Patuxent River
Water Quality and Habitat Assessment

Maryland Department of Natural Resources
Tidewater Ecosystem Assessment

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The electronic version of the report is available at
http://mddnr.chesapeakebay.net/eyesonthebay/tribsums.cfm

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?"

How healthy is the Patuxent River?

Upper River

Sediment loadings from the upper river watershed increased but nitrogen loadings decreased (Table 1). In the non-tidal waters of the Patuxent, phosphorus levels decreased; non-tidal nitrogen levels increased at the upstream station but decreased at the fall line station. There were no trends in sediment levels at the non-tidal stations.

In the tidal portion of the upper river, water quality is fair and nitrogen, phosphorus and sediment levels are improving. However, nutrient levels are still too high throughout and sediment levels are too high in the lower portion (Table 2). Habitat quality is poor due to low water clarity and moderate algal abundances. Summer bottom dissolved oxygen levels are good.

Algal populations are unhealthy at the downstream tidal station, especially in the summer. Underwater grasses covered larger areas in the early 2000s, meeting restoration goals, but have not been as widespread in more recent years and were especially limited in 2012. Bottom dwelling animal populations are healthy.

Middle River

In the middle river, water quality is poor. Nitrogen and phosphorus levels improved at the upstream station. However, nutrient and sediment levels are too high to provide healthy habitat for underwater grasses. Habitat quality is poor due to moderate algal densities, low water clarity and unhealthy dissolved oxygen levels at the downstream station. Habitat quality has degraded in the middle river.

Algal populations are unhealthy at the upstream station. Underwater grasses covered areas close to restoration goals until the last several years but were especially limited in 2012. Bottom dwelling animal populations are degraded or severely degraded in many areas and have degraded over the longer term period.

Table 1. Summary of trends for non-tidal loadings (WY2002-2011) and non-tidal water quality parameters trends (1999-2012).
Annual trends ether ‘Increase’ or ‘Decrease’ if significant at $p \leq 0.01$. Improving trends are in green, degrading trends are in red. Gray boxes indicate there is no data to evaluate that component.

	Loadings			Water Quality		
STATION	Nitrogen	Phosphorus	Sediments	Nitrogen	Phosphorus	Sediments
Unity			INCREASING	INCREASING	DECREASING	
Rocky Gorge						
Bowie (Fall Line)	DECREASING			DECREASING	DECREASING	

Table 2. Summary of tidal habitat quality and water quality indicators.
Algal densities, water clarity, inorganic phosphorus and sediments either ‘Meet’ or ‘Fail’ SAV habitat requirements. 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 1999-2012 ether ‘Increase’ or ‘Decrease’ if significant at $p \leq 0.01$ or ‘Maybe Increase’ or ‘Maybe Decrease’ 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. Data is from the long-term monitoring program (2010-2012). Gray boxes indicate there is no data to evaluate that component.

		Habitat Quality			Water Quality		
	Station	Algal densities	Water Clarity	Summer Bottom Dissolved Oxygen	Nitrogen	Phosphorus	Sediments
Western Branch	Upper Western Branch	MEET Maybe Improving			FAIL IMPROVING	MEET	MEET
Western Branch	Mouth Western Branch	FAIL	FAIL		FAIL IMPROVING	FAIL IMPROVING	MEET IMPROVING
Upper River	Waysons Corner	MEET	FAIL		FAIL IMPROVING	FAIL IMPROVING	MEET IMPROVING
Upper River	Jackson Landing	FAIL	FAIL		FAIL IMPROVING	MEET IMPROVING	FAIL IMPROVING
Upper River	Nottingham	FAIL Maybe Improving	FAIL	MEET	FAIL IMPROVING	FAIL IMPROVING	FAIL Maybe Improving
Middle River	Lower Marlboro	FAIL	FAIL	MEET DEGRADING	FAIL IMPROVING	FAIL IMPROVING	FAIL Maybe Improving
Middle River	Jack's Creek	MEET DEGRADING	FAIL	MEET	FAIL	FAIL	FAIL
Middle River	Long Pt.	FAIL	FAIL Maybe degrading	MEET	MEET	FAIL	MEET
Lower River	Jack Bay	FAIL DEGRADING	FAIL DEGRADING	FAIL	MEET DEGRADING	MEET DEGRADING	MEET
Lower River	Petersons Pt.	MEET DEGRADING	MEET	FAIL	MEET	MEET Maybe Degrading	MEET
Lower River	Pt. Patience	MEET Maybe Degrading	MEET	FAIL	MEET	MEET	MEET
Lower River	Drum Pt.	MEET Maybe Degrading	MEET Maybe degrading	FAIL DEGRADING	FAIL	MEET	MEET

Lower River

In the lower river, water quality is good. Nitrogen, phosphorus and sediment levels are low enough to provide healthy habitat for underwater grasses. However, nitrogen and phosphorus levels increased at the upstream station. Habitat quality is poor in the upstream area due to poor water clarity, high algal abundances and unhealthy dissolved oxygen levels. Habitat quality is poor in the downstream area due to unhealthy dissolved oxygen levels. Habitat quality has degraded in the lower river overall.

Algal populations are unhealthy at the upstream station. Very limited areas of underwater grass beds are present in this section of the river. Bottom dwelling animal populations are degraded or severely degraded in many areas and have degraded over the longer term period.

How does the Patuxent River compare to other Maryland rivers?

The Patuxent River is in the 'High Urban, Low Agriculture' land use category (Figure 1). Compared to other similar systems, the Patuxent has lower nitrogen levels, moderate sediment levels and high phosphorus levels (Figure 2). Algal densities are relatively low and slightly higher than the reference level of 15µg/l. Water clarity is moderate for similar systems and summer bottom dissolved oxygen levels are moderate compared to similar systems but are below the 5 mg/l threshold for healthy systems.

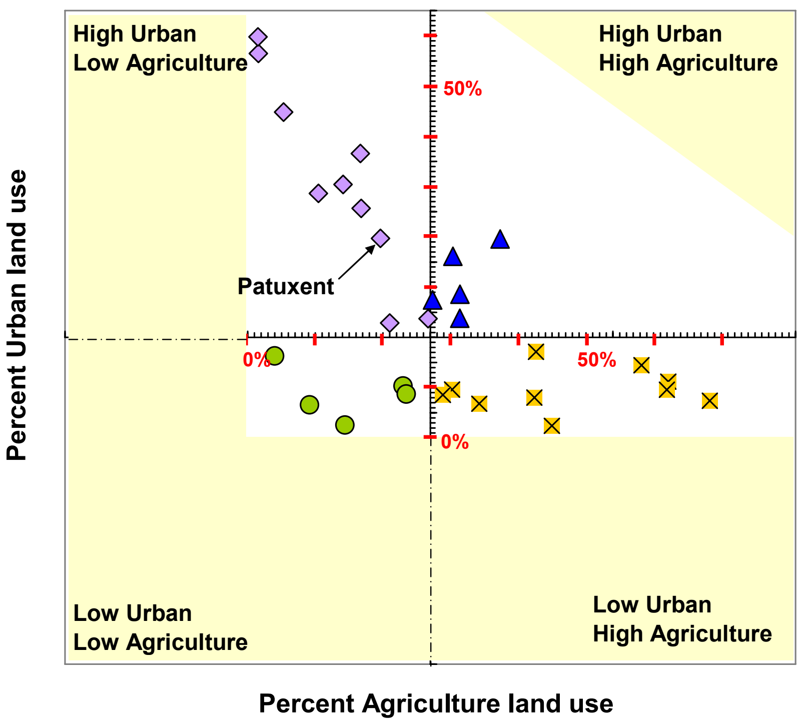

Figure 1. Classification of Maryland rivers and bays by land use.
The medians of all systems percent agriculture and percent urban land use are used to create a grid with four categories. Systems with percent urban less than the median are considered low urban. Systems with percent agriculture less than 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.

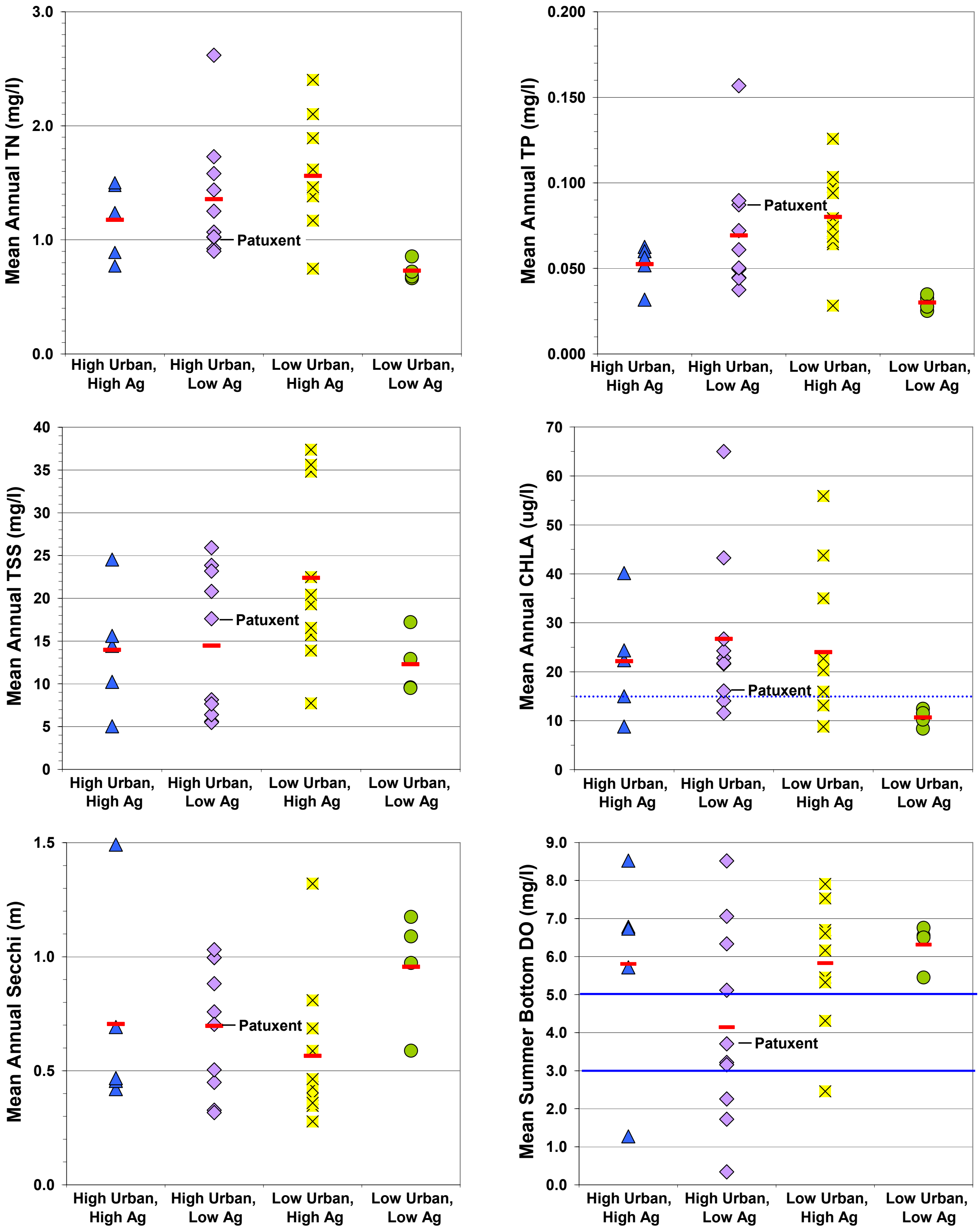

Figure 2. Comparison of the Patuxent River to similar systems.
The mean annual concentration or depth (bottom dissolved oxygen is only summer) for 2010-2012 data. Total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), chlorophyll *a* (CHLA), Secchi depth and summer bottom dissolved oxygen (DO). Red bars indicate the mean of all systems within a category. Reference lines are included on the CHLA and summer bottom DO graphs.

What needs to be done to make the Patuxent River healthy?

The biggest water quality and habitat issues are moderate to high nutrient and sediment levels and poor water clarity in the upper and middle river and dangerously low dissolved oxygen levels in the lower river. Even though nutrient and sediment levels have improved, habitat quality has degraded. By further lowering nutrients and sediments, water clarity should improve which will improve habitat quality for underwater grasses. Lower nutrients will also lead to lower algal densities and further improve habitat quality. Lower algal densities will improve dissolved oxygen conditions and improve habitat for bottom dwelling animals.

In the upper river, point sources were the largest contributor of nitrogen and phosphorus and agriculture was the largest source of sediments. In the middle river, agriculture was the largest source of nitrogen, phosphorus, and sediment loadings. In the lower river, septic was the largest source of nitrogen; point sources and agriculture were the major sources of phosphorus; agriculture and urban runoff were the major sources of sediment loadings. Upgrades to wastewater treatment plants will reduce nitrogen and phosphorus loadings, and these improvements are already complete or under construction. Reducing nutrient and sediment loadings from agriculture should also be a priority. In heavily urbanized sub-watersheds, retrofitting existing structures with alternatives to conventional building materials and methods should be used to reduce the amount of impervious surfaces and prevent additional degradation of water quality.

What has already been done to improve water and habitat quality in the Patuxent River?

A variety of actions have already been taken to lower nitrogen, phosphorus and sediment loadings. Upgrades to the largest wastewater treatment plant that discharges to the Patuxent River are under construction and will be completed by 2014. Previous upgrades to the largest facilities have already reduced nitrogen loadings by half. Managing stormwater runoff has reduced nitrogen loadings and prevented 18,200 pounds of nitrogen from entering the river since 2003, and almost 270 septic systems retrofits were completed between 2008-2011.

To reduce nutrient inputs from agricultural lands, over 13,560 acres of cover crops were planted in between growing seasons to absorb excess nutrients and prevent sediment erosion. Fencing on over 8,000 acres of farmland was used to keep livestock out of streams and prevent streambank erosion. Almost 2,600 acres of stream buffers were also in place, allowing areas next to streams to remain in a natural state with grasses, trees and wetlands. More than 240 containment structures have 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.

To reduce the impacts of continued development, Program Open Space projects have conserved more than 230 acres of land for outdoor recreation opportunities. Rural Legacy Program projects have protected more than 6,170 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 3,000 acres. Maryland Agricultural Land Preservation Program projects have preserved more than 800 acres of agricultural land from development.

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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 Patuxent River 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 long-term non-tidal and tidal water quality monitoring programs 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 Patuxent River is the largest river completely in Maryland. This area includes portions of St. Mary's, Calvert, Charles, Anne Arundel, Prince George's, Howard, and Montgomery Counties (Figure 3). Its basin drains approximately 900 square miles of land within 8 sub-watersheds. The Patuxent River Basin lies both in the Piedmont and Coastal Plain physiographic provinces. Major towns include Columbia, Bowie and Laurel.

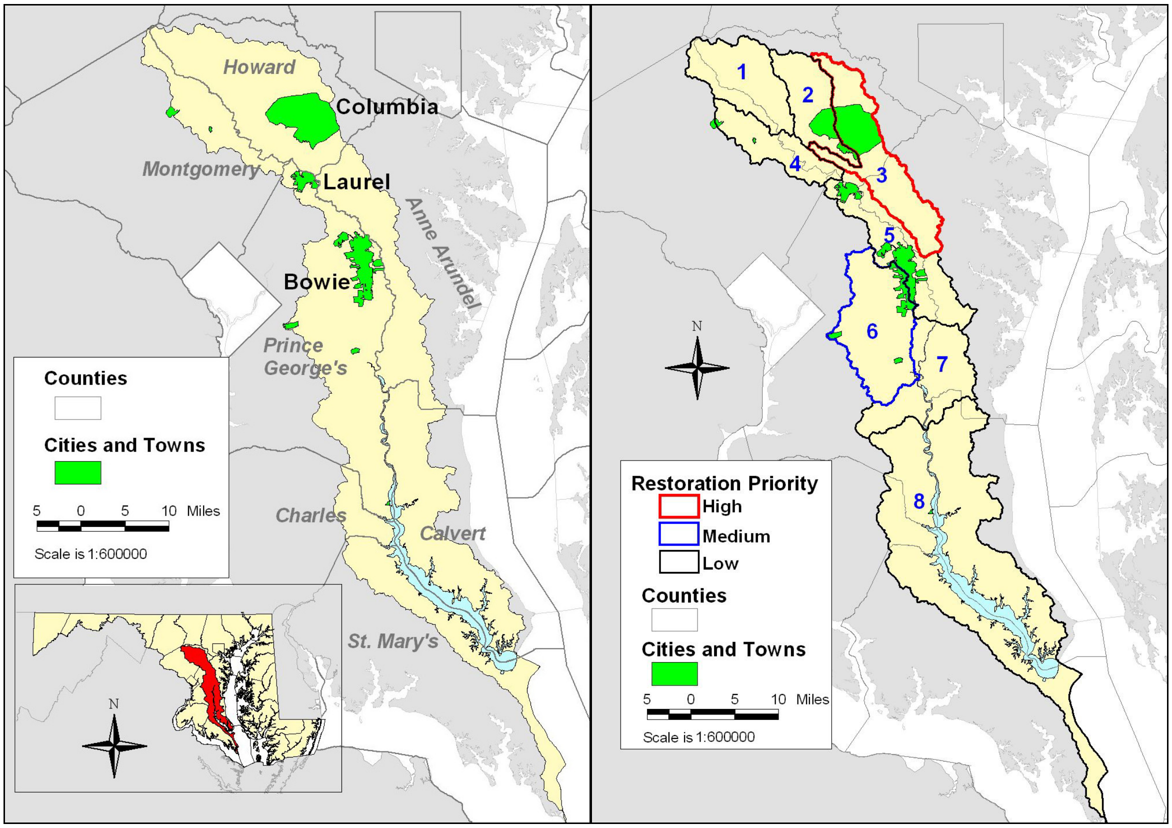

Figure 3. Patuxent River watershed and sub-watersheds.
Counties and cities and towns are shown. Trust Fund Restoration Priority designation (high, medium, low and sub-watersheds (8-digit) are shown in the right-hand panel. Sub-watersheds are: 1-Brighton Dam, 2- Middle Patuxent River, 3- Little Patuxent River, 4- Rocky Gorge Dam, 5- Patuxent River Upper, 6- Western Branch, 7- Patuxent River middle, and 8-Patuxent River lower.

In 2010 there were approximately 714,000 people living in the watershed.[1] Population density was mostly low (between 100-1,000 people per square mile), though moderate densities (1,000-10,000 people per square mile) were common in the areas surrounding cities and towns (Figure 4). There were also a few pockets of lower population density (10-100 people per square mile) and very high density (10,000-100,000 people per square mile).

In 2010 land use in the Patuxent River watershed as a whole was roughly 40% urban and 40% forest (Figure 5, Appendix 1).[2] Approximately 20% of the watershed was used for agriculture. Agricultural land use was highest in the uppermost portions of the watershed, in Brighton Dam and Middle Patuxent River sub-watersheds. Little Patuxent River, Western Branch and Rocky Gorge Dam sub-watersheds in the central watershed were 45% or more urban. The lower portion of the basin was largely forested (Patuxent River Lower, Patuxent River Middle).

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

[2] Maryland Department of Planning data for 2010 available at http://www.planning.maryland.gov/OurWork/landUse.shtml

Between 2000 and 2010, urban land use increased by 11%. Greatest increases in urban land use occurred in the Brighton Dam, Middle Patuxent River and Rocky Gorge Dam sub-watersheds. Impervious surfaces cover 9% of the basin overall. Impervious surfaces covered 19% of the Little Patuxent River sub-watershed and 14% of the Western Branch sub-watershed.

The Little Patuxent River sub-watershed is a high priority Trust Fund Restoration watershed and Western Branch sub-watershed is a medium priority watershed.[3] Stream health in all of the sub-watersheds is categorized as fair.[4] A Watershed Restoration Action Strategy (WRAS) was developed for the Little Patuxent River in 2001, for the Upper Patuxent River in 2002, and for Western Branch and the Lower Patuxent River in 2003.[5]

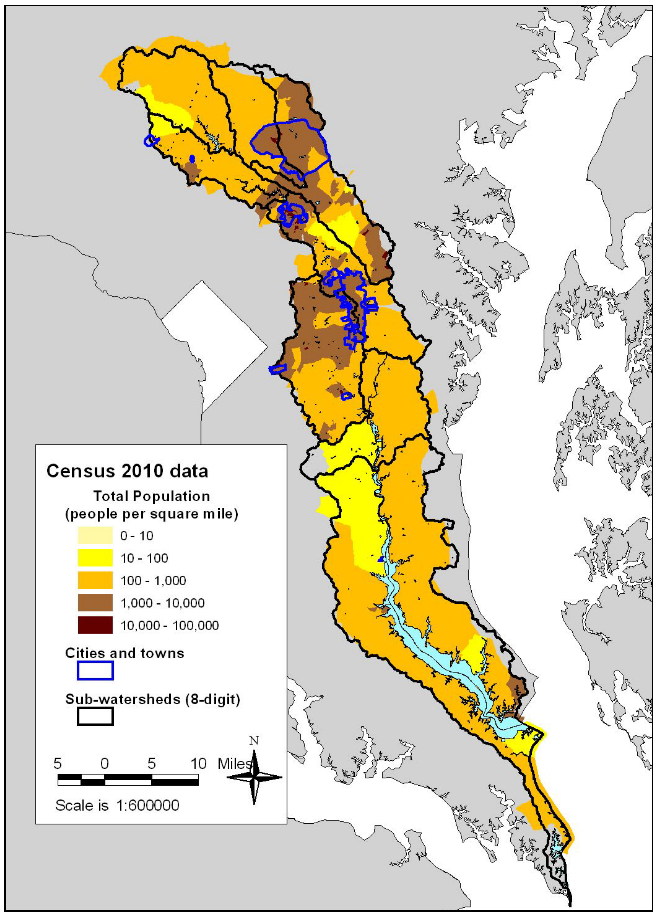

Figure 4. Patuxent River watershed 2010 Census data for total population by block group. Total population per square mile is shown using a log scale. Differences between the watershed boundaries and the Census bureau block group boundaries result in non-exact matching of the population data to the given watershed.

[3] Information on Maryland's Trust Fund is available at http://www.dnr.maryland.gov/ccp/funding/pdfs/TrustFundPriorities.pdf

[4] Maryland Department of Natural Resources data available at www.streamhealth.maryland.gov/stream_health.asp

[5] Detailed reports are available at http://dnr.maryland.gov/watersheds/surf/proj/wras.html.

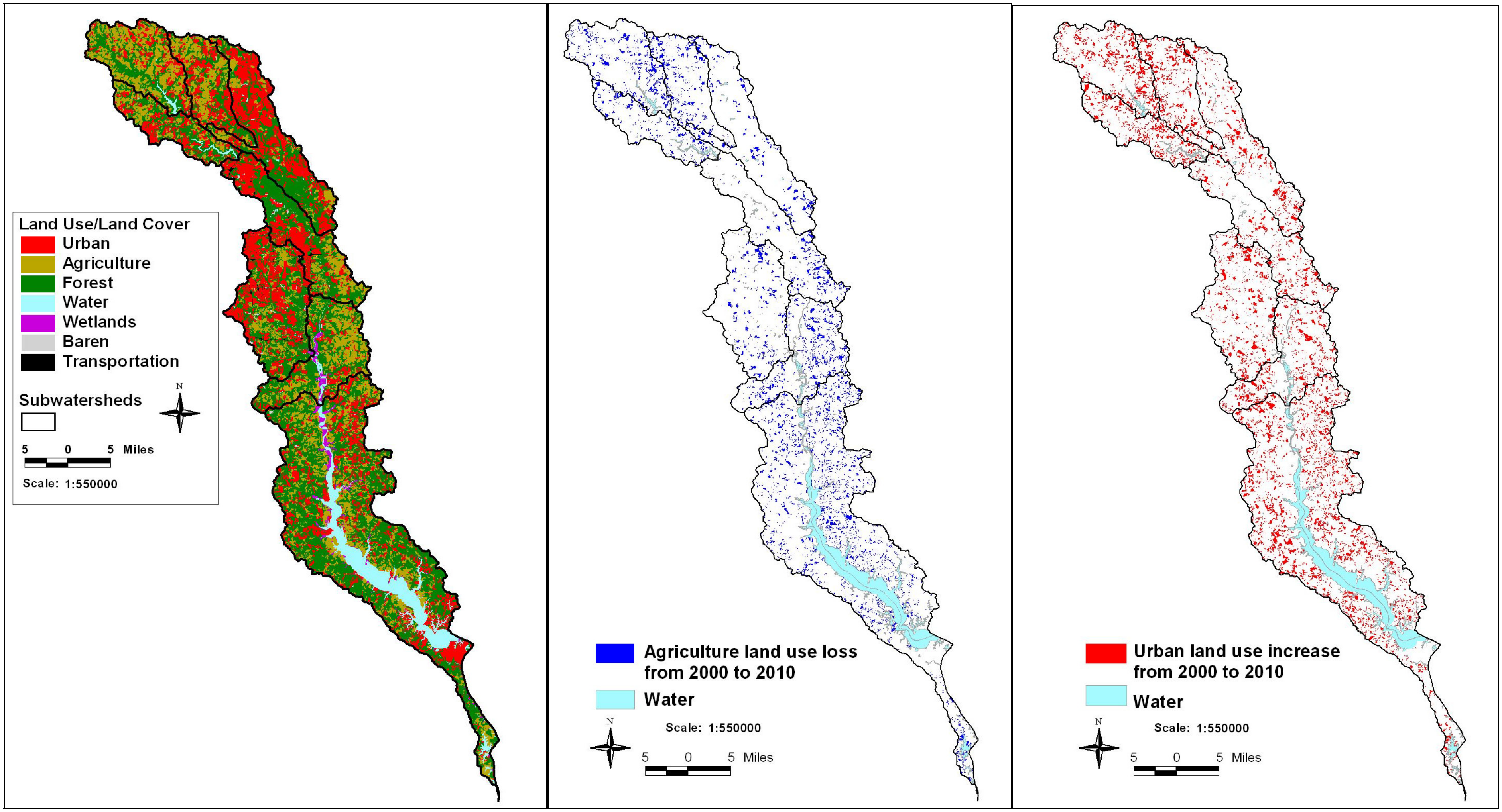

Figure 5. Land use/land cover data for 2010.
See Appendix 1 for detailed land use/land cover information. Left panel shows all land use categories for 2010. Middle panel shows change in agricultural land use in blue. Right panel shows change in urban land use in red.

Maryland has a number of programs in place to reduce the impacts of continued development and increasing amounts of impervious surfaces in the Patuxent River watershed. Program Open Space projects have conserved more than 230 acres of land for outdoor recreation opportunities.[6] Rural Legacy Program projects have protected more than 6,170 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 3,000 acres. Maryland Agricultural Land Preservation Program projects have preserved more than 800 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.[7] 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.[8] The Final Target Loads for the Patuxent River are 3.10 million pounds per year of nitrogen, 0.24 million pounds per year of phosphorus and 123 million pounds per year of sediments. The information below is loadings in 2009.

Upper River

The Upper River segment includes watershed area that drains to the tidal fresh region of the Patuxent River. This segment includes all of the sub-watersheds with the exception of the Patuxent River Lower sub-watershed and a portion of the Western Branch sub-watershed (Figure 6). The Upper River receives 1.75 million lbs/yr of nitrogen, 0.15 million lbs/yr of phosphorus, and 67 million lbs/yr of sediment from the surrounding watershed (Appendix 2). Point sources were the largest contributor of nitrogen (34%) and phosphorus (37%) to the upper river (Figure 6). Agriculture was the largest contributor of sediments (42%). Urban runoff was also an important source of nitrogen (20%), phosphorus (31%) and sediment loadings (35%).

Western Branch

The Western Branch segment receives 0.24 million lbs/yr of nitrogen, 0.03 million lbs/yr of phosphorus, and 23 million lbs/yr of sediment from the surrounding watershed. Urban runoff was the largest source of nitrogen (41%), phosphorus (72%) and sediment (49%) loadings. Agriculture was also an important source of sediment loadings (39%), and forest was an important source of nitrogen loadings (26%).

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[6] Information on land conservation programs in Maryland is available at http://www.dnr.state.md.us/land/landconservation.asp
[7] 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
[8] Progress toward meeting the 2011-2013 milestones is available on BayStat at www.baystat.maryland.gov/milestone_information.html

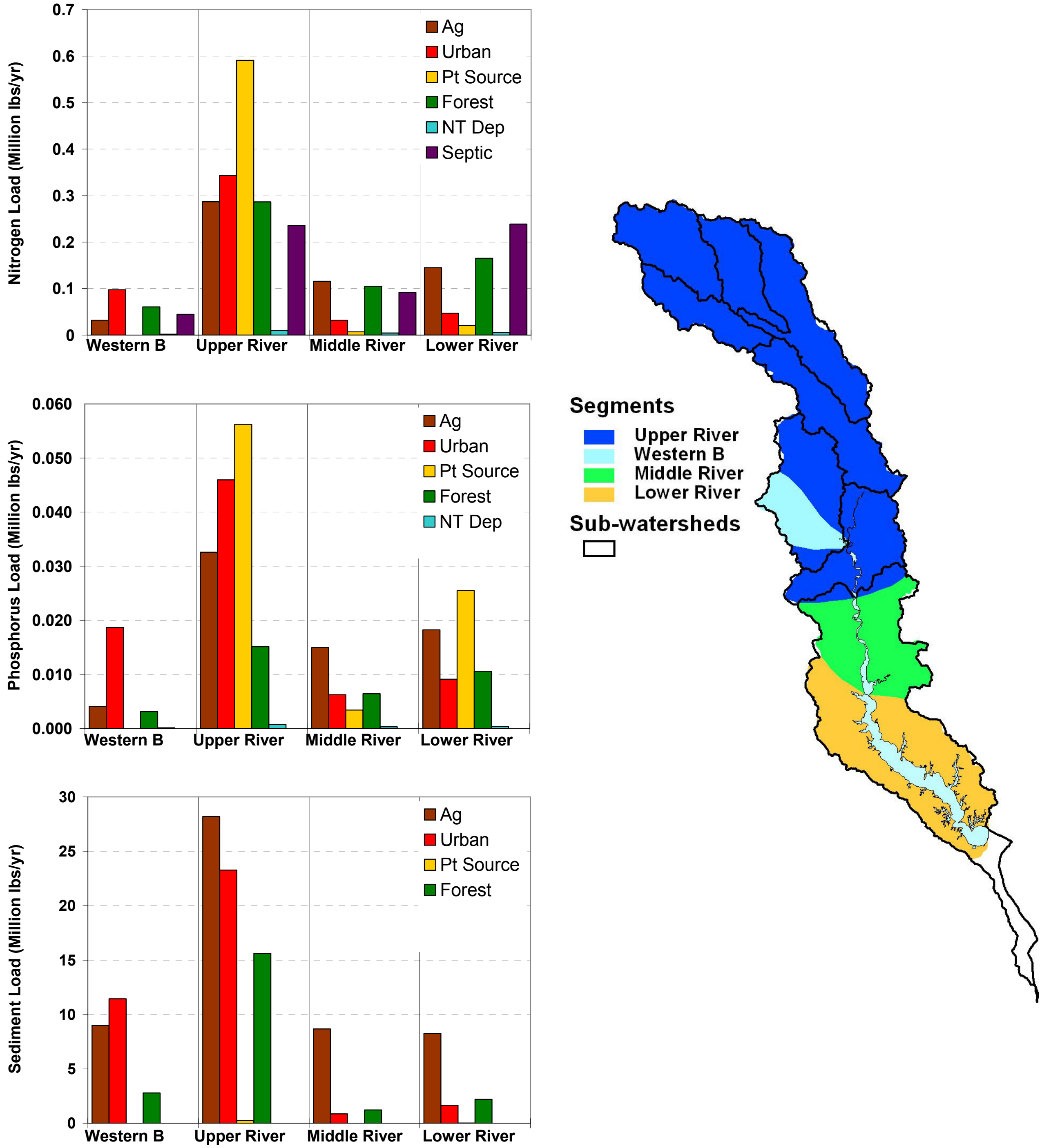

Figure 6. Nitrogen, phosphorus and sediment loadings per year.
Delivered loadings by category in million lbs/yr. Septic is not a source of phosphorus or sediment loadings and water deposition (NT Deposition) is not a source of sediment loadings. See Appendix 2 for additional detail. Map insert shows how Chesapeake Bay Program Loadings segments are designated versus the 8-digit sub-watersheds.

Middle River

The Middle River segment includes watershed area that drains to the oligohaline region of the Patuxent River. This segment includes the upper third of the Patuxent River lower sub-watershed. The Middle River receives 0.36 million lbs/yr of nitrogen, 0.03 million lbs/yr of phosphorus, and 11 million lbs/yr of sediment from the surrounding watershed. Agriculture was the largest source of nitrogen (33%), phosphorus (48%) and sediment (80%) loadings. Septic and forest sources were roughly equal and as important as agriculture to nitrogen loadings (30% each), and forest and urban were important sources of phosphorus loadings (20% each).

