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AN UPDATE OF CURRENT STATUS AND LONG-TERM TRENDS IN WATER QUALITY AND LIVING RESOURCES IN THE VIRGINIA TRIBUTARIES TO CHESAPEAKE BAY FROM 1985 THROUGH 2006

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I. Introduction

The period prior to the implementation of the Chesapeake Bay Monitoring Program was characterized by a marked decline in the water quality of the Chesapeake Bay. The disappearance of submerged aquatic vegetation in certain regions of the Bay, declines in the abundance of some commercially and recreationally important species, increases in the incidence of low dissolved oxygen events, changes in the Bay's food web, and other ecological problems have been related to the deteriorating water quality (e.g. USEPA, 1982,1983;Officer et al.,1984; Orth and Moore, 1984). The results of concentrated research efforts in the late 1970s and early 1980s stimulated the establishment of Federal and state directives to better manage the Chesapeake Bay watershed. By way of the Chesapeake Bay Agreements of 1983, 1987 and 2000, the State of Maryland, the Commonwealths of Virginia and Pennsylvania, and the District of Columbia, agreed to share the responsibility for improving environmental conditions in the Chesapeake Bay. As part of these agreements, a long-term monitoring program of the Chesapeake Bay was established and maintained in order to: 1) track long-term trends in water quality and living resource conditions over time, 2) assess current water quality and living resource conditions, and 3) establish linkages between water quality and living resources communities. By tracking long-term trends in water quality and living resources, managers may be able to determine if changes in water quality and living resource conditions have occurred over time and if those changes are a reflection of management actions. Assessments of current status may allow managers to identify regions of concern that could benefit from the implementation of pollution abatement or management strategies. By identifying linkages between water quality and living resources it may be possible for managers to determine the impact of water quality management on living resource communities.

Water quality and living resource monitoring in the Virginia main stem and tributaries began in 1985 and has continued for 22 years. Detailed assessments of the status and long-term trends in water quality and living resources in Chesapeake Bay and its tributaries have been previously conducted (Alden et al., 1991,1992; Carpenter and Lane, 1998; Dauer, 1997; Dauer et al., 1998a,1998b, 2002b; Lane et al.,1998; Marshall, 1994,1996; Marshall and Burchardt, 1998, 2003, 2004a, 2004b, 2005; Marshall et al., 1998;2005a;2005b;2006). This report summarizes the status of and long-term trends in water quality and living resource conditions for the Virginia tributaries through 2006 and updates the previous reports (Dauer et al., 2005a, 2005b, 2005c;2006).

II. Methods and Materials

A. Monitoring Program Descriptions

Non-tidal water quality samples were collected from 1988 through 2005 at six stations at or near the fall-line in each of the major tributaries as part of the U. S. Geological Survey's (USGS) and the Virginia Department of Environmental Quality’s (DEQ) River Input Monitoring Program (Figure 1). Tidal water quality was regularly monitored at 28 sites in the Bay Mainstem and at 27 sites in the James, York and Rappahannock rivers (Figure 2) beginning in July, 1985 and continuing through 2006. Six permanent water quality monitoring sites were established in the Elizabeth River in 1989 and an additional six were added to the Elizabeth River in 1998 (Figure 2). Details of changes in the monitoring program sampling regime are provided elsewhere (Dauer et al., 2005a, 2005b, 2005c) while sample collection and processing protocols are provided on the World Wide Web at http://www.chesapeakebay.net/qatidal.htm.

Phytoplankton monitoring was conducted at seven stations in the Chesapeake Bay Mainstem beginning in 1985 and at six sites in the major tributaries beginning in 1986 (Figure 3). Two phytoplankton monitoring programs stations (SBE5 and SBE2) were added in the Elizabeth River in 1989 although SBE2 was eventually discontinued. Epi-fluorescent picoplankton and C^{14} primary productivity analysis were added to all stations in 1989. Details of changes in the monitoring program, field sampling and laboratory procedures are described by Dauer et al. (2005a, 2005b, 2005c).

Benthic monitoring was conducted at sixteen fixed point stations in the lower Chesapeake Bay Mainstem and its tributaries beginning in 1985. Sampling at five additional stations, two in the Elizabeth River and one in each of the three other tributaries, began in 1989 (Figure 3). Details of, and changes to, the fixed point monitoring program sampling regime and laboratory procedures are described by Dauer et al. (2005a, 2005b, 2005c).

In 1996, the benthic monitoring program was modified to add a probability-based sampling regime to supplement data collected at fixed-point stations and estimate the area of Chesapeake Bay and its tributaries that met restoration goals as indicated by the B-IBI (Ranasinghe et al., 1994; Weisberg et al., 1997; Alden et al., 2002). Data are collected at 25 randomly allocated stations in each of four separate strata in Virginia: 1) the James River, 2) the York River (including the Pamunkey and Mattaponi rivers), 3) the Rappahannock River, and 4) the Mainstem of the Chesapeake Bay. An additional set of 25 random locations have been collected in the Elizabeth River as a part of DEQ's Elizabeth River Monitoring Program beginning in 1999. Probability-based monitoring data are used to assess biological impairment in Chesapeake Bay at different spatial scales on an annual basis. Details of the sampling, laboratory and assessment protocols are provided in Dauer et al. (2005a,2005b,2005c) and Llansó et al. (2005).

B. Statistical Analysis

Tabular summaries of land-use coverages are modified from the USEPA's Chesapeake Bay Program Watershed Profile website: http://www.chesapeakebay.net/wspv31/. Discharged point source nutrients were obtained from the USEPA Chesapeake Bay Program's point source data base available on the World Wide Web at http://www.chesapeakebay.net/data/index.htm and plotted on an annual basis to assess changes in total point source loadings over time. A comparison of the relative importance of point and non-point sources was made by comparing delivered loads of nutrients and sediments for the two sources as well as percent changes estimated for the period from 1985 to 2005. These estimates were provided by the Virginia Department of Environmental Quality and are based on the Year 2005 Progress Run of the Chesapeake Bay Watershed Model using estimates of Best Management Practices as produced by the Virginia Department of Conservation and Recreation.

To ensure that long-term trends in water quality and living resource data are correctly interpreted, a unified approach for conducting the statistical analyses and interpreting their results was developed. Statistical analytical procedures used in this study were based on guidelines developed by the CBP Monitoring Subcommittee's Tidal Monitoring and Assessment Workgroup. For both status and trend analyses, the stations were grouped into segments based on the segmentation scheme developed by the Data Analysis Workgroup (Figure 2) and data were analyzed for different time periods or “seasons” as defined for each monitoring component in Table 1.

Status of tidal water quality for each Chesapeake Bay program segment was determined using two methods: 1) the relative status as described in Dauer et al. (2005a,2005b, 2005c), and 2) by comparing three year median values during the SAV growing season to SAV habitat criteria (see Table 2) using a Mann-Whitney U-test. The terms good, fair, and poor used in conjunction with relative status are statistical classifications for comparison between areas of similar salinity within Chesapeake Bay. Though useful in comparing current conditions among different areas of Chesapeake Bay, these terms are not absolute evaluations but only appraisals relative to other areas of what is generally believed to be a degraded system.

Status for phytoplankton involved the calculation of relative status for various phytoplankton community indicators using the same technique as described for water quality. Status of benthic communities at each station was characterized using the three-year mean value (2004 through 2006) of the B-IBI (Weisberg et al., 1997). Status of the benthic community was classified as follows: values less than or equal to 2 were classified as severely degraded, values greater than 2.0 to 2.6 were classified as degraded, values greater than 2.6 but less than 3.0 were classified as marginal, and values of 3.0 or more were classified as meeting goals. Status of benthic communities was also quantified by using the probability-based sampling to estimate the bottom area of each stratum populated by benthos classified as impaired using the B-IBI (Llansó et al., 2007).

Trend analyses of non-tidal water quality parameters used a seven parameter regression model that took into account the effects of flow, time, seasonal effects and other predictors (Langland et al., In Review) conducted on flow-adjusted concentrations using a non-parametric Kendall-Theil analysis. Trend analyses of freshwater flow at the fall-line were conducted using a seasonal Kendall test for monotonic trends (Gilbert, 1987). Trend analyses of tidal water quality parameters were conducted using a “blocked” seasonal Kendall approach (Gilbert, 1987) for nutrients in order to account for method changes early in the program and using a seasonal Kendall test for monotonic trends and the Van Belle and Hughes tests for homogeneity of trends between stations, seasons, and station-season combinations for all other parameters (Gilbert, 1987). Trend analyses for phytoplankton communities and benthic communities were conducted using the same approach as that used for non-nutrient water quality parameters.

III. Results and Discussion

A. James River Basin

1. Basin Characteristics

The James River basin has the largest population, the highest population density, the largest percentage of developed land, and the largest percentage of land with impervious surfaces of the three Virginia tributaries while at the same time having the highest total area and percentage of forested land, and the lowest percentage of agricultural land (Table 3A). Above the fall-line, the James River is predominantly rural with the dominant land use type being forest coupled with some agricultural lands. The tidal portion of the river is characterized by two large urbanized regions (Richmond and Hampton Roads) with high population densities, higher percentages of impervious surfaces, relatively lower forest cover and fewer riparian buffer miles separated by large areas of predominantly forest land and open water with some agricultural land (Table 3B).

Non-point sources are estimated to account for 58% of the 16,803,156 kg/yr of nitrogen loads and 72% of the 2,440,531 kg/yr of phosphorus loads entering the James River in 2005 (Table 4). Nutrient reduction activities are estimated to have resulted in 10% and 15% reductions in nitrogen and phosphorus non-point sources loads, respectively and 33% and 62% reductions in total nitrogen and total phosphorus point source loads, respectively from 1985 through 2005 (Table 4).

Annual point source loadings of nitrogen were from five to eleven times higher below the fall-line (BFL) than above the fall-line (AFL). Annual AFL point source loadings of total nitrogen ranged between approximately 2,000,000 to 3,000,000 kg/yr from 1985 through 2003 with values prior to 1998 being generally 200,000 to 400,000 kg/yr higher (Figure 4). Following an initial increase from 22,140,000 kg/yr in 1985 to nearly 27,100,000 kg/yr in 1989, annual BFL loadings of total nitrogen declined steadily to approximately 12,300,000 kg/yr in 1999. During the next four years, BFL total nitrogen loadings have shown a slight but steady increase reaching approximately 14,600,000 kg/yr in 2003 (Figure 4).

