET	22.7	FAIL	0.039	MEET	0.0207	FAIL	0.60	FAIL	3.5	LOW	9.6	MH	1.15	0.0884	23
		2010	12.1	MEET	17.0	FAIL	0.061	MEET	0.0126	FAIL	0.60	FAIL	3.5	LOW	9.1	MH			22.2
	WIW0089	2008	15.0	MEET	21.0	FAIL	0.276	FAIL	0.0114	FAIL	0.40	FAIL	4.9	LOW	6.6	MH	1.169	0.0565	23.2
	WIW0141	2008	33.9	FAIL	24.5	FAIL	0.546	FAIL	0.0093	MEET	0.30	FAIL	6.7	MEET	0.9	OH	1.881	0.0975	25.5
		2009	24.2	FAIL	24.0	FAIL	1.121	FAIL	0.0136	MEET	0.40	FAIL	8.0	MEET	0.0	TF	2.017	0.0978	22
		2010	41.1	FAIL	24.4	FAIL	1.055	FAIL	0.0082	MEET	0.30	FAIL	7.7	MEET	0.2	OH	1.943	0.0927	23.8
	WIW0144	2008	43.4	FAIL	37.3	FAIL	0.640	FAIL	0.0079	MEET	0.30	FAIL	7.1	MEET	0.4	OH	1.761	0.1111	24.4
	WIW0198	2008	67.7	FAIL	18.0	FAIL	1.587	FAIL	0.0110	MEET	0.40	FAIL	7.2	MEET	0.0	TF	2.899	0.1533	23.6
	XCI3696	2008	9.0	MEET	9.5	MEET	0.024	MEET	0.0032	MEET	0.70	FAIL	6.4	MEET	10.8	MH	0.849	0.0364	27
	XCI4078	2008	9.3	MEET	14.7	MEET	0.024	MEET	0.0032	MEET	0.50	FAIL	7.1	MEET	12.0	MH	0.734	0.0372	21.3
		2009	7.8	MEET	11.6	MEET	0.062	MEET	0.0027	MEET	0.60	FAIL	7.4	MEET	11.9	MH	0.78	0.0346	22.8
		2010	11.8	MEET	13.3	MEET	0.017	MEET	0.0035	MEET	0.40	FAIL	7.5	MEET	11.3	MH	0.964	0.04	23.7
	XCJ5200	2008	15.5	FAIL	18.7	FAIL	0.062	MEET	0.0042	MEET	0.50	FAIL	6.6	MEET	11.1	MH	0.915	0.0496	23.1
	XCJ6023	2008	13.0	MEET	29.0	FAIL	0.092	FAIL	0.0068	MEET	0.40	FAIL	6.3	MEET	8.1	MH	0.979	0.0541	23.55

Shallow water monitoring data for prior to 2008 compared to SAV habitat requirements in the Lower Eastern Shore Rivers. All data for a station (water quality mapping and continuous monitoring) were used to calculate a monthly median. Monthly medians for April-October were used to calculate the SAV growing season median, which was compared to habitat requirements (Appendix 5). Note that the long-term stations include data from long-term and water quality mapping sampling. In 2010, DIN and PO_4 was not measured at some stations.