Lower River

The Lower River segment includes watershed area that drains to the mesohaline region of the Patuxent River. This segment includes lower two-thirds of the Patuxent River sub-watershed. The Lower River receives 0.62 million lbs/yr of nitrogen, 0.06 million lbs/yr of phosphorus, and 12 million lbs/yr of sediment from the surrounding watershed. Septic was the largest source of nitrogen (38%) and forest (27%) and agriculture (23%) were also important. Point sources and agriculture were the major sources of phosphorus (40% and 29%, respectively). Sediment loadings were from agriculture (48%) and urban runoff (33%).

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).[9] The program is working to complete ENR upgrades to 67 major WWTPs, including 7 facilities in the Patuxent River watershed.[10]

Point sources were the largest contributor of nitrogen and phosphorus to the Upper River segment. All seven major WWTPs discharge within this area; no major WWTPs discharge in the other segments of the Patuxent (Figure 7).

Western Branch WWTP is the largest facility with a capacity of 30 million gallons per day (MGD). Western Branch WWTP contributes 29% of the nitrogen and 48% of the phosphorus load from WWTPs to the Patuxent River. Biological nutrient removal (BNR) was implemented in 1995. Construction of ENR upgrades began in 2011 and is scheduled to be complete by mid 2014. Even before full BNR implementation, nitrogen loadings had dropped to below the loading cap. Loads stayed at about the same level until 2004, and from 2005-2011 were only one-third the initial levels (Figure 8). Phosphorus levels decreased in 2010-2011 to close to the loading cap, and have dropped by roughly 20% from the previous levels.[11]

[9] 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.
[10] Major wastewater treatment plants are those with greater than 0.5 million gallons per day (MGD) design flow.
[11] 2012 loads are not yet available.

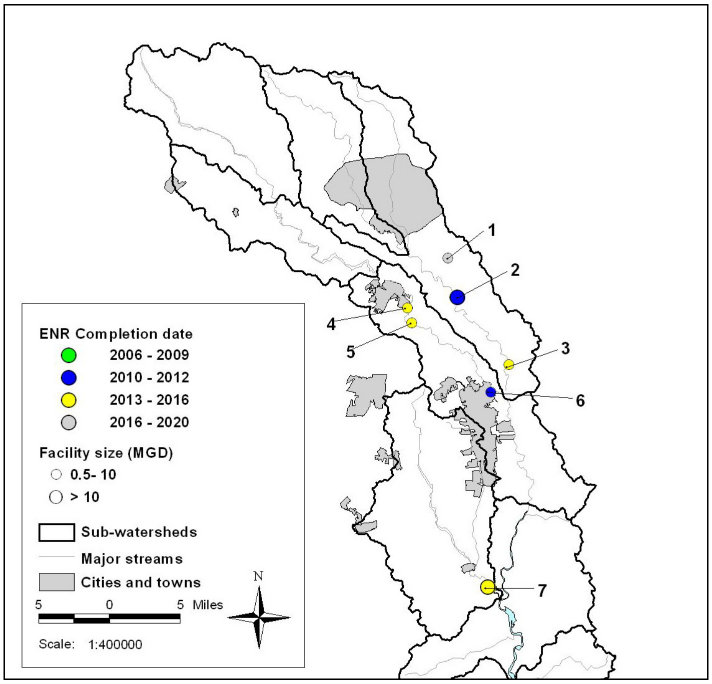

Figure 7. Major wastewater treatment plants discharging to the Patuxent River.
Design flow (in million gallons per day, MGD) shown along with completion year of upgrades to ENR. Cities and towns, larger streams, and sub-watersheds also shown. Facilities are 1-Dorsey Run, 2- Little Patuxent, 3-Patuxent, 4-Maryland City, 5-Parkway, 6-Bowie, 7-Western Branch.

The Little Patuxent WWTP has a 25 MGD capacity. The Little Patuxent River WWTP contributes 42% of the nitrogen and 29% of the phosphorus load from WWTPs. BNR was implemented in 1999. Construction of ENR upgrades began in 2009 and was completed by the end of 2012. As at Western Branch WWTP, nitrogen loadings at Little Patuxent WWTP had dropped even before BNR implementation, and from 2005-2011 were below the loading cap. Nitrogen levels in 2010-2011 were less than half the highest levels pre-BNR. Phosphorus levels were more variable but were below the loading cap in almost all years.

The Parkway WWTP (7.5 MGD) contributes 12% of the nitrogen and 10% of the phosphorus load. BNR was implemented in 1992. ENR upgrades began in 2011 and be complete by mid 2013. Nitrogen and phosphorus loadings at the Parkway WWTP were below loading caps in most years after implementation of BNR.

The remaining major WWTPs contribute less than 5% of the nitrogen and phosphorus loads.

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.[12] 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.[13] 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.[14] In 2011 there were more than 13,560 acres of cover crops planted in between growing seasons to absorb excess nutrients and prevent sediment erosion. Fencing on more than 8,000 acres of farmland was used to keep livestock out of streams and prevent streambank erosion. More than 240 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. Almost 2,600 acres of stream buffers were also in place, allowing areas next to streams to remain in a natural state with grasses, trees and wetlands.

Urban runoff is important to nitrogen, phosphorus and sediment loadings in the upper portion of the basin, and septic sources are also important to nitrogen loads throughout the basin. Stormwater retrofits have reduced nitrogen loadings from urban and suburban sources and prevented more than 18,200 pounds of nitrogen from entering streams. Almost 270 septic upgrades have also been completed.

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

[13] For more information see http://mda.maryland.gov/resource_conservation/Documents/scwqplan.pdf

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

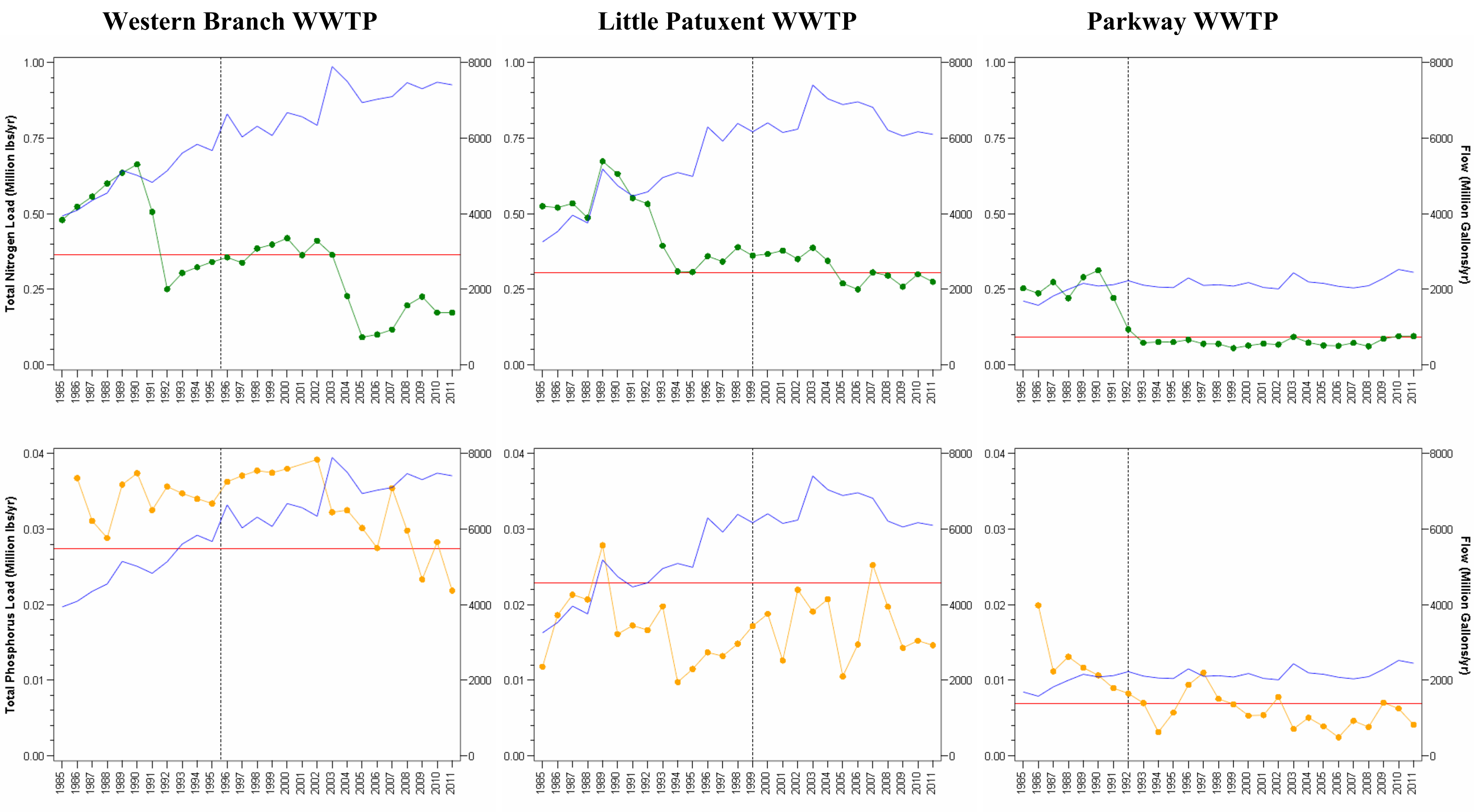

Figure 8. Annual total nitrogen and total phosphorus loadings and effluent flow from WWTPs to the Patuxent River. Top graphs are total nitrogen load (green) and bottom graphs are total phosphorus load (orange) plotted on the left axis. Blue line on each graph shows total annual effluent flow (right axis). Red horizontal line indicates the loading cap for the facility following implementation of ENR. The dotted vertical line indicates when BNR or ENR was implemented. Note that the 1985 Total Phosphorus Load for Western Branch WWTP is off the scale at 0.0969 million lbs/yr.

Water and Habitat Quality

Non-tidal water quality monitoring is done year-round at three stations to characterize conditions in free-flowing freshwater (Figure 9, Appendix 3). Samples are collected once a month. For these sites, only surface measurements are collected. Stream gauges are installed at all three stations and collect flow data. The USGS uses the flow data and the nutrient data to calculate nitrogen, phosphorus and sediment loadings to the streams.[15] Flow data has been collected since 1985.

Tidal water quality monitoring is done year-round at eleven stations that have been monitored since 1985 (Figure 9, Appendix 3). Samples are collected once a month.

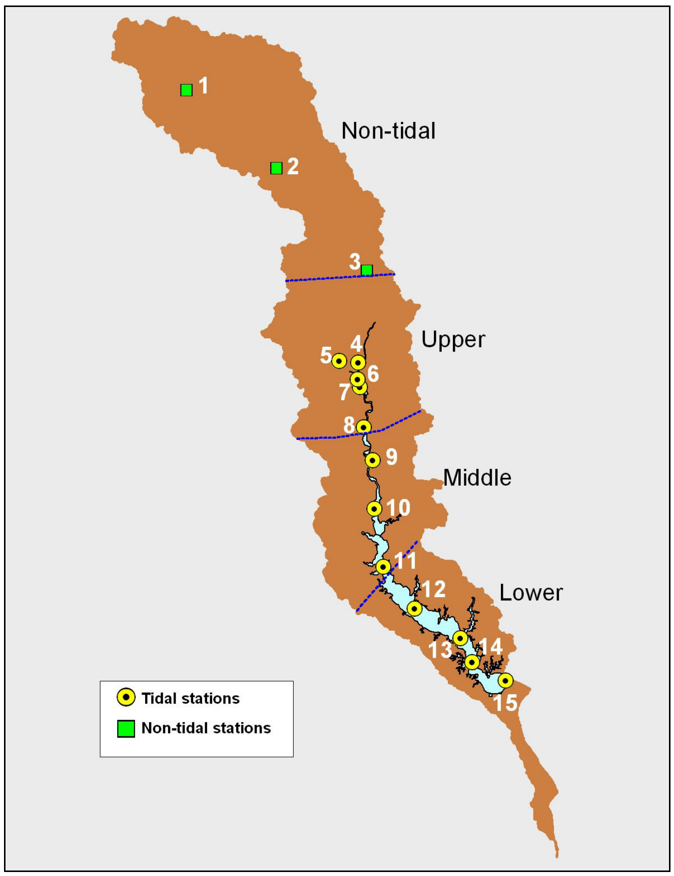

Figure 9. Long-term non-tidal and tidal water quality monitoring stations. Regions of the river (non-tidal, upper, middle, lower) are indicated. Nontidal stations are 1: Unity (PXT0972), 2: Rocky Gorge (PXT0809), 3: Bowie (TF1.0). Upper river stations are 5: Upstream Western Branch (TF1.2), 6: Western Branch mouth (WXT0001), 4: Waysons Corner (TF1.3), 7: Jackson Landing (TF1.4), 8: Nottingham (TF1.5). Middle river stations are 9: Lower Marlboro (TF1.6), 10: Jack's Creek (TF1.7), 11: Long Point (RET1.1). Lower river stations are 12: Jack Bay (LE1.1), 13: Petersons Pt. (LE1.2), 14: Pt. Patience (LE1.3), 15: Drum Pt. (LE1.4). See Appendix 3 for detailed station information.

[15] Trends are determined for nitrogen, phosphorus and sediment loads at two of these stations (PXT0972 and TF1.0). For USGS methods see http://md.water.usgs.gov/publications/sir-2006-5178/index.html

Assessment methods are described in Appendix 4. For non-tidal and tidal stations, the following parameters were evaluated: total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS). For tidal stations, additional parameters were evaluated: 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), summer bottom dissolved oxygen (BDO), salinity and water temperature.

Selected graphical results are included with the text. Non-tidal and tidal water quality trends results discussed in the text refer to the 1999-2012 trends. Significant trends for 1985-2012 (tidal) or 1986-2012 (non-tidal) are noted in the footnotes. Seasons for 1999-2012 tidal trends are: spring (March-May), summer (July-September)[16] and SAV growing season (Apr-October). Significant trends for 1985-2012 (tidal) or 1986-2012 (non-tidal) are noted in the footnotes. Figure and Appendix references are given only the first time referenced. Summary results are presented in Table 1 and Table 2 in the 'Overall Assessment' section. Detailed tabular results are included in Appendices 6, 7 and 8.

Non-tidal streams

Phosphorus loadings at the station near Unity decreased from WY1985-2011, but sediment loadings increased from WY2002-2011 (Figure 10).[17] Nitrogen, phosphorus and sediment loadings at the river input station near Bowie decreased from WY1985-2011, and nitrogen loadings also decreased from WY2002-2011 (Figure 11).

TN levels in the water increased at the station near Unity, but decreased at the station at Bowie (Figure 12).[18] TP levels decreased at both Unity and Bowie, but there were no trends at the station at Rocky Gorge.[19] There were no trends in sediment levels in the water at the non-tidal stations.

[16] For summer bottom dissolved oxygen analysis, the months used are June-September.
[17] Non-tidal loadings trends are from USGS (http://cbrim.er.usgs.gov/loads_query.html) and are analyzed by water year (WY), October-September.
[18] From 1986-2012 TN levels in the water increased at Unity but may have decreased at Rocky Gorge. A non-linear trend in TN levels at Bowie indicates TN decreased at the Bowie station until the mid 2000s.
[19] From 1986-2012 TP levels decreased at Unity and Rocky Gorge. A non-linear trend in TP levels at Bowie indicates TP decreased at the Bowie station until the mid 2000s.

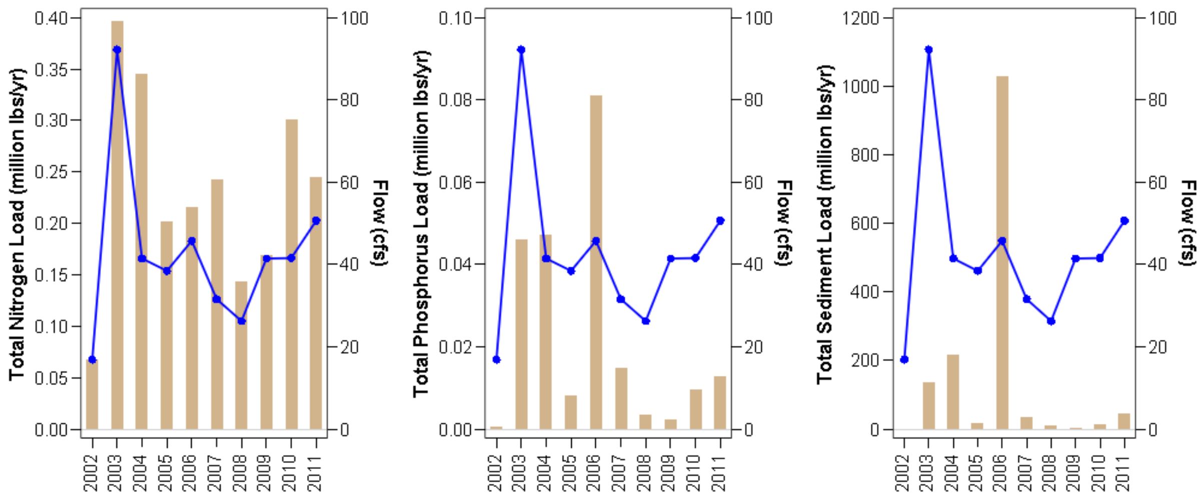

Figure 10. Annual nitrogen, phosphorus and sediment loads for the non-tidal station near Unity. Nitrogen loads are shown in the left-hand graph. Phosphorus loads are shown in the middle graph. Sediment loads are shown in the right-hand graph. Annual flow is shown in blue on each of the graphs.

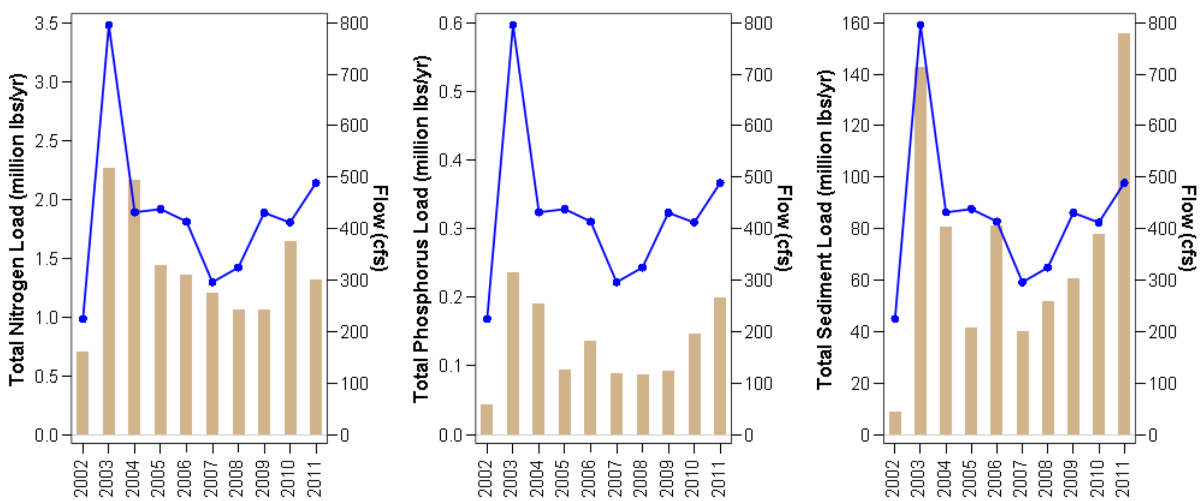

Figure 11. Annual nitrogen, phosphorus and sediment loads for the non-tidal station near Bowie. Nitrogen loads are shown in the left-hand graph. Phosphorus loads are shown in the middle graph. Sediment loads are shown in the right-hand graph. Annual flow is shown in blue on each of the graphs.

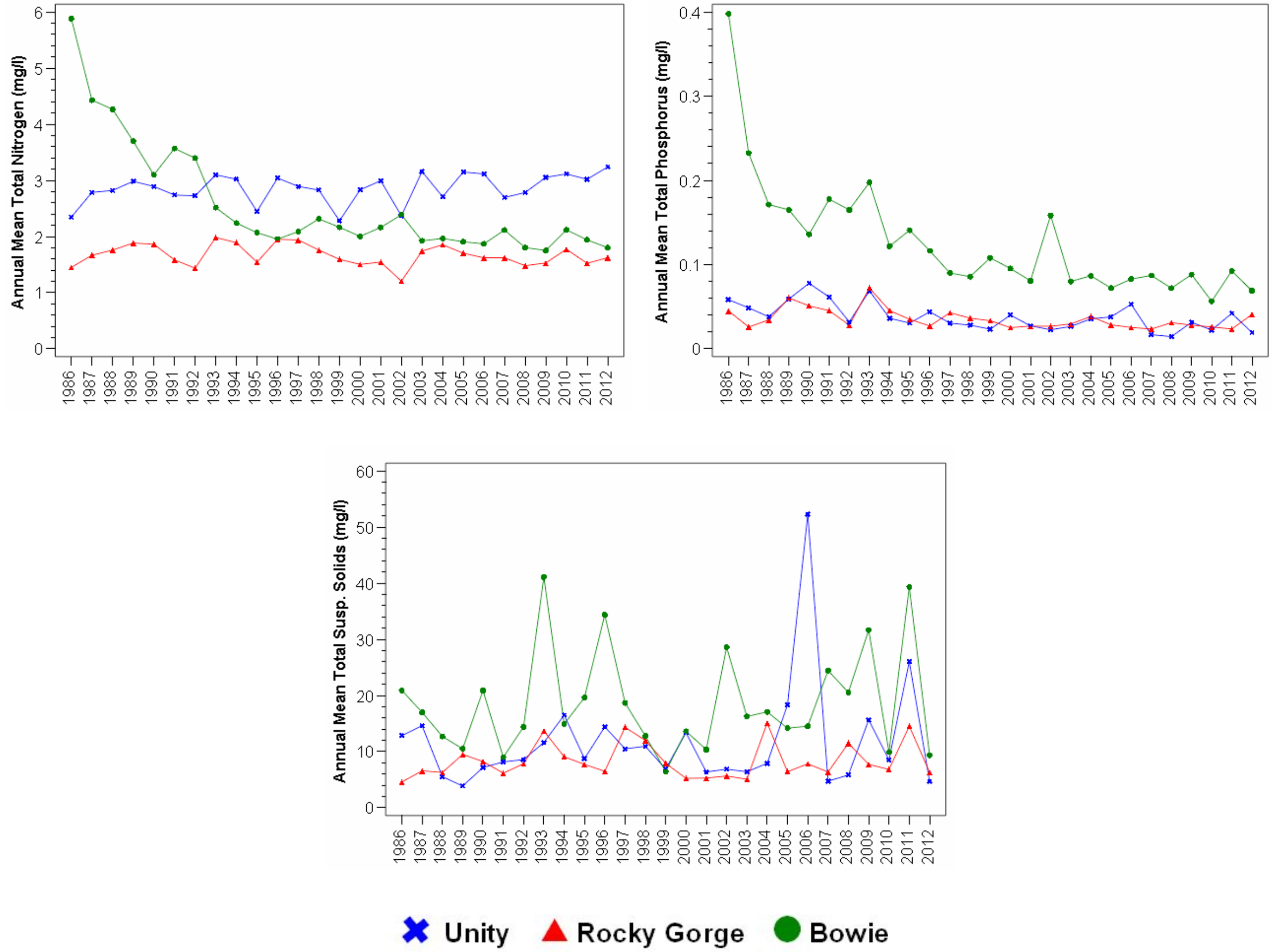

Figure 12. Annual nitrogen, phosphorus and total suspended solids levels for non-tidal stations in the Patuxent River watershed.
TN levels are shown in the upper left-hand graph; TP levels shown in the upper right-hand graph. TSS levels are shown in the bottom graph.

Tidal river

Upper River

The upper river extends downstream to just past the station at Nottingham. This region includes three stations in tidal fresh zone of the mainstem river (Appendix 3). Two stations are also monitored on Western Branch.

Nitrogen levels were relatively good in the upper river with the exception of relatively poor TN and DIN levels at the upstream station near Waysons Corner. TN and DIN levels improved annually at all stations.[20] TN levels improved or may have improved at all stations in the summer and the SAV growing season. TN levels also may have improved in spring at lower Western Branch and Jackson Landing. DIN levels improved in all seasons in Western Branch and in the summer and SAV growing season at Waysons Corner. DIN levels also may have improved in the SAV growing season at Nottingham. TN levels were highest upstream near Waysons Corner and lowest at the upstream Western Branch station (Figure 13). DIN levels were lowest in the summer at the downstream station near Nottingham.

TP levels were relatively good at the upstream Western Branch and the Waysons Corner stations, but relatively poor at the other stations. PO_4 levels were relatively good at all stations. TP levels improved at Waysons Corner and Jackson Landing in all seasons.[21] TP levels improved annually and may have improved in the summer and the SAV growing season at Nottingham. TP improved annually and in the SAV growing season and may have improved in the spring at the mouth of Western Branch. PO_4 levels improved at the Waysons Corner station in all seasons, annually and spring at the other two main river stations, improved in summer at Jackson Landing, and may have improved in summer at Nottingham. PO_4 levels improved at the mouth of Western Branch annually and may have improved in the spring at both stations in Western Branch. PO_4 levels failed to meet the SAV habitat requirement at Waysons Corner, mouth of Western Branch and Nottingham, but in 2012 only Waysons Corner failed to meet the habitat requirement. TP levels were highest at the Nottingham, Jackson Landing and mouth of Western Branch stations. PO_4 levels were much higher at the mouth of the Western Branch station in all years prior to 2010, but were similar to the other stations in 2011-2012.

TSS levels were relatively good at both Western Branch stations and at Waysons Corner. TSS levels were relatively poor at the Jackson Landing and Nottingham stations. TSS levels improved annually, in the summer and in the SAV growing season at the Waysons Corner and mouth of Western Branch stations.[22] TSS levels at Jackson Landing improved annually and in the SAV growing season and may have improved in the summer. TSS levels also may have improved annually at Nottingham. TSS levels were highest at the Nottingham station. TSS levels met the SAV habitat requirement at the two Western Branch stations and the Waysons Corner station.

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[20] TN levels improved from 1985-2012 at all stations, but there were also significant non-linear trends indicating improvements did not continue after the mid 2000s. DIN levels improved from 1991-2012 but non-linear trends at the mouth of Western Branch indicate levels began to increase in 2009.
[21] TP levels improved from 1991-2012 at all stations. PO_4 levels at all stations for 1991-2012 improved but non-linear trends at three of the stations indicate that levels have increased in the last few years.
[22] TSS levels may have improved at the lower Western Branch station from 1991-2012.

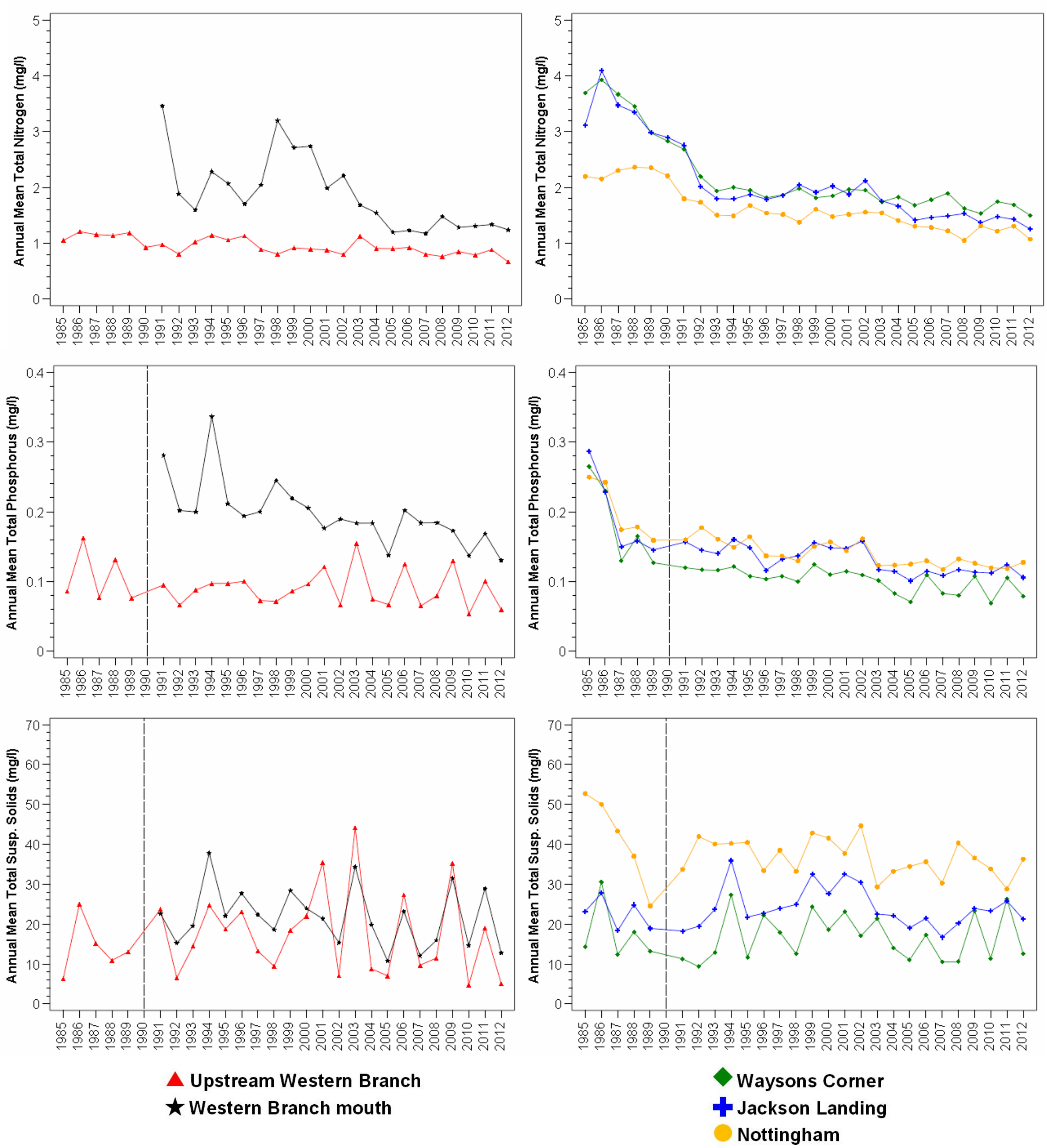


Figure 13. Annual means for total nitrogen, total phosphorus and total suspended solids in the upper Patuxent River.
Dotted line (1990) indicates when the lab change occurred that may have impacted TP and TSS. Caution should be used in making comparisons for TP and TSS from before to after the lab change. Scales for the y-axes are the same as in Figures 19 and 23.

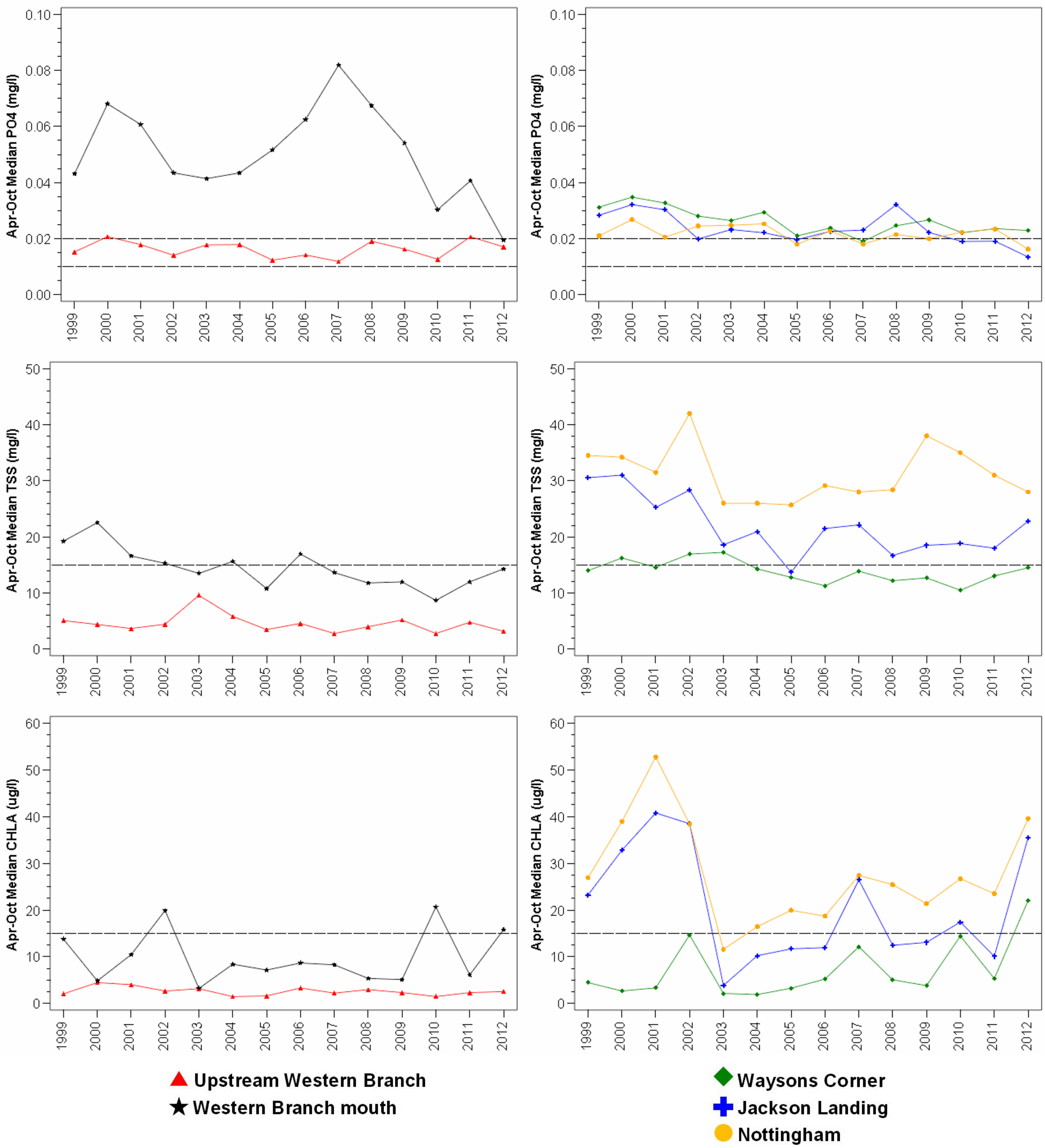


Figure 14. PO_4, TSS and CHLA levels in the upper Patuxent River compared to SAV habitat requirements. SAV growing season (April-October) median values for PO_4, TSS and CHLA. Threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of PO_4, TSS and CHLA need to be lower than the threshold. All stations are in the tidal fresh zone.

