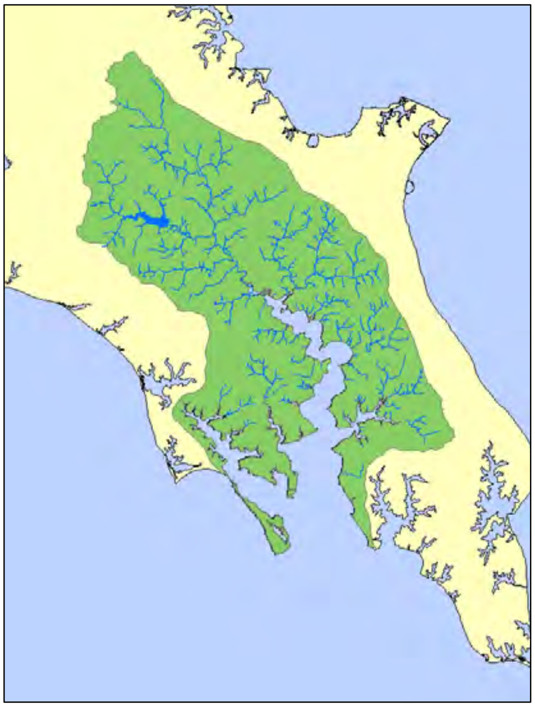
St. Mary's River
Water Quality Assessment



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September 30, 2008

Financial assistance provided by the Coastal Zone Management Act of 1972, as amended, administered by the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration (NOAA). A report of the Maryland Coastal Zone Management Program, Department of Natural Resources pursuant to NOAA Award No. NA06NOS4190237. Additional financial support provided by the Chesapeake Bay Trust Stewardship Grant (#9181).

Summary

On April 1, 2008, St. Mary’s County began the preparation of a Watershed Restoration Action Strategy (WRAS) for the St. Mary’s River watershed. Only one other WRAS has been completed in St. Mary’s County, and this was for the Breton Bay watershed with the substantial involvement and support of the Watershed Services Division of Maryland Department of Natural Resources (DNR). In this project, conducted by St. Mary’s College of Maryland faculty and students, DNR support came through an Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration (NOAA) grant (NOAA Award No. NA06NOS4190237). The data collection phase of the project, which was completed on September 30, 2008, includes a Stream Corridor and Tidal Shoreline Assessment (SCA), a Synoptic Survey, and this Water Quality Assessment. The partners in this WRAS include St. Mary’s County government, St. Mary’s College of Maryland, and the St. Mary’s River Watershed Association (SMRWA).This water quality assessment study reports on water quality, land use and cover, living resources, and habitat. Because the St. Mary’s River Project at St. Mary’s College of Maryland has been actively collecting very detailed water quality, habitat, and biological resource data since 1999, the focus of this study rests heavily on those resources as well as data collected by the Maryland Department of Natural Resources (DNR).

The St. Mary’s River watershed is located in Southern Maryland and is one of the state’s significant waterways. It has both the tidal and non-tidal portions in approximately 47,000 acres, and it is contained entirely within St. Mary’s County. Ten subwatersheds and 174 miles (280 km) of streams contribute freshwater to the tidal river before it flows into the lower Potomac River . The tidal St. Mary’s River is approximately 12 km in length and is fed by numerous tidal creeks, but these contribute little freshwater flow to the river.

St. Mary’s Counties population has just passed the 100,000 mark, and the county is one of the 3 fastest jurisdictions in the state. The St. Mary’s River and its watershed are endangered by rapid development. The headwaters of many of the tidal river’s tributaries originate in the Lexington Park development District, the center of the county’s growth. But the watershed is also the site of the first English settlement and capital of Maryland. In addition, the river’s legacy goes beyond just its historical significance to that of an important commercial and recreational resource.

In general, water quality in the St. Mary’s River and its tributaries is good under baseline, low flow conditions. But, storm events have a major impact on the river and streams by carrying sediments and nutrients downstream and into the tidal river. Here, especially in summer, the nutrients spur algal growth, and when these algae die, sink, and decompose in the bottom waters of the tidal river, they remove dissolved oxygen for extended periods of time. This, of course, is detrimental to benthic and other bottom-dwelling organisms. This predictable, annual event begins in the early spring and extends into the early fall. Wet springs and summers exacerbate the situation and promote anoxia in the bottom waters, while droughts lead to clear water with good light penetration and healthy SAV growth. Sediments carried by storms originate in the watershed, and are mobilized by erosion, and this is enhanced by impervious surfaces. Sediments seem to have their greatest impacts on both stream and estuarine habitat. The major impact is smothering of the substrates required for organism’s survival. Clearly, stream degradation is strongly coupled to storm events and land use practices.

The problems in the St. Mary’s watershed are localized and are mostly centered in the watershed’s urban areas. Yet, much of the undeveloped parts of the watershed are almost pristine, and vigilance will be required to protect these streams and their habitats.

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Introduction

One of the key commitments made by the Chesapeake Bay Program (CBP) partners in the Chesapeake 2000 agreement is: “by 2010, work with local governments, community groups and watershed organizations to develop and implement locally supported watershed management plans in two-thirds of the Bay watershed covered by this Agreement. These plans would address the protection, conservation and restoration of stream corridors, riparian forest buffers and wetlands for the purposes of improving habitat and water quality, with collateral benefits for optimizing stream flow and water supply.” (Chesapeake Bay Program, 2008). Watershed management plans address the protection, conservation and restoration of stream corridors, riparian forest buffers, wetlands, parklands and other open space for the purposes of preserving watershed health while enhancing the quality of life in local communities. By the end of 2007, watershed management plans were in place for 13 million acres of the Bay watershed, approximately 57% of the two-thirds goal (Chesapeake Bay Program, 2008).

On April 1, 2008, St. Mary’s County began the preparation of a Watershed Restoration Action Strategy (WRAS) for the St. Mary’s River watershed. Only one other WRAS has been completed in St. Mary’s County, and this was for the Breton Bay watershed with the substantial involvement and support of the Watershed Services Division of Maryland Department of Natural Resources (DNR). In this project, conducted by St. Mary’s College of Maryland faculty and students, DNR support came through an Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration (NOAA) grant (NOAA Award No. NA06NOS4190237). The data collection phase of the project, which was completed on September 30, 2008, includes a Stream Corridor and Tidal Shoreline Assessment (SCA), a Synoptic Survey, and this Water Quality Assessment. Typically, characterization reports have information on water quality, land use and cover, living resources, and habitat. The partners in this WRAS include St. Mary’s County government, St. Mary’s College of Maryland, and the St. Mary’s River Watershed Association (SMRWA).

The St. Mary’s River watershed is located in Southern Maryland (Figure 1) is one of the state’s significant waterways. It has both the tidal and non-tidal portions in approximately 47,000 acres, and it is contained entirely within St. Mary’s County. Ten subwatersheds and 174 miles (280 km) of streams contribute freshwater to the tidal river before it flows into the lower Potomac River (Figures 2 and 3). The tidal St. Mary’s River is approximately 12 km in length and is fed by numerous tidal creeks, but these contribute little freshwater flow to the river.

The St. Mary’s River is endangered by rapid development in its watershed. The site of the first English settlement and capital of Maryland, the river’s legacy goes beyond just its historical significance to that of an important commercial and recreational resource. One of the most pristine watersheds on the western side of the Chesapeake Bay, the river supported a commercially viable oyster fishery. However, population growth is the cause of housing, commercial and industrial development around the headwaters of the St. Mary’s River watershed, particularly in the vicinity of Lexington Park where the Naval Air Warfare Center is located (Figures 4 and 5). The major transportation artery to and from the county and navy base is State Route 235. This six-lane highway defines the northern limit of the St. Mary’s River watershed since it is situated on the ridge dividing the Potomac and Patuxent River drainages. The highway has been extensively widened to accommodate increasing vehicular traffic Impervious surface development due to urbanization already is above 12% in some subwatersheds of the St. Mary’s River watershed and expected to climb to 20-25% in Lexington Park, specifically (Brown, 2001). Because these impervious surfaces (Figure 5) severely impact small freshwater streams like those feeding the St. Mary’s River; there is strong concern about their proliferation and resulting water quality degradation (Doppelt et al., 1993; Stranko and Rodney, 2001). To address these issues the St. Mary’s River Watershed Association was recently established with a mission to “protect, improve, and promote the well-being of the St. Mary's River Watershed through the collaborative efforts of economic, agricultural, environmental, social, cultural, and political stakeholders in the community”.

While development in the region is inevitable, it has been recommended that future development needs to be consolidated in the St. Mary’s River watershed in order to control urban sprawl into forest lands that cover approximately 64% of the watershed (KCI, 1998). As part of the St. Mary’s County Comprehensive Master Plan, the county government intends to promote the protection, restoration and preservation of the county’s sensitive coastal area resources. Development will be concentrated in Growth Areas including the Lexington Park and Leonardtown Development Districts. Rural Areas and the Rural Preservation Districts are to be preserved for economic and aesthetic reasons. These preservation areas are comprised of prime farmland, timberland and mineral resource lands, agriculturally related industries and limited non-farm cottage industries, and low-density non-farm residential developments (Board of County Commissioners, 1999). Resource Protection Areas will include sensitive areas (steep slopes, floodplains, wetlands, streams corridors, hydric soils, critical natural habitats) where development is hazardous or detrimental. Agricultural Districts are proposed designated areas of very low-density development with a concentration of prime agricultural soils. They are also designated to preserve lands potentially viable for agricultural activity. The county has proposed a network of greenways and scenic easements that will encompass a significant percentage of sensitive areas. Large contiguous tracts of sensitive areas are outside of designated growth areas and are zoned for rural or resource protection.

The county is directing intense development away from areas that are in proximity to watercourses. The county requires development to locate as far from watercourses as possible and to establish permanent protection measures for priority riparian areas. It is a goal of the county to establish minimum tidal and non-tidal wetland buffers according to state and federal law and require a setback from these buffers to limit disturbance in the buffers during construction (KCI, 1998). In 2000, the St. Mary’s Board of County Commissioners finalized contracts with the Baltimore District Office of the Army Corps of Engineers to conduct a feasibility study for restoration and recovery projects in the non-tidal portion of the river (Brown, 2001). These projects will focus on the riparian zones of candidate streams that are degraded.

In addition, St. Mary’s County government is in the process of implementing Lower Potomac and Patuxent River Tributary Strategies to achieve the cap of nutrient pollution in the Chesapeake Bay at 40% of the 1985 nutrient loads. The goal is to limit and mitigate point and non-point source impacts that result from discharged pollutants. This includes minimizing runoff and erosion, protecting sensitive habitats, and maintaining and enhancing productivity of prime agricultural lands. Best management practices are to be used to control and minimize soil erosion and runoff from developed sites. Hydric and highly erodible soils are to be minimally disturbed, and natural patterns of surface and underground hydrology are to be maintained (KCI, 1998).

In addition to government initiatives, increasing numbers of concerned citizens have become involved in organizations working to protect and restore Maryland’s and St. Mary’s County’s biological and aquatic resources. Many such organizations focus their work on a particular river basin or stream. In the Lower Potomac River basin, Citizen Monitors of St. Mary’s County promote public education and are creating a citizen’s monitoring network for the county. IN the past the St. Mary’s Environmental Umbrella Group coordinated various activities of environmental and civic groups concerned with the environment, sustainable development and ecosystem management (Boward et al., 1998), but this function has been largely subsumed by the St. Mary’s River Watershed Association. Additionally, the Alliance for the Chesapeake Bay, the Chesapeake Bay Foundation, the Audubon Society, St. Mary’s County Commission on the Environment, the Potomac River Association, Sierra Club and other local and regional environmental organizations are quite active in St. Mary’s County.

While local environmental organizations foster environmental awareness and education, the St. Mary’s County schools are also heavily involved in environmental education. Environmental education takes place in all the primary and secondary public and parochial schools of the county. It is also a component of the county’s (College of Southern Maryland) and the state’s (St. Mary’s College of Maryland’s) higher education agenda. Many educational partnerships between St. Mary’s College and the public schools are being established around environmental issues in the county. As a consequence, a sense of community is being engendered as students, teachers and parents collaborate and work across many grade levels around the common goal of environmental protection. For example, several county elementary and secondary schools have “adopted” streams and environments for protection and study, and college students volunteer in these schools to offer their expertise in and out of the classrooms.

Despite considerable interest in and dedication to preserving and protecting the St. Mary’s River, very little information is available about the ecological status and health of the river prior to 1999. Historical records of habitat quality and biological resources are virtually non-existent for the non-tidal watershed. The Maryland Department of Environment (MDE) historically collected fecal coliform and some limited water quality data in the tidal river because of its commercial shellfish harvests. DNR personnel sampled two non-tidal streams (Pembrook and Jarboesville Runs) in their 1995 assessment of Lower Potomac River tributaries (Roth et al., 1996). In 1997, the Alliance for the Chesapeake Bay and the Biology Department faculty at St. Mary’s College established three shore stations in the tidal St. Mary’s River to determine the feasibility of restoring species of SAV. Only spotty water quality data was available for the tidal St. Mary’s River in the 1990’s, other than data collected by college students as part of class projects. Consequently, at the beginning of the St. Mary’s River Project there was no systematic, comprehensive water quality monitoring being performed in the St. Mary’s River and its watershed.

Since 1999, a considerable body of environmental information has been gathered on the St. Mary’s River and its watershed with the implementation of the St. Mary’s River Project (SMRP), initially a U.S. EPA sponsored project. SMRP was continued with support from the U.S. Department of Housing and Urban Development (HUD)-2000-2005, National Fish and Wildlife Foundation- 2001 and 2002, the U.S. EPA again in 2005-2007, and through various contracts with Maryland DNR. In addition, the U.S. Army Corps of Engineers (Brown, 2001) and Maryland DNR (Roth et al., 1996; Boward et al., 1998; Stranko and Rodney, 2001) have conducted their own studies in the watershed. As a consequence, we have gained a reasonably good understanding of the overall health of the St. Mary’s River watershed (Paul, 2006; Paul and Tanner, 2001, 2005).

Throughout the history of the St. Mary’s River Project, the primary goal was to establish a water quality-monitoring program in both the tidal estuary and St. Mary’s River watershed to provide critical information for the protection, restoration and management of this historically and ecologically important river in the face of rapid growth and development in the watershed. Another goal was to support research that will lead to restoration of resources in the river or will help to identify potential environmental problems and stressors, and their effects on the river ecosystem. The third goal was to increase public awareness of the ecological health of the St. Mary’s River and to build a sense of stewardship for the river. The final goal was to make the information generated by the project useful and available to decision makers at the local, state and regional levels. This report covers the detailed work of the project from June of 1999 through September of 2008.

Physical Characteristics

Approximately 38% of the total Lower Potomac River basin area is forested, 35% is covered by water, and 16% of the land is used for agriculture. La Plata, Waldorf, and Lexington Park are the urban centers and represent another 10% of the basin. The northern portion of the basin ranges from level to strongly sloping with moderately- to well-drained silty or loamy soils. Upland soils may have an underlying impervious layer of gravel and are either severely eroded or subject to severe erosion. Upland areas average 150 feet above sea level. Soils in the more southerly part of the basin are predominately clay and are nearly level to moderately sloping (Gibson, 1978). Forests are pine-hardwood associations with Virginia Pine, loblolly pine, southern red oak, white oak, sweet gum, yellow poplar and red maple predominating. On poorer sandy soils in southern St. Mary's County loblolly pine predominates (Boward et al., 1998).

Within the St. Mary's River watershed, elevations range from 165 feet in the northwest corner of the watershed near the junction of Route 235 and Route 4 (Figure 6). The watershed divide between the Patuxent and Potomac Rivers runs from northwest to southeast and is approximated by the course of Route 235 southward (Figure 5). The slope of the St. Mary's River watershed, which is the last catchment in the Potomac River basin before it enters the Chesapeake Bay, is a gentle slope from the Route 235 ridge to the tidal river. Many of the small tributaries of the St. Mary's River follow deeply incised channels that have been cut into the soft Coastal Plain substrate. These channels predominate in the middle and upper subwatersheds of the St. Mary's River watershed where the topographical gradient is relatively steep. The lower subwatersheds, near the mouth of the tidal river, have low elevational gradients and stream channels are not so deeply incised (Figure 6).

There are 77 soil types contained within the St. Mary's River watershed (Figure 7). Gibson (1978) in his Soil Survey of St. Mary's County, Maryland, gives the details of these different Atlantic Coastal Plain soils. They are all derived from thick unconsolidated beds of sand, silt, clay, and gravel laid down as marine deposits. Many of these soils and their complexes (Caroline, Matapeake, Othello, Sassafras Woodstown) located on slight slopes (less that 5%) are prime agricultural soils and have been used in agriculture since the arrival of the Maryland colonists. These soils The St. Mary's River watershed lies in a transition zone from the upland plateau in the northern part of the county where elevations are over 100 feet to the low, flat coastal plain at sea level. Because of this slope and the erosion potential of the soils, over 17% of the soils are alluvial (soil types Aa and Ad) and made up of sediments washed toward the stream channels and St. Mary's River. These depositional soils are variable, and they are composed of silts and sands derived from the eroded upland soils.

Soils are classified into groups and soil types based on their origins, composition, slope, and erosion potential. Because water quality is really a measure of water's chemical (dissolved) and physical (particulate) composition, a watershed's soil characteristics are of central importance to a watershed's streams, rivers, and estuaries. In particular, soil erodibility is of special interest because these characteristics give an indication of the potential for suspended solids (sediments) and dissolved nutrients to enter receiving water courses through erosion. Two watershed characteristics, soil type and slope, are the primary determinants of whether a watershed will have water quality problems due to soil composition. In general, St. Mary's River watershed soils are moderately eroded or erodible (Figure 8). Soils that have a low potential for erosion and that carry fewer sediments into the St. Mary's River are located on the flatter areas throughout the watershed. The soils that are classified as severely eroded or with strong erosion potential are generally located on steep slopes. These are concentrated in the upper part of watershed, near the non-tidal main stem, where the tributaries run through a narrow valleys with steep slopes. For the most part, soils within the watershed are deep and rich and this especially evident on the alluvial floodplain where soils are classified mostly as Aa or Ad . In the St. Mary's River watershed these make up a large proportion of the hydric soils.

Over 50% of the watershed is forested (Figure 9), and it is likely that the amount of forest cover has increased substantially in the last 50 years as the number of acres committed to agriculture has declined. Of the total 45,198 acres, 6,012 are urban and include impervious surfaces that make up 5.3% of the watershed. Most of St. Mary's County is forested (27,364 acres) and the county has 11,269 acres of agriculture. There are also 358 acres of wetlands which make up a small part of the total 17% of land that is classified as non-forested stream buffer (MDE, 2008). Development in St. Mary's County, the St. Mary's River watershed cannot be assessed without an underlying understanding of population growth in the county. In 1970 the county's population was 47,388 and it is projected to be 100,800 people in 2010. Between 1996 and 2001 the population in the county grew by 9.2%. Over the same period personal income in St. Mary's County grew by 54.9%, substantially higher than Southern Maryland, the state, and the country. In May 2003 the County's unemployment rate was 2.4%; the lowest in Southern Maryland. Figure 10 is based 2000 U.S. Census Data and local areas within the Hilton Run are census blocks (areas used to classify the national data). There are a total of 5,429 buildings in the entire St. Mary's River watershed and most of these are residences. The low density parcels contain the least number of buildings, followed by high density (apartment buildings) and finally medium density has the largest number of structures. Nearly half the population of St. Mary's County lives in the St. Mary's River watershed (46,000 people). Population density (individuals/square mile) was computed for the watershed census blocks and Figure 10 shows that the highest population density (almost 4500 individuals/square mile) is located in the central part of the watershed in the vicinity of Lexington Park and the Route 235 corridor.

Sixty years ago, St. Mary's County was very rural. There was no electricity south of Leonardtown or south of what is now Lexington Park. There were no refrigerators, air conditioning, or running water. The roads were mostly dirt and gravel. Some main roads were covered with a coating of tar over the gravel; many were almost impassable in the spring thaw. No family had more than one vehicle, many had none. It was not uncommon to see a tractor parked at a rural store or being used for local transportation. The roads to and from Baltimore were long and difficult.

With the decline in traditional farming has come a rapid upswing in business, commercial, and professional activities within the county and land use in the county has recently (Figure 11) reflected this change. As of 1999, 35 businesses with 100 or more workers were operating in the county. The navy base employs some 18,000 people, and many of these families are resident in Hilton Run. The County is making an effort to concentrate development in the Lexington Park development district adjacent to the base and encompassing much of the land at Hilton Run's northern end. Social security payments and other retiree remittances are another major factor in the County's economy. Average household income in the County is now $71,000, considerably higher than for the U.S. as a whole. Though no fine tuned calculation exists for the watershed, average family income there is doubtless far lower. Development has, in short, brought the people of the watershed to a point far away from this area's rural past and in far greater proximity to the mainstream of modern conveniences, traffic congestion, pollution, and sprawl. Such economic benefits as modern development has brought to them must be offset against the inconveniences that also form part of the package.

As long as the Patuxent River Naval Air Base maintains at least its current level of activity, it will continue to be the dominant economic engine in the County and the principal factor governing the pressures on The St. Mary's River watershed. A continuation of current development trends and prosperity would be likely. This scenario is, of course, constantly in jeopardy because of the ongoing possibility that in a future round of congressionally mandated military base closings the Patuxent River Naval Air Station might abruptly cease to exist or diminish in size. In this instance, economic planners would have to fall back on alternative strategies to counter the threat of a severely depressed local economy. Tourism, recreation and leisure activities would loom as more prominent in the mix. From a long range planning standpoint, consideration of both scenarios would be prudent.

St. Mary's River watershed precipitation data have been compiled and analyzed in detail for the past 10 years by the St. Mary's River project (Paul 2006) and are up dated through 2008 here. Over the last 10 years precipitation was variable (Figure 12) ranging from trace amounts to 21.67 cm in a 24 hour period. An initial summer drought from June (3.05 cm) to August (6.12 cm) 1999 was followed by heavy precipitation when Tropical Storm Floyd (9/16/1999) pushed the monthly precipitation total for September to 29.41 cm. In the summer of 2000 several large, repeated storms created an abnormally wet summer, but average monthly precipitation was well below the historical average (8 cm/month) in the fall (October – December). Precipitation was higher than normal during all summers during the SMRP study period, with the exception of 2007 (Figure 13). Over the entire study period the annual precipitation was highest in 2003 (155.9 cm) and 2004 (147.4 cm).

The St. Mary's River has a single U.S. Geological Survey gaging station (Gage #01661500) at SMRP non-tidal sampling site NT09 (Table 3, Figure 17). Data from the gaging station reflects overall fluctuations in watershed discharge into the tidal river as it is located on the main stem of the river and has the largest flow rate of any of the St. Mary's River tributaries. This station has been in service since 1946 to today, with a one year break in 2006, so more than 50 years of historical data are available. Daily discharge rates over the 10-year period ranged between 0.005 m^3/sec and 75.05 m^3/sec (Figures 12 and 13) and were closely correlated with precipitation (Figure 13). This comparison showed that watershed discharge rates were closely related to the amount of precipitation. Monthly discharge values during the study period where also compared to the average monthly historic (1946-2008, missing 2006) record to determine if river flows were below or above normal (Figures 15 and 16). This analysis reflects the overall weather patterns during the study. Droughts occurred in the summers of 1999 and 2002 and wet summers were recorded for 2000, 2003, 2004, 2007, and 2008. In September of 1999 Tropical Storm Floyd caused extremely high discharge rates, exceeding the historic highest daily mean discharge previously recorded at the station (64.0 m^3/sec on August 13, 1955). Overall, average monthly discharge for the St. Mary's River between 1999 and mid 2008 were reasonably close to historical averages during most of the year. Discharge during the summer months is generally higher than the historic average with the exception of the years 2001, 2002, and 2005.

Water Quality

The waters of the Lower Potomac River basin range from non-tidal freshwater to mesohaline (5 to 18 parts per thousand salinity) and include 651 miles of non-tidal streams. First order streams make up 77% of the total stream miles, while second and third order constitute 15% and 7% of the non-tidal stream miles, respectively (Boward et al., 1998). Water quality in the lower Potomac River is generally good (Batuik et al., 1992; data from the Chesapeake Bay Water Quality Monitoring Program), meeting the habitat requirements established for submerged aquatic vegetation (Dennison et al., 1993). Nutrients, sediment and bacterial runoff from agricultural and urban lands are the primary causes of water quality problems in the basin. Some shellfish harvesting water of the lower estuarine part is periodically suspended due to high counts of bacteria cells (MDE, 1994). There are 30 municipal sewage treatment plant discharges and 18 industrial discharges with National Pollution Discharge Elimination System (NPDES) permits in the basin (Boward et al., 1998). Each of these point sources discharges to surface waters. In some non-tidal streams in the basin, nutrient and sediment runoff and limited flushing contribute to water quality degradation. Based on data collected in 1992 by the Maryland Department of Natural Resources, 80% of the basin’s non-tidal sites had potential water quality problems (MDE, 1994).

The Aquia and the Nanjamoy/Piney Point aquifers currently supply over 95% of the necessary potable water for the Lexington Park development district. Both aquifers are currently stressed by demand and the Aquia is approaching Safe Sustainable Yield (SSY) in the Lexington Park area. A third series of sands known as the Patapsco Aquifer lies below the Aquia and Nanjamoy/Piney Point aquifers. At this time, the Patapsco SSY is largely unknown. Caution on its future potential yield should be exercised since this aquifer has reached maximum utility in LaPlata and is unproductive in near locations in Calvert County. Forecasts suggest a possible water shortage in 2020 for the Lexington Park area.

There are a total of 174.9 stream miles in the St. Mary’s River watershed, a small number (23) of these streams are perennial or seasonal and only have water when sufficient precipitation provides enough surface run off for stream flow (Table 2). The Western Branch of the St. Mary’s River contains the largest number (10) of seasonal streams. When all streams within the St. Mary’s River drainage were separated into individual stream segments and these segments were classified by stream order (Horton, 1945), a total of 498 individual stream segments were identified (Table 2). By far, the most numerous were first order, headwater streams (75.5 %) and these dominated all subwatersheds. Subwatershed 710, the Middle St. Mary’s River, has total of 109 first order streams which is more than twice as many as the next subwatershed, and this subwatershed also has the largest number of second order streams. Only 4 subwatersheds have fourth order streams, and two of these (717 and 718) are the two major non-tidal, East and West Branches, respectively, of the non-tidal St. River. Once these two major branches join, the St. Mary’s River becomes a fifth order stream and runs for 3.4 miles before becoming tidal. The USGS stream gage (Gage #01661500) is located in this segment of the river.

Monitoring Sites

Twenty-five stations have been sampled historically by the SMRP, with 15 established on non-tidal streams within the St. Mary’s River watershed, and another 10 in the tidal St. Mary’s River (Figure 17, Tables 3 and 4). In addition to the main stem St. Mary’s River, 3 tidal creeks have also been sampled. These creeks were selected for sampling stations because all have populations of SAV (*Ruppia maritima* and *Zannichellia palustris*), and two of them, St. Inigoes and St. George, have been the location of attempts to establish populations of another species of SAV, *Zostera marina*, by the Alliance for the Chesapeake Bay and St. Mary’s College faculty and students (Page and Davis, 1998). One of the goals of the SMRP project is the restoration of SAV habitat to the St. Mary’s River. An understanding of long-term water quality trends is critical for selecting potential restoration sites (Batiuk et al., 2000).

In addition to the stations established by the St. Mary's River Project, St. Inigoes Creek and St. George Creek had citizen monitoring shore stations near SAV restoration sites to assess habitat characteristics. These two stations were established in 1997 by the Alliance for the Chesapeake Bay (Page and Davis 1998). Faculty and students at St. Mary's College provided technical assistance for these stations and established a third citizen monitoring station at the College's pier (SMC, Figure 17). At the onset of the St. Mary's River Project, these stations were considered to be important supplemental stations for providing inshore data above SAV communities. However, due to loss of citizen monitors over time, these shore stations in the creeks were eventually dropped. The station at the College pier was sampled until December 10, 1999 when it was decided that Horseshoe Bend, the section of the river adjacent to the College, was adequately sampled at stations T04 and T05 (Figure 17). In August of 2000 a continuous monitoring station (tidal level, water temperature, conductivity and salinity, pH, oxygen, redox, chlorophyll fluorescence, turbidity, air temperature, wind speed and direction, irradiance) was established at the College pier to provide higher resolution data than the bi-weekly sampling schedule and to provide data during storm events.

Data from the Chesapeake Bay Program water quality stations in the lower Potomac River near the mouth of the St. Mary's River (LE2.3) and off of Ragged Point (LE2.2) were also examined. These stations provided information on long-term trends, data which are unavailable for within the St. Mary's River.

Data Collection Methods

Water quality monitoring at tidal and non-tidal stations began in June 1999 and is currently ongoing. In the tidal river, monitoring occurred twice a month from March through October, according to the Chesapeake Bay Program monitoring schedule for the lower Potomac River. From November through February, sampling occurred monthly. Non-tidal stations were monitored once a month from 1999 through 2002, and then sampled quarterly thereafter. Light measurements, which were taken at all tidal sites and the St. Mary's River Lake (NT04), were taken between 1000 and 1400 hours to maximize light intensity.

All water quality parameters and their analytical methods are given in Table 5 for both tidal samples and non-tidal samples. Samples were collected and analyzed for total suspended solids (TSS), total volatile solids (VSS), ammonium (NH_4^+), phosphate (PO_4^{3-}), combined nitrite - nitrate ($NO_2^- + NO_3^{-2}$), total dissolved nitrogen (TDN), total dissolved phosphorus (TDP), total particulate nitrogen (TPN), dissolved organic carbon (DOC), sulfates (SO_4) and total alkalinity. In May of 2004, particulate carbon (PC), particulate nitrogen (PN), particulate phosphorus (PP), and particulate inorganic phosphorus (PIP) were added to the analyses performed at all tidal and non-tidal stations. With the exception of sulfates and total alkalinity, these water quality parameters were also collected at tidal stations, but sampling also included: separate analyses of nitrite (NO_2^-) and nitrate (NO_3^{-2}), chlorophyll-*a* (chl-*a*) content, Silica (Si), particulate carbon/particulate nitrogen. Replicate samples for chlorophyll-*a* and nutrients were taken only at 3-4 randomly selected sampling during each sampling period (1-2 sites for tidal stations and 2 sites for non-tidal stations).

Yellow Springs Instrument (YSI, Yellow Springs, OH) multi-parameter water quality sondes (Model 6600) were used to measure water temperature, salinity, dissolved oxygen (DO), pH, turbidity, and *in situ* chlorophyll fluorescence at the tidal station (Table 2) at 0.5, 1.0, 2.0 and 3.0 m. Sondes were calibrated in the laboratory using manufacture's specifications prior to each sampling trip. Nutrient samples were taken from May through August at the surface. All sampling equipment used in the filtering process was rinsed three times with sample water. After filtering was complete all filter pads were stored in aluminum foil envelopes on ice in sealed polyethylene bags. All tidal samples were returned on ice to the laboratory on the same day that they were collected. Nutrient samples were immediately frozen in a secured freezer before being transported to the Analytical Chemistry Laboratory at Chesapeake Biological Laboratory–CBL (University of Maryland) in Solomons.

Total Suspended Solids and Volatile Suspended Solids (TSS/VSS)
Two pre-fired, pre-weighed Whatman 47mm GF/F 0.7 μm filters (provided by Chesapeake Biological Laboratory, CBL) were placed in a dual filtering manifold. The water sample was agitated and a 100ml volumetric pipette used to transfer 300 ml of sample water to each filter. In the case of an extremely turbid sample volume was reduced. All volumes filtered were recorded on the filter envelope and the datasheet. Vacuum was provided using hand held pumps at a vacuum of no more than 20 cm Hg. After the sample water had passed through the filter, the funnel and filter were rinsed with distilled water. Each filter was removed, folded in half, and placed in an aluminum foil envelope pre-labeled with the CBL filter number.

Particulate Carbon and Particulate Nitrogen (PC/PN)
After agitating the sample a 100 ml volume was filtered through a pre-combusted Whatman 25mm GF/F 0.7 μm filter. The filter was then folded in half and placed in an aluminum foil envelope. After again agitating the sample, a 100 ml volume was filtered through another 25mm GF/F filter. This filter was folded in half and placed in the foil envelope with the first filter making sure they did not touch one another.

Particulate Phosphorus and Particulate Inorganic Phosphorus (PP/PIP)
A dual manifold filtration system was used in the TSS/VSS analysis and was loaded with Whatman 47mm GF/F 0.7 μm filters. The sample was agitated and a 100 ml volumetric pipette used to transfer 300 ml to each filter. If the volume was reduced for the TSS/VSS analysis because of high turbidity, then the same volume was used for this analysis. After the sample was rinsed with distilled water, the filters were folded in half and placed in an aluminum foil envelope so that they did not touch.

Chlorophyll *a* (Chla)
A single 47mm filtering manifold was set up using a Whatman GF/F 0.7 μm filter, after disposing of the filtrate from previous filtering. The sample was agitated and a 100 ml volumetric pipette used to transfer 200 ml of sample to the filter apparatus. Vacuum was applied using a hand pump to a vacuum of no more than 20 mg Hg. The filter was then folded in half and placed in an aluminum foil envelope.

The filtrate from the chlorophyll analysis was collected for additional nutrient analyses. All vials and bottles were rinsed three times with the filtrate. Four 4.0 ml polystyrene sample cups with conical bottoms (Evergreen Scientific, 127-0066-010) were filled for: nitrite + nitrate (NO_2^-+NO_3^-), ammonium (NH_4^+), and phosphorus (orthophosphate). One glass tube was filled with 10 ml for TDN/TDP analysis. In addition, a 60 ml polystyrene bottle was filled as a TDN/TDP duplicate. One 30 ml Teflon bottle was filled for carbon (DOC) analysis. All these samples were then stored on ice in sealed polyethylene bags. Secchi disk depth was measured with a standard 20 cm disk.

Samples were returned on ice to the laboratory on the same day that they were collected. Nutrient samples were immediately frozen in a secured freezer before being transported to CBL for analysis. Total phosphorus, nitrogen, and carbon were calculated by summing dissolved and particulate fractions. All analytical data or sample tracking data was entered on computer storage devices.

All SMRP non-tidal stations were accessed by vehicle, and water samples were collected and analyzed using methods similar to those used at the tidal station (Table 4). Water sampling was done by discrete grab sampling (a surface sample taken with a bucket) or by instrument. A Yellow Springs Instrument (YSI, Yellow Springs, OH) multi-parameter water quality sonde (Model 600XLM) was used to measure water temperature, conductivity, dissolved oxygen (DO), and pH (Table 4). The YSI sonde was calibrated in the laboratory using manufacture's specifications prior to each non-tidal sampling trip. Grab sample water was used for all analyses. All sampling equipment used in the filtering process was rinsed three times with sample water. After filtering was complete all filter pads were stored in aluminum foil envelopes on ice in sealed polyethylene bags. The same procedures listed above for tidal sampling were employed at non-tidal stations.

All non-tidal samples were returned on ice to the laboratory on the same day that they were collected. Nutrient samples were immediately frozen in a secured freezer before being transported to CBL for analysis on July 12, 2008. The Nutrient Analytical Services Laboratory of the Chesapeake Biological Laboratory maintains published analytical procedures, SOPs, and QA/QC protocols and these are also detailed on their web site (http://www.cbl.umces.edu/nasl/).

Non-tidal Water Quality, 1999-2008

Temperature

Water temperature ranges throughout the study period were approximately 25^{o}C for all non-tidal sites (Figure 18). Temperatures ranged from near 0^{o}C at the coldest site (NT13) during winter to 32.8^{o}C at the warmest sites (NT 01 and NT04) during the summer. The warmest minimum and maximum water temperatures were at St. Mary's Lake NT04. Release of lake water into the Western Branch of the St. Mary's River is from a surface intake structure near the impoundment. Because lake surface water receives thermal energy from solar radiation throughout the year, direct heating has a strong impact on St. Mary's River thermal properties downstream in the Western Branch site, NT03. All the other sites in the upper St. Mary's River, however, have considerably cooler median water temperatures compared to those of the lake sites. This is especially apparent during summer when a deciduous leaf canopy shades most of the smaller tributaries that make up the upper St. Mary's River. As a consequence, summer high temperatures at NT03 and NT04 are moderated downstream to the point that NT09 (USGS gaging station site) below the confluence of all upper river tributaries nearly 5^{o}C cooler than at the lake. These temperature patterns were not extreme but are of considerable importance because they influence dissolved oxygen concentrations and other chemical/biological characteristics of the watershed. The only other non-tidal site with high temperatures during the study was Locust Grove (NT01), which is tidally influenced.

Dissolved Oxygen

Dissolved oxygen concentration as a percentage of saturation (%DO) and as an absolute concentration (mg/L) was consistently high at all stations throughout the study period (Figures 19 and 20, respectively). For the most part median %DO was ranged between 85 and 100%. The tidally influenced sites (NT01 and NT14) experienced low %DO during summer when water temperatures were high, but median concentrations were above 80% (Figure 19). Several very high saturation seen at sites NT01, NT11, and NT14 (172%, 170% and 255%, respectively) and the very low saturation at site NT05 (-21.4%) were anomalies. Therefore, we believe these values are outliers and possibly due to instrument error.

The range of %DO was fairly narrow and consistently high at all non-tidal sites, and this generally indicates that water quality, as determined by dissolved oxygen, was fairly good. Relatively low minimum %DO values corresponded to higher summer temperatures when oxygen concentrations are depressed. Overall, oxygen levels are good and above those reported for other streams in the southern Potomac drainage (Boward et al., 1998).

Alkalinity, pH, and Dissolved Organic Carbon (DOC)

Alkalinity was sampled between the years 1999-2006. During this time, virtually all the streams sampled in our study had alkalinity values consistently less than 50 mg/L $CaCO_3$ (Figure 21). In general, low stream alkalinity reflect the marine origin; sand, silt, clay and gravel composition; and the low pH of St. Mary's County soils (Gibson, 1978). Some variability in alkalinity exists at NT01-06 where values exceed 40 mg/L $CaCO_3$, and these are probably due to isolated, storm related events. Throughout the study pH values were also very consistent at all sites and ranged between 4.0 and 10.19 (Figure 23). In general, there was a slight depression in mean pH at all sites in the fall through winter as dissolved organic matter (Figure 24) (as measured by dissolved organic carbon-DOC) leached from the soil and entered streams. DOC concentrations were, for the most part, quite low (<10 mg/L), but the tidally influenced station at Locust Grove Cove (NT01) was consistently the highest DOC site (Figure 24).

Total Suspended Solids

Generally, the mean TSS values over all time periods were relatively low (<20 mg/L) in the St. Mary's River watershed, but some upper St. Mary's River sites (NT05 and 06), and eastern shore tributaries (NT12 - NT14), had high ranges of TSS and were periodically variable (Figure 25) also highest fluctuation. Variability in TSS seemed to be closely tied to precipitation during storm events. In the eastern branches, Pembrook Run (NT 12), Fisherman Creek (NT13), and Church Creek (NT14), all had high TSS variability and this variability likewise was correlated with precipitation during storms. Church Creek, in particular, is known as a highly turbid site because in the vicinity of our sample site (where State Route 5 crosses Church Creek) the steep road, poor storm water control structures and very high discharges cause erosion problems. Sediment is carried into St. Inigoes Creek, and residents have complained to the County Soil Conservation Service about the sediment load.

Pembrook Run seems to be impacted by development and strong erosion caused by surface run off in the upper portions of this sub-watershed. Fisherman Creek also carries a heavy sediment load at certain times of the year, and it is likely that steep slopes and highly erodible soils in the sub-watershed contribute to the high range and mean TSS values. The area immediately upstream from the sampling site is used for off-road recreation (bicycles and 4 wheel all terrain vehicles). Despite good vegetative cover in the watershed and little imperviousness, many eroded trails could contribute sediments to the stream. Storm events likely contribute to surface runoff and promote erosion because, although not quantified, the stream and tidal portion of Fisherman Creek is visually very turbid following storm events.

Because mean TSS values and their standard deviations were rather low at all sites compared to their TSS ranges that exceeded 80 mg/l (Figure 25), it is likely that TSS loading of these streams was due to sediments released by elevated erosion during storm events (Figures 12-16). The sampling regime used in this study did not allow for TSS to be systematically taken in conjunction with storms, and this makes it is difficult to state definitively that precipitation and stream TSS levels are correlated. However, it is likely that erodible watershed soils, steep slopes in certain stream segments, impervious surfaces in the headwaters of some streams, and heavy precipitation all contributed to large fluctuations in TSS. It is also likely that TSS levels return to low levels quickly as St. Mary's River watershed streams are quite small and seem to export their suspended material rapidly. Even the very heavy flooding and high TSS observed visually during Tropical Storm Floyd (September 15-16, 1999) diminished quickly, so that by the October 9, 1999 sampling date, TSS levels returned to very low levels.

Some high (>80 mg/L) mean TSS values were not associated with heavy precipitation during storms (Figures 12-16), and it is likely that these results were due to filter contamination. In other instances heavy precipitation lead to only moderate increases in TSS. Although not specifically assessed, the frequency of storms and/or the saturation of the soil prior to a storm seem to play a role in mobilizing sediments and their ultimate transport into streams.

Nutrients

Mean and median total dissolved phosphorus (TDP) concentrations were quite low (less than 0.05 mg/l) at all but one non-tidal sites (Figure 26). Tidally influenced Locust Grove Cove (NT01) was an exception with a high range and median (0.12 mg/l) of TDP. This trend at NT01 was also true for particulate inorganic phosphorus (Figure 27), particulate carbon (Figure 28) and particulate nitrogen (Figure 29). Locust Grove Cove also had the highest DOC concentration and one of the higher TDN concentrations of all non-tidal sites (Figure 30). However, ammonia (Figure 31) and nitrite/nitrate (Figure 32) concentrations were relatively low at NT01, suggesting that nutrient contamination at Locust Grove Cove came from organic sources. Compared to other non-tidal sites, Locust Grove Cove was highly enriched with nutrients.

Variability in total dissolved nitrogen concentrations (Figure 30) at all sites appears to be influenced by either high ammonia (Figure 31) or high nitrite/nitrate concentrations (Figure 32). For example, NT05 (Landfill tributary) had high TDP, ammonia, and nitrite/nitrate values, showing the contribution of the county’s St. Andrew’s Church Road landfill to the stream’s nutrient levels. The Landfill tributary watershed is also experiencing rapid urbanization/increased imperviousness, and this may also be influencing the nutrient content of this stream.

Almost all the variability in overall ammonia was caused by the Landfill (NT05) site and secondarily by NT06 (Hickory Hills tributary). Hickory Hills tributary, which drains the land area further to the east of the Landfill tributary, has consistently high ammonia and nitrate/nitrite concentrations perhaps from runoff and development as land use is changing rapidly in this area. Both ammonia and nitrite/nitrate concentrations were consistently low at NT03, but particulate nitrogen and carbon were high at NT03 suggesting that nitrogen is utilized and retained in St. Mary’s Lake phytoplankton.

Site NT05 consistently had the highest ammonia concentrations of all sites (Figure 31), and this suggests that decomposition of organic matter is contributing ammonia to the Landfill Tributary. Other extreme nitrogen values occurred in the upper St. Mary’s River. Interestingly, NT07, the site below both NT05 and NT06 had relatively low ammonia and nitrite/nitrate concentrations. These trends in nitrogen concentration in the uppermost part of the watershed were consistent during the course of the study and suggest to us that nitrogen perturbations at these sites are localized upstream and accompanied by a downstream nutrient recovery zone or sink. Heavy precipitation probably plays a major role in transporting nutrients into the St. Mary’s River tributaries in much the same way as precipitation influences TSS. However, there seems to be no clear relationship between precipitation on a specific sampling date and nutrients entering a water body. Our inability to establish linkage between nutrient concentrations and storm events was probably due to the sampling regime that we employed which was specific to date rather than to storm events. Storm events during or just prior to sampling may have influenced nutrient results. However, without a controlled protocol that sampled for elevated nutrients in response to storm events, it is impossible to state conclusively that nutrient levels are linked to surface runoff.

Tidal Water Quality, 1999-2008

Generally, tidal station results (Figures 33-50; Table 6) were quite similar at the surface (temperature, pH, and oxygen) but tended to differ with depth. The deepest stations (SMT04, SMT06, and SMT07) tended to be different compared to the shallow tidal station up river (SMT02) and tidal creek and shallow tidal stations down river (SMT09, SMT10, XBE8396 and XBF6843) were different compared to the mainstem stations. Much of the variability in tidal results seems to be driven by seasonal weather patterns, precipitation, algal growth and decay, and oxygen profiles in the water column.

Salinity and Water Temperature

Except for station T01 (Adkins Road) at the upper end of the estuary, the tidal St. Mary's River is largely a partially-mixed, mesohaline estuary with salinities above 10 ppt (parts per thousand) and below 20 ppt (Figures 35 and 36). However, dramatic drops in salinity occur after major storm events such as Hurricane Floyd in September of 1999 and major rain event on July 27, 2000, and again in July of 2001, as well as particularly wet months such as April 2004 and March 2007 (Figures 12-14). A wet summer in 2003 that continued into 2004 depressed salinity at all tidal sites. Salinity did not return to levels comparable to those before this event until the particularly dry years of 2006 and 2007. In general salinity at the surface and at the bottom was similar at all tidal stations across time. Large differences between surface salinity and bottom salinity on specific dates were due to storm events causing a depression in surface salinity but having little effect if any on bottom salinity. This trend was most pronounced during the summer months (Figure 36). Because of the short duration of these events and the biweekly sampling schedule, rapid changes in salinity due to storms were often missed except when special efforts were made to sample immediately following a storm. Salinity showed an annual cycle with highest levels in the fall and early winter and lowest levels in late spring and summer.

Water temperature showed pronounced seasonal variation at all tidal stations, and values range from 0ºC to above 30ºC (Figures 33 and 34). Surface temperatures were highest in mid-summer (July or August). In the fall, surface temperatures cooled quickly, reaching the lowest values in late December and January. In the summer, vertical temperature gradients were observed with cooler temperatures on the bottom. As surface waters cooled in the fall, the relationship periodically reversed with warmer, more saline water on the bottom. By February, the pattern of cooler water on the bottom re-established itself (Figure 35). For most of the year the water column was partially mixed, with relatively continuous gradients of salinity and temperature from top to bottom. However, distinct haloclines and/or thermoclines were observed during several sampling periods, indicating that the St. Mary's River can become highly stratified.

Dissolved Oxygen and pH

The surface waters of the tidal St. Mary's River were well oxygenated from 1999 through 2008 (Figure 37). The two shallow water stations, T01 and T02, and especially T01, showed little difference between surface and bottom water dissolved oxygen. A cyclical dissolved oxygen pattern was seen at T02, but not at T01, again owing to its shallow nature. At the other stations (T03-10) bottom waters were hypoxic or anoxic at stations at depths of 3 meters or more from the late spring through summer (Figure 37). Low bottom oxygen concentrations were likely related to high chlorophyll concentrations observed at these times of the year (Figures 44 and 45) and thermal stratification of the water column (Figure 34), preventing the downward mixing of oxygen. Decreased levels of oxygen in bottom waters of the Chesapeake Bay during the late spring and summer months are often related to the decomposition of algal cells (Day et al., 1989). Phytoplankton blooms are common in the upper reaches of the estuary in the spring with increased watershed discharge and nutrient loading. Many of these algal cells settle out of the euphotic zone (where there is sufficient light for photosynthesis), die and decompose, removing oxygen from the water. Particulates from these blooms can move downstream along the bottom, causing high biological oxygen demands and nutrient regeneration during the summer (Kemp and Boynton, 1984).

The bottom waters of lower Potomac River are usually hypoxic from May through September and can become anoxic at times. Bottom water oxygen levels in the lower Potomac (Chesapeake Bay program station LE2.3) were lower than average in the spring and summer in 2000 (Chesapeake Bay Program, 2005). However, the low levels of oxygen in the bottom waters of the much shallower St. Mary's River (7 to 8 meters vs. 20 meters maximum depth) were surprising. Our main channel stations in the St. Mary's

River (T03-07) all showed the same pattern of hypoxia or anoxia at the bottom every summer during the study. Our tidal creek stations (T08-10) showed the same annual pattern of oxygen depression during the summer months, but the depression was not as severe as that seen in the main channel of the St. Mary's River. The data collected from the St. Mary's River over the past nine years indicates an ongoing trend of oxygen depletion during summer months. We also believe that this pattern is caused by nutrient enrichment during spring runoff (Figures 39-43) that fuel algal blooms, that subsequently die and decompose, and as a consequence reduce oxygen in the lower part of the water column. Low dissolved oxygen is often associated with water quality degradation related to anthropogenic stresses, and frequent low dissolved oxygen events negatively affect communities of benthic organisms (Dauer et al., 2000).

For the most part pH was highest in the spring, lowest in the summer and showed a decrease with depth at these times of year (Figure 38). Biological processes help to explain these patterns as photosynthesis increases pH while respiration lowers pH (Day et al., 1989). Increases in pH at the surface in the spring reflect higher phytoplankton photosynthesis rates as indicated by increased chlorophyll concentrations (Figures 44 and 45), whereas lower pH in bottom waters indicate higher rates of respiration caused in part by the decomposition of sinking algal cells during the spring and summer months. The sites located furthest up-river tended to display the lowest pH values and the most variation because these sites are more directly effected by activities on land and are farther from the cleansing and stabilizing forces of oceanic waters, explaining the lower and more variable pH of T01 at the upper most end of the tidal river. Oxidation-reduction potentials (ORP), although not shown on graphs, indicate the relative degree of oxidation and reduction in the water column with higher values indicating more oxidizing conditions, such as when oxygen is abundant. ORP values generally corresponded to the availability or lack of oxygen at tidal sites (Figure 37).