Annual point source loadings of phosphorus were generally two to eight times higher below the fall-line (BFL) than above the fall-line (AFL). AFL total phosphorus loadings were near or above 500,000 kg/yr prior to 1988, declined sharply during the next two years to nearly 330,000 kg/yr in 1989 but have risen steadily since then to nearly 600,000 kg/yr in 2003 (Figure 5). Following a peak at just over 4,070,000 kg/yr in 1986, BFL total phosphorus loadings declined sharply and have generally continued to steadily decline reaching approximately 1,050,000 kg/yr in 2003 (Figure 5).

2. Water Quality

There were no significant trends in freshwater flow in either the James, Appomattox or Chickahominy rivers at the fall-line ($p > 0.01$; Seasonal Kendall test). In general, water quality above the fall-line in the James River appear to be improving as indicated by the decreasing trends in concentrations of nitrate-nitrites, total phosphorus and dissolved inorganic phosphorus parameters. No trends in nutrients or suspended solids were observed above the fall-line in either the Appomattox or Chickahominy rivers (Table 5).

Relative status of most nutrients in the tidal James River was good or fair except in the lower river (JMSMH) where status of surface dissolved inorganic phosphorus was poor (Figure 6). Relative status of surface chlorophyll *a* was good in all segments except the Chickahominy River (CHKOH) and the James River Mouth (JMSPH) where it was fair and poor, respectively. Status of total suspended solids and secchi was fair or poor throughout the James River. Status of bottom dissolved oxygen was good in all segments of the James River (Figure 7). Most long-term and post method change trends in nutrients observed indicated improving water quality conditions except in the Upper James (JMSTF2) where degrading trends in surface and bottom total nitrogen were detected during the post-method change period (Figure 6). An improving long-term trend in surface chlorophyll *a* was detected in the Chickahominy River (CHKOH) but a degrading trend in this parameter was detected at the James River Mouth (JMSPH). Degrading trends in bottom total suspended solids were detected in the Chickahominy River (CHKOH) and the Lower James River (JMSMH) while degrading trends in secchi depth were detected in one segment of the Upper James River (JMSTF1), the Chickahominy River (CHKOH), and at the James River Mouth (JMSPH). Improving trends in Summer bottom dissolved oxygen were detected in the Appomattox River (APPTF), one segment in the Upper James River (JMSTF1) and at the James River Mouth (JMSPH) (Figure 7).

SAV habitat requirements for nutrients, where applicable, were met or borderline in all segments except in the Lower James River (JMSMH) where the habitat requirement for surface dissolved inorganic phosphorus was not met (Figure 8). SAV habitat requirements were met in all segments for surface chlorophyll *a* except in the Appomattox River (APPTF) where surface chlorophyll *a* was borderline. SAV habitat requirements were not met or borderline for all segments for both surface total suspended solids and secchi depth except at the James River Mouth (JMSPH) were the requirement for surface total suspended solids was met (Figure 8). Long-term trends during the SAV growing season were degrading for surface total nitrogen in the lower river (JMSMH) but improving for surface total nitrogen in the Upper James River (segment JMSTF1 only) and for surface dissolved inorganic phosphorus in segment JMSTF2. Post-method change degrading trends in surface dissolved inorganic nitrogen were also detected in the Chickahominy River (CHKOH) and the Middle James River (JMSOH) (Figure 8). Improving trends in surface chlorophyll *a* were detected in the Appomattox River (APPTF), the Upper James River (segment JMSTF1 only) and the Chickahominy River (CHKOH) during the SAV growing season. However, a degrading trend in surface chlorophyll *a* was detected in the James River Mouth (JMSPH). Although no trends were detected in total suspended solids, degrading trends in secchi depth were detected in all the upper segments of the James River (APPTF, JMSTF2, JMSTF1 and CHKOH) as well as the James River Mouth (JMSPH) (Figure 8). An improving trend in bottom dissolved oxygen was detected in the James River Mouth (JMSPH).

Status of all nutrients was either fair or poor in all segments of the Elizabeth River (Figure 9). Status of chlorophyll *a* was poor in the Western Branch (WBEMH) and Lafayette River (LAFMH), fair in the Eastern Branch (EBEMH) and Elizabeth River main stem (ELIPH) and good in the Southern

Branch (SBEMH). Status for surface and bottom total suspended solids was fair or poor in all segments except for bottom total suspended solids in the Southern Branch (SBEMH) and Eastern Branch (EBEMH). Status of Secchi depth was poor throughout the Elizabeth River (Figure10). Status of bottom dissolved oxygen was good or fair throughout the Elizabeth River. No significant trends in nutrients were detected in the Western Branch (WBEMH), Lafayette River (LAFMH) and Elizabeth River Mainstem (ELIPH). Improving trends in either surface or bottom total nitrogen and also in surface dissolved inorganic nitrogen were detected in the Southern Branch (SBEMH) and the Eastern Branch (EBEMH). Improving trends in both total phosphorus and dissolved inorganic phosphorus were also detected in these two segments (Figure 9). There were no significant trends in chlorophyll *a* in the Elizabeth River. Improving trends in surface and bottom total suspended solids were observed in the Southern Branch (SBEMH), Eastern Branch (EBEMH) and Elizabeth River main stem (ELIPH). A degrading trend in Secchi depth was detected in the Elizabeth River mainstem (ELIPH). Improving trends in dissolved oxygen were detected in all Elizabeth River segments except the Western Branch (WBEMH) and Elizabeth River main stem (ELIPH) (Figure 10). Increasing trends in either surface or bottom water temperature were detected in all segments except the Lafayette River (LAFMH).

SAV habitat requirement for nutrients was not met or borderline in all segments of the Elizabeth River (Figure 11). SAV habitat requirement for chlorophyll *a* was met in most segments of the Elizabeth River. For surface total suspended solids, SAV habitat requirement was met only in the Southern Branch (SBEMH) and Eastern Branch (EBEMH). The SAV habitat requirement was borderline or not met in all segments for Secchi depth (Figure 11). With respect to nutrients during SAV growing season, trends were limited to a long-term improving trends in surface total phosphorus in the Southern Branch (SBEMH). Improving trends were also detected for surface chlorophyll *a* Southern Branch (SBEMH) and for surface total suspended solids in the Southern Branch and the Elizabeth River main stem (ELIPH). A degrading trend in Secchi depth was detected in the Elizabeth River main stem (ELIPH) during the SAV growing season (Figure 11).

3. Living Resources

In the main stem of the James River, status of most phytoplankton bioindicators was fair or poor with Margalef species diversity, and cyanobacteria biomass being poor at all stations. Status of primary productivity was poor at all stations except SBE5 in the Southern Branch of the Elizabeth River. Chlorophyte and cryptophyte biomass was good at all stations (Figure 12). Most of the long term trends in phytoplankton indicators observed were improving with diatom and chlorophyte biomass improving trends detected at all stations and improving trends in picoplankton biomass being detected at most stations (Figure 12). Degrading trends in Margalef species diversity were detected at stations RET5.2 in the Middle James River (JMSOH) and SBE5 in the Southern Branch (SBEMH) of the Elizabeth River. Degrading trends in cyanobacteria abundance and biomass were detected at all stations in the James River except RET5.2 in the Middle James River (JMSOH). The increasing cyanobacteria abundance and biomass was associated with a significant *Microcystis aeruginosa* bloom at the TF5.5 location. In addition, degrading trends in primary productivity and dinoflagellate biomass were detected at stations TF5.5 in the Upper James (JMSTF1) and station LE5.5 at the James River Mouth (JMSPH). Improving trends were detected in the biomass to abundance ratio, chlorophyte biomass and picoplankton biomass at stations TF5.5 in the Upper James (JMSTF1) and RET5.2 in the Middle James (JMSOH) and in diatom biomass at stations TF5.5 and LE5.5 in the James River Mouth (JMSPH) and in primary productivity at station RET5.2 (Figure 12). The more favorable algal composition as a food and oxygen source in this estuary would be the diatoms and chlorophytes. However, accompanying these positive components are the increasing presence of the less favorable cyanobacteria and their potential for increased algal bloom production and degrading influence on the water quality. In addition, the increasing abundance of dinoflagellates in the lower sub-estuaries of the James has become more prevalent. Of these, *Cochlodinium polykrikoides* has become a consistent summer bloomer in the Elizabeth and Lafayette rivers, with additional high concentrations at other locations along the lower James River. In 2007, the expanse of these blooms reached the Virginia Beach oceanfront before their abundance decreased in September. The increased presence and areal bloom coverage of these taxa would also contribute to the lower Secchi disc readings occurring in these waters. Of additional concern is that both *M. aeruginosa* and *C. polykrikoides* are also part of the HAB category of potentially harmful algae.

The B-IBI met restoration goals at only two stations in the main stem of James River: station LE5.1 in the Middle James River (JMSOH) and, station LE5.4 in the Lower James River (JMSMH). Status of the B-IBI at all other stations in the James River was either degraded or marginal. Status of the B-IBI at both stations in the Elizabeth River was degraded (Figure 13). Improving trends in the B-IBI were detected at station RET5.2 in the Middle James River (JMSOH) and at both stations SBE5 and SBE2 in the Southern Branch (SBEMH) of the Elizabeth River (Figure 13). In 2006, results of the probability-based benthic monitoring indicate that 56% of the total area of the James River is degraded (Llanso et al., 2007). Previous studies suggest that anthropogenic contaminant may account for much of the degradation in the James River (Dauer et al., 2005a; Llansó et al.,2005).

4. Management Issues

Trends at the fall-line indicate that in general water quality is improving in the James River basin with respect to nutrient concentrations although no change in suspended solids was observed. Nutrients in the tidal portions of this estuary, although not as elevated as in other tributaries, do exceed desirable levels in some areas. A persistent and predominant water quality issue in the James River is water clarity which is generally poor and deteriorating in many segments of the river. Phytoplankton communities throughout the James River were characterized by fair or poor relative status for the biomass-to-abundance ratio, Margalef species diversity, and cyanobacteria abundance and biomass and exhibited long-term degrading trends at most stations. Also, many of the lower James River sites and sub-estuaries are experiencing additional dinoflagellate blooms which have created increased public concern and represent potential impact to our local biota. These issues need to be addressed. With respect to the fixed point stations, benthos in the lower portion of the estuary met restoration goals while the upstream stations were marginal or degraded. Probability based monitoring indicated that a high percentage (56%) of the total area of the river was degraded. A probable source of this stress is anthropogenic contamination.