Algal abundance was relatively poor at Jackson Landing and Nottingham but relatively good in the rest of the upper river. CHLA levels may have improved annually at Nottingham and may have improved annually, in the summer and in the SAV growing seasons at the upper Western Branch station. However, CHLA levels may have degraded in the SAV growing season at Waysons Corner. CHLA levels met the habitat requirement at the upstream Western Branch and Waysons Corner stations, but in 2012 only the upstream Western Branch station met the habitat requirement.

Water clarity was relatively poor at the Waysons Corner, Jackson Landing and Nottingham stations but relatively good at the mouth of Western Branch (Figure 15).[23] Secchi depth degraded at the Waysons Corner station in the spring. Secchi depth did not meet the habitat requirements at any of the stations. There were no trends in salinity, but water temperatures increased in the summer and SAV growing season at all stations and increased or may have increased annually at all stations.[24] Water temperatures in the SAV growing season increased at the Waysons Corner and Nottingham stations, and may have increased at the mouth of Western Branch.

DIN levels were too high in the upper river for nitrogen limitation of algal growth to occur, except in the summer at Nottingham (Figures 16-17). PO_4 levels were too high to cause phosphorus limitation of algal growth at all stations in all seasons, with the exception of occurring in the winter and fall in some years at the upstream Western Branch station (Figure 16).

Summer bottom dissolved oxygen levels at the Nottingham station were almost always above 5 mg/l (Figure 18).[25]

[23] Water depth is too shallow to measure water clarity by Secchi disc at the upper Western Branch station. At the Nottingham station, Secchi depth increased until the mid 1990s and has since decreased.
[24] Water temperature increased from 1985-2012 at Nottingham and non-linear trends at the upper Western Branch, Waysons Corner and Jackson Landing stations indicate temperatures began increasing in the late 1990s-early 2000s.
[25] Except for the Nottingham station, water depths are too shallow to measure a distinct bottom dissolved oxygen level. Summer bottom DO degraded at the Nottingham station from 1985-2012.

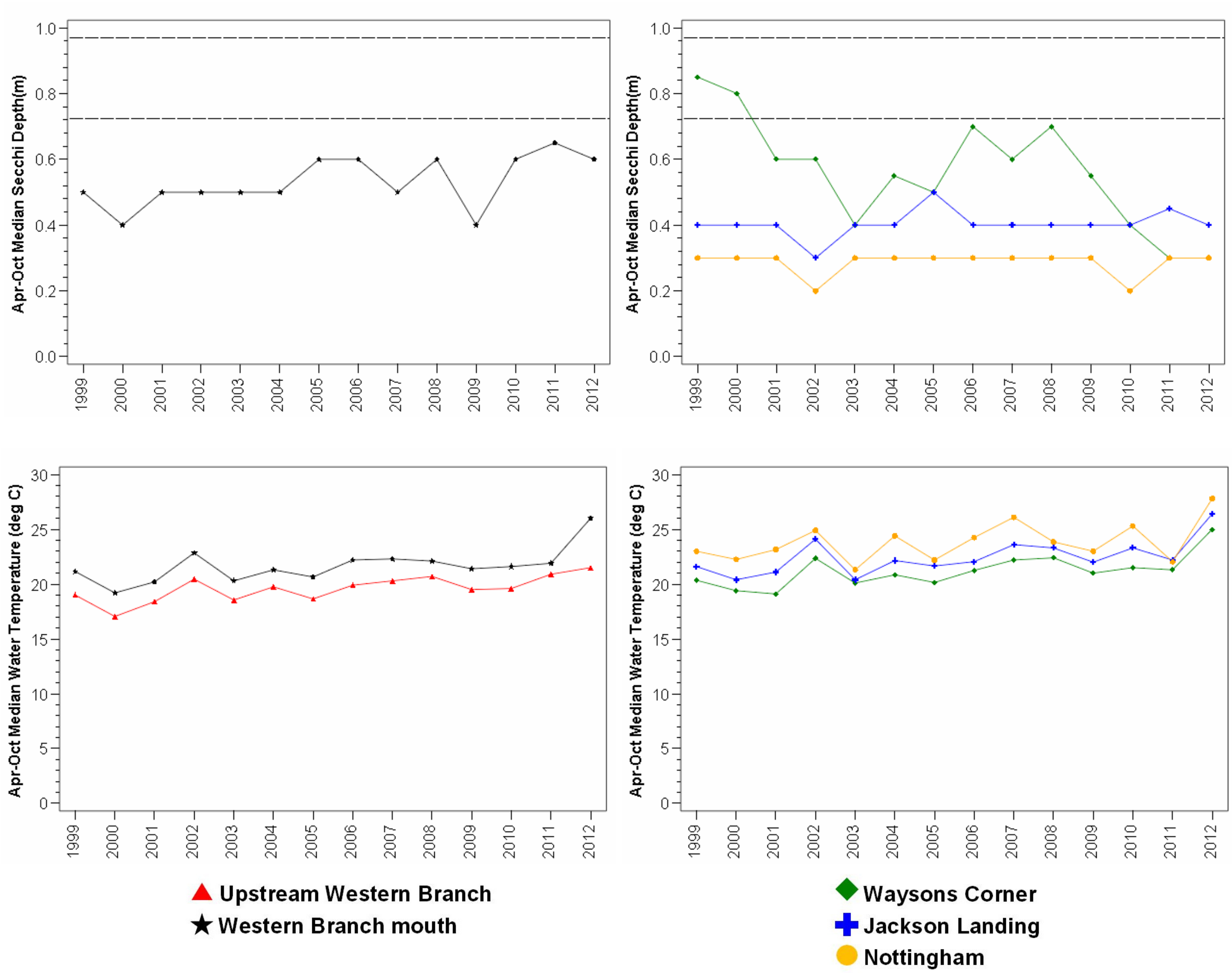
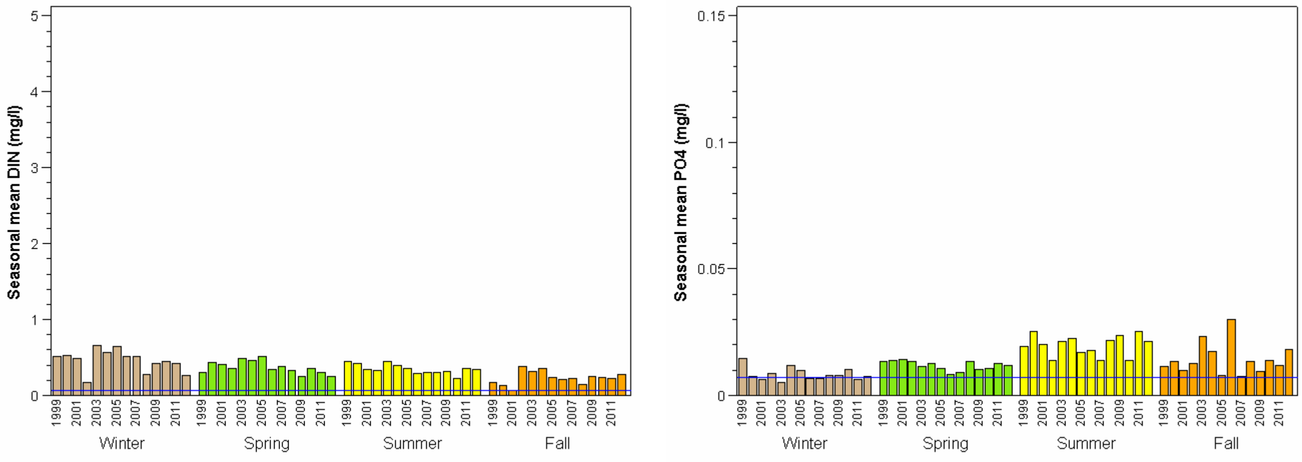


Figure 15. SAV growing season median Secchi depth and water temperature in the upper Patuxent River. Threshold value for Secchi depth is shown with dashed lines (Appendix 5). To meet or pass the habitat requirement, Secchi depth needs to be above the threshold. All stations are in the tidal fresh zone. The station at the upstream Western Branch is too shallow for Secchi depth measurements.

Upstream Western Branch



Western Branch mouth

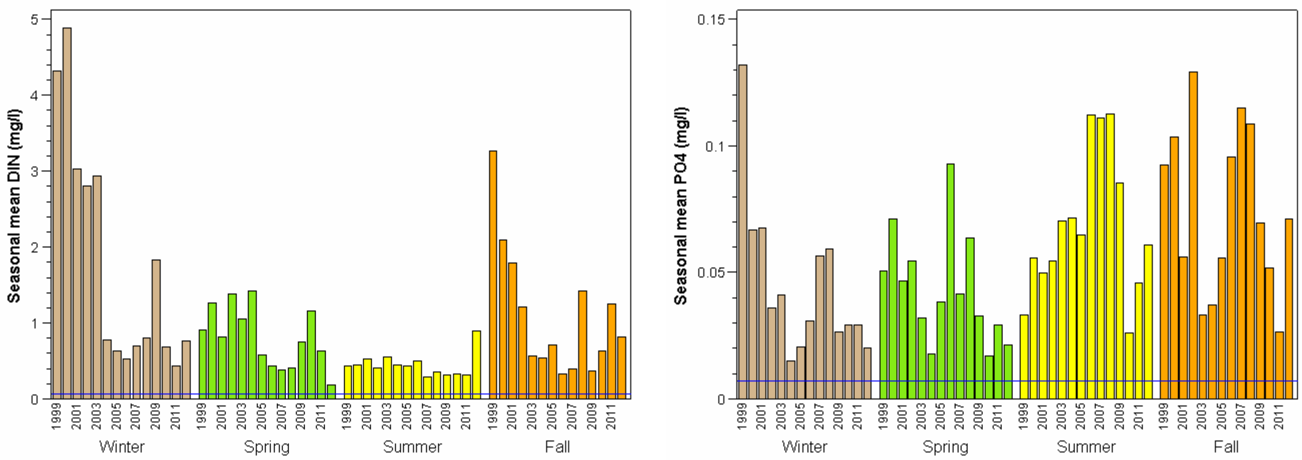
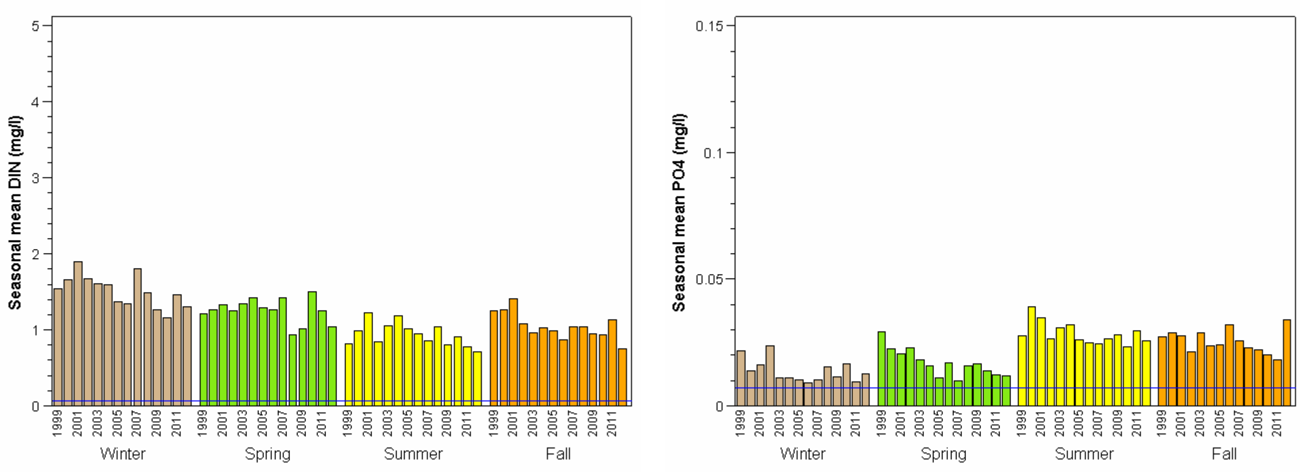
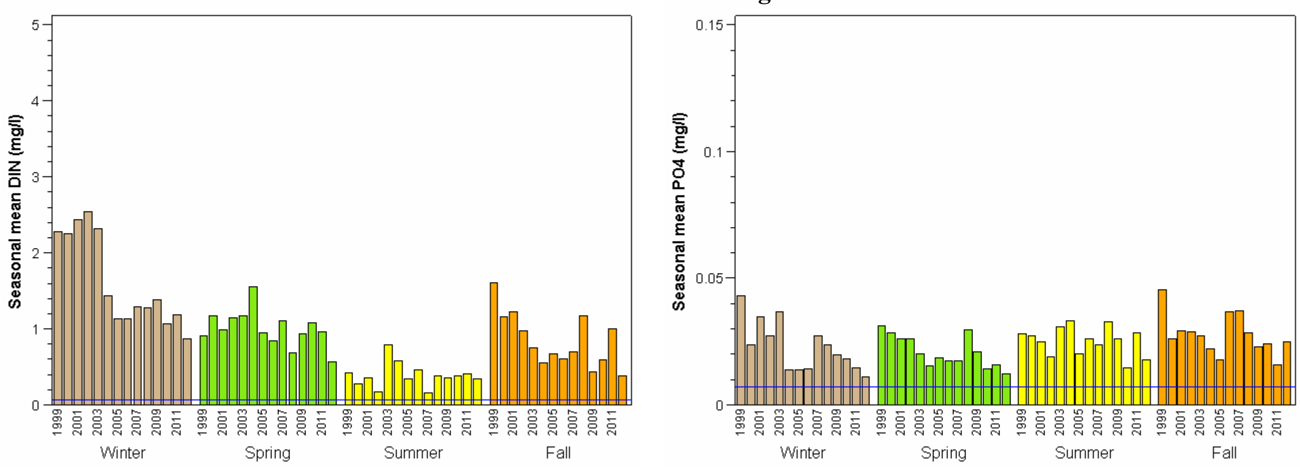


Figure 16. Nutrient limitation by season in the Western Branch.
Seasonal mean DIN levels are shown in the left-hand graphs. Seasonal mean PO_4 levels are shown in the right-hand graphs. Data is annual values for 1999-2012. The blue line indicates the threshold for either nitrogen limitation (0.07 mg/l DIN, left-hand) or phosphorus limitation (0.007 mg/l PO_4, right hand). 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.

Waysons Corner



Jackson Landing



Nottingham

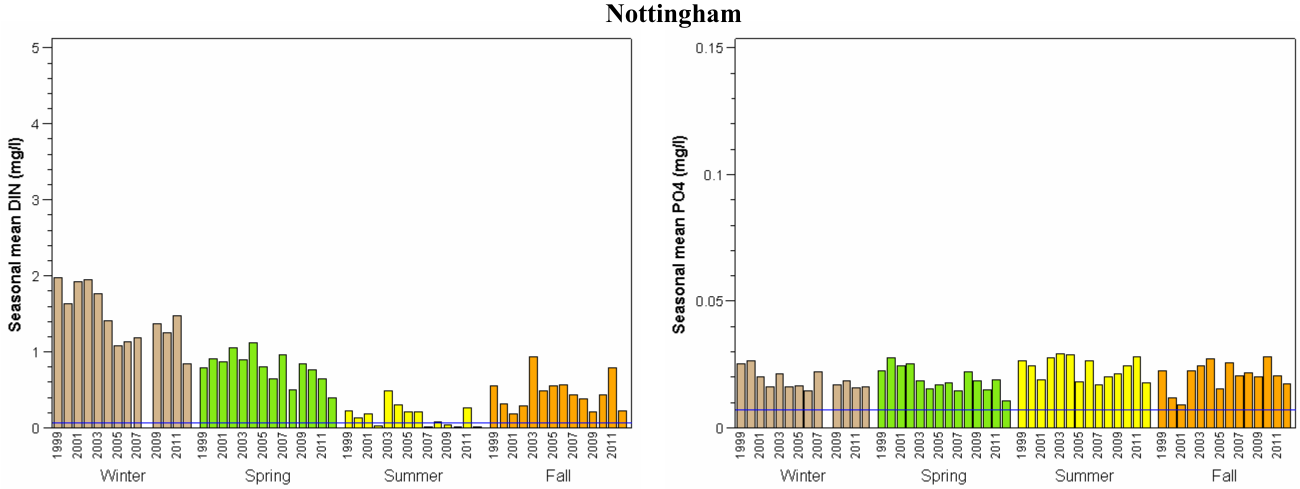


Figure 17. Nutrient limitation by season in the upper Patuxent River.
Seasonal mean DIN levels are shown in the left-hand graphs. Seasonal mean PO_4 levels are shown in the right-hand graphs. Data is annual values for 1999-2012. The blue line indicates the threshold for either nitrogen limitation (0.07 mg/l DIN, left-hand) or phosphorus limitation (0.007 mg/l PO_4, right hand). 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.

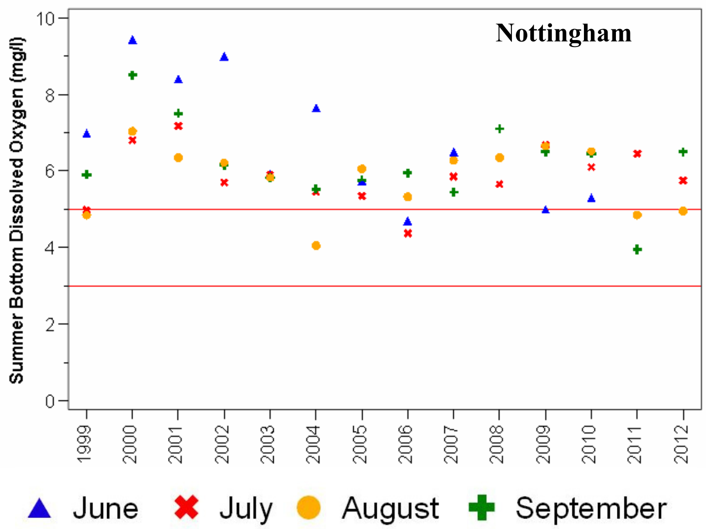


Figure 18. Summer bottom dissolved oxygen levels in the upper Patuxent River.
Monthly bottom dissolved oxygen levels with threshold values of 5 mg/l and 3 mg/l shown with red reference lines.

Middle River

The middle river extends downstream of Nottingham to just past the station at Long Point. This region includes two stations in tidal fresh zone and one station in the oligohaline zone of the mainstem river (Appendix 3).

Nitrogen levels were relatively good in the middle river with the exception of relatively poor TN levels at Long Point. TN and DIN levels improved annually and improved or may have improved in the spring, summer and SAV growing season at the Lower Marlboro station (Figure 19).[26] DIN levels improved annually at the Lower Marlboro and Jack's Creek stations. DIN levels also improved annually, in the summer and SAV growing season at the Jack's Creek station. TN levels were higher upstream at Lower Marlboro and Jack's Creek and decreased downstream.

Total phosphorus levels were relatively poor at all three stations. TP levels improved annually, in the summer and in the SAV growing season at the Lower Marlboro station.[27] TP levels degraded in the SAV growing season and may have degraded in the summer at the Jack's Creek station. PO_4 levels were relatively good at all stations. PO_4 levels improved in spring and may have improved annually at Jack's Creek and may have improved in spring at Lower Marlboro, but PO_4 levels may have degraded in summer at Long Point.[28] PO_4 levels failed to meet the SAV habitat requirement at all stations. TP levels were highest upstream at Lower Marlboro and Jack's Creek and decreased downstream. PO_4 levels were highest at the Jack's Creek station.

[26] TN levels decreased from 1985-2012 at all three middle river stations but non-linear trends at Lower Marlboro indicate levels started increasing in 2010. DIN levels improved at all stations from 1991-2012.
[27] TP levels improved at Lower Marlboro from 1991-2012.
[28] PO_4 levels improved at Jack's Creek from 1991-2012 and may have improved at Lower Marlboro, but non-linear trend at Long Point indicates levels increased starting in the early 2000s.

TSS levels were relatively poor at all three stations. TSS levels may have improved annually at Lower Marlboro.[29] TSS levels were lower at the Long Point station than at the Lower Marlboro and Jack's Creek stations. TSS levels at the Long Point station were close to the habitat requirement in most years, and met the habitat requirement in 2010 and 2012. TSS levels failed to meet the habitat requirement at the two upstream stations.

Algal abundance was relatively fair at Lower Marlboro and relatively poor at Jack's Creek and Long Point. CHLA levels degraded annually and in the SAV growing season and may have degraded in the summer at Jack's Creek.[30] CHLA levels met SAV habitat criteria at Jack's Creek and Lower Marlboro in most years. CHLA levels at the Long Point station were close to the SAV habitat requirement but still failed to meet the criteria in most years. All three stations failed to meet the requirement in 2012.

Water clarity was relatively poor at all three stations and degraded in the SAV growing season and in the summer at the Jack's Creek station.[31] Water clarity may also have degraded annually and in the SAV growing season at Long Point. Water clarity failed to meet the habitat requirements at all three stations.

Water temperature increased in summer and the SAV growing season at all three stations.[32] Water temperature also increased annually at Lower Marlboro and Long Point and may have increased annually at Jack's Creek.

DIN levels were lowest in the summer and nitrogen limitation may have occurred in recent years at all three stations. DIN levels in the rest of the year were too high for nitrogen limitation to occur at the upper two stations. Nitrogen limitation may have occurred in some years in other seasons at the Long Point station. PO_4 levels were too high to cause phosphorus limitation of algal growth in all seasons at Lower Marlboro and Jack's Creek, but were low enough in some years in winter and spring at the Long Point station (Figure 21).

Summer bottom dissolved oxygen levels often fell below 5 mg/l at the Lower Marlboro and Jack's Creek station, but never fell below 3 mg/l (Figure 21). Summer bottom DO levels at Long Point were almost always below 5 mg/l, and below 3 mg/l about half of the time.[33]

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[29] TSS levels may have improved at Lower Marlboro and Long Point from 1991-2012 but may have degraded at Jack's Creek.

[30] CHLA levels degraded at the Jack's Creek and Long Point stations from 1985-2012. At Lower Marlboro, CHLA levels improved 1985-2012.

[31] Secchi depth degraded at Jack's Creek and Long Point from 1985-2012. At Lower Marlboro, Secchi depth increased until the mid-1990s and has since decreased.

[32] Salinity decreased at all three stations from 1985 to the early 2000s but increased after. Water temperature increased at all three stations from 1985-2012.

[33] Summer DO levels degraded at the Lower Marlboro 1985-2012.

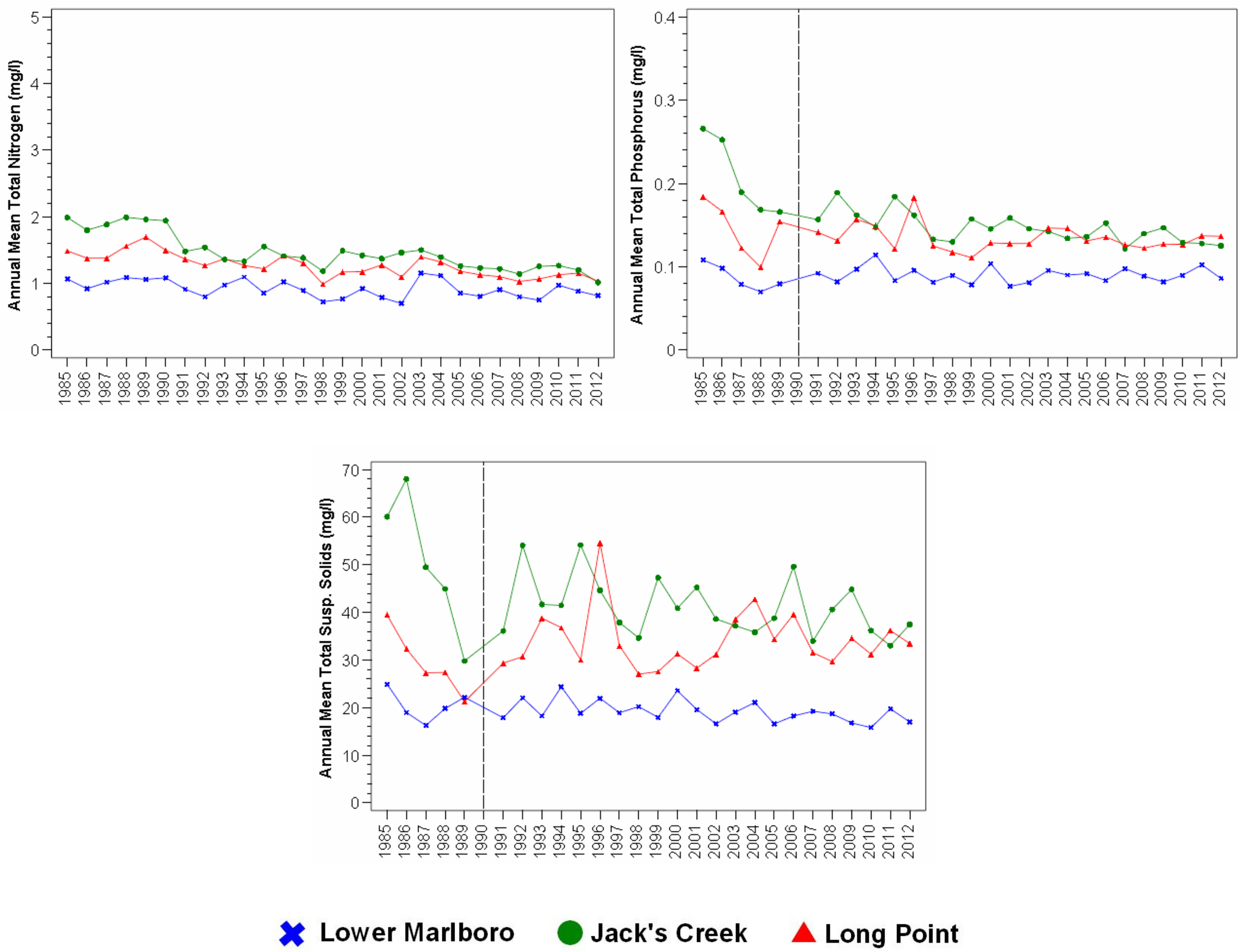


Figure 19. Annual means for total nitrogen, total phosphorus and total suspended solids in the middle Patuxent River.

Dotted line (1990) 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. Scales for the y-axes are the same as in Figures 13 and 23.

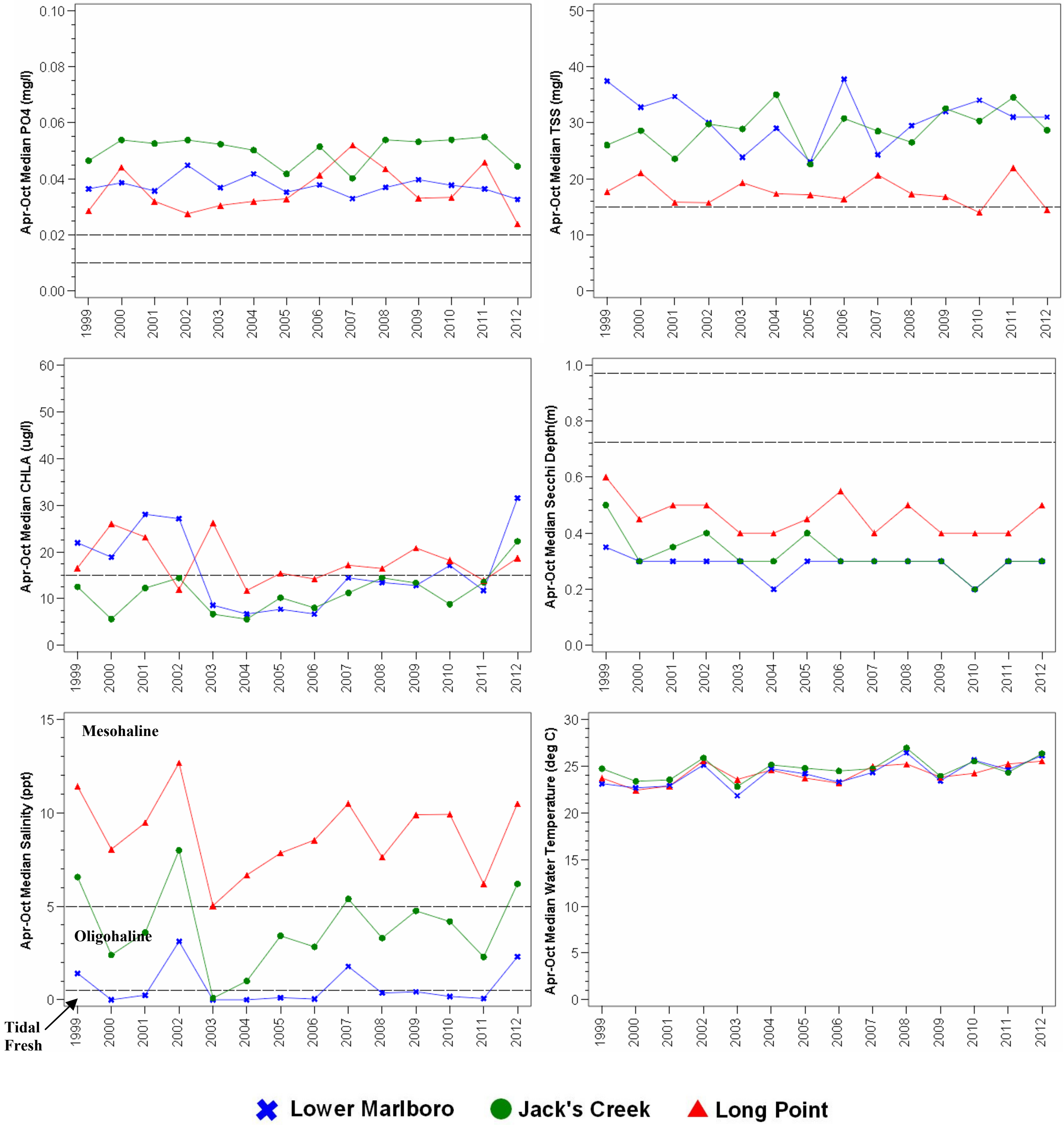


Figure 20. SAV habitat requirement parameters in the middle Patuxent River.
SAV growing season (April-October) median values for PO_4, TSS, CHLA and Secchi depth. Salinity and water temperature are also shown. Threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of PO_4, TSS and CHLA need to be lower than the threshold and Secchi depth needs to be above the threshold. Lower Marlboro is in the tidal fresh zone. Jack's Creek is in the oligohaline zone. Long Point is in the mesohaline zone.