Nutrients

All analytical forms of nitrogen and phosphorus were collected by SMRP sampling by 2006, and the most important species collected between 1999 and 2006. Ammonia (NH_3), nitrite and nitrate (NO_2 and NO_3) and total dissolved nitrogen (TDN) were collected throughout the study, but particulate nitrogen (PN) and total nitrogen (TN) were only collected after 2006 and are not discussed here. Likewise, orthophosphate (PO_4) and total dissolved phosphorus (TDP) were collected throughout the study, but particulate inorganic phosphorus (PIP), and total phosphorus (TP) were only collected after 2006 as well and are not discussed here.

Perhaps, the best standard to be applied to nutrient data for the identification of problems are the criteria used by the Chesapeake Bay Program to assess habitat requirements for submerged aquatic vegetation (SAV) growth and survival (Batuik et al., 2000). These criteria have been applied in the examination of our mesohaline nutrient data. Over the course of the SMRP study, nitrogen concentrations (ammonia, nitrite-nitrate, and total dissolved nitrogen) were quite variable, but generally occurred in relatively low concentrations at all sites (Figures 39 and 40). Overall, ammonia and nitrite-nitrate seemed to cycle together and clearly contributed to total dissolved nitrogen concentrations across all dates and sites. Ammonia was present in relatively low concentrations (<0.1 mg/L) at all sites and across all time periods. Ammonia, nitrite-nitrate, and total dissolved nitrogen were highest in late winter and early spring, and we suspect that like other tributaries in the Chesapeake Bay, nitrogen is carried into the surface water of the St. Mary's River through runoff during spring storm events. Our tidal station located the furthest upstream and closest to freshwater sources (T01- Adkins Road) consistently had the highest nitrogen levels, 0.282 mg/L of dissolved inorganic nitrogen (DIN) overall compared to all the other tidal stations, and this indicates that freshwater tributaries are contributing to the nitrogen loading of the tidal St. Mary's River.

In order to assess nitrogen concentrations more carefully, DIN concentrations were studied relative to the 0.15 mg/L standard for SAV habitat (Figures 40 and 41). DIN was highest from the late winter through spring and decreased during the summer (Figure 40). Again, we believe that this pattern is attributable to DIN surface runoff and then uptake by algae during the summer months. When a mean DIN value was computed for each tidal station for all the data collected at that station, the highest mean values were at the ends of the tidal reach, N01 – furthest upstream (0.348 mg/L) and at T07- the mouth of the St. Mary's River (0.240 mg/L). All other tidal stations had mean DIN values less that 0.220 mg/L. Over 80% (80 out of 98) of the DIN samples analyzed for station T01 were above the recommended threshold of 0.15 mg/L for SAV habitat. Despite the fact that this station is more oligohaline than downstream mesohaline stations and that criteria differ based on salinity, it is clear that nitrogen entering the tidal reaches comes from the nontidal St. Mary's River. Downstream stations, in comparison to T01, had substantially fewer DIN samples that exceeded the Chesapeake Bay Program standard. For example: T02 had 97 of 136, T03 had 109 of 166, and T06 had 97 of 151 DIN samples that exceeded the 0.15 mg/L threshold value (Figure 40). Wet spring-summer periods during 2003, 2004, and 2005, produced distinct and repeated peaks in ammonia, nitrite-nitrate, and TDN at virtually all tidal sites (Figure 39).

Dissolved Inorganic Phosphorus (DIP) is also used by the Chesapeake Bay Program to assess nutrient levels that impede SAV growth and reproduction (Batiuk et al., 2000). In mesohaline waters, this threshold value should be less than 0.01 mg/L. We measured DIP as orthophosphate ($PO_4^=$) and also measured total dissolved phosphorus (TDP) throughout the SMRP study period (Figure 42). From 1999 through 2008, there was close correspondence between orthophosphate ($PO_4^=$) and total dissolved phosphorus (TDP) on each sampling date. When we analyzed total dissolved phosphorus in relation to orthophosphate there was not a significant correlation, presumably because of the undocumented dissolved phosphorus concentrations. However, there was close correspondence between DIP and TDP when the concentrations of both were low (as seen in the bottom left-hand corner of Figure 43). Overall, phosphorus (both orthophosphate and TDP) showed gradual increases in the spring, followed by summer peaks, then declines through the fall and winter (Figure 42). This was most likely due to phosphorus being a relatively rare and conserved nutrient that is quickly taken up and used by algae in the water column (Boynton et al., 1982) or unavailable because it is tightly adsorbed onto clay particles (Lind, 1985). The dynamics of phosphorus are greatly influenced by algal photosynthesis and decomposition (Valiela, 1984), and the general pattern that we observed for phosphorus seems to indicate low levels when algal blooms were present and higher concentrations when the algae were dying and being decomposed, thus releasing their phosphorus. Overall and like nitrogen, phosphorus concentrations were higher and more variable at the upstream station (T01, Figure 42), and most downstream stations showed lower concentrations in the water column, presumably because of algal uptake of phosphorus.

Chlorophyll

Chlorophyll was used as an indirect assessment of phytoplankton in the water column. Both chlorophyll-*a*, measured in discrete water samples and *in situ* total chlorophyll, an estimate of chlorophyll made with a fluorometric probe, were used to determine chlorophyll. Here, we analyze only the chlorophyll-*a* results because filtration and analytical quantification results were more reliable than probe analysis results. In surface waters chlorophyll *a* concentrations increased rapidly in the spring at all tidal stations for every year during the study period (Figure 44). The dinoflagellate, *Prorocentrum minimum*, a common member of the springtime phytoplankton and cause of mahogany tides (from the reddish brown pigments of the dinoflagellate) was probably responsible for the highest concentrations of chlorophyll *a*. Maryland DNR (2000) reported the highest densities observed in the past 20 years during late April and in May of 2000. Normally, cell densities are less 5,000 cells/mL, with blooms under 10,000 cells/mL. In early May of 2000, cell densities of 169,000 cells/mL were counted (DNR, 2000). Phytoplankton blooms are stimulated by a combination of factors including high nutrient levels and light. Temperature and salinity also play a role. The mahogany tide in the spring of 2000 was thought to be responsible for low oxygen concentrations in the lower Potomac estuary that led to fish kills in Breton and St. Clement Bay. While fish kills were not reported for the St. Mary's River, observations of a mahogany color to the surface waters and the high levels of chlorophyll (Figure 44) indicate that a bloom occurred here as well. The highest chlorophyll levels during our study were recorded in the spring of 2000, and the summers of 2001 and 2003. For the most part, chlorophyll concentrations were consistent between stations with peak concentrations coinciding by date in the main stem of the St. Mary's River (T01-T07). The tidal creeks (T08-T10) showed a similar pattern to the main stem of the St. Mary's River, but St. Inigoes Creek did not show the algal blooms seen at all other stations in the spring or 2000 or the summer of 2001, but had the highest chlorophyll concentration (>120 ug/L) of any station on any date in the fall of 2003.

When a mean chlorophyll *a* concentration was computed for all stations across the entire study period (Figure 44), the cyclical pattern of increasing and decreasing chlorophyll in the St. Mary's River and its tidal tributaries could be readily seen. In order to compare these mean values to the threshold habitat value of 15 ug/L of chlorophyll *a* for SAV growth and survival (Batiuk et al., 2000), this value was also plotted in Figure 45. Again, the reoccurring pattern of high chlorophyll concentrations in 2000, 2001 and 2003 can be seen as the threshold was exceeded in the spring and/or summer of these years. While the threshold is exceeded in the spring and/or summer of most years, 2000, 2001, and 2003, display the highest peak chlorophyll levels. September of 2003 was a particularly wet, in a historically dry month (Figures 12 and 13) and strong nutrient inputs at that time (Figures 39-42) seem to have promoted particularly high chlorophyll levels as the mean, median and range of chlorophyll were the highest of the study period. Some of the highest sustained depressions of salinity also occurred at this point during this study (Figure 35), and this was undoubtedly due to heavy precipitation through the summer and into the fall.

I also feel that high chlorophyll and algal concentrations contributed to the strong depression of oxygen in the bottom water of the St. Mary's River and its tidal tributaries. As algal cells use up and compete for the limited nitrogen and phosphorus in the water column, algal mortality increases and nutrients become scarce. As nutrient starved algal cells die and sink, they remove oxygen as decomposer activity increases toward the bottom. All nutrient, dissolved oxygen, chlorophyll and Secchi disk depth data support this general conclusion. As expected, as chlorophyll concentrations increased at all stations, water clarity at the surface declined, and so did the depth of light penetration as measured by Secchi disk. With virtually every instance of chlorophyll concentration increase there was a corresponding decline in Secchi disk depth at all stations over time. This inverse relationship between water clarity and chlorophyll concentration (Figure 46) was not statistically significant, but was very apparent. We can, therefore, conclude that algae are a major factor controlling light penetration in the tidal St. Mary's River, and while other material suspended in the water column (TSS) also diminishes light penetration, the algae in the river is a problem for SAV.

Total Suspended Solids, Turbidity, and Secchi Disk Depth

Total suspended solids (TSS) concentrations were variable between stations and sampling periods, ranging between less than 5 mg/L to nearly 100 mg/L (Figure 47). TSS was highest at upstream stations (T01 and T02) and in St. George Creek (T09), a pattern that is typical of estuaries (Day et al., 1989). The lowest TSS values were in Carthagena and St. Inigoes Creeks (T08 and T10, respectively). In general, the cyclical nature of TSS was highest and linked to precipitation during the spring and summer months and relatively low during the fall and winter months when precipitation was also low. Higher TSS levels following storm events were sometimes recorded, such as on July 27, 2000, when spikes of TSS were recorded for most sites (Figure 47) following a storm on July 26. This storm produced 2.3 cm of precipitation and was preceded by two days of rain. Discharge rates at the St. Mary's stream gage increased from 0.5 m^3/sec on July 25 to 15.9 m^3/sec on July 26 and continued to be high for several days.

Other major storm events, such as Hurricane Floyd on September 16, 1999, were mostly missed as a result of the monitoring schedule. During Hurricane Floyd discharge rates at the gaging station jumped from 0.1 m^3/sec on September 15 to 75 m^3/sec on September 16, 1999. Observations from the shore indicated that TSS levels were extremely high, and the TSS level taken at the St. Mary's College pier on September 17 was 39 mg/L (Church Point in Figure 17). However, by September 20 (the next regular sampling period) TSS had dropped to pre-storm levels (Figure 47).

Median levels of TSS of less than 15 mg/L during the growing season (April through October) are considered a requirement for SAV growth and survival in mesohaline segments of the Chesapeake Bay (Batiuk et al., 2000). Of the 997 TSS readings for which there were corresponding Secchi disk measurements, 317 readings or 32% exceeded the 15 mg/L threshold. We analyzed all the TSS sample concentrations against the 15 mg/L standard by tidal station to determine the percentage of time that stations exceeded Batiuk's and his colleagues (2000) threshold. This analysis also revealed that the upstream stations T01 and 02, the main stem station T05, St. George Creek- T09, and the new tidal stations XCD 7904-St. George's Creek, XCC9680, and XCD3765, all had turbidity problems because they had greater than 15 mg/L TSS in more than 25% of their samples.

Suspended solids increase the turbidity of water, resulting in reduced water clarity and potentially stressing communities of benthic plants. From 1999 through 2008, Secchi depth ranged from 0.20 meters to nearly 4.5 meters depth, with shallower Secchi disk depths found upstream and in tidal creeks (Figure 48). Median Secchi disk depths greater than 1 meter during the growing season are considered to be the requirement for SAV growth and survival in mesohaline estuaries (Batiuk et al., 2000). Again, we used the Secchi disk depth threshold of 1.0 meter to assess the percentage of samples failing to meet the standard. The results were similar to those for TSS because the upstream stations (T01, T02) and one of the tidal creeks- St. George Creek- (T09) did not meet this standard during the growing season. Mainstem channel stations (T01 through T07) showed a gradual and steady increase in mean and median Secchi disk depth when all sampling dates were considered (Figure 50).

General Conclusions about Tidal Sites

A closer examination of precipitation patterns over the course of the SMRP study period was necessary to interpret the results obtained from tidal sampling, and this analysis explained the dramatic shifts in nutrient, water clarity, and chlorophyll data late in the study period (2003 and 2004). The lower than normal precipitation and watershed discharge for the first three years of the study period (1999-2001) resulted in overall higher salinities in the tidal river (and possibly led to lower TSS, nutrients and phytoplankton densities (as indicated by chlorophyll), and better water clarity. Precipitation in 2002 was high in the 4th quarter of the year, but below the quarterly means for the study period, resulting in an "average" designation for the year. Both 2003 and 2004 were very wet years, with the 2nd and 3rd quarters being extremes and driving salinities far below seasonal norms (Figure 35). This very heavy precipitation resulted in the highest nutrient concentrations during the study period at both nontidal (Figures 26-32) and tidal (Figures 39-42) sites. As a consequence of this nutrient enrichment in the summer of 2003, the tidal stations responded with very strong increases in algal production as evidenced by the high chlorophyll concentrations of the study period (Figures 44 and 45). Not surprising were the low Secchi disk depths during this time period (Figures 46 and 48) or sustained low oxygen in bottom water (Figure 37). Interestingly, the very heavy precipitation in late summer and early fall of 2004 did not yield the same nutrient, Secchi disk depth, or chlorophyll response. I believe that the July-September precipitation in 2004 (more than 60 cm) was so strong that it drove salinities to their lowest levels of the SMRP study period, and this occurred after the initial algal growing season. Therefore, the algal community did not respond as strongly as in the previous year (2003) when heavy precipitation occurred earlier in the spring and summer. In 2005, the heavier precipitation and consequences of the previous two years were again seen; however, the precipitation levels were not as extreme as in the previous two years. In 2006, the gauging station was shut down, creating an absence of precipitation data; however in 2007 the watershed experienced a harsh drought during the summer with only moderate precipitation in the fall and winter.

Examination of individual tidal station data shows that the two most upstream tidal stations (T01, T02) and St. George Creek (T09) are the most heavily impacted areas in the tidal St. Mary's River. For the most part, the main stem channel stations (T03-07) and two tidal creek stations (T08 and T10) had relatively good water quality because they met most standards established for SAV habitat requirements. Submerged aquatic vegetation increased by a factor of 10 in 1999 relative to 1998, and increased again in 2000 and 2001. This is possibly a result of improved water quality and dry summer conditions. However, most of the increase in SAV was in the lower river, below Chancellors Point, suggesting conditions in the upper river may not be good enough to support beds of SAV (Abdella et al., 2003).

Of particular concern is the hypoxic/anoxic water observed at the bottom of the river for extended periods of time during the spring and summer months. This is surprising, considering the relatively shallow depth of the river. We hypothesize that increased precipitation in the spring and the unusually wet summers of 2003-2005 led to higher watershed discharge and flushing of sediments and nutrients from the watershed into the estuary. Higher nutrients coupled with a stratified water column that kept phytoplankton within the euphotic zone (upper part of the water column with sufficient light for photosynthesis) stimulated algal blooms and the dinoflagellate *Prorocentrum minimum* ("mahogany tide"). As cells died, they eventually sank to the bottom and were decomposed by microorganisms, depleting oxygen in near-bottom waters in the process. The stratification of the water column inhibited the downward mixing of oxygen from the surface to replace that used in decomposition processes. While this hypothesis seems to fit the data for the spring of 2000 and 2001, we know less about what may have caused the hypoxic conditions during the summer months. Because this pattern was seen consistently for 9 summers and because the intensity of oxygen depression seems to be related to precipitation, runoff and transport of sediments and nutrients into the St. Mary's River must be the driving force of this annual phenomenon. Clearly, this scenario is of concern as low dissolved oxygen can cause fish kills and negatively impact benthic organisms, including oyster communities. Furthermore, increasing human activities in the watershed can cause an increase in the frequency and duration of low oxygen events, leading to further degradation of the ecosystem.

There were many significant storm events during the study period, including Hurricane Floyd and several summer storms. It is clear that these events have severe short term effects on water quality which are often missed with current water monitoring protocols. We speculate that storm events and the resulting decline of water quality strongly affect habitats and organisms in upper regions of the tidal river, possibly explaining why SAV is largely found in the lower tidal river. However, much more research is needed to test this hypothesis and to determine what role storm events play in the survival of organisms in the tidal St. Mary's River.

Biological Resources

Submerged Aquatic Vegetation (SAV)

Submerged Aquatic Vegetation (SAV) has been studied intensively in the St. Mary's River by Christopher E. Tanner and his St. Mary's College students for well over a decade. In addition, Abdella and her colleagues (2003) conducted an in depth assessment of the potential of the St. Mary's River to support a SAV restoration project and concluded that various sites near the mouth of the river (Figure 51) could be used for restoration efforts.

Annual aerial surveys of submerged aquatic vegetation in the Chesapeake are conducted by the Virginia Institute of Marine Sciences (e.g. Orth et al., 2000). We conducted surveys by boat to ground-truth the location of SAV communities and to provide information of what species are present and their densities. Two species of SAV, *Ruppia maritima* (widgeon grass) and *Zannichellia palustris* (horned pondweed) were observed in the St. Mary’s River. *Zannichellia palustris* grows primarily in the spring and early summer, declines rapidly in the summer and is largely gone by the late summer and early fall. Horned pondweed favors oligohaline salinities (0.5 to 5 ppt), but is frequently found in mesohaline (5 to 18 ppt) regions of the bay. In the late spring of 1999 we found *Z. palustris* throughout the river, with the largest beds above Tippity Witchity Island (between stations T01 and T02, Figure 1). Smaller beds were also observed in Carthagena Creek.

Unlike *Z. palustris*, *Ruppia maritima* persists throughout the year and has a wide range of salinity tolerance. In mesohaline regions of the bay, *R. maritima* tends to be a dominant species, often in association with *Zostera marina* (eelgrass) in higher salinity areas. Over the period of the study *R. maritima* was found along the shores of the lower St. Mary’s River, from just above Chancellors Point (T05) south. Our boat surveys indicated a dramatic increase of *R. maritima* beds. Aerial surveys showed a 10x increase in the area covered by SAV in 1999 relative to the previous year and further increases in 2000, 2001, and 2002, but then declines in 2003 and 2004 (see maps and tables in Orth et al. 1999-2003 and Virginia Institute of Marine Science, 2004). The lack of longitudinal data makes it difficult to determine the reasons for such a dramatic increase in *R. maritima*; however, we speculate that the lower than normal precipitation and watershed discharge led to higher salinities, lower TSS and nutrients, and better water clarity from 1999 through 2002, improving the conditions for the growth and reproduction of *R. maritima*. However, conditions deteriorated in 2003 and 2004 when the reverse conditions prevailed and SAV area coverage declined (Orth et al. 2003; Virginia Institute of Marine Science, 2004).

With improving water quality, SAV has shown dramatic increases in coverage in areas of the lower Potomac. However, most revegetation has been limited to two species (widgeon grass, horned pondweed), and some areas still have little SAV. Based upon an analysis of historic SAV distribution, SAV water quality habitat characteristics and appropriate species for restoration, Abdella et al. (2003) recommended that one or more large scale (greater than 1 acre) SAV restoration projects be targeted in each of the five areas of the lower Potomac that pass field assessments and test plantings. The objective of the these projects would be to support the Chesapeake Bay Program goal of accelerating SAV restoration by planting 1,000 acres of new SAV beds by the end of 2008 and to increase the diversity of SAV species currently in the main stem and tidal tributaries of the lower Potomac River.

An eight-year process is anticipated for these projects. Using a modified Preliminary Transplant Suitability Index (PTSI), areas have been identified that have potential for SAV restoration. The modified PTSI uses historic and current SAV distribution, primary and secondary SAV habitat requirements, and shoreline exposure (based on fetch) to rank the suitability of areas for restoration. During the first year, these areas are field assessed for restoration suitability using spatially intensive habitat assessments (Dataflow), analyses of sediment characteristics, species composition and shoreline configuration. Based upon these a second PTSI that includes field assessments is used to identify specific sites for test plantings. In the fall of the first year test plots are planted at identified sites with one or two species per site, and fixed monitoring stations are established at least one test site in each tributary with potential restoration sites. In the second year habitat assessment is continued with spatially intensive habitat assessments and fixed monitoring stations, test plantings are evaluated, if, considered necessary, a second round of test plantings is conducted in the spring and/or fall. At the end of the fall growing season, the suitability of each test site is evaluated and sites for large scale plantings are selected. Sites for large scale restoration are planted over a three-year period. During this time, SAV habitat requirements and planting success are monitored. In the sixth through eight year, overall planting success is evaluated, and conclusions and recommendations for future restoration work in the area are made available to Bay scientists and managers. Four species are recommended for use in SAV restoration in the lower Potomac: eelgrass, redhead grass, sago pondweed and wild celery. Assuming that habitat requirements are met for species used, the primary risks involved with SAV restoration include a reversal in the trend of improving water quality related to storm events, higher than normal precipitation and/or changes in land uses in the watersheds. Plantings can also be disturbed by mute swans and cow nose rays although this has not been a major problem in existing projects in the St. Mary’s River (Abdella et al., 2003).

Macroinvertebrates

Macroinvertebrates have been collected at non-tidal stations in the St. Mary’s River Project (SMRP) in the spring of 1999, 2000, 2001, 2003, and 2008, however the specific stations sampled in each of these years was different (Table 6). In addition, three new stations, not previously sampled, were added in 2008: on Indian Bridge Road just below the bridge crossing the St. Mary’s River (Below IRB), the St. Mary’s River at the kayak launch park in Great Mills (Kayak Park), and Craney Creek. In 2008, a total of 536 individuals in 36 families and 8 orders were obtained in kick net samples (Table 7). By comparison, in all the SMRP studies from 1999 through 2006, 57 families of aquatic insects have been found at St. Mary’s River watershed non-tidal stations. Therefore, the collections made in 2008 seem to be good representations of macroinvertebrates based on our historic sampling and because a comprehensive study of aquatic insects (Boward et al., 1998) found 56 families of insects in the entire lower Potomac watershed.

When we compared all the insects collected in 2008 by order (Figure 3), we found that Diptera (31.6%) and Ephemeroptera (29.7%) were the most common orders followed by Odonata (14.0%), Plecoptera (9.6%), Trichoptera (7.9%), and Coleoptera (6.3%). Megaloptera (0.8%) and Hemiptera (0.2%) were relatively rare in the 2008 samples. The number of insect families at each station in 2008 was variable with between 4 and 20 families (Table 7). Generally, the insects found reflected specific stream conditions. When we examined the aquatic insect results by station (Figure 6), it was readily apparent that Craney Creek had a poor community as represented by few insects and minimal diversity. NT06 (Hickory Hills) and NT11 (Pembrooke Run) also had reduced numbers relative to the other stations, but the results were not as bad as found at Craney Creek.

The EPA Rapid Bioassessment Protocol for Use in Streams and Rivers (Plafkin et al., 1989) uses community diversity in assessing water quality. The absence of pollution sensitive aquatic insect orders (Ephemeroptera, Plecoptera, and Trichoptera) and dominance of pollution-tolerant groups (Oligochaetes or Chironomids), is indicative of pollution. The presence or absence of aquatic insect indicators or of an indicator species or indicator community reflects environmental conditions. Absence of a species is not as meaningful as it might seem as there may be reasons, other than pollution, that result in a species absence (e.g., predation, competition, or geographic barriers which prevented it from ever being at the site). Absence of multiple species of different orders with similar tolerance levels that were present previously at the same site is more indicative of pollution than absence of a single species. In addition, it is clearly necessary to know which species should be found at a site or in a system.

Overall, low richness of benthic macroinvertebrates may indicate impairment. However, naturally low nutrient levels in pristine headwaters may be the cause of low productivity and few benthic macroinvertebrate species exist in these conditions. While there are many insect species that serve as excellent indicators of both good and poor water quality, the identification of aquatic insects to the species level is difficult and requires specialized training. More general appraisals, such as the proportion of Ephemeroptera, Plecoptera, and Trichoptera (EPT) families to all other families are a relatively good measure of the aquatic insect community's health. While Maryland DNR uses the more sophisticated Index of Biological Integrity (IBI) to assess the health of macroinvertebrate communities (e.g. Roth et al., 1996; Boward et al., 1998), there were difficulties in our using this index to compare our results over the nearly 10- year SMRP time span. The problems arose primarily because different metrics were apparently used to compute IBI scores in different years. Therefore, we opted to compute the less sophisticated EPT ratios in order to compare our St. Mary's River watershed stations in 2008.

The numbers of insects in EPT orders was quite variable with NT11 lacking both Ephemeroptera and Trichoptera, and Craney Creek lacking both Ephemeroptera and Plecoptera (Figure 5, Table 7). Clearly, both these stations, in general, had poor diversity. Most of the other stations, with the exceptions of NT 02 and NT 9.5, had total EPT counts comprised mostly of Emphemeroptera. A comparison of insects at each site

in 2008 by their proportion of EPT (Figure 8) indicated that all stations except NT02 had at least 30% of their total count in EPT orders. The mean percentage of EPT in all samples was 37.4% for all stations. Yet, some of these results are misleading when EPT proportions were compared to total numbers of individuals and families. For example, the lowest aquatic insect abundance (8 individuals) and the fewest taxa (4) occurred at Craney Creek. However, at this site 3 of the 8 individuals were trichopterans giving a false impression of high insect diversity based on the EPT ratio (37.5%). This is the first year that Craney Creek was sampled for insects, and the site is not monitored for water quality. Therefore, it is difficult to determine whether this site is perturbed or has historical problems. Stations NT06 and NT11 also had few insects with 23 and 24 individuals, respectively; however, both had high EPT percentages. NT06 had 56.5% EPT and NT11 had 41.1%. The only other time that NT06 was sampled for insects was in the year 2000, and that sample also yielded 23 individuals (Paul and Tanner, 2004). Site NT11, by contrast, had 78 individuals in 2005, so the high EPT percentage at this site is an anomaly especially with both Plecoptera and Trichoptera entirely absent in 2008.

The highest numbers of individuals (94) were found at the Below IBR station. The next highest numbers were at NT02 (93 individuals), and at NT05 (85 individuals). Despite the high number of insects at NT02, the site had an EPT percentage of only 10.8, the lowest of any of the sampled stations and no mayflies (Emphemeroptera) were found there.

There were also other confusing results. The Below IBR site had a fairly low EPT ratio of 31.9%, despite having the highest number of insects (94 individuals). NT05 (Landfill Tributary), had the most surprising results of all because it had a large number (85) of insects (Figure 5) and a 42.3% EPT ratio (Figure 6). These results are curious because the station is characterized by very heavy bank erosion and siltation, and these conditions were coupled with very high ammonia concentrations relative to all other stations (Table 3). In addition, this station has had historic water quality problems, yet this station has had relatively high aquatic insect densities in past years (90 individuals in 2000) but low densities (the number dropped to 32 in 2005) as well (Paul, 2006; Paul and Tanner, 2001, 2005).

In general, many of these results echo the results found in previous years. Aquatic insect abundance, diversity and community structure found in the 2008 collections support SMRP results and those of MBSS studies (Boward et al. 1998; Stranko and Rodney, 2001). The 2008 aquatic insect results also reflect the current physical and chemical conditions at non-tidal St. Mary's River stations. The anomalies encountered in 2008 at some stations might be explained by repeated sampling at these stations in the future.

Fish

A total of 817 individual fish belonging to26 species and representing 10 families were collected in 2008 (Table 8). Tessellated darters (24%) and American eels (20%) were the most common species, while the percentage of Red-breasted sunfish (5%) and Least brook lampreys (6%) were considerably lower in number from the previous collections. Petromyzonidae (eels), Anguillidae (lampreys), Centrachidae (sunfish) and Percidae (darters) when combined made up 70% of all fish collected (Figure 7). Over a third (13 out 41) of all species collected in 2008 were relatively rare and were collected at 3 or fewer stations out of 13 total stations (Table 8).

Since 1999 the number of non-tidal stations sampled for fish during the MBSS Summer Index Period has not been consistent, but nearly all stations were collected in 1999, 2001, and 2008 (Table 9). Over the entire study period (1999-2008), a total of 6,612 individual fish representing 11 families and 41 species have been collected and identified (Paul, 2006, plus this synoptic survey). Nearly 80% of all fish collected in both 1999 and 2001 were very common: American eel (27%, 19%), Least brook lamprey (19%, 29%), Tessellated darter (19%, 16%) and Red-breasted sunfish (12%, 9%), respectively for 1999 and 2001 (Table 10). When 1999 and 2001 data were compared, many of the same species were found again at the second sampling in 2001. For example, at NT06 (Hickory Hills) 13 species were reported in 1999 and 12 species in 2001 and 10 were in common for both years.

Yet, some 1999 and 2001 data comparisons also show some anomalies. For example, no Largemouth bass were collected in 1999 but in 2001 10 were captured at five sites, and in 2008 only 4 Largemouth bass were collected at only 3 stations, NT02, NT03, and NT14. Some changes were seen between the 2008 data and those of previous years. A large decrease was seen in the percentage of Least brook lampreys. In 1999, 19% of all fish sampled were Least brook lampreys, in 2005 they constituted 24.1% of fish, but by 2008 their percentage had shrunk to only 5.6%. It is possible that this was affected by conditions unrelated to the habitat of the streams, such as sampling efficiency. Many of the stations (for example, NT02, NT08, and NT12) that had 100 individuals at each station in 1999 had less than 10 individuals in 2008 (Table 10).

In a 1995 fish survey of the lower Potomac watershed by the Maryland Biological Stream Survey (MBSS) of DNR, 73 sites (including 2 in the St. Mary's River watershed: Jarboesville Run-NT08 and Pembrook Run-NT11) yielded 41 species in 13 families (Boward et al., 1998). In this study, just 6 species of fish represented 75% of the total abundance. Three of these species were common in both the Lower Potomac study and our St. Mary's River watershed study: American eel, Least brook lamprey, and Tessellated darter. An analysis of the fish found in the 1995 MBSS study and our 1999 and 2001 samples for Jarboesville Run (NT08) showed complete agreement, as all 3 samples had the same 12 species. However, there was strong disagreement in the results for Pembrook Run.

Again, when we looked at our fish results across all years of sampling (Table 10) we found that all sites (except for NT13- Fisherman Creek which had only 4 species) had at least 9 fish species and 100 individuals in 1999. These results lead us to believe the fish communities were healthy except for Fisherman Creek. But in subsequent years through 2005, the number of species collected at Fishermans Creek increased to 8 species, then declined in 2008 when only 6 species were found. In any case, Fishermans Creek seems to have low fish diversity overall and this is probably attributable to poor habitat conditions in the station’s 75 m sampling segment.

Many stations (NT 06, NT 09, NT 11, and NT12, for example) were consistent in the number of species collected across nearly 10 years (Table 10). In 2008, NT 9.5 had the most species (17) and also had the greatest number of (191) individuals of all sations. When this site was sampled in 2000 by a MBSS survey crew, they found a total of 218 fish in 15 species (Stranko and Rodney, 2001), a strikingly similar finding. Other results sharply contrasted one another. At Jarboesville Run (NT08), for example (Table 11), MBSS collected 308 fish (the largest collection out of 7 sites) in 12 species, but this synoptic survey found only 17 total fish in just 4 species. In addition, when we compared MBSS 2000 results to SMRP 2000 or 2001 results, there was some strong disagreement between the collections as well (Table 11). For example, at the 5 stations that we had in common, there was a huge discrepancy in the number of Eastern mudminnows, a notoriously tolerant species, with 237 found by MBSS and only 30 found by SMRP. Likewise, 123 fathead minnows were found by MBSS at NT06 (Table 11), but SMRP has never collected a fathead minnow.

Yet, there were points of agreement between the MBSS-SMRP samples in more general terms. We agree, for example, that the dominant species are Eastern mudminnow, Least brook lamprey, American eel, and Tessellated darter, but we do not agree that their abundance is in this order. We also agree that Hickory Hills tributary (NT06) has a fish community that is declining in numbers and diversity. And the same is true for Jarboesville Run because 12 and 13 species, respectively, were found in 1999 and 2000 at Jarboesville Run (Table 10), and subsequent sampling (Table 10) revealed that fish diversity was declining seriously at this station. It is probable that urbanization in these two subwatersheds is having a profound impact on the fish in these streams. The discrepancy between MBSS and SMRP fish collections is attributable to professional expertise. It is likely that the field identification of some rare species in SMRP samples (Bridled shiner, Warmouth, and Satin fin shiner) was incorrect because of the inexperience of SMRP field assistants. In addition, it is probable that MBSS and SMRP had different sampling segments with different fish assemblages in each.

In an attempt to further compare our fish results with MBSS data and specifically with Boward et al.’s (1998) fish IBI results, we computed provisional Indices of Biological Integrity (IBI) using Roth et al.’s (1996) method. We did this for fish sampled by SMRP between 1999 and 2005 (Figure 11), but did not compute IBI’s for 2008 because the parameters, matrices, and classification of fish were inconsistent between pre-2008 and 2008 data sets.

Despite the inability to compare 2008 data to previous data with IBI’s, most of our stations showed very strong agreement between 1999 and 2001 fish collections (Figures 11 and 12). Over all years and all stations, 36 IBI scores were obtained for fish samples between 1999 and 2005 (Table 12, Figure 11). Of these scores, 67% (24) were > 4.0 and classified as “Good” stations, 28% (10) had mean IBI values between 3.0 and 4.0 and were classified as “Fair” stations, with only 5% (2) with IBI scores <3 (“Poor” stations).
When IBI results were considered on a year-by-year basis, 1999 and 2001 had strikingly similar results, and this was probably due to the fact that 11 of 13 stations were the same in these two years (Figure 12). IBI proportions based on 2001 and 2003 data were also similar, but the number of stations sampled was considerably fewer, 4 and 6, respectively. The IBI proportions shown in Figure 10 for 2005 were based on only 4 stations being sampled in that year.

Table 12 and Figures 11 and 13 show IBI scores by station across the span of SMRP sampling years. It is clear that Church Creek (NT14) had the lowest scores, and while this is based on only two sample years, 2000 and 2001, the station has poor habitat and a strong fish community is not supported. The4 site with the highest mean IBI scores and with at least 4 scores was NT02, Warehouse Run. In contrast to Church

Creek, Warehouse Run has good in-stream habitat, a high aquatic insect diversity (Table 7), and cold water temperatures year-round. John's Creek only has a single SMRP score of 4.5 from 2001, but it also has a MBSS score of 4.75 (Table 12), making this stream the highest scoring station for those with less than 4 fish samples. Some other stations with high IBI scores, such as NT11 (Pembrook Run), have fairly high IBI score despite clear signs of habitat degradation. For the most part, year-to-year IBI scores were consistent and did not range greater than one 1.0 IBI score. Therefore, we feel that the conditions at stations, as measured by fish community diversity, are relatively stable and have not changed much since 1999.

Biological Summary

Water quality data collected in this Synoptic Survey parallel the data collected by SMRP during the period from 1999 through 2006 (Paul, 2006) as well as the data compiled by MDE in early 2008. Non-tidal streams in the watershed are thermally stable with relatively low summer maximal temperatures. These low temperatures and no point sources of pollution combine to produce high dissolved oxygen concentrations in all St. Mary's watershed streams sampled. St. Mary's streams are either neutral of slightly acidic because their buffering capacity (alkalinity) is low and this is partially reflected in the streams' consistently low conductivity values. Likewise, nutrients are also relatively low, with some minor exceptions. Nitrogen concentrations (nitrite-nitrate) are usually well below 1.0 mg/L, and phosphorus (orthophosphate) averaged well below 0.005 mg/L.

The exception to these excellent water quality results is Locust Grove Cove (NT01) where water quality was often poor. Although this site is tidally influenced, it has a historical record (Paul 2006) of poor water quality. Some of the nutrient results at this site can be explained by its estuarine characteristics (phytoplankton growth contributing to high particulate carbon, inorganic phosphorus, dissolved organic carbon concentrations), low Secchi disk depths, and general eutrophication. St. George Creek, the receiving water body of Locust Grove Cove, also has water quality problems, and these sites are water bodies have the watershed's worst water quality. The source of these problems is unclear, but this area is the site of the Harry Lundeberg School of Seamanship farm and cattle operation. St. George Creek also has older residential properties (Andover Estates) and other close-to-the-water properties, where septic systems prevail, and these may be failing.

It should be mentioned that non-tidal water quality assessment in this synoptic survey was only taken on two days, July 10th and 11th, when conditions were dry and had been for sometime. There is good reason to believe (Paul, 2006) that the watershed's water quality problems are driven by storm events. These promote erosion, which carry sediments and nutrients into the streams and eventually into the estuarine waters. However, since our sampling did not include storm events, this scenario is somewhat speculative and based on observation rather than a body of collected evidence. Yet, tidal samples collected during May and June storm events show a pattern of tidal response to storms, and this was particularly true for salinity, algae, turbidity, and dissolved oxygen.

For the most part, tidal water quality at the mid-point in the St. Mary's River estuary (St. Mary's College dock) was also good. Dissolved oxygen was near saturation across most dates and at most depths, with the exceptions of two dates (May 14th and June 11th). Secchi disk depths were below 1 m for the entire study, again with the exception of the storm-driven events in June. An algal bloom early in the study, April 30th, drove chlorophyll levels above 20 ug/L, but this seemed like an isolated, not very severe incident.

Our biological results also support our historical data and reflect the water quality conditions documented in this study. Macroinvertebrate survey data and our analysis of aquatic insects provide a biological appraisal of conditions in 2008. However, because these surveys were done very early in the study period at only 9 stations, and only 6 of these could be compared to previous studies, the assessment is rather limited. When these data are taken together with historic SMRP data from 1999 to 2006, however, a general picture of relatively strong biological heath emerges. In-stream aquatic habitat for insects is generally good in the watershed, and stream insect communities reflect this health. But some subwatersheds and their streams which have their headwaters in the Lexington Park Development District are showing signs of impact. There were some surprising anomalies encountered in 2008 compared to other years and these are difficult to explain. Historically, the Landfill Tributary (NT 02) has had poor insect diversity but the reverse was true in 2008, and conversely Warehouse Run has had excellent insect diversity sionce 1999, but poor results in 2008. These confusing results could be better understood with repeated spring sampling at these stations in the future.

Four subwatersheds, in particular, seem to be impacted the most as evaluated by aquatic insect diversity: NT06- Hickory Hills Tributary, NT08- Jarboesville Run, NT11 Pembrooke Run, and NT14 – Church Creek. The first three sites have their headwaters in the development district, and it is fairly clear from stream channel morphology and imbeddedness that the bottom habitat of these streams has been altered by sedimentation. It is likely that up-stream erosion is the culprit and this is probably promoted by impervious surface development and poor storm water management practices. Church Creek has been long know to have difficulties because of poor storm water management off Route 5 in the vicinity of Villa Road. The State Highway Administration has attempted to rectify this problem with a storm water catchment but it is probably ineffectual.

Fish samples taken in 2008 were supportive of the fish and macroivertebrate conclusions from previous years at three stations in particular, NT06- Hickory Hills, NT08- Jarboesville Road, and NT14- Church Creek. But some additional stations sampled for fish in 2008, point to problems at NT07- Norris Road, and NT10- Hilton Run. Norris Road has rather poor fish habitat, but Hilton Run is something of a surprise because many (4) previous samples at this station showed pretty good fish diversity as measured by IBI.

In conclusion, the results of the synoptic survey tend to support the idea that the tidal creeks of the St. Mary's River have poorer water quality that the open main stem of the river. Storm events seem to be the dominant perturbation force in the river, bring nutrients and sediments into the tidal main stem, from as far away as the development district. Yet, the impacts of sediment generation through erosion seem to be more localized near their points of production. The main impact here is habitat degradation affecting the biological resources of the streams. In the tidal river, nutrients and sediments fuel algal production, which diminishes light passage through the water column, and lowers dissolved oxygen content of the water as the algae die, sink, and Table 6. Non-tidal stations sampled for macroinvertebrates (X) each year in the St. Mary's River watershed.

Tables

Table 1. St. Mary's River subwatersheds and stream characteristics.

12 digit watershed code	Subwatershed name	Seasonal Stream Count	Total Length (mi)	Percent of watershed miles (%)	Land + water area (acres)	Water area- (acres)	Land Only (acres)	% Land
709	Lower St. Mary's River	4	10.9	6.3	13686.5	6465.3	7221.2	15.9
710	Middle St. Mary's River	4	31.8	18.4	10790.2	2947.0	7843.2	17.3
711	Church Creek	0	3.2	1.8	1218.3		1218.3	2.7
712	Fishermans Creek	0	10.6	6.1	1709.6		1709.6	3.8
713	Craney Creek	0	4.4	2.6	765.6		765.6	1.7
714	Johns Creek	0	22.6	13.1	5027.2		5027.2	11.1
715	Hilton Run	0	12.7	7.3	2090.1		2090.1	4.6
716	Pembrooke Run	2	22.5	13.0	3713.6		3713.6	8.2
717	Eastern Branch	2	13.2	7.6	3482.1		3482.1	7.7
718	Western Branch	10	21.4	12.4	6870.7		6870.7	15.2
719	Upper St. Mary's River	1	19.7	11.4	5354.8		5354.8	11.8
Totals:		23	173.0	100.0	54708.7	9412.3	45296.4	

Table 2. St. Mary's River watershed streams classified according to their stream order by subwatershed.

12 digit code	Name	1st Order		2nd Order		3rd Order		4th Order		5th Order		Total
		Number	Length (miles)	Number	Length (miles)	Number	Length (miles)	Number	Length (miles)	Number	Length (miles)	Length (miles)
709	Lower St. Mary's River	19	7.2	6	2.4	1	1.2					10.9
710	Middle St. Mary's River	109	23.5	25	7.5	4	0.8					31.8
711	Church Creek	5	1.7	2	1.1	1	0.4					3.2
712	Fishermans Creek	23	7.6	9	1.4	2	0.6	1	1.0			10.6
713	New Creek	9	3.4	4	0.7	1	0.2					4.4
714	Johns Creek	32	10.3	8	4.9	2	4.0			1	3.4	22.6
715	Hilton Run	36	6.4	8	3.8	1	2.6					12.7
716	Pembrooke Run	49	18.4	13	2.2	2	0.7	1	1.2			22.5
717	Eastern Branch	18	6.5	3	3.1	1	1.0	1	2.6			13.2
718	Western Branch	46	12.3	13	5.9	3	3.2	1	1.9			23.3
719	Upper St. Mary's River	30	11.7	6	5.8	2	2.2					19.7
	TOTALS	376	109.1	97	38.6	20	16.9	4	6.8	1	3.4	174.9

Table 3. List of SMRP sampling site locations. Station LE2.3 is sampled by the Chesapeake Bay Program.

STATION	DESCRIPTION	LATITUDE	LONGITUDE
Non-Tidal Stations			
Western Shore			
SMNT01	Locust Cove Grove	38.1658°	76.5013°
SMNT02	Warehouse Run	38.2207°	76.4897°
Upper St. Mary's River			
SMNT03	Below St. Mary’s Lake	38.2522°	76.5327°
SMNT04	St. Mary's Lake	38.2525°	76.5413°
SMNT05	Landfill Tributary	38.2813°	76.5172°
SMNT06	Hickory Hills	38.2792°	76.5133°
SMNT07	Norris Road	38.2727°	76.5120°
SMNT08	Jarboesville	38.2527°	76.5068°
SMNT09	USGS Gaging Station	38.2417°	76.5035°
SMNT09.5	Johns Creek	38.2367°	76.5009°
SMNT10	Hilton Run	38.2307°	76.4650°
Eastern Branch			
SMNT11	Pembrook Run	38.2243°	76.4553°
SMNT12	Eastern Branch	38.2293°	76.4288°
Eastern Shore			
SMNT13	Fisherman Creek	38.2016°	76.4192°
SMNT14	Church Creek	38.1625°	76.5003°
Tidal Stations			
SMSMC	St. Mary's College	38.1893°	76.4337°
SMT01	Adkins Road	38.2257°	76.4903°
SMT02	Tippity Witchity	38.2102°	76.4657°
SMT03	Short Point	38.2000°	76.4493°
SMT04	Church Point	38.1887°	76.4398°
SMT05	Chancellor's Point	38.1693°	76.4480°
SMT06	Priest Point	38.1510°	76.4495°
SMT07	Mouth of St. Mary's River	38.1118°	76.4433°
SMT08	Carthagena Creek	38.1602°	76.4718°
SMT09	St. George Creek	38.1652°	76.5200°
SMT10	St. Inigoes	38.1657°	76.4177°
LE2.3	Lower Potomac River	38.0215°	76.3477°

Table 4. Sampling dates for the 14 SMRP tidal sites used between 1999 and 2008 showing beginning and ending date of each.

T01	6/22/99	5/18/04	T08	7/20/99	4/26/04
T02	6/21/99	3/30/06	T09	7/20/99	6/16/08
T03	6/21/99	5/6/02	T10	7/7/99	6/16/08
T04	6/21/99	6/16/08	XBF7904	4/10/06	6/16/08
T05	6/21/99	5/6/02	XBF6843	1/13/05	3/30/06
T06	6/21/99	6/16/08	XCC9680	4/14/06	6/16/08
T07	6/21/99	6/16/08	XCD3765	4/14/06	6/16/08

Table 5. SMRP parameters, methods and analytical laboratories performing analyses for water quality samples taken at all stations. A YSI 6600 sonde was used at the tidal station and a YSI 600XLM sonde used at non-tidal stations for ISM - *in situ* measurement. D indicates a discrete grab sample. * indicates that the parameter was sampled only at tidal stations or St. Mary's Lake (NT04).

Samples	Parameter Title	CIMS code	Units	Method	EPA Method
D	Chlorophyll a *	CHLA	UG/L	L03	-
D	Dissolved organic carbon	DOC	MG/L	L02	415.1
D	Ammonia	NH4F	MG/L	L01	350.1
D	Nitrite	NO2F	MG/L	L01	353.2
D	Nitrite-Nitrate	NO23F	MG/L	L01	353.2
D	Particulate carbon	PC	MG/L	L01	440.0
D	Particulate inorganic phosphorus	PIP	MG/L	L01	-
D	Particulate nitrogen	PN	MG/L	L01	440.0
D	Orthophosphate	PO4F	MG/L	L01	365.1, 365.5
D	Particulate phosphorus	PP	MG/L	L01	-
D	Total dissolved nitrogen	TDN	MG/L	L01	-
D	Total dissolved phosphorus	TDP	MG/L	L01	-
D	Total suspended solids	TSS	MG/L	L01	160.2
D	Volatile suspended solids	VSS	MG/L	L01	160.4
ISM	Water temperature	WTEMP	DEG C	F01	170.1
ISM	Specific Conductance	COND	UMHOS/CM	F01	-
ISM	Salinity	SALINITY	PPT	F01	-
ISM	Dissolved Oxygen-Saturation	DO_SAT	PCT	F01	-
ISM	Dissolved Oxygen-Concentration	DO	MG/L	F01	360.1
ISM	pH	PH	SU	F01	150.1
ISM	Chlorophyll a *	CHLA	UG/L	F01	-
ISM	Secchi Disk Depth *	SECCHI	M	F01	-

Table 6. Mean, minimum, and maximum values of all tidal water quality variables by sampling station from 1999 to 2008.

Station	mean	min	max	mean	min	max	mean	min	max
	Water Temp (^oC)			Salinity (ppt)			pH		
SMT02	16.91	4.78	32.42	11.23	6.37	15.51	8.07	5.58	8.82
SMT04	16.22	4.22	31.44	11.72	7.09	16.06	7.89	6.90	9.06
SMT06	15.65	4.36	29.55	12.02	6.78	16.25	7.75	6.28	8.98
SMT07	15.35	3.27	29.48	12.03	6.77	16.42	7.89	7.02	9.00
SMT09	16.05	2.97	32.01	11.71	8.45	15.57	8.21	7.60	8.95
SMT10	16.74	5.91	32.52	11.84	6.81	16.07	8.23	7.55	8.83
XBE8396	13.98	3.23	30.13	11.86	7.84	16.55	8.39	8.02	8.71
XBF6843	13.79	3.52	29.77	12.03	6.36	16.33	8.39	7.96	8.84
	Bottom DO (mg/L)			Surface DO (mg/L)			Secchi disk depth (m)		
SMT02	9.73	0.12	13.95	10.23	3.76	15.19	1.2	0.7	2.0
SMT04	6.95	0.10	14.39	10.93	6.20	15.69	1.4	1.0	2.3
SMT06	6.63	0.12	13.29	10.68	5.56	15.43	1.6	1.0	2.3
SMT07	6.91	0.26	12.40	10.47	5.19	15.01	1.8	0.9	3.3
SMT09	9.33	5.20	13.45	9.75	5.38	13.46	0.9	0.3	1.7
SMT10	9.38	1.02	15.44	10.42	4.37	15.40	1.4	0.8	2.0
XBE8396	10.35	5.06	14.14	10.66	5.05	14.15	1.2	0.9	1.7
XBF6843	10.71	4.11	15.45	10.91	4.60	15.44	1.2	0.6	1.5
	Total suspended solids (mg/L)			Chlorophyll (µg/L)			Orthophosphate- PO_4 (mg/L)		
SMT02	9.7	3.3	27.7	14.91	4.76	36.88	0.00265	0.0017	0.0041
SMT04	10.3	3.6	54.0	28.42	4.68	234.79	0.00258	0.0008	0.0061
SMT06	10.8	3.7	42.2	16.74	5.89	47.11	0.00317	0.0013	0.0070
SMT07	9.9	3.6	49.8	17.61	4.94	47.77	0.00284	0.0012	0.0047
SMT09	19.7	5.5	84.8	16.23	4.13	37.62	0.00306	0.0013	0.0062
SMT10	10.6	3.7	41.5	14.95	5.14	34.27	0.00240	0.0008	0.0034
XBE8396	12.0	2.4	53.5	17.01	6.33	34.61	0.00294	0.0019	0.0070
XBF6843	16.3	3.3	46.5	16.13	4.91	35.17	0.00327	0.0019	0.0065

Table 6 (continued).