Intense urbanization resulting in high non-point source runoff into the Elizabeth River coupled with high point source nutrient loadings result in poor water quality in this tributary. Recent BMPs and reductions in point source loadings may be ameliorating these problems as indicated by improving trends in both nutrient concentrations and living resource conditions and expansion of these practices should result in further improvements. Increasing trends in cyanobacteria biomass and abundance and decreasing trends in Margalef species diversity in the Elizabeth River are an important concern. Benthic communities in the Elizabeth River were impaired but conditions appear to be improving. The primary stress to these communities appears to be anthropogenic contamination due to a variety of sources including historical contamination, municipal and industrial point sources, non-point source storm water run-off, and automobile emissions.

B. York River Basin

1. Basin Characteristics

Although the York River watershed has the second highest total area and percentage of developed land and the second highest overall population density of all three of the Virginia tributaries, it is predominantly rural as indicated by the high percentages of forested and agricultural land with forested land accounting for over 60% of the total area. In addition, the York River has the highest percentages of open water and wetlands of all of the Virginia tributaries, as well as, the highest percentage of shoreline with a riparian buffer (Table 3A). Total area of developed land in all sub-watersheds of the York River was low and percent area of developed land was comparable between sub-watersheds. Total areas and percentages of impervious surface were always less than 3% of the total sub-watershed area. Total area and percentages of total sub-watershed area in agricultural land was generally higher in the upstream and non-tidal portions of the Pamunkey and Mattaponi rivers than in the tidal portion of the York River. Forested land decreases substantially moving downstream to the Lower Tidal York River both in total area and percent of the total sub-watershed area due primarily to an increase in open water (Table 3C).

Non-point sources accounted for 85% of the approximately 3,339,301 kg/yr of the total nitrogen loadings to the York River. There has been an estimated 18% reduction of non-point source loadings to the watershed due to the application of best management practices and point source loadings decreased by an estimated 12% since 1985 (Table 4). Non-point sources accounted for 81% of the 332,383 kg/yr of total phosphorus loadings to the York River in 2005. Nutrient reduction strategies and the phosphate ban have resulted in an estimated overall reduction of 19% and 67% in non-point and point source loadings to the river since 1985 (Table 4).

Point source loadings of total nitrogen above the fall-line in the Pamunkey River increased steadily from 1985 until 2000 when they decreased substantially (Figure 14). In the Upper Mattaponi River (MPNTF), point source nitrogen loadings declined in 1985 through 1998 and then increased in subsequent years remaining above 500,000 through 1999 when they declined to levels below those observed in 1985 (Figure 14). Following a substantial decline from in 1985 through 1987, point source loadings of total nitrogen in the Lower York River increased in the last 16 years to reach nearly 757,000 kg/yr, an increase of nearly 18% since 1985. Point source total nitrogen loadings in Mobjack Bay increased overall from 1985 through 1992 but declined substantially in 1993 and thereafter, have remained below 2,000 kg/yr in most years (Figure 14).

Point source loadings in total phosphorus in all segments experienced an initial decline in 1985 of varying magnitudes probably in response to the phosphate ban. In the Upper Mattaponi River, the Lower York River, and Mobjack Bay these declines were followed by several years of fluctuations and a period of stability at levels substantially less those observed in 1985 (Figure 15). However, above the fall-line in the Pamunkey River, total phosphorus loadings increased after 1991 and continued to do so reaching over 57,000 kg/yr in 2003 (Figure 15).

2. Water Quality

There were no trends in freshwater flow in either the Pamunkey or Mattaponi rivers ($p>0.01$; seasonal Kendall test). Water quality conditions above the fall-line in the Pamunkey River appear to be degrading as indicated by the increasing trends in flow adjusted concentrations of nitrogen and phosphorus parameters observed at the fall-line station near Hanover. In contrast, water quality above the fall-line in the Mattaponi appears to be improving as indicated by the improving trends in both total nitrogen and nitrate-nitrite concentrations observed near Beulahville (Table 5).

Status of nitrogen parameters was fair or good in all segments . Status of phosphorus parameters was good in the Upper Pamunkey River (PMKTF), the Upper Mattaponi River (MPNTF) and Mobjack Bay (MOBPH) but fair in the lower segments of the Pamunkey and Mattaponi (PMKOH and MPNOH) and the Lower York River (YRKMH and YRKPH). Status of phosphorus parameters in the Middle York River (YRKMH) was generally poor (Figure 16). Status of surface chlorophyll *a* was good in the Pamunkey River and Mattaponi River segments, but fair in remaining segments. Status of total suspended solids was poor or fair in most segments except in the Upper Pamunkey River (PMKTF), the Upper Mattaponi River (MPNTF) and Mobjack Bay (MOBPH) where it was generally good. Status of secchi depth was poor in all segments of the York River except in the upper segments of the Pamunkey and Mattaponi rivers where it was fair and good, respectively. Status of Summer bottom dissolved oxygen was good or fair in all segments (Figure 17).

Degrading long-term or post method change trends in surface and/or bottom nitrogen parameters were detected in all segments except Mobjack Bay (MOBPH) where improving trends in both total and dissolved inorganic nitrogen were detected. Degrading long term trends were detected in surface or bottom total phosphorus in the Upper and Lower Pamunkey River (PMKTF and PMKOH) and the Middle York River (YRKMH). Post method change improving trends in surface and bottom dissolved inorganic phosphorus were detected in the Upper Pamunkey River (PMKTF) and Upper Mattaponi River (MPNTF) (Figure 16). A degrading trend in surface chlorophyll *a* was detected in the Lower York River (YRKPH). Degrading trends in bottom total suspended solids were detected in the Middle York River (YRKMH) and Lower York River (YRKPH) while improving trends in both surface and bottom total suspended solids were detected in Mobjack Bay (MOBPH). Degrading trends in secchi depth were detected in all segments of the York River except the Lower Pamunkey and Mattaponi River (PMKOH and MPNOH) and the Middle York River (YRKMH). An improving trend in Summer bottom dissolved oxygen was detected in Mobjack Bay (MOBPH) (Figure 17).

With respect to SAV habitat requirements, both surface dissolved inorganic nitrogen and phosphorus were either borderline or met the requirement in all segments, except in the Middle York River, where surface dissolved inorganic phosphorus failed to meet the SAV criteria. Surface chlorophyll *a* met the SAV habitat requirement in all segments while surface total suspended solids and Secchi depth were borderline or failed to meet the SAV criteria in most segments (Figure 18). During the SAV growing season degrading trends in nitrogen parameters were detected in all segments except the Lower Pamunkey River (PMKOH) and the Lower Mattaponi River where no long-term trends were detected and in Mobjack Bay (MOBPH) where an improving trend was detected. There were no trends in phosphorus parameters except for a long-term improving trend and a post-method change improving trend in surface dissolved inorganic phosphorus in the Upper Pamunkey River (PMKTF) and Upper Mattaponi River (MPNTF). A degrading trend in surface chlorophyll *a* was detected in Lower York River (YRKPH) but there were no trends in surface total suspended solids. Degrading trends in Secchi depth were detected in the Upper Mattaponi River (MPNTF), the Lower York River (YRKPH) and Mobjack Bay (MOBPH) during the SAV growing season. Improving trends in bottom dissolved oxygen were detected during the SAV growing season in the Upper Pamunkey River (PMKTF) and Mobjack Bay (MOBPH).

3. Living Resources

Relative status of the most station/parameter combinations for phytoplankton was poor with total biomass, the biomass to abundance ratio and Margalef diversity being poor throughout the York River while productivity was poor in the Middle York River (YRKMH) and Mobjack Bay (MOBPH) (Figure 19). Degrading trends in cyanobacteria abundance and biomass were detected at all stations of the York River and degrading trends in Margalef species diversity and primary productivity were observed at station WE4.2 in Mobjack Bay (MOBPH). Improving trends were detected in chlorophyte biomass at station TF4.2 in the Upper Pamunkey River (PMKTF) and station RET4.3 in the Middle York River (YRKMH) (Figure 19). In addition to the increasing trends among the unfavorable cyanobacteria in the river, the Lower York River is the site of re-occurring dinoflagellate blooms. The cyanobacterium of most concern is *Microcystis aeruginosa*, this is a common HAB species that has been associated with toxin production in the Potomac River. Concern is associated with any signs of increased bloom production for the species. In addition, *Cochlodinium polykrikoides*, another HAB, has been an annual summer bloom producer in the lower York. The blooms for this species, along with other dinoflagellates, were also common throughout many of the estuaries in the Tidewater region.

Benthic community status, as measured with the B-IBI, was good only at stations LE4.3 in the Lower York River (YRKPH) and either degraded or severely degraded at all other stations (Figure 20). An improving trend in the B-IBI was detected at station LE4.3B in the Lower York River (YRKPH) but no other trends in the B-IBI were detected (Figure 20). In 2006, results of the probability-based benthic monitoring indicate that 68% of the total area of the York River was degraded (Llansó et al.,2006). Previous studies indicate that a combination of anthropogenic contamination, eutrophication and low dissolved oxygen adversely affect benthic communities in the York River (Dauer et al., 2005b; Llansó et al.,2005).

4. Management Issues

Water quality in the non-tidal portion of the Pamunkey River appears to be degrading as indicated by increasing trends observed in both nitrogen and phosphorus parameters. Despite the generally good relative status, increasing trends in both nitrogen and to a lesser degree phosphorus parameters indicate that water quality in the tidal portion of the York River may be degrading possibly in response to the trends observed above the fall-line. Poor water clarity is a persistent and widespread problem in the York River as indicated by the poor relative status and SAV habitat requirement failures of secchi depth throughout the estuary coupled with the degrading trends observed in some segments. Source of the water clarity problem is unknown. Localized increases in discharged point source nutrients were observed in portions of the York River. Although the increases in point source nutrients observed were relatively small, the small total area and low flow rates of the York River may make it more susceptible to changes in point or non-point source nutrient loadings.