	Station	year	Chla mg/l		TSS mg/l		DIN mg/l		PO4 mg/l		Secchi Depth		Dissolved		Salinity		TN	TP	wtemp
CHICAMACOMICO RIVER	CCM0069	2003	16.4	FAIL	14.0	MEET	0.442	FAIL	0.0358	FAIL	0.30	FAIL	5.2	FAIL	0.0	TF	1.77	0.164	21.9
		2004	15.3	FAIL	13.0	MEET	0.098	FAIL	0.0187	MEET	0.30	FAIL	6.9	MEET	0.1	OH	1.67	0.114	23.9
		2005	29.9	FAIL	13.0	MEET	0.026	MEET	0.0251	FAIL	0.30	FAIL	6.5	MEET	0.1	OH	1.64	0.115	28.0
	XCH8097	2003	11.1	MEET	20.5	FAIL	0.040	MEET	0.0046	MEET	0.40	FAIL	7.2	MEET	10.0	MH	1.04	0.046	24.1
		2004	6.8	MEET	21.6	FAIL	0.049	MEET	0.0048	MEET	0.50	FAIL	7.0	MEET	11.2	MH	0.96	0.042	22.3
		2005	7.9	MEET	21.8	FAIL	0.039	MEET	0.0029	MEET	0.40	FAIL	6.9	MEET	10.2	MH	0.94	0.046	23.7
FISHING BAY	EE3.0	2003	13.5	MEET	17.8	FAIL	0.085	FAIL	0.0041	MEET	0.60	FAIL	7.3	MEET	10.4	MH	0.98	0.036	22.3
		2004	11.4	MEET	22.5	FAIL	0.049	MEET	0.0036	MEET	0.50	FAIL	6.9	MEET	10.7	MH	0.85	0.037	23.3
		2005	15.7	FAIL	13.0	MEET	0.040	MEET	0.0029	MEET	0.50	FAIL	7.6	MEET	9.8	MH	0.93	0.035	24.0
	XCH4378	2003	10.8	MEET	11.5	MEET	0.068	MEET	0.0030	MEET	0.60	FAIL	7.4	MEET	10.8	MH	0.77	0.032	24.2
		2004	10.1	MEET	11.5	MEET	0.034	MEET	0.0041	MEET	0.70	FAIL	8.1	MEET	11.7	MH	0.83	0.029	24.0
		2005	9.0	MEET	11.5	MEET	0.018	MEET	0.0022	MEET	0.50	FAIL	7.9	MEET	11.9	MH	0.86	0.025	24.2
	XCH8973	2003	16.1	FAIL	20.8	FAIL	0.039	MEET	0.0023	MEET	0.40	FAIL	7.5	MEET	8.6	MH	1.03	0.039	24.0
		2004	10.1	MEET	15.0	FAIL	0.078	FAIL	0.0033	MEET	0.40	FAIL	6.8	MEET	9.7	MH	0.97	0.034	24.0
		2005	13.5	MEET	17.5	FAIL	0.020	MEET	0.0028	MEET	0.30	FAIL	7.7	MEET	9.1	MH	1.00	0.037	23.6
	XCI4821	2003	10.2	MEET	12.3	MEET	0.063	MEET	0.0037	MEET	0.70	FAIL	7.0	MEET	11.0	MH	0.83	0.036	23.5
		2004	10.0	MEET	24.0	FAIL	0.032	MEET	0.0034	MEET	0.50	FAIL	7.6	MEET	12.0	MH	0.85	0.033	23.3
		2005	8.2	MEET	11.0	MEET	0.063	MEET	0.0034	MEET	0.60	FAIL	7.5	MEET	11.7	MH	0.82	0.028	23.5
	XCI5506	2003	12.6	MEET	9.5	MEET	0.096	FAIL	0.0028	MEET	0.70	FAIL	7.4	MEET	11.0	MH	0.82	0.032	23.8
	XDI1306	2003	24.2	FAIL	31.4	FAIL	0.068	MEET	0.0037	MEET	0.30	FAIL	6.7	MEET	5.4	MH	1.43	0.056	23.2
TRANSQ RIVER	TRQ0088	2003	26.2	FAIL	40.6	FAIL	0.087	FAIL	0.0128	MEET	0.25	FAIL	4.8	FAIL	2.5	OH	1.71	0.126	22.4
		2004	20.2	FAIL	78.7	FAIL	0.058	MEET	0.0080	MEET	0.20	FAIL	4.9	FAIL	5.3	MH	1.75	0.103	24.1
		2005	20.9	FAIL	52.0	FAIL	0.057	MEET	0.0082	MEET	0.20	FAIL	4.7	FAIL	4.2	OH	1.71	0.096	24.6

Shallow water monitoring data for prior to 2008 compared to SAV habitat requirements in the Lower Eastern Shore Rivers (continued). All data for a station (water quality mapping and continuous monitoring) were used to calculate a monthly median. Monthly medians for April-October were used to calculate the SAV growing season median, which was compared to habitat requirements (Appendix 5). Note that the long-term stations include data from long-term and water quality mapping sampling. In 2010, DIN and PO_4 was not measured at some stations.