Station	mean	min	max	mean	min	max	mean	min	max
	Total dissolved phosphorus (mg/L)			Ammonium- NH_4 (µg/L)			Nitrite-nitrate- NO_{2-3} (mg/L)		
SMT02	0.03058	0.0070	0.3700	0.0452	0.003	0.137	0.0748	0.002	0.240
SMT04	0.03284	0.0071	0.4000	0.0168	0.003	0.079	0.0978	0.002	0.642
SMT06	0.03421	0.0084	0.4300	0.0226	0.002	0.193	0.1284	0.003	0.694
SMT07	0.03538	0.0075	0.4500	0.0151	0.003	0.054	0.1521	0.002	0.678
SMT09	0.03210	0.0073	0.3600	0.0457	0.001	0.429	0.0639	0.003	0.271
SMT10	0.03258	0.0060	0.4200	0.0209	0.003	0.144	0.1147	0.002	0.652
XBE8396	0.03989	0.0073	0.4700	0.0290	0.003	0.181	0.1757	0.002	0.557
XBF6843	0.04053	0.0065	0.4600	0.0263	0.003	0.138	0.1774	0.003	0.731
	Total dissolved nitrogen (mg/L)								
SMT02	0.5450	0.370	0.980						
SMT04	0.5190	0.300	0.990						
SMT06	0.6081	0.380	1.290						
SMT07	0.5445	0.290	1.030						
SMT09	0.5305	0.360	0.900						
SMT10	0.5114	0.350	0.960						
XBE8396	0.6000	0.310	0.890						
XBF6843	0.5847	0.340	1.020						

Table 7. Number of macroinvertebrates collected in each family at each site in 2008.

Order	Family	NT02	NT 05	NT 06	NT9.5	NT10	NT11	Below IBR	Craney Creek	Kayak Park	Total	Percent
COLEOPTERA	Gyrinidae	3	4	2	0	0	0	3	0	0	12	2.30
COLEOPTERA	Psephenidae	0	2	0	0	1	0	0	0	0	3	0.57
COLEOPTERA	Dryopidae	0	2	0	0	0	0	0	0	0	2	0.38
COLEOPTERA	Veliidae	0	1	0	0	0	0	0	0	0	1	0.19
COLEOPTERA	Elmidae	0	7	0	0	7	1	0	0	0	15	2.87
DIPTERA	Tabanidae	3	0	1	0	1	0	4	0	0	9	1.72
DIPTERA	Chironomidae	69	16	2	19	5	2	6	3	15	137	26.25
DIPTERA	Pupa	1	0	0	0	0	0	0	0	0	1	0.19
DIPTERA	Tipulidae	1	0	0	1	3	0	1	0	12	18	3.45
EPHEMEROPTERA	Baetidae	1	0	1	8	1	0	48	0	0	59	11.30
EPHEMEROPTERA	Ephemerellidae	0	0	3	0	0	0	0	0	0	3	0.57
EPHEMEROPTERA	Heptageniidae	0	25	4	3	0	6	18	0	22	78	14.94
EPHEMEROPTERA	Leptophlebiidae	0	0	0	0	0	2	0	0	0	2	0.38
EPHEMEROPTERA	Metretopodidae	0	0	0	0	0	1	0	0	0	1	0.19
EPHEMEROPTERA	Tricorythidae	0	0	0	0	12	0	0	0	0	12	2.30
HEMIPTERA	Saldidae	0	0	0	0	1	0	0	0	0	1	0.19
MEGALOPTERA	Corydalidae	0	1	0	0	2	0	0	0	0	3	0.57
MEGALOPTERA	Sialidae	0	1	0	0	0	0	0	0	0	1	0.19
ODONATA	Aeshnidae	1	5	1	0	4	0	1	0	0	12	2.30
ODONATA	Cordulegastridae	1	0	1	1	0	0	0	0	0	3	0.57
ODONATA	Corduliidae	0	1	0	2	0	1	0	0	0	5	0.96
ODONATA	Gomphidae	1	0	0	0	2	0	1	2	1	7	1.34
ODONATA	Calopterygidae	1	3	0	4	3	0	0	0	0	11	2.11
ODONATA	Coenagrionidae	1	3	2	12	2	3	0	0	0	23	4.41
ODONATA	Lestidae	0	1	0	0	1	7	0	0	0	9	1.72
ODONATA	Gomphidae	0	2	0	0	0	1	0	0	0	3	0.57
PLECOPTERA	Chloroperlidae	1	3	2	12	0	0	0	0	0	18	3.45
PLECOPTERA	Perlidae	1	2	2	7	4	0	2	0	2	20	3.83
PLECOPTERA	Perlodidae	0	0	0	0	0	0	0	0	12	12	2.30
TRICHOPTERA	Hydropsychidae	8	2	1	3	0	0	9	0	0	23	4.41
TRICHOPTERA	Limnephilidae	0	1	0	0	0	0	1	1	0	3	0.57
TRICHOPTERA	Phryganeidae	0	0	0	0	0	0	0	2	0	2	0.38
TRICHOPTERA	Polycentropodidae	0	3	1	1	7	0	0	0	1	13	2.49
Total number of individuals		**93**	**85**	**23**	**73**	**56**	**24**	**94**	**8**	**65**	**522**	
Total number of families		**14**	**20**	**13**	**12**	**16**	**9**	**11**	**4**	**7**		

Table 8. Total number of fish by family collected at all non-tidal stations in July of 2008.

Family - Species	**Common name**	**NT 02**	**NT 03**	**NT 05**	**NT 06**	**NT 07**	**NT 08**	**NT 09**	**NT 9.5**	**NT 10**	**NT 11**	**NT 12**	**NT 13**	**NT 14**	**Total**
Petromyzontidae															
Lampetra aepyptera	(Least Brook Lamprey)	7	0	2	2	1	1	7	6	2	1	7	10	0	46
Anguillidae															
Anguilla rostrata	(American eel)	21	13	7	11	6	6	22	3	6	14	12	17	22	160
Ictaluridae															
Ameiurus nebulosus	(Brown Bullhead)	0	0	0	0	0	0	0	3	0	0	0	21	3	27
Noturus gyrinus	(Tadpole Madtom)	1	16	1	0	0	0	4	2	0	0	5	0	0	29
Noturus insignis	(Margined Madtom)	0	2	1	2	1	0	4	1	5	0	2	0	0	18
Esocidae															
Esox niger	(Chain Pickerel)	0	0	0	0	0	0	0	0	0	1	0	2	0	3
Aphredoderidae															
Aphredoderus sayanus	(Pirate Perch)	7	0	0	0	0	0	0	3	4	0	0	0	0	14
Umbridae															
Umbra pygmaea	(Eastern Mudminnow)	6	0	0	1	0	0	1	2	0	0	0	2	1	13
Cyprinidae															
Cyprinella spiloptera	(Spotfin Shiner)	0	13	3	6	5	0	6	4	0	0	0	0	0	37
Luxilus chrysocephalus	(Striped shiner)	0	1	0	0	0	0	3	13	0	0	0	0	0	17
Notemigonus crysoleucas	(Golden Shiner)	1	1	0	0	0	0	0	8	0	0	0	3	0	13
Notropis amoenus	(Comely Shiner)	0	0	0	0	0	0	0	0	0	2	2	0	0	4
Notropis procne	(Swallowtail shiner)	0	0	0	0	0	0	0	0	0	15	1	0	0	16
Rhinicthys atratulus	(Blacknose dace)	3	0	0	0	0	0	1	30	0	0	0	0	0	34
Notropis bifrenatus	(Bridal shiner)	0	1	0	0	0	0	11	30	1	0	5	0	0	48

Table 8 (continued).

Family - Species	Common name	NT 02	NT 03	NT 05	NT 06	NT 07	NT 08	NT 09	NT 9.5	NT 10	NT 11	NT 12	NT 13	NT 14	Total
Catostomidae															
Moxostoma erythrurum	(Golden Redhorse)	0	0	0	0	0	0	0	0	0	0	0	8	0	8
Moxostoma macrolepidotum	(Shorthead redhorse)	4	0	0	0	1	0	2	1	1	0	0	0	0	9
Fundulidae															
Fundulus heteroclitus	(Mummichog)	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Percidae															
Etheostoma flabellare	(Fantail darter)	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Etheostoma olmstedi	(Tessellated Darter)	27	9	1	16	10	8	35	66	0	17	7	0	0	196
Centrarchidae															
Lepomis auritus	(Redbreast Sunfish)	6	1	5	2	4	0	12	7	2	3	1	0	0	43
Lepomis cyanellus	(Green sunfish)	2	0	0	0	0	0	0	8	0	0	2	0	0	12
Lepomis gibbosus	(Pumpkinseed)	7	0	2	0	0	2	1	4	0	0	0	8	5	29
Lepomis macrochirus	(Bluegill)	0	5	12	4	1	0	3	0	1	0	0	0	8	34
Lepomis punctatus	(spotted sunfish)	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Micropterus salmoides	(Largemouth Bass)	1	1	0	0	0	0	0	0	0	0	0	0	2	4
Total number of fish		93	63	34	44	29	17	112	191	22	54	44	71	43	817
Number of species		10	11	9	8	8	4	14	17	8	8	10	8	8	26

Table 9. Non-tidal stations sampled for fish (X) during the MBSS Summer Index Period.

Site #	Site Name	1999	2000	2001	2003	2005	2008
NT02	Warehouse Run	X	-	X	X	X	X
NT03	Below SM Lake	X	-	-	-	-	X
NT05	Landfill Trib	-	X	X	X	X	X
NT06	Hickory Hills	X	-	X	X	-	X
NT07	Norris Road	X	-	X	X	-	X
NT08	Jarboesville Run	X	-	X	-	-	X
NT09	US Gaging Station	X	-	X	-	-	X
NT09.5	Johns Creek	-	-	X	-	-	X
NT10	Hilton Run	X	-	X	X	X	X
NT11	Pembrook Run	X	X	X	X	X	X
NT12	Eastern Branch	X	-	X	-	-	X
NT13	Fisherman's Creek	X	X	X	X	-	X
NT14	Church Creek	-	X	X	-	-	X

Table 10. Number of fish of each species sampled at each site in 1999, 2000, 2001, 2003, 2005, and 2008.

		NT 02					NT 03		NT05					NT 06			
Genus species	**Common name**	1999	2001	2003	2005	2008	1999	2008	2000	2001	2003	2005	2008	1999	2001	2003	2008
Petromyzontidae																	
Lampetra aepyptera	(Least Brook Lamprey)	100	42	43	24	7	1	0	41	24	2	77	2	44	13	60	2
Petromyzon marinus	(Sea Lamprey)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0
Anguillidae																	
Anguilla rostrata	(American eel)	87	36	25	30	21	138	13	11	4	6	7	7	49	22	20	11
Ictaluridae																	
Ameiurus melas	(Black Bullhead)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ameiurus nebulosus	(Brown Bullhead)	0	1	0	3	0	0	0	7	0	0	0	0	0	0	0	0
Noturus gyrinus	(Tadpole Madtom)	18	4	5	0	1	0	16	0	3	1	1	1	7	5	0	0
Noturus insignis	(Margined Madtom)	0	0	1	0	0	0	2	0	0	0	0	1	3	0	2	2
Esocidae																	
Esox niger	(Chain Pickerel)	1	1	1	1	0	0	0	4	3	1	0	0	10	2	0	0
Aphredoderidae																	
Aphredoderus sayanus	(Pirate Perch)	25	6	8	0	7	0	0	10	0	0	1	0	20	2	4	0
Umbridae																	
Umbra pygmaea	(Eastern Mudminnow)	5	9	12	37	6	0	0	15	13	5	1	0	15	13	21	1
Cyprinidae																	
Cyprinella spiloptera	(Spotfin Shiner)	0	0	0	0	0	0	13	0	0	0	0	3	0	0	0	6
Hybognathus regius	(E. Silvery Minnow)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Luxilus chrysocephalus	(Striped shiner)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Notemigonus crysoleucas	(Golden Shiner)	0	1	0	5	1	5	1	0	0	0	0	0	0	0	0	0
Notropis amoenus	(Comely Shiner)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notropis analostanus	(Satinfin shiner)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notropis chalybaeus	(Ironcolor shiner)	0	0	0	0	0	0	0	0	0	3	0	0	0	0	8	0
Notropis hudsonius	(Spottail Shiner)	2	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0
Notropis procne	(Swallowtail shiner)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhinicthys atratulus	(Blacknose dace)	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0
Notropis bifrenatus	(Bridal shiner)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Poeciliidae																	
Gambusia holbrooki	(Eastern mosquitofish)	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 10. (continued)

		NT 02					NT 03		NT05					NT 06			
Genus species	**Common name**	1999	2001	2003	2005	2008	1999	2008	2000	2001	2003	2005	2008	1999	2001	2003	2008
Catostomidae																	
Erimyzon oblongus	(Creekchub Sucker)	9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Moxostoma erythrurum	(Golden Redhorse)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moxostoma macrolepidotum	(Shorthead redhorse)	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Fundulidae																	
Fundulus diaphanus	(Banded killifsh)	1	0	0	0	0	0	0	0	0	0	0	0	75	0	0	0
Fundulus heteroclitus	(Mummichog)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Percidae																	
Etheostoma flabellare	(fantail darter)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Etheostoma olmstedi	(Tessellated Darter)	78	27	25	27	27	8	9	6	6	1	5	1	75	25	25	16
Perca flavescens	(Yellow perch)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centrarchidae																	
Enneacanthus gloriosus	(Bluespotted Sunfish)	0	0	0	0	0	1	0	0	0	2	0	0	1	2	0	0
Lepomis auritus	(Redbreast Sunfish)	31	11	9	6	6	72	1	13	9	8	14	5	2	9	8	2
Lepomis cyanellus	(Green sunfish)	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Lepomis gibbosus	(Pumpkinseed)	0	0	2	0	7	0	0	0	0	1	0	2	1	1	2	0
Lepomis gulosus	(Warmouth)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepomis macrochirus	(Bluegill)	0	0	8	0	0	9	5	2	0	4	0	12	0	5	5	4
Lepomis punctatus	(spotted sunfish)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micropterus salmoides	(Largemouth Bass)	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0
Pomoxis nigromaculatus	(Black crappie)	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
Clupeidae																	
Alosa psuedoharengus	(Alewife)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atherinidae																	
Menidia beryllina	(Inland Silverside)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		**2371**	**2139**	**2143**	**2138**	**2101**	**2243**	**2071**	**2111**	**2064**	**2038**	**2111**	**2042**	**2301**	**2100**	**2162**	**2052**
Number of species		14	11	13	9	14	10	12	11	9	13	8	10	13	12	14	9

Table 10. (continued)

		NT 07			NT 08			NT 09			NT9.5		NT 10				
Genus species	**Common name**	1999	2001	2008	1999	2001	2008	1999	2001	2008	2001	2008	1999	2001	2003	2005	2008
Petromyzontidae																	
Lampetra aepyptera	(Least Brook Lamprey)	10	6	1	94	79	1	41	24	7	26	6	15	12	5	4	2
Petromyzon marinus	(Sea Lamprey)	0	3	0	10	0	0	4	0	0	1	0	0	1	0	0	0
Anguillidae																	
Anguilla rostrata	(American eel)	48	20	6	36	24	6	87	26	22	18	3	51	38	41	25	6
Ictaluridae																	
Ameiurus melas	(Black Bullhead)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Ameiurus nebulosus	(Brown Bullhead)	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	0
Noturus gyrinus	(Tadpole Madtom)	6	8	0	3	2	0	0	16	4	6	2	5	1	0	0	0
Noturus insignis	(Margined Madtom)	0	0	1	5	3	0	7	4	4	0	1	25	10	15	3	5
Esocidae																	
Esox niger	(Chain Pickerel)	3	2	0	0	1	0	1	0	0	0	0	0	5	0	3	0
Aphredoderidae																	
Aphredoderus sayanus	(Pirate Perch)	4	3	0	4	6	0	9	1	0	5	3	5	3	1	3	4
Umbridae																	
Umbra pygmaea	(Eastern Mudminnow)	2	0	0	3	8	0	6	5	1	7	2	4	2	0	1	0
Cyprinidae																	
Cyprinella spiloptera	(Spotfin Shiner)	0	0	5	0	0	0	0	0	6	0	4	0	0	0	4	0
Hybognathus regius	(Eastern Silvery Minnow)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luxilus chrysocephalus	(Striped shiner)	0	0	0	0	0	0	0	0	3	0	13	0	0	0	0	0
Notemigonus crysoleucas	(Golden Shiner)	0	3	0	0	0	0	0	0	0	0	8	0	0	0	5	0
Notropis amoenus	(Comely Shiner)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notropis analostanus	(Satinfin shiner)	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Notropis chalybaeus	(Ironcolor shiner)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Notropis hudsonius	(Spottail Shiner)	0	0	0	24	0	0	25	0	0	0	0	5	0	0	0	0
Notropis procne	(Swallowtail shiner)	0	3	0	1	0	0	0	42	0	5	0	0	1	0	0	0
Rhinicthys atratulus	(Blacknose dace)	0	0	0	0	0	0	0	0	1	5	30	0	0	0	0	0
Notropis bifrenatus	(Bridal shiner)	0	0	0	0	0	0	0	0	11	0	30	0	0	0	0	1
Poeciliidae																	
Gambusia holbrooki	(Eastern mosquitofish)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

Table 10. (continued)

		NT 07			NT 08			NT 09			NT9.5		NT 10				
Genus species	**Common name**	1999	2001	2008	1999	2001	2008	1999	2001	2008	2001	2008	1999	2001	2003	2005	2008
Catostomidae																	
Erimyzon oblongus	(Creekchub Sucker)	1	0	0	1	3	0	0	1	0	0	0	4	2	0	0	0
Moxostoma erythrurum	(Golden Redhorse)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moxostoma macrolepidotum	(Shorthead redhorse)	0	0	1	0	0	0	0	0	2	0	1	0	0	0	0	1
Fundulidae																	
Fundulus diaphanus	(Banded killifsh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fundulus heteroclitus	(Mummichog)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Percidae																	
Etheostoma flabellare	(fantail darter)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Etheostoma olmstedi	(Tessellated Darter)	15	14	10	84	26	8	125	54	35	23	66	17	0	24	30	0
Perca flavescens	(Yellow perch)	0	0	0	0	0	0	0	2	0	0	0	0	33	0	0	0
Centrarchidae																	
Enneacanthus gloriosus	(Bluespotted Sunfish)	10	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0
Lepomis auritus	(Redbreast Sunfish)	19	5	4	32	26	0	1	31	12	19	7	34	17	18	18	2
Lepomis cyanellus	(Green sunfish)	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0
Lepomis gibbosus	(Pumpkinseed)	0	0	0	0	2	2	0	0	1	0	4	0	0	0	0	0
Lepomis gulosus	(Warmouth)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepomis macrochirus	(Bluegill)	0	0	1	0	2	0	0	0	3	6	0	2	3	8	2	1
Lepomis punctatus	(spotted sunfish)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micropterus salmoides	(Largemouth Bass)	0	0	0	0	1	0	0	3	0	1	0	0	0	0	0	0
Pomoxis nigromaculatus	(Black crappie)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clupeidae																	
Alosa psuedoharengus	(Alewife)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atherinidae																	
Menidia beryllina	(Inland Silverside)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		**2117**	**2069**	**2037**	**2296**	**2184**	**2025**	**2313**	**2210**	**2120**	**2123**	**2199**	**2166**	**2131**	**2119**	**2107**	**2030**
Number of species		11	12	9	13	14	5	13	13	15	13	18	12	15	9	14	9

Table 10. (continued)

		NT 11						NT 12			NT 13					NT14		
Genus species	**Common name**	1999	2000	2001	2003	2005	2008	1999	2001	2008	1999	2000	2001	2003	2008	2000	2001	2008
Petromyzontidae																		
Lampetra aepyptera	(Least Brook Lamprey)	25	30	15	19	49	1	113	86	7	0	58	154	62	10	0	0	0
Petromyzon marinus	(Sea Lamprey)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Anguillidae																		
Anguilla rostrata	(American eel)	105	37	30	39	30	14	12	20	12	15	31	38	28	17	3	33	22
Ictaluridae																		
Ameiurus melas	(Black Bullhead)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ameiurus nebulosus	(Brown Bullhead)	5	0	0	0	0	0	0	1	0	0	0	1	0	21	0	0	3
Noturus gyrinus	(Tadpole Madtom)	2	2	0	1	0	0	18	1	5	0	0	0	0	0	0	0	0
Noturus insignis	(Margined Madtom)	0	0	0	0	2	0	8	4	2	0	0	0	0	0	0	0	0
Esocidae																		
Esox niger	(Chain Pickerel)	4	6	5	1	2	1	5	3	0	0	1	2	2	2	0	0	0
Aphredoderidae																		
Aphredoderus sayanus	(Pirate Perch)	1	0	4	3	2	0	3	6	0	0	0	0	0	0	0	1	0
Umbridae																		
Umbra pygmaea	(Eastern Mudminnow)	1	0	0	3	2	0	10	11	0	5	5	30	99	2	0	31	1
Cyprinidae																		
Cyprinella spiloptera	(Spotfin Shiner)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hybognathus regius	(Eastern Silvery Minnow)	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luxilus chrysocephalus	(Striped shiner)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notemigonus crysoleucas	(Golden Shiner)	5	0	7	0	2	0	0	0	0	0	0	0	2	3	0	2	0
Notropis amoenus	(Comely Shiner)	0	6	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0
Notropis analostanus	(Satinfin shiner)	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0
Notropis chalybaeus	(Ironcolor shiner)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Notropis hudsonius	(Spottail Shiner)	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Notropis procne	(Swallowtail shiner)	0	0	21	0	0	15	0	0	1	0	0	0	0	0	0	0	0
Rhinicthys atratulus	(Blacknose dace)	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Notropis bifrenatus	(Bridal shiner)	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Poeciliidae																		
Gambusia holbrooki	(Eastern mosquitofish)	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 10. (continued)

		NT 11						NT 12			NT 13					NT14		
Genus species	**Common name**	1999	2000	2001	2003	2005	2008	1999	2001	2008	1999	2000	2001	2003	2008	2000	2001	2008
Catostomidae																		
Erimyzon oblongus	(Creekchub Sucker)	0	0	9	0	0	0	7	0	0	17	7	13	5	0	0	10	0
Moxostoma erythrurum	(Golden Redhorse)	0	2	0	0	0	0	0	0	0	0	1	0	0	8	0	0	0
Moxostoma macrolepidotum	(Shorthead redhorse)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fundulidae																		
Fundulus diaphanus	(Banded killifsh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Fundulus heteroclitus	(Mummichog)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	2	1
Percidae																		
Etheostoma flabellare	(Fantail darter)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Etheostoma olmstedi	(Tessellated Darter)	17	0	32	16	31	17	24	17	7	0	0	0	0	0	0	0	0
Perca flavescens	(Yellow perch)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centrarchidae																		
Enneacanthus gloriosus	(Bluespotted Sunfish)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepomis auritus	(Redbreast Sunfish)	71	15	8	3	8	3	22	6	1	0	0	0	0	0	0	0	0
Lepomis cyanellus	(Green sunfish)	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Lepomis gibbosus	(Pumpkinseed)	8	0	1	2	0	0	0	0	0	29	0	8	3	8	0	11	5
Lepomis gulosus	(Warmouth)	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0
Lepomis macrochirus	(Bluegill)	10	16	8	2	0	0	0	0	0	0	0	0	0	0	4	0	8
Lepomis punctatus	(spotted sunfish)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Micropterus salmoides	(Largemouth Bass)	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	4	2
Pomoxis nigromaculatus	(Black crappie)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clupeidae																		
Alosa psuedoharengus	(Alewife)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0
Atherinidae																		
Menidia beryllina	(Inland Silverside)	0	0	0	0	5	0	0	0	0	0	0	0	0	0	15	0	0
Total		**2259**	**2125**	**2142**	**2111**	**2146**	**2062**	**2221**	**2156**	**2052**	**2065**	**2114**	**2247**	**2205**	**2079**	**2190**	**2098**	2051
Number of species		14	11	13	12	14	9	11	11	11	5	8	8	9	9	6	10	9

Table 11. Comparison of fish collected by SMRP in 2000 or 2001 to MBSS in 2000 at stations in common to both sampling periods.

	NT06		NT08		NT9.5		NT10		NT11			
	2001	2000	2001	2000	2001	2000	2001	2000	2000	2001	2000	
	SMRP	MBSS	SMRP	MBSS	SMRP	MBSS	SMRP	MBSS	SMRP	SMRP	MBSS	Total
American eel	22	1	24	7	18	-	38	2	37	30	23	202
Blacknose dace	-	-	-	-	5	-	-	-	-	-	-	5
Bluegill	5	2	2	9	6	3	3	-	-	-	6	36
Bluespotted sunfish	2	-	-	-	-	-	-	-	16	8	-	26
Brown bullhead	-	-	-	-	-	-	2	-	-	-	8	10
Chain pickerel	2	-	1	5	-	2	5	1	-	-	1	17
Comely shiner	-	-	-		-	-	-	-	6	5	-	11
Creekchub sucker	-	-	3	15	-	2	2	-	6	-	1	29
Eastern mudminnow	13	34	8	145	7	13	2	45	-	9	-	276
Fathead minnow	-	123	-	-	-	-	-	-	-	-	-	123
Golden Shiner	-	5	-	9	-	-	-	-	2	-	2	18
Green sunfish	-	-	-	-	-	-	-	-	-	7	-	7
Ironcolor shiner	-	-	-	27	-	-	-	-	-	-	-	27
Largemouth bass	-	-	1	-	1	-	-	-	-	-	-	2
Least brook lamprey	13	-	79	33	26	66	12	2	1	1	4	237
Margined madtom	5	-	3	0	-	3	10	-	30	15	3	69
Pirate perch	2	-	6	20	5	5	3	-	-	-	2	43
Pumpkinseed	1	1	2	7	-	4	-	-	-	-	-	15
Redbreast sunfish	9	-	26	6	19	35	17	-	-	4	33	149
Satinfin shiner	-	-	-	-	-	-	-	-	-	1	-	1
Sea Lamprey	-	-	-	-	1	4	1	-	15	8	-	29
Spotted sunfish	-	-	-	23	-	-	-	-	-	-	-	23
Swallowtail shiner	-	-	-	-	5	-	1	-	-	-	2	8
Tadpole madtom	-	-	2	-	6	4	1	-	-	-	3	16
Tessellated darter	25	-	26	2	23	50	-	10	-	21	19	176
Warmouth	-	-	-	-	-	-	-	-	2	-	-	2
Yellow perch	-	-	-	-	-	-	33	-	-	32	-	65
Total fish	99	166	183	308	122	191	130	60	125	131	107	

Table 12. Fish IBI scores at each non-tidal station, 1999-2005, and MBSS IBI scores for sites sampled in 2000 (Stranko and Rodney, 2001).

Station Number	Site Name	SMRP IBI’s					MBSS IBI’s
		1999	2000	2001	2003	2005	2000
NT02	Warehouse Run	4.25	-	4.75	4.50	4.25	-
NT03	Below SM Lake	4.00	-	-	-	-	-
NT05	Landfill Trib	-	4.25	3.75	4.00	3.25	-
NT06	Hickory Hills	3.50	-	4.00	4.50	-	2.75
NT07	Norris Road	3.50	-	4.00	-	-	-
NT08	Jarboesville Run	4.25	-	4.25	-	-	3.75
NT09	US Gaging Station	3.75	-	3.50	-	-	-
NT09.5	Johns Creek	-	-	4.50	-	-	4.75
NT10	Hilton Run	4.25	-	4.50	3.50	4.00	3.00
NT11	Pembrook Run	4.25	4.00	4.25	3.75	4.25	4.25
NT12	Eastern Branch	4.50	-	4.75	-	-	-
NT13	Fisherman's Creek	2.75	3.50	4.50	4.50	-	-
NT14	Church Creek	-	3.50	2.50	-	-	-

Figures

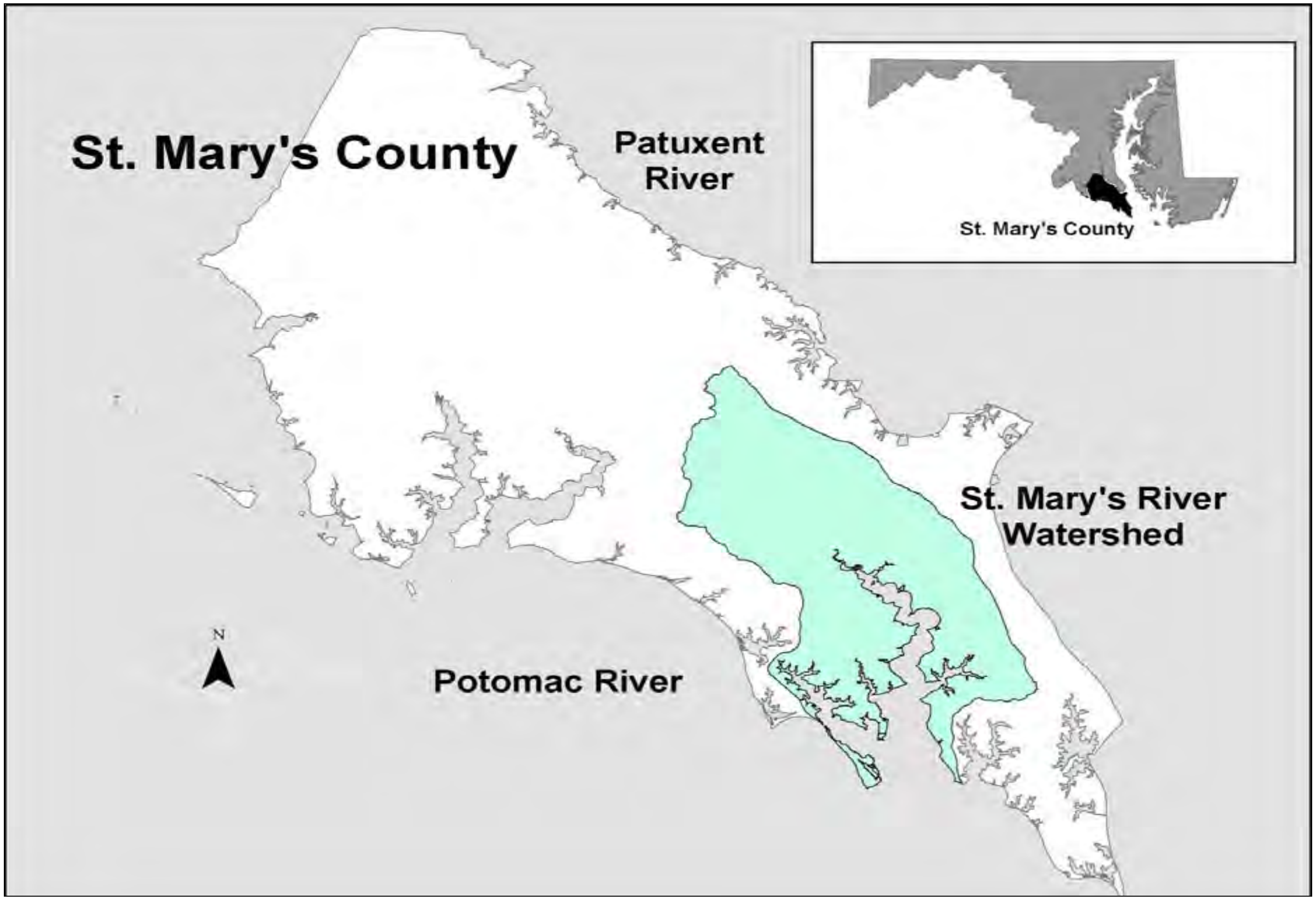


Figure1. Location of St. Mary’s County within Maryland and the St. Mary’s River watershed in the lower Potomac River drainage basin.

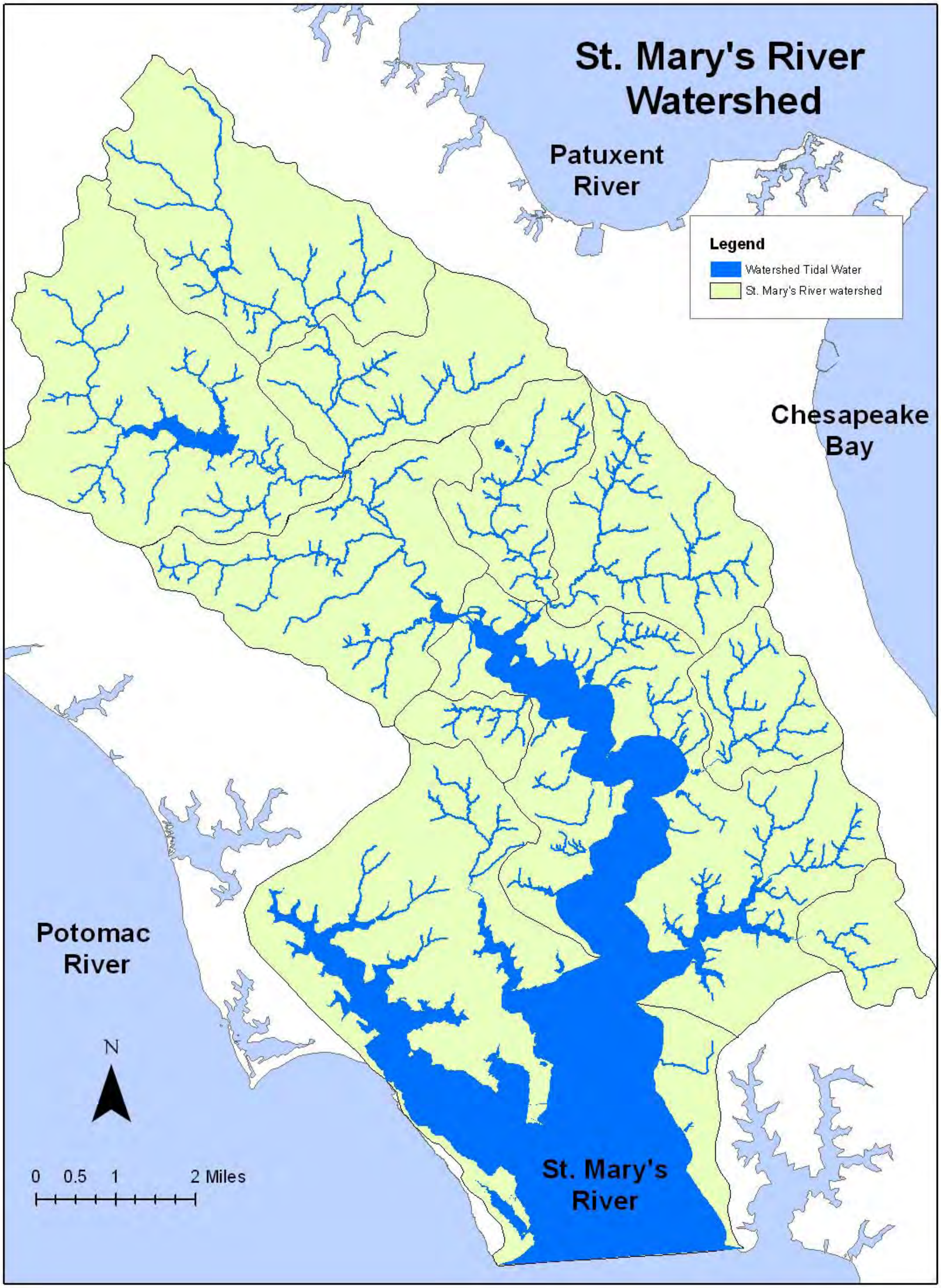


Figure 2. St. Mary's River watershed and watershed streams.

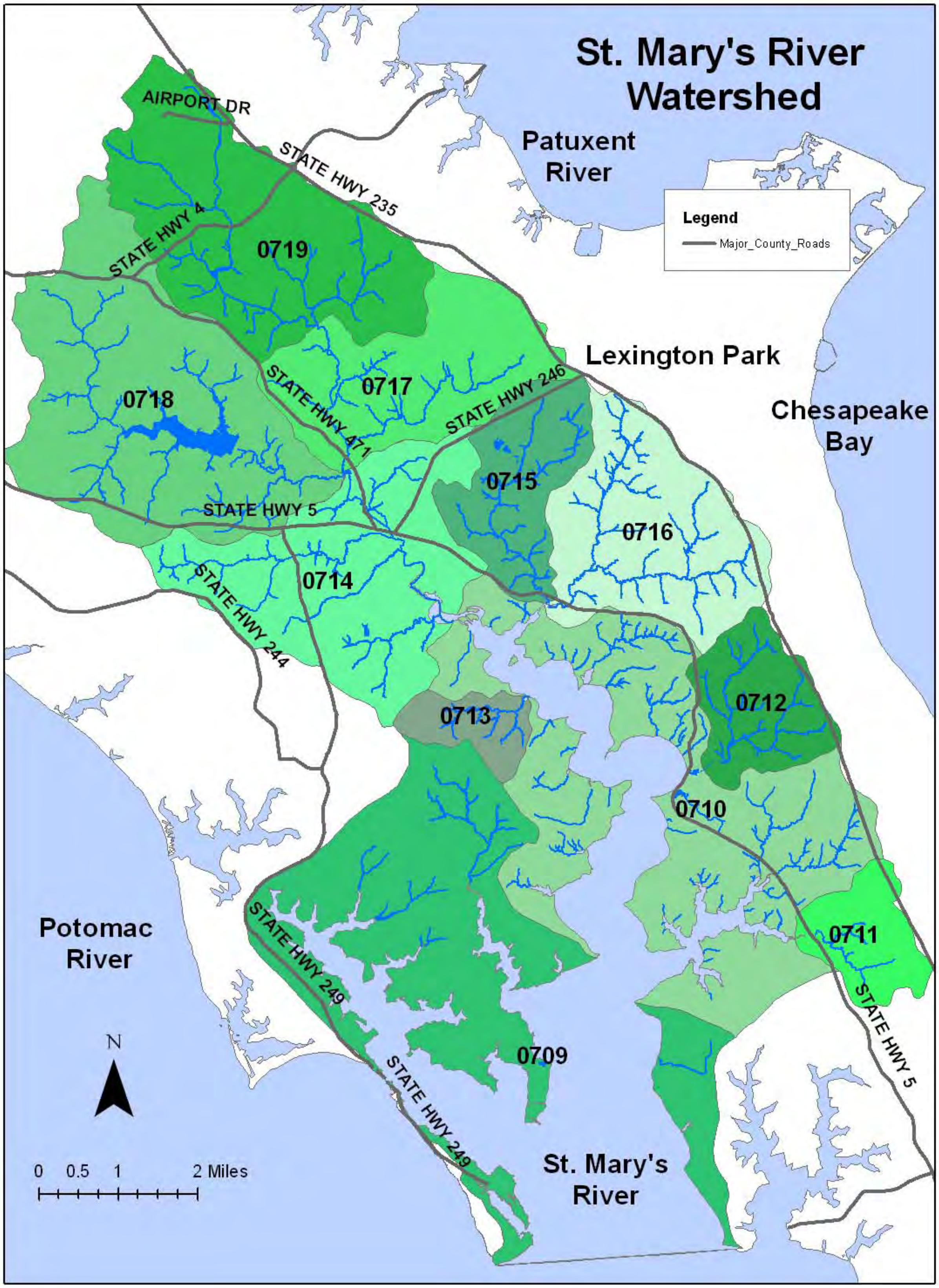


Figure 3. St. Mary's River watershed and 12 digit subwatersheds with major state highways.

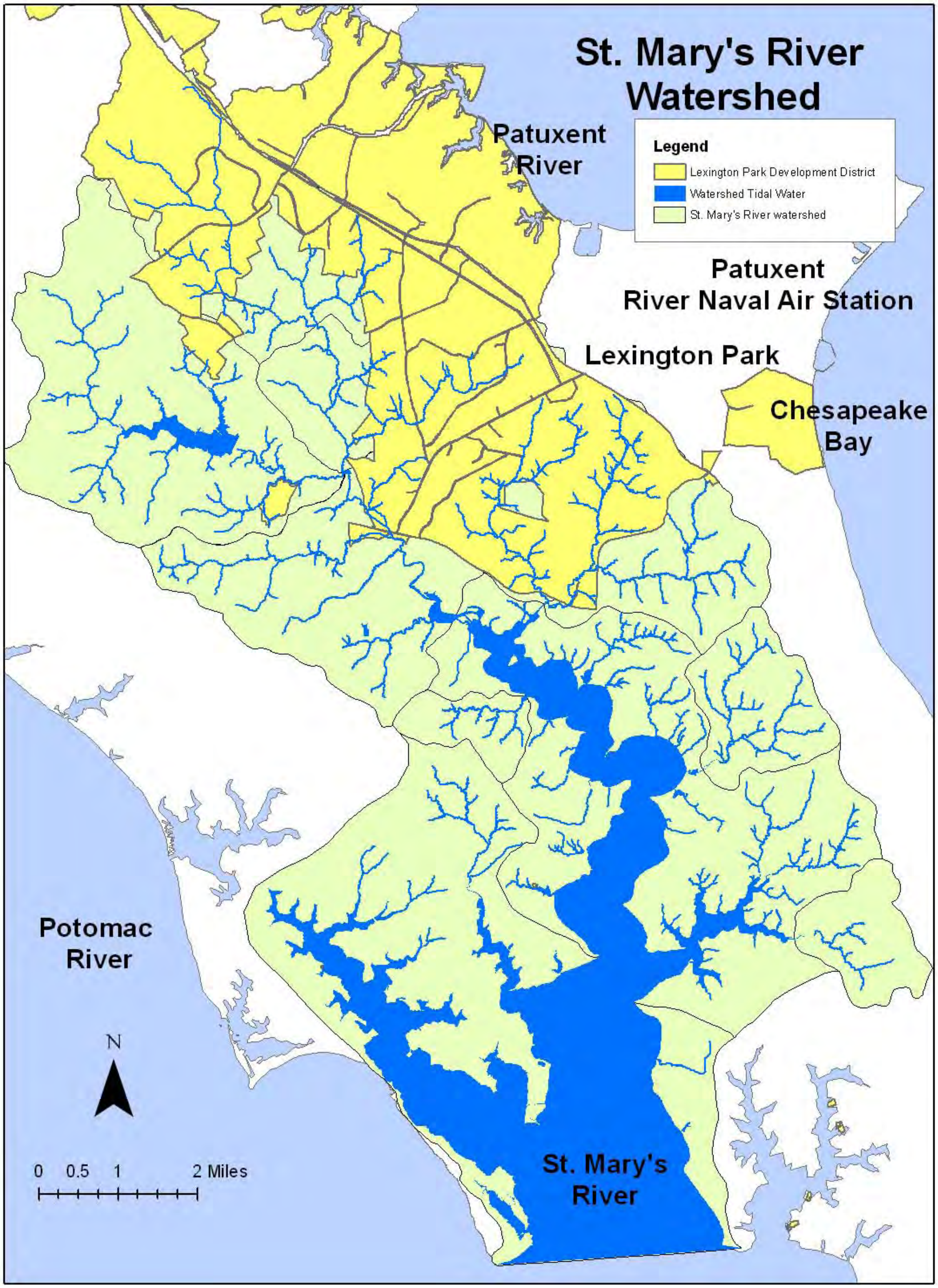


Figure 4. Lexington Park Development District and the Patuxent River Naval Air Station in relation to the St. Mary's River watershed.

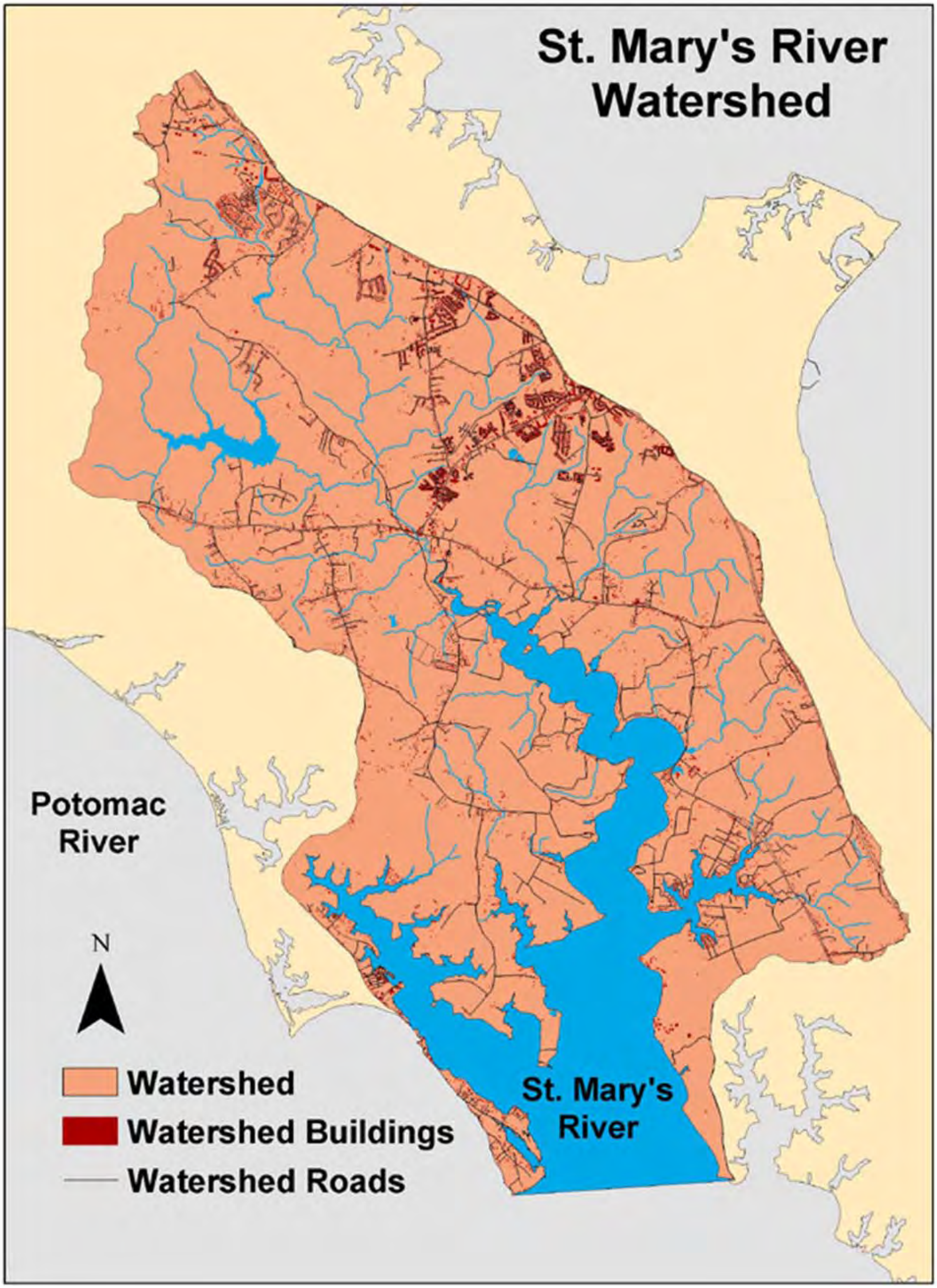


Figure 5. Watershed roads and building concentrations within the St. Mary's River watershed.