Poor status of several phytoplankton indicators and increasing long-term trends in abundance and biomass among the cyanobacteria are of concern and are probably related to the increasing trends in nutrients observed. Increases in cyanobacteria may adversely affect water clarity and could result in the degrading trends in phytoplankton species diversity observed. Although sporadic in their occurrence, the downstream dinoflagellate blooms are often extensive in areal coverage and in the duration of their development. On these occasions, they represent a serious influence to the general degradation of water quality of the area.

All but one of the fixed point monitoring stations in the York River were degraded and probability-based sampling indicated that 69% of the bottom of the York River does not met the restoration goals for benthic communities. Previous studies suggest that anthropogenic contamination appears to be the predominant source of stress to the benthos but eutrophication and low dissolved oxygen also play a role (Dauer et al., 2005b). There is a possibility that physical disturbance of the benthos caused by seabed mixing, a natural source of stress, may also be an important factor determining benthic community status in the York River (Dellapenna et al., 1998; 2003).

C. Rappahannock River Basin

1. Basin Characteristics

The Rappahannock River is predominantly rural with lowest overall population density and percentage of developed land of all three Virginia tributaries coupled with high percentages of agricultural and forest land use types. It has the second highest area of agricultural cropland of all three of the Virginia tributaries (Table 3A). Sub-watershed specific percentages of agricultural land were generally near or greater than 20% and decreased moving downstream from above the fall-line while percentages of forest land were above 40% and also decreased moving downstream. The percentage of shoreline with a riparian buffer was 35.6% overall in the basin and decreased moving downstream from the Upper Tidal portion of the river (Table 3D).

Non-point sources are estimated to have accounted for 92% of the nearly 3,370,000 kg/yr of nitrogen loads and almost 94% of the 403,800 kg/yr of phosphorus loads entering the Rappahannock River in 2005 (Table 4). Nutrient reduction activities have resulted in an estimated 20% reduction in both nitrogen and phosphorus non-point sources loads and a 12% increase and 70% reduction in nitrogen and phosphorus point source loads to the Rappahannock from 1985 through 2005 (Table 4).

Point source loadings of nitrogen were generally higher below the fall-line than above. AFL point source loadings of nitrogen typically ranged between 160,000 kg/yr to 200,000 kg/yr and peaked at 312,000 kg/yr and 283,000 kg/yr in 1996 and 2003, respectively. BFL point source loadings of nitrogen increased initially from 330,000 kg/yr in 1985 to 470,000 kg/yr in 1989, declined to levels near or below 300,000 during the next eight years, peaked at 491,000 kg/yr in 1998 and generally declined during the next six years (Figure 21A).

Annual BFL point source loadings of phosphorus were typically higher than AFL values for the period of 1985 through 1995 but have become comparable during the last eight years following substantial and generally steady declines in both regions that began in 1989 following the phosphate ban (Figure 21B).

2. Water Quality

No significant trends in freshwater flow at the Rappahannock River fall-line were detected. There were no significant trends in nutrient or total suspended solids above the fall-line in the Rappahannock River (Table 5).

Relative status of nutrients was good for all parameter/segment combinations in the Rappahannock River except for bottom total phosphorus in the Middle Rappahannock River (RPPOH) for which the status was fair (Figure 22). Status of chlorophyll *a* was fair in all segments except the Upper Rappahannock River where it was good. Status of surface and bottom total suspended solids was fair or poor except in the Corrotoman River (CRRMH) where it was good. Status of Secchi depth was poor in all segments of the Rappahannock River except for the Corrotoman River (CRRMH) where it was fair. Status of Summer bottom dissolved oxygen was good in all segments except the Lower Rappahannock River (RPPMH) where it was fair (Figure 23).

A degrading long-term trend was detected in bottom total nitrogen in the Middle Rappahannock River (RPPOH). Degrading trends in surface and bottom dissolved inorganic nitrogen in the Upper Rappahannock River (RPPTF) while an improving trend in surface dissolved inorganic nitrogen was detected in the Corrotoman River (CRRMH). Degrading trends were observed in surface total phosphorus and bottom total phosphorus in the Corrotoman River (CRRMH) and the Middle Rappahannock River (RPPOH), respectively. An improving long-term trend in bottom dissolved inorganic phosphorus was observed in the Middle Rappahannock River (RPPOH) while improving post-method change trends in surface and bottom dissolved inorganic phosphorus were detected in the Upper Rappahannock River (RPPTF) (Figure 22). Degrading trends in surface chlorophyll *a* were detected in the Middle Rappahannock River (RPPOH) and Lower Rappahannock River (RPPMH) and degrading trends in secchi depth were also detected in the Middle Rappahannock

River (RPPOH) and the Corrotoman River (CRRMH). Decreasing trends in salinity were detected in all segments of this tributary River except for the Upper Rappahannock River (RPPTF) (Figure 23).

SAV habitat requirements for nutrients were met in all applicable segments. Surface chlorophyll *a* was either borderline or met the SAV habitat criteria throughout the Rappahannock River. Both surface total suspended solids and secchi depth failed to meet the SAV habitat criteria in both the Upper Rappahannock River (RPPOH) and the Middle Rappahannock River (RPPMH) but were borderline or met the criteria elsewhere. During the SAV growing season, a improving long-term trend in surface dissolved inorganic nitrogen was detected in the Corrotoman River as well as degrading trends in surface chlorophyll *a* in the Middle Rappahannock River (RPPOH) and the Lower Rappahannock River (RPPMH). Degrading trends in secchi depth were observed in all segments of this tributary except the Upper Rappahannock River (RPPTF) (Figure 24).

3. Living Resources

The status of most phytoplankton indicators was poor with total biomass, the biomass to abundance ratio, and primary productivity being poor throughout the Rappahannock River. However, the status of cryptophyte biomass was good throughout the Rappahannock River (Figure 25). Status of diatom biomass was fair in all segments. Improving trends in the diatom and chlorophyte biomass occurred at stations TF3.3 in the Middle Rappahannock River (RPPOH) and RET3.1 in the Lower Rappahannock River (RPPMH) along with improving trends in the biomass to abundance ratio and picoplankton abundance at station TF3.3 in the Middle Rappahannock River (RPPOH) and station LE3.6 in the Middle Rappahannock River (RPPMH), respectively. Degrading trends were detected in cyanophyte biomass, cyanobacteria abundance and primary productivity throughout the Rappahannock River. Degrading trends in Margalef diversity and dinoflagellate biomass were also observed at station LE3.6 in the Lower Rappahannock River (RPPMH) (Figure 25). There is a similar pattern in the Rappahannock, as in the James and York, of increasing cyanobacteria abundance and biomass. Within this category is the HAB species *Microcystis aeruginosa*, a known toxin producer. Any increase pattern of development of this taxon within the cyanobacteria category is important relative to the health status in these waters. An additional concern is that there appears to be no significant positive biomass trends for the more favorable diatoms and chlorophytes in the lower reaches of the Rappahannock, plus the increasing trend in dinoflagellate biomass. Dinoflagellates of concern here are *Prorocentrum minimum* and *Cochlodinium polykrikoides*, with any increase in growth for these HAB taxa unfavorable for this region.

Benthic community status met the restoration goals only at station TF3.3 in the Middle Rappahannock River (RPPOH) and in general became more degraded moving downstream with most stations in the Lower Rappahannock River (RPPMH) being severely degraded. A degrading trend in the B-IBI was detected at station RET3.1 in the Middle Rappahannock River (RPPMH) (Figure 26). Probability-based benthic monitoring results indicated that 76% of the total area of the Rappahannock River is impaired (Llansó et al., 2007). Previous studies indicate benthic degradation in the Upper Rappahannock River appears to be the result of anthropogenic contamination while degradation in the lower segments of the river may be the result of a combination of contamination and low dissolved oxygen effects (Dauer et al., 2005c; Llansó et al.,2005).

4. Management Issues

Water quality problems appear to be more severe in the upper segments of the Rappahannock River and include poor status and violations of SAV habitat criteria for both suspended solids and secchi depth along with increasing trends in either total or dissolved nitrogen concentrations. Water clarity may also be degrading in the lower portion of the river as indicated by decreasing trends in secchi depth observed during the SAV growing season. Issues with phytoplankton communities include poor status and degrading trends in cyanobacteria biomass, cyanobacteria abundance and primary productivity throughout the basin, as well as, poor status and degrading trends in Margalef species diversity and dinoflagellate abundance in the Lower Rappahannock River. The pattern of increasing trends in cyanobacteria development is exhibited not only in each of the Virginia rivers mentioned in this report, but also the Potomac River located north of the Rappahannock River. Already major blooms of cyanobacteria occur annually in the Potomac. If the increasing trends among the cyanobacteria continue, management concerns will include the impact of any long term, extensive development of these taxa within Virginia rivers. It is noted that several of the cyanobacteria identified in Virginia rivers through this monitoring are potential toxin producers. One of the most common species is *Microcystis aeruginosa*, which to date has not produced major toxic blooms in the James, York, or Rappahannock Rivers, but has been associated with blooms and the toxin microcystin in several of the Virginia bays and streams bordering the Potomac River. Status of benthic communities for fixed point monitoring stations was degraded at stations in the Lower Rappahannock River probably as a result of low dissolved oxygen. Degrading trends were detected in B-IBI and at the uppermost station of Lower Rappahannock River (RPPMH). Probability-based monitoring results indicated that a large proportion of the total area of the Rappahannock River is degraded probably as a result of both anthropogenic contamination and low dissolved oxygen.

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Tables

Table 1. Definitions of seasonal time periods for status and trend analyses conducted for of the tidal monitoring programs. A “x” indicates the analysis was conducted for the season and parameter group combination while a “-“ indicates that no analysis was conducted. Benthic status and trend analyses were conducted on data collected from July 15 through September 30*.

		Water Quality			Plankton		Benthos	
Season	Definition	Status	Trend	SAV Goals	Status	Trend	Status	Trend
Annual	Entire year	x	x	-	x	x	-	-
SAV1	March through May and September through November	x	x	x	x	x	-	-
SAV2	April through October	x	x	-	x	x	-	-
Summer1	June through September	x	x	-	x	x	-	-
Summer2	July through September	x	x	-	x	x	x*	x*
Spring1	March through May	x	x	-	x	x	-	-
Spring2	April through June	x	x	-	x	x	-	-
Fall	October through December	-	x	-	x	x	-	-
Winter	January and February	-	x	-	x	x	-	-

Table 2. Habitat requirements for growth and survival of SAV (from Batiuk et al., 1992; 2000).