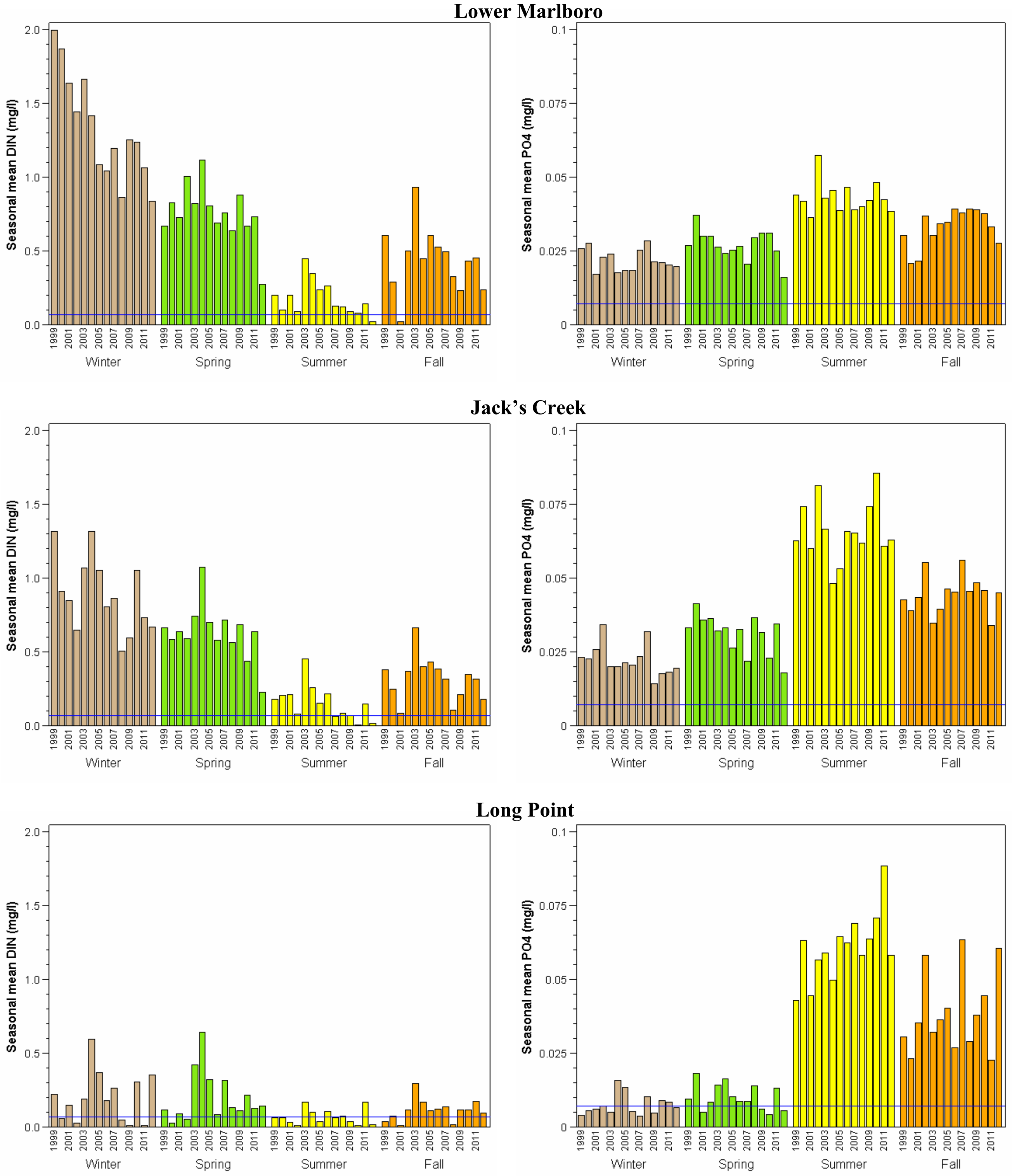


Figure 21. Nutrient limitation by season in the middle Patuxent River.
Seasonal mean DIN levels are shown in the left-hand graphs. Seasonal mean PO_4 levels are shown in the right-hand graphs. Data is annual values for 1999-2012. The blue line indicates the threshold for either nitrogen limitation (0.07 mg/l DIN, left-hand) or phosphorus limitation (0.007 mg/l PO_4, right hand). 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.

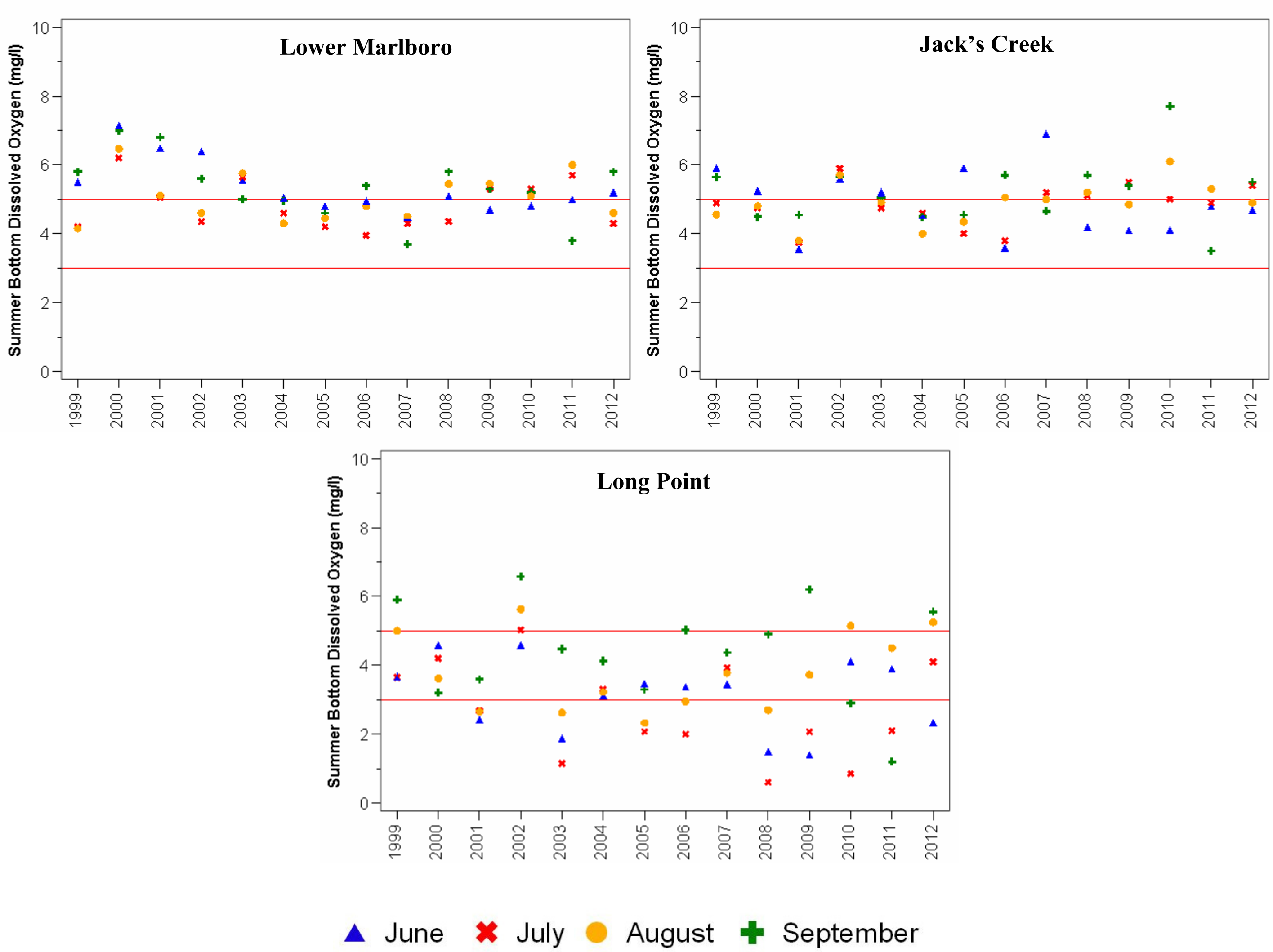


Figure 22. Summer bottom dissolved oxygen levels in the middle Patuxent River.
Monthly bottom dissolved oxygen levels with threshold values of 5 mg/l and 3 mg/l shown with red reference lines.

Lower River

The lower river extends downstream from below Long Point to the mouth of the river off of Drum Pt. This region includes four stations that are all in the mesohaline zone (Appendix 3).

Nitrogen levels were relatively good in the lower river, but TN levels degraded at the Jack Bay station annually and in the summer and may have degraded in the SAV growing season (Figure 23).[34] TN and DIN levels were similar at all four stations.

[34] TN levels improved from 1985-2012 at all four lower river stations. DIN levels improved at the three lower stations an may have improved at Jacks Bay from 1991-2012.

TP levels were relatively good at the lower three stations but relatively poor at Jack Bay. PO_4 levels were relatively good at all stations. TP levels degraded annually, in summer and in the SAV growing season at Jack Bay, and may have degraded annually at Petersons Pt.[35] TP levels were highest upstream at Jack Bay and decreased moving downstream. PO_4 levels followed the same pattern in most years. PO_4 levels met the SAV habitat requirement at all stations.

TSS levels were relatively fair at the Jack Bay station and relatively good at the other stations. TSS levels may have improved in the spring and in the SAV growing season at Petersons Pt. and Pt. Patience.[36] TSS levels met the habitat requirement at all four stations. TSS levels were highest at the Jack Bay station. TSS level were similar at the other three stations in most years.

Algal abundance was relatively poor at all stations. CHLA levels degraded annually, in summer and SAV growing season at the Jack Bay station.[37] CHLA also degraded annually at Petersons Pt. and may have degraded annually at Pt. Patience and Drum Pt. CHLA levels met the habitat requirement in most years at the three lower stations except in 2011 when all four stations failed to meet the requirement.

Water clarity was relatively poor at Jack Bay and Petersons Pt., relatively fair at Pt. Patience and relatively good at Drum Pt. Secchi depth degraded annually and may have degraded in summer and SAV growing season at Jack Bay. Secchi depth may also have degraded annually at Drum Pt. [38] Water clarity failed to meet the SAV habitat requirement at Jack Bay but met the requirement at the other stations in most years.

Salinity decreased annually at all stations.[39] Water temperature increased annually, in the summer and SAV growing seasons at all stations.[40]

Winter and spring PO_4 levels were low enough in almost all years and DIN levels were low enough in some years to limit algal growth at the upper three stations (Figures 25 and 26). DIN levels at the Drum Point station in winter and spring were too high for nitrogen limitation, but PO_4 levels were low enough in all years for phosphorus limitation. Summer DIN levels were low enough but PO_4 levels were too high to limit algal growth throughout the lower river. Nitrogen limitation likely occurred in the fall in most years at all stations, but PO_4 levels were too high in most years for phosphorus limitation in fall.

Summer bottom dissolved oxygen levels were poor at the Jack Bay and Petersons Pt. stations but fair at Pt. Patience and Drum Pt. (Figure 27). Summer bottom DO levels were almost always below 3 mg/l at Jack Bay, and predominantly below 3 mg/l at Petersons Pt. Summer bottom DO levels at Pt. Patience and Drum Point were predominantly below 5mg/l and occasionally below 3 mg/l. Summer bottom DO levels degraded at Drum Pt.[41] Summer bottom DO was unusually high at all stations in 2012.

[35] TP levels degraded at Drum Pt. and may have degraded at Pt. Patience from 1991-2012. Non-linear trend in PO_4 levels at Jacks Bay indicate levels increased starting in the early 2000s.
[36] Non-linear trends in TSS levels indicate levels improved starting in the early 2000s.
[37] CHLA levels degraded at the Petersons Pt., Pt. Patience, and Drum Pt. stations from 1985-2012.
[38] Secchi depth degraded at all four stations in the lower river from 1985-2012.
[39] Salinity decreased from 1985-2012.
[40] Water temperature increased at all stations in the lower river from 1985-2012.
[41] Summer bottom DO levels degraded at Drum Pt 1985-2012.

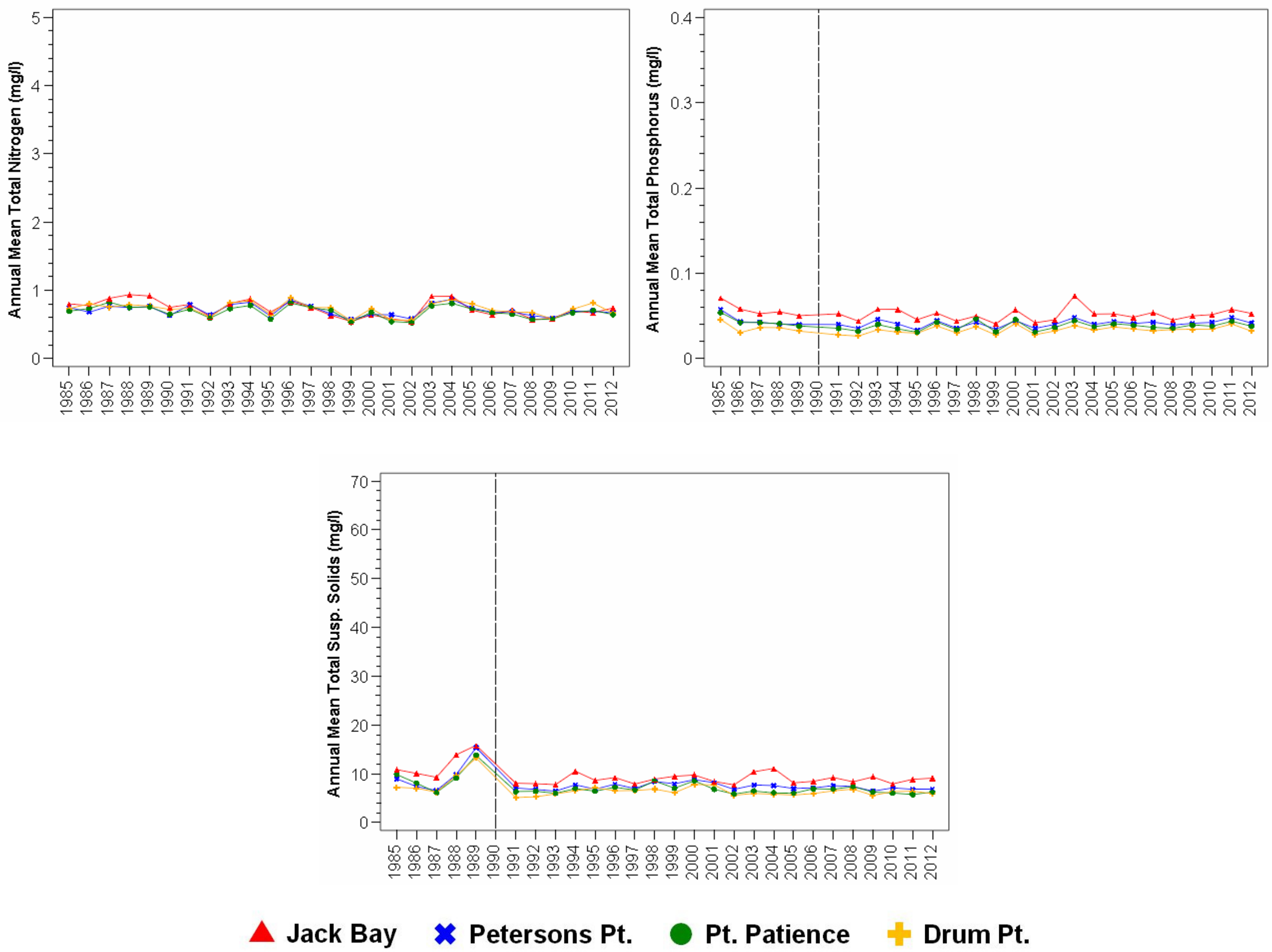


Figure 23. Annual means for total nitrogen, total phosphorus and total suspended solids in the lower Patuxent River.
Dotted line (1990) indicates when the lab change occurred that may have impacted TP and TSS. Caution should be used in making comparisons for TP and TSS from before to after the lab change. Scales for the y-axes are the same as in Figures 13 and 19.

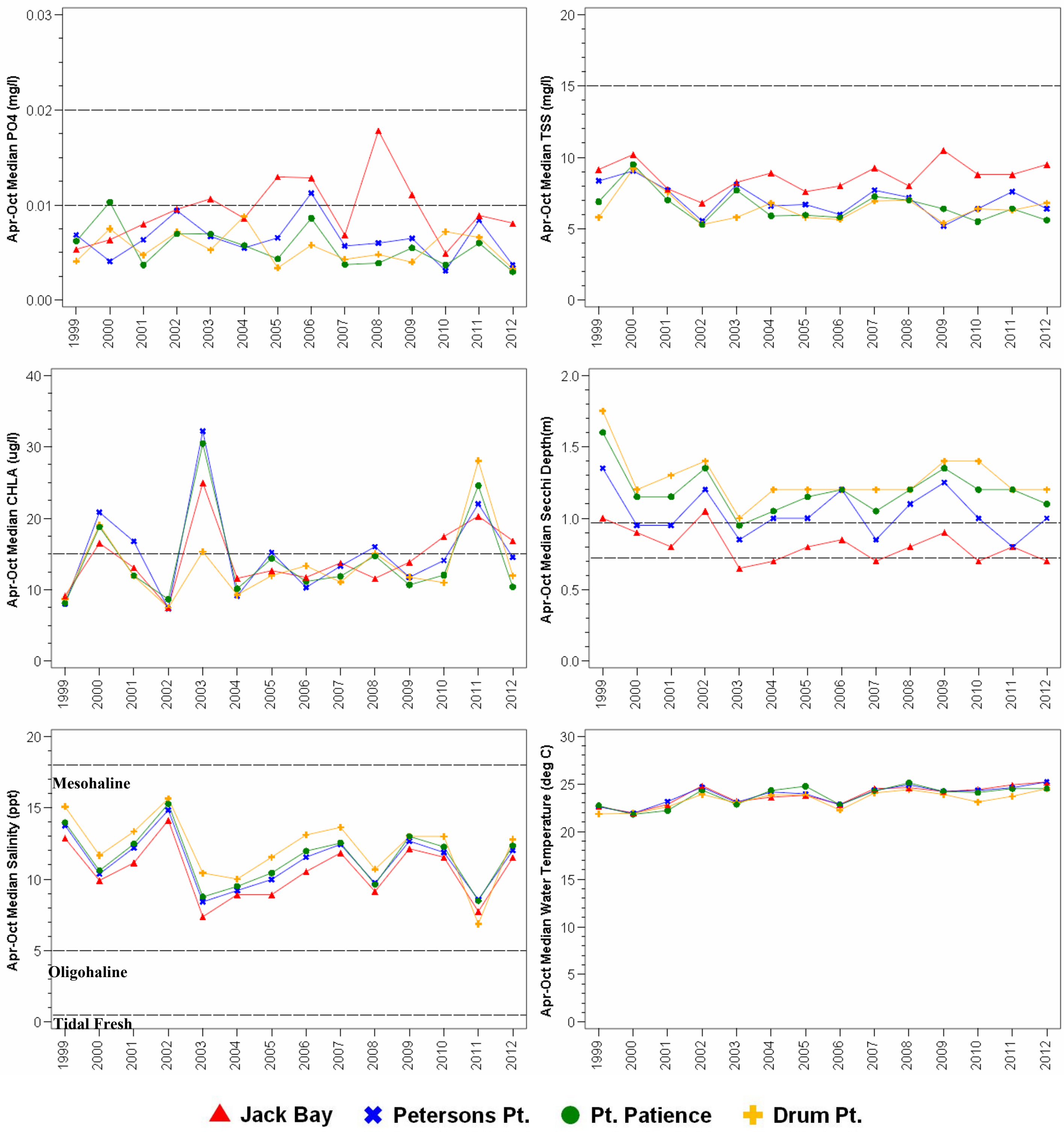
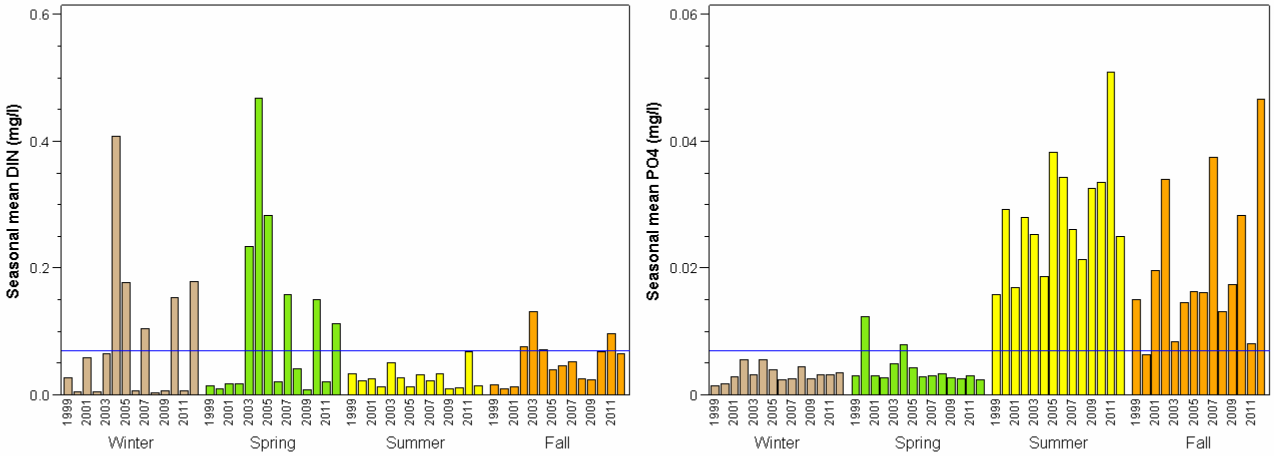


Figure 24. SAV habitat requirement parameters in the lower Patuxent River.
SAV growing season (April-October) median values for PO_4, TSS, CHLA and Secchi depth. Salinity and water temperature are also shown. Threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of PO_4, TSS and CHLA need to be lower than the threshold and Secchi depth needs to be above the threshold. Salinity and water temperature are also shown. All four stations need to meet the mesohaline thresholds.

Jack Bay



Petersons Pt.

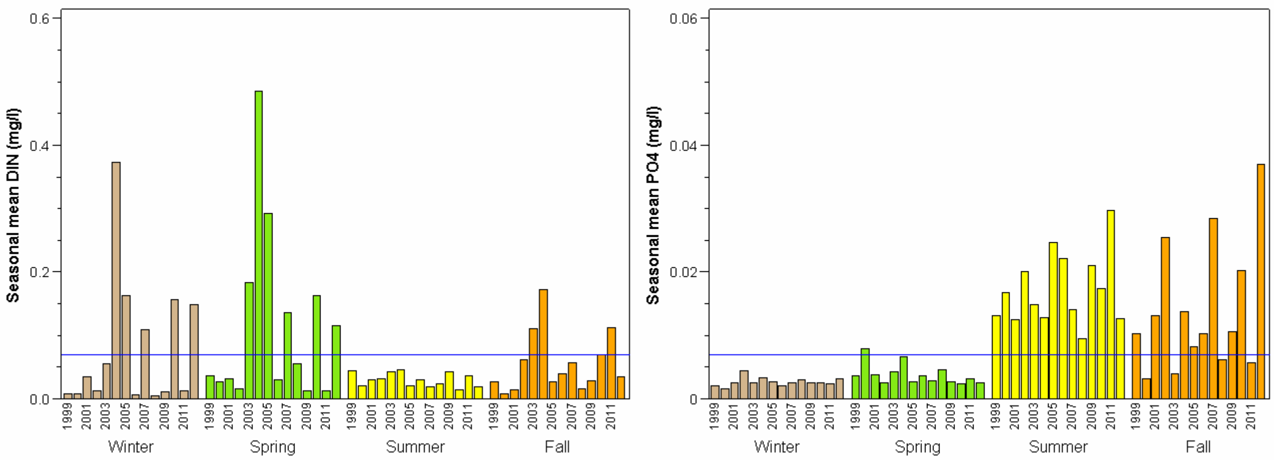


Figure 25. Nutrient limitation by season at Jack Bay and Petersons Pt.
Seasonal mean DIN levels are shown in the left-hand graphs. Seasonal mean PO_4 levels are shown in the right-hand graphs. Data is annual values for 1999-2012. The blue line indicates the threshold for either nitrogen limitation (0.07 mg/l DIN, left-hand) or phosphorus limitation (0.007 mg/l PO_4, right hand). 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.

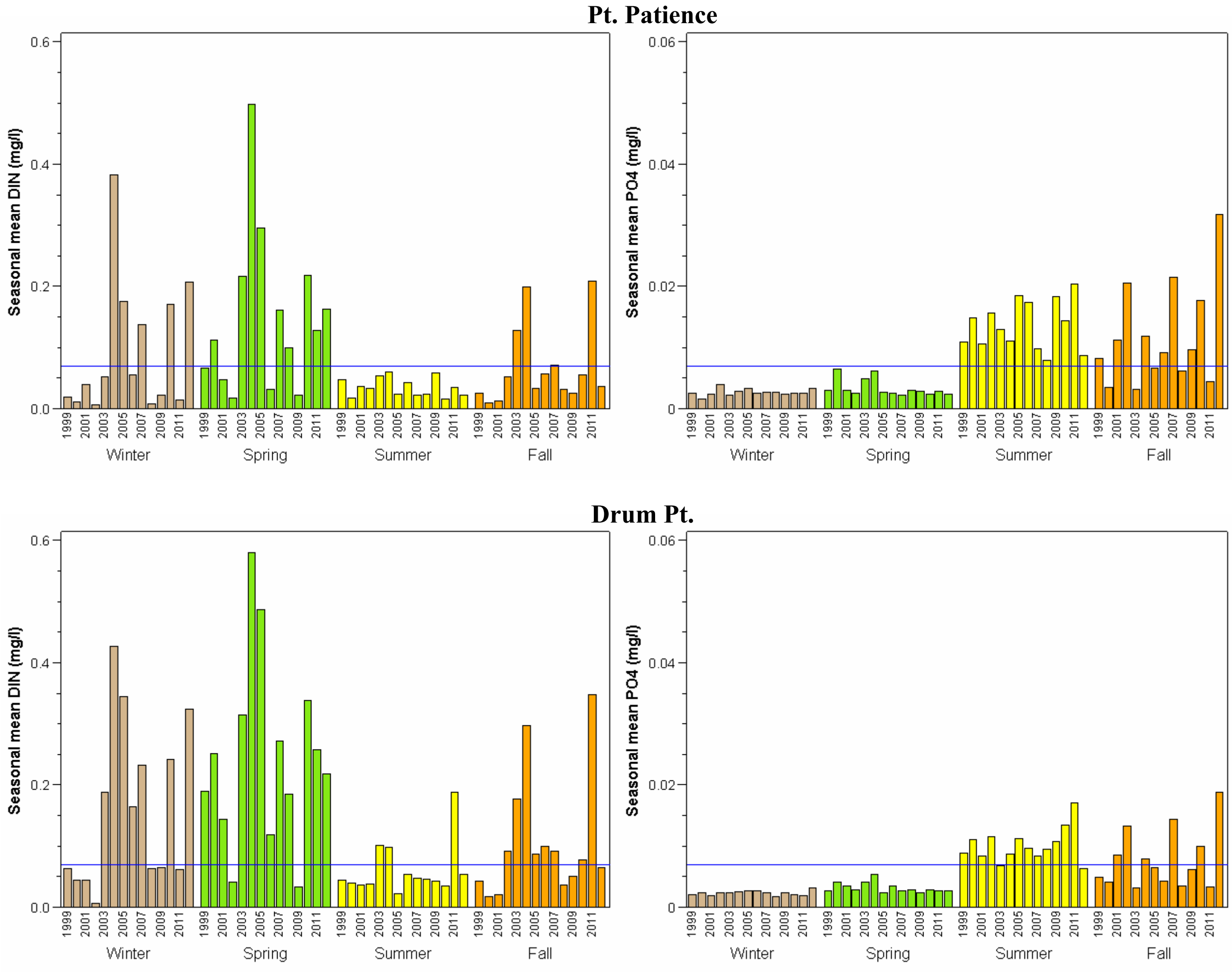


Figure 26. Nutrient limitation by season at Pt. Patience and Drum Pt.
Seasonal mean DIN levels are shown in the left-hand graphs. Seasonal mean PO_4 levels are shown in the right-hand graphs. Data is annual values for 1999-2012. The blue line indicates the threshold for either nitrogen limitation (0.07 mg/l DIN, left-hand) or phosphorus limitation (0.007 mg/l PO_4, right hand). 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.

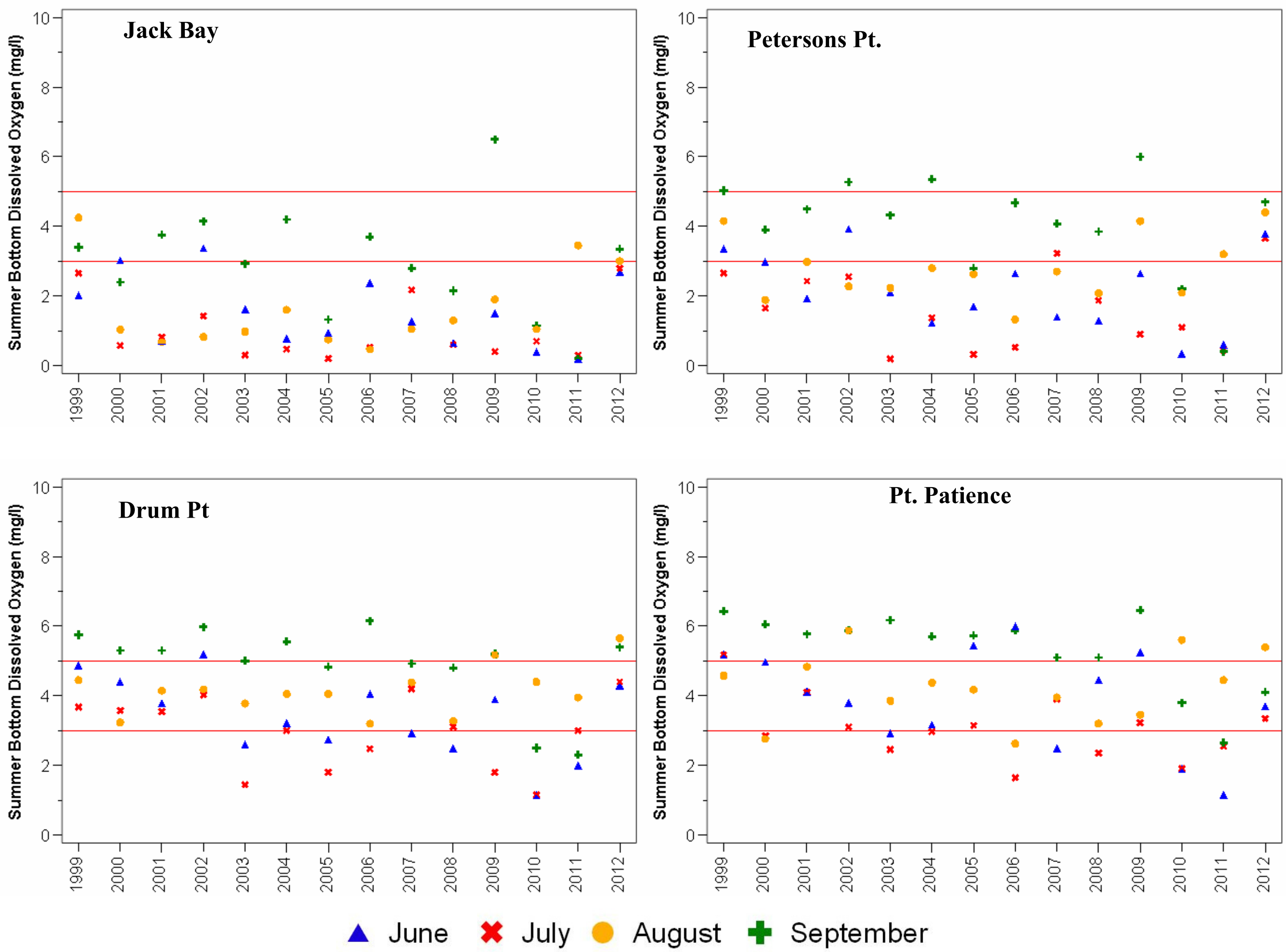


Figure 27. Summer bottom dissolved oxygen levels in the lower Patuxent River.
Monthly bottom dissolved oxygen levels with threshold values of 5 mg/l and 3 mg/l shown with red reference lines.

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.[42] 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.