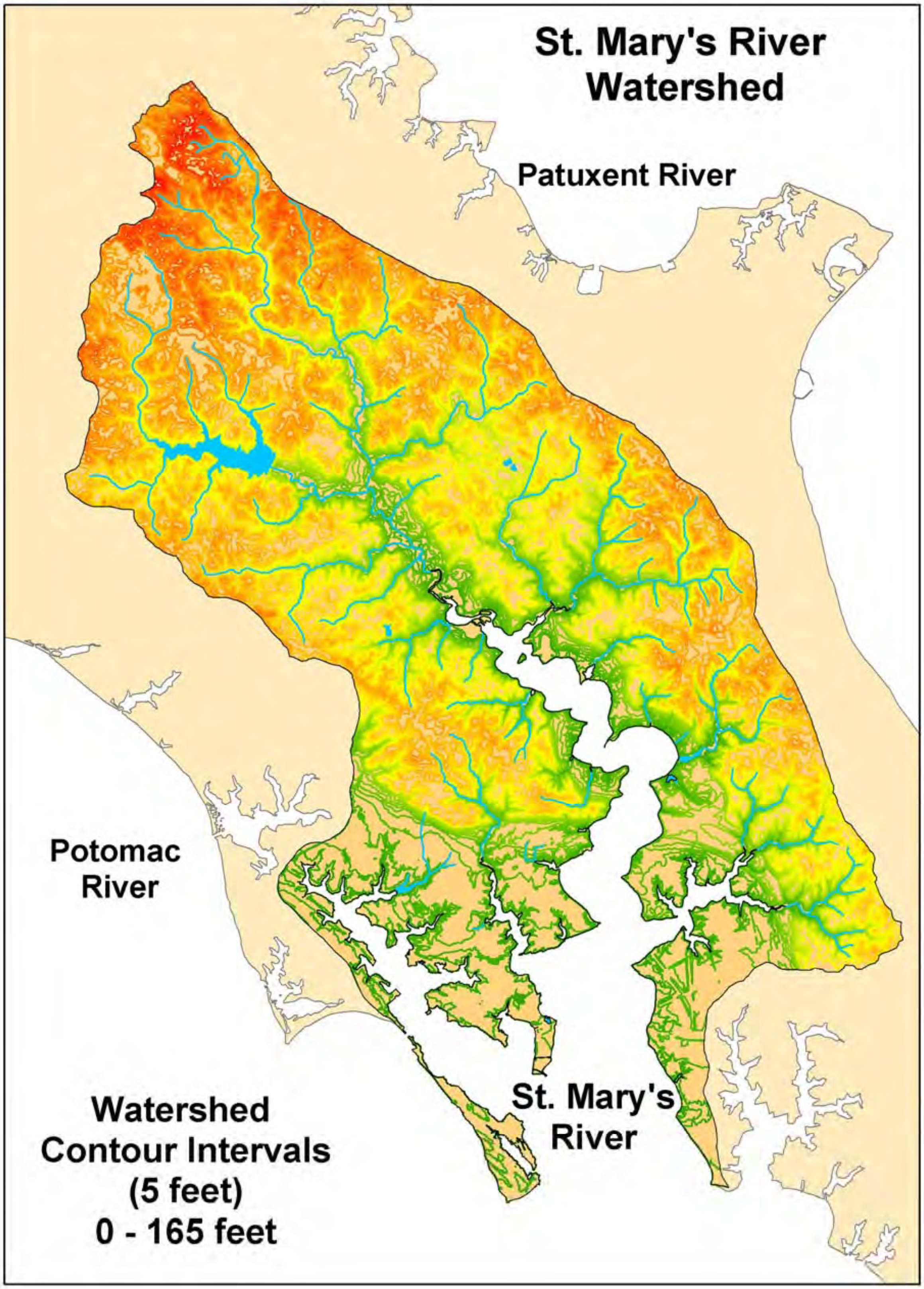


Figure 6. St. Mary's River watershed elevations as shown by 5-foot topographic lines. Watershed elevation range: 0-165 feet.

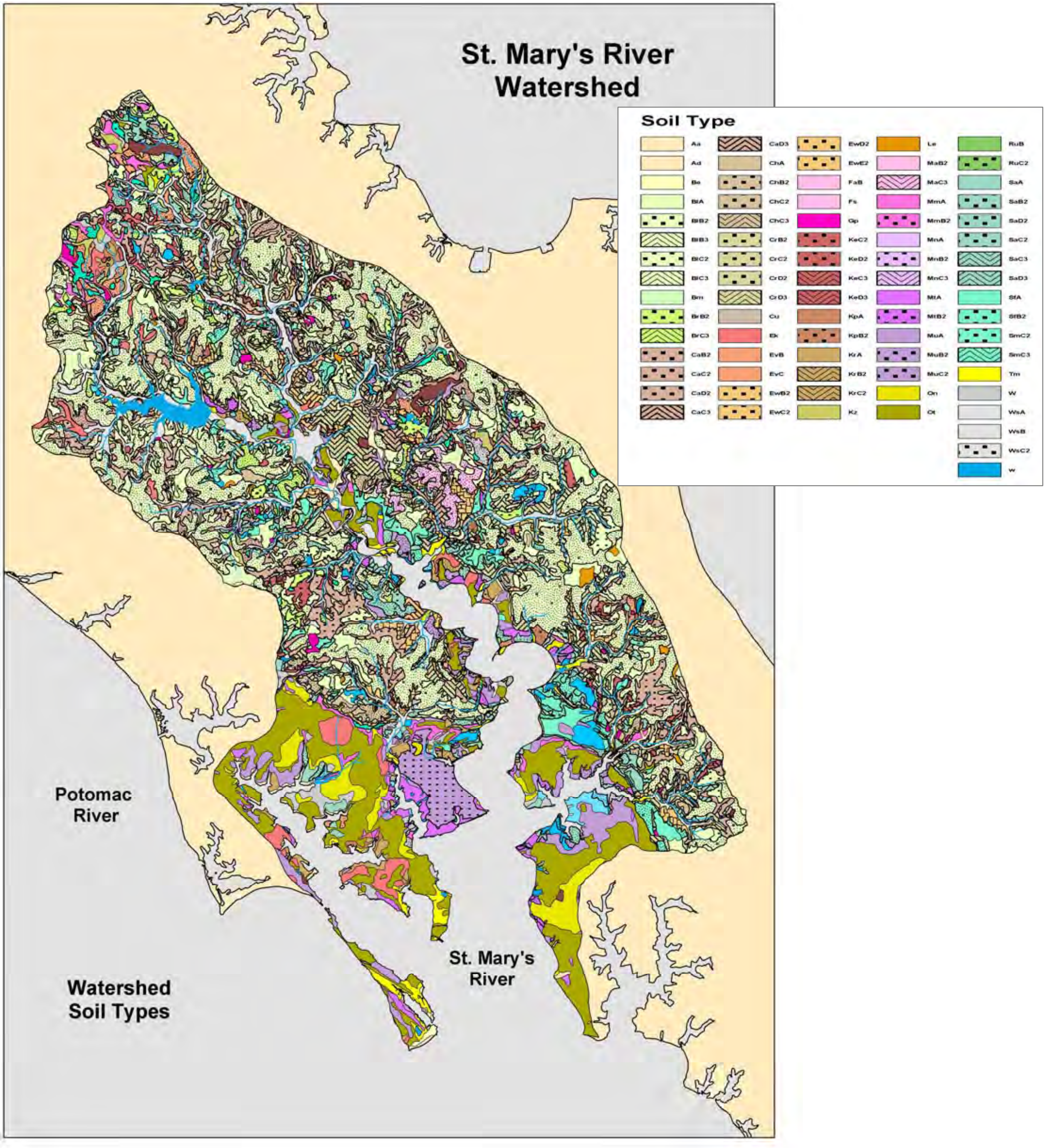


Figure 7. St. Mary's River watershed soils. Map is derived from Gibson (1978), Soil Survey of St. Mary's County, Maryland, Soil Conservation Service, United States Department of Agriculture.

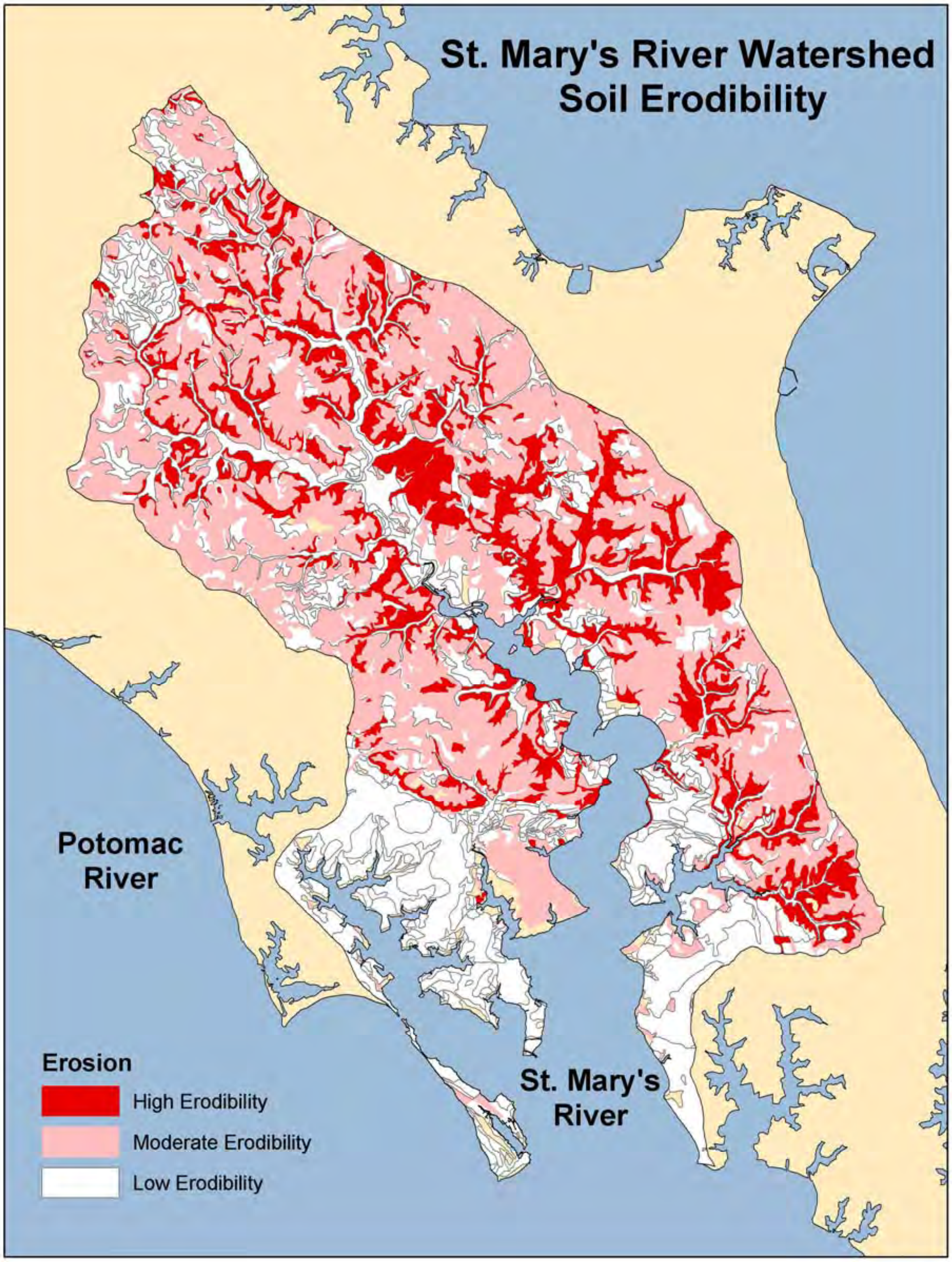


Figure 8. Erodibility of soils in the St. Mary's River watershed.

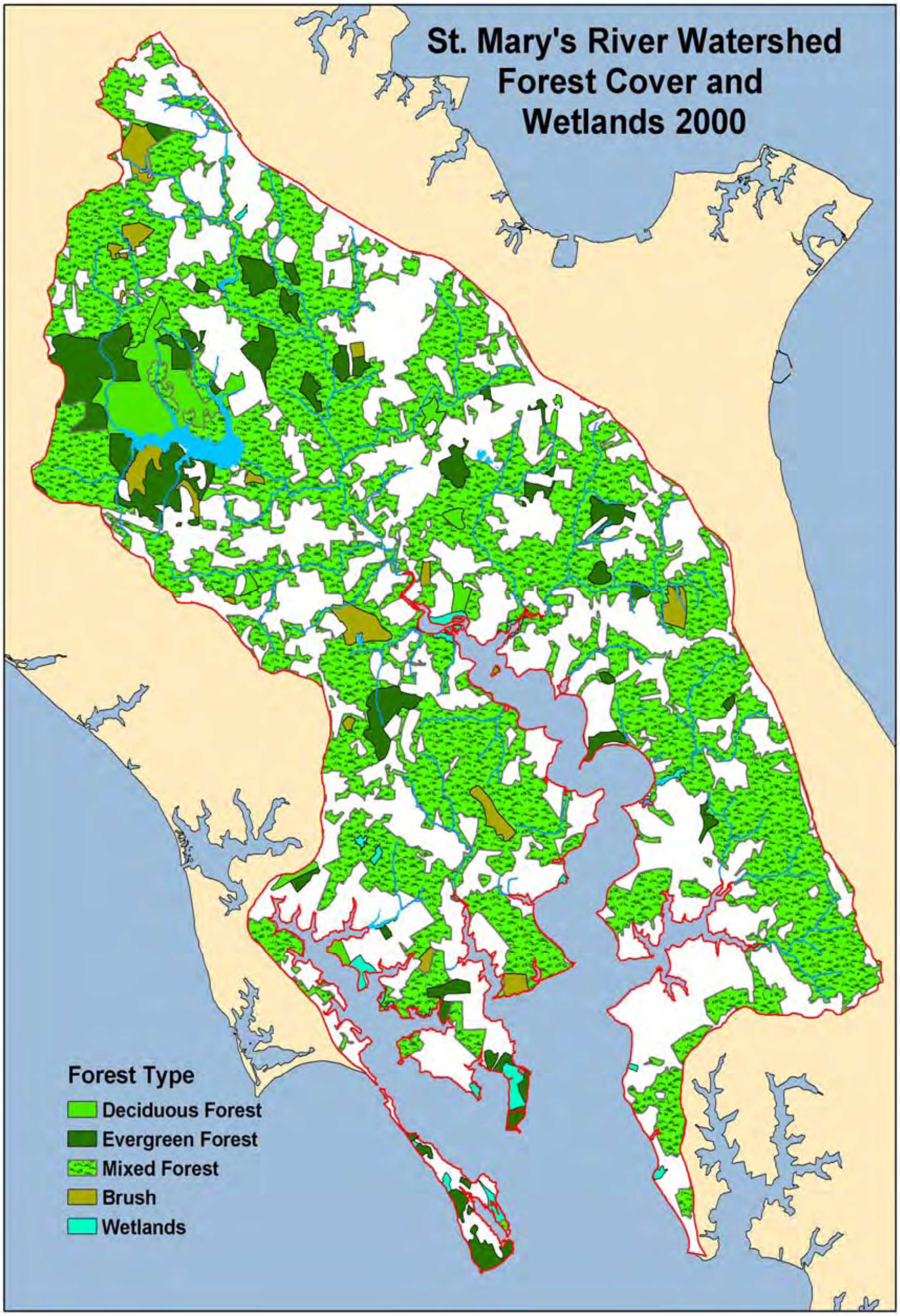


Figure 9. Forest cover and wetlands in the St. Mary's River watershed in 2000.

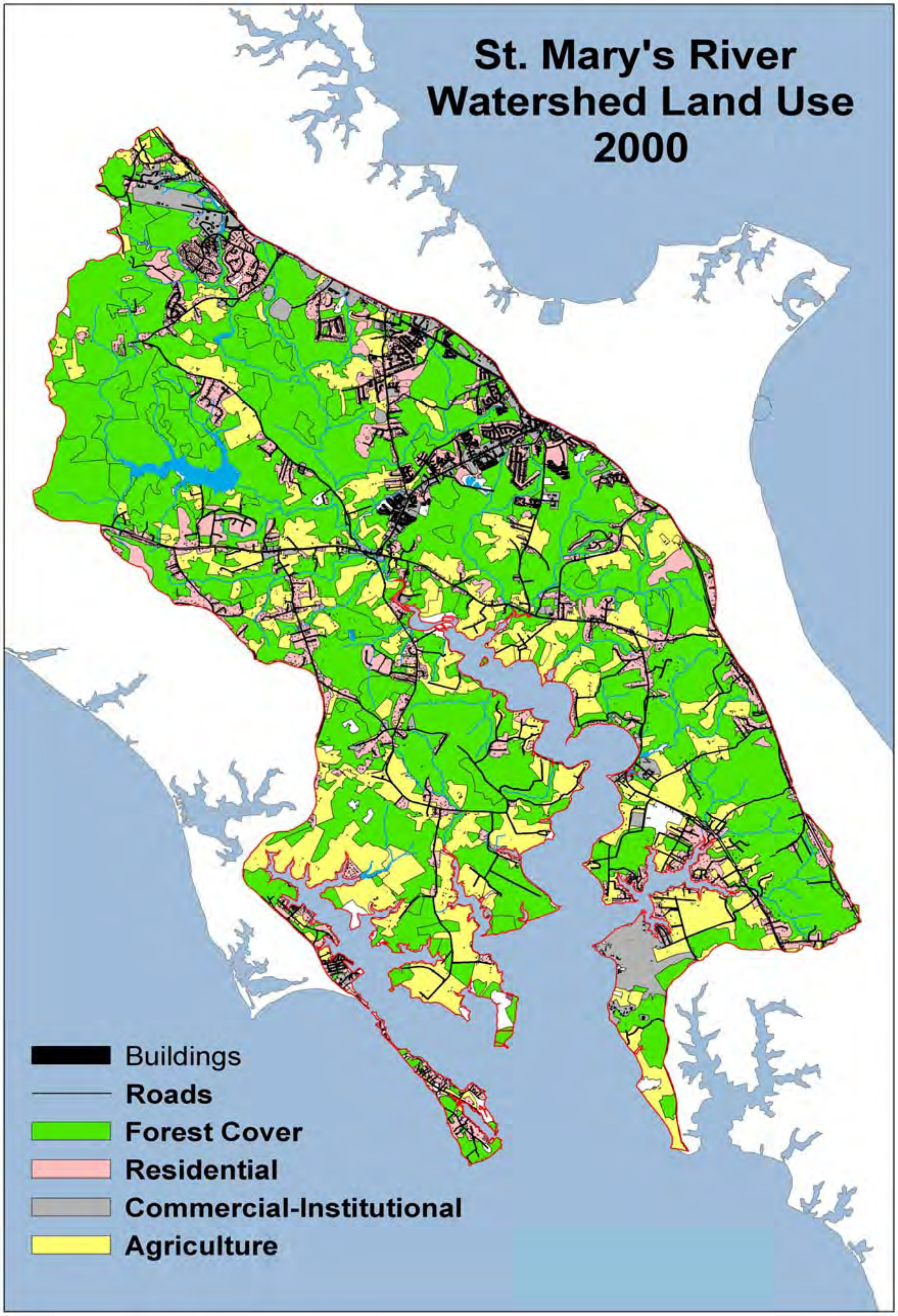


Figure 10. Land use in the St. Mary’s River watershed in 2000.

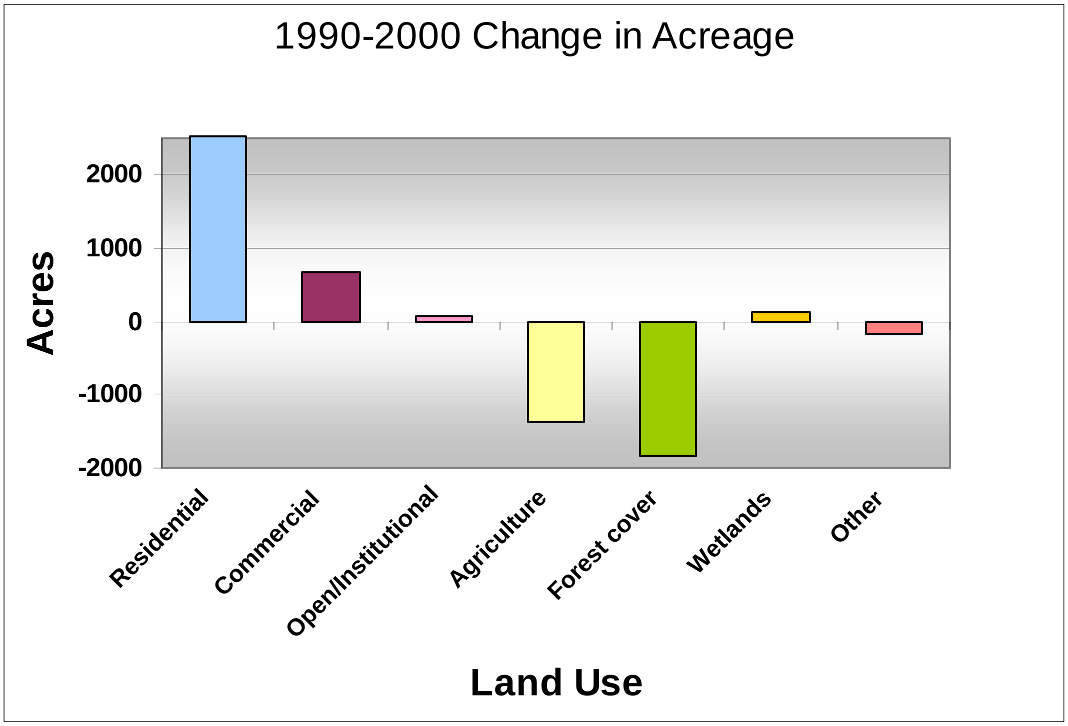


Figure 11. Land use change in the St. Mary's River Watershed between 1990 and 2000.

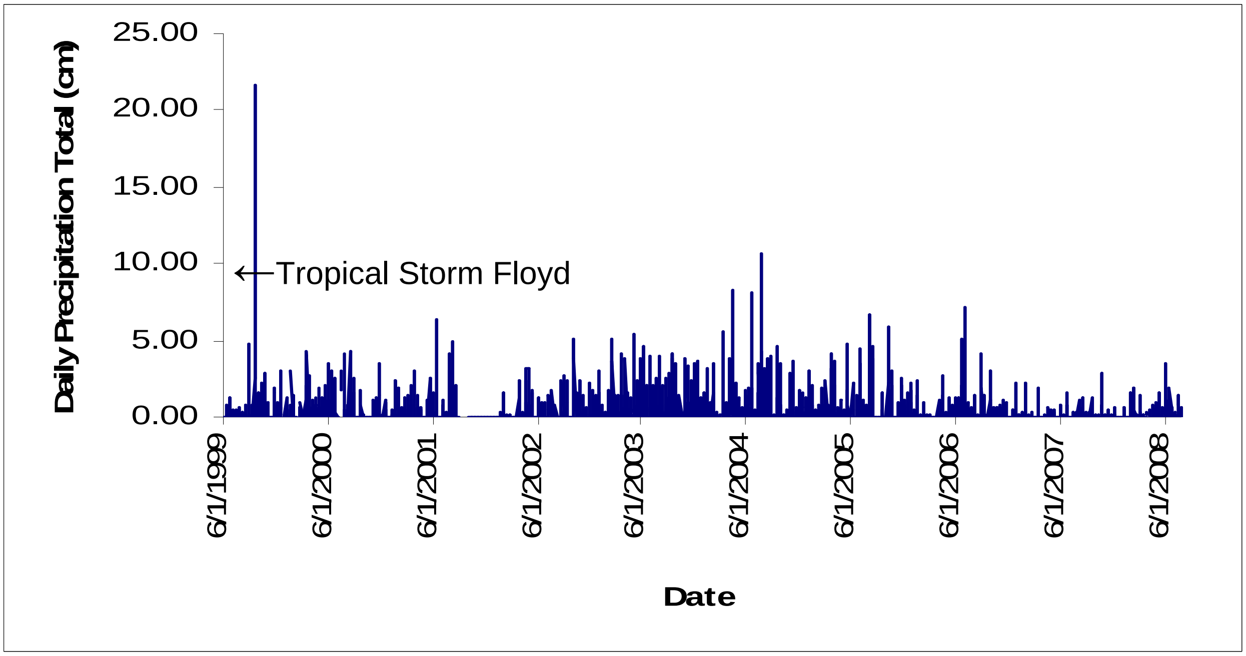


Figure 12. Daily precipitation collected at Patuxent River Naval Air Station, Lexington Park, Maryland from 1999 through 2008.

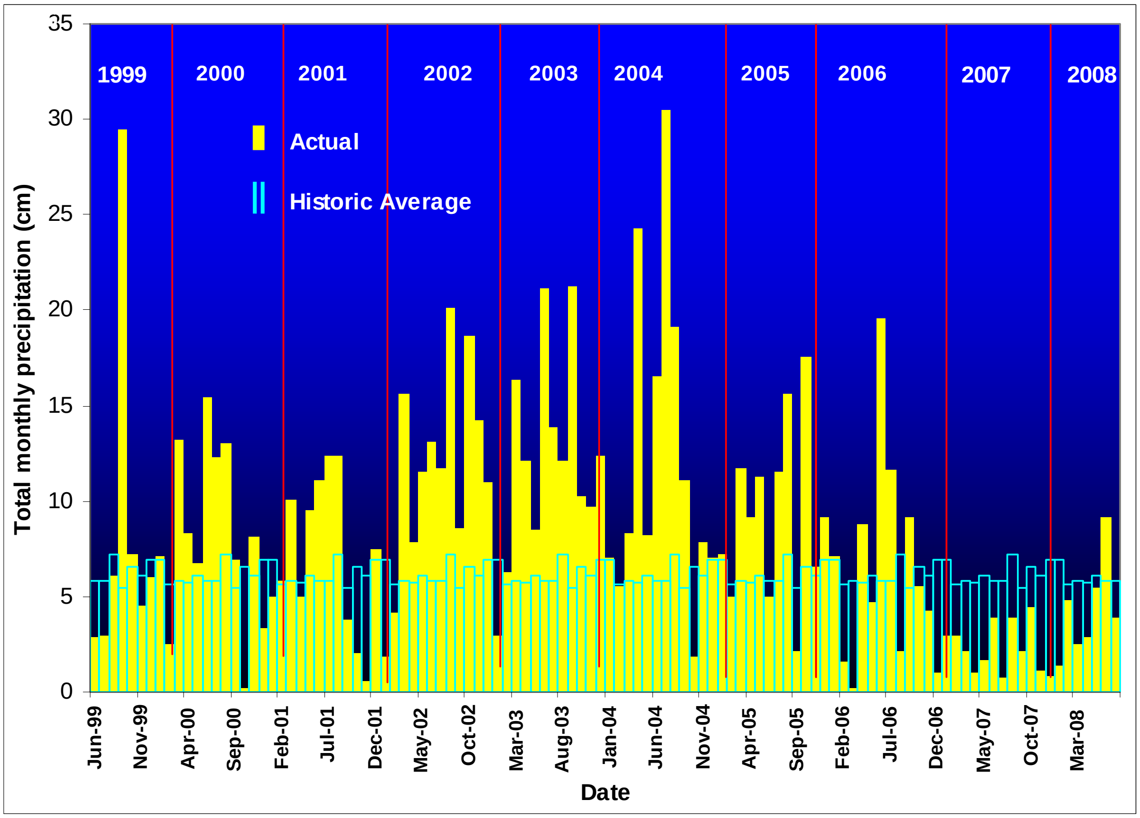


Figure 13. Total monthly precipitation and historic average monthly for 1999-2008. Precipitation data collected at the Patuxent River Naval Air Station, Lexington Park, MD. Discharge measured by the USGS Great Mills Road gage (gage # 01661500).

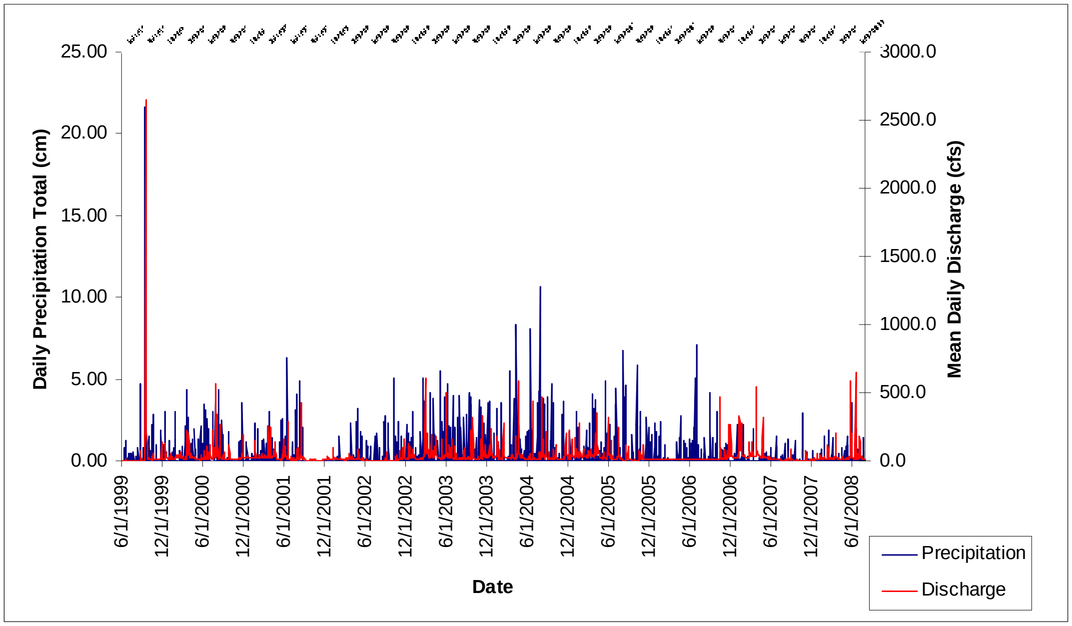


Figure 14. Precipitation and discharge during the 1999-2008 SMRP study period. Precipitation data collected at the Patuxent River Naval Air Station, Lexington Park, MD; Discharge measured by the USGS St. Mary's River gage (gage # 01661500).

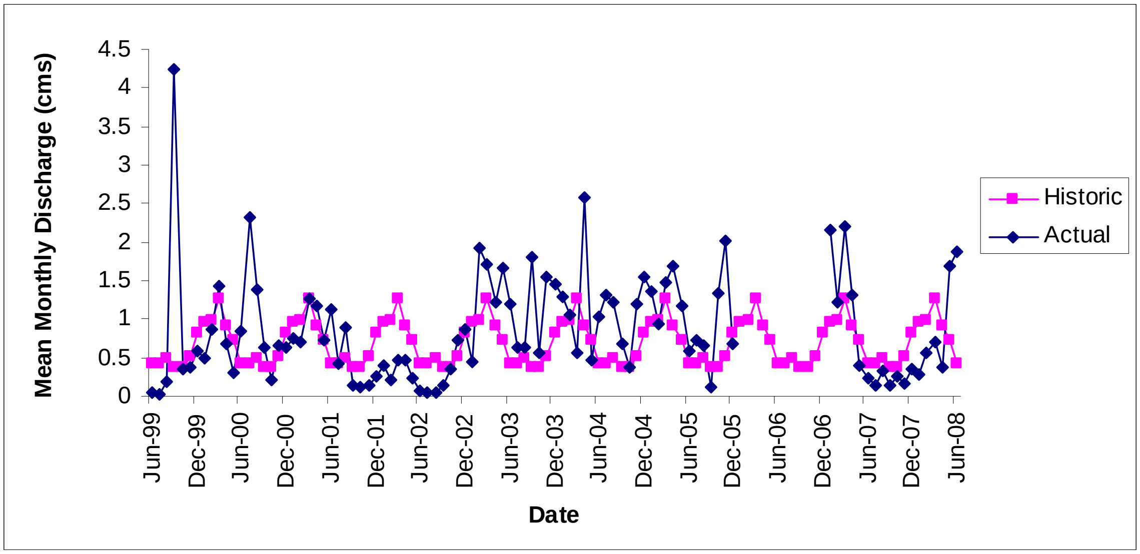


Figure 15. Actual and historic mean monthly from 1999 through 2008 from historic (1946-2008, missing 2006) mean monthly discharge. Discharge measured by the USGS St. Mary's River gage (gage # 01661500).

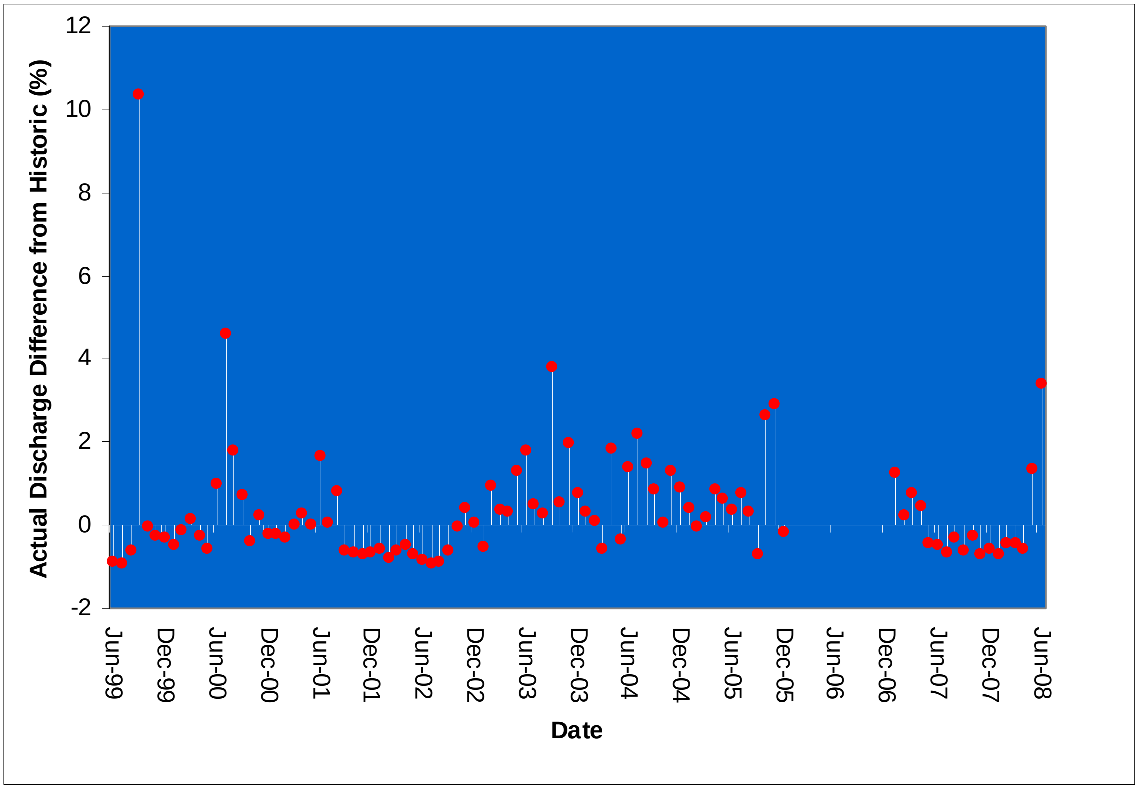


Figure 16. Difference between average monthly discharge from 1999 until 2008 from historic (1946-2008, missing 2006) mean monthly discharge. Discharge measured by the USGS St. Mary's River gage (gage # 01661500).

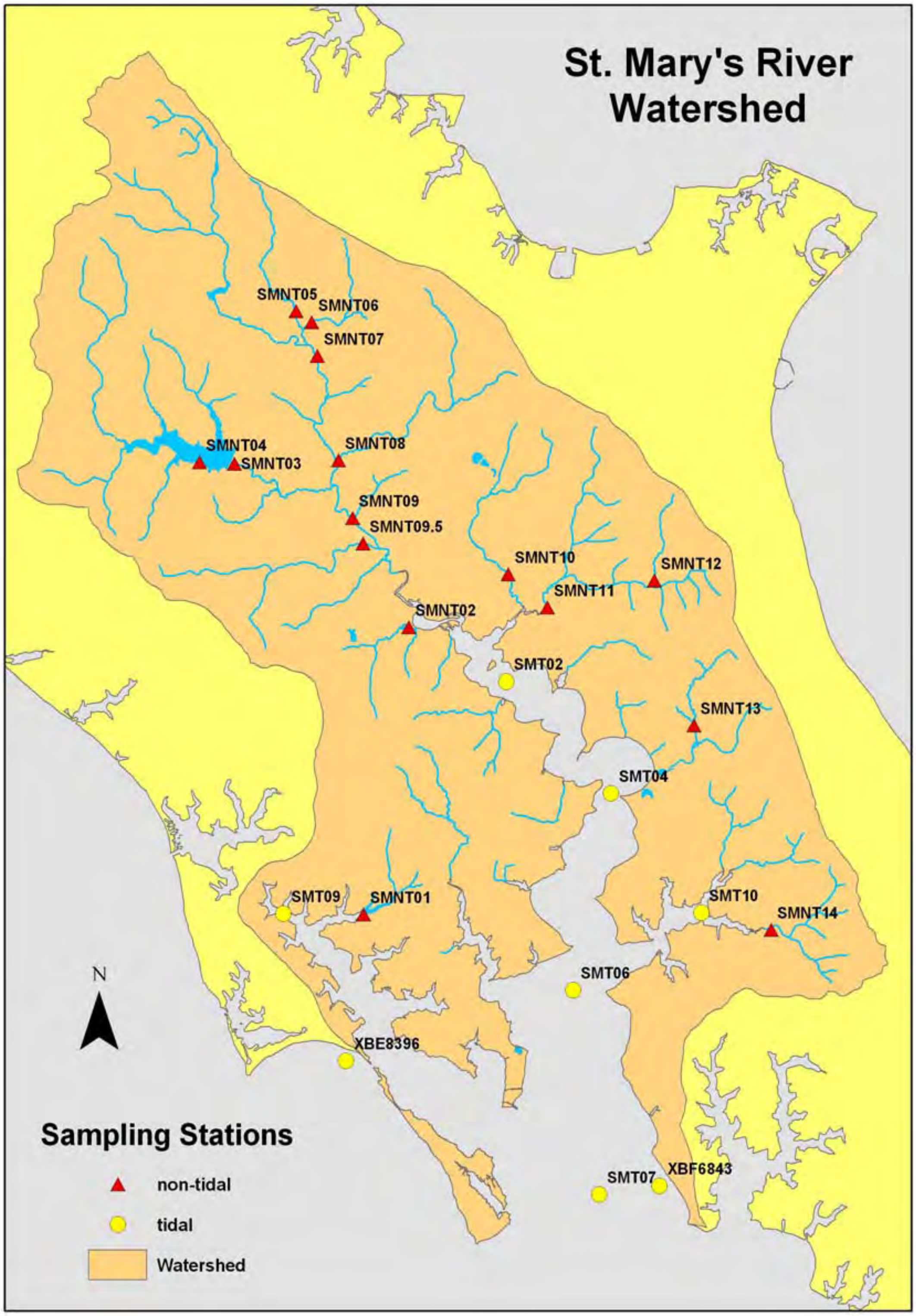


Figure 17. St. Mary's River watershed showing the tidal (SMT and XB…) and non-tidal (SMNT) sampling stations used in the St. Mary's River Project studies (Paul 2006; Paul and Tanner, 2001, 2005).

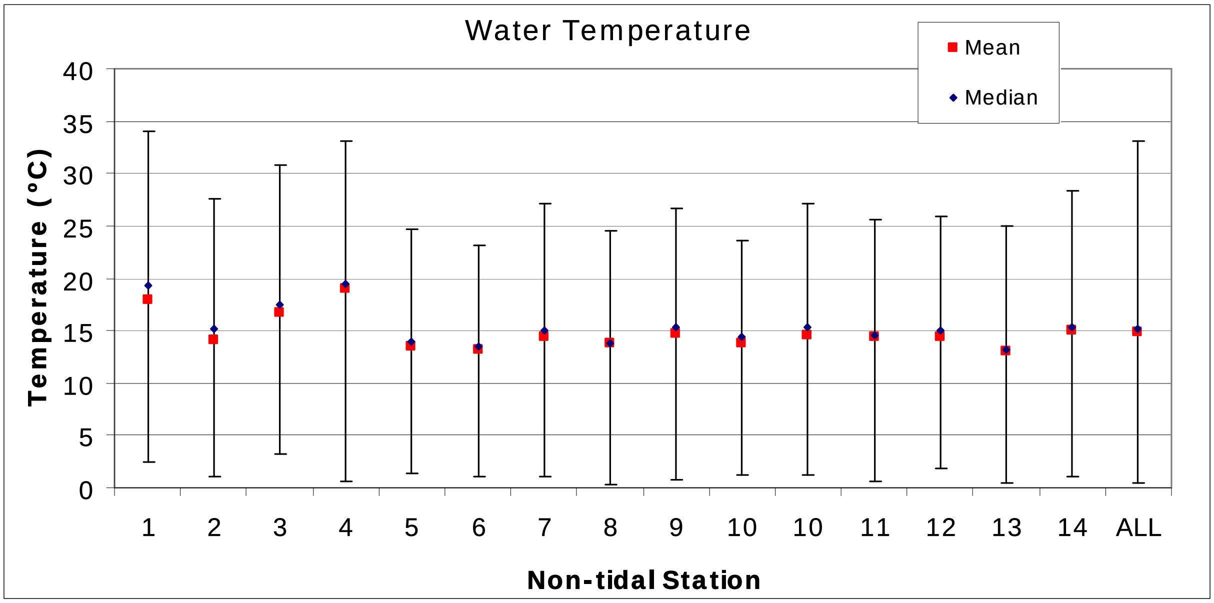


Figure 18. Mean (■), median (♦), minimum (⊥), and maximum (⊤) water temperature at non-tidal sites (June 1999-June 2008). Site 9.5 was added June 2001.

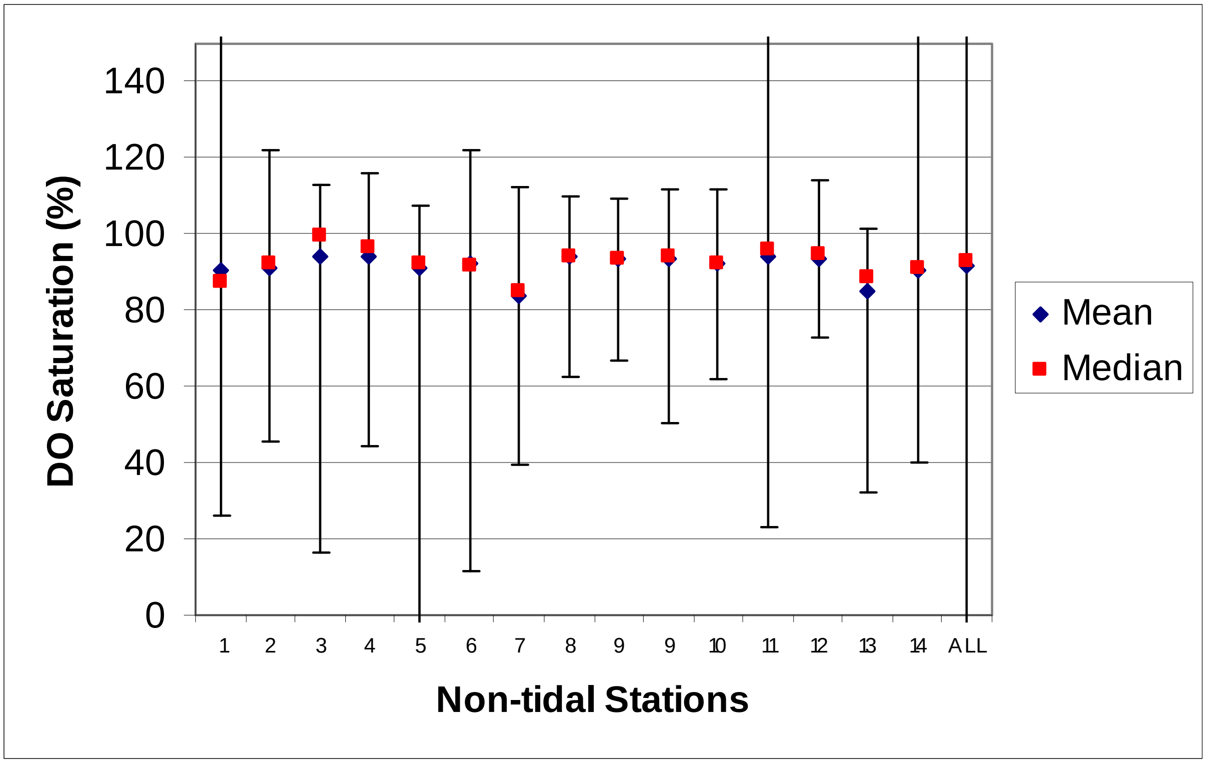


Figure 19. Median (■), mean (♦), minimum (⊥), and maximum (⊤) dissolved oxygen concentration as percent saturation for non-tidal sites June 1999-June 2008).
Site 9.5 was added June 2001.

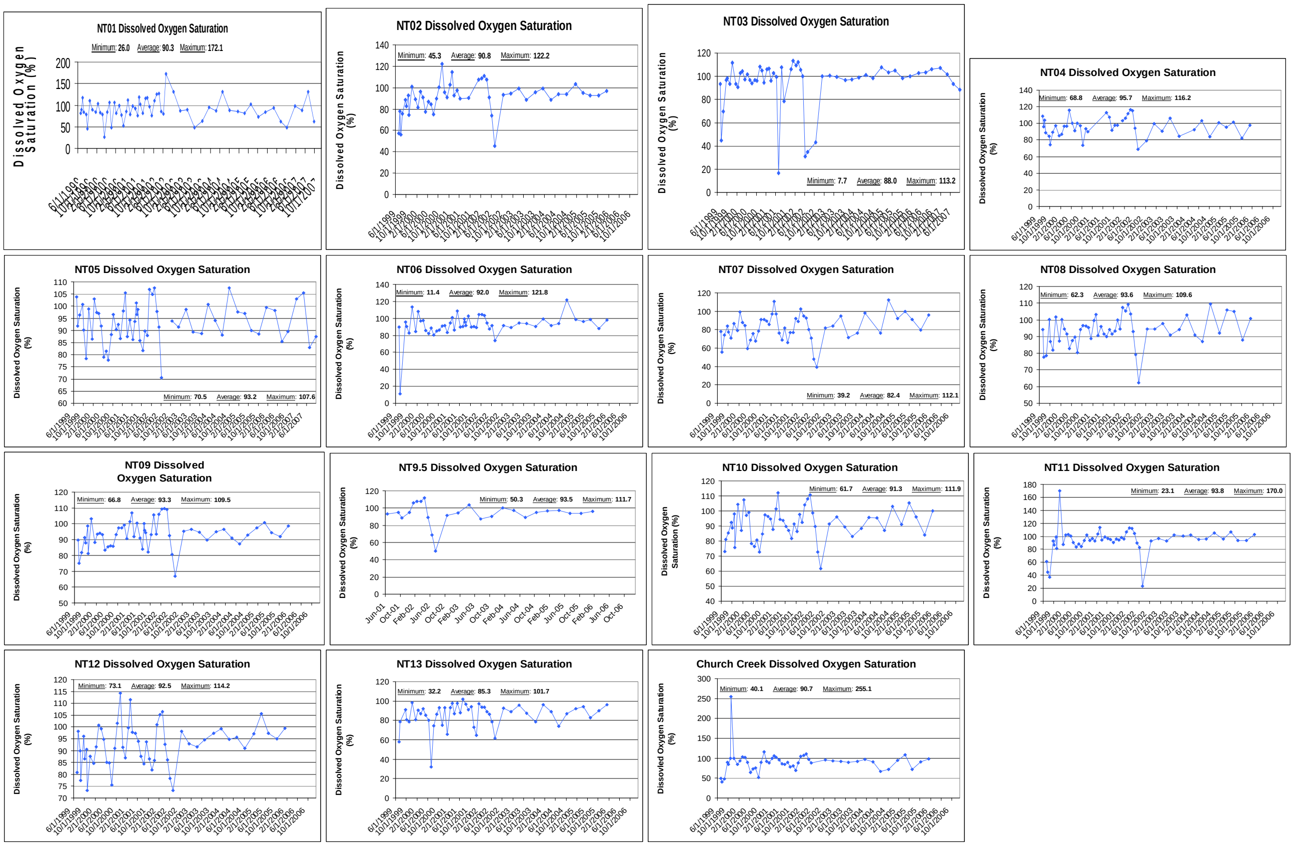


Figure 20. Dissolved oxygen concentration as percent saturation for non-tidal sites June 1999-June 2008). Site 9.5 was added June 2001.

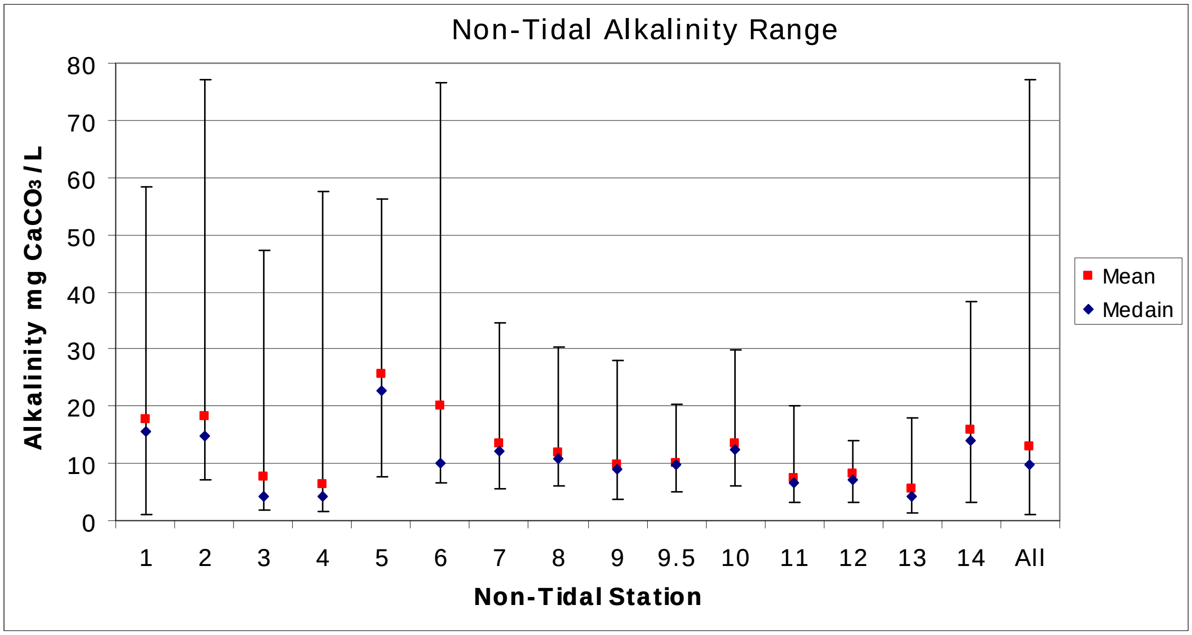


Figure 21. Mean (■), median (♦), minimum (⊥), and maximum (⊤) total alkalinity for non-tidal sites (June 1999—July 2006). Site NT09.5 was added June 2001.