Salinity Regime	SAV Growth Season	Secchi Depth (m)	Total Suspended Solids (mg/l)	Chlorophyll *a* (µg/l)	Dissolved Inorganic Nitrogen (mg/l)	Dissolved Inorganic Phosphorus (mg/l)
Tidal Freshwater	Apr.-Oct.	<2	<15	<15	none	<0.02
Oligohaline	Apr.- Oct.	<2	<15	<15	none	<0.02
Mesohaline	Apr.-Oct.	<1.5	<15	<15	<0.15	<0.01
Polyhaline	Mar.-May, Sep.-Nov.	<1.5	<15	<15	<0.15	<0.01

Table 3. Comparison of land use and population patterns between A. Watersheds of the Virginia portion of Chesapeake Bay, B. Sub-watersheds of the James River, C. Sub-watersheds of the York River and D. Sub-watersheds of the Rappahannock River. Land use values are expressed as the total area in km^2 within each watershed or sub-watershed and in parentheses as percentages of the total area within the watershed or sub-watershed. Note that the Impervious Surface land use category encompasses portions of the other land use types. Riparian buffers are measured in km of shoreline with a 30 m riparian buffer. Population values are provided as both total number per watershed or sub-watershed and densities expressed in the number of individuals per km^2. All land use and population data presented were provided by and/or modified from data available from the USEPA's Chesapeake Bay Program Watershed Profiles website: http://www.chesapeakebay.net/wspv31/.

A. Watersheds of the Virginia portion of Chesapeake Bay

	Land Use Area in km^2 (percent of total)									
Watershed	**Total Area**	**Developed**	**Agriculture**	**Forested**	**Open Water**	**Wetland**	**Barren**	**Impervious Surfaces**	**Riparian Buffers (%)**	**Pop. Number/ Density(#/km^2)**
Chesapeake Bay	171,944	6,239(3.6)	48,938(28.5)	103,343(60.1)	7,415(4.3)	4,421(2.6)	1,551(0.9)	3,026(1.8)	110,134 (58.5)	15,594,241(91)
James River	27,019	1,222(4.5)	4,605(17.0)	19,119(70.8)	989(3.7)	704(2.6)	365(1.4)	511(1.9)	16,636(60.2)	2,522,583(93)
York River	8,469	192(2.3)	1,761(20.8)	5,159(60.9)	647(7.6)	575(6.8)	135(1.6)	81(1.0)	6,062(60.3)	372,488(44)
Rappahannock River	7,029	124(1.8)	2,207(31.4)	4,009(57.0)	443(6.3)	171(2.4)	75(1.1)	46(0.7)	3,672(35.6)	240,754(34)

B. Sub-watersheds of the James River

	Land Use Area in km^2 (percent of total)									
Subwatershed	**Total Area**	**Developed**	**Agriculture**	**Forested**	**Open Water**	**Wetland**	**Barren**	**Impervious Surfaces**	**Riparian Buffers (%)**	**Pop. Number/ Density(#/km^2)**
AFL Upper James	7,938	67(0.8)	1158(14.6)	6630(83.5)	44(0.6)	10(0.1)	26(0.3)	24(0.3)	4427(40)	313780(40)
AFL North of Hopewell	642	171(26.6)	127(19.8)	280(43.5)	31(4.8)	18(2.8)	16(2.4)	68(10.6)	359(33)	367126(572)
AFL Piedmont	12,362	184(1.5)	2173(17.6)	9438(76.3)	114(0.9)	212(1.7)	243(2.0)	49(0.4)	8061(40)	186360(15)
AFL Richmond	790	91(11.5)	179(22.6)	461(58.4)	23(3.0)	28(3.6)	8(1.0)	30(3.8)	478(37)	60550(77)
AFL Swift Creek	471	21(4.4)	60(12.6)	376(79.7)	8(1.6)	3(0.5)	5(1.1)	10(2.1)	346(43)	188746(400)
AFL Upper Chickahominy	787	137(17.4)	148(18.8)	394(50.0)	10(1.3)	91(11.5)	8(1.0)	49(6.3)	739(32)	85669(109)
Appomattox	212	47(22.0)	44(20.7)	101(47.6)	5(2.4)	8(2.7)	8(3.7)	19(9.0)	121(32)	84765(399)
Lower Chickahominy	430	5(1.2)	52(12.0)	277(64.5)	39(9.0)	52(12.0)	5(1.2)	2(0.4)	537(34)	10343(24)
Upper Tidal James	730	18(2.5)	135(18.4)	445(61.0)	93(12.8)	31(4.3)	5(0.7)	9(1.2)	419(34)	36769(50)
Middle Tidal James	368	13(3.5)	62(16.9)	168(45.8)	96(26.1)	28(7.7)	3(0.7)	7(1.9)	311(35)	39886(108)
Lower Tidal James	803	73(9.0)	137(17.1)	256(31.9)	272(33.9)	62(7.7)	5(0.6)	30(3.8)	371(26)	166367(207)
Nansemond	559	28(5.1)	181(32.4)	197(35.2)	60(10.6)	85(15.3)	10(1.9)	14(2.5)	248(22)	49578(89)
Elizabeth River/Hampton Roads	668	259(38.8)	114(17.1)	52(7.8)	163(24.4)	67(10.1)	13(1.9)	141(21.1)	74(9)	594760(890)

Table 3. Continued. Land use values are expressed as the total area in km^2 within each watershed or sub-watershed and in parentheses as percentages of the total area within the watershed or sub-watershed. Note that the Impervious Surface land use category encompasses portions of the other land use types. Riparian buffers are measured in km of shoreline with a 30 m riparian buffer. Population values are provided as both total number per watershed or sub-watershed and densities expressed in the number of individuals per km^2. All land use and population data presented were provided by and/or modified from data available from the USEPA's Chesapeake Bay Program Watershed Profiles website: http://www.chesapeakebay.net/wspv31/.

C. Sub-watersheds of the York River										
	Land Use Area in km^2 (percent of total)									
Sub-watershed	**Total Area**	**Developed**	**Agriculture**	**Forested**	**Open Water**	**Wetland**	**Barren**	**Impervious Surfaces**	**Riparian Buffers (%)**	**Pop. Number/ Density(#/km^2)**
Above Fall-Line Pamunkey	2748	31(1.1)	645(23.5)	1870(68.0)	67(2.5)	75(2.7)	62(2.3)	11(0.4)	1720(65)	55111(20)
Upper Pamunkey	785	21(2.6)	243(31.0)	425(54.1)	13(1.7)	67(8.6)	13(1.7)	6(0.8)	686(74)	33911(43)
Lower Pamunkey	282	3(0.9)	44(15.6)	150(53.2)	31(11.0)	49(17.4)	5(1.8)	1(0.5)	189(38)	3696(13)
Above Fall-Line Mattaponi	1023	16(1.5)	199(19.5)	717(70.1)	10(1.0)	52(5.1)	23(2.3)	13(1.3)	816(81)	32564(32)
Upper Mattaponi	805	3(0.3)	179(22.2)	541(67.2)	10(1.3)	54(6.8)	16(1.9)	2(0.3)	774(87)	8430(10)
Lower Mattaponi	534	5(1.0)	111(20.9)	350(65.5)	23(4.4)	47(8.7)	3(0.5)	2(0.4)	482(67)	7577(14)
Upper Tidal York	523	10(2.0)	80(15.3)	293(55.9)	91(17.3)	47(8.9)	3(0.5)	5(1.0)	376(53)	23676(45)
Lower Tidal York	215	10(4.8)	26(12.0)	78(36.1)	85(39.8)	13(6.0)	0(0)	5(2.2)	91(31)	21072(98)
Mobjack Bay	671	10(1.5)	88(13.1)	272(40.5)	205(30.5)	93(13.9)	5(0.8)	5(0.7)	270(27)	24929(37)
D. Sub-watersheds of the Rappahannock River										
	Land Use Area in km^2 (percent of Sub-watershed total)									
Sub-Watershed	**Total Area**	**Developed**	**Agriculture**	**Forested**	**Open Water**	**Wetland**	**Barren**	**Impervious Surfaces**	**Riparian Buffers (%)**	**Pop. Number/ Density(#/km^2)**
AFL Rappahannock	4035	57(1.4)	1466(36.3)	2463(61.0)	16(0.4)	10(0.3)	28(0.7)	16(0.4)	1470(32.2)	101306(25)
Upper Tidal Rappahannock	878	41(4.7)	223(25.4)	521(59.3)	31(3.5)	47(5.3)	16(1.8)	21(2.4)	682(41.3)	97960(112)
Middle/Lower Rappahannock	982	16(1.6)	282(28.8)	502(51.2)	85(8.7)	80(8.2)	16(1.6)	5(0.5)	825(38.7)	12373(13)
Lower Rappahannock	694	8(1.1)	155(22.4)	339(48.9)	155(22.4)	28(4.1)	13(1.9)	3(0.4)	449(37.2)	10480(15)
Mouth of Rappahannock	440	8(1.8)	80(18.2)	184(41.8)	155(35.3)	8(1.8)	5(1.2)	2(0.5)	244(32.0)	10786(24)

Table 4. Nutrient and Sediment A. Non-point Source and B. Point Source and C Total Loadings for Virginia tributaries for 2005, modified from data provided by the Virginia Department of Environmental Quality. Phosphorous and nitrogen loads are in kg/yr and sediment loads are metric tonnes per year (t/yr). Percent changes compare 2005 data to 1985 data. Non-point source loads are results based on the Year 2005 Progress Run of the Chesapeake Bay Watershed Model and calculated reductions for calendar year 2005 Best Management Practices (BMPs) as monitored by the Department of Conservation and Recreation and are expressed as delivered loads. Point source loadings are expressed as delivered loads. Number of major point sources for each watershed are provided in parentheses to the right of the watershed name.