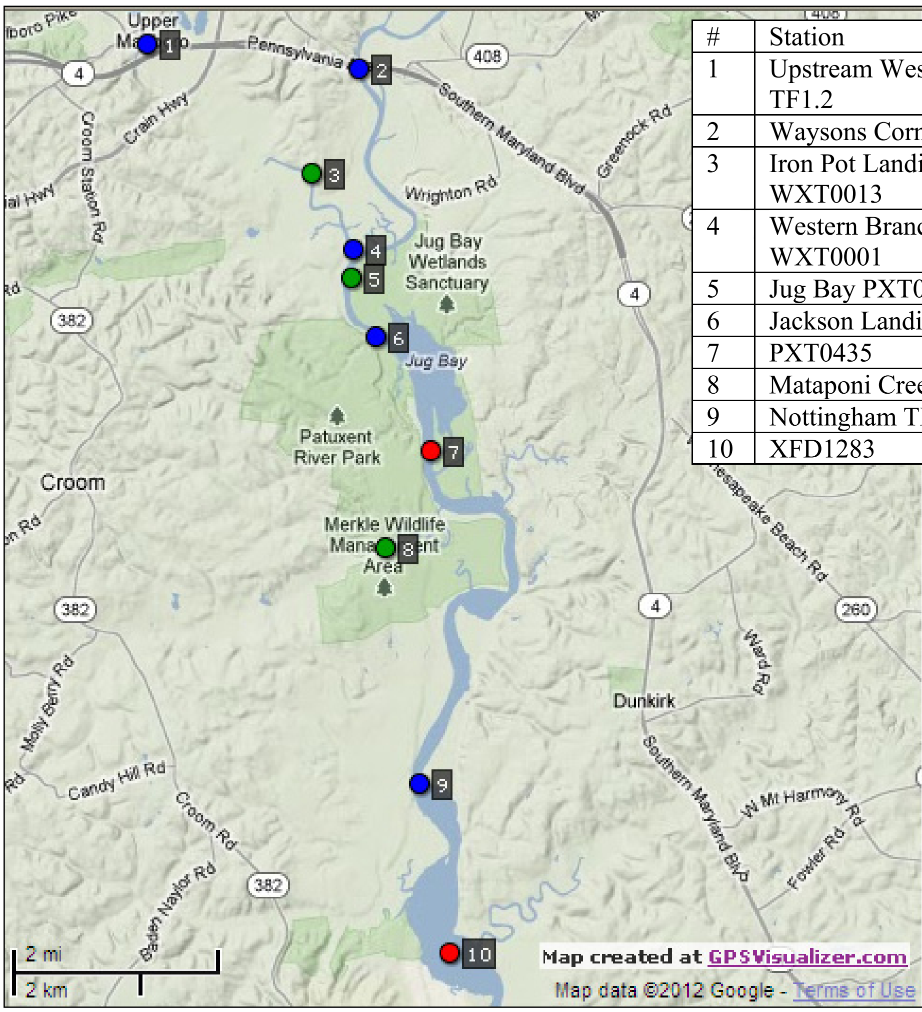
The Shallow Water Monitoring Program conducted an intensive monitoring and assessment study of the Patuxent River during the years 2003-2005. Continuous monitors were placed throughout the river (Figure 28-30, Appendix 3).[43] Three stations in the upper Patuxent (Iron Pot Landing, Jug Bay, Mataponi Creek) were located within the Chesapeake Bay National Estuarine Research Reserve (NERR) at Jug Bay. With funding provided by the NOAA NERR System, monitoring at these sites continues to the present. Water quality mapping was also conducted during 2003-2005 (Figure 28-30, Appendix 3).[44]

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.

[42] Nutrient samples are collected twice a month instead of continuously.
[43] An interactive map of all continuous monitoring stations and complete archived data are available at http://mddnr.chesapeakebay.net/newmontech/contmon/archived_results.cfm.
[44] Interpolated maps for all cruises are available on the Maryland Department of Natural Resources "Eyes on the Bay" website http://mddnr.chesapeakebay.net/sim/dataflow_data.cfm

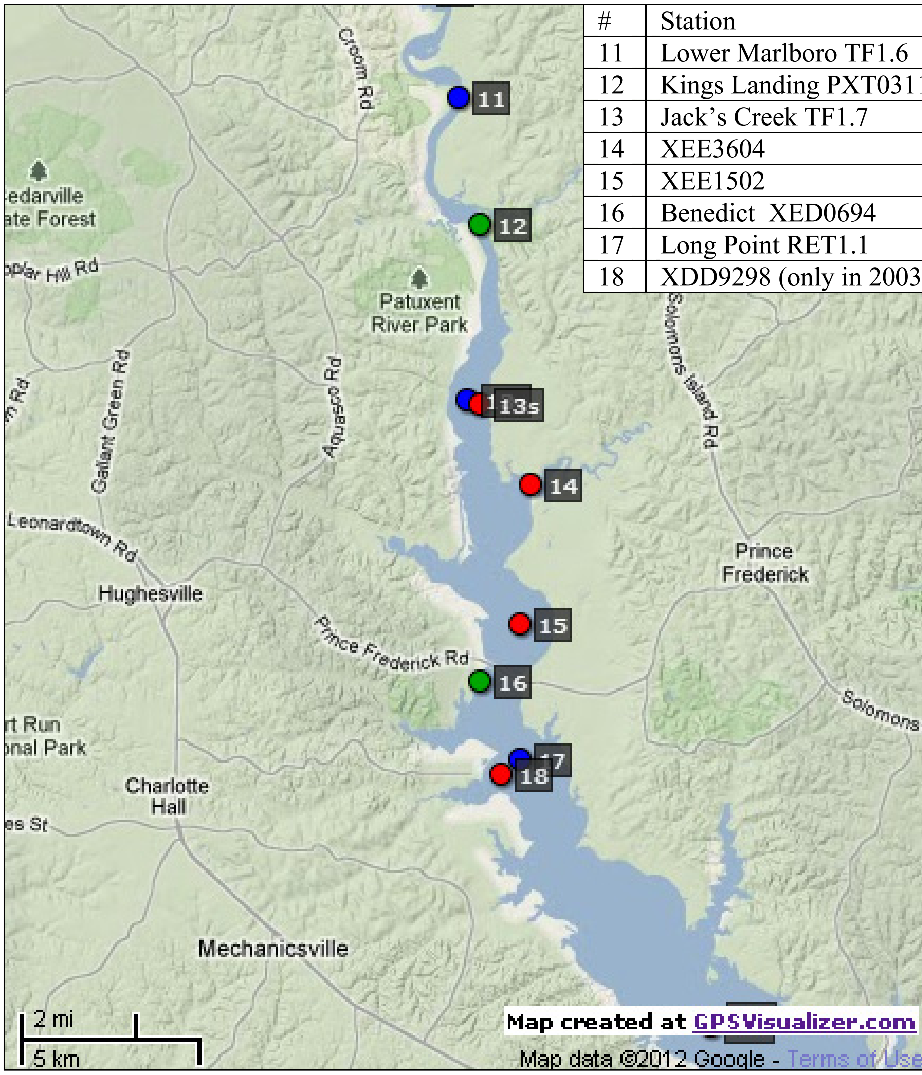
Percent failures are defined as the percent of values in each year that did not meet the water quality thresholds (see Appendix 4 for methods). Data for the years 2003-2012 were used. Chlorophyll and turbidity measurements collected during the SAV growing season (April through October) and summer dissolved oxygen values (June through September) were included in the analysis.

The 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 9). Water quality and habitat conditions were also compared between the shallow water stations and the long-term stations.



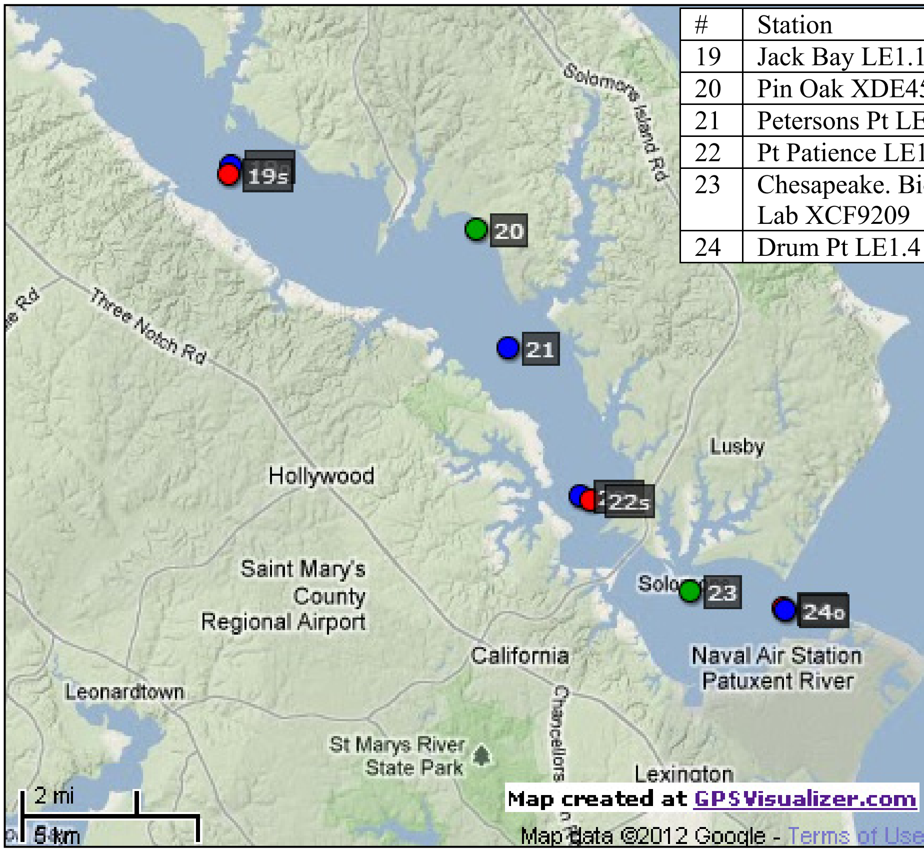
#	Station	Type
1	Upstream Western Branch TF1.2	LT
2	Waysons Corner TF1.3	LT
3	Iron Pot Landing WXT0013	CM
4	Western Branch mouth WXT0001	LT
5	Jug Bay PXT0045	CM
6	Jackson Landing TF1.4	LT
7	PXT0435	WQM
8	Mataponi Creek MTI0013	CM
9	Nottingham TF1.5	LT
10	XFD1283	WQM

Figure 28. Shallow water calibration stations in the upper Patuxent River.
Green circles show the continuous monitoring (CM) locations. Red circles show water quality mapping (WQM) calibration stations. Long-term water quality monitoring stations (LT) are shown with blue circles.



#	Station	Type
11	Lower Marlboro TF1.6	LT
12	Kings Landing PXT0311	CM
13	Jack's Creek TF1.7	LT/WQM
14	XEE3604	WQM
15	XEE1502	WQM
16	Benedict XED0694	CM
17	Long Point RET1.1	LT
18	XDD9298 (only in 2003)	WQM

Figure 29. Shallow water calibration stations in the middle Patuxent River.
Green circles show the continuous monitoring (CM) locations. Red circles show water quality mapping (WQM) calibration stations. Long-term water quality monitoring stations (LT) are shown with blue circles.



#	Station	Type
19	Jack Bay LE1.1	LT/WQM
20	Pin Oak XDE4587	CM
21	Petersons Pt LE1.2	LT
22	Pt Patience LE1.3	LT/WQM
23	Chesapeake. Biological Lab XCF9209	CM
24	Drum Pt LE1.4	LT/WQM

Figure 30. Shallow water calibration stations in the lower Patuxent River.
Green circles show the continuous monitoring (CM) locations. Red circles show water quality mapping (WQM) calibration stations. Long-term water quality monitoring stations (LT) are shown with blue circles.

Temporal conditions

For the stations in the Patuxent, Iron Pot Landing had the most favorable dissolved oxygen conditions, with no measurements below 3.2 mg/l for 2003-2009 and only a few values below 3.2 mg/l for 2010-2012 (Table 3). Jug Bay also had few observations below 3.2 mg/l during all years. At Mataponi Creek, 15%-45% of observations failed the 3.2 mg/l dissolved oxygen threshold. Farther downstream, dissolved oxygen dropped below 3.2 mg/l less than 15% of the time at Benedict and less than 1% of the time at Kings Landing. The most downstream stations, Pin Oak and Chesapeake Biological Laboratory, consistently had less than a 3% failure of the 3.2 mg/l threshold.

Failures of the 15 µg/l chlorophyll threshold were generally infrequent (less than 10% of observations) at Iron Pot Landing, Mataponi, and Kings Landing during 2003-2011. In 2012, Mataponi had an unusually high percentage of chlorophyll values exceed the 15 µg/l threshold (approximately 50%). At Jug Bay, and from the Benedict station downstream to Chesapeake Biological Laboratory, chlorophyll percent failures were generally between 10% and 50%.

The stations at Jug Bay, Kings Landing, and Benedict all had more than 95% of measurements fail the 7 NTU turbidity threshold during 2003-2012. Iron Pot Landing had slightly better turbidity conditions with a failure rate between 80%-95%. At Mataponi Creek and Pin Oak, 65%-99% and 20%-35% of turbidity measurements, respectively, were greater than 7 NTU. Chesapeake Biological Laboratory had the best turbidity conditions in the Patuxent River, exceeding the turbidity threshold less than 10% of the time.

The percent failure analysis determines how often dissolved oxygen levels were below healthy levels, but not how long at any one time dissolved oxygen levels were dangerously low. This is important because most benthic animals and fish can survive in low dissolved oxygen for short periods but not extended periods. To examine duration of low dissolved oxygen conditions, a special study was done of the continuous monitoring data from Maryland rivers for 2003-2010 and included the data for four shallow water stations in the Patuxent River: Jug Bay (2003-2008), Benedict (2003-2005), Pin Oak (2003-2007) and Chesapeake Biological Laboratory (2003-2005). This study found that periods of dissolved oxygen levels below 3.2 mg/l at different locations throughout the Bay lasted from as little as 15 minutes to as long as 5.7 days.[45] The longest continuous period of extremely low dissolved oxygen per year at the station in Jug Bay varied from 0-11 hours. For Benedict, the longest measured continuous period of extremely low dissolved oxygen varied from 6-9 hours. At Pin Oak, the maximum duration of extremely low dissolved oxygen levels varied from 0-2 hours, and at Chesapeake Biological Laboratory varied from 7-16 hours.

[45] Boynton et al (2011) available online at http://www.gonzo.cbl.umces.edu/documents/water_quality/Level1Report28.pdf

Table 3. Shallow water dissolved oxygen, chlorophyll and turbidity levels in 2004-2012
The percent of instantaneous values in each year that did not meet the thresholds:
dissolved oxygen > 3.2 mg/l, chlorophyll *a* < 15 µg/l, turbidity < 7 NTU.

	Station	Location	Year	Dissolved Oxygen % < 3.2 mg/l	Chlorophyll % > 15 ug/l	Turbidity % > 7 NTU
Upper	WXT0013	Iron Pot Landing	2003	0.00	2.14	87.80
			2004	0.00	0.11	96.03
			2005	0.00	0.37	82.36
			2006	0.00	1.39	80.51
			2007	0.00	8.38	82.38
			2008	0.00	2.87	87.50
			2009	0.00	0.63	92.03
			2010	0.02	2.81	78.05
			2011	0.02	2.12	78.63
			2012	0.03	1.23	78.67
	PXT0455	Jug Bay	2003	0.00	2.29	99.80
			2004	0.18	12.12	99.85
			2005	1.19	10.00	99.48
			2006	0.07	25.79	100.00
			2007	0.00	47.42	98.60
			2008	0.43	21.48	99.84
			2009	0.03	9.47	99.93
			2010	0.47	23.16	99.63
			2011	0.03	16.70	98.66
			2012	0.11	51.04	99.86
	MTI0015	Mataponi Creek	2003	44.44	0.02	82.70
			2004	42.86	0.20	80.56
			2005	32.35	1.34	64.58
			2006	26.39	5.64	65.72
			2007	26.72	13.22	62.50
			2008	18.49	3.13	69.52
			2009	16.56	0.28	65.75
			2010	30.84	5.82	66.32
			2011	20.87	5.38	76.62
			2012	30.27	49.67	99.54
Middle	PXT0311	Kings Landing	2003	0.00	0.29	100.00
			2004	0.55	3.89	100.00
			2005	0.20	3.53	100.00
	XED0694	Benedict	2003	8.91	26.03	96.30
			2004	3.51	14.52	97.51
			2005	14.64	28.52	96.11
Lower	XDE4587	Pin Oak	2003	2.32	45.65	30.45
			2004	0.65	20.48	58.55
			2005	2.82	34.27	36.93
			2006	1.43	24.95	22.89
			2007	1.20	36.25	35.13
	XCF9029	Ches. Biological Lab	2003	1.22	31.58	1.59
			2004	0.96	23.31	6.04
			2005	1.49	19.11	7.76

Legend
< 10 % failure
10 - 40 % failure
40 - 70 % failure
> 70 % failure

Western Branch

Intensive sample period (2003-2005)

From 2003-2005, monitoring was done at two long term stations on Western Branch (Upper Western Branch and Western Branch Mouth) and at one continuous monitoring station (Iron Pot Landing).[46] The Iron Pot Landing station was located between the two long term monitoring stations and very close to the Patuxent River WWTP. DIN levels were significantly lower at the upstream Western Branch station but similar at the other two stations (Figure 31). DIN levels were too high at all three stations for nitrogen limitation to occur. PO_4 levels were significantly higher at Iron Pot Landing than the other two stations and also significantly higher than any of the other stations in the Upper Patuxent River. PO_4 levels only met the SAV habitat requirement at the upstream Western Branch station.

TSS levels were also significantly higher at Iron Pot Landing than at the other two Western Branch stations (Figure 32). TSS levels met the habitat requirement at both long term stations and were close to but did not meet the habitat requirement at Iron Pot Landing. CHLA levels were significantly higher at the mouth of Western Branch station than at the other stations, but similar between Iron Pot Landing and upstream Western Branch. CHLA levels met the requirement at all three stations. Secchi depth was similar at Iron Pot Landing and the Western Branch mouth station (not measured at upstream Western Branch), but both failed to meet the Secchi depth requirement (Figure 33).

Current (2010-2012)

At Iron Pot Landing, DIN levels were too high for nitrogen limitation to have occurred and PO_4 levels failed to meet the habitat requirement. TSS levels met the habitat requirement in 2010 and 2011, and CHLA levels met the requirement in all years. Water clarity met the requirement all three years.

Upper River

Intensive sample period (2003-2005)

From 2003-2005, water and habitat quality in the upstream portion of the upper river was monitored at three long term stations (Waysons Corner, Western Branch mouth and Jackson Landing), one continuous monitoring station (Jug Bay), and one WQM calibration station (PXT0435).[47] DIN levels at Waysons Corner were significantly higher than all other stations in the Patuxent River. DIN levels in shallow water at Jug Bay and PXT0435 were similar to levels at Jackson Landing but were significantly different from each other. Jug Bay was also significantly higher than the Western Branch mouth. DIN levels were too high at all five stations for nitrogen limitation to occur. PO_4 levels were similar at both shallow water stations to the open water stations except at the mouth of Western Branch, but only PXT0435 was low enough to meet the SAV habitat requirement. TSS levels at both shallow water stations were similar to

[46] There were no water quality mapping stations in Western Branch.
[47]The long term station at the mouth of Western Branch is located within the upstream Upper River as well as in Western Branch; comparisons between this station and Western Branch stations are discussed above and comparisons to the upstream Upper River stations are included in this section.

each other and Jackson Landing but significantly higher than Waysons Corner; TSS levels at Jug Bay were also significantly higher than levels at the mouth of Western Branch. Both shallow water stations failed to meet the TSS habitat requirement. CHLA levels were significantly higher at PXT0435 than all but Jackson Landing; levels at Jug Bay were significantly higher than Waysons Corner but similar to the mouth of Western Branch and Jackson Landing. Only PXT0435 CHLA levels failed to meet the habitat requirement. Secchi depths at Jug Bay were similar to all of the stations, but PXT0435 and Jackson Landing were significantly lower than the other stations, and all stations failed to meet the habitat requirement.

From 2003-2005, water and habitat quality in the downstream portion of the upper river was monitored at one long-term (Nottingham), one continuous monitoring (Mataponi Creek) and one WQM calibration station (XFD1283). DIN and PO_4 levels in shallow water in Mataponi Creek were significantly lower than at XDE1283 and Nottingham. DIN levels were too high at all three stations for nitrogen limitation to occur. PO_4 levels were significantly higher at XFD1283 than at the other two stations and failed to meet the SAV habitat requirement. PO_4 levels at Nottingham and Mataponi Creek stations were similar and met the requirement. TSS levels in Mataponi Creek were significantly lower than at the other two stations, but TSS levels at XDE1283 and Nottingham were similar. Only Mataponi Creek met the TSS habitat requirement. CHLA levels were significantly different among all three stations, lowest at Mataponi Creek and highest at Nottingham. All three stations met the CHLA habitat requirement in 2003, but Nottingham failed to meet the requirement in 2004 and 2005. Secchi depths were similar at XDE1283 and Nottingham, but both were significantly lower than Secchi depth in Mataponi Creek.[48] All three stations failed to meet the water clarity SAV habitat requirement.

Current (2010-2012)

Jug Bay and Mataponi DIN levels were too high for nitrogen limitation to occur. PO_4 levels met the habitat requirement at both stations. TSS levels at Jug Bay failed to meet the requirement. TSS levels in Mataponi Creek met the requirement in 2010-2011 but failed to meet the requirement in 2012. CHLA levels at Jug Bay were borderline in 2010-2011 but were much higher in 2012 and failed to meet the requirement. In Mataponi Creek, CHLA levels met the requirement in 2010-2011 and also were much higher and failed to meet the requirement in 2012. Water clarity failed to meet the requirement at both stations.

[48] Secchi depth often was greater than water depth in Mataponi Creek.

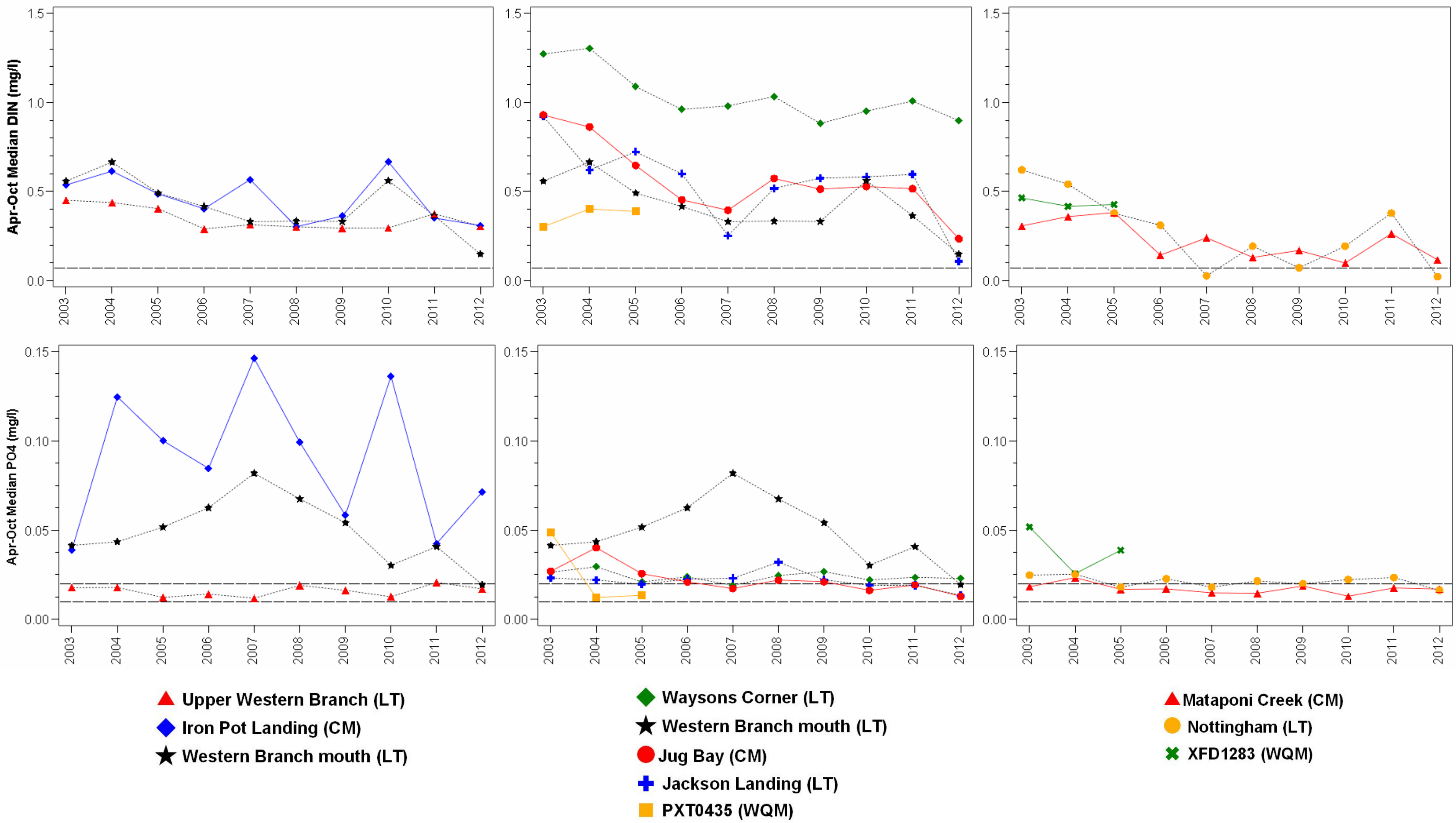


Figure 31. Shallow water and open water DIN and PO_4 levels in Western Branch and Upper Patuxent River. SAV growing season median values for DIN (top graphs) and PO_4 (bottom graphs). Nitrogen limitation (DIN) and SAV habitat requirement (PO_4) threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of DIN and PO_4 need to be lower than the threshold. Long-term monitoring stations (LT) have dashed lines. Continuous monitoring (CM) and Water Quality Mapping (WQM) calibration stations have solid lines. WQM data was only collected in 2003-2005.

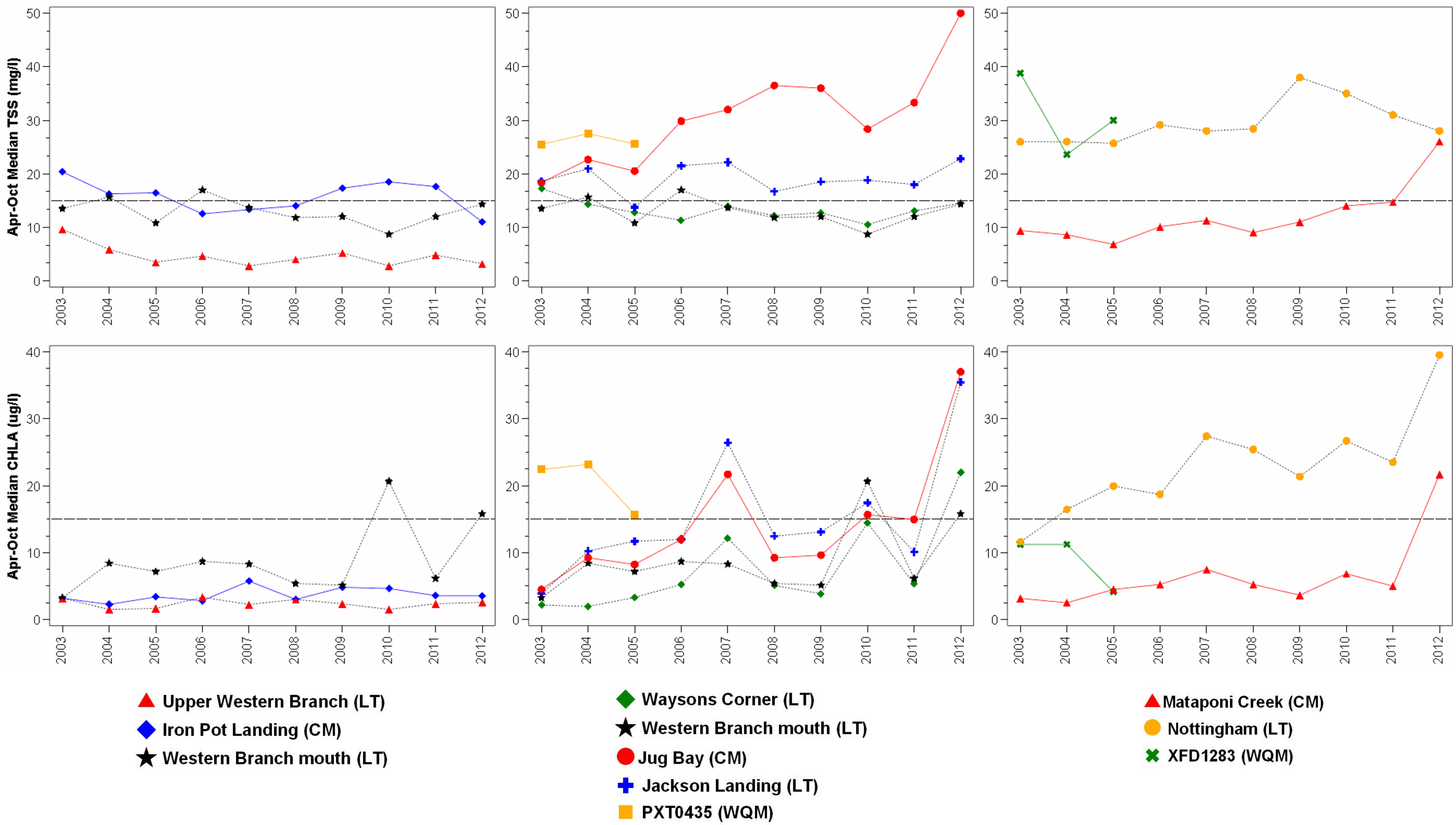


Figure 32. Shallow water and open water TSS and CHLA levels in Western Branch and Upper Patuxent River. SAV growing season median values for TSS (top graphs) and CHLA (bottom graphs). Habitat requirement threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of TSS and CHLA need to be lower than the threshold. Long-term monitoring stations (LT) have dashed lines. Continuous monitoring (CM) and Water Quality Mapping (WQM) calibration stations have solid lines. WQM data was only collected in 2003-2005.

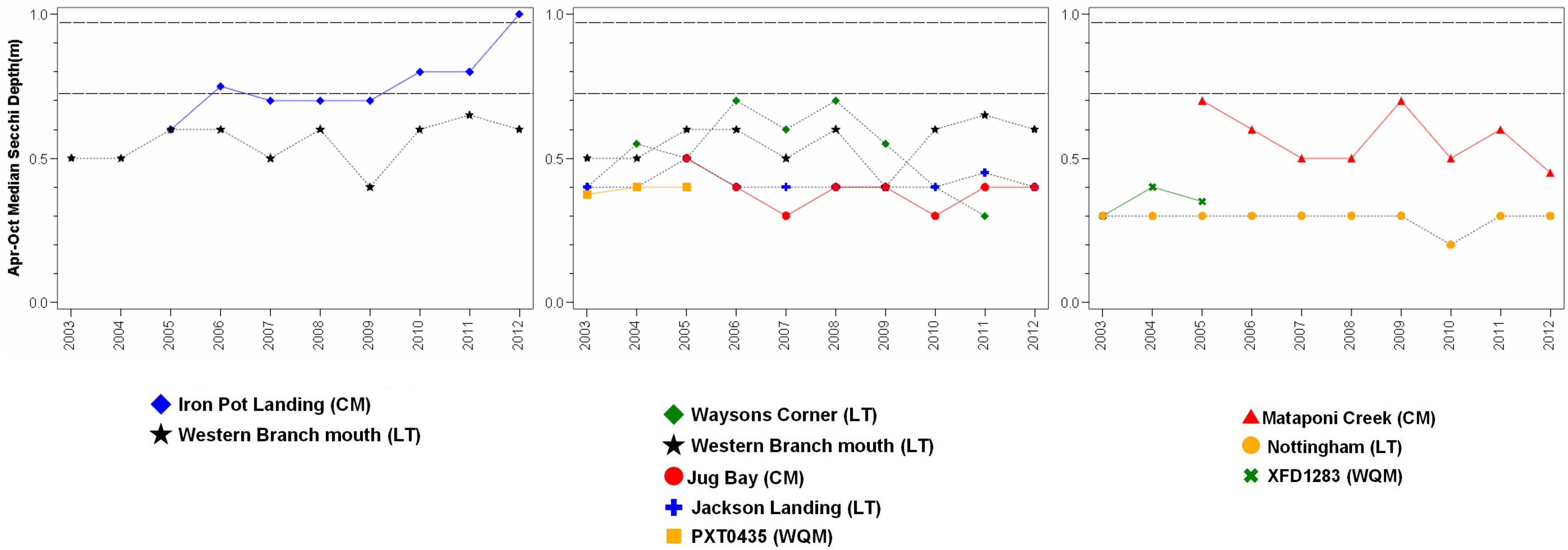


Figure 33. Shallow water and open water water clarity in Western Branch and Upper Patuxent River.
SAV growing season median values for Secchi depth. The habitat requirement threshold value is shown with dashed lines (Appendix 5). To meet or pass the habitat requirement, Secchi depth needs to be lower than the threshold. Long-term monitoring stations (LT) have dashed lines. Continuous monitoring (CM) and Water Quality Mapping (WQM) calibration stations have solid lines. Secchi depth is not measured at the Upper Western Branch station. WQM data was only collected in 2003-2005. Secchi depth often was greater than water depth in Mataponi Creek.

Middle River

Intensive sample period (2003-2005)

From 2003-2005, water and habitat quality was monitored in the middle portion of the river at three long term stations (Lower Marlboro, Jack's Creek, Long Point), two continuous monitoring stations (King's Landing, Benedict), and three WQM calibration stations (Jack's Creek, XEE3604, XEE1502).[49] DIN levels decreased from upstream to downstream. Stations furthest downstream (Benedict and Long Point) had significantly lower DIN levels than the upstream long-term stations (Lower Marlboro and Jack's Creek). DIN levels were too high for nitrogen limitation to occur at all sites in 2003 and 2004, but were low enough in 2005 at the downstream stations (XEE3604, XEE1502, Benedict and Long Point) (Appendix 9).