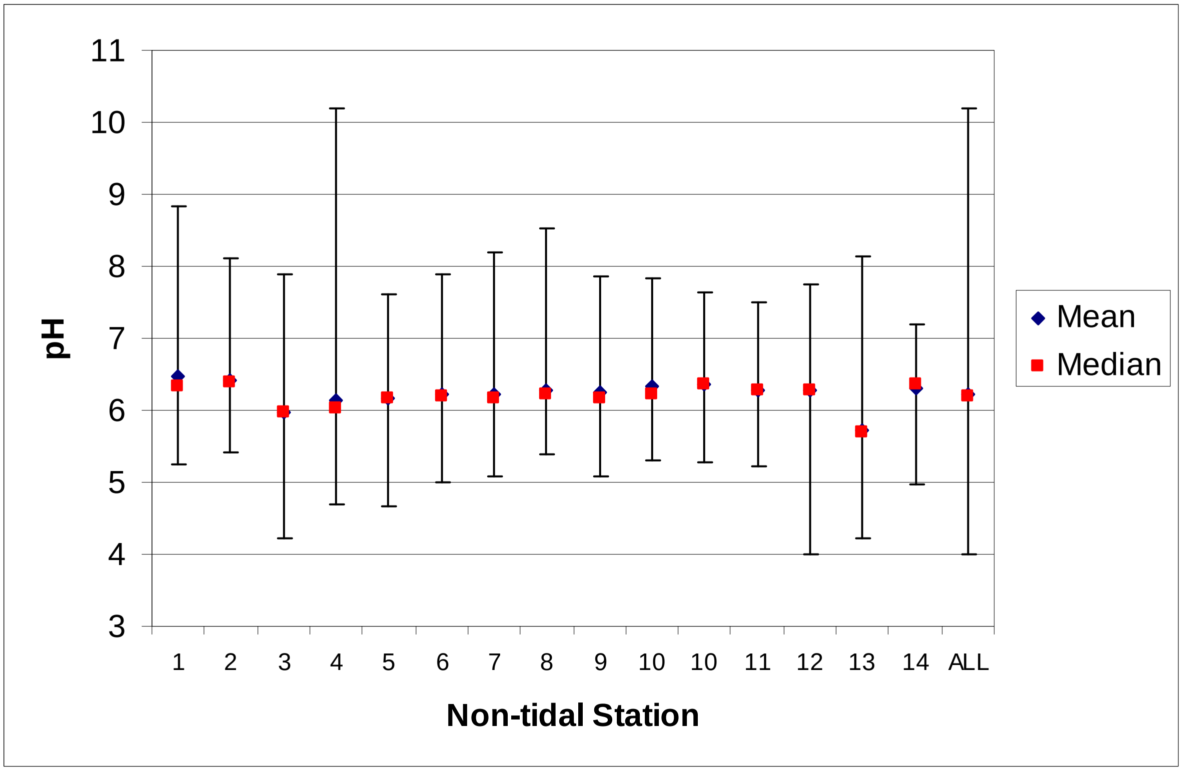


Figure 22. Median (■), mean (♦), minimum (⊥), and maximum (⊤) pH for non-tidal sites (June 1999-June 2008). Site NT09.5 was added in June 2001.

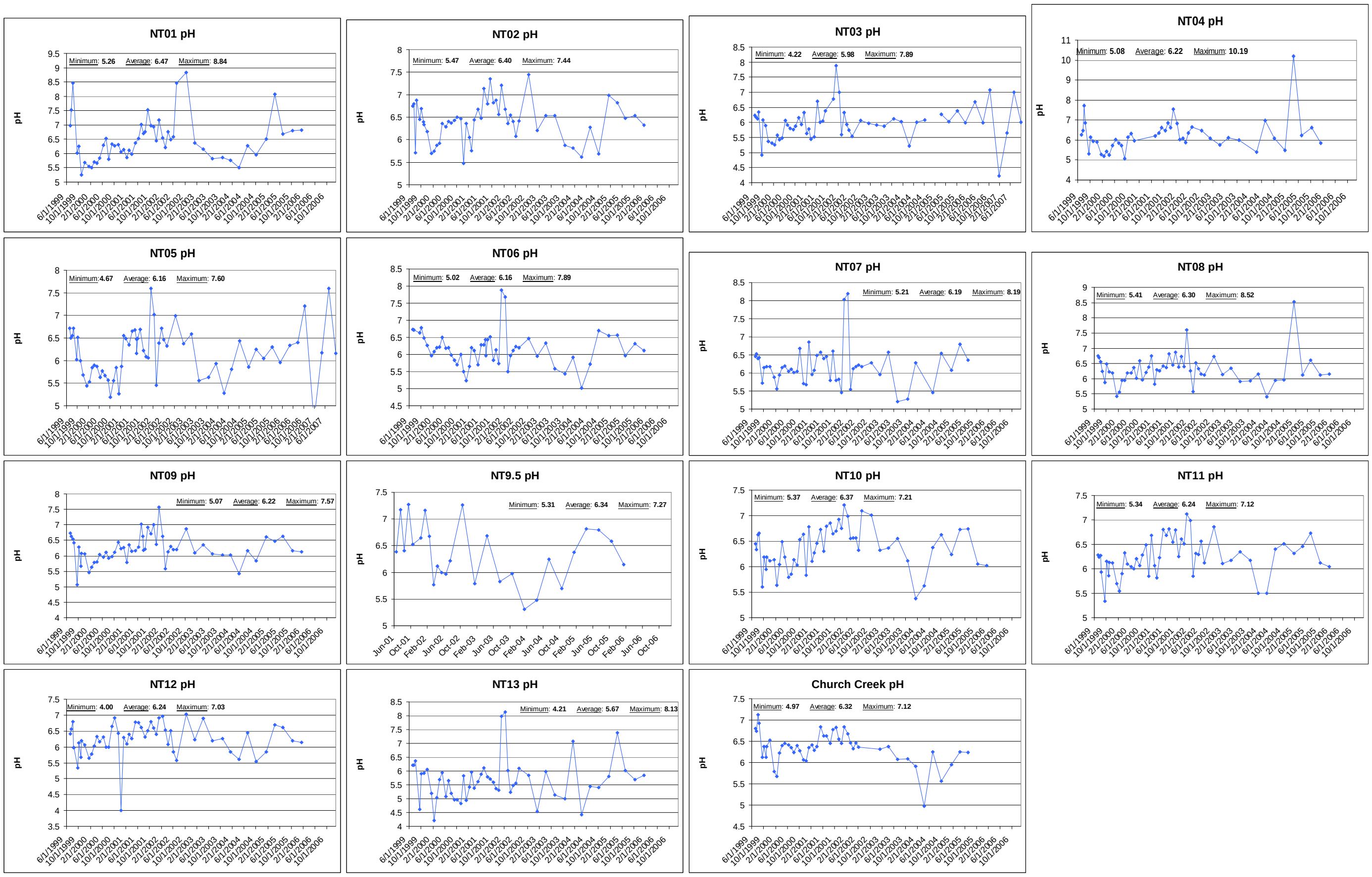


Figure 23. Measured pH for each non-tidal site (June 1999-June 2008).
Site NT09.5 was added in June 2001.

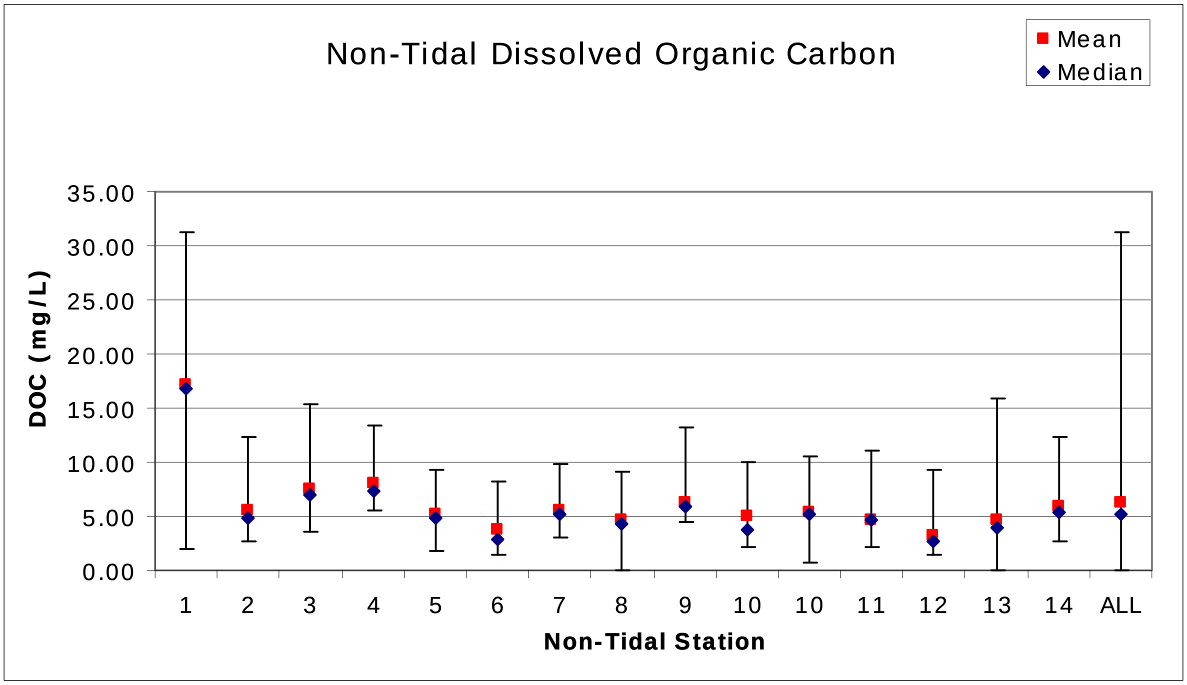


Figure 24. Mean (🟥), median (◆), minimum (┴), and maximum (┬) dissolved organic carbon (DOC) for non-tidal sites (June 1999-June 2008). Site NT09.5 was added in June 2001.

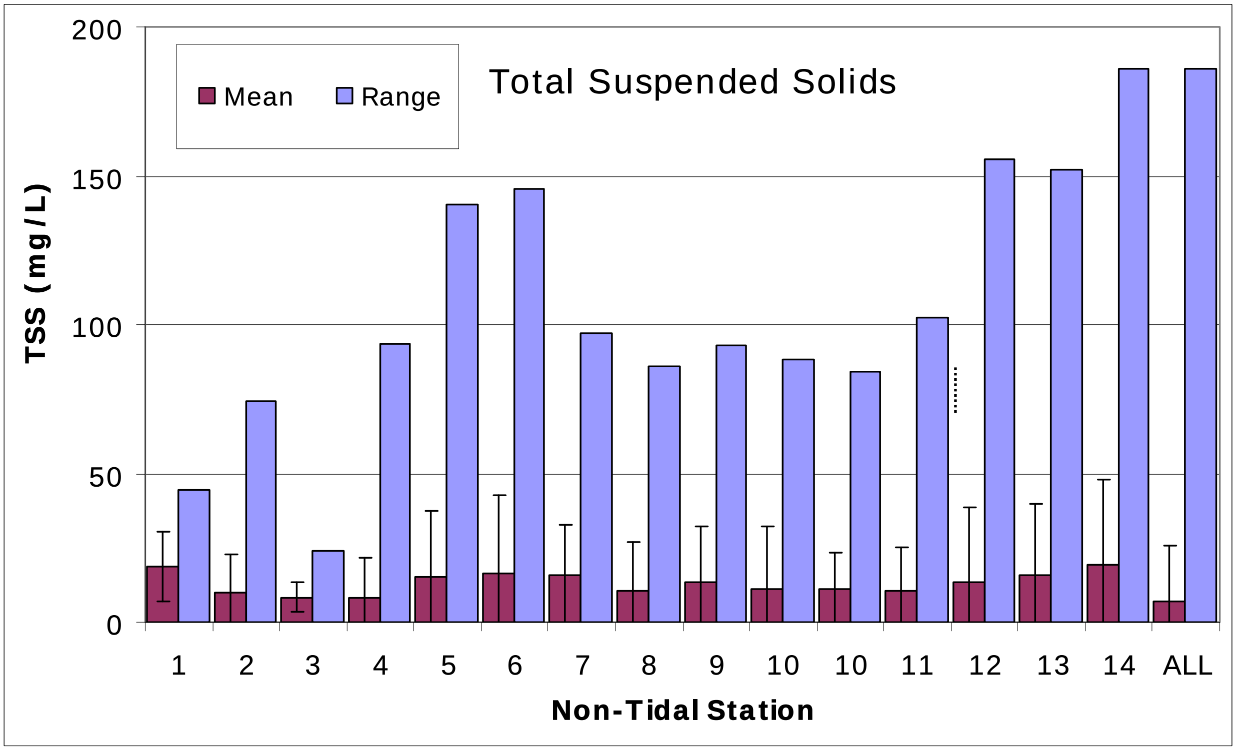


Figure 25. Range and mean (± 1 standard deviation) total suspended solids (TSS) at non-tidal sites (June 1999-June 2008). Site NT09.5 was added June 2001.

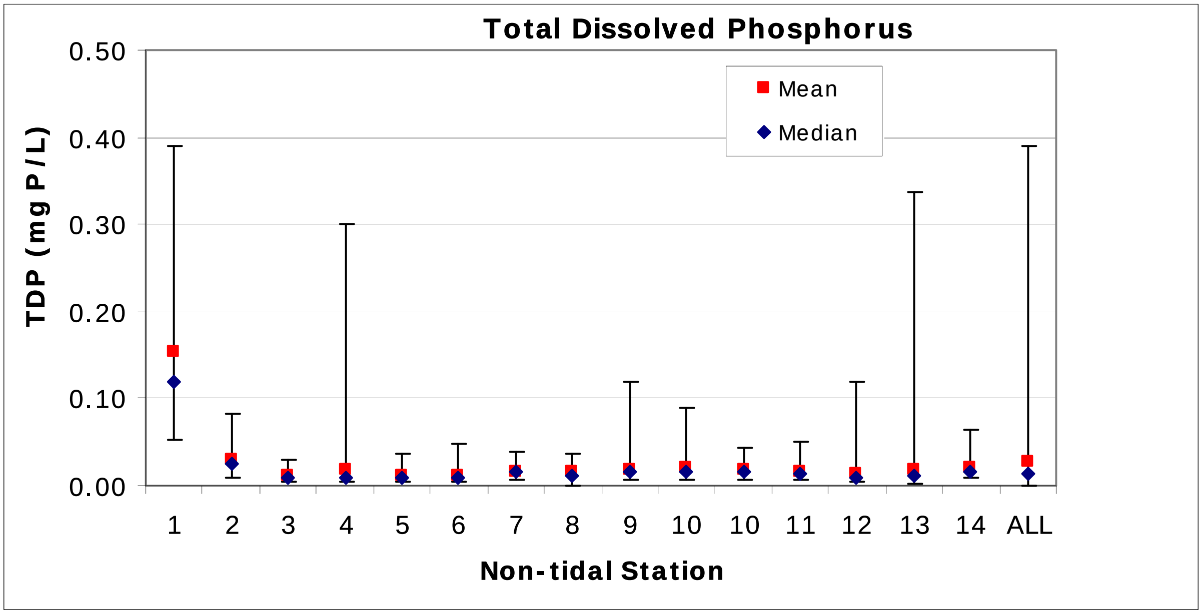


Figure 26. Median (■), mean (♦), minimum (┴), and maximum (┬), total dissolved phosphorus (TDP) for non-tidal sites (June 1999—June 2008). Site NT09.5 was added June 2001.

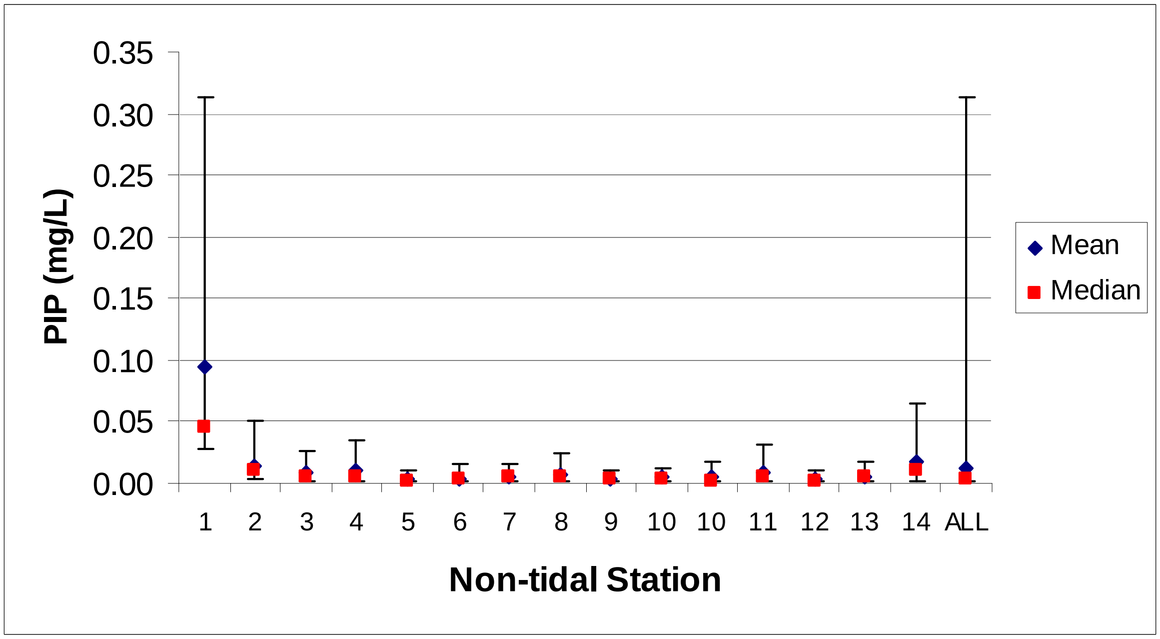


Figure 27. Median (■), mean (♦), minimum (┴), and maximum (┬) particulate inorganic phosphate for non-tidal sites (June 1999—Jun 2008). Site NT09.5 was added June 2001.

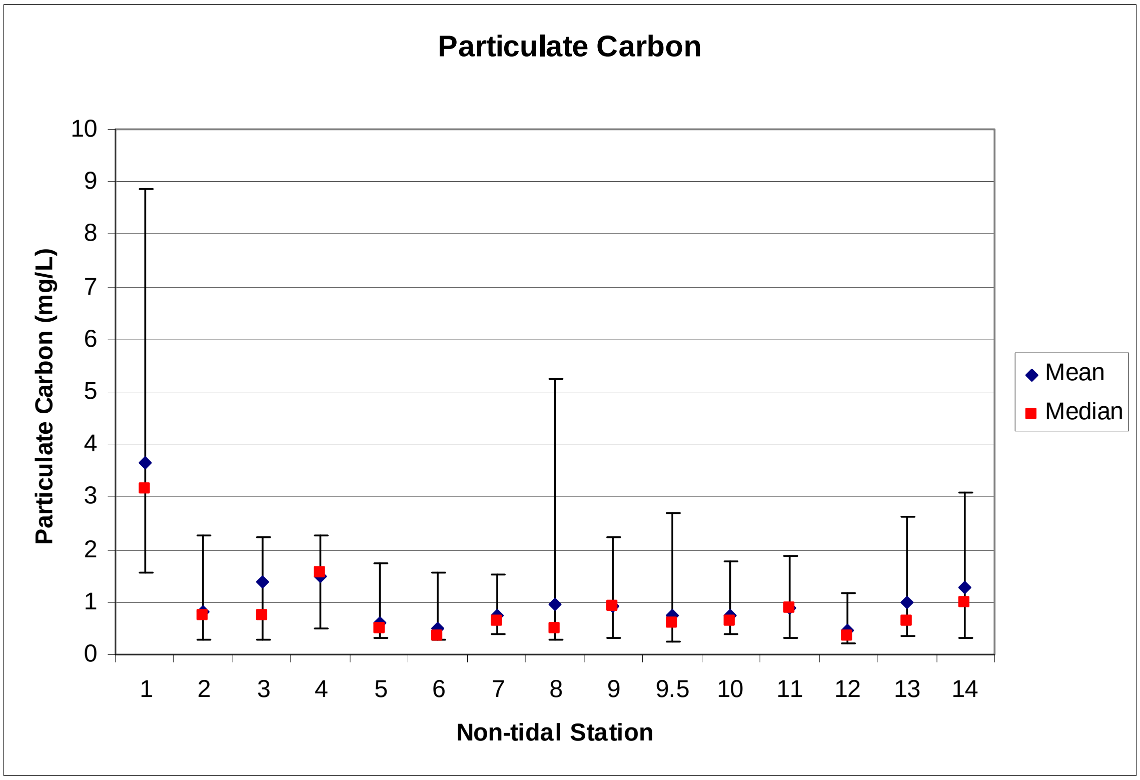


Figure 28. Median (■), mean (♦), minimum (┴), and maximum (┬) particulate carbon for non-tidal sites (October 2004—Jun 2008).

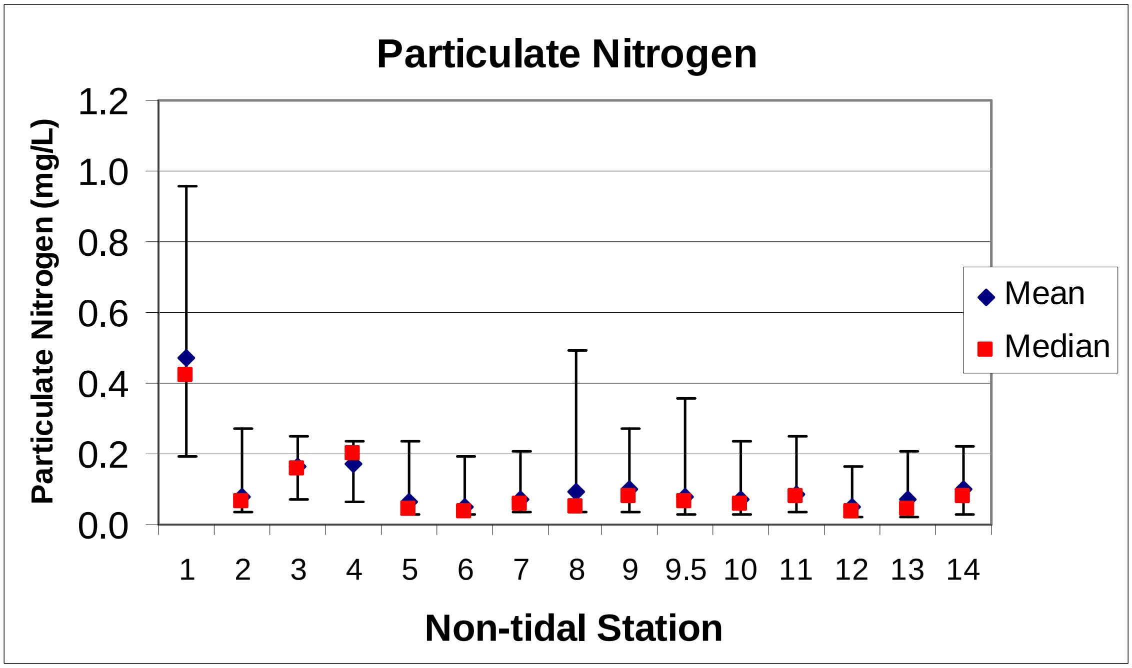


Figure 29. Median (■), mean (♦), minimum (┴), and maximum (┬) particulate nitrogen for non-tidal sites (October 2004—Jun 2008).

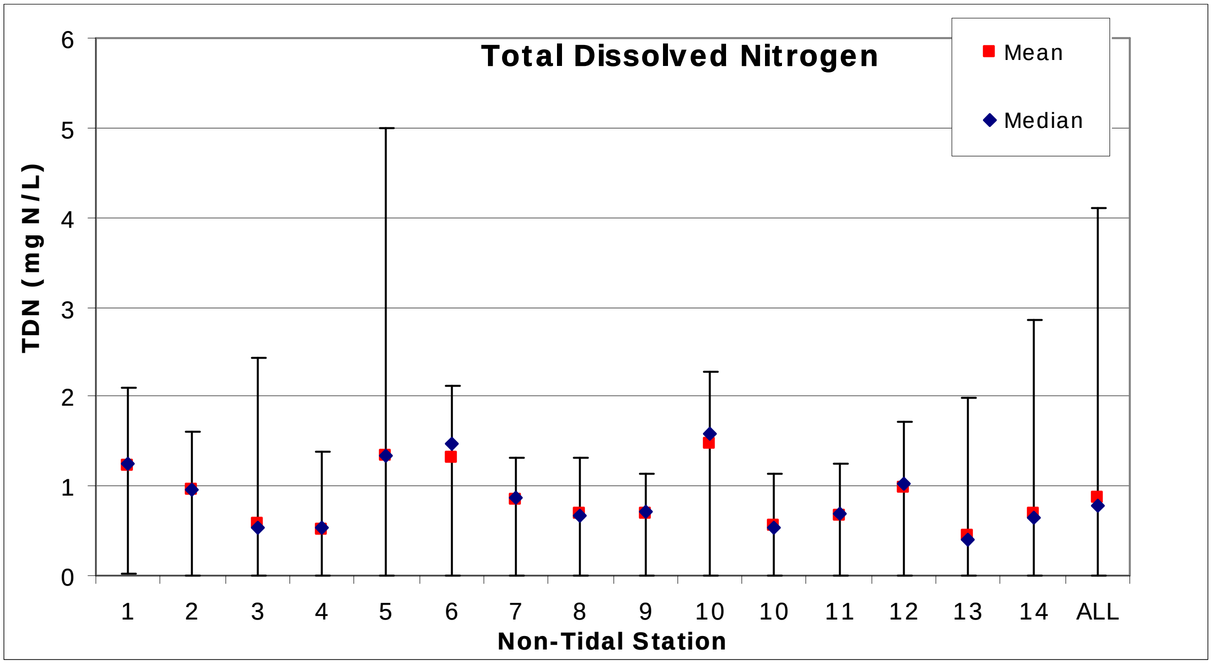


Figure 30. Mean (■), median (♦), minimum (⊥), and maximum (⊤), total dissolved nitrogen (TDN) for non-tidal sites (June 1999—June 2008). Site NT09.5 was added June 2001.

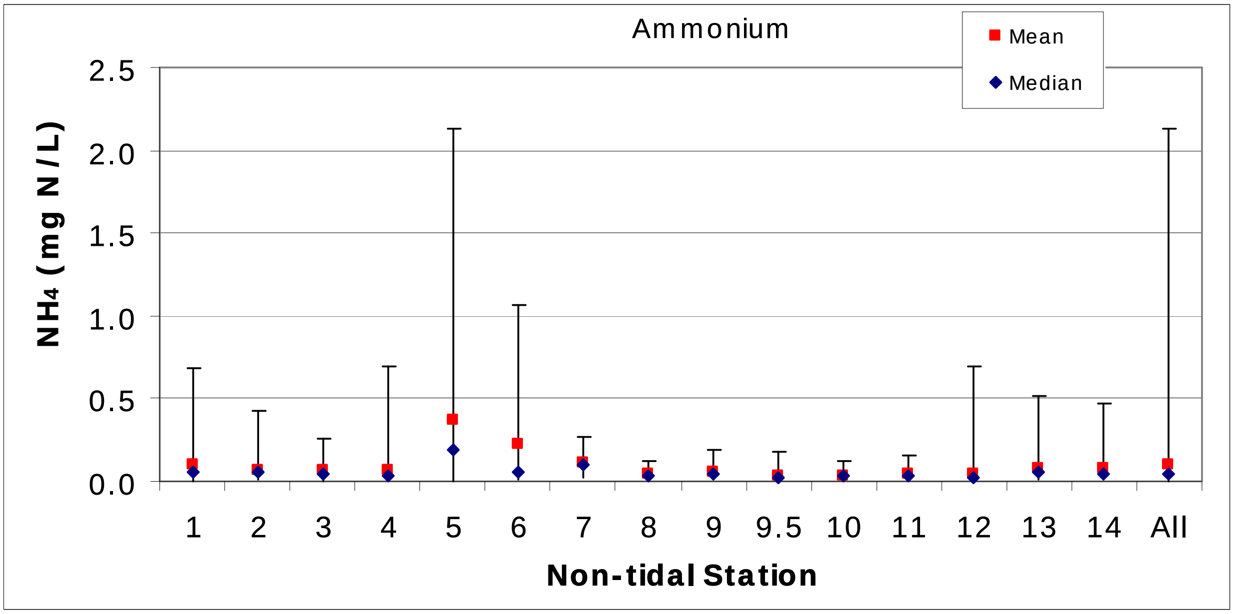


Figure 31. Mean (■), median (♦), minimum (⊥), and maximum (⊤) ammonium for non-tidal sites (June 1999—June 2008). Site NT09.5 was added June 2001.

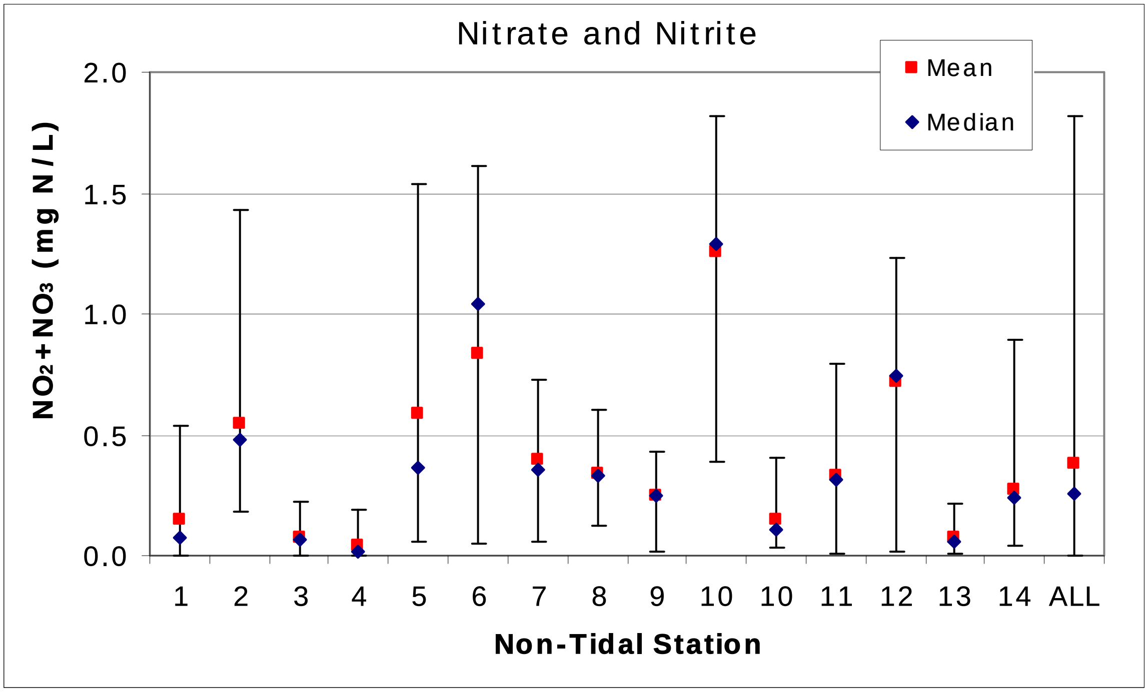


Figure 32. Mean (■), median (♦), minimum (⊥), and maximum (⊤) nitrite and nitrate for non-tidal sites (June 1999—Jun 2008). Site NT09.5 was added June 2001.

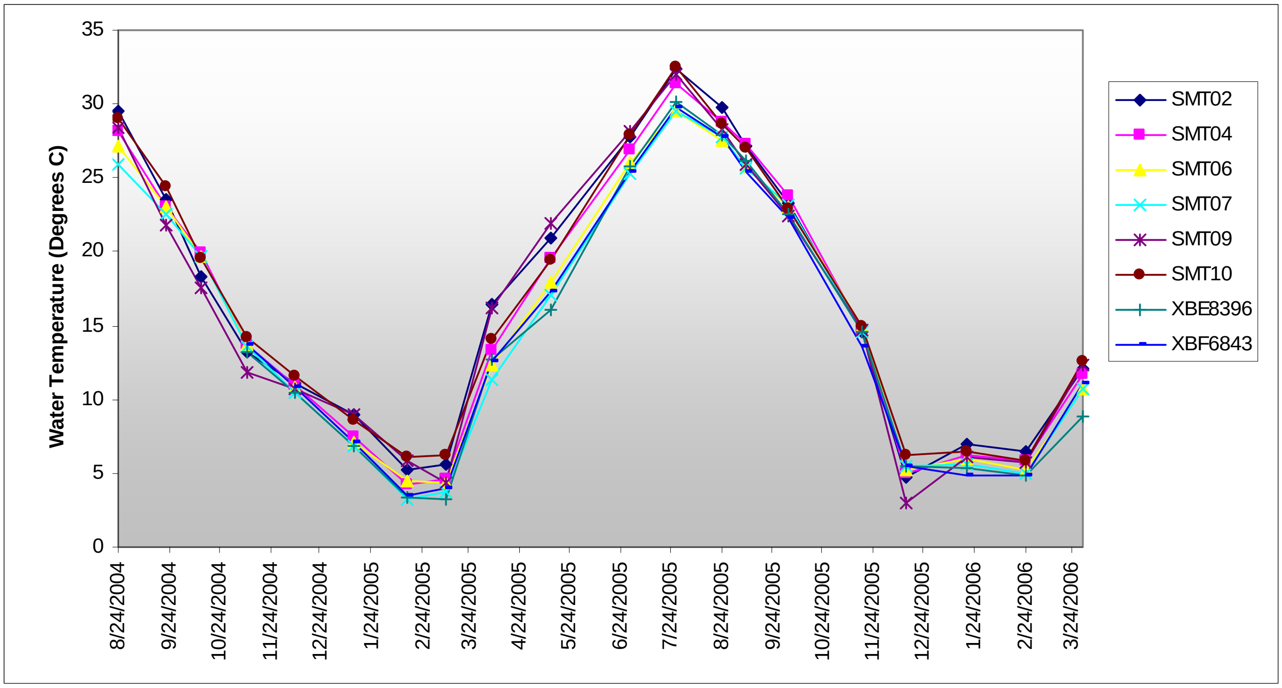


Figure 33. Surface water temperatures at all tidal stations from 1999 through 2008.

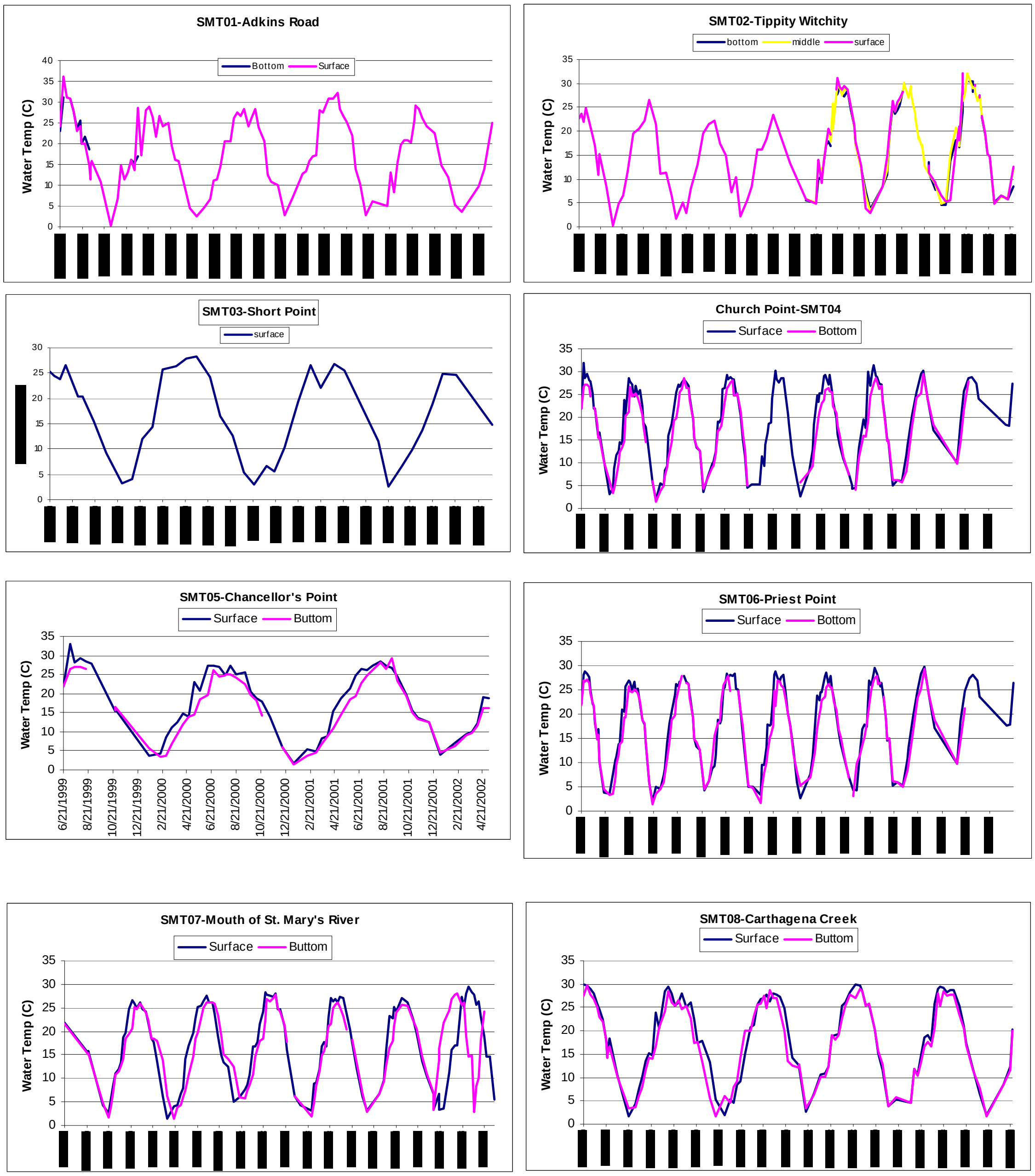


Figure 34. Water temperatures at all SMRP tidal sites (- Surface, - Middle, - Bottom) from 1999-2008.

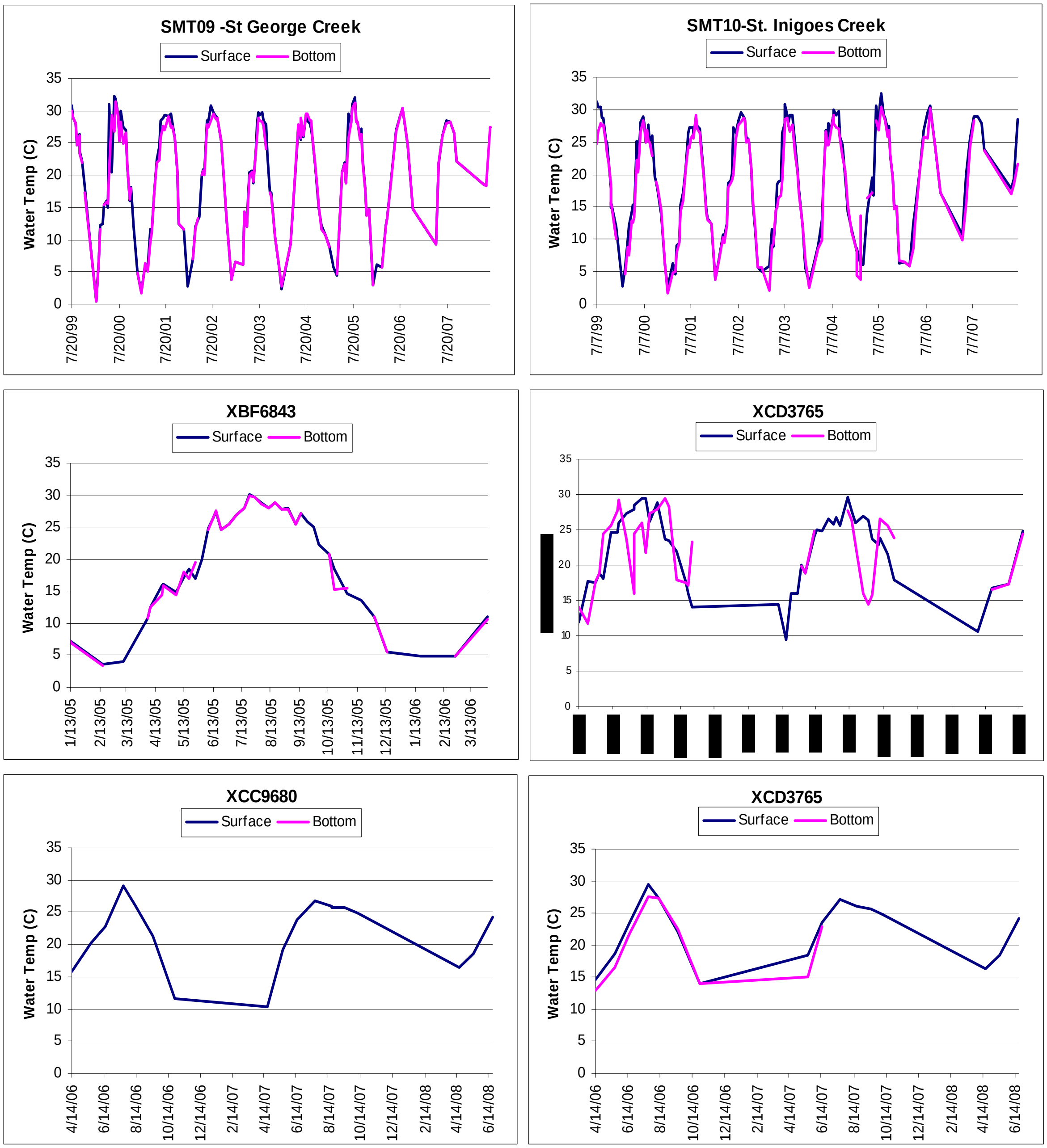


Figure 34 (continued). Water temperatures at all SMRP tidal sites (- Surface, - Bottom) from 1999-2008.

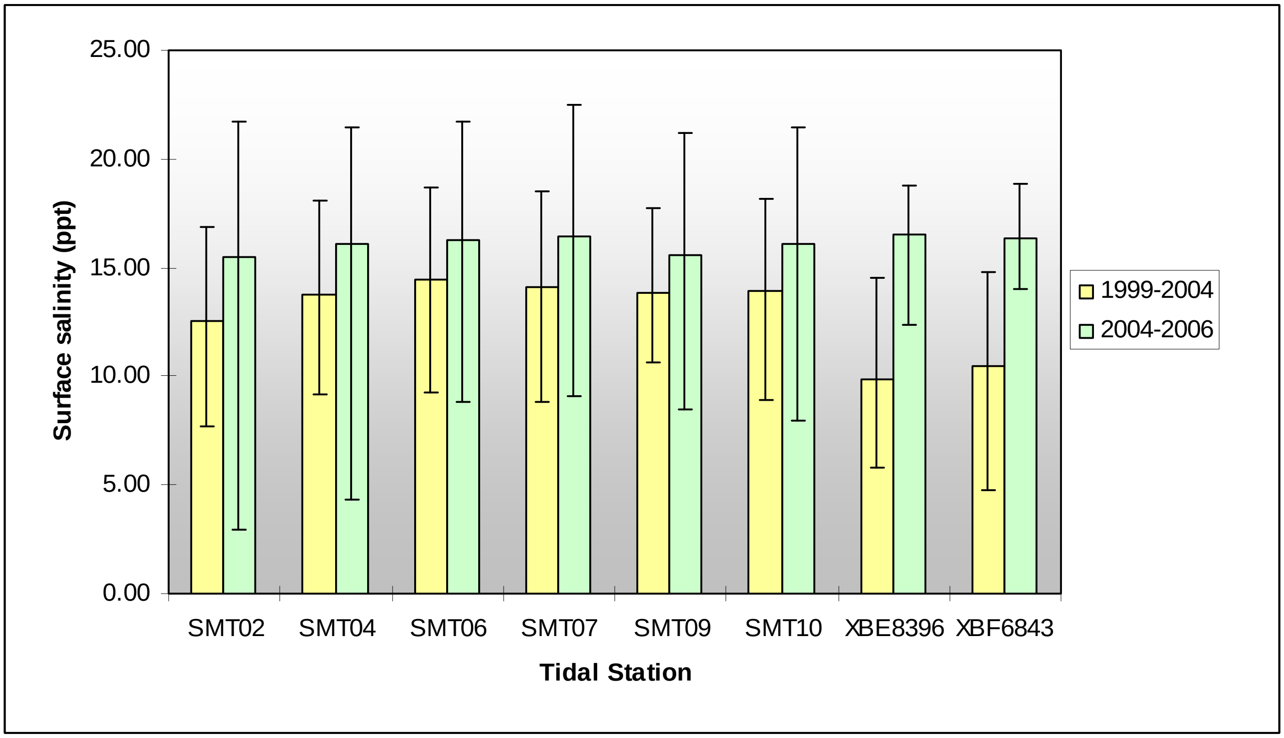


Figure 35. Comparison of mean, minimum, and maximum surface salinity prior to August 1, 2004 and after August 1, 2004. The period of record for all stations was June 1999-April 2006, except for station XBE 8396 (March 2003-April 2006) and XBF 6843 (May 2004-April 2006).

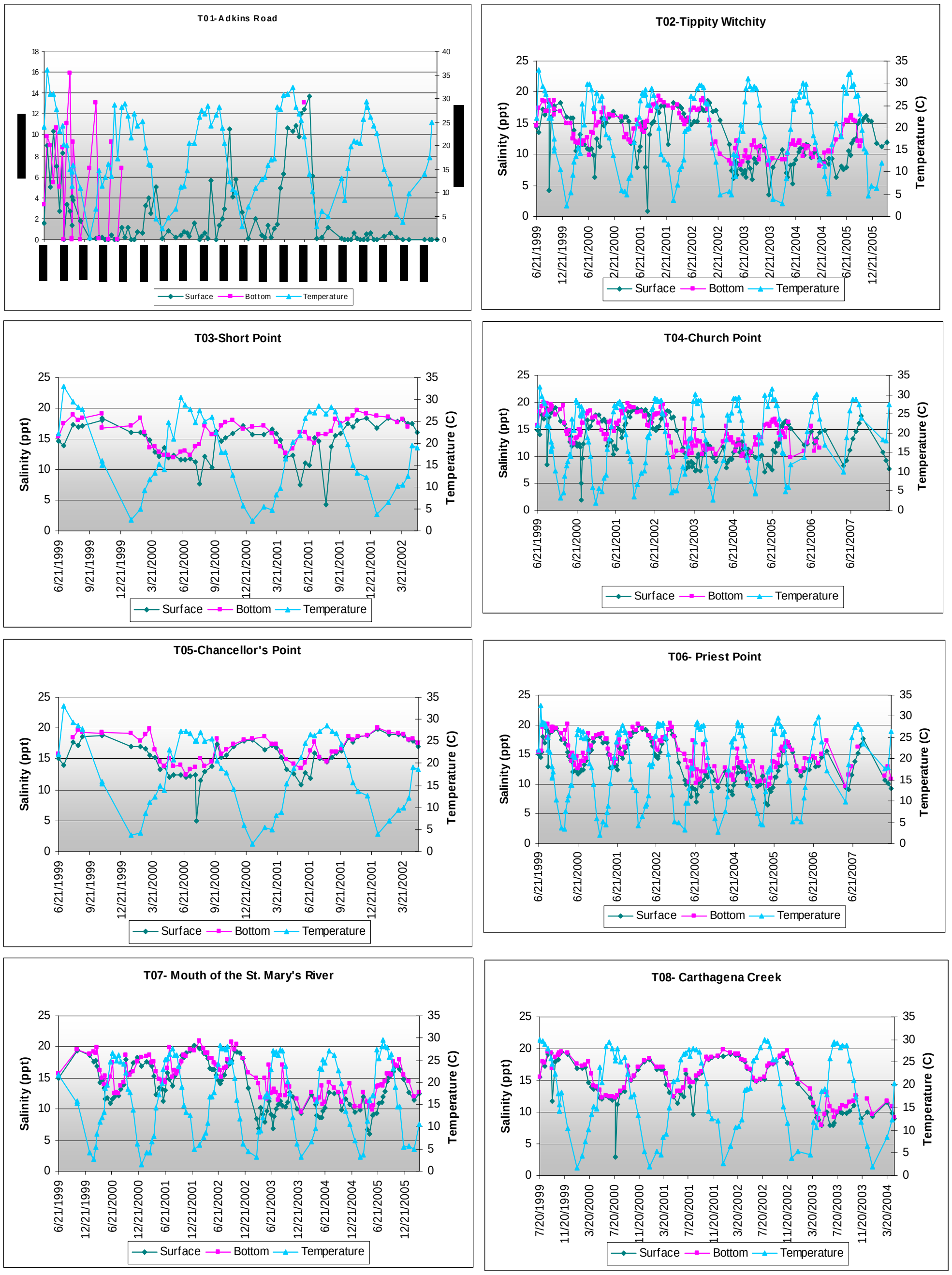


Figure 36. Surface and bottom salinity (ppt) and surface water temperature at all SMRP tidal sites, 1999-2008.