A. Non point Sources

Tributary	2005 Phosphorus Loads (kg/yr)	% Change	2005 Nitrogen Loads (kg/yr)	% Change	2005 Sediment Loads (kg/yr)	% Change
James	1,760,581	-15	9,662,332	-10	1,007,791	-13
York	268,426	-19	2,823,614	-18	111,330	-22
Rappahannock	378,556	-23	3,114,229	-26	285,506	-25
Potomac	1,540,053	-15	18,326,447	-10	1,546,638	-16
Eastern Shore	83,170	-15	830,857	-11	17,875	-7

B. Point Sources

Tributary	2005 Phosphorus Loads (kg/yr)	% Change	2005 Nitrogen Loads (kg/yr)	% Change
James (37)	679,950	-62	7,140,824	-33
York (10)	63,957	-67	515,687	-12
Rappahannock (18)	25,245	-70	255,471	+12
Potomac (39)	400,415	-33	5,463,945	-53
Eastern Shore (5)	2,803	+1	55,169	-58

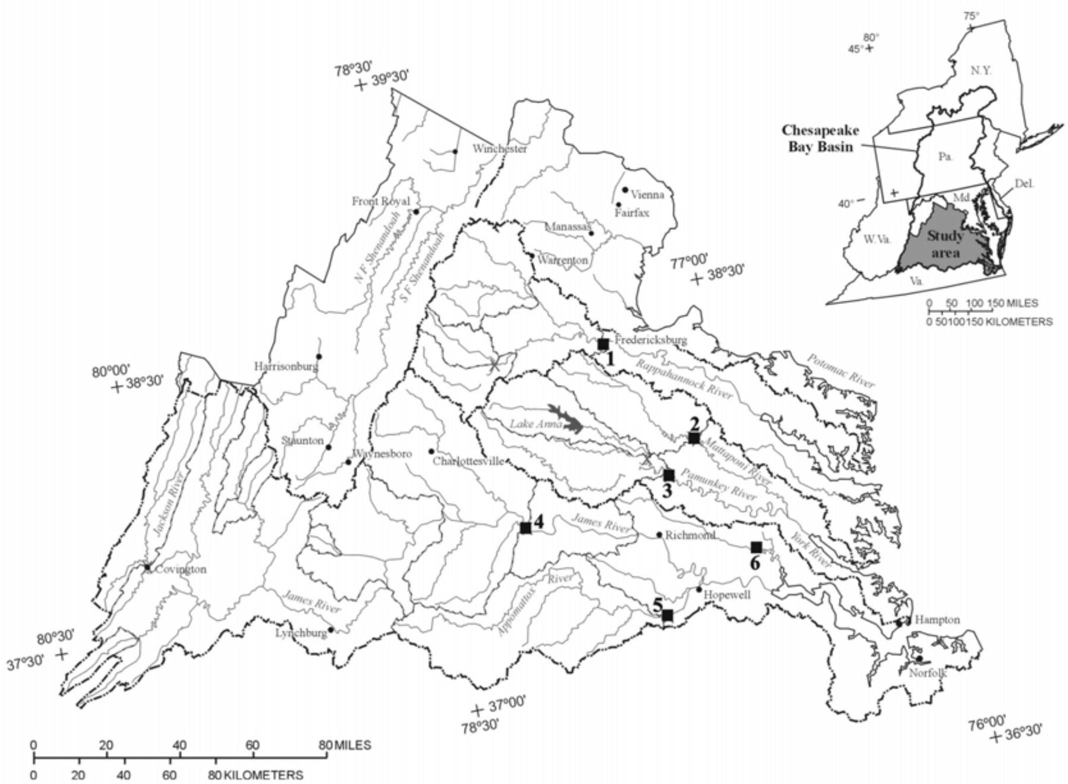
C. Total

Tributary	2005 Phosphorus Loads (kg/yr)	% Change	2005 Nitrogen Loads (kg/yr)	% Change	2005 Sediment Loads (kg/yr)	% Change
James	2,440,531	-37	16,803,156	-21	1,007,791	-13
York	332,383	-36	3,339,301	-18	111,330	-22
Rappahannock	403,801	-30	3,369,699	-24	285,506	-25
Potomac	1,940,468	-19	23,790,393	-26	1,546,638	-16
Eastern Shore	85,974	-14	886,027	-17	17,875	-7

Table 5. Long-term trends in nutrients and total suspended solids at Chesapeake Bay River Input Monitoring Program stations located at or near the fall-line for each of the major Virginia tributaries for the period of 1984 through 2006. Results provided and modified from U.S. Geological Survey.

Station	Location	Parameter	P-Value	Slope	% Change	Direction
01668000	Rappahannock River near Fredericksburg	TN	0.9293	0.0185	2	No trend
01668000	Rappahannock River near Fredericksburg	NO23	0.2496	-0.3974	-33	No trend
01668000	Rappahannock River near Fredericksburg	TP	0.6497	-0.1687	-16	No trend
01668000	Rappahannock River near Fredericksburg	DIP	0.6501	0.0932	10	No trend
01668000	Rappahannock River near Fredericksburg	TSS	0.6727	0.2114	24	No trend
01673000	Pamunkey River near Hanover	NO23	<0.0001	0.398	49	Degrading
01673000	Pamunkey River near Hanover	TP	<0.0001	0.6066	83	Degrading
01673000	Pamunkey River near Hanover	DIP	<0.0001	1.3159	273	Degrading
01673000	Pamunkey River near Hanover	TSS	0.1006	0.5031	65	No trend
01674500	Mattaponi River near Beulahville	TN	0.0167	-0.1607	-15	Improving
01674500	Mattaponi River near Beulahville	NO23	0.0087	-0.3717	-31	Improving
01674500	Mattaponi River near Beulahville	TP	0.0639	-0.2011	-18	No trend
01674500	Mattaponi River near Beulahville	DIP	0.2145	0.1477	16	No trend
01674500	Mattaponi River near Beulahville	TSS	0.6878	0.0829	9	No trend
02035000	James River at Cartersville	TN	0.2779	-0.1602	-15	No trend
02035000	James River at Cartersville	NO23	0.0008	-0.6626	-49	Improving
02035000	James River at Cartersville	TP	<0.0001	-0.8097	-56	Improving
02035000	James River at Cartersville	DIP	<0.0001	-1.589	-80	Improving
02035000	James River at Cartersville	TSS	0.4016	-0.3207	-27	No trend
02041650	Appomattox River at Matoaca	TN	0.6562	0.0335	3	No trend
02041650	Appomattox River at Matoaca	NO23	0.2472	-0.1914	-17	No trend
02041650	Appomattox River at Matoaca	TP	0.7882	0.0426	4	No trend
02041650	Appomattox River at Matoaca	DIP	0.1119	-0.2122	-19	No trend
02041650	Appomattox River at Matoaca	TSS	0.7844	-0.0591	-6	No trend
02042500	Chickahominy River near Providence Forge	TN	0.9609	0.0036	0	No trend
02042500	Chickahominy River near Providence Forge	NO23	0.5301	-0.2839	-25	No trend
02042500	Chickahominy River near Providence Forge	TP	0.0596	0.2544	29	No trend
02042500	Chickahominy River near Providence Forge	TSS	0.8265	0.0501	5	No trend

Figures



1 Station 01668000 - Rappahannock River near Fredericksburg
2 Station 01674500 - Mattaponi River near Beulahville
3 Station 01673000 - Pamunkey River near Hanover
4 Station 02035000 - James River at Cartersville
5 Station 02041650 - Appomattox River
6 Station 02042500 - Chickahominy River

Figure 1. Locations of the USGS/DEQ River Input Monitoring stations in each of the Virginia tributaries.

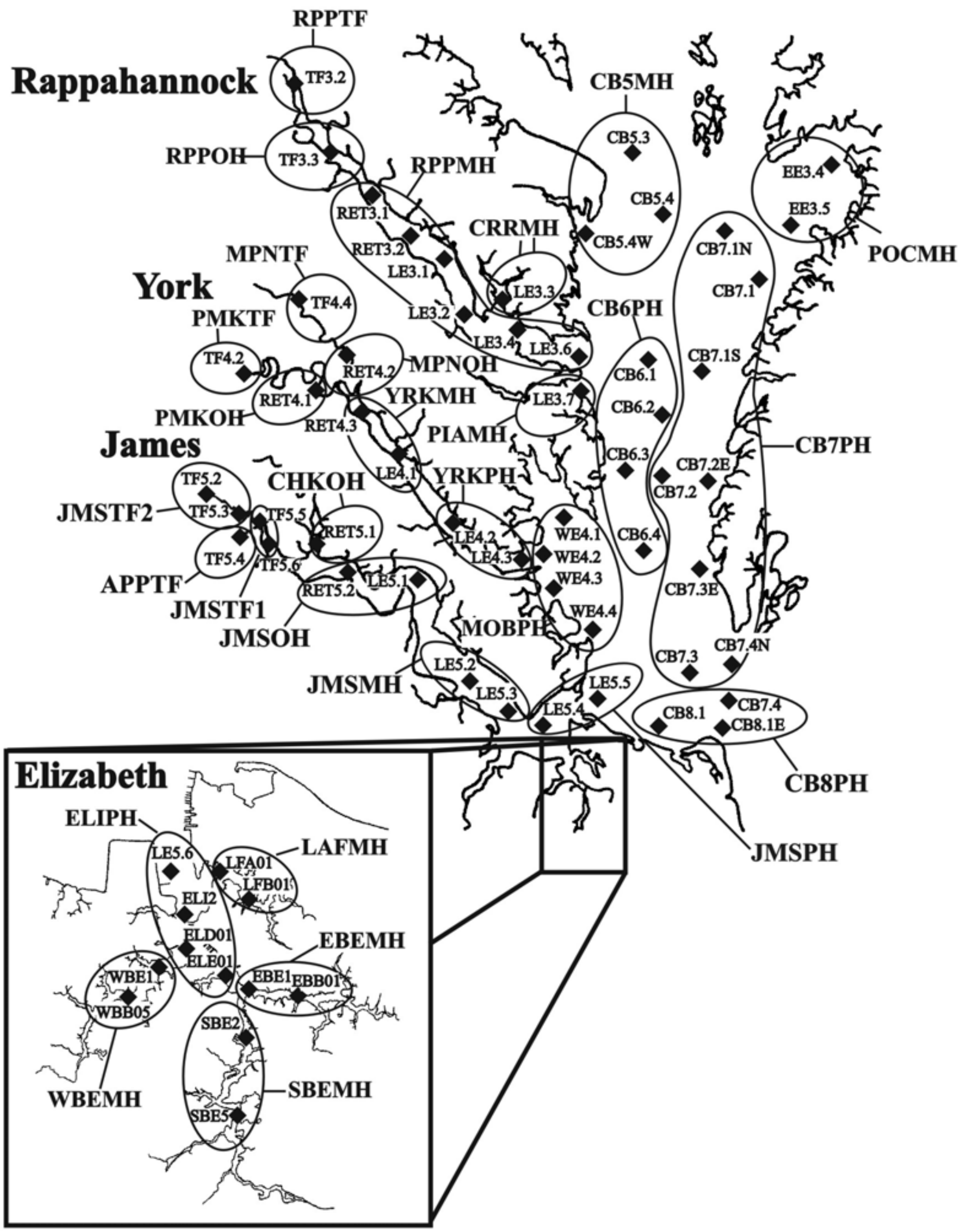


Figure 2. Map showing the locations of the water quality monitoring stations in the Virginia tributaries and the Lower Chesapeake Bay main stem used in the statistical analyses. Also shown are ellipses that delineate the Chesapeake Bay Program segmentation scheme.