PO_4 levels were lowest at the shallow water stations at King's Landing and Benedict, but only passed the habitat requirement at King's Landing in 2003. PO_4 levels were highest at Jack's Creek and XEE1502.

TSS levels decreased from King's Landing downstream to Long Point. TSS levels at all stations were significantly lower than at King's Landing. TSS levels did not meet the SAV habitat requirement at any station.

CHLA levels were significantly higher downstream than upstream, and only met the SAV habitat requirement in all three years at the upstream stations (Lower Marlboro, King's Landing and Jack's Creek).[50] CHLA levels at the shallow water station at Benedict met the requirement in 2004 and 2005.

Secchi depths were higher at the shallow water stations than at the closest open water stations, and were significantly higher in the downstream area. All stations failed to meet the SAV habitat requirement.

At King's Landing, DIN levels were significantly lower than at the closest open water station upstream at Lower Marlboro, and TSS levels and Secchi depth were significantly higher. PO_4 levels were significantly lower at King's Landing than at the closest open water station downstream at Jack's Creek. CHLA levels were similar to both long-term stations.

At the WQM stations XEE3604 and XEE1502, TSS levels were significantly lower and CHLA levels and Secchi depths were significantly higher than at the nearest open water station at Jack's Creek. PO_4 levels XEE3604 were also significantly lower than at Jack's Creek.[51]

At Benedict, TSS levels were significantly higher than at the nearest open water station at Long Point, but all other parameters were similar.

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[49] Long-term station at Jack's Creek (TF1.7) was also sampled as a water quality mapping calibration station. A fourth WQM station, XDD9298, was only monitored in 2003 and is not included in the comparisons.
[50] CHLA levels at Benedict were significantly lower than the upstream stations; the test was not able to detect a significant difference at the WQM downstream stations due to a smaller sample size at WQM stations compared to CM and LT stations. Graphical analysis suggests that levels were significantly higher at the downstream WQM stations as well.
[51] No significant differences were found between XEE1502 and the long term station at Long Point.

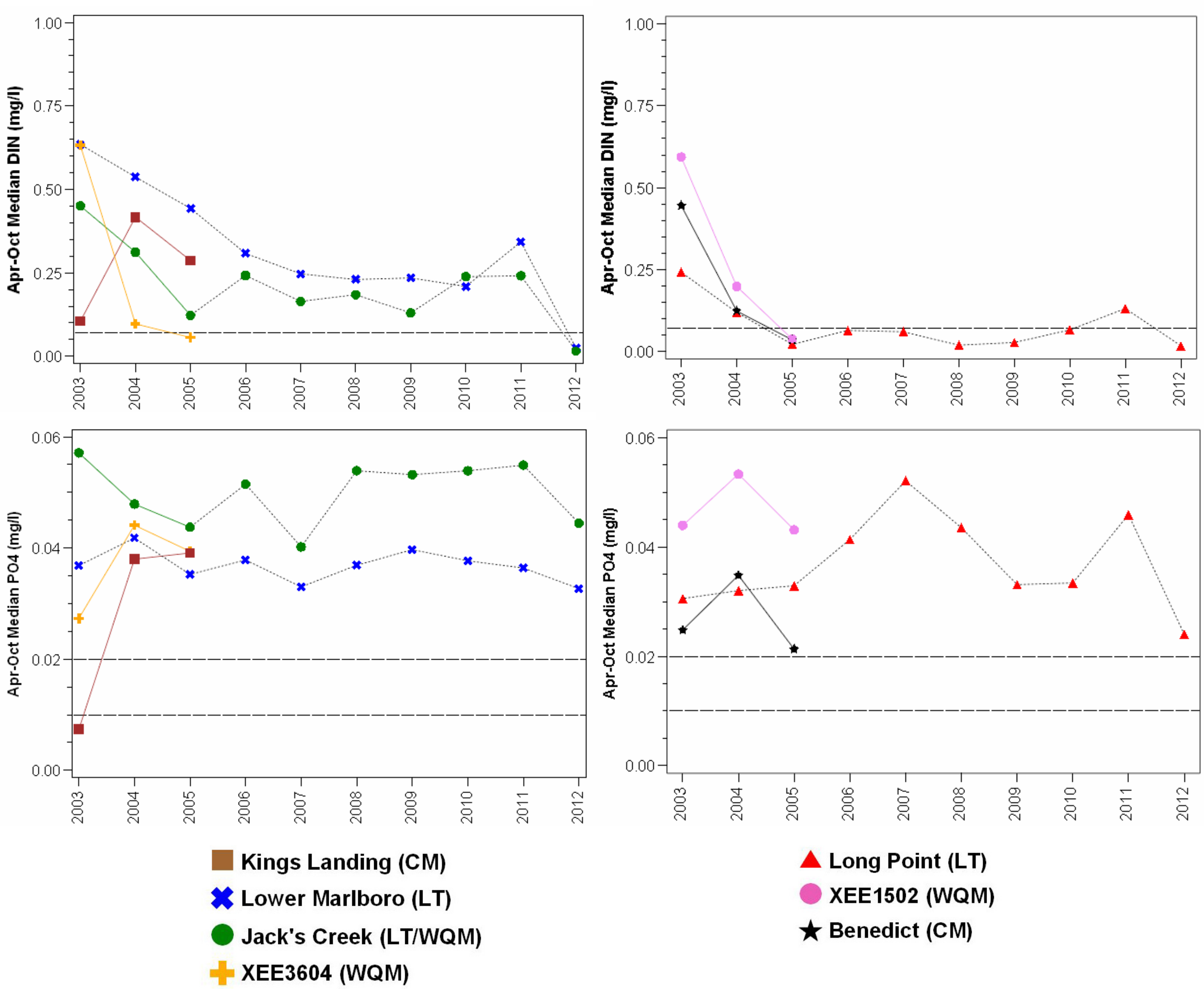

Figure 34. Shallow water and open water DIN and PO_4 levels in Middle Patuxent River. SAV growing season median values for DIN (top graphs) and PO_4 (bottom graphs). Habitat requirement threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of DIN and PO_4 need to be lower than the threshold. Long-term monitoring stations (LT) have dashed lines. Continuous monitoring (CM) and Water Quality Mapping (WQM) calibration stations have solid lines. CM and WQM data was only collected in 2003-2005. For Jack's Creek station, 2003-2005 data includes WQM calibration and long-term data (solid line); for 2006-2012 is only long-term data (dashed line).

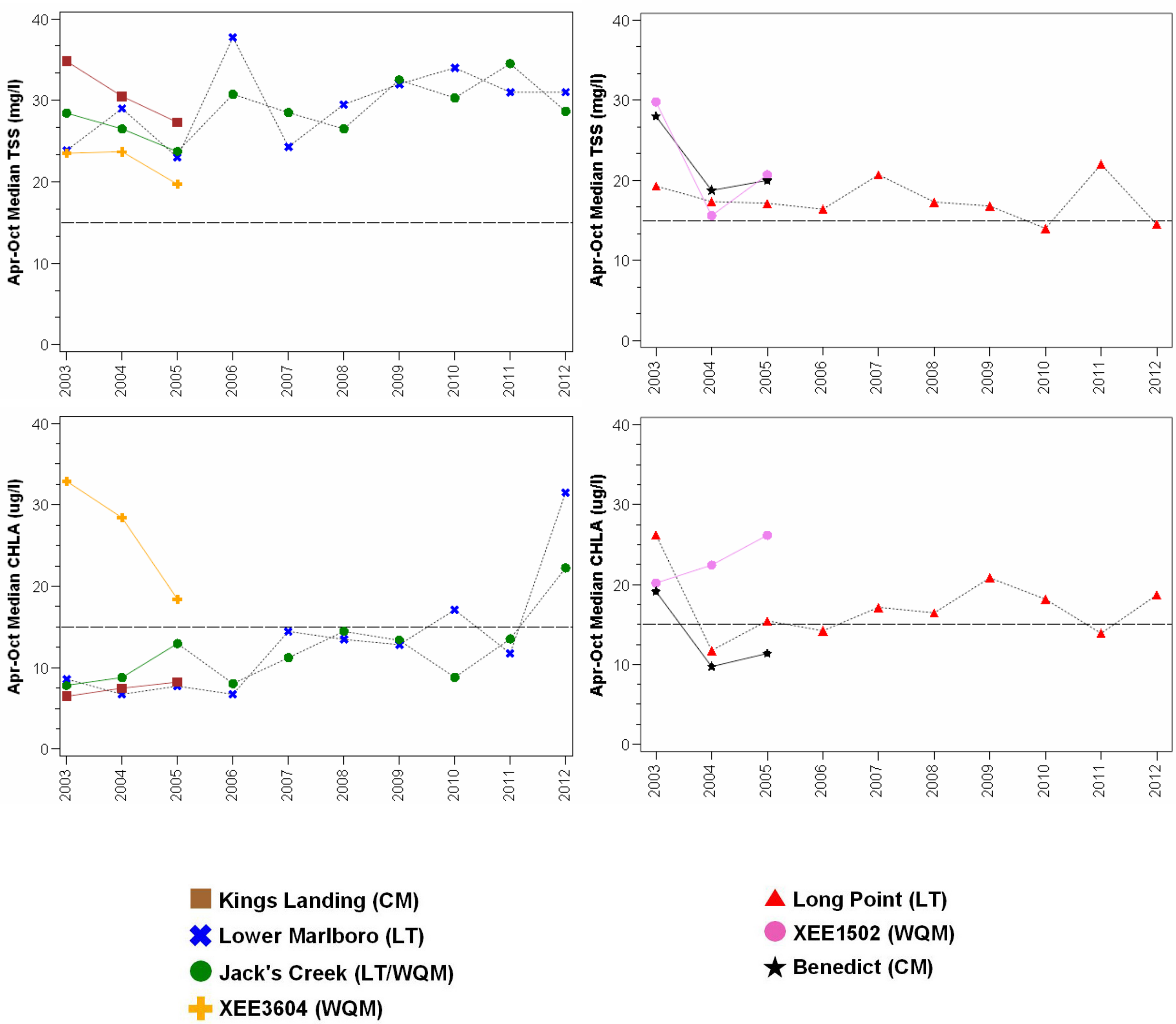

Figure 35. Shallow water and open water TSS and CHLA levels in Middle Patuxent River. SAV growing season median values for TSS (top graphs) and CHLA (bottom graphs). Habitat requirement threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of TSS and CHLA need to be lower than the threshold. Long-term monitoring stations (LT) have dashed lines. Continuous monitoring (CM) and Water Quality Mapping (WQM) calibration stations have solid lines. CM and WQM data was only collected in 2003-2005. For Jack's Creek station, 2003-2005 data includes WQM calibration and long-term data (solid line); for 2006-2012 is only long-term data (dashed line).

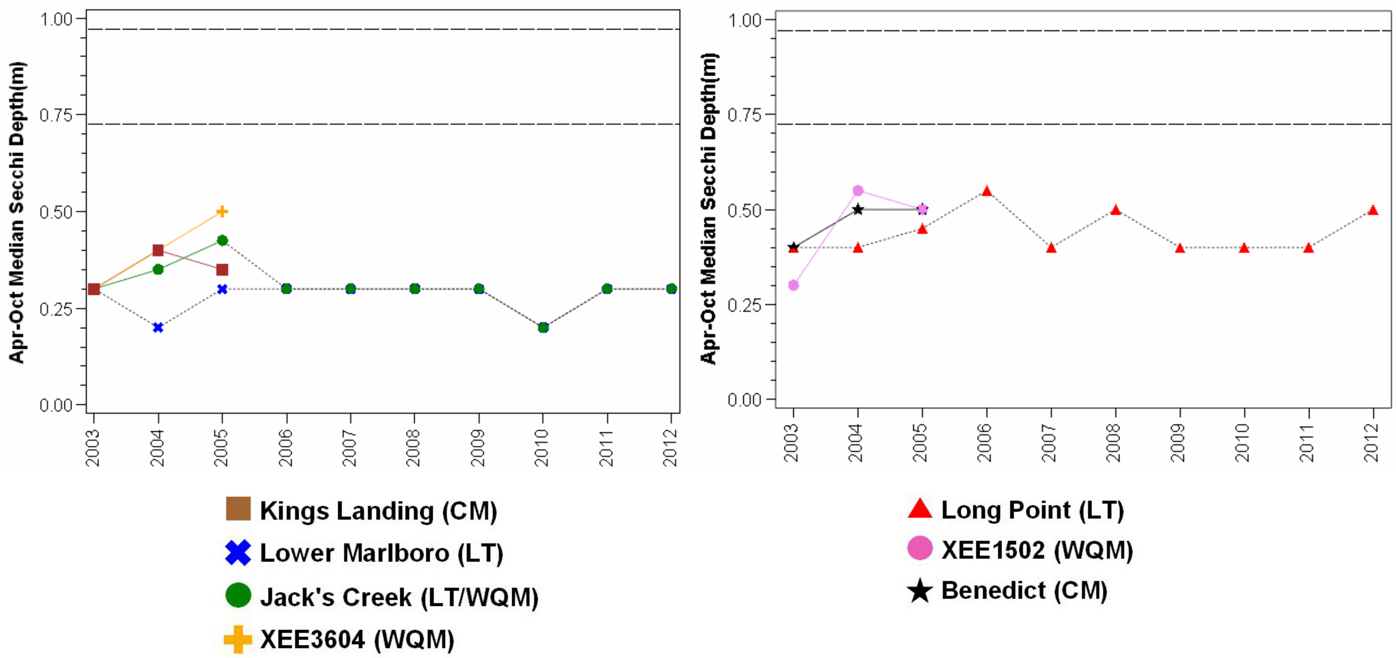

Figure 36. Shallow water and open water water clarity in Middle Patuxent River.
SAV growing season median values for Secchi depth. The habitat requirement threshold value is shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, Secchi depth needs to be lower than the threshold. Long-term monitoring stations (LT) have dashed lines. Continuous monitoring (CM) and Water Quality Mapping (WQM) calibration stations have solid lines. Secchi depth is not measured at the Upper Western Branch station. CM and WQM data was only collected in 2003-2005. For Jack's Creek station, 2003-2005 data includes WQM calibration and long-term data (solid line); for 2006-2012 is only long-term data (dashed line).

Lower River

Intensive sample period (2003-2005)

From 2003-2005, the lower river was monitored at four long term stations (Jack Bay, Petersons Pt., Pt. Patience, and Drum Pt.) and two continuous monitoring stations (Pin Oak and Chesapeake Biological Laboratory). All but the Petersons Pt. station were also monitored as WQM calibration stations. Water quality mapping was continued in 2006; continuous monitoring was continued in 2006 and 2007 at Pin Oak.

DIN levels were higher at the mouth of the river than at the upstream stations. DIN levels in the shallow water at Chesapeake Biological Lab were significantly higher than at all of the upstream stations, and levels at Drum Pt. were significantly higher than at Jack Bay. DIN levels at the shallow water stations were not significantly different from levels at the closest long term station. DIN levels were low enough for nitrogen limitation to occur at the upstream stations (Jack Bay to Pt. Patience) in most years, with the exception of 2004 when DIN levels were elevated at all stations. Nitrogen limitation likely also occurred at the stations at the mouth of the river (Drum Pt. and Chesapeake Biological Laboratory) in most years except 2003 and 2004.

With the exception of 2003, PO_4 levels were highest at Jack Bay and lowest at Chesapeake Biological Laboratory. In 2003, Chesapeake Biological Laboratory had the highest SAV season median PO_4 level due to much higher measurements from June-July than in other years. PO_4 levels met the SAV habitat requirement in all years at the downstream stations (with the exception of 2003 levels at Chesapeake Biological Lab), in most years at Pt. Patience, and in some years at Drum Pt. PO_4 levels at Jack Bay were significantly lower than the rest of the stations except Petersons Pt., but levels at the shallow water stations were not significantly different from levels at the closest long term station.

TSS levels generally decreased from upstream to downstream, but were significantly higher at the shallow water stations than at the nearest long term station. Overall, TSS levels were significantly higher at Pin Oak than the rest of the stations, but TSS levels were higher at Chesapeake Biological Laboratory in June, July and September 2003 and August 2006. All stations except Pin Oak met the habitat requirement in all years; Pin Oak levels met the requirement in 2004 and 2006, and were borderline in 2005.

CHLA levels also generally decreased from upstream to downstream, but overall were not significantly different between stations. Open water stations had much higher CHLA levels in 2003 than in the other years, due to much higher levels from April-July. CHLA levels met habitat requirements or were borderline at all stations in all years except 2003 levels at open water stations.

Secchi depths increased from upstream to downstream, and were significantly lower at the shallow water stations than at the closest long term station. Secchi depth failed to meet the habitat requirement at Jack Bay in all years and at Pin Oak and Petersons Pt. in some years. Water clarity met the requirement at Pt. Patience and Drum Pt. in all years and in most years at Chesapeake Biological Laboratory.

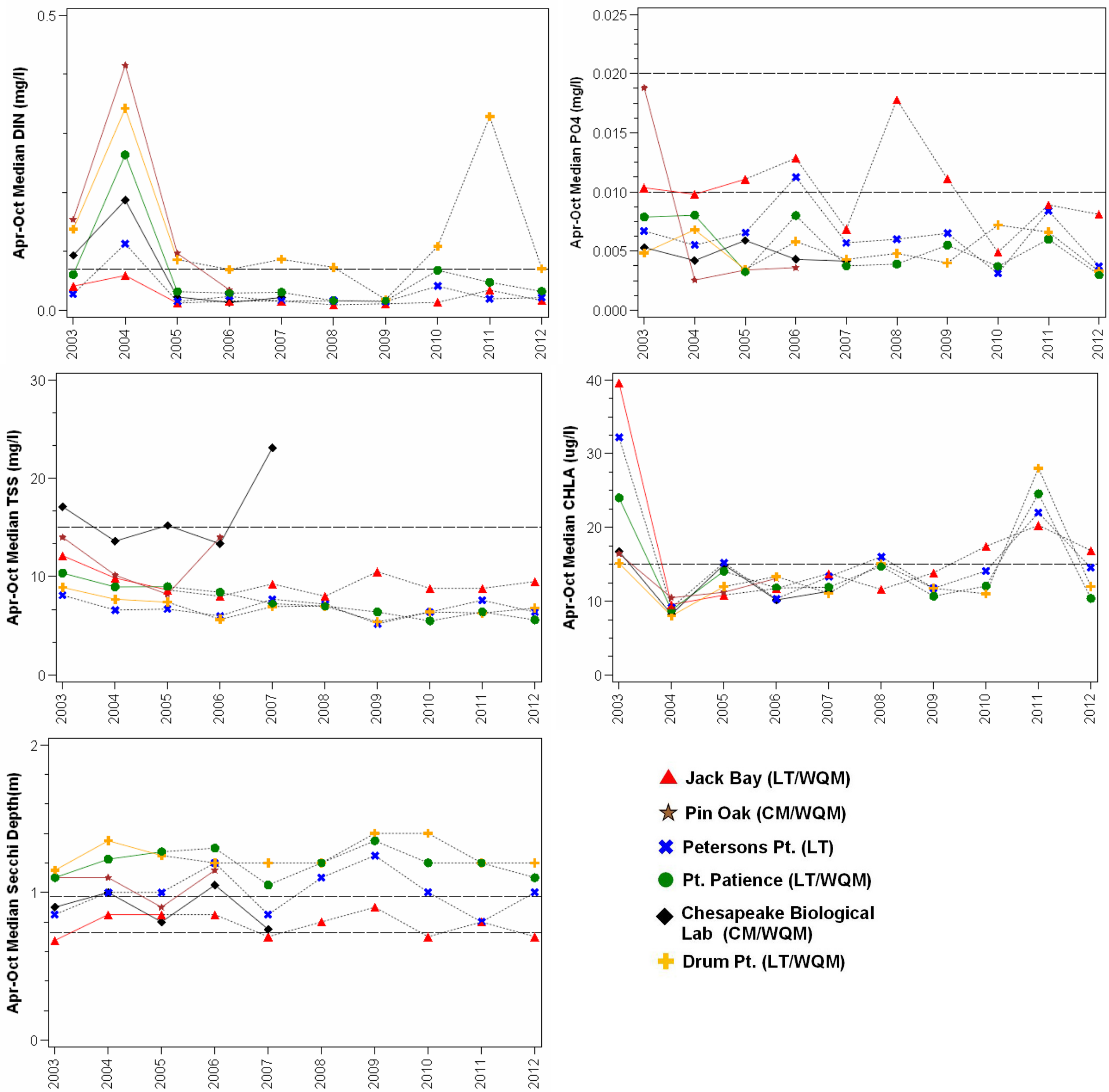

Figure 37. Shallow water and open water DIN, PO_4, TSS and CHLA levels and Secchi depths in Lower Patuxent River.
SAV growing season median values are shown. Habitat requirement threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of PO_4, TSS and CHLA need to be lower than the threshold, Secchi depth needs to be above the threshold. Long-term monitoring stations (LT) have dashed lines. Continuous monitoring (CM) and Water Quality Mapping (WQM) calibration stations have solid lines. CM and WQM data was collected in 2003-2005. WQM was continued in 2006; continuous monitoring was continued in 2006 and 2007 at Pin Oak. For Jack Bay, Pt. Patience and Drum Pt. stations, 2003-2005 data includes WQM calibration and long-term data (solid line); for 2006-2012 is only long-term data (dashed line).

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 was sampled at three of the long-term tidal water quality stations in the Patuxent (Nottingham, Lower Marlboro, Jack Bay) in spring and summer. The phytoplankton index of biotic integrity (PIBI) assesses the health of the community. [52] A PIBI score of greater than 3 is considered meeting the goal for phytoplankton community health criteria.[53] From 1985-2010, PIBI scores at Jack Bay may have degraded in the spring and the summer, but there were no significant trends for the other stations. Spring and summer PIBI scores at all stations did not meet the goal for most years. Summer PIBI scores were very low at the Nottingham station in most years.

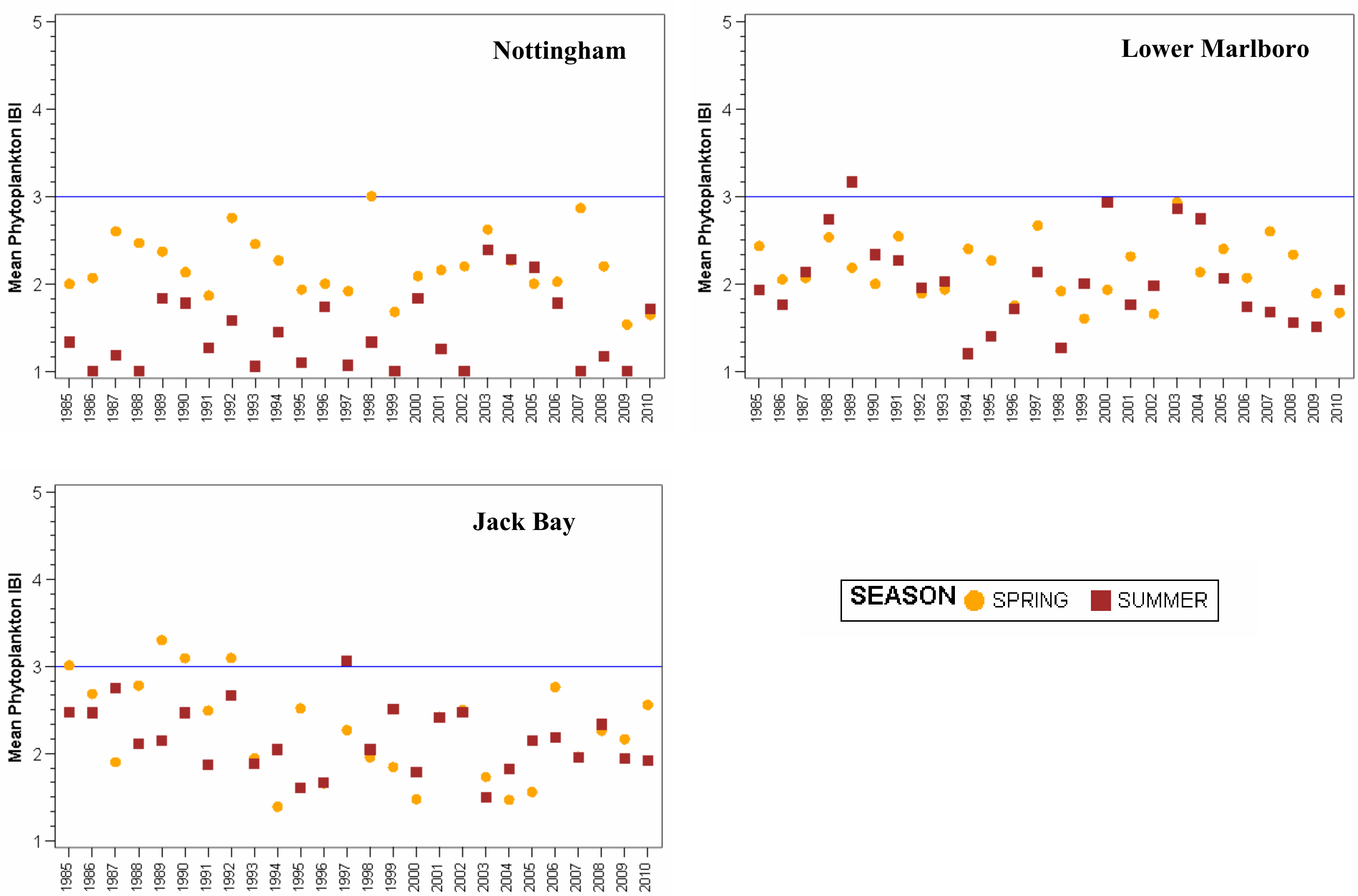

Figure 38. Spring and summer Phytoplankton Index of Biotic Integrity (PIBI) scores 1985-2010.

[52] Methods for calculation of the PIBI are available at http://www.chesapeakebay.net/images/indicators/5387/indicator_survey_phyto_ibi_2012_final.docx
[53] PIBI scores calculated by J. Johnson, Interstate Commission on the Potomac River Basin/Chesapeake Bay Program.

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. 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.[54]

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 22). 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. The tidal Patuxent river has recurrent mahogany tides (*Prorocentrum minimum*), usually in the area from Morgantown to the mouth of the river and into the mainstem Bay. Some bloom events have been associated with fish kills.

Figure 39. 'Mahogany tide' harmful algal bloom.

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

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).[55]

Upper Patuxent
The tidal fresh Patuxent River saw a remarkable growth of SAV since 1993. The 2005 aerial survey indicated there were 324 acres of SAV, the most ever recorded and 158% of the revised goal (Figure 32). In 2007, SAV coverage dropped to 116 acres; however, SAV steadily increased and in 2010, SAV acreage reached 148 acres or 72% of the restoration goal. SAV was found from Waysons Corner downstream to Nottingham, including Jug Bay, with dense patches fringing the shoreline. In 2012, SAV coverage dropped again to 30 acres, only 15% of the restoration goal

Middle Patuxent
The middle Patuxent area also saw remarkable re-vegetation in recent years. Beginning in 1994, when SAV first reappeared in this region with 53 acres, the SAV coverage increased to 125 acres in 2005 or 108% of the revised goal of 115 acres for this segment of the Patuxent. SAV was variable in the last few years with coverage decreasing to 66 acres (67%) in 2010, and to 16 acres in 2012 (14%). Ground-truthing by citizens has found seven species of SAV in Cocktown Creek, with the most commonly identified ones being hydrilla, naiads and coontail.

Lower Patuxent
The lower Patuxent River did not have a recovery similar to the upper two reaches. The VIMS annual aerial survey found only very small SAV beds (less than 25 acres) since 1987, though 2002 had 140 acres. This is well below the revised goal of 1,634 acres for this segment of the Patuxent. In recent years, SAV acreage had hovered around 40 acres, with no SAV mapped in 2005 or 2006. In 2010-2012, SAV acreage was 20 acres or less, 1% or less of the restoration goal. The few beds that were found in the last few years were in the Parker Wharf and Broomes Island areas or near Solomons Island.

[55] 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

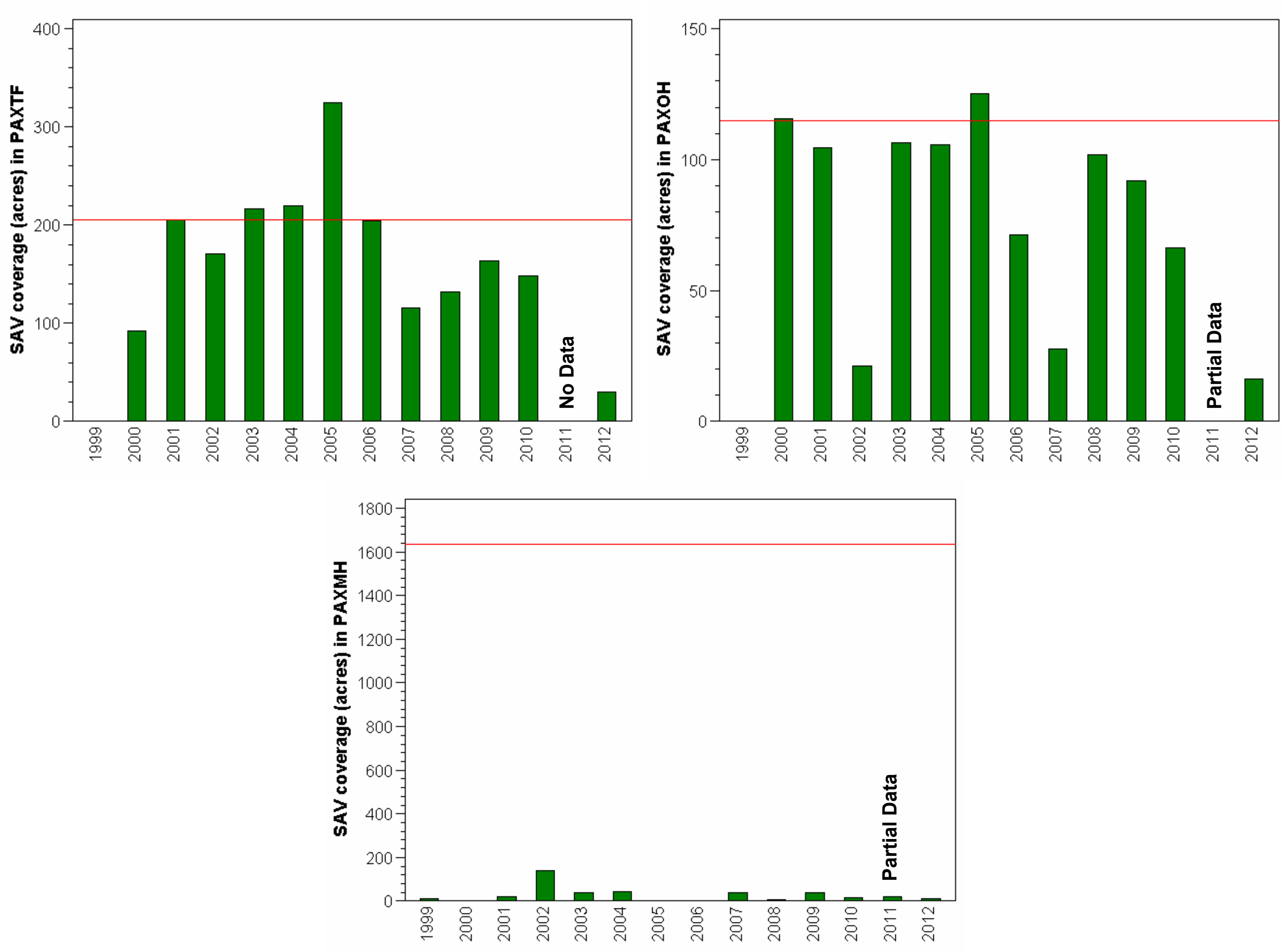

Figure 40. SAV coverages in the Patuxent River 1999-2012.
SAV data provided by the Virginia Institute of Marine Science. Red line shows the restoration goal for each river. Data for 2012 is preliminary.