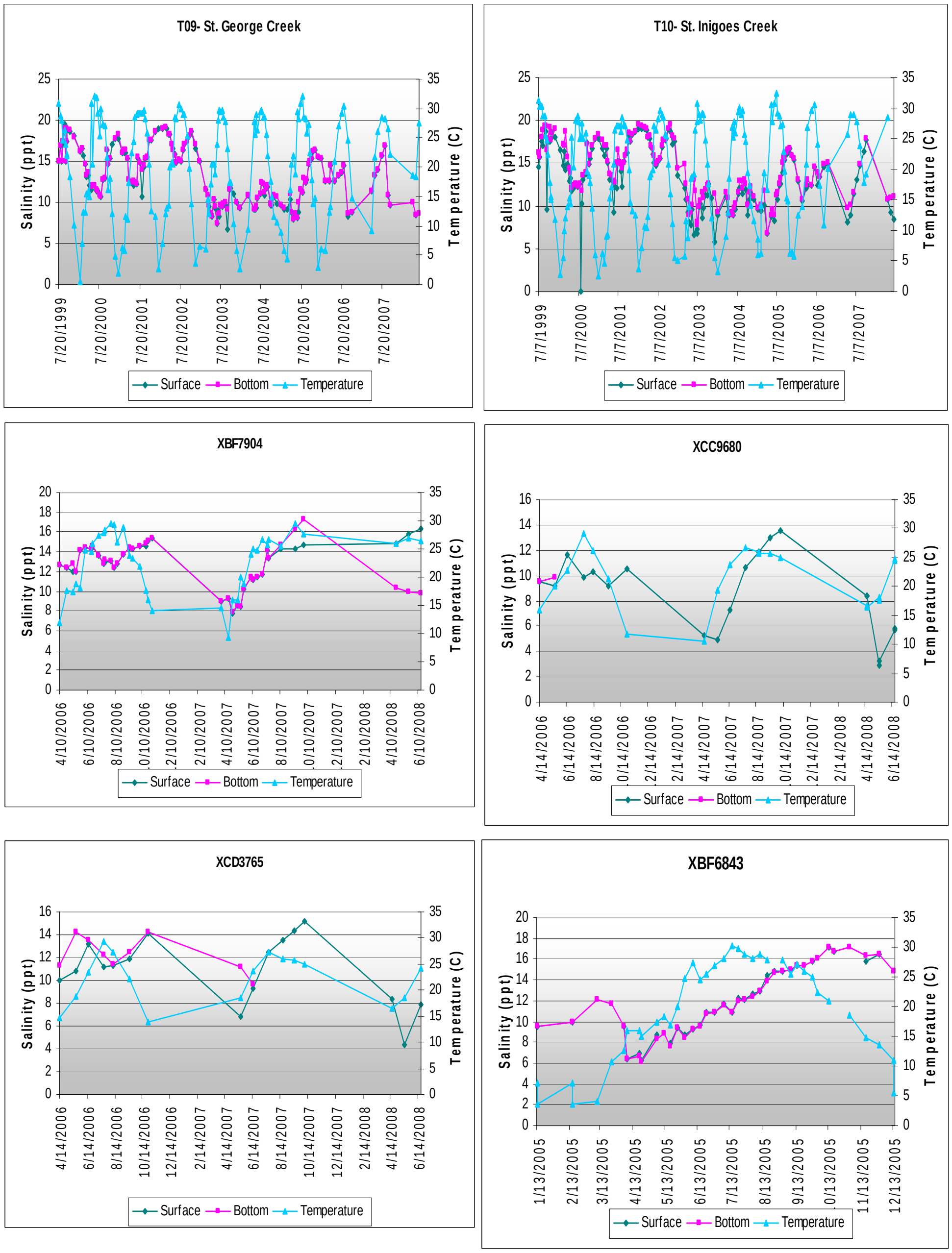


Figure 36 (continued). Surface and bottom salinity (ppt) and surface water temperature at all SMRP tidal sites, 1999-2008.

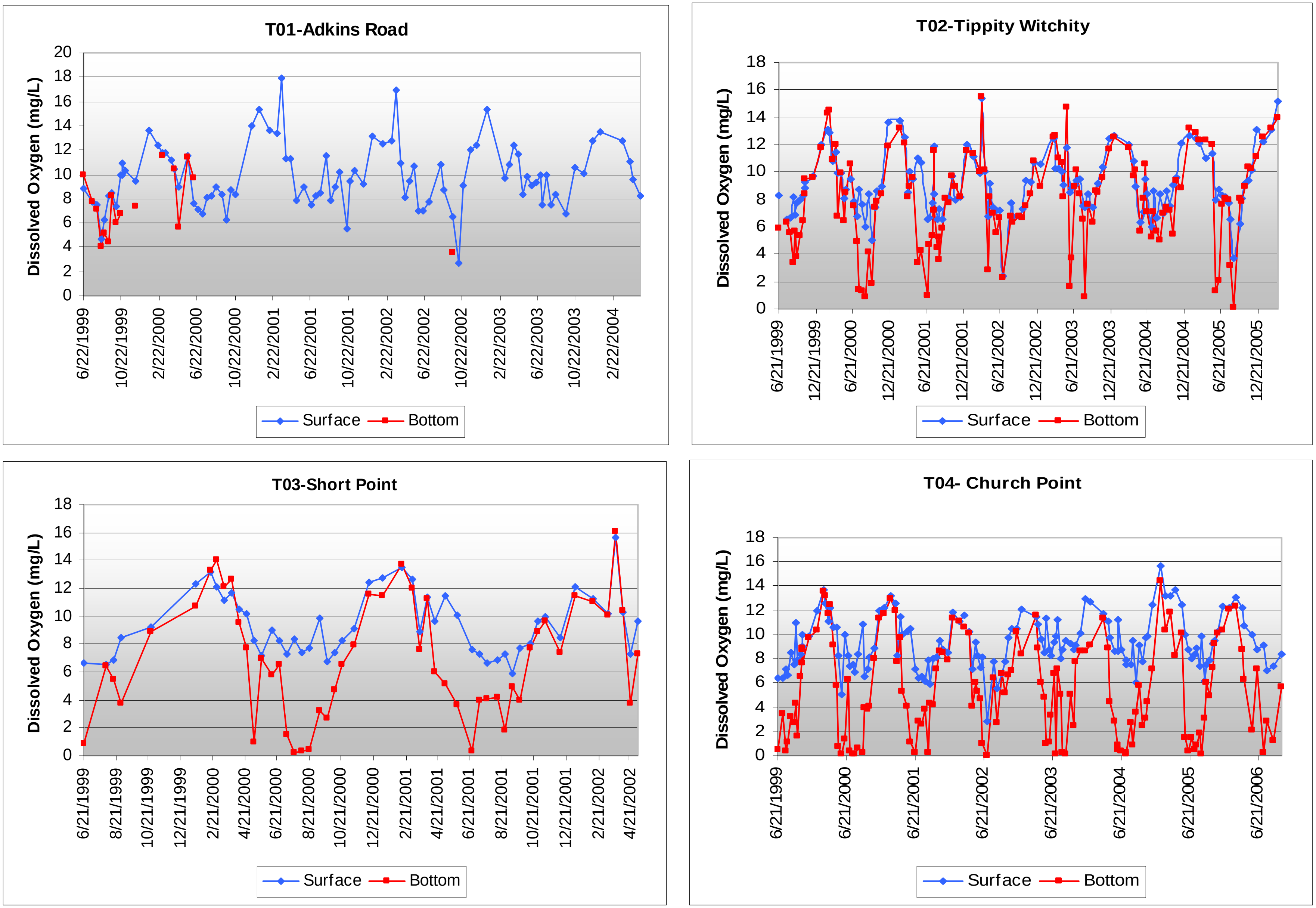


Figure 37. Surface and bottom dissolved oxygen at all tidal sampling sites (June 1999-December 2008).

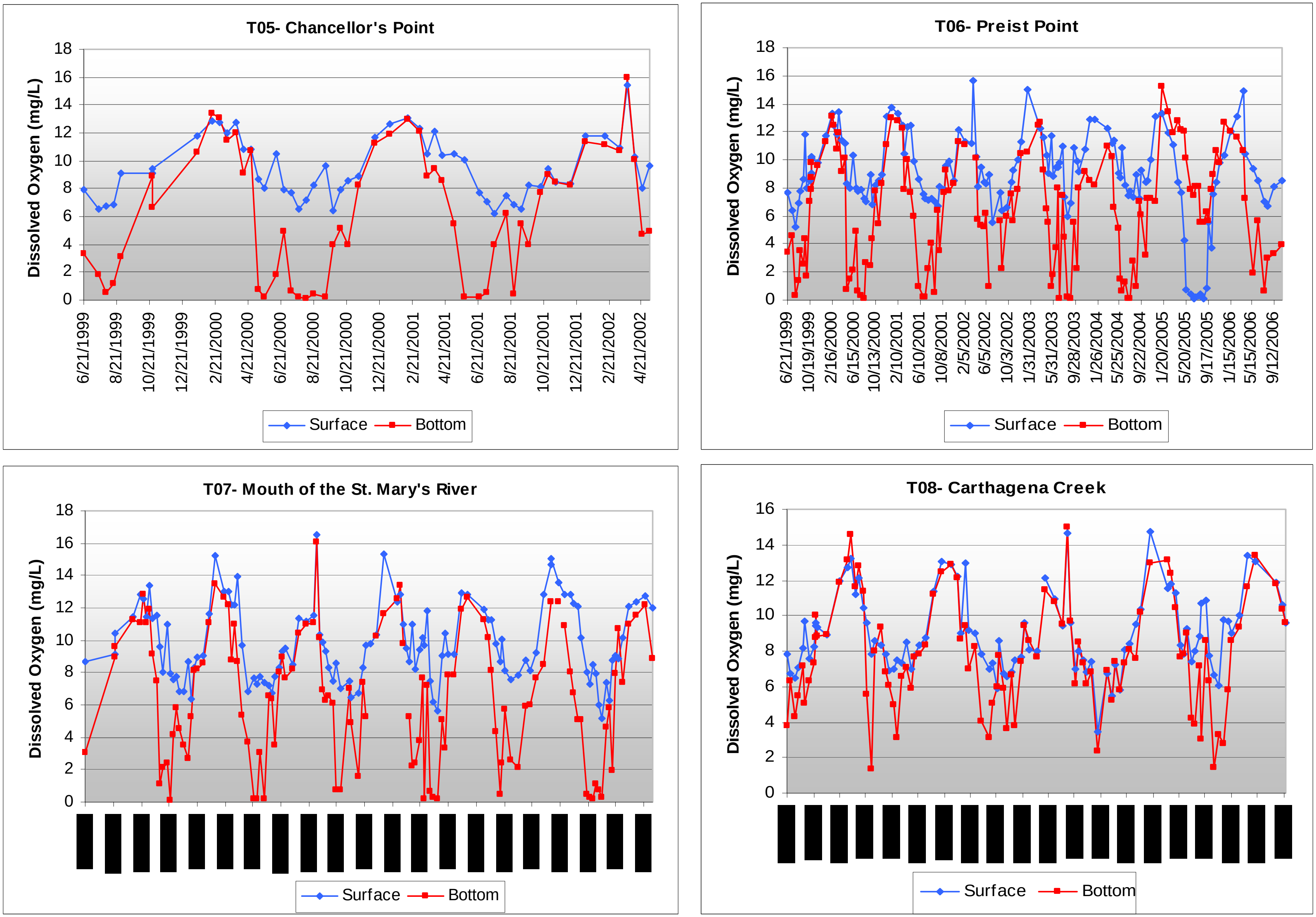


Figure 37 (continued). Surface and bottom dissolved oxygen at all tidal sampling sites (June 1999-December 2008).

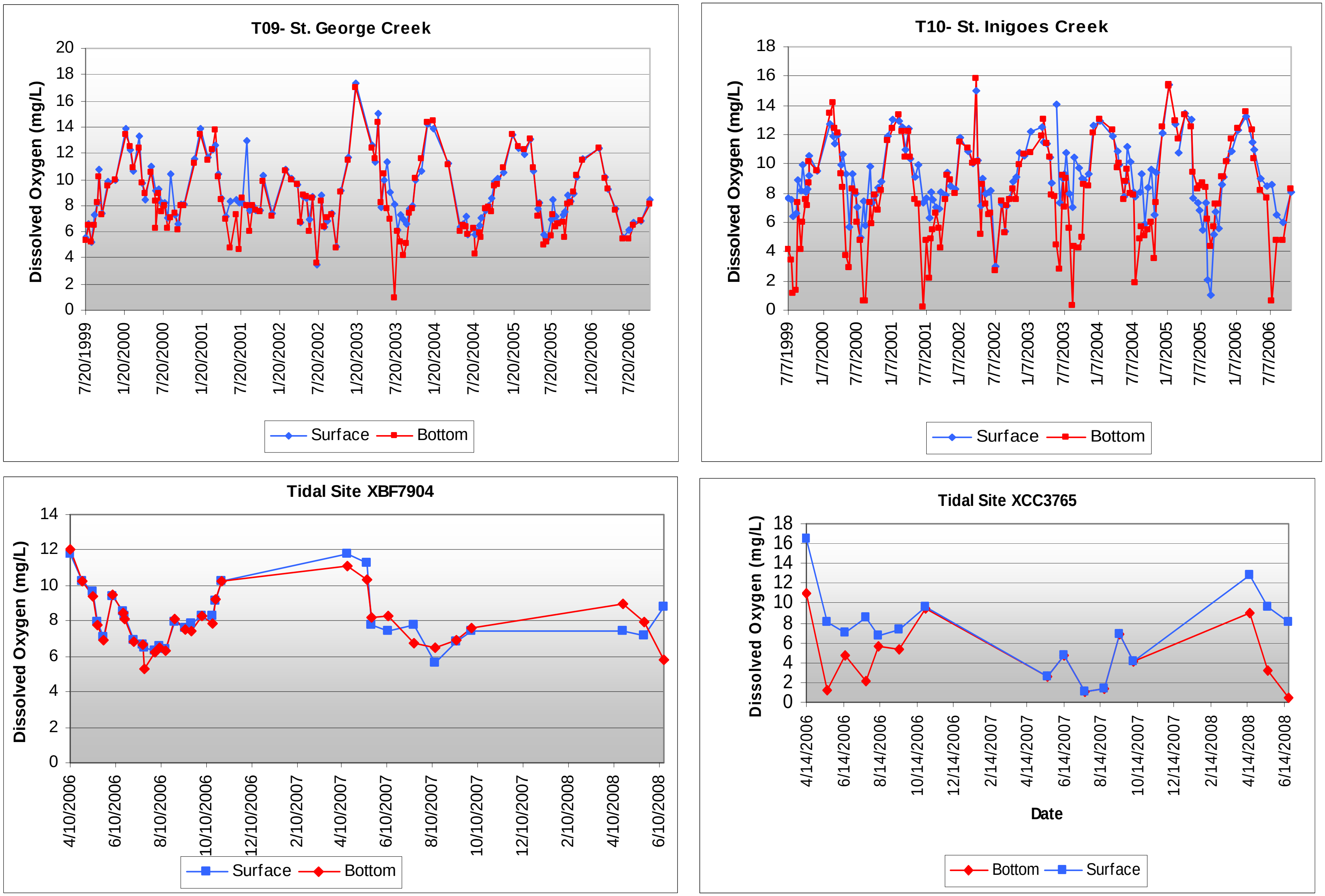
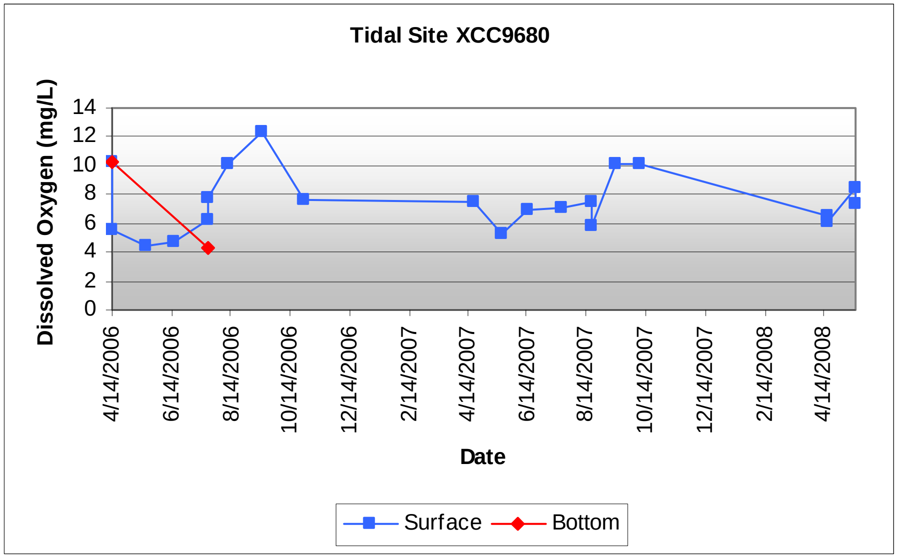


Figure 37 (continued). Surface and bottom dissolved oxygen at all tidal sampling sites (June 1999-December 2008).



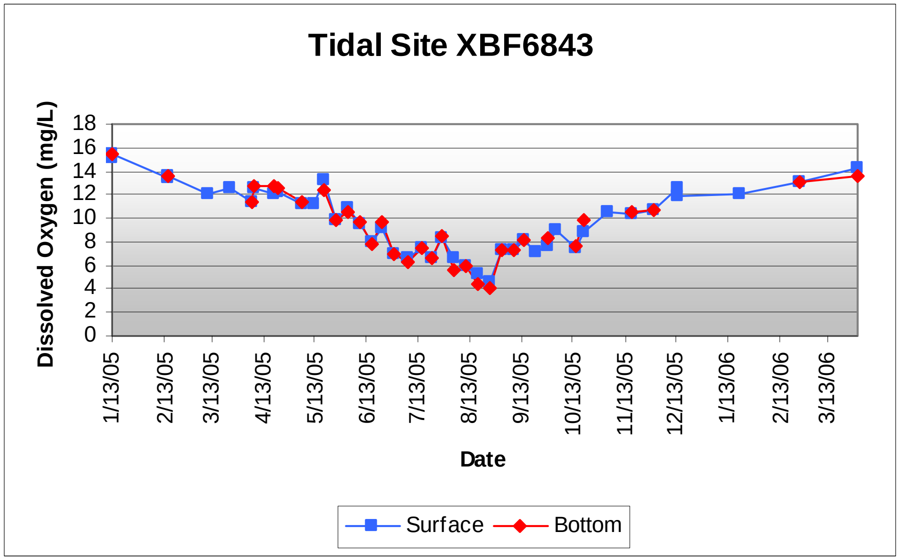


Figure 37 (continued). Surface and bottom dissolved oxygen at all tidal sampling sites (June 1999-December 2008).

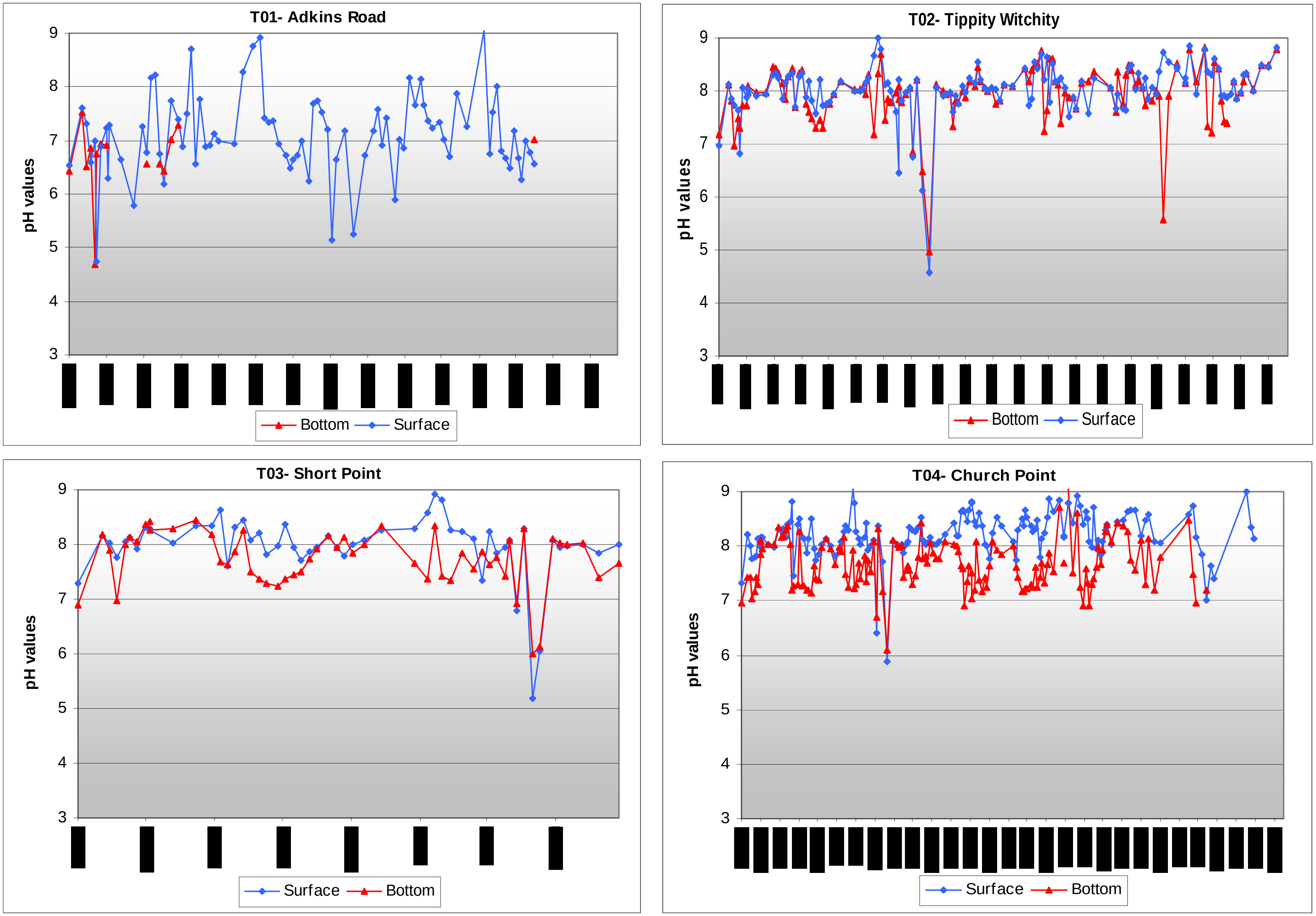


Figure 38. pH values for the surface and bottom water of tidal sites sampled 1999-2008.

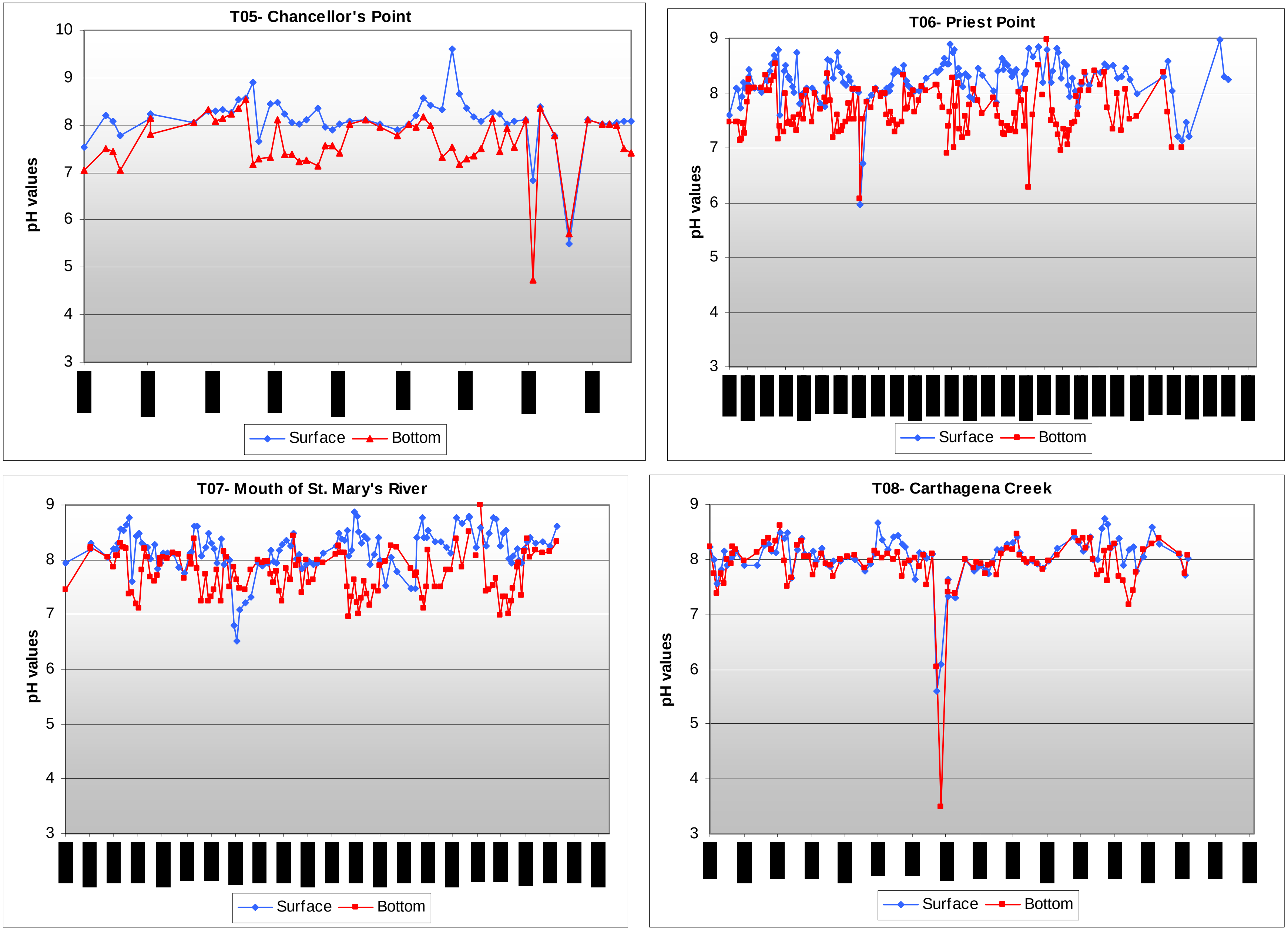


Figure 38 (continued). pH values for the surface and bottom water of tidal sites sampled 1999-2008.

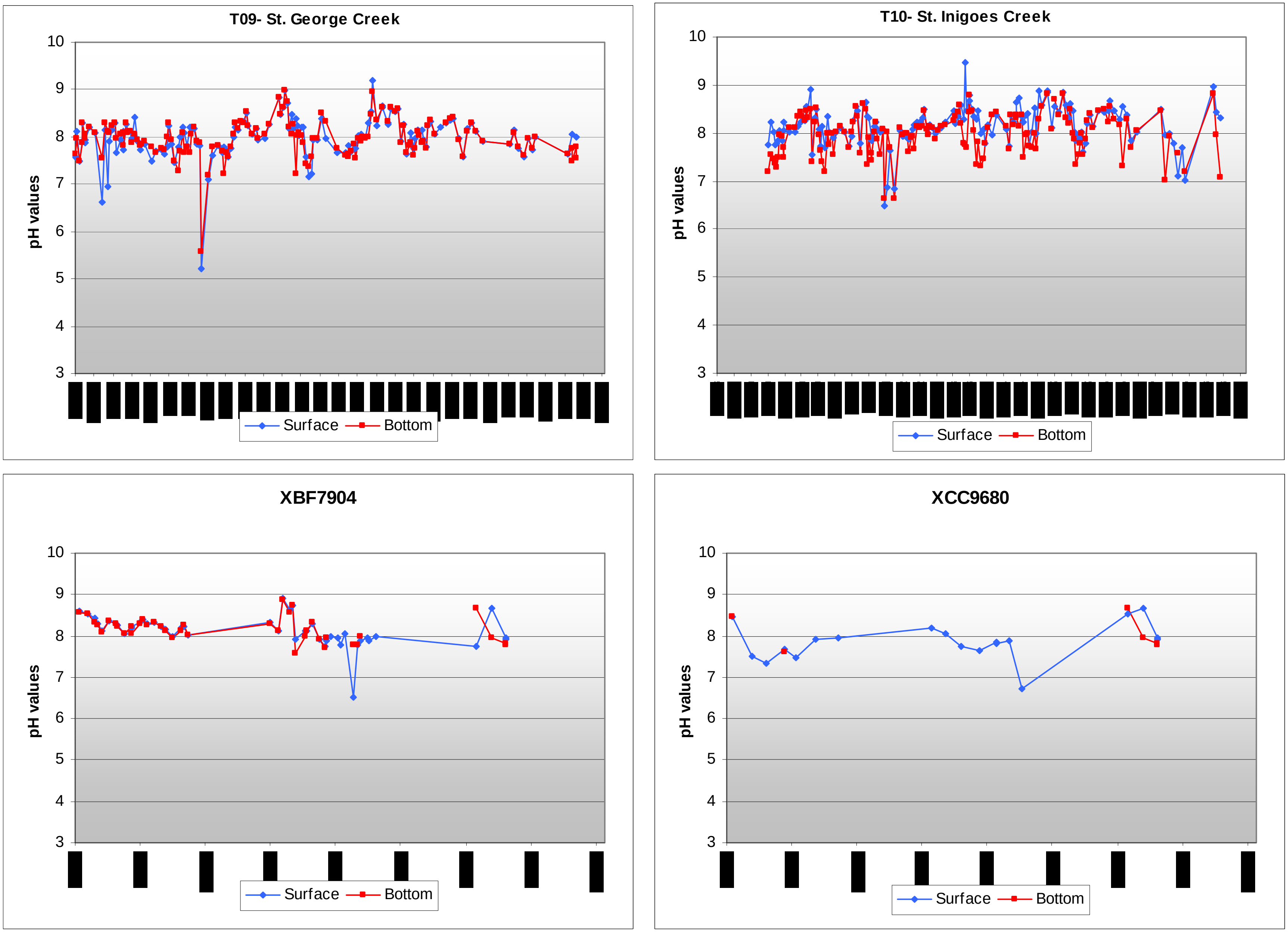


Figure 38 (continued). pH values for the surface and bottom water of tidal sites sampled 1999-2008.

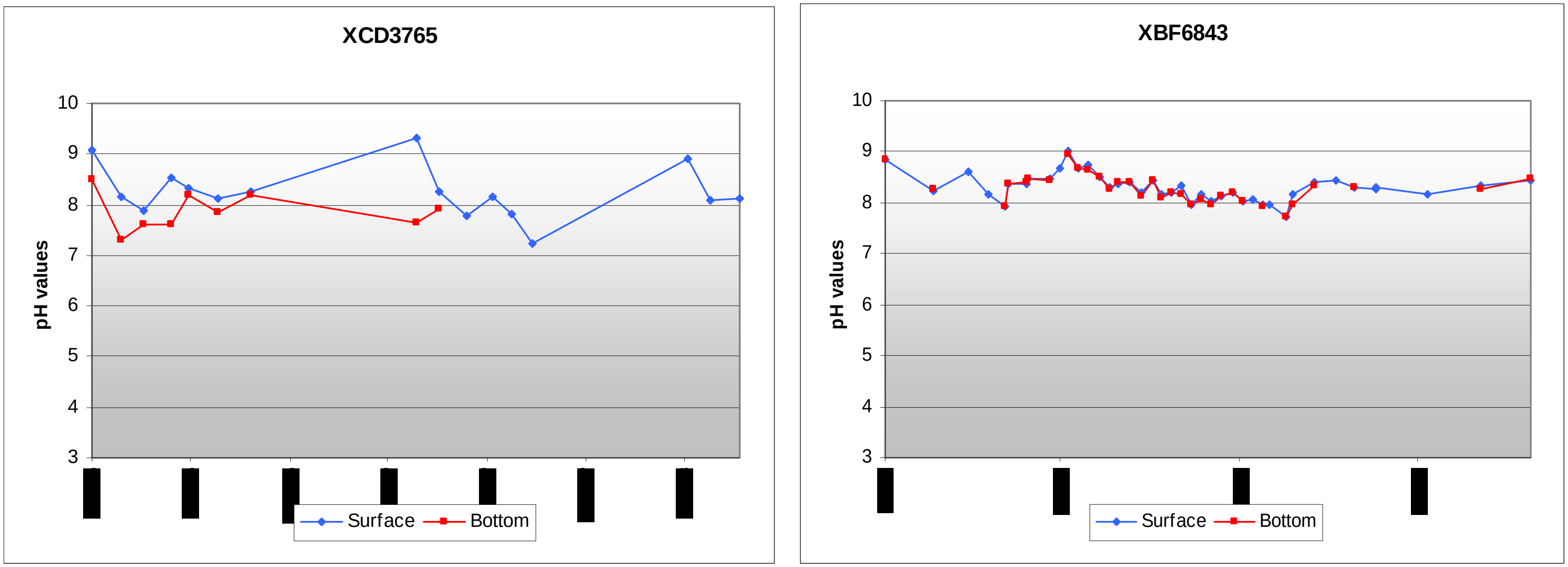


Figure 38 (continued). pH values for the surface and bottom water of tidal sites sampled 1999-2008.

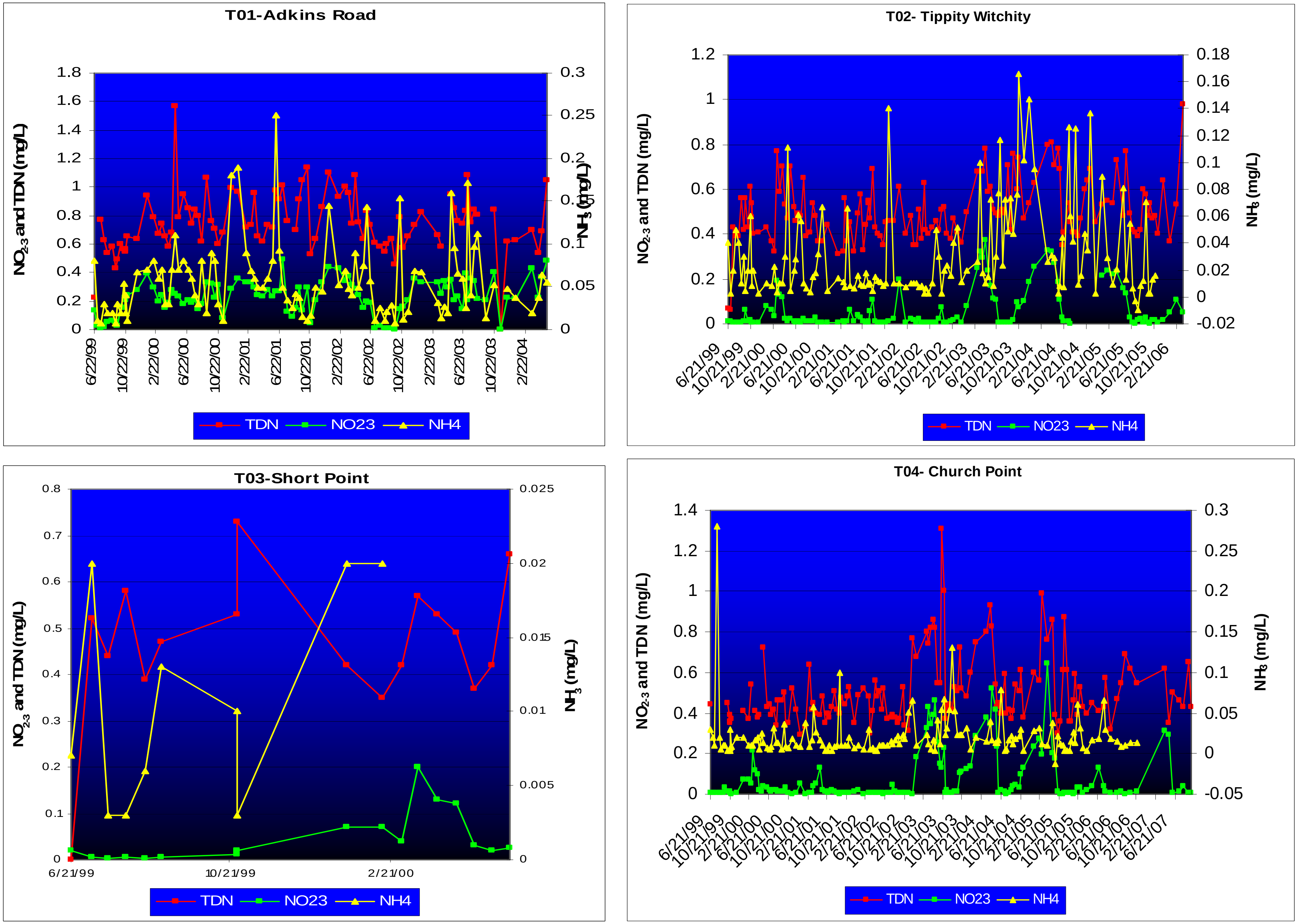


Figure 39. Total dissolved nitrogen (TDN), nitrite and nitrate (NO23), and ammonia (NH3) for all tidal sites from 1999 through 2008.

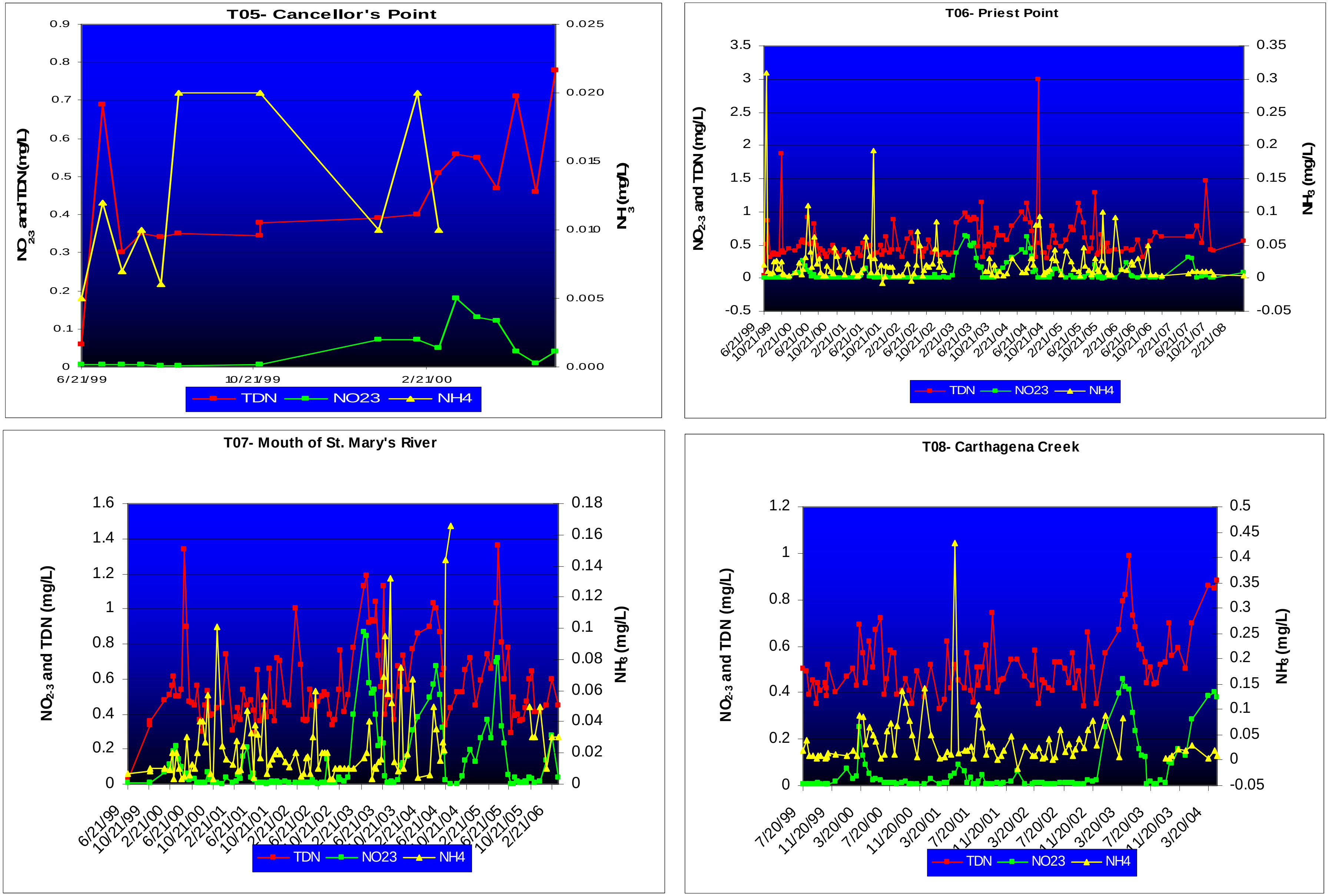


Figure 39 (continued). Total dissolved nitrogen (TDN), nitrite and nitrate (NO23), and ammonia (NH3) for all tidal sites from 1999 through 2008.

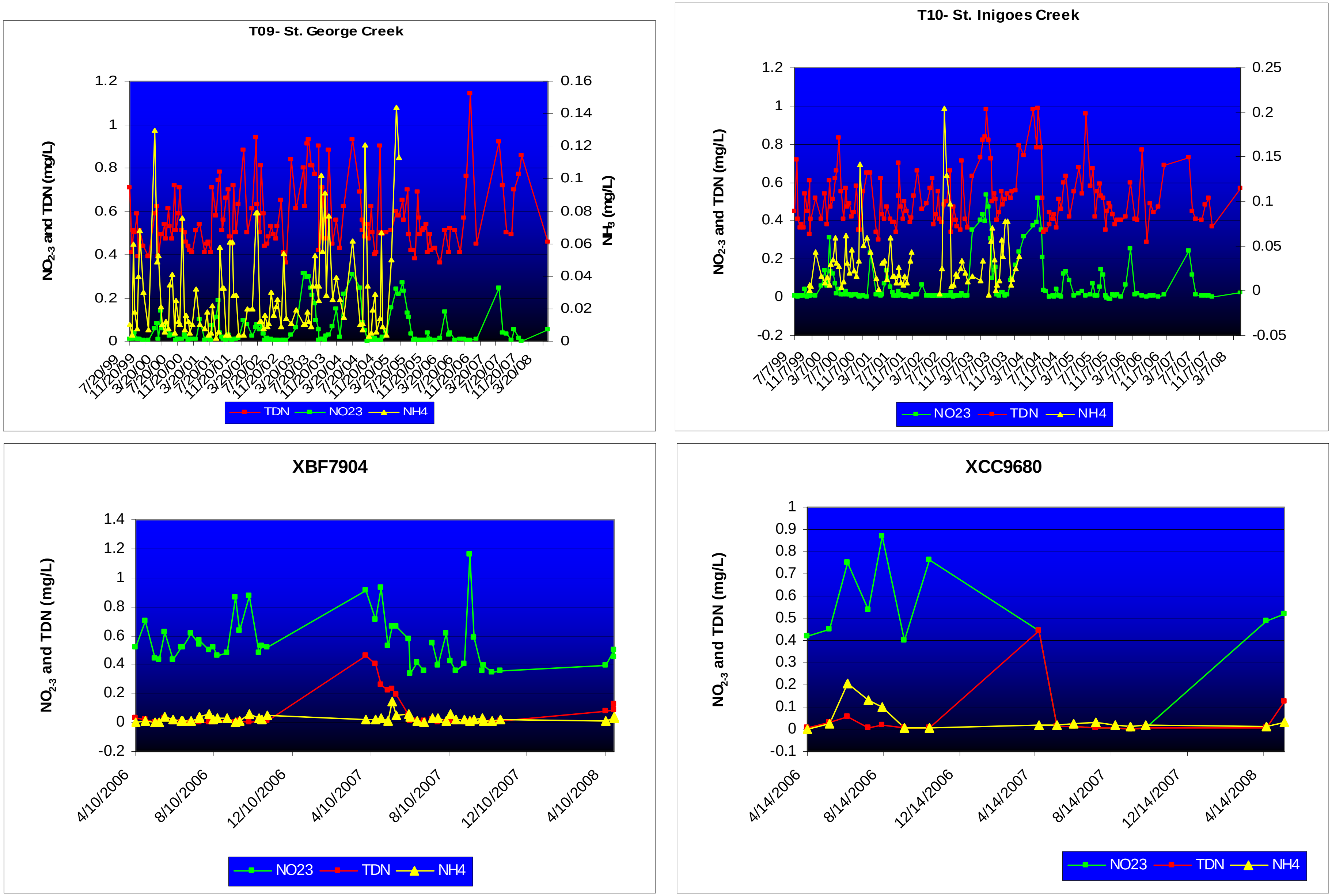


Figure 39 (continued). Total dissolved nitrogen (TDN), nitrite and nitrate (NO23), and ammonia (NH3) for all tidal sites from 1999 through 2008.

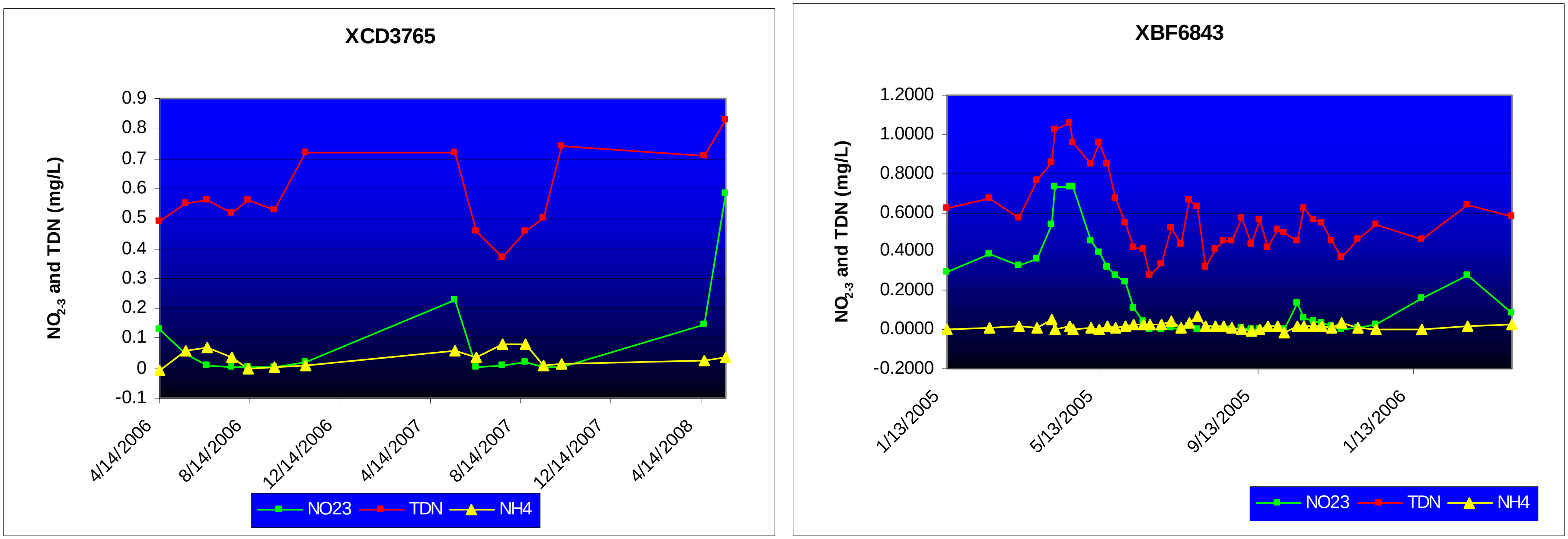


Figure 39 (continued). Total dissolved nitrogen (TDN), nitrite and nitrate (NO23), and ammonia (NH3) for all tidal sites from 1999 through 2008.

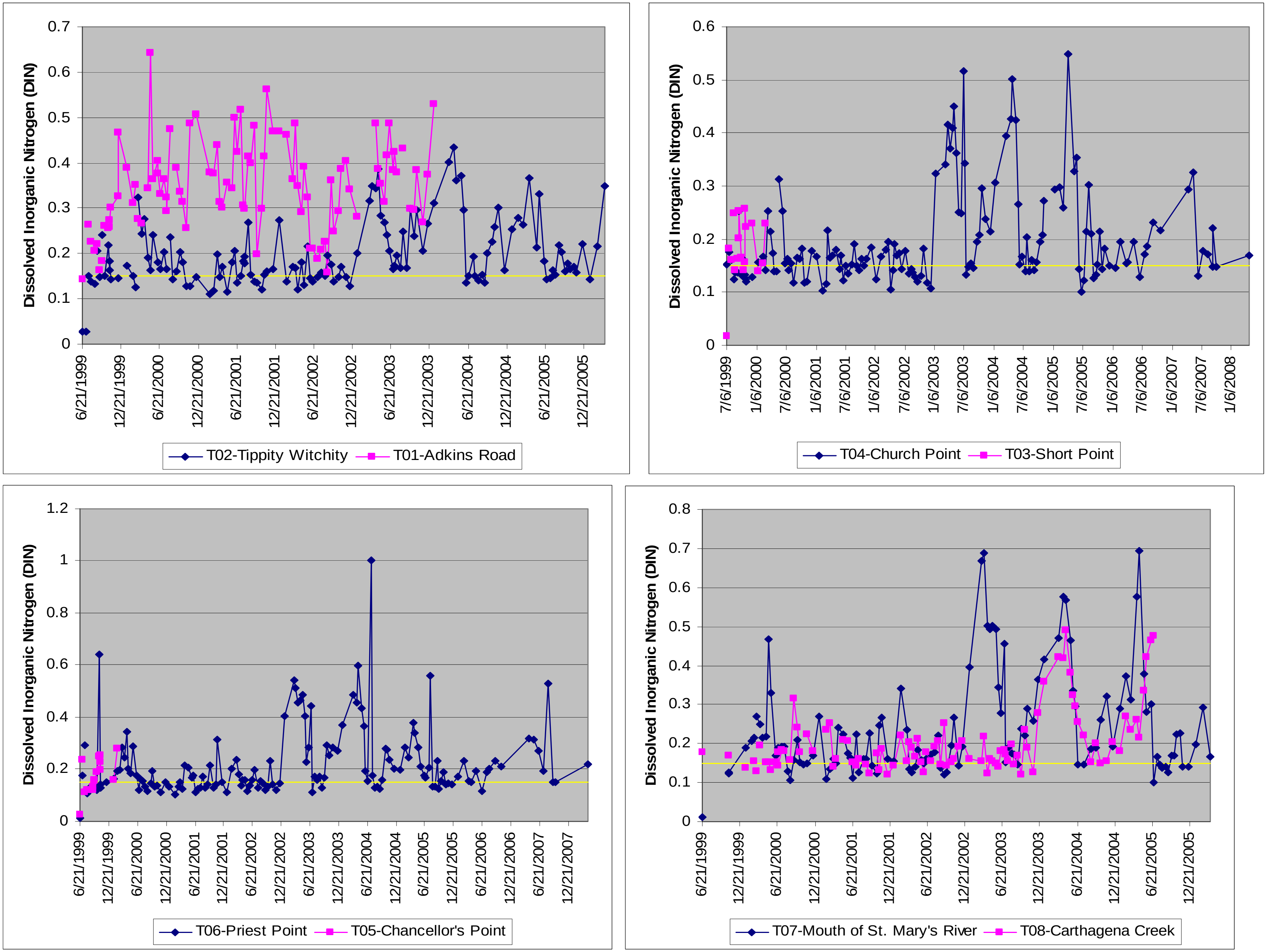


Figure 40. Mean dissolved inorganic nitrogen (sum of NO_{2-3} and NH_3) for all tidal sites and 0.15 mg/L threshold for SAV.