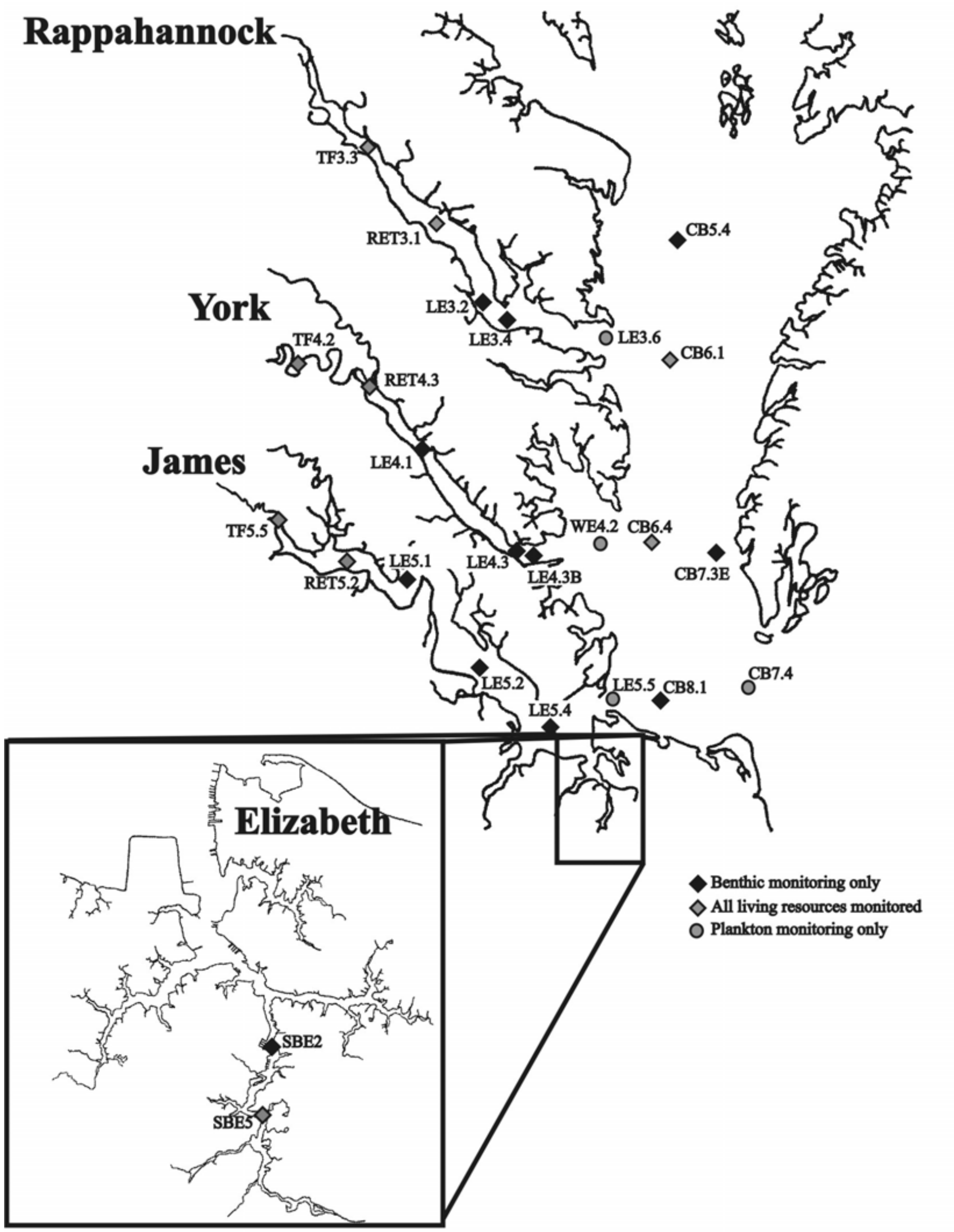


Figure 3. Location of living resource monitoring stations in the Virginia tributaries and the Lower Chesapeake Bay main stem.

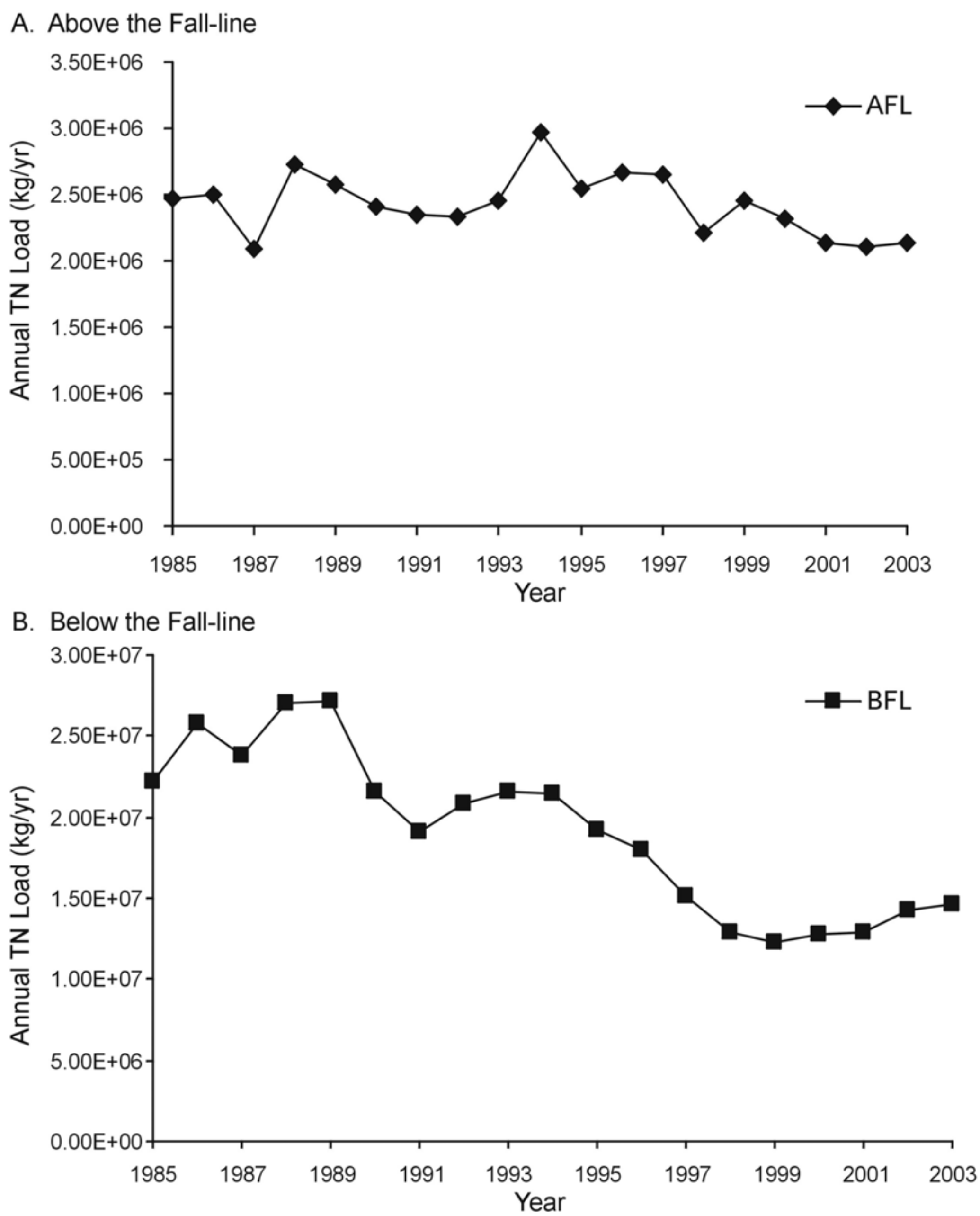


Figure 4. Long-term changes in above fall-line (AFL) and below fall-line (BFL) point source Total Nitrogen Loadings A. Above the Fall-line, and B. Below the Fall-line in the James River for 1985 through 2003.