	Station	year	Chla mg/l		TSS mg/l		DIN mg/l		PO4 mg/l		Secchi Depth		Dissolved		Salinity		TN	TP	wtemp
WICOMICO RIVER	ET7.1	2006	11.1	MEET	17.5	FAIL	0.296	FAIL	0.0061	MEET	0.50	FAIL	6.6	MEET	6.6	MH	1.17	0.040	22.3
		2007	12.5	MEET	16.0	FAIL	0.151	FAIL	0.0060	MEET	0.40	FAIL	6.7	MEET	9.5	MH	0.95	0.060	21.5
	LMN0028	2006	11.2	MEET	22.0	FAIL	0.044	MEET	0.0222	FAIL	0.50	FAIL	4.2	FAIL	9.6	MH	1.15	0.102	21.3
		2007	15.9	FAIL	33.4	FAIL	0.022	MEET	0.0085	MEET	0.40	FAIL	4.6	FAIL	12.8	MH	1.22	0.077	24.8
	WIW0141	2006	24.9	FAIL	26.5	FAIL	1.328	FAIL	0.0118	MEET	0.40	FAIL	6.7	MEET	0.0	TF	2.24	0.085	23.2
		2007	59.4	FAIL	24.8	FAIL	0.872	FAIL	0.0074	MEET	0.40	FAIL	9.6	MEET	0.4	OH	2.24	0.094	23.0
	XCI4078	2006	11.1	MEET	12.0	MEET	0.053	MEET	0.0038	MEET	0.50	FAIL	6.9	MEET	11.5	MH	0.78	0.032	17.6
		2007	11.5	MEET	17.5	FAIL	0.059	MEET	0.0033	MEET	0.50	FAIL	7.9	MEET	12.0	MH	0.91	0.041	20.2
	WIW0089	2006	10.0	MEET	17.0	FAIL	0.735	FAIL	0.0152	MEET	0.40	FAIL	5.2	MEET	4.5	OH	1.36	0.063	22.8
		2007	13.5	MEET	20.7	FAIL	0.189	FAIL	0.0103	FAIL	0.50	FAIL	5.4	MEET	5.1	MH	1.33	0.059	24.9
	WIW0144	2006	33.9	FAIL	31.4	FAIL	1.217	FAIL	0.0120	MEET	0.30	FAIL	7.0	MEET	0.0	TF	2.30	0.103	23.9
		2007	32.4	FAIL	29.0	FAIL	1.119	FAIL	0.0076	MEET	0.40	FAIL	7.5	MEET	0.3	OH	2.39	0.097	25.6
	WIW0198	2006	52.8	FAIL	23.0	FAIL	3.445	FAIL	0.0156	MEET	0.40	FAIL	7.2	MEET	0.0	TF	3.92	0.133	21.5
		2007	70.3	FAIL	20.5	FAIL	2.786	FAIL	0.0114	MEET	0.50	FAIL	7.6	MEET	0.0	TF	4.26	0.148	27.1
	XCI3696	2006	10.2	MEET	14.7	MEET	0.024	MEET	0.0041	MEET	0.50	FAIL	6.9	MEET	11.4	MH	0.90	0.040	22.1
		2007	10.1	MEET	12.0	MEET	0.026	MEET	0.0049	MEET	0.50	FAIL	7.0	MEET	13.7	MH	0.84	0.044	26.7
	XCJ5200	2006	9.7	MEET	17.0	FAIL	0.138	FAIL	0.0059	MEET	0.40	FAIL	6.1	MEET	9.1	MH	0.95	0.051	22.5
		2007	10.8	MEET	19.5	FAIL	0.151	FAIL	0.0050	MEET	0.50	FAIL	6.4	MEET	11.1	MH	0.93	0.049	25.4
	XCJ6023	2006	12.0	MEET	28.7	FAIL	0.213	FAIL	0.0091	MEET	0.40	FAIL	6.3	MEET	7.6	MH	1.05	0.058	23.8
		2007	10.5	MEET	31.8	FAIL	0.067	MEET	0.0062	MEET	0.40	FAIL	6.0	MEET	8.2	MH	1.12	0.058	25.1