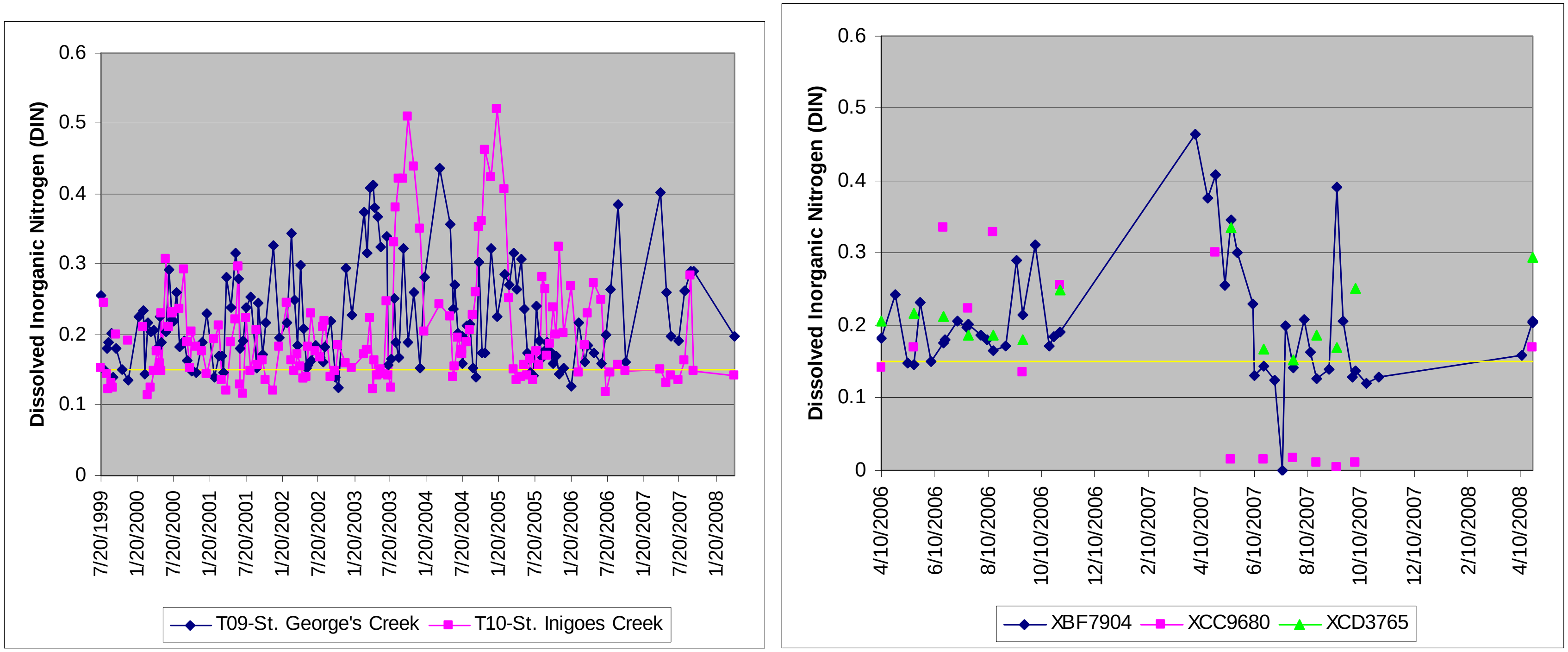


Figure 40 (continued). Mean dissolved inorganic nitrogen (sum of $NO_{2\text{-}3}$ and NH_3) for all tidal sites and 0.15 mg/L threshold for SAV.

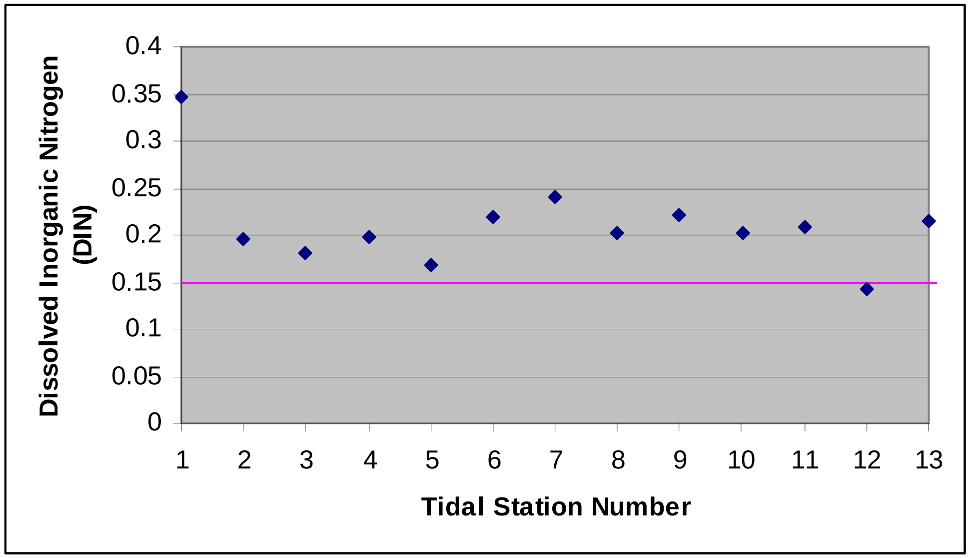


Figure 41. Tidal station mean dissolved inorganic nitrogen over all sampling dates relative to the maximum value for good SAV habitat. Tidal station numbers represent T01-T10 as well as XBF7904, XCC9680, and XCD3765.

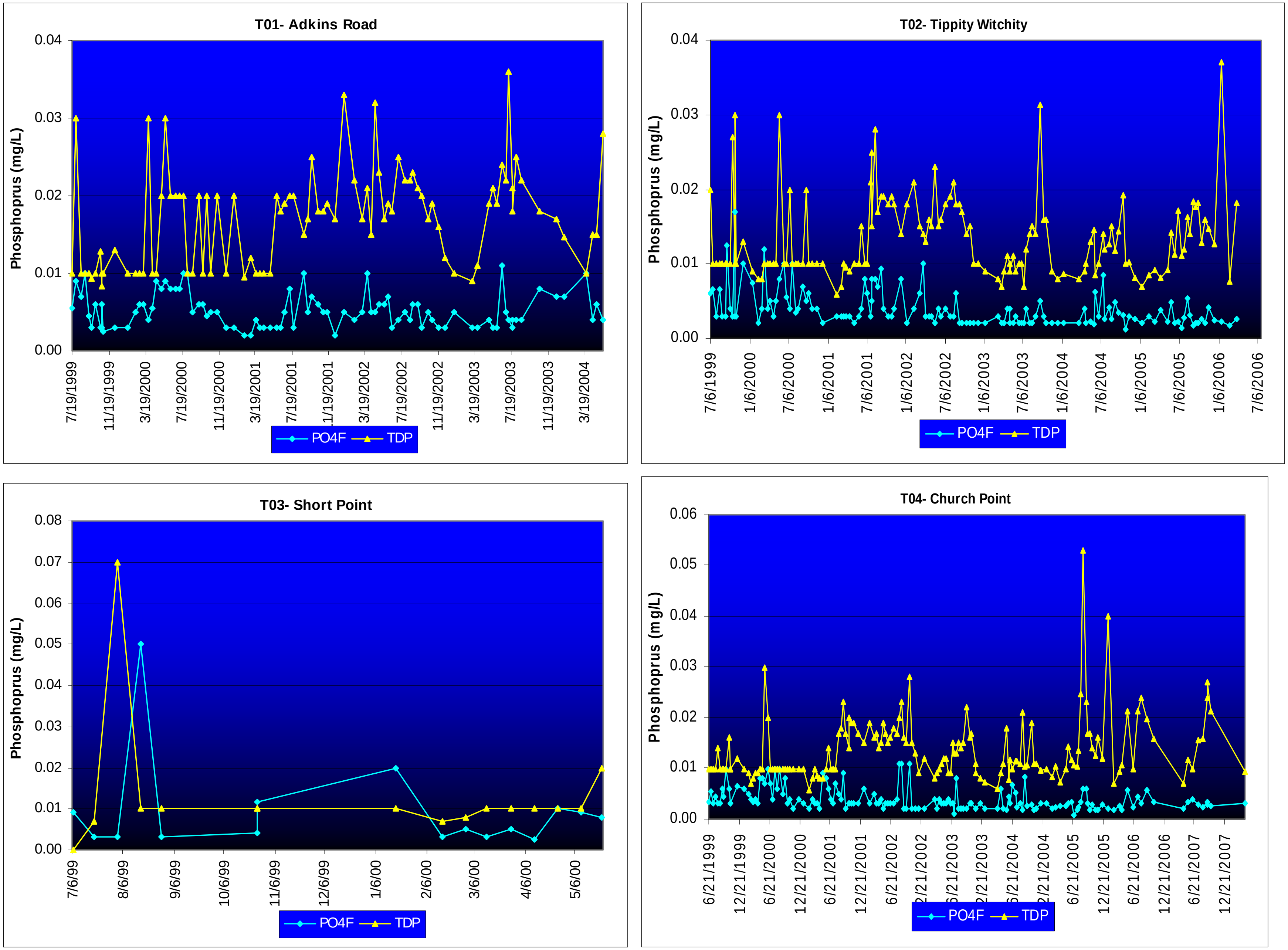


Figure 42. Phosphorus as orthophosphate (PO_4) and total dissolved phosphate (TDP) at all tidal sites from 1999 through 2008.

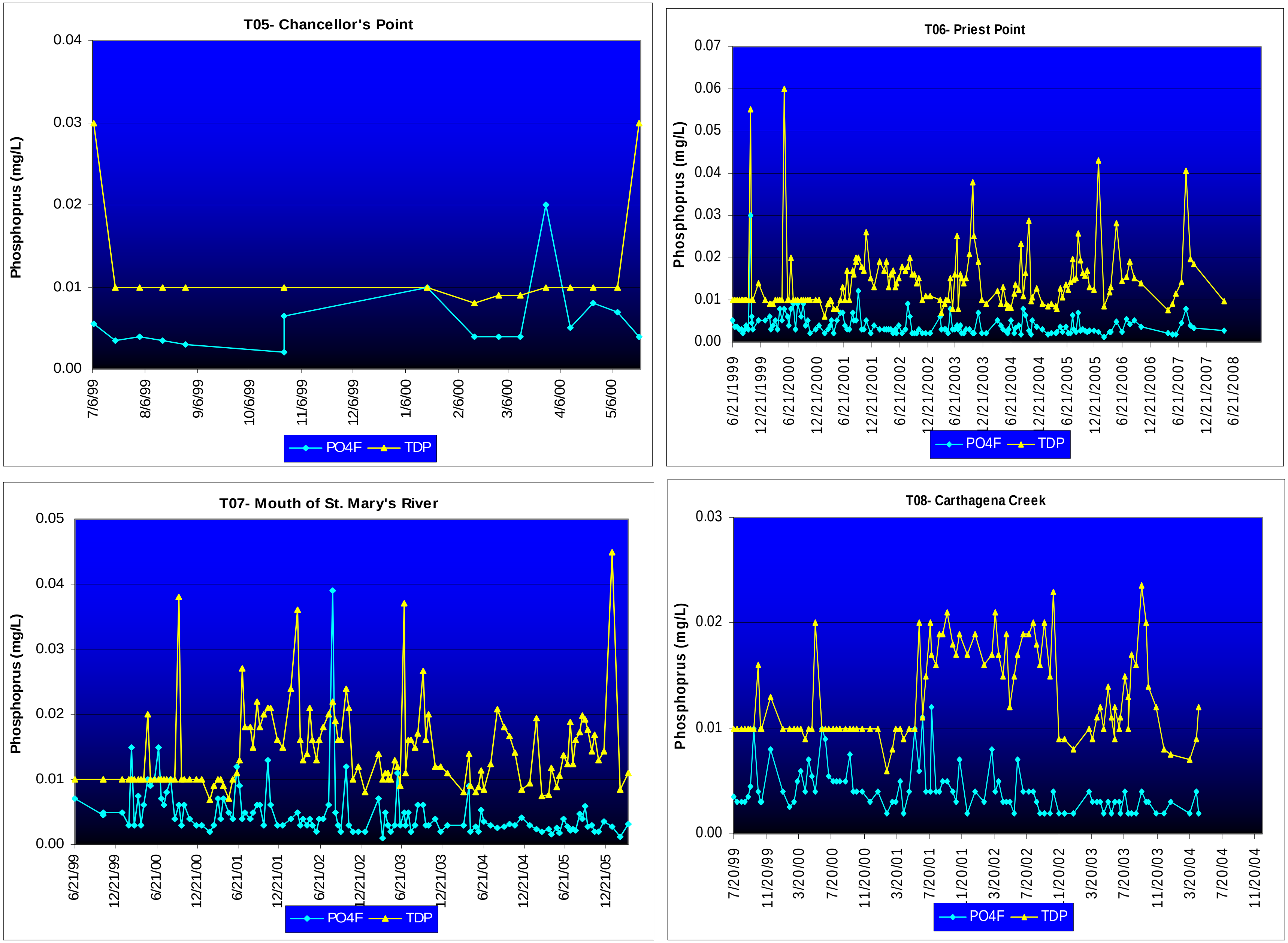


Figure 42 (continued). Phosphorus as orthophosphate (PO_4) and total dissolved phosphate (TDP) at all tidal sites from 1999 through 2008.

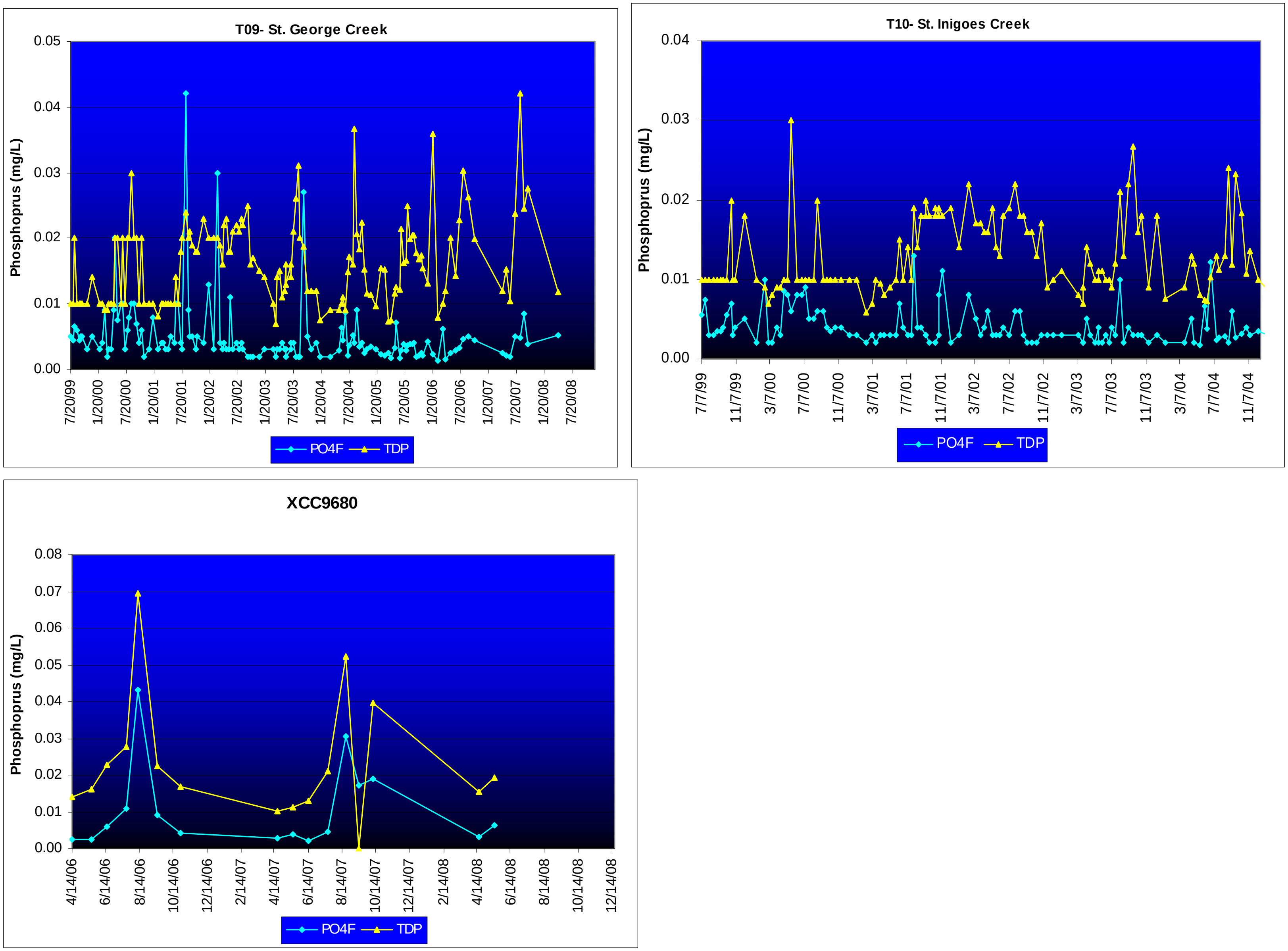


Figure 42 (continued). Phosphorus as orthophosphate (PO_4) and total dissolved phosphate (TDP) at all tidal sites from 1999 through 2008.

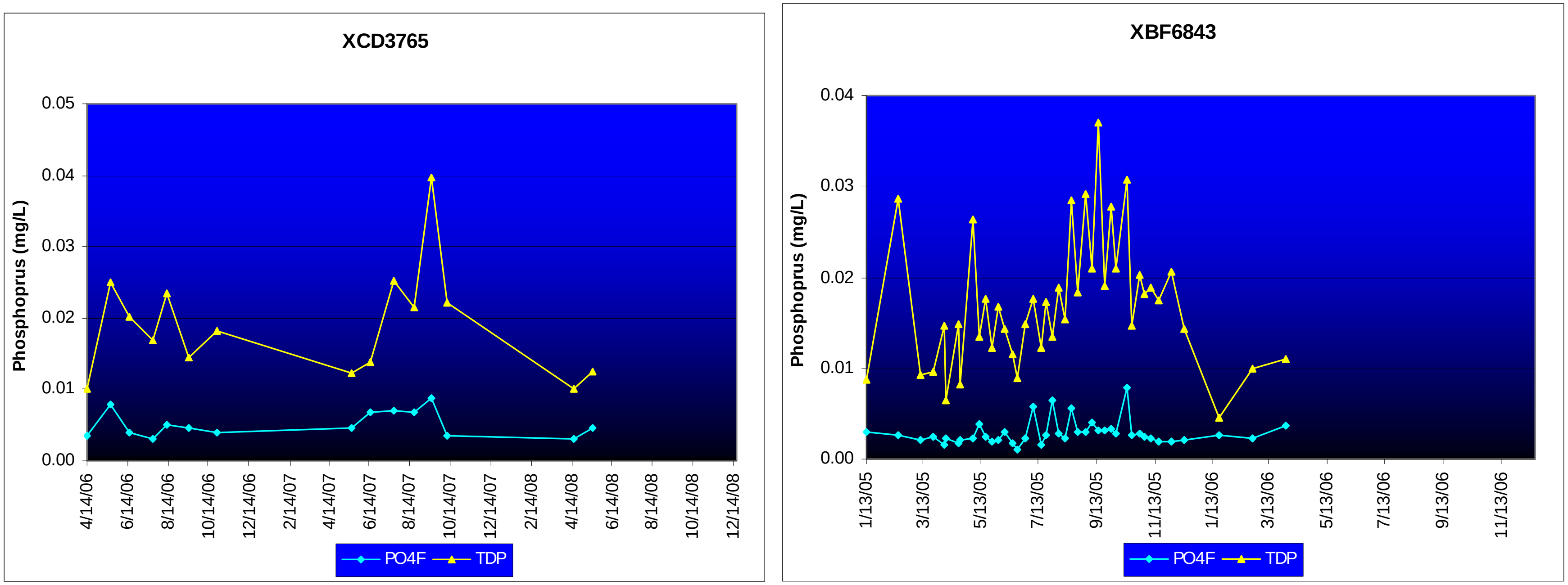


Figure 42 (continued). Phosphorus as orthophosphate (PO_4) and total dissolved phosphate (TDP) at all tidal sites from 1999 through 2008.

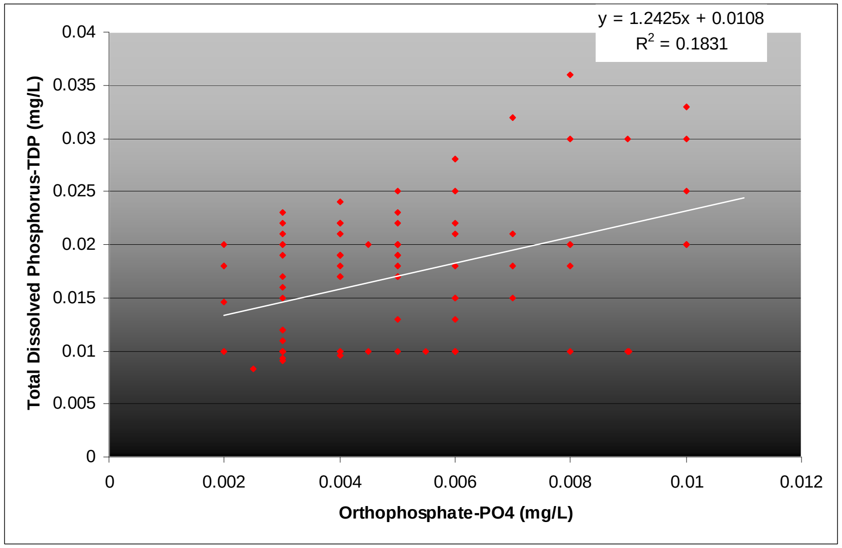


Figure 43**.** Relationship between orthophosphate and TDP at all tidal sites.

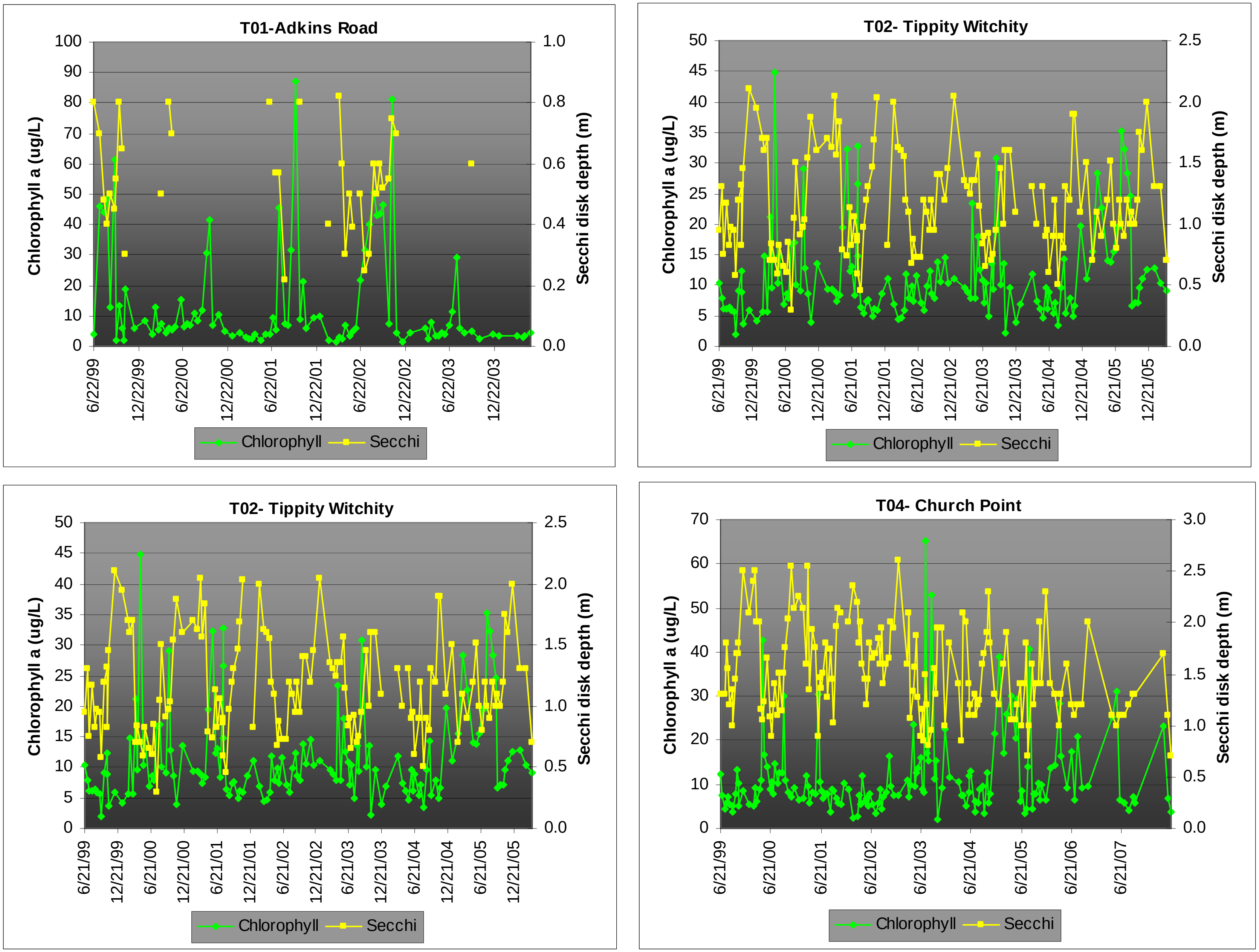


Figure 44. Mean concentration of chlorophyll a and Secchi disk depth at all tidal stations. Scales for chlorophyll and Secchi disk depth vary by site. Secchi depth at T01 was inconsistent because of the shallow depth of the site.

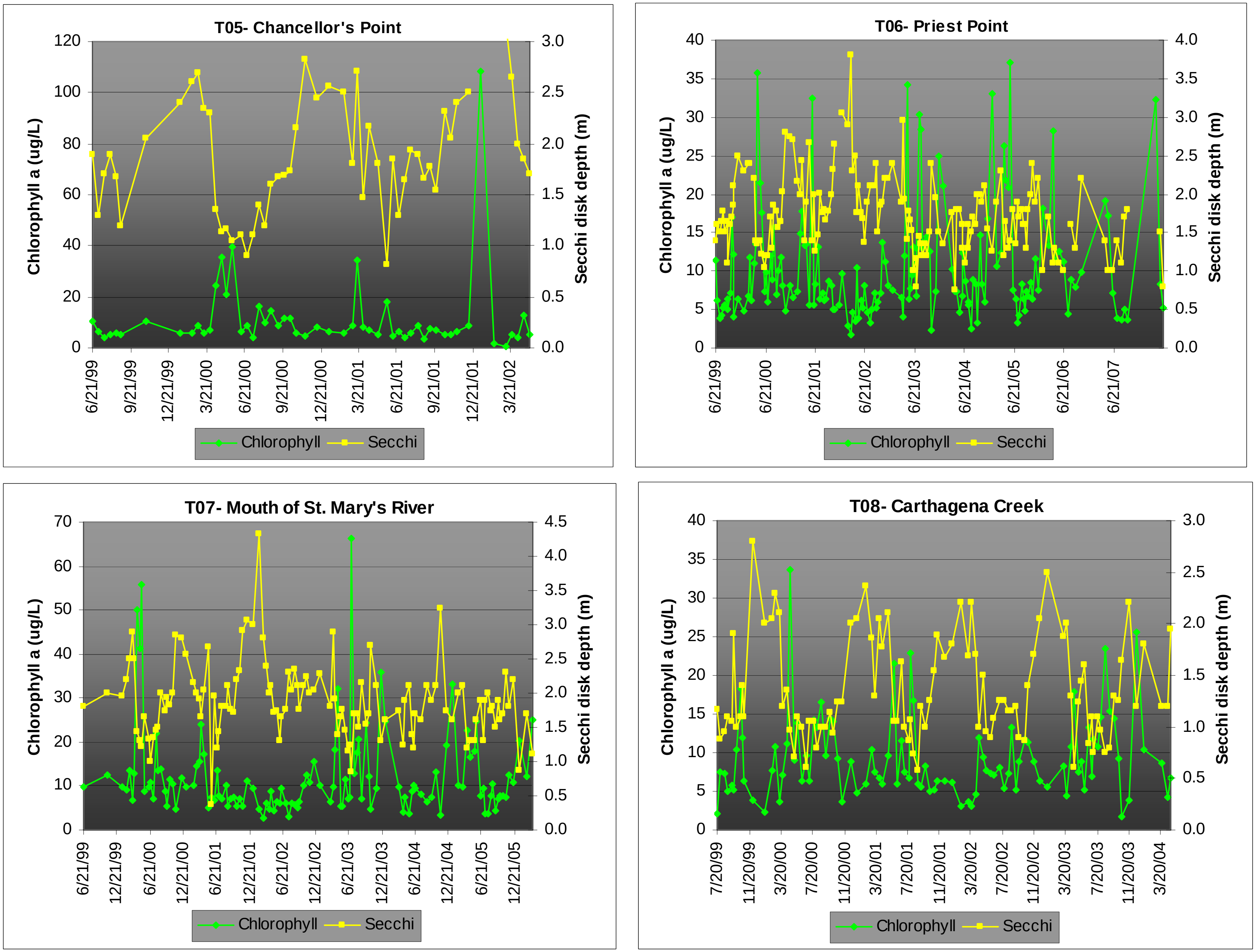


Figure 44 (continued). Mean concentration of chlorophyll *a* and Secchi disk depth at all tidal stations. Scales for chlorophyll and Secchi disk depth vary by site.

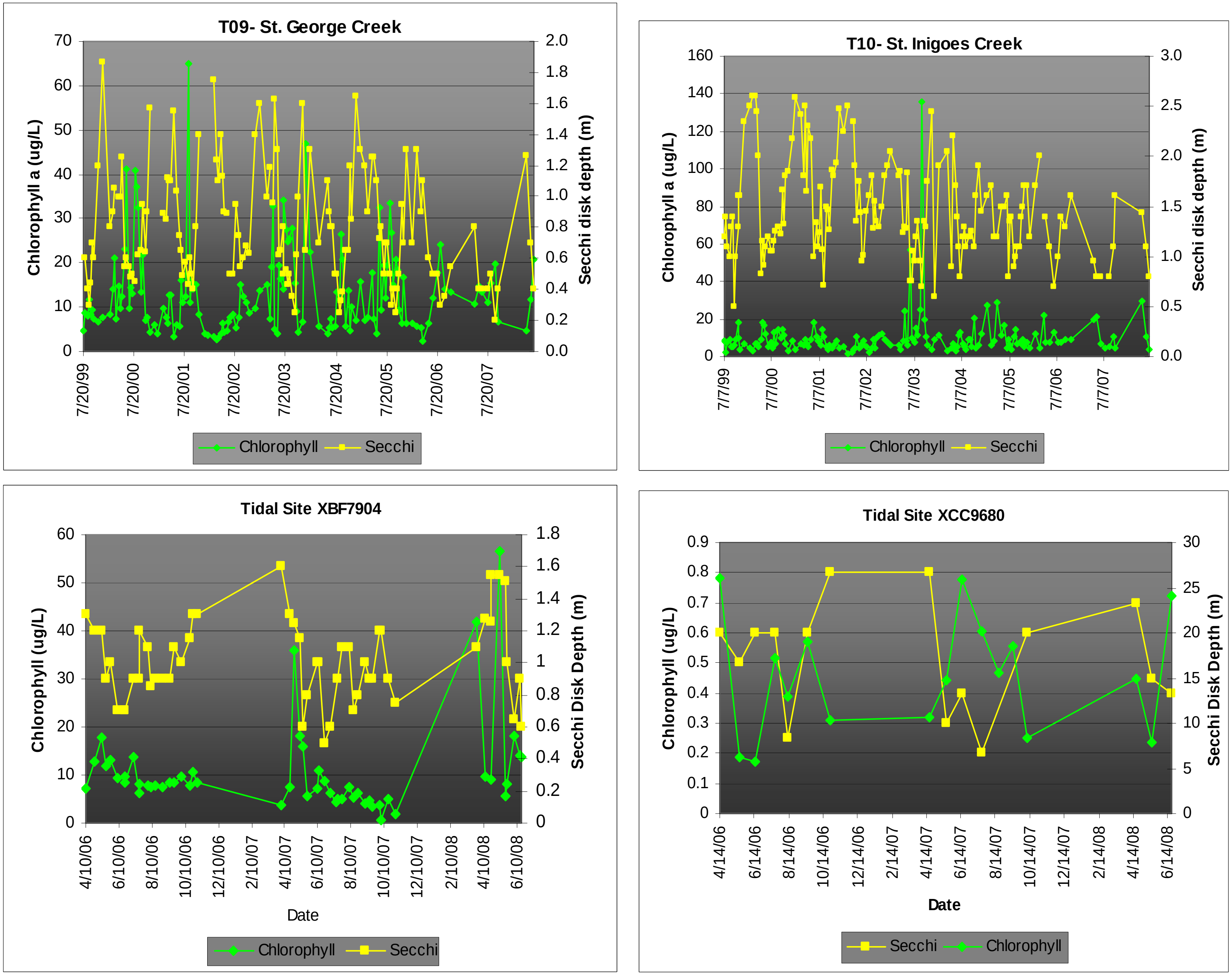


Figure 44 (continued). Mean concentration of chlorophyll *a* and Secchi disk depth at all tidal stations. Scales for chlorophyll and Secchi disk depth vary by site.

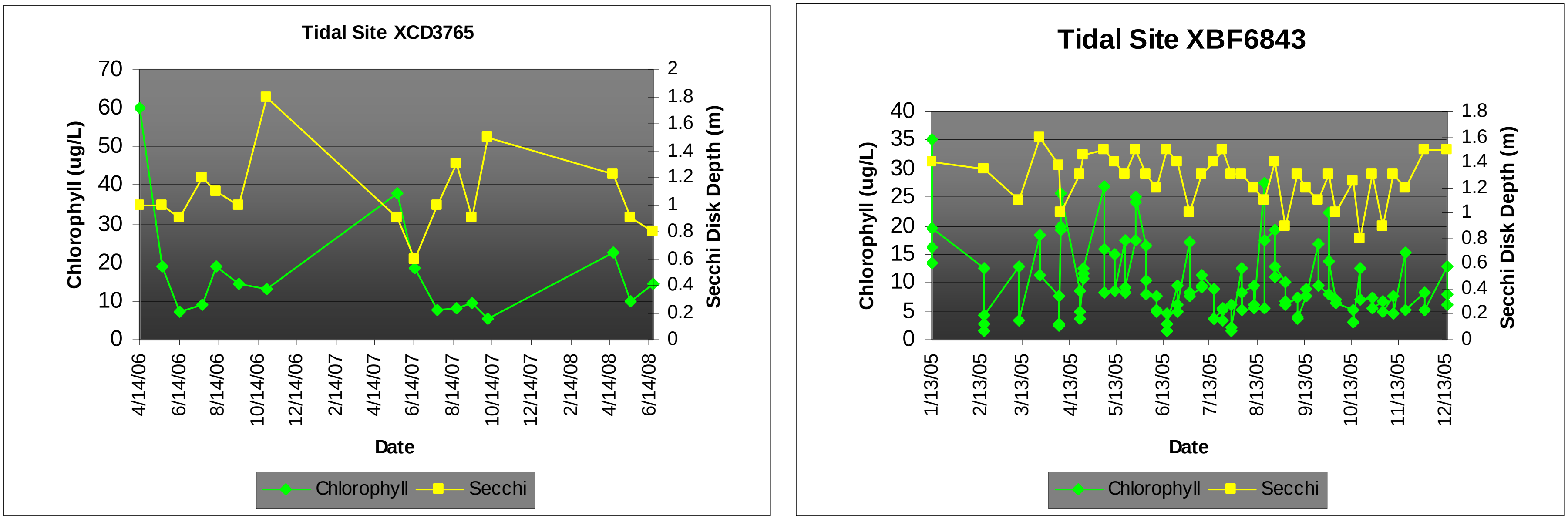


Figure 44 (continued). Mean concentration of chlorophyll *a* and Secchi disk depth at all tidal stations. Scales for chlorophyll and Secchi disk depth vary by site.

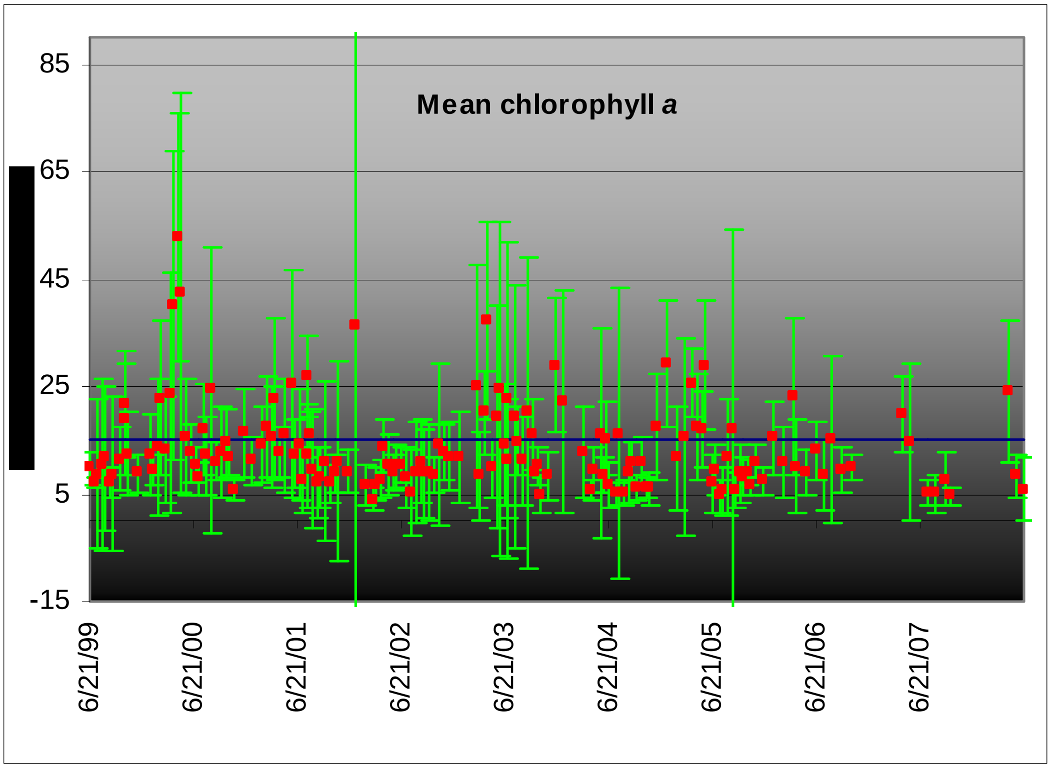


Figure 45. Mean chlorophyll *a* ± one std for all tidal stations.

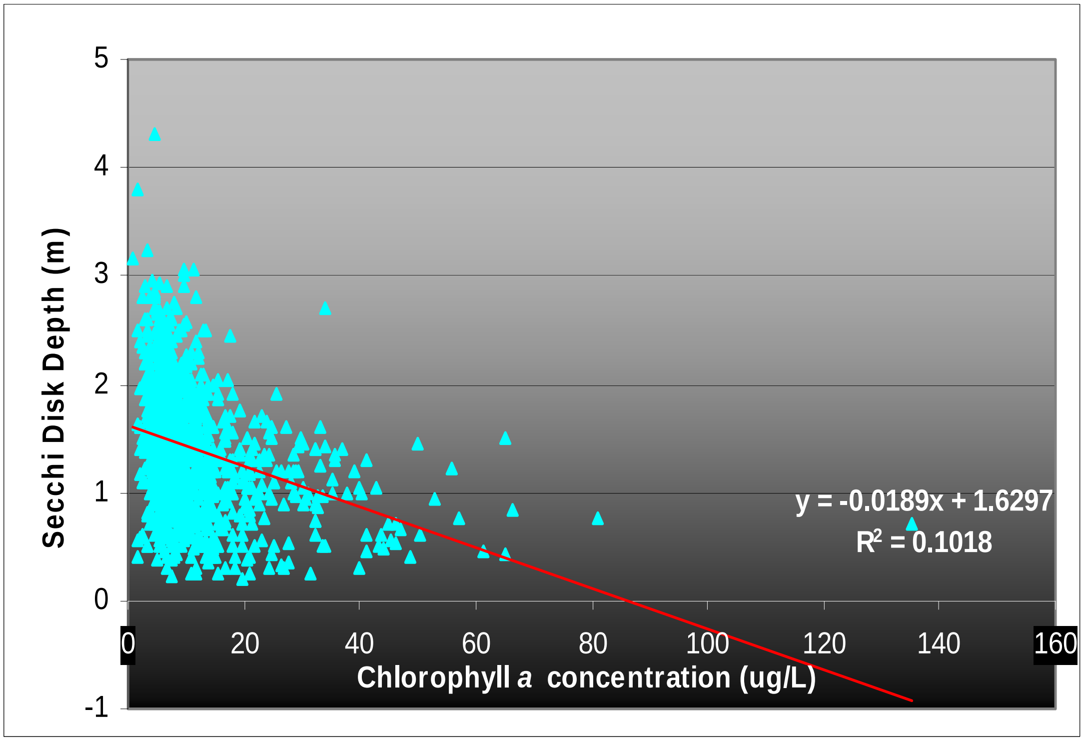


Figure 46. Secchi disk depth plotted against chlorophyll *a* concentration.

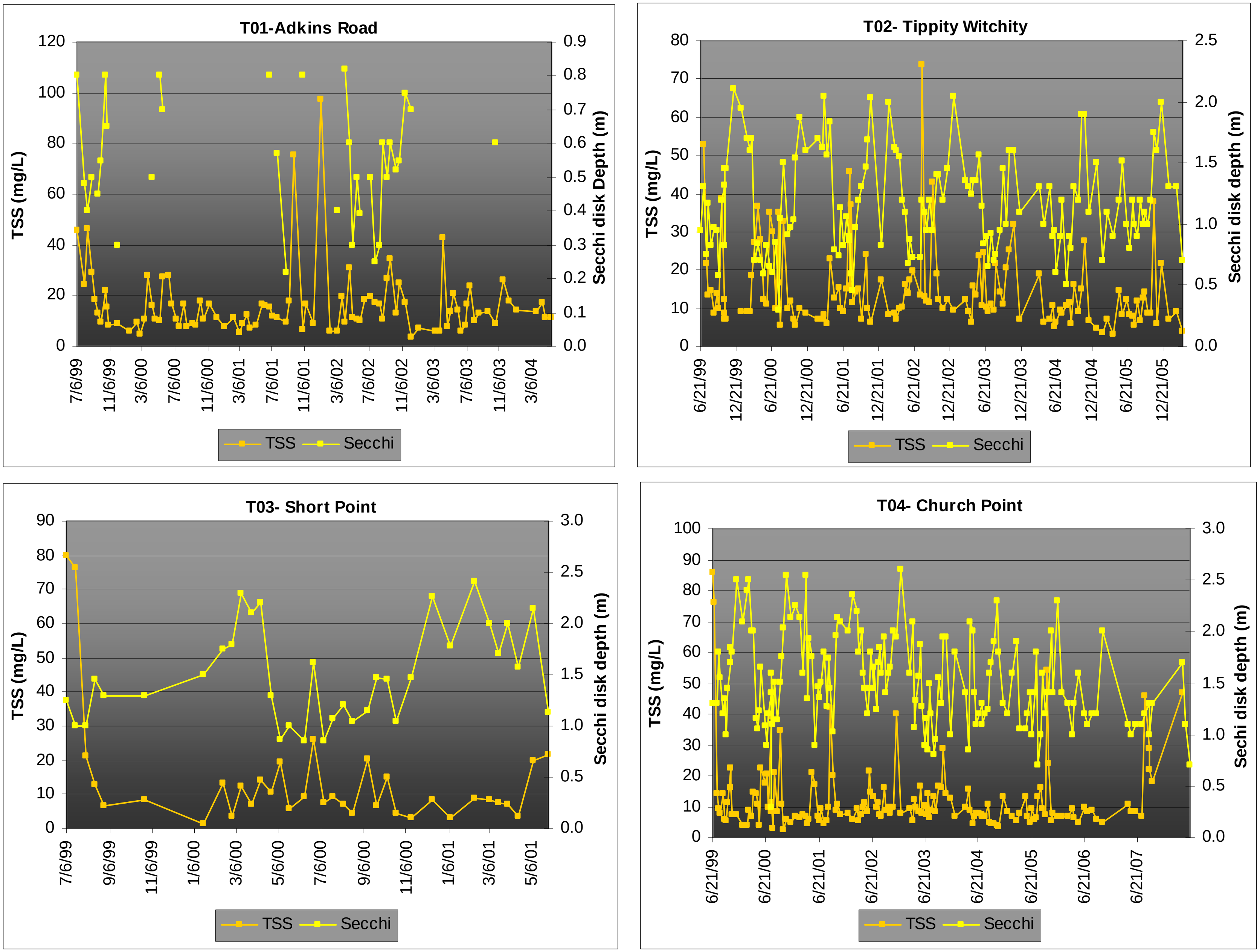
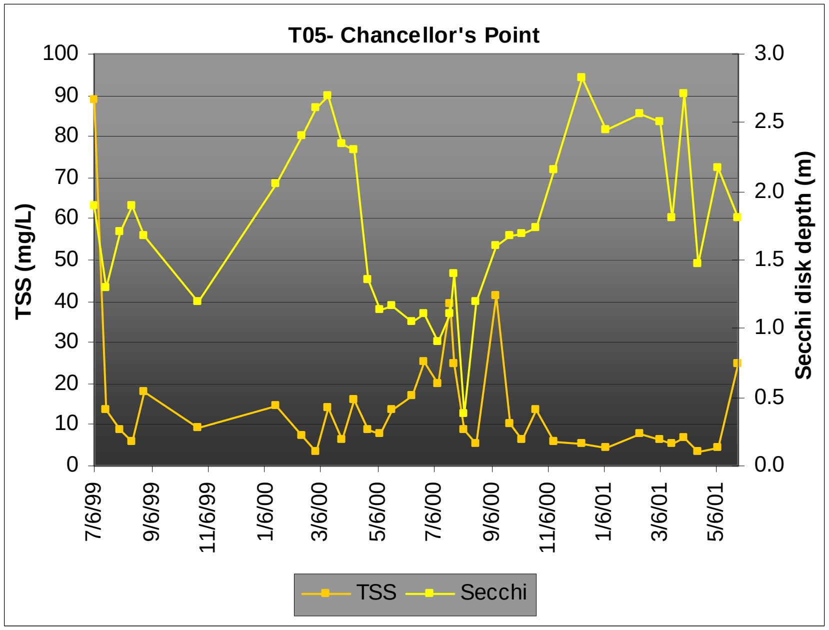
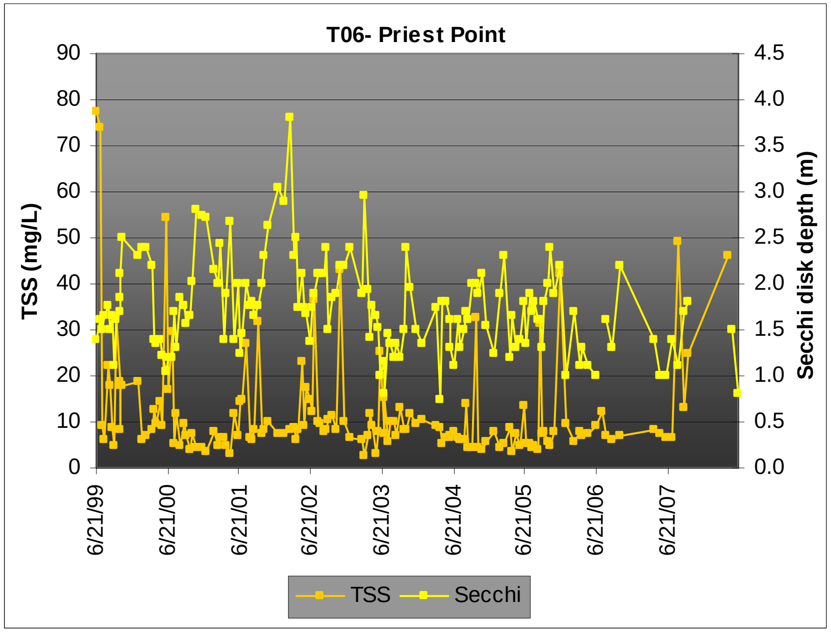
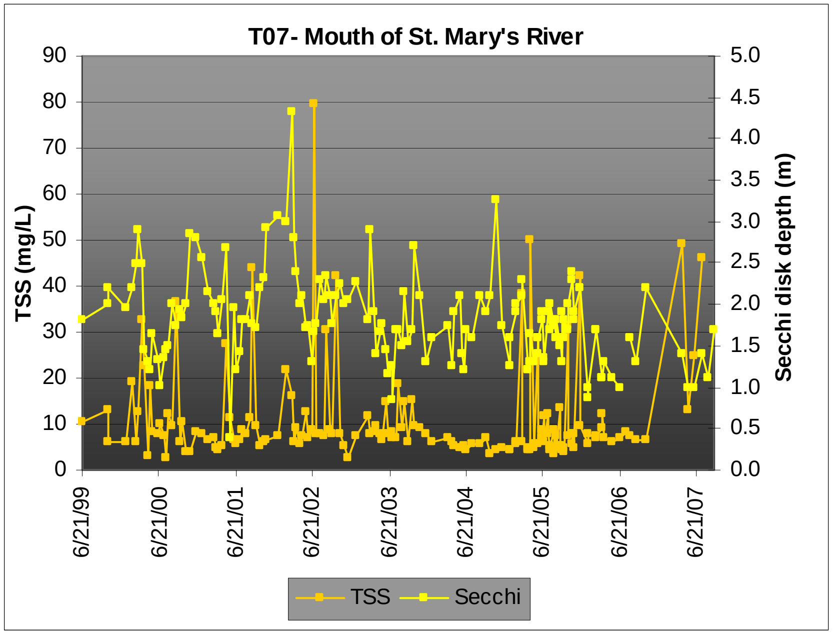


Figure 47. Mean concentration of total suspended solids (TSS) and Secchi disk depth at all tidal stations. Scales for TSS and Secchi

disk depth vary by site. Secchi depth at T01 was inconsistent because of the shallow depth of the site.