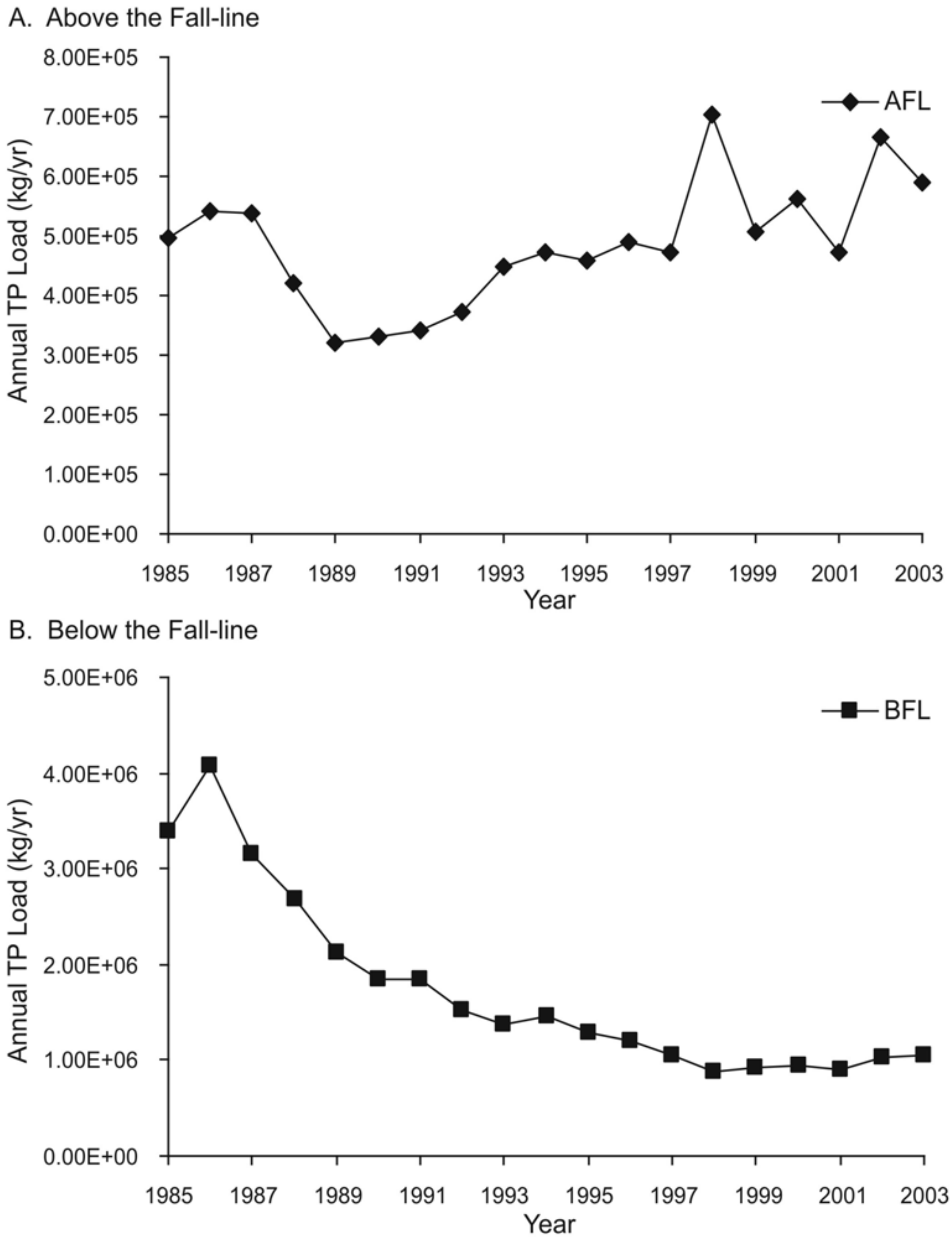
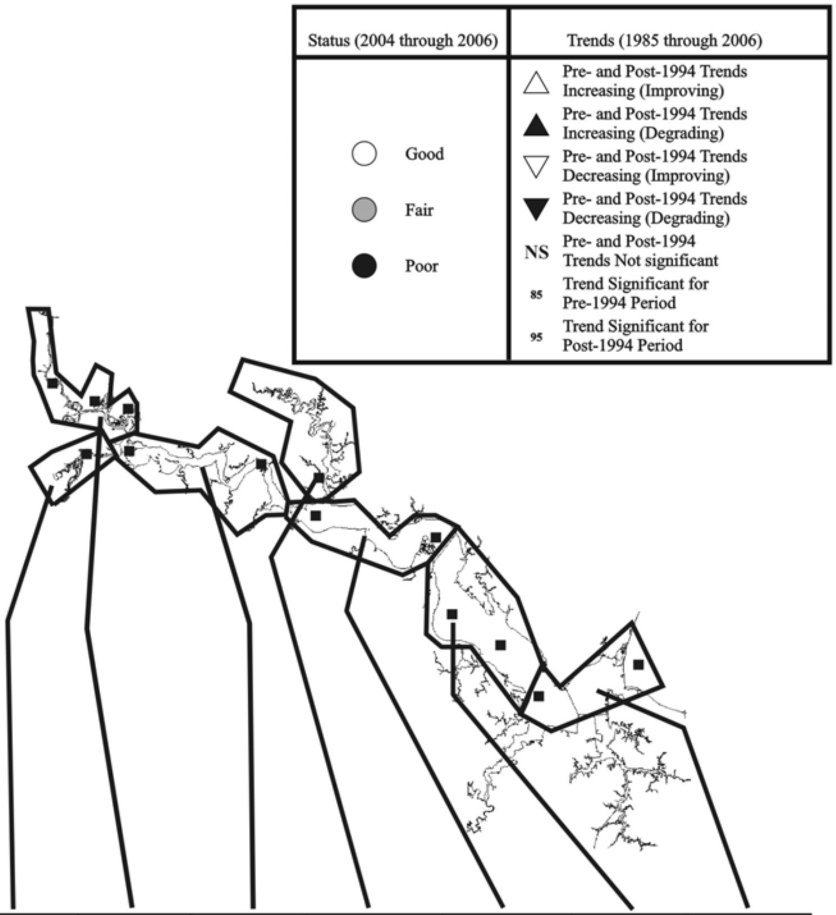
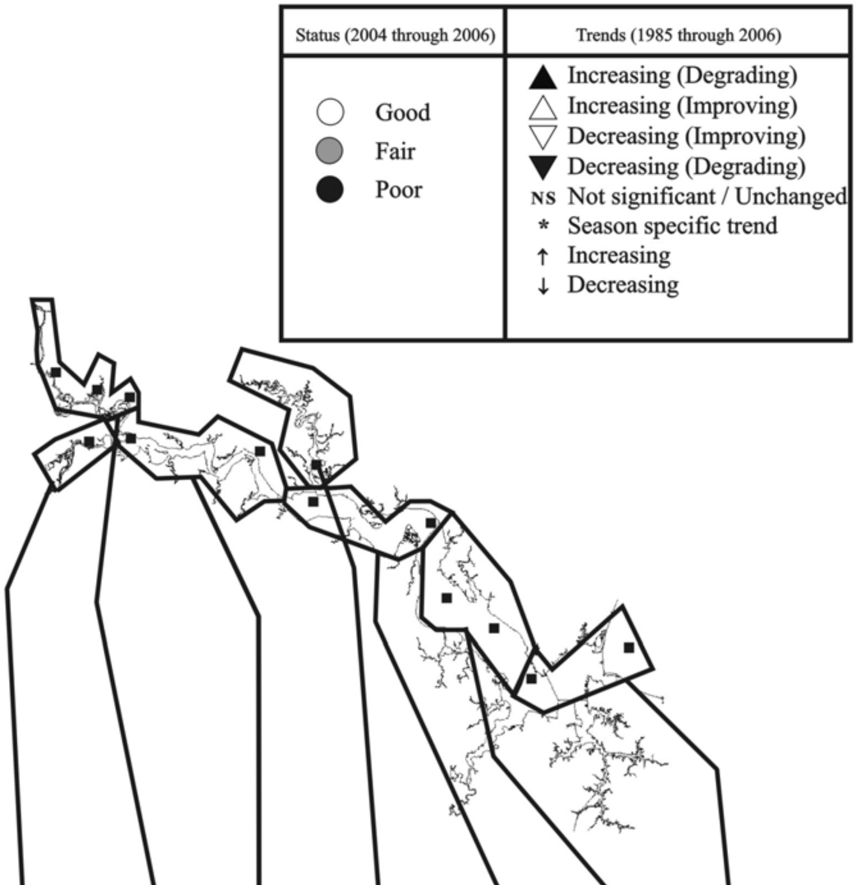


Figure 5. Long-term changes in above fall-line (AFL) and below fall-line (BFL) point source Total Phosphorus Loadings A. Above the Fall-line, and B. Below the Fall-line in the James River for 1985 through 2003.



Parameter	Appomattox	Upper James 2	Upper James 1	Chickahominy	Middle James	Lower James	River Mouth
STN	○ NS	○ ▽85 ▲95	○ ▽	○ NS	○ NS	○ NS	○ NS
BTN	○ NS	○ ▽85 ▲95	○ ▽95	○ NS	○ NS	○ NS	◍ NS
SDIN	○ NS	○ ▽85	○ NS	○ NS	○ ▽85	◍ NS	○ NS
BDIN	○ NS	○ ▽85	○ NS	○ NS	○ ▽85	◍ NS	◍ NS
STP	○ NS	○ ▽85	○ ▽95	○ NS	○ NS	◍ ▲85	◍ NS
BTP	○ NS	○ ▽85	○ ▲85 ▽95	○ ▽95	◍ ▲85	◍ ▲85	◍ NS
SDIP	○ ▽	◍ ▽	○ ▽	○ NS	◍ NS	● NS	◍ NS
BDIP	○ ▽	◍ ▽	◍ ▽	○ NS	◍ NS	◍ NS	○ NS

Figure 6. Map of the James River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2006. Abbreviations for each parameter are: TN=total nitrogen, DIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.



Parameter	Appomattox	Upper James 2	Upper James 1	Chickahominy	Middle James	Lower James	River Mouth
SCHLA	Good NS	Good NS	Good NS	Fair ▽	Good NS	Good NS	Poor ▲
STSS	Poor NS	Fair NS	Poor NS	Fair NS	Poor NS	Fair NS	Fair NS
BTSS	Fair NS	Fair NS	Poor NS	Poor ▲	Poor NS	Poor ▲	Fair NS
SECCHI	Poor NS	Fair NS	Fair ▼	Fair ▼	Poor NS	Poor NS	Poor ▼
BDO	Good △	Good NS	Good △	Good NS	Good NS	Good NS	Good △
SSALIN	NS	NS	NS	NS	NS	NS	↓
BSALIN	NS	NS	NS	NS	NS	NS	↓
SWTEMP	↑	NS	NS	NS	NS	NS	NS
BWTEMP	NS	NS	NS	NS	NS	NS	↑

Figure 7. Map of the James River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2006. Abbreviations for each parameter are: CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=secchi depth, DO=dissolved oxygen, WTEMP=water temperature, SALIN=salinity. The prefixes S and B refer to surface and bottom measurements, respectively.