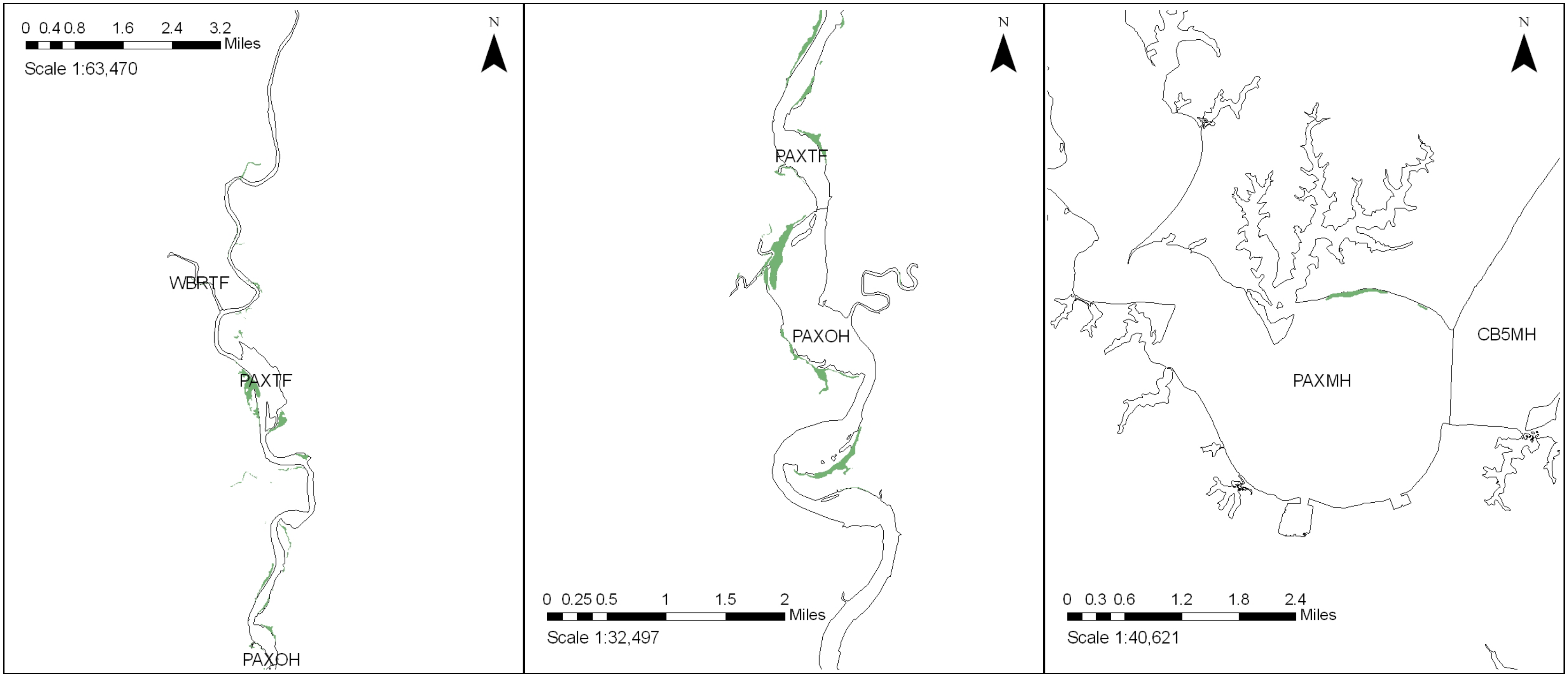

Figure 41. SAV beds in the Patuxent River in 2010.
Green areas show location SAV beds. Data provided by the Virginia Institute of Marine Science. River segment is also shown: WBRTF-Western Branch tidal fresh, PAXTF- Patuxent tidal fresh, PAXOH- Patuxent oligohaline, PAXMH – Patuxent mesohaline. Note that panels are not to the same scale and that some overlap occurs between the left panel and the middle panel. Data from 2010 is shown due to limited SAV presence in 2012.

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 in the summer at four long-term benthic monitoring stations in the Patuxent River. The Patuxent River stations have been monitored since 1984. The benthic index of biotic integrity (BIBI) assesses the health of the benthic community.[56] A BIBI score of greater than 3 is considered meeting the goal for benthic community health.

Benthic communities in the tidal fresh river (below Jug Bay) and lower oligohaline (near Chalk Point) met goals for 2010-2012. Benthic communities in the upper oligohaline near Holland Cliffs were degraded for 2010-2012, and have degraded from meeting goals in 1985-1987. The benthic community in the lower mesohaline river (off Broomes Island) was severely degraded for 2010-2012 and degraded since 1985.

Starting in 1996, samples were also collected from all of the rivers and mainstem Bay each year from randomly selected locations. The tidal Patuxent is sampled as a single area for the Benthic Monitoring Program. Twenty-five samples are randomly selected from the entire Patuxent River each year.

Over the entire 1996-2012 period, the Patuxent has been sampled in 425 locations. Degraded or severely degraded conditions were found in 57% of the locations. For the 2010-2012 period, 30 (40%) were severely degraded, 19 (25%) were degraded, 9 (12%) were marginal and 17 (23%) meet or exceed restoration goals. Most of the severely degraded locations were within the deep channel of the lower river, where dissolved oxygen is almost always depleted (hypoxic or anoxic) during the summer months.

On average, the area of bottom habitat that is degraded or severely degraded was 73 km^2 (57%). In three years (2002, 2009, 2012) more than 75% of the total area (97-102 acres) was found to be degraded or severely degraded. In 2010 the area that was degraded or severely degraded was 56%, in 2011 it was 64%, and in 2012 it was 76%.

[56] Methods for calculation of the BIBI are available at http://www.baybenthos.versar.com/DsgnMeth/Analysis.htm

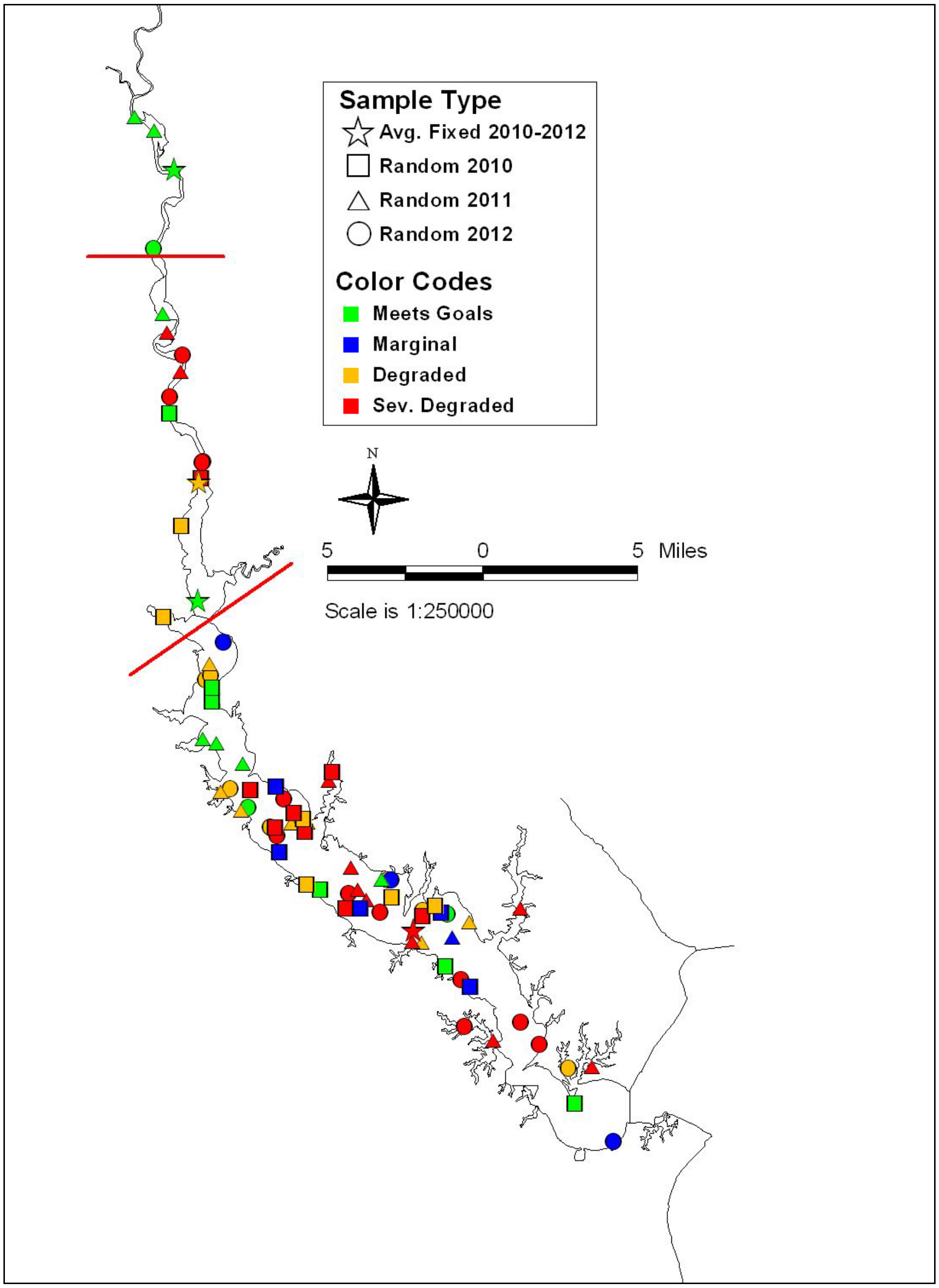

Figure 42. Benthic Index of Biotic Integrity results.
Random samples were collected in 75 locations in 2010-2012. Yellow circles show locations of long-term tidal water quality monitoring stations. A BIBI score of 3 or greater Meets Goals. BIBI scores of 2.7-2.9 are Marginal, 2.1-2.6 are Degraded and 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.

Land use in the Patuxent River watershed as a whole was roughly 40% urban and 40% forest. Approximately 20% of the watershed was used for agriculture. Agricultural land use was highest in the uppermost portions of the watershed, while the central watershed was 45% or more urban. The lower portion of the basin was largely forested. Between 2000 and 2010, urban land use increased by 11%, with largest increases in the Brighton Dam, Middle Patuxent River and Rocky Gorge Dam sub-watersheds. Impervious surfaces cover 9% of the basin overall.

Human population density was mostly low, though moderate densities were common in the areas surrounding cities and towns. There were also a few pockets of lower population density and of very high density. Stream health is fair. The Little Patuxent River sub-watershed is a high priority Trust Fund Restoration watershed and Western Branch sub-watershed is a medium priority watershed.

In the upper river, point sources were the largest contributor of nitrogen and phosphorus and agriculture was the largest contributor of sediments. Urban runoff was also an important source of nitrogen, phosphorus and sediment loadings to the upper river. In the middle river, agriculture was the largest source of nitrogen, phosphorus, and sediment loadings, but septic and forest sources were as important as agriculture for nitrogen loadings, and forest and urban were important sources of phosphorus loadings. In the lower river, septic was the largest source of nitrogen and forest and agriculture were also important. Point sources and agriculture were the major sources of phosphorus in the lower river, and sediment loadings were from agriculture and urban runoff.

All seven major wastewater treatment plants discharge to the upper river. Construction of ENR upgrades at the largest facility, Western Branch, began in 2011 and are scheduled to be complete by mid 2014. Construction of ENR upgrades at the second largest facility, Little Patuxent, began in 2009 and were completed by the end of 2012. At both facilities, nitrogen loadings in 2010-2011 were less than half previous levels. Phosphorus levels were more variable but were below the loading caps.

To reduce the impacts of continued development and increasing amounts of impervious surfaces in the Patuxent River watershed, multiple programs have protected more than 7,500 acres of land from development. To reduce impacts of agricultural lands, cover crops, fencing, containment structures and stream buffers have also been implemented in the basin. Stormwater retrofits have reduced nitrogen loadings from urban and suburban sources and prevented more than

18,200 pounds of nitrogen from entering streams. Almost 270 septic upgrades have been completed to reduce loadings from septic systems

Upper River

In the non-tidal area, phosphorus loadings decreased over the longer term, but sediment loadings increased over the shorter term. Also, phosphorus levels in the water decreased over the shorter term, but nitrogen levels in the water increased. There were no trends in sediment levels in the water at the non-tidal stations.

Nitrogen, phosphorus and sediment loadings at the fall line near Bowie decreased over the long term, and nitrogen loadings also decreased over the shorter term. Nitrogen and phosphorus levels in the water also decreased over the shorter term.

Nitrogen and phosphorous levels improved in the tidal waters of the Upper Patuxent River but levels were still too high to limit algal growth or to provide healthy habitat for underwater grasses. Sediment levels also improved but remained too high in the lower portion. Algal abundance may have improved in the upper Western Branch and the lower portion, but algal abundance has degraded in the middle of this section of the river. Algal abundance was too high to meet the SAV habitat requirement in most of the upper river. Water clarity was too low for healthy SAV habitat, but bottom dissolved oxygen levels were good.

During the intensive sampling program in 2003-2005, nitrogen, phosphorus and sediment levels and water clarity were similar between upstream shallow water areas and nearby open water areas. Nitrogen and sediment levels and algal abundance in Mataponi Creek were significantly lower than the main river, but phosphorus levels were similar. Water clarity was significantly higher in Mataponi Creek than the main river. However, summer dissolved oxygen levels at Mataponi Creek were below 3.2 mg/l around 30-40% of the time.

Algal populations were unhealthy at the downstream tidal station in the Upper Patuxent River, especially in the summer. Underwater grasses covered larger areas in the early 2000s, meeting restoration goals, but have not been as widespread in more recent years and were especially limited in 2012. Bottom dwelling animal populations were healthy.

Middle River

Nitrogen levels improved at the upper two stations and nitrogen limitation may have occurred in the summer in most years. Phosphorus levels improved at the upper station but degraded at the middle station. Phosphorus levels were still too high to provide healthy habitat for underwater grasses.

Sediment levels may have improved at the upper station but sediment levels were still too high at the two upstream stations. Algal densities degraded at the middle station, but levels were low enough at the two upstream stations in most years to indicate good habitat for underwater grasses.

Water clarity degraded at the middle station and may also have degraded at the downstream station. Water clarity was too low at all three stations. Water temperature increased at all three stations.

Summer bottom dissolved oxygen levels often fell to unhealthy levels at the upper two stations, and at the lower station were dangerously low about half of the time and degraded over the longer term period.

During the intensive sampling period from 2003-2005, nitrogen levels at a shallow water station in the upper portion of the Middle Patuxent were significantly lower and sediment levels and water clarity were significantly higher than at the nearby open water station upstream. Phosphorus levels at the shallow water station were significantly lower than at the nearby open water station downstream. Shallow water algal densities were similar to both open water stations.

In shallow waters in the mid-section of the Middle Patuxent, sediment levels were significantly lower and algal densities and water clarity were significantly higher than at the nearby open water station upstream. Phosphorus levels at one shallow water area were also significantly lower than at the nearby open water station.

Shallow waters in the lower Middle Patuxent at Benedict had significantly higher sediment levels than the nearby open water station downstream, but all other parameters were similar.

Algal populations were unhealthy at the upstream station in the Middle Patuxent River. Underwater grasses covered areas close to restoration goals until the last several years but were especially limited in 2012. Bottom dwelling animal populations were degraded or severely degraded in many areas and have degraded over the longer term period.

Lower River

Nitrogen levels improved at all stations in the lower river over the longer term, but over the shorter term nitrogen levels degraded at the upstream station. Phosphorus levels also degraded at the upstream station, and may have degraded at the next station downstream. However, phosphorus levels were low enough for healthy underwater habitat at all stations and both nitrogen and phosphorus levels were low enough to allow seasonal nutrient limitation of algal growth in the lower river.

Sediment levels may have improved at the two middle stations, and levels were low enough to provide healthy underwater grass habitat. Algal abundance degraded at all stations over the shorter term and at the three downstream stations over the longer term. Still, algal abundance was low enough to indicate good underwater grass habitat in most years at the three lower stations except in 2011 when all four stations failed to meet the requirement.

Water clarity degraded at all stations over the longer term and at the upstream and downstream stations over the shorter term. Water clarity failed to meet the underwater grass habitat requirement at the upstream station but met the requirement at the other stations in most years. Salinity decreased and water temperatures increased throughout the lower river over both the shorter and longer terms periods.

Summer bottom dissolved oxygen levels were dangerously low at the two upstream stations. At the two stations farthest downstream, summer bottom dissolved levels were higher but still too low. However, summer bottom dissolved oxygen was unusually high at all stations in 2012. Summer bottom dissolved oxygen also degraded at the upstream station over both the shorter and longer term periods.

During the intensive sampling period from 2003-2005, nitrogen and phosphorus levels and algal densities at the shallow water stations were not significantly different from levels at the closest open water station. Sediment levels were significantly higher and water clarity was significantly lower at the shallow water stations than at the nearest open water station.

Algal populations were unhealthy at the upstream station in the Lower Patuxent River and may have degraded over the longer term period. Very limited areas of underwater grass beds were present in this section of the river. Bottom dwelling animal populations were degraded or severely degraded in many areas and have degraded over the longer term period.

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 is available at www.planning.maryland.gov/OurWork/landUse.shtml. 2000 data is available from Maryland Department of Planning, Planning Data Services, (410) 767-4450. Use codes are 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
Brighton Dam	AGRICULTURE	42.94	**53%**	30.71	**39%**	12.24	13%
	BARREN LAND	0.01	0%	0.00	0%	0.01	0%
	FOREST	26.64	**33%**	23.53	**30%**	3.11	3%
	TRANSPORTATION	0.00	0%	0.13	0%	-0.13	0%
	URBAN	11.93	15%	23.64	**30%**	-11.71	**-16%**
	WETLANDS	0.05	0%	0.04	0%	0.02	0%
	IMPERVIOUS SURFACE	1.88	2%	2.73	3%	-0.85	-1%
Middle Patuxent River	AGRICULTURE	21.10	**36%**	16.16	**28%**	4.94	8%
	BARREN LAND	0.11	0%	0.10	0%	0.01	0%
	FOREST	16.52	**28%**	13.48	**23%**	3.04	5%
	TRANSPORTATION	0.00	0%	0.58	1%	-0.58	-1%
	URBAN	20.37	**35%**	27.75	**48%**	-7.38	**-13%**
	WETLANDS	0.00	0%	0.00	0%	0.00	0%
	IMPERVIOUS SURFACE	3.72	6%	5.01	9%	-1.29	-2%
Little Patuxent River	AGRICULTURE	13.15	13%	7.73	7%	5.43	5%
	BARREN LAND	0.16	0%	1.36	1%	-1.20	-1%
	FOREST	38.53	**37%**	32.81	**32%**	5.72	6%
	TRANSPORTATION	0.00	0%	2.57	2%	-2.57	0%
	URBAN	51.59	**50%**	59.00	**57%**	-7.41	**-7%**
	WETLANDS	0.02	0%	0.01	0%	0.00	0%
	IMPERVIOUS SURFACE	15.30	15%	19.46	19%	-4.16	-4%
Rocky Gorge Dam	AGRICULTURE	14.98	**29%**	11.46	**22%**	3.51	7%
	BARREN LAND	0.00	0%	0.04	0%	-0.04	0%
	FOREST	20.42	**39%**	16.86	**32%**	3.56	7%
	TRANSPORTATION	0.00	0%	0.11	0%	-0.11	0%
	URBAN	16.57	**32%**	24.06	**46%**	-7.49	**-14%**
	WETLANDS	0.00	0%	0.00	0%	0.00	0%
	IMPERVIOUS SURFACE	3.15	6%	3.36	6%	-0.21	0%
Patuxent River upper	AGRICULTURE	15.98	18%	12.37	14%	3.61	4%
	BARREN LAND	0.43	0%	0.57	1%	-0.14	0%
	FOREST	39.20	**45%**	37.39	**42%**	1.81	2%
	TRANSPORTATION	0.74	1%	0.99	1%	-0.26	0%
	URBAN	31.67	**36%**	36.61	**42%**	-4.94	**-6%**
	WETLANDS	0.00	0%	0.14	0%	-0.14	0%
	IMPERVIOUS SURFACE	9.31	11%	10.04	11%	-0.74	-1%
Western Branch	AGRICULTURE	16.79	15%	13.11	12%	3.69	3%
	BARREN LAND	1.15	1%	2.85	3%	-1.70	-2%
	FOREST	44.03	**39%**	38.88	**35%**	5.14	5%
	TRANSPORTATION	1.60	1%	1.22	1%	0.38	0%
	URBAN	47.61	**43%**	55.04	**49%**	-7.43	**-7%**
	WETLANDS	0.36	0%	0.36	0%	0.00	0%
	IMPERVIOUS SURFACE	15.25	14%	15.88	14%	-0.63	-1%
Patuxent River middle	AGRICULTURE	32.35	**38%**	25.20	**29%**	7.16	8%
	BARREN LAND	0.15	0%	0.35	0%	-0.20	0%
	FOREST	37.99	**44%**	35.27	**41%**	2.72	3%
	TRANSPORTATION	0.04	0%	0.36	0%	-0.32	0%
	URBAN	12.22	14%	21.53	**25%**	-9.31	**-11%**
	WETLANDS	2.78	3%	2.77	3%	0.01	0%
	IMPERVIOUS SURFACE	1.93	2%	2.82	3%	-0.89	-1%
Patuxent River lower	AGRICULTURE	77.08	**24%**	57.28	18%	19.79	6%
	BARREN LAND	0.38	0%	0.55	0%	-0.17	0%
	FOREST	167.57	**51%**	146.47	**45%**	21.10	6%
	TRANSPORTATION	0.00	0%	0.95	0%	-0.95	0%
	URBAN	73.29	**23%**	112.73	**35%**	-39.44	**-12%**
	WETLANDS	7.14	2%	6.94	2%	0.20	0%
	IMPERVIOUS SURFACE	15.18	5%	18.91	6%	-3.73	-1%
Entire Basin	AGRICULTURE	234.38	**26%**	174.01	19%	60.36	7%
	BARREN LAND	2.39	0%	5.81	1%	-3.42	0%
	FOREST	390.89	**43%**	344.69	**38%**	46.20	5%
	TRANSPORTATION	2.37	0%	6.92	1%	-4.54	-1%
	URBAN	265.26	**29%**	360.37	**40%**	-95.11	**-11%**
	WETLANDS	10.35	1%	10.26	1%	0.09	0%
	IMPERVIOUS SURFACE	65.72	7%	78.22	9%	-12.50	-1%

Appendix 2

Delivered Loads to the Patuxent River

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)

Loadings by source
Loadings > 20% are in **BOLD**

section	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
Western Branch	WBRTF	Agriculture	0.032	13%	0.0041	16%	9.00	**39%**
		Forest	0.061	**26%**	0.0031	12%	2.79	12%
		NT Water Dep	0.002	1%	0.0001	0%		
		Septic	0.045	19%				
		Urban Runoff	0.097	**41%**	0.0187	**72%**	11.44	**49%**
		Point Source	0.000	0%	0.0000	0%	0.00	0%
		TOTAL	**0.236**		**0.0260**		**23.23**	
Tidal Fresh	PAXTF	Agriculture	0.287	16%	0.0326	**22%**	28.20	**42%**
		Forest	0.286	16%	0.0151	10%	15.60	**23%**
		NT Water Dep	0.010	1%	0.0007	0%		
		Septic	0.236	13%				
		Urban Runoff	0.343	20%	0.0460	**31%**	23.28	**35%**
		Point Source	0.591	**34%**	0.0562	**37%**	0.25	0%
		TOTAL	**1.753**		**0.1506**		**67.34**	
Oligohaline	PAXOH	Agriculture	0.116	**33%**	0.0150	**48%**	8.68	**80%**
		Forest	0.105	**30%**	0.0064	**20%**	1.23	11%
		NT Water Dep	0.004	1%	0.0003	1%		
		Septic	0.091	**26%**				
		Urban Runoff	0.032	9%	0.0062	20%	0.88	8%
		Point Source	0.007	2%	0.0034	11%	0.00	0%
		TOTAL	**0.355**		**0.0313**		**10.78**	
Mesohaline	PAXMH	Agriculture	0.145	**23%**	0.0182	**29%**	8.25	**68%**
		Forest	0.165	**27%**	0.0106	17%	2.20	18%
		NT Water Dep	0.005	1%	0.0004	1%		
		Septic	0.239	**38%**				
		Urban Runoff	0.047	8%	0.0091	14%	1.66	14%
		Point Source	0.021	3%	0.0255	**40%**	0.02	0%
		TOTAL	**0.622**		**0.0638**		**12.13**	
Entire River		Agriculture	0.579	20%	0.0699	**26%**	54.12	**48%**
		Forest	0.617	**21%**	0.0352	13%	21.83	19%
		NT Water Dep	0.021	1%	0.0015	1%		
		Septic	0.611	**21%**				
		Urban Runoff	0.519	18%	0.0800	**29%**	37.26	**33%**
		Point Source	0.618	**21%**	0.0851	**31%**	0.28	0%
		TOTAL	**2.966**		**0.2717**		**113.49**	

Appendix 3

Station names, locations and descriptions

Long-term non-tidal and tidal water quality stations

Station Name	Location/Depth	Latitude/ Longitude (NAD83 DMS)	Characterizes
PXT0972	At bridge on Route 97 near Unity Gage (USGS gage 01591000)	39° 14.358'N 77° 33.713'W	free-flowing freshwater
PXT0809	At gage station below Rocky Gorge Dam (USGS gage 01592500)	39° 7.008' N 76° 52.496'W	free-flowing freshwater
TF1.0	At bridge on US Rt. 50 (upstream side of bridge; USGS gage 01594440); 3.0 m.	38° 57.334'N 76° 41.647'W	tidal fresh
TF1.2	Midstream of Western Branch at Water Street crossing in Upper Marlboro, MD; 3.0 m.	38° 48.858'N 76° 45.052'W	tidal fresh
WXT0001	Western Brach from pier at Mt Calvert House in Upper Marlboro, 0.1 miles above mouth; 1.0 m.	38° 47.123'N 76° 42.806'W	tidal fresh
TF1.3	Mid-channel from MD Rt. 4 bridge near Waysons Corner; 3.7 m.	38° 48.655'N 76° 42.736'W	tidal fresh
TF1.4	West Shore from main pier at Jackson Landing; just below confluence with Western Branch; 3.0 m.	38° 46.381'N 76° 42.556'W	tidal fresh
TF1.5	Mid-channel at Nottingham, 11.1m.	38° 42.607'N 76° 42.088'W	tidal fresh
TF1.6	Mid-channel off the wharf at Lower Marlboro, 6.0 m.	38° 39.507'N 76° 41.029'W	transition zone
TF1.7	Mid-channel on a transect heading of approx. 115 degrees from Jack's Creek; 3.1 m.	38° 34.926'N 76° 40.860'W	transition zone
RET1.1	Mid channel, 0.5 km ENE of Long Point, 11.1 m.	38° 29.454'N 76° 39.857'W	transition zone
LE1.1	Mid-channel SSW of Jack Bay sand-spit. NE of Sandgates; 12.5 m.	38° 25.521'N 76° 36.106'W	lower estuarine
LE1.2	Mid-channel,1.6 km SW of Petersons Pt.; 17.8 m.	38° 22.732'N 76° 30.679'W	lower estuarine
LE1.3	Mid-channel 1200 m due N of Pt. Patience, ESE of Half Pone Pt; 23.1 m.	38° 20.453'N 76° 29.293'W	lower estuarine
LE1.4	Mid-channel on a transect between Drum Pt. and Fishing Pt; 16.5 m.	38° 18.720'N 76° 25.291'W	lower estuarine

Shallow water monitoring locations and dates

Segment	Station Name	Station	Years deployed	LAT (NAD83)	LONG (NAD83)
WBRTF	Iron Pot Landing	WXT0013	2003 – present	38° 47.760’ N	76° 43.248’ W
PAXTF	Jug Bay	PXT0455	2003 – present	38° 46.877’ N	76° 42.822’ W
	Mataponi Creek	MTI0015	2003 – present	38° 44.599’ N	76° 42.446’ W
	Water quality mapping calibration station	PXT0435	2003 – 2005	38° 45.426’ N	76° 41.958’ W
PAXOH	Kings Landing	PXT0311	2003 – 2005	38° 37.578’ N	76° 40.608’ W
	Additional Water quality mapping calibration stations	TF1.7	2003 – 2005	38° 34.866’ N	76° 40.602’ W
		XEE3604	2003 – 2005	38° 33.630’ N	76° 39.630’ W
		XFD1283	2003 – 2005	38° 41.178’ N	76° 41.748’ W
PAXMH	Benedict	XED0694	2003 – 2005	38° 30.618’ N	76° 40.632’ W
	Pin Oak	XDE4587	2003 – 2007	38° 24.528’ N	76° 31.308’ W
	Chesapeake Biological Laboratory	XCF9029	2003 – 2005	38° 19.002’ N	76° 27.156’ W
	Additional Water quality mapping calibration stations	LE1.1	2003 – 2005	38° 25.368’ N	76° 36.126’ W
		LE1.3	2003 – 2006	38° 20.388’ N	76° 29.094’ W
		LE1.4	2003 – 2005	38° 18.756’ N	76° 25.332’ W
		XDD9298	2003	38° 29.220’ N	76° 40.218’ W
		XEE1502	2003 – 2005	38° 31.518’ N	76° 39.840’ 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 concentrations 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 designated use (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 concentrations for 2008-2010 for PO_4, TSS and CHLA 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. For non-tidal water quality stations, concentrations of TN, TP and TSS were evaluated. For tidal water quality stations, 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 bottom DO, 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 concentrations (TN:TP, DIN:PO_4) that may explain more about nutrient use by aquatic plants and limitations of available nutrients.

Non-tidal water quality data was tested for linear trends for 1999-2010 and 1986-2010. Tidal water quality data were tested for linear trends for 1985-1997, 1999-2010 and 1985-2010. Tests for non-linear trends were also done for 1985-2010 with the tidal water quality data. 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 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. 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 depths 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

Annual trends results from non-tidal water quality stations
Trend results from 1999-2012 and 1986-2012

Data is from the surface layer. Red colored results indicate degrading conditions. Green colored results indicate improving conditions. Grey shading of the 1986-2012 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 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 $p < 0.05$.

	map#	STATION	1999-2012 Linear	1986-2012 Linear	1986-2012 Non Linear	1986-2012 NLN inflection
TN	1	PXT0972	INC	INC		
	2	PXT0809	NT	NT-DEC		
	3	TF1.0	DEC	DEC	U	Aug-05
TP	1	PXT0972	DEC	DEC		
	2	PXT0809	NT	DEC		
	3	TF1.0	DEC	DEC	U	Mar-06
TSS	1	PXT0972	NT	NT-SLOPE = 0		
	2	PXT0809	NT	NT		
	3	TF1.0	NT	NT		

Appendix 7

Current status and annual trends results from the tidal water quality stations.
Trend results from 1991-2012, 1999-2012 and 1985-2012

Data is from the surface layer with the exception of dissolved oxygen, which is from the bottom and the dissolved oxygen trends are for summer only (June-September). Red colored status and trends results indicate poor or degrading conditions. Green colored status and trends results indicate good or improving conditions. Blue colored status indicates fair status. Blue colored trends indicate decreasing trends where a qualitative assessment (improving or degrading) is not applicable; purple colored trends indicate increasing trends in the same parameters. Grey shading of the 1991-2012 and 1985-2012 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 $0.01 < p \leq 0.05$, NT (no trend) precedes the abbreviation. NT alone indicates trend is not significant at $p < 0.05$. '*' indicates too much of the data was below detection limits to calculate the trend.