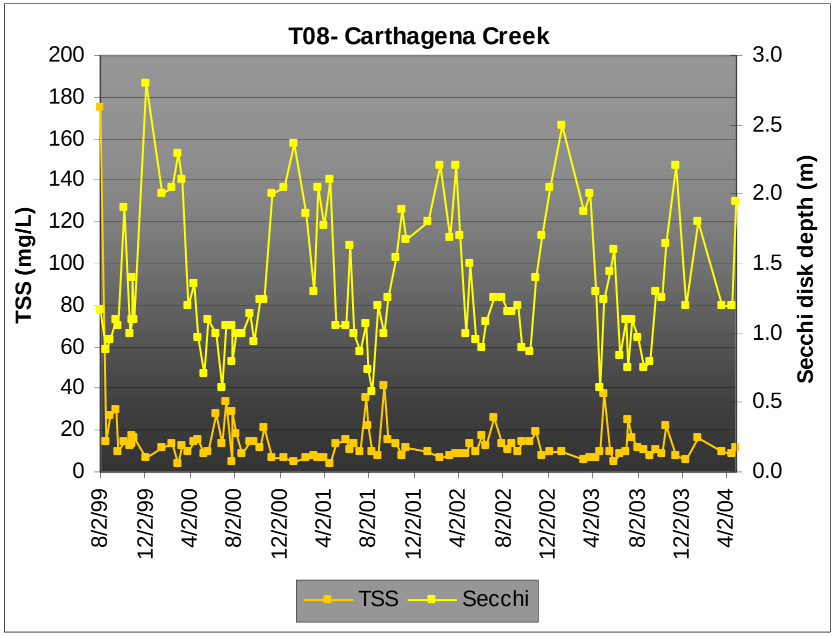
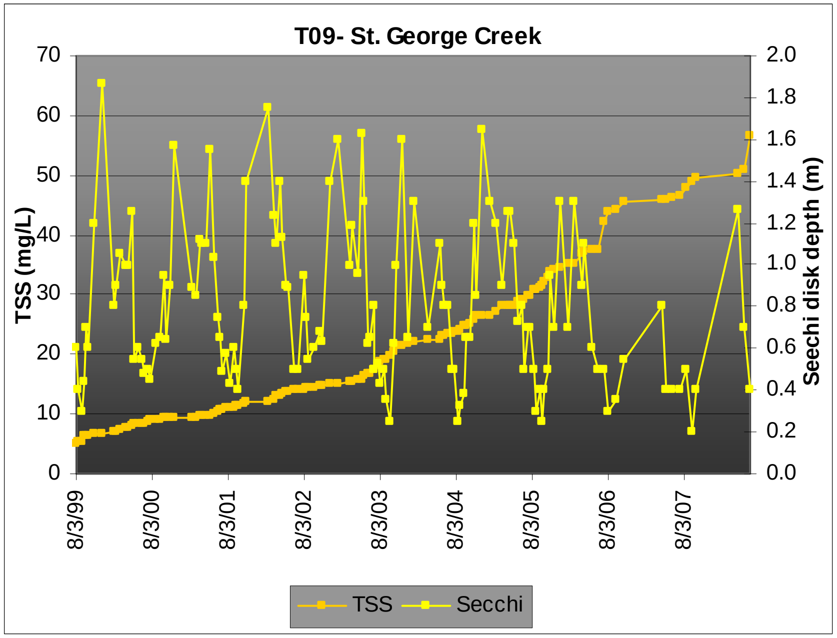
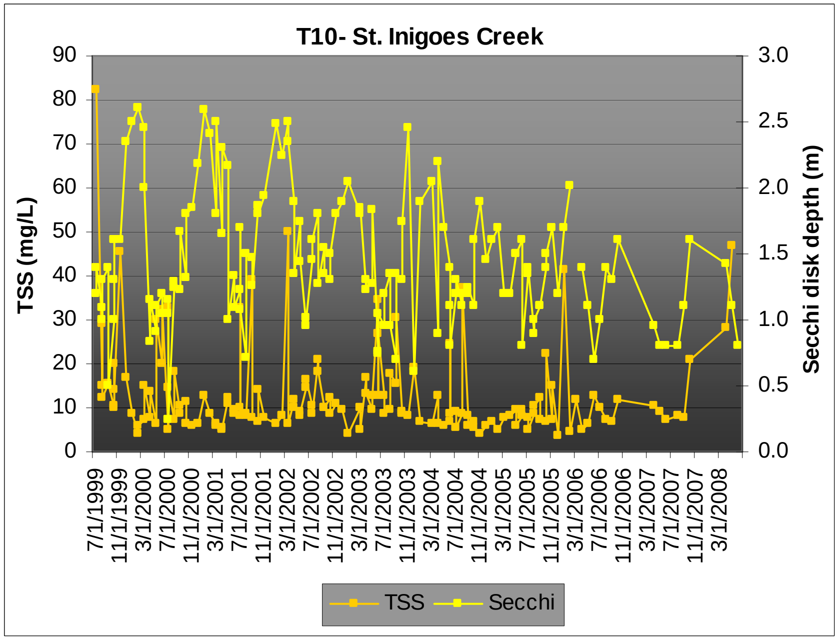


Figure 47 (continued). Mean concentration of total suspended solids (TSS) and Secchi disk depth at all tidal stations. Scales for TSS and Secchi disk depth vary by site.





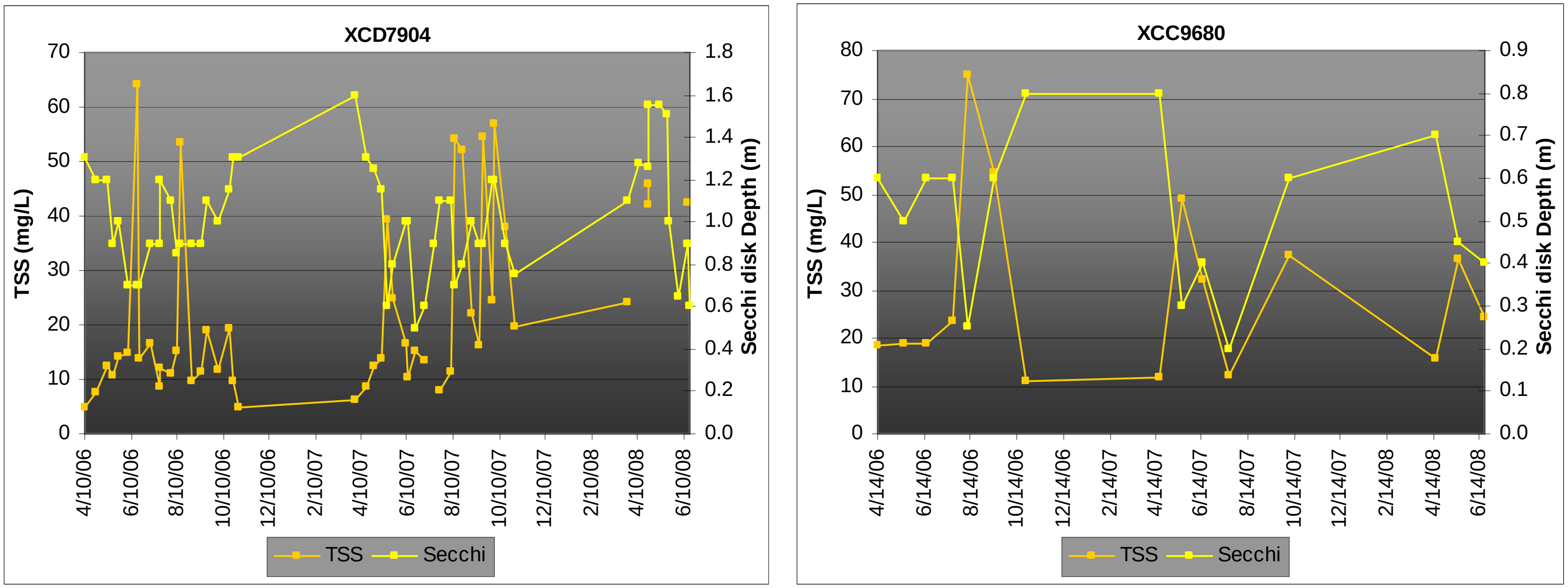


Figure 47 (continued). Mean concentration of total suspended solids (TSS) and Secchi disk depth at all tidal stations. Scales for TSS and Secchi disk depth vary by site.

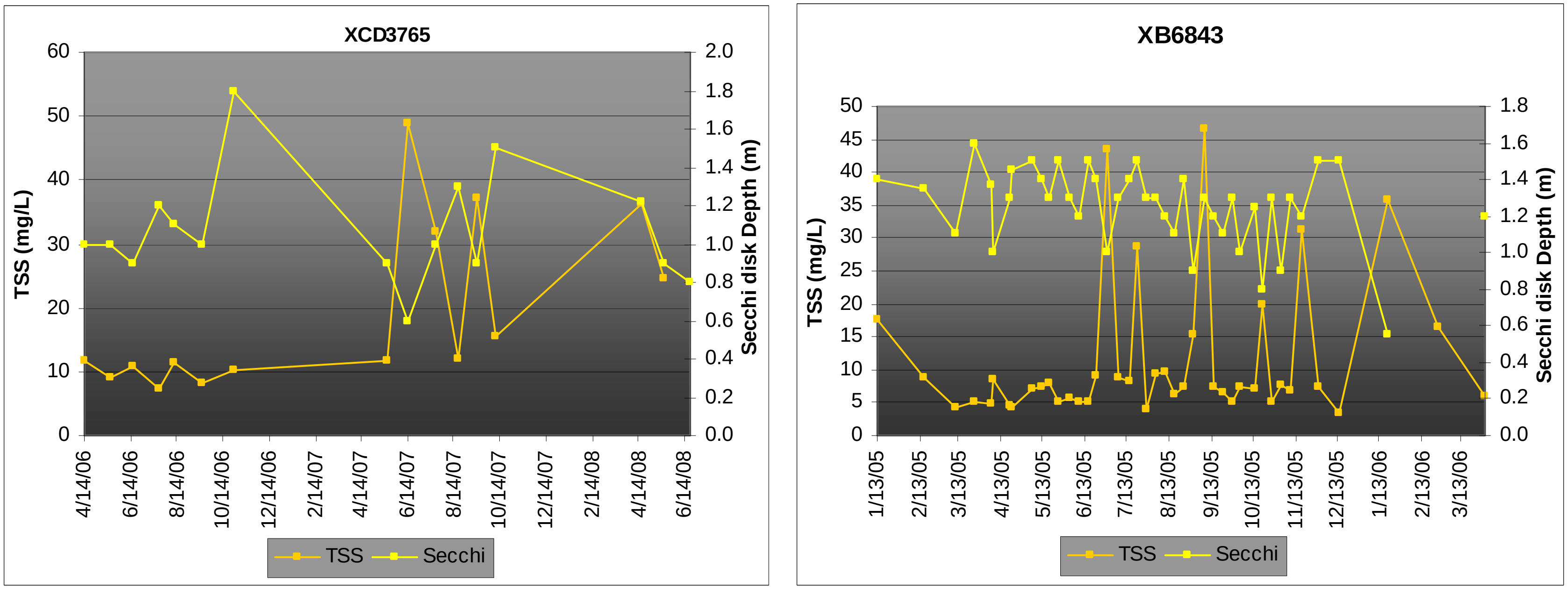


Figure 47 (continued). Mean concentration of total suspended solids (TSS) and Secchi disk depth at all tidal stations. Scales for TSS and Secchi disk depth vary by site.

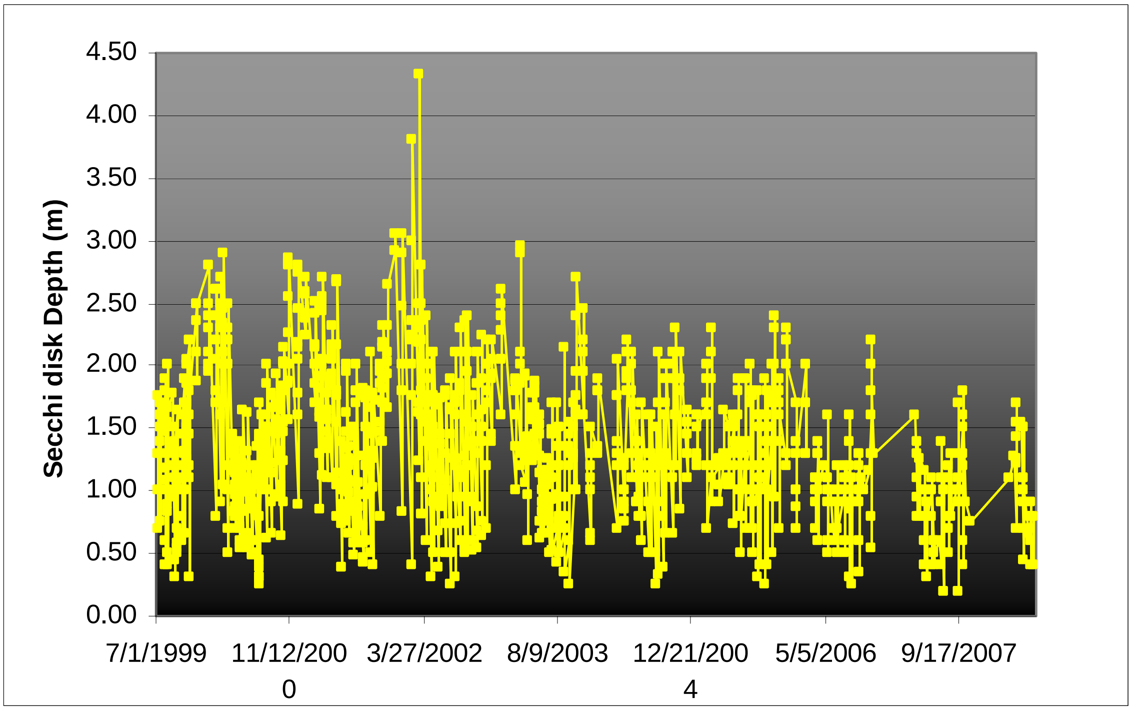


Figure 48. Secchi disk depths at all tidal stations from 1999 through 2008.

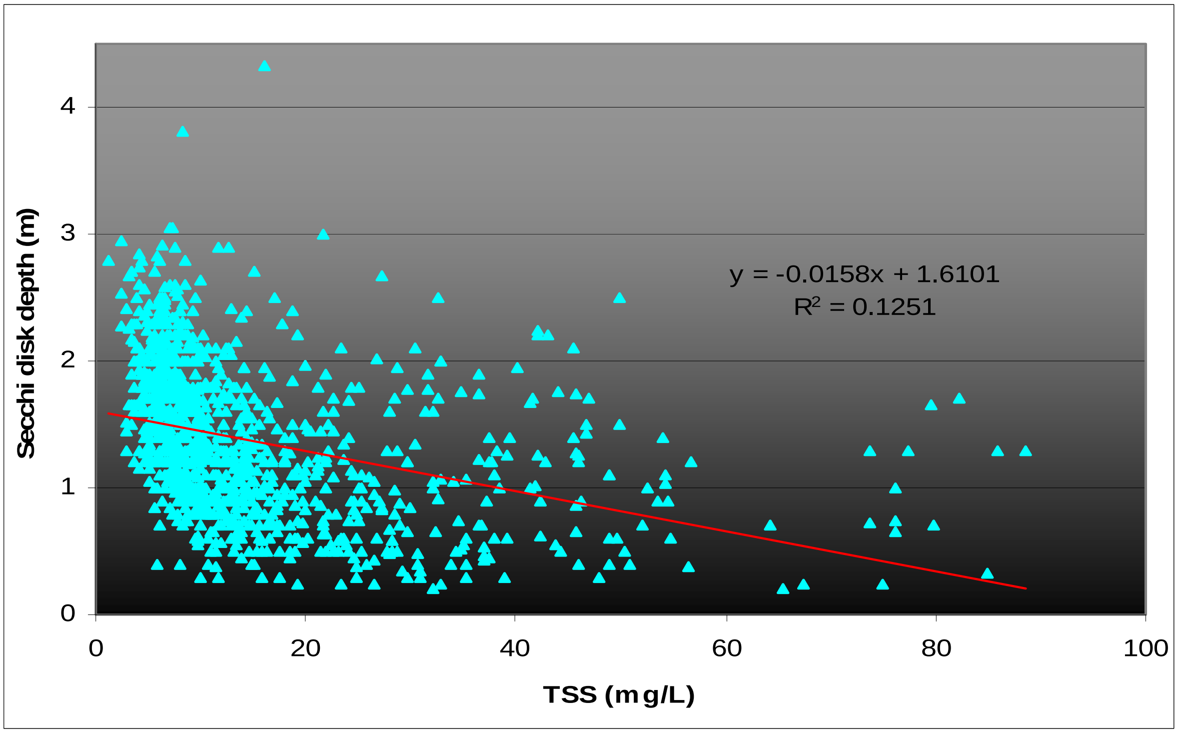


Figure 49. Secchi disk depths in relation to total suspended solids (TSS).

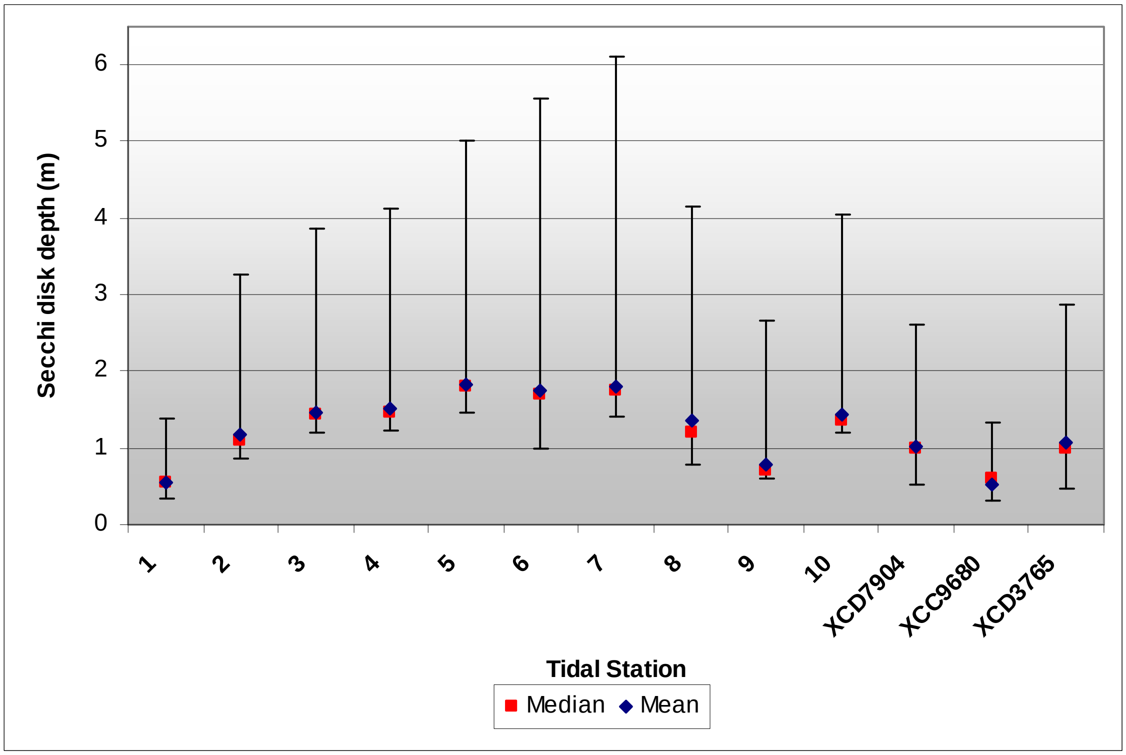


Figure 50. Mean (■), median (♦), minimum (┴), and maximum (┬) Secchi disk depth for all tidal stations (June 1999—July 2008).

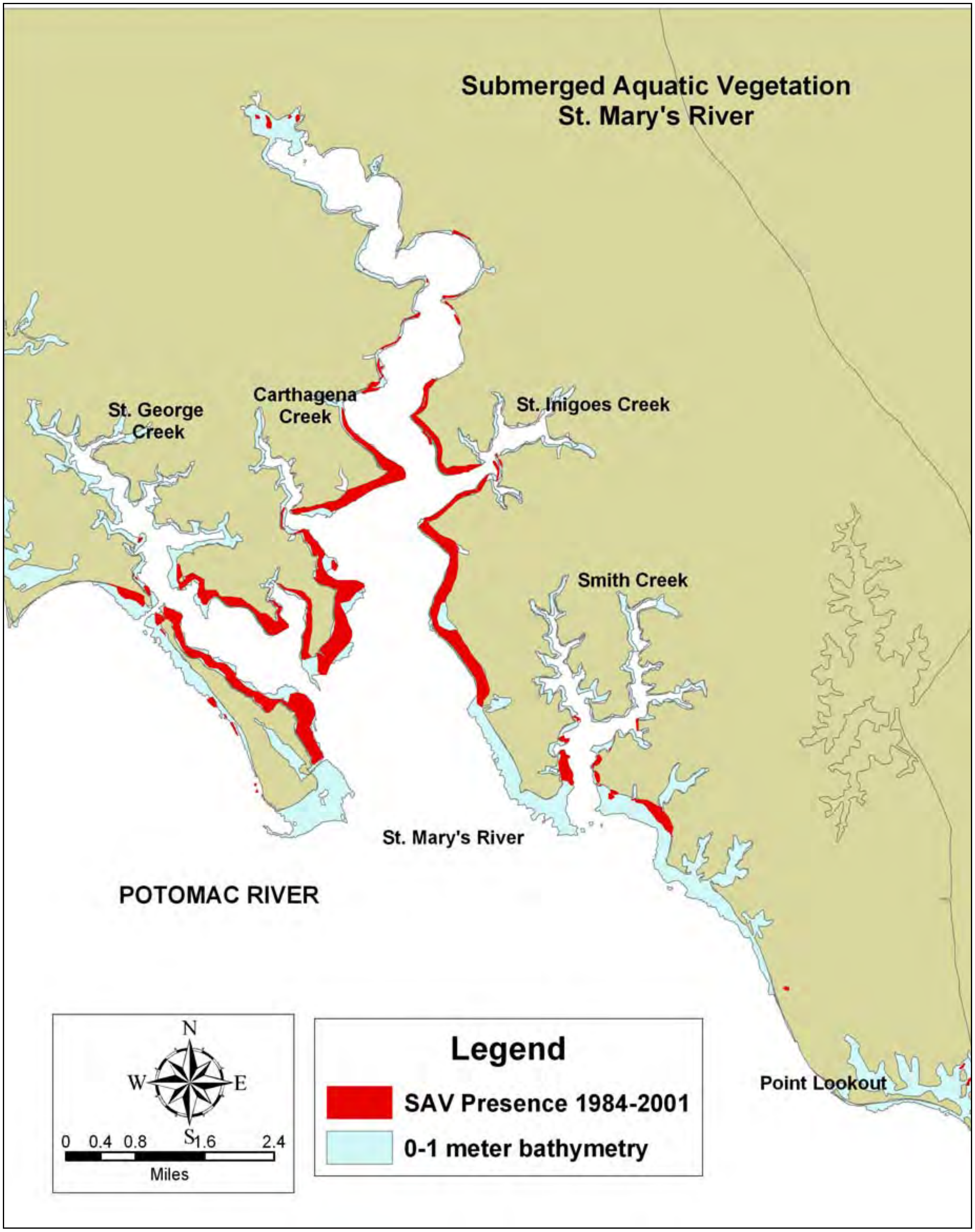


Figure 51. Historic(1984-2001) occurrence of SAV in the St. Mary's River and possible restoration sites with depths ≤ 1 meter.

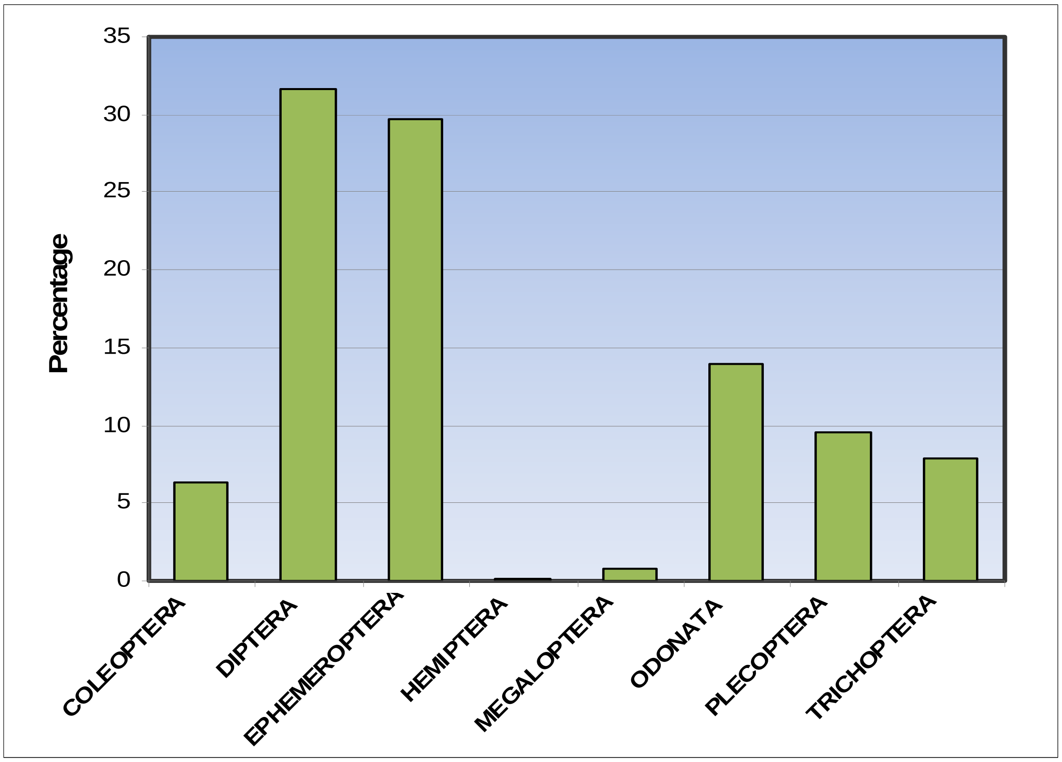


Figure 52. Percentage of insects in each order collected from all sites in 2008.

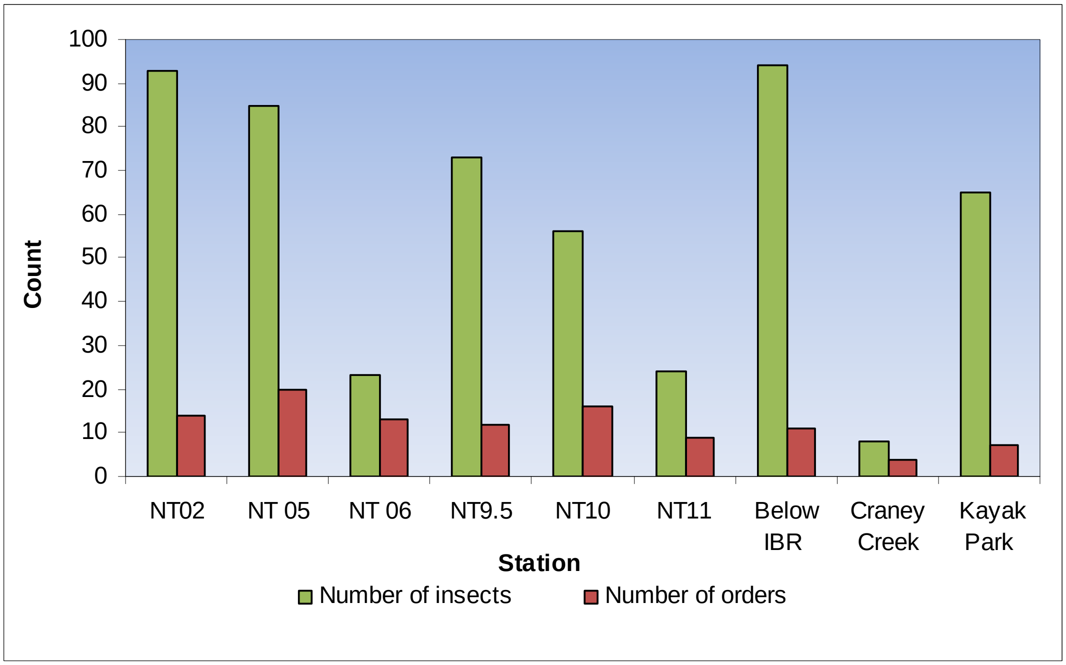


Figure 53. Number of insects and number of orders found at each sampling station in April of 2008.

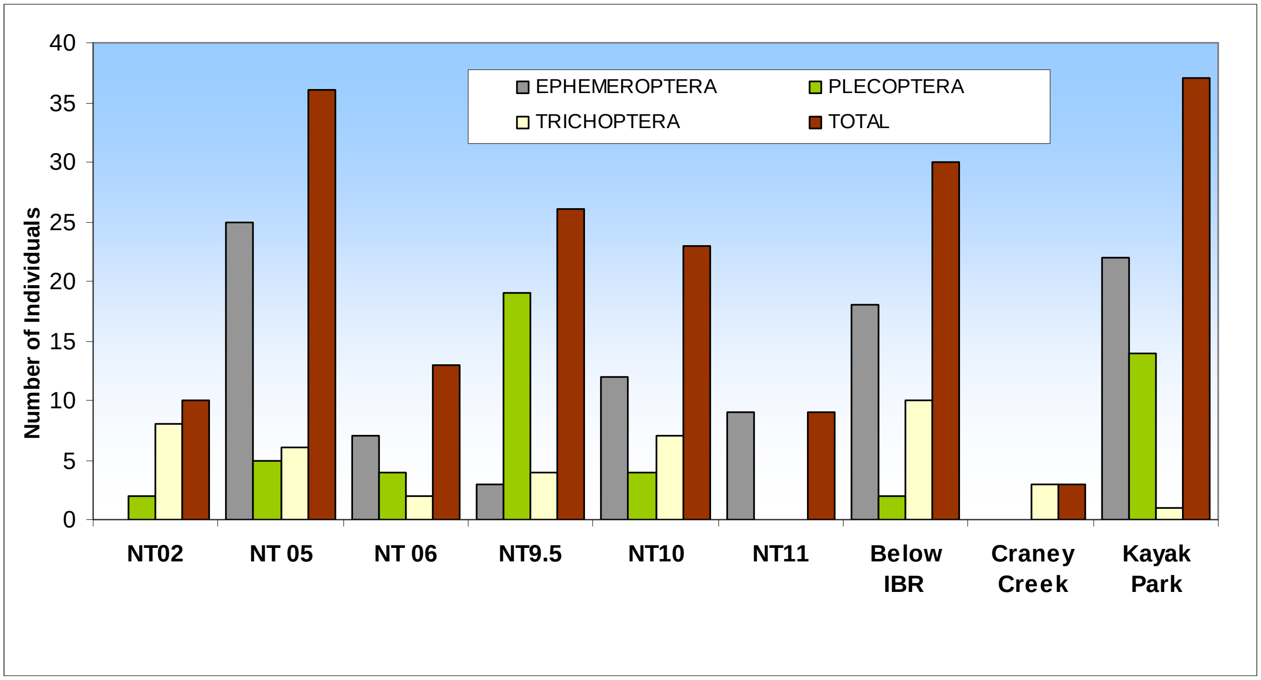


Figure 54. Total number of individuals in Ephemeroptera, Trichoptera, and Plecoptera orders from all stations sampled in the spring of 2008.

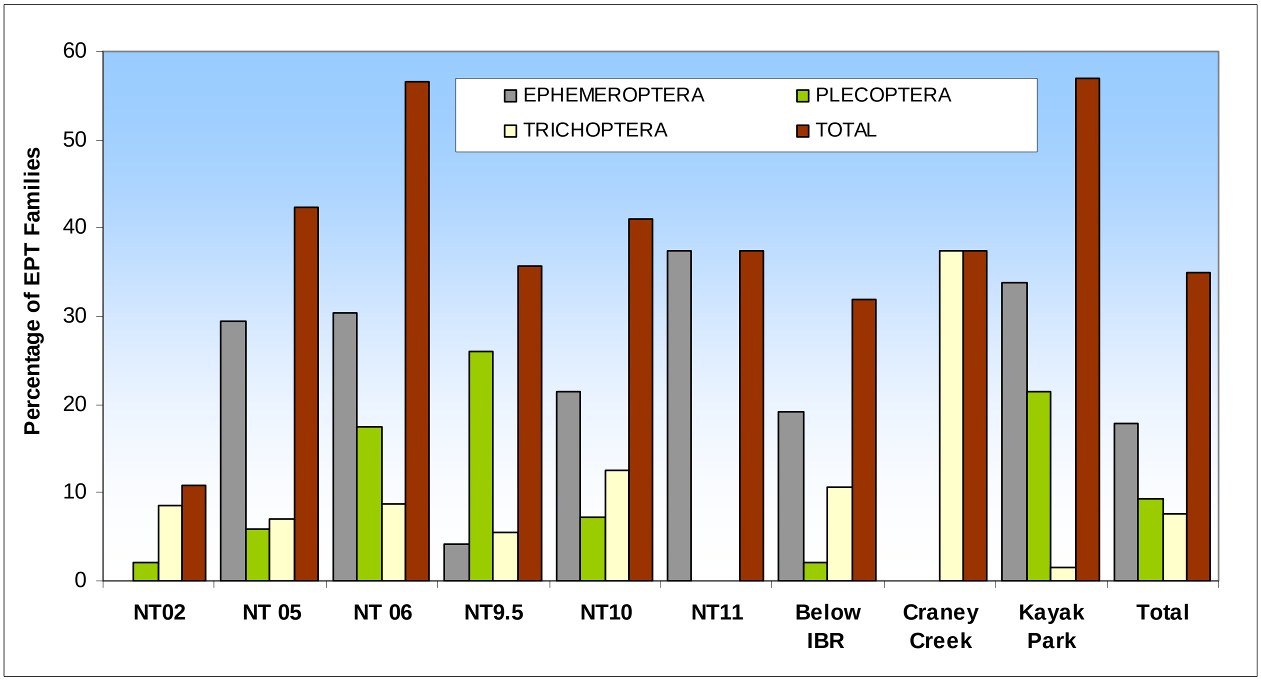


Figure 55. Percentage of Ephemeroptera, Trichoptera, and Plecoptera (ETP) families from all stations in the Spring of 2008. Total bars represent the percentage of EPT families to all other families at each station.

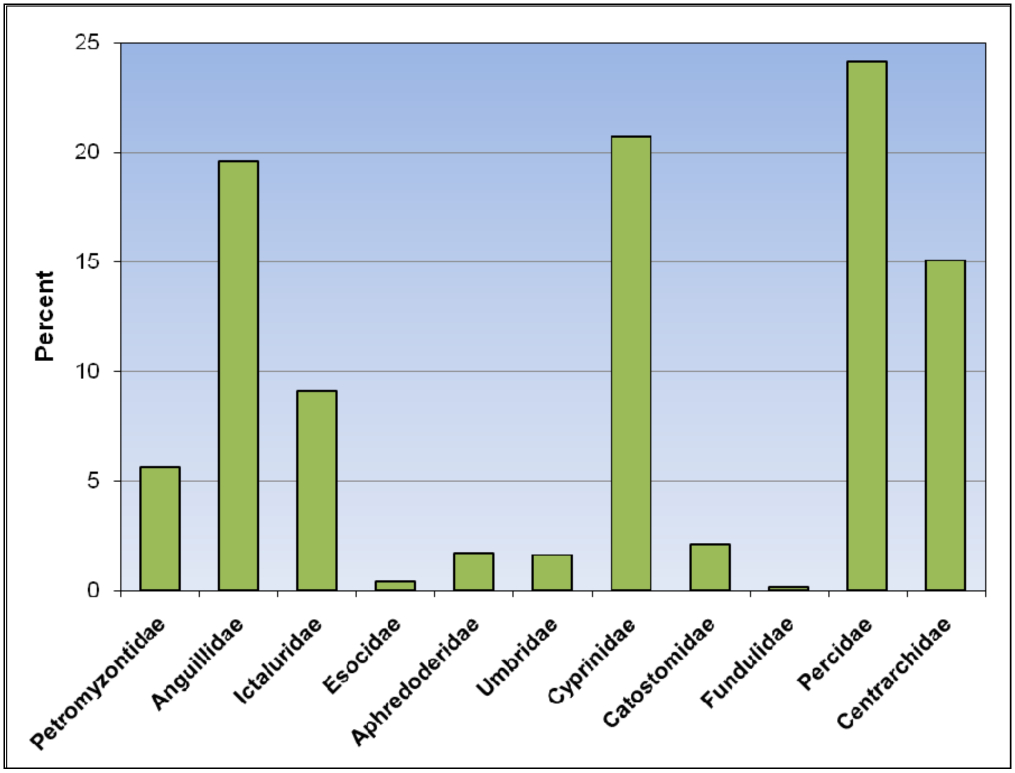


Figure 56. Families of fish collected in August of 2008 as a percentage of the total fish collected.

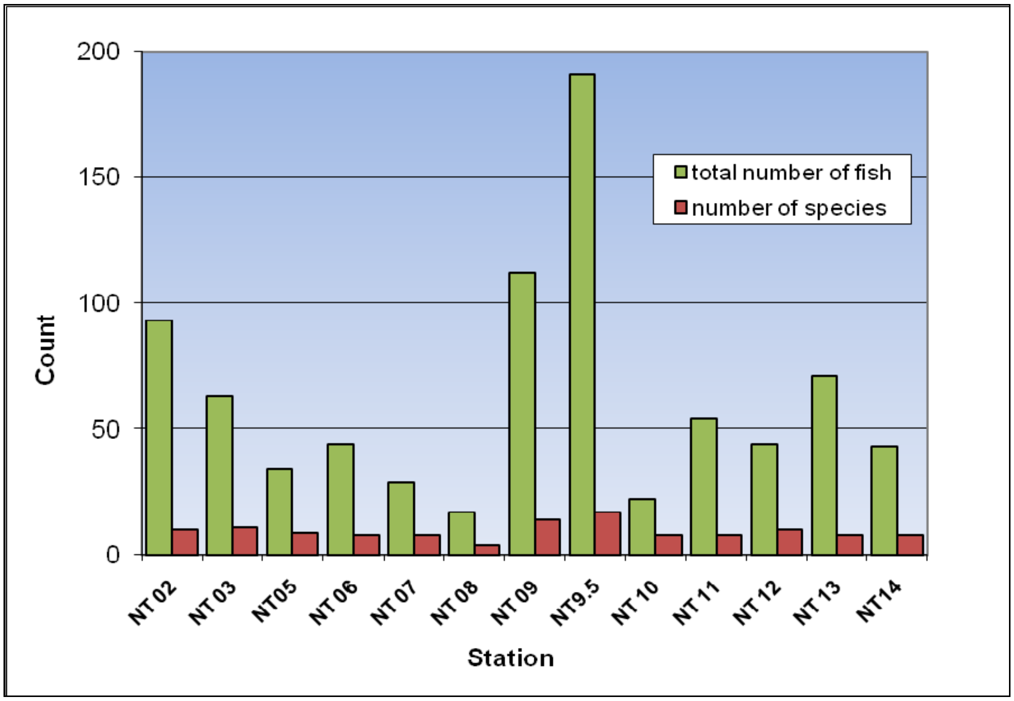


Figure 57. Total number of fish and number of species collected at all non-tidal stations during August of 2008.

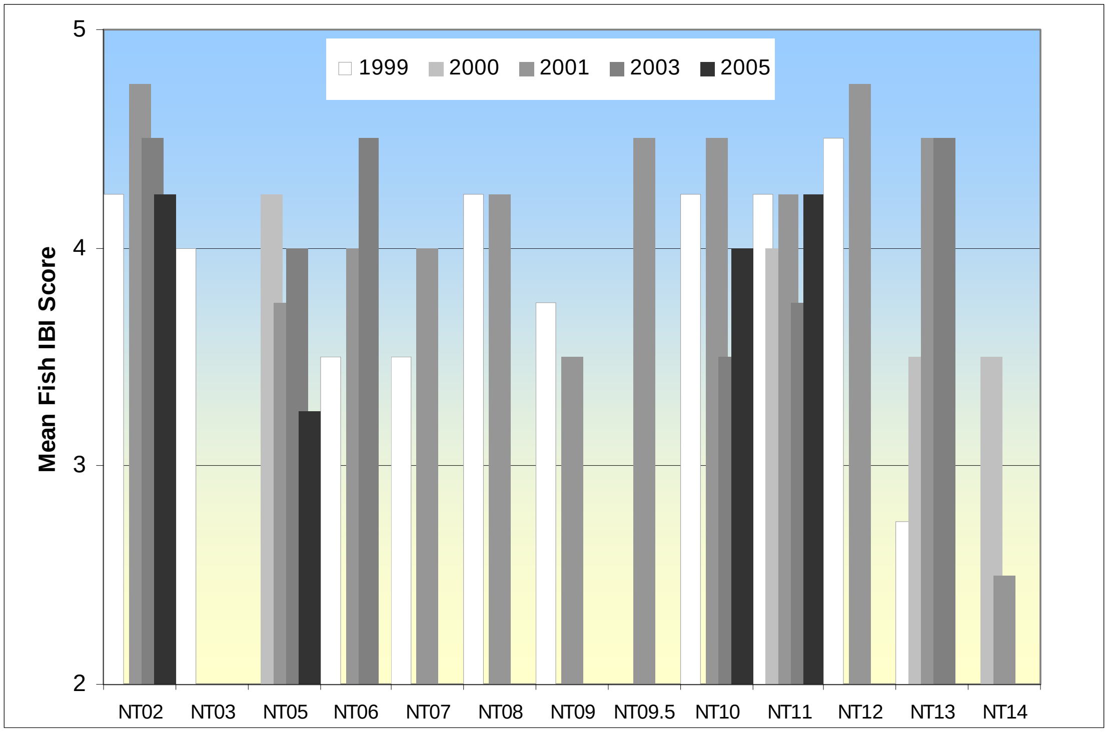


Figure 58. Mean score of Index of Biological Integrity (IBI) for non-tidal fish communities at St. Mary's River Project stations. Mean scores >4 = good, 4- 3 = fair, <3 = poor (after Roth et al., 1996).

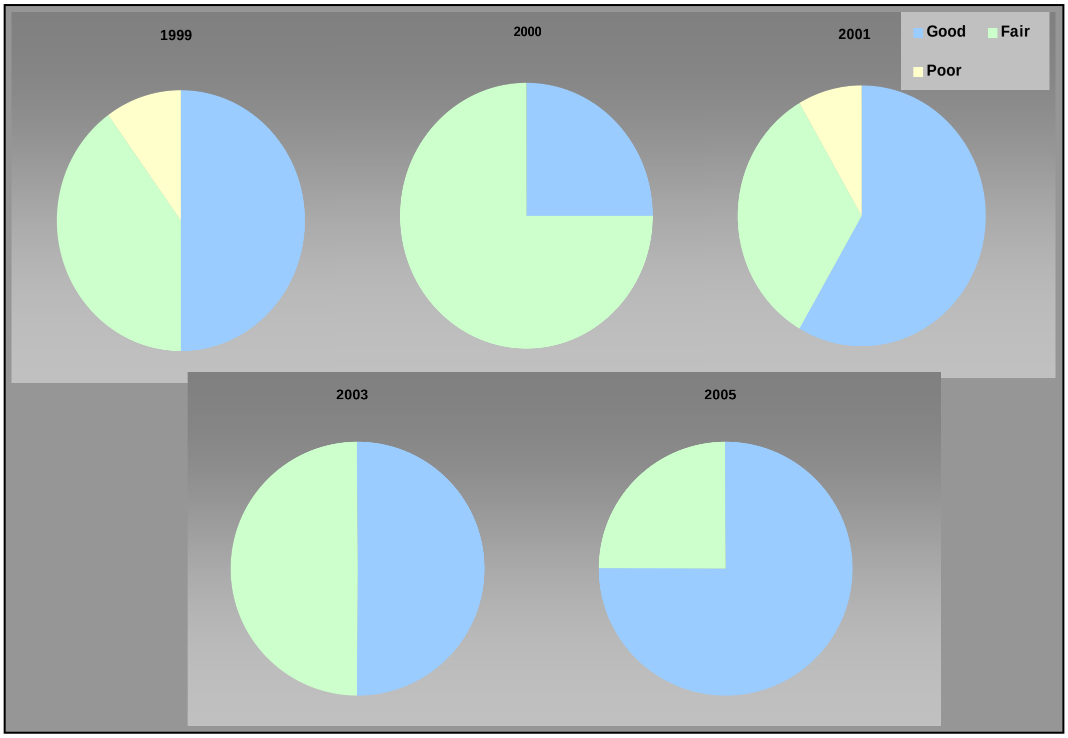


Figure 59. Percentage of fish IBI scores for SMRP samples by year for the period, 1999-2005. Good IBI >4, Fair IBI = 4- 3, Poor IBI <3.

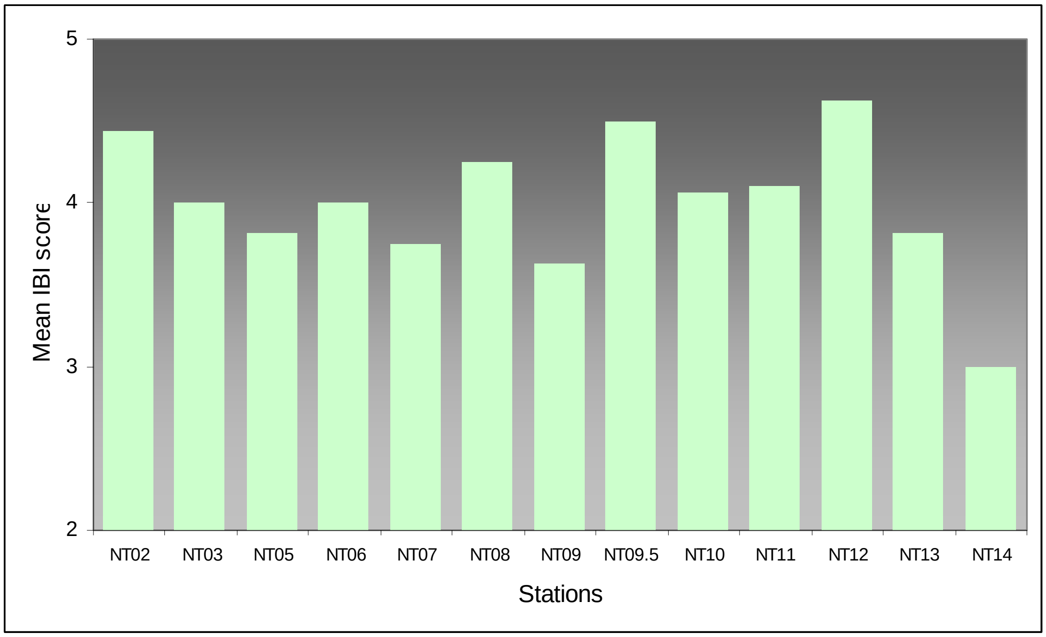


Figure 60. Mean fish IBI scores for all non-tidal stations, 1999-2005.

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