PARAM	River portion	Station	2010-2012 Median	2010-2012 Status	1999-2012 Linear Trend	1991-2012 Linear Trend	1991-2012 Non-Linear Trend	1991-2012 NLN Inflection	1985-2012 Linear Trend	1985-2012 Non-Linear Trend	1985-2012 NLN Inflection
TN	Western Branch	TF1.2	0.75	GOOD	IMP	IMP			IMP		
		WXT0001	1.15	GOOD	IMP	IMP			no data		
	Upper River	TF1.3	1.65	POOR	IMP	IMP	U	2011	IMP	U	2004
		TF1.4	1.32	GOOD	IMP	IMP			IMP	U	2007
		TF1.5	1.09	GOOD	IMP	IMP			IMP	U	2008
	Middle River	TF1.6	1.05	GOOD	IMP	IMP	INV-U	1994	IMP	U	2010
		TF1.7	1.00	GOOD	NT	IMP			IMP		
		RET1.1	0.82	POOR	NT	NT			IMP		
	Lower River	LE1.1	0.71	GOOD	DEG	NT			IMP		
		LE1.2	0.67	GOOD	NT	NT			IMP		
		LE1.3	0.66	GOOD	NT	NT			IMP		
		LE1.4	0.73	GOOD	NT	NT			IMP		
DIN	Western Branch	TF1.2	0.307	GOOD	IMP	IMP			Not evaluated due to lab change		
		WXT0001	0.424	GOOD	IMP	IMP					
	Upper River	TF1.3	1.053	POOR	IMP	IMP	U	2009	Not evaluated due to lab change		
		TF1.4	0.711	GOOD	IMP	IMP					
		TF1.5	0.416	GOOD	IMP	IMP					
	Middle River	TF1.6	0.394	GOOD	IMP	IMP	INV-U	1999	Not evaluated due to lab change		
		TF1.7	0.291	GOOD	IMP	IMP	INV-U	1996			
		RET1.1	0.070	GOOD	NT	IMP					
	Lower River	LE1.1	0.022	GOOD	NT	NTIMP			Not evaluated due to lab change		
		LE1.2	0.028	GOOD	NT	IMP					
		LE1.3	0.044	GOOD	NT	IMP					
		LE1.4	0.103	GOOD	NT	IMP					
TP	Western Branch	TF1.2	0.058	GOOD	NT	IMP			Not evaluated due to lab change		
		WXT0001	0.126	POOR	IMP	IMP					
	Upper River	TF1.3	0.080	GOOD	IMP	IMP			Not evaluated due to lab change		
		TF1.4	0.109	POOR	IMP	IMP					
		TF1.5	0.122	POOR	IMP	IMP					
	Middle River	TF1.6	0.122	POOR	IMP	IMP			Not evaluated due to lab change		
		TF1.7	0.136	POOR	NT	NT					
		RET1.1	0.086	POOR	NT	NT					
	Lower River	LE1.1	0.045	POOR	DEG	NT			Not evaluated due to lab change		
		LE1.2	0.038	GOOD	NTDEG	NT					
		LE1.3	0.033	GOOD	NT	NTDEG					
		LE1.4	0.029	GOOD	NT	DEG					

PARAM	River portion	Station	2010-2012 Median	2010-2012 Status	1999-2012 Linear Trend	1991-2012 Linear Trend	1991-2012 Non-Linear Trend	1991-2012 NLN Inflection	1985-2012 Linear Trend	1985-2012 Non-Linear Trend	1985-2012 NLN Inflection
PO4	Western Branch	TF1.2	0.0121	GOOD	NT	IMP	U	2007	Not evaluated due to lab change		
		WXT0001	0.0291	GOOD	IMP	IMP					
	Upper River	TF1.3	0.0150	GOOD	IMP	IMP	U	2010	Not evaluated due to lab change		
		TF1.4	0.0144	GOOD	IMP	IMP	INC_T_ASYM	2013			
		TF1.5	0.0193	GOOD	IMP	IMP					
	Middle River	TF1.6	0.0283	GOOD	NT	NTIMP			Not evaluated due to lab change		
		TF1.7	0.0325	GOOD	NTIMP	IMP					
		RET1.1	0.0132	GOOD	NT	NTIMP	U	2002			
	Lower River	LE1.1	0.0041	GOOD	NT	NT	U	2001	Not evaluated due to lab change		
		LE1.2	0.0031	GOOD	NT	NT					
		LE1.3	0.0031	GOOD	NT	NT					
		LE1.4	0.0033	GOOD	NT	NT					
TSS	Western Branch	TF1.2	3.4	GOOD	NT	*			Not evaluated due to lab change		
		WXT0001	10.6	GOOD	IMP	IMP					
	Upper River	TF1.3	11.6	GOOD	IMP	NT			Not evaluated due to lab change		
		TF1.4	18.8	POOR	IMP	NT					
		TF1.5	29.5	POOR	NTIMP	NT					
	Middle River	TF1.6	31.0	POOR	NTIMP	NTIMP			Not evaluated due to lab change		
		TF1.7	31.8	POOR	NT	NTDEG					
		RET1.1	15.1	POOR	NT	NTIMP					
	Lower River	LE1.1	8.8	FAIR	NT	NT			Not evaluated due to lab change		
		LE1.2	6.4	GOOD	NT	NT	INV-U	2001			
		LE1.3	5.5	GOOD	NT	NT	INV-U	2000			
		LE1.4	6.4	GOOD	NT	NT	INV-U	2002			
CHLA	Western Branch	TF1.2	2.4	GOOD	NTIMP	NTIMP			IMP		
		WXT0001	5.6	GOOD	NT	NT			no data		
	Upper River	TF1.3	5.3	GOOD	NT	NT			NT		
		TF1.4	7.8	POOR	NT	NT			NTDEG		
		TF1.5	22.4	POOR	NTIMP	IMP			IMP		
	Middle River	TF1.6	10.2	FAIR	NT	IMP			IMP		
		TF1.7	12.0	POOR	DEG	NTDEG			DEG		
		RET1.1	19.1	POOR	NT	DEG			DEG		
	Lower River	LE1.1	17.6	POOR	DEG	DEG			DEG		
		LE1.2	15.4	POOR	DEG	DEG			DEG		
		LE1.3	12.7	POOR	NTDEG	DEG	INV-U	2004	DEG		
		LE1.4	13.3	POOR	NTDEG	DEG			DEG		

PARAM	River portion	Station	2010-2012 Median	2010-2012 Status	1999-2012 Linear Trend	1991-2012 Linear Trend	1991-2012 Non-Linear Trend	1991-2012 NLN Inflection	1985-2012 Linear Trend	1985-2012 Non-Linear Trend	1985-2012 NLN Inflection
SECCHI	W. Branch	WXT0001	0.60	GOOD	NT	NT			no data		
	Upper River	TF1.3	0.45	POOR	NT	NT			NT		
		TF1.4	0.40	POOR	NT	NT			NT		
		TF1.5	0.30	POOR	NT	SLOPE=0			SLOPE=0	INV-U	1996
	Middle River	TF1.6	0.30	POOR		SLOPE=0			SLOPE=0	INV-U	1995
		TF1.7	0.30	POOR	SLOPE=0	DEG			DEG		
		RET1.1	0.50	POOR	NTDEG	DEG			DEG		
	Lower River	LE1.1	0.80	POOR	DEG	DEG			DEG		
		LE1.2	1.00	POOR	NT	DEG			DEG		
		LE1.3	1.20	FAIR	NT	DEG			DEG		
		LE1.4	1.35	GOOD	NTDEG	DEG			DEG		
DO	Upper River	TF1.5	5.8	GOOD	NT	DEG			DEG		
	Middle River	TF1.6	5.2	GOOD	NT	DEG			DEG		
		TF1.7	5.0	FAIR	NT	NT			NT		
		RET1.1	3.8	FAIR	NT	NT			NT		
	Lower River	LE1.1	1.1	POOR	NT	NT			NT		
		LE1.2	2.0	POOR	NT	NT			NT		
		LE1.3	3.0	FAIR	NT	NTDEG			NT		
		LE1.4	2.8	FAIR	DEG	DEG			DEG		
SALINITY	Western Branch	TF1.2	0.0	Not applicable	SLOPE=0	SLOPE=0	NT		SLOPE=0		
		WXT0001	0.0		NT		NT		no data		
	Upper River	TF1.3	0.0								
		TF1.4	0.0		NT		NT		SLOPE=0		
		TF1.5	0.0		NT	NT	NT		NT		
	Middle River	TF1.6	0.1		NT	NT	NT		SLOPE=0	U	2002
		TF1.7	3.0		NT	NT	NT		DEC	U	2003
		RET1.1	10.7		NTDEC	NT	NT		DEC	U	2005
	Lower River	LE1.1	11.7		DEC	NT	NT		DEC		
		LE1.2	12.2		DEC	NT	NT		DEC		
		LE1.3	12.6		DEC	NT	NT		DEC		
		LE1.4	13.3		DEC	NT	NT		DEC		

PARAM	River portion	Station	2010-2012 Median	2010-2012 Status	1999-2012 Linear Trend	1991-2012 Linear Trend	1991-2012 Non-Linear Trend	1991-2012 NLN Inflection	1985-2012 Linear Trend	1985-2012 Non-Linear Trend	1985-2012 NLN Inflection
WTEMP	Western Branch	TF1.2	14.1	Not applicable	INC	NT	NT		NT	U	2000
		WXT0001	16.7		INC	NT	NT		no data		
	Upper River	TF1.3	15.2		INC	NT	NT		NT	U	1998
		TF1.4	15.5		NTINC	NTINC	NT		NT	U	1998
		TF1.5	18.6		INC	INC	NT		INC		
	Middle River	TF1.6	16.0		INC	INC	NT		INC		
		TF1.7	16.7		NTINC	INC	NT		INC		
		RET1.1	16.9		INC	INC	NT		INC		
	Lower River	LE1.1	16.4		INC	INC	NT		INC		
		LE1.2	16.4		INC	INC	NT		INC		
		LE1.3	16.1		INC	INC	NT		INC		
		LE1.4	16.3		INC	INC	NT		INC		
TN:TP	Western Branch	TF1.2	23.7	Not applicable	NT	NT	NT		Not evaluated due to lab change		
		WXT0001	18.6		NTDEC	NT	NT				
	Upper River	TF1.3	38.4		NTINC	NTINC	NT		Not evaluated due to lab change		
		TF1.4	27.3		NT	NT	NT				
		TF1.5	20.5		NT	NT	NT				
	Middle River	TF1.6	18.1		NT	NT	NT		Not evaluated due to lab change		
		TF1.7	16.8		DEC	DEC	NT				
		RET1.1	21.5		NT	NT	NT				
	Lower River	LE1.1	31.6		NT	NT	NT		Not evaluated due to lab change		
		LE1.2	37.7		NT	DEC	NT				
		LE1.3	42.3		NT	DEC	U	2005			
		LE1.4	48.8		NT	DEC	U	2005			
DIN:PO4	Western Branch	TF1.2	46.4	Not applicable	NTDEC	NT	INV-U	2002	Not evaluated due to lab change		
		WXT0001	26.2		DEC	NT	NT				
	Upper River	TF1.3	152.4		NTINC	INC	NT		Not evaluated due to lab change		
		TF1.4	80.1		NT	NT	NT				
		TF1.5	36.5		NTDEC	NT	INV-U	2002			
	Middle River	TF1.6	26.3		DEC	NT	INV-U	2001	Not evaluated due to lab change		
		TF1.7	17.2		DEC	NT	NT				
		RET1.1	6.9		NT	NT	NT				
	Lower River	LE1.1	16.3		NT	NT	NT		Not evaluated due to lab change		
		LE1.2	36.9		NT	NTDEC	NT				
		LE1.3	57.2		NT	DEC	NT				
		LE1.4	79.1		NT	DEC	NT				

PARAM	River portion	Station	2010-2012 Median	2010-2012 Status	1999-2012 Linear Trend	1991-2012 Linear Trend	1991-2012 Non-Linear Trend	1991-2012 NLN Inflection	1985-2012 Linear Trend	1985-2012 Non-Linear Trend	1985-2012 NLN Inflection
NH4	Western Branch	TF1.2	0.048	Not applicable	NT	NT	NT		Not evaluated due to lab change		
		WXT0001	0.066		IMP	IMP	NT				
	Upper River	TF1.3	0.055		IMP	IMP	NT		Not evaluated due to lab change		
		TF1.4	0.059		NTIMP	IMP	NT				
		TF1.5	0.033		NTIMP	NT	NT				
	Middle River	TF1.6	0.074		IMP	NT	NT		Not evaluated due to lab change		
		TF1.7	0.058		IMP	IMP	NT				
		RET1.1	0.015		NT	NTIMP	NT				
	Lower River	LE1.1	0.037		*	*	NT		Not evaluated due to lab change		
		LE1.2	0.022		*	*	NT				
		LE1.3	0.019		*	*	NT				
		LE1.4	0.022		NT	NT	NT				
NO23	Western Branch	TF1.2	0.248	Not applicable	IMP	IMP	NT		Not evaluated due to lab change		
		WXT0001	0.302		IMP	IMP	NT				
	Upper River	TF1.3	1.075		IMP	IMP	U	2009	Not evaluated due to lab change		
		TF1.4	0.593		IMP	IMP	NT				
		TF1.5	0.352		IMP	IMP	NT				
	Middle River	TF1.6	0.342		IMP	IMP	INV-U	1999	Not evaluated due to lab change		
		TF1.7	0.252		IMP	IMP	INV-U	1998			
		RET1.1	0.027		NT	IMP	NT				
	Lower River	LE1.1	0.045		NT	IMP	NT		Not evaluated due to lab change		
		LE1.2	0.047		NT	IMP	NT				
		LE1.3	0.065		NT	IMP	NT				
		LE1.4	0.072		NT	IMP	NT				

Appendix 8

Seasonal trends results for long-term tidal water quality data

Seasonal trends results for surface data from 1999-2012. Color codes and abbreviations are the same as used in Appendix 7.

param	River portion	STATION	ANNUAL Jan-Dec 2012	SPRING Mar-May 2012	SUMMER Jun-Sep 2012	SAV Apr-Oct 2012
TN	Western Branch	TF1.2	**IMP**	NT	NTIMP	NTIMP
		WXT0001	**IMP**	NTIMP	**IMP**	**IMP**
	Upper River	TF1.3	**IMP**	NT	**IMP**	**IMP**
		TF1.4	**IMP**	NTIMP	NTIMP	**IMP**
		TF1.5	**IMP**	NT	**IMP**	**IMP**
	Middle River	TF1.6	**IMP**	NTIMP	NTIMP	**IMP**
		TF1.7	NT	NT	NT	NT
		RET1.1	NT	NT	NT	NT
	Lower River	LE1.1	**DEG**	NT	**DEG**	NTDEG
		LE1.2	NT	NT	NT	NT
		LE1.3	NT	NT	NT	NT
		LE1.4	NT	NT	NT	NT
DIN	Western Branch	TF1.2	**IMP**	**IMP**	**IMP**	**IMP**
		WXT0001	**IMP**	**IMP**	**IMP**	**IMP**
	Upper River	TF1.3	**IMP**	NT	**IMP**	**IMP**
		TF1.4	**IMP**	NT	NT	NT
		TF1.5	**IMP**	NT	NT	NTIMP
	Middle River	TF1.6	**IMP**	NTIMP	NTIMP	NTIMP
		TF1.7	**IMP**	NT	**IMP**	**IMP**
		RET1.1	NT	NT	NT	NT
	Lower River	LE1.1	NT	NT	NT	NT
		LE1.2	NT	NT	NT	NT
		LE1.3	NT	NT	NT	NT
		LE1.4	NT	NT	NT	NT
TP	Western Branch	TF1.2	NT	NT	NT	NT
		WXT0001	**IMP**	NTIMP	NT	**IMP**
	Upper River	TF1.3	**IMP**	**IMP**	**IMP**	**IMP**
		TF1.4	**IMP**	**IMP**	**IMP**	**IMP**
		TF1.5	**IMP**	NT	NTIMP	NTIMP
	Middle River	TF1.6	**IMP**	NT	**IMP**	**IMP**
		TF1.7	NT	NT	NTDEG	**DEG**
		RET1.1	NT	NT	NT	NT
	Lower River	LE1.1	**DEG**	NT	**DEG**	**DEG**
		LE1.2	NTDEG	NT	NT	NT
		LE1.3	NT	NT	NT	NT
		LE1.4	NT	NT	NT	NT

param	River portion	STATION	ANNUAL Jan-Dec 2012	SPRING Mar-May 2012	SUMMER Jun-Sep 2012	SAV Apr-Oct 2012
PO4	Western Branch	TF1.2	NT	NTIMP	NT	NT
PO4	Western Branch	WXT0001	**IMP**	NTIMP	NT	NT
PO4	Upper River	TF1.3	**IMP**	**IMP**	**IMP**	**IMP**
PO4	Upper River	TF1.4	**IMP**	**IMP**	NT	**IMP**
PO4	Upper River	TF1.5	**IMP**	**IMP**	NT	NTIMP
PO4	Middle River	TF1.6	NT	NTIMP	NT	NT
PO4	Middle River	TF1.7	NTIMP	**IMP**	NT	NT
PO4	Middle River	RET1.1	NT	NT	NTDEG	NT
PO4	Lower River	LE1.1	NT	NT	NT	NT
PO4	Lower River	LE1.2	NT	NT	NT	NT
PO4	Lower River	LE1.3	NT	NT	NT	NT
PO4	Lower River	LE1.4	NT	NT	NT	NT
TSS	Western Branch	TF1.2	NT	NT	NT	UNKNOWN
TSS	Western Branch	WXT0001	**IMP**	NT	**IMP**	**IMP**
TSS	Upper River	TF1.3	**IMP**	NT	**IMP**	**IMP**
TSS	Upper River	TF1.4	**IMP**	NT	NTIMP	**IMP**
TSS	Upper River	TF1.5	NTIMP	NT	NT	NT
TSS	Middle River	TF1.6	NTIMP	NT	NT	NT
TSS	Middle River	TF1.7	NT	NT	NT	NT
TSS	Middle River	RET1.1	NT	NT	NT	NT
TSS	Lower River	LE1.1	NT	NT	NT	NT
TSS	Lower River	LE1.2	NT	NTIMP	NT	NTIMP
TSS	Lower River	LE1.3	NT	NTIMP	NT	NTIMP
TSS	Lower River	LE1.4	NT	NT	NT	NT
CHLA	Western Branch	TF1.2	NTIMP	NT	NTIMP	NTIMP
CHLA	Western Branch	WXT0001	NT	NT	NT	NT
CHLA	Upper River	TF1.3	NT	NT	NT	NTDEG
CHLA	Upper River	TF1.4	NT	NT	NT	NT
CHLA	Upper River	TF1.5	NTIMP	NT	NT	NT
CHLA	Middle River	TF1.6	NT	NT	NT	NT
CHLA	Middle River	TF1.7	**DEG**	NT	NTDEG	**DEG**
CHLA	Middle River	RET1.1	NT	NT	NT	NT
CHLA	Lower River	LE1.1	**DEG**	NT	**DEG**	**DEG**
CHLA	Lower River	LE1.2	**DEG**	NT	NT	NT
CHLA	Lower River	LE1.3	NTDEG	NT	NT	NT
CHLA	Lower River	LE1.4	NTDEG	NT	NT	NT
SECCHI	W. Branch	WXT0001	NT	NT	NT	NT
SECCHI	Upper River	TF1.3	NT	**DEG**	NT	NT
SECCHI	Upper River	TF1.4	NT	NT	NT	NT
SECCHI	Upper River	TF1.5	NT	NT	NT	NT
SECCHI	Middle River	TF1.6		NT	NT	NT
SECCHI	Middle River	TF1.7	SLOPE=0	NT	**DEG**	**DEG**
SECCHI	Middle River	RET1.1	NTDEG	NT	NT	NTDEG
SECCHI	Lower River	LE1.1	**DEG**	NT	NTDEG	NTDEG
SECCHI	Lower River	LE1.2	NT	NT	NT	NT
SECCHI	Lower River	LE1.3	NT	NT	NT	NT
SECCHI	Lower River	LE1.4	NTDEG	NT	NT	NT

param	River portion	STATION	ANNUAL Jan-Dec 2012	SPRING Mar-May 2012	SUMMER Jun-Sep 2012	SAV Apr-Oct 2012
SALINITY	Western Branch	TF1.2	SLOPE=0			
		WXT0001	NT			NT
	Upper River	TF1.3				
		TF1.4	NT		NT	NT
		TF1.5	NT	NT	NT	NT
	Middle River	TF1.6	NT		NT	NT
		TF1.7	NT	NT	NT	NT
		RET1.1	NTDEC	NT	NT	NT
	Lower River	LE1.1	**DEC**	NT	NT	NT
		LE1.2	**DEC**	NT	NT	NT
		LE1.3	**DEC**	NT	NT	NT
		LE1.4	**DEC**	NT	NT	NT
WTEMP	Western Branch	TF1.2	**INC**	NT	**INC**	**INC**
		WXT0001	**INC**	NT	**INC**	**INC**
	Upper River	TF1.3	**INC**	NT	**INC**	**INC**
		TF1.4	NTINC	NT	**INC**	**INC**
		TF1.5	**INC**	NT	**INC**	**INC**
	Middle River	TF1.6	**INC**	NT	**INC**	**INC**
		TF1.7	NTINC	NT	**INC**	**INC**
		RET1.1	**INC**	NT	**INC**	**INC**
	Lower River	LE1.1	**INC**	NT	**INC**	**INC**
		LE1.2	**INC**	NT	**INC**	**INC**
		LE1.3	**INC**	NT	**INC**	**INC**
		LE1.4	**INC**	NT	**INC**	**INC**

Appendix 9

Shallow water monitoring water and habitat quality

Spatial Assessment

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 2010-2012, some parameters were no longer measured.

	Station		map #	year	Chla mg/l		TSS mg/l		DIN mg/l		PO4 mg/l		Secchi Depth (m)		DO mg/l		Salinity	Salinity Zone	TN mg/l	TP mg/l	Wtemp °C
Upper River	**WXT0013**	**Iron Pot Landing**	3	2003	2.2	MEET	30.7	FAIL	0.499	FAIL	0.0335	FAIL			6.5	MEET	0.0	TF	1.223	0.2607	19.5
				2004	2.2	MEET	16.5	FAIL	0.572	FAIL	0.1080	FAIL			6.9	MEET	0.0	TF	1.303	0.1975	21.3
				2005	3.4	MEET	16.5	FAIL	0.437	FAIL	0.1000	FAIL	0.6	FAIL	6.4	MEET	0.0	TF	1.086	0.1866	19.6
				2006	3.0	MEET	19.3	FAIL	0.385	FAIL	0.0890	FAIL	0.8	MEET	7.0	MEET	0.0	TF	1.093	0.2188	21.4
				2007	7.3	MEET	16.4	FAIL	0.568	FAIL	0.1683	FAIL	0.6	FAIL	7.2	MEET	0.0	TF	1.207	0.3319	21.1
				2008	2.7	MEET	14.0	MEET	0.315	FAIL	0.0938	FAIL	0.8	MEET	6.8	MEET	0.0	TF	0.938	0.2145	20.8
				2009	5.0	MEET	19.3	FAIL	0.334	FAIL	0.0544	FAIL	0.6	FAIL	6.9	MEET	0.0	TF	1.006	0.2215	21.7
				2010	5.0	MEET	25.4	FAIL	0.687	FAIL	0.1360	FAIL	0.8	MEET	6.4	MEET	0.0	TF			21.9
				2011	3.2	MEET	18.9	FAIL	0.353	FAIL	0.0347	FAIL	0.8	MEET	6.9	MEET	0.0	TF			21.4
				2012	3.9	MEET	12.8	MEET	0.331	FAIL	0.0712	FAIL	1.0	MEET	5.9	MEET	0.0	TF			20.8
	PXT0455	**Jug Bay**	2	2003	4.5	MEET	18.7	FAIL	0.904	FAIL	0.0293	FAIL			5.9	MEET	0.0	TF	1.525	0.1300	18.6
				2004	12.0	MEET	25.0	FAIL	0.876	FAIL	0.0383	FAIL			5.2	FAIL	0.0	TF	1.784	0.1779	22.1
				2005	11.0	MEET	21.9	FAIL	0.650	FAIL	0.0237	FAIL	0.5	FAIL	6.2	MEET	0.0	TF	1.270	0.1034	21.8
				2006	14.0	MEET	30.7	FAIL	0.453	FAIL	0.0197	MEET	0.4	FAIL	5.6	MEET	0.0	TF	1.375	0.1458	22.0
				2007	18.4	FAIL	32.5	FAIL	0.386	FAIL	0.0173	MEET	0.3	FAIL	6.9	MEET	0.0	TF	1.307	0.1406	20.4
				2008	8.2	MEET	26.0	FAIL	0.642	FAIL	0.0217	FAIL	0.4	FAIL	5.8	MEET	0.0	TF	1.236	0.1365	19.2
				2009	8.0	MEET	32.0	FAIL	0.513	FAIL	0.0190	MEET	0.4	FAIL	5.9	MEET	0.0	TF	1.162	0.1639	23.4
				2010	16.7	FAIL	40.0	FAIL	0.275	FAIL	0.0163	MEET	0.3	FAIL	5.7	MEET	0.0	TF			21.4
				2011	15.0	MEET	34.2	FAIL	0.553	FAIL	0.0186	MEET	0.4	FAIL	4.8	FAIL	0.0	TF			21.2
				2012	34.4	FAIL	58.5	FAIL	0.235	FAIL	0.0134	MEET	0.4	FAIL	5.8	MEET	0.0	TF			21.8
	PXT0435		16	2003	22.4	FAIL	25.5	FAIL	0.303	FAIL	0.0486	FAIL	0.4	FAIL	6.3	MEET	0.0	TF	1.329	0.1173	19.5
				2004	23.2	FAIL	27.5	FAIL	0.402	FAIL	0.0123	MEET	0.4	FAIL	7.5	MEET	0.0	TF	1.489	0.1186	24.4
				2005	15.7	FAIL	25.6	FAIL	0.388	FAIL	0.0135	MEET	0.4	FAIL	7.2	MEET	0.0	TF	1.231	0.1043	25.8
	MTI0015	**Mataponi**	1	2003	2.6	MEET	9.3	MEET	0.318	FAIL	0.0151	MEET			4.2	FAIL	0.0	TF	0.811	0.1202	19.2
				2004	2.5	MEET	6.7	MEET	0.222	FAIL	0.0244	FAIL			5.1	FAIL	0.0	TF	0.809	0.0891	20.5
				2005	5.4	MEET	4.5	MEET	0.401	FAIL	0.0161	MEET	0.7	FAIL	2.8	FAIL	0.0	TF	0.956	0.0863	19.4
				2006	4.2	MEET	9.5	MEET	0.121	FAIL	0.0170	MEET	0.6	FAIL	6.1	MEET	0.0	TF	1.040	0.0925	23.2
				2007	7.5	MEET	11.3	MEET	0.217	FAIL	0.0160	MEET	0.6	FAIL	6.7	MEET	0.0	TF	0.969	0.1068	18.9
				2008	5.2	MEET	12.0	MEET	0.111	FAIL	0.0132	MEET	0.5	FAIL	4.4	FAIL	0.0	TF	0.778	0.0969	17.0
				2009	2.1	MEET	11.0	MEET	0.169	FAIL	0.0187	MEET	0.7	FAIL	5.8	MEET	0.0	TF	0.732	0.1103	22.8
				2010	13.4	MEET	13.0	MEET	0.084	FAIL	0.0130	MEET	0.5	FAIL	5.1	FAIL	0.0	TF			19.7
				2011	5.0	MEET	13.9	MEET	0.250	FAIL	0.0163	MEET	0.6	FAIL	5.2	FAIL	0.0	TF			21.5
				2012	21.7	FAIL	25.0	FAIL	0.127	FAIL	0.0157	MEET	0.5	FAIL	3.7	FAIL	0.0	TF			20.7
	XFD1283		15	2003	11.2	MEET	38.8	FAIL	0.464	FAIL	0.0517	FAIL	0.3	FAIL	5.5	FAIL	0.0	TF	1.143	0.1241	21.1
				2004	11.2	MEET	23.6	FAIL	0.417	FAIL	0.0256	FAIL	0.4	FAIL	6.3	MEET	0.0	TF	0.943	0.0997	24.4
				2005	4.1	MEET	30.0	FAIL	0.427	FAIL	0.0387	FAIL	0.4	FAIL	5.2	FAIL	0.0	TF	0.959	0.1221	25.8

Region	Station	map #	year	Chla mg/l		TSS mg/l		DIN mg/l		PO4 mg/l		Secchi Depth (m)		DO mg/l		Salinity	Salinity Zone	TN mg/l	TP mg/l	Wtemp °C
Middle River	PXT0311	7	2003	6.5	MEET	34.3	FAIL	0.103	FAIL	0.0072	MEET	0.3	FAIL	6.2	MEET	0.2	OH	1.161	0.1587	22.5
			2004	7.9	MEET	25.9	FAIL	0.371	FAIL	0.0391	FAIL	0.4	FAIL	5.4	MEET	0.9	OH	0.962	0.1162	25.0
			2005	8.8	MEET	26.3	FAIL	0.257	FAIL	0.0396	FAIL	0.4	FAIL	5.5	MEET	2.2	OH	0.859	0.1153	26.3
	TF1.7 longterm	*13*	2003	8.3	MEET	30.8	FAIL	0.412	FAIL	0.0601	FAIL	0.3	FAIL	5.0	MEET	0.8	OH	1.035	0.1531	22.6
			2004	10.3	MEET	24.3	FAIL	0.282	FAIL	0.0473	FAIL	0.4	FAIL	5.0	MEET	2.5	OH	0.877	0.1093	25.1
			2005	15.5	FAIL	21.7	FAIL	0.181	FAIL	0.0354	FAIL	0.4	FAIL	5.3	MEET	4.7	OH	0.944	0.1254	25.9
	XEE3604	14	2003	32.9	FAIL	23.5	FAIL	0.632	FAIL	0.0274	FAIL	0.3	FAIL	5.9	MEET	2.8	OH	0.892	0.1328	22.9
			2004	28.4	FAIL	23.7	FAIL	0.097	FAIL	0.0441	FAIL	0.4	FAIL	6.5	MEET	5.0	OH	1.015	0.1251	23.7
			2005	18.4	FAIL	19.7	FAIL	0.056	MEET	0.0394	FAIL	0.5	FAIL	6.0	MEET	5.1	MH	0.952	0.1120	25.9
	XEE1502	12	2003	20.2	FAIL	29.8	FAIL	0.593	FAIL	0.0439	FAIL	0.3	FAIL	5.3	MEET	3.9	OH	1.095	0.1443	22.4
			2004	22.4	FAIL	15.6	FAIL	0.198	FAIL	0.0533	FAIL	0.6	FAIL	6.1	MEET	6.2	MH	0.924	0.1157	23.2
			2005	26.2	FAIL	20.7	FAIL	0.037	MEET	0.0431	FAIL	0.5	FAIL	5.3	MEET	8.0	MH	1.070	0.1547	26.2
	XED0694 Benedict	6	2003	14.4	MEET	30.2	FAIL	0.277	FAIL	0.0240	FAIL	0.4	FAIL	6.8	MEET	5.8	MH	0.941	0.1269	25.0
			2004	10.8	MEET	23.0	FAIL	0.096	FAIL	0.0423	FAIL	0.5	FAIL	7.5	MEET	6.9	MH	0.910	0.0845	24.6
			2005	12.1	MEET	25.2	FAIL	0.050	MEET	0.0245	FAIL	0.5	FAIL	5.5	MEET	8.0	MH	0.818	0.0916	25.7
	XDD9298	11	2003	237.7	FAIL	38.8	FAIL	0.071	FAIL	0.0056	MEET	0.3	FAIL			4.9	OH	2.980	0.5051	17.1
Lower River	*LE1.1 longterm*	*8*	2003	46.7	FAIL	12.9	MEET	0.049	MEET	0.0106	FAIL	0.7	FAIL	3.7	FAIL	7.3	MH	0.919	0.0719	23.7
			2004	14.6	MEET	13.7	MEET	0.053	MEET	0.0129	FAIL	0.9	FAIL	5.8	MEET	8.7	MH	0.868	0.0538	23.6
			2005	12.5	MEET	10.3	MEET	0.015	MEET	0.0119	FAIL	1.0	FAIL	4.6	FAIL	8.9	MH	0.691	0.0676	24.3
	XDE4587 Pin Oak	5	2003	15.3	FAIL	17.4	FAIL	0.091	FAIL	0.0053	MEET	0.9	FAIL	6.2	MEET	8.8	MH	0.755	0.0729	23.0
			2004	10.7	MEET	13.6	MEET	0.078	FAIL	0.0050	MEET	1.0	MEET	7.5	MEET	9.1	MH	0.747	0.0484	23.8
			2005	14.0	MEET	17.1	FAIL	0.033	MEET	0.0045	MEET	0.8	FAIL	7.3	MEET	10.3	MH	0.715	0.0618	26.5
			2006	11.4	MEET	14.5	MEET	0.019	MEET	0.0060	MEET	1.1	MEET	8.1	MEET	11.3	MH	0.685	0.0471	23.7
			2007	11.5	MEET	21.5	FAIL	0.023	MEET	0.0036	MEET	0.9	FAIL	8.4	MEET	12.3	MH	0.883	0.0534	25.7
	LE1.3 longterm	*9*	2003	33.2	FAIL	10.3	MEET	0.064	MEET	0.0079	MEET	1.3	MEET	4.6	FAIL	8.9	MH	0.848	0.0739	22.8
			2004	10.3	MEET	8.8	MEET	0.244	FAIL	0.0105	FAIL	1.3	MEET	6.8	MEET	9.4	MH	0.765	0.0425	23.2
			2005	11.2	MEET	8.2	MEET	0.072	FAIL	0.0032	MEET	1.3	MEET	5.8	MEET	10.2	MH	0.672	0.0466	23.1
	XCF9029 CBL	4	2003	23.2	FAIL	15.0	MEET	0.329	FAIL	0.0194	FAIL	1.3	MEET	7.0	MEET	10.2	MH	0.938	0.0608	22.1
			2004	9.2	MEET	11.5	MEET	0.397	FAIL	0.0039	MEET	1.1	MEET	9.6	MEET	9.6	MH	0.842	0.0311	22.8
			2005	10.3	MEET	10.3	MEET	0.109	FAIL	0.0034	MEET	1.0	FAIL	7.5	MEET	11.9	MH	0.728	0.0474	24.6
			2006	13.1	MEET	14.0	MEET	0.035	MEET	0.0036	MEET	1.2	MEET	6.5	MEET	12.3	MH	0.637	0.0350	23.2
	LE1.4 longterm	*10*	2003	21.6	FAIL	9.6	MEET	0.116	FAIL	0.0058	MEET	1.3	MEET	4.8	FAIL	10.3	MH	0.805	0.0551	22.1
			2004	7.3	MEET	7.7	MEET	0.323	FAIL	0.0064	MEET	1.3	MEET	5.5	MEET	9.6	MH	0.912	0.0352	22.6
			2005	9.6	MEET	7.5	MEET	0.121	FAIL	0.0045	MEET	1.3	MEET	5.3	MEET	11.5	MH	0.771	0.0513	22.9
	XCF7068	na	2003	10.1	MEET	21.2	FAIL	0.062	MEET	0.0100	FAIL	1.1	MEET	7.0	MEET	12.6	MH	0.704	0.0326	23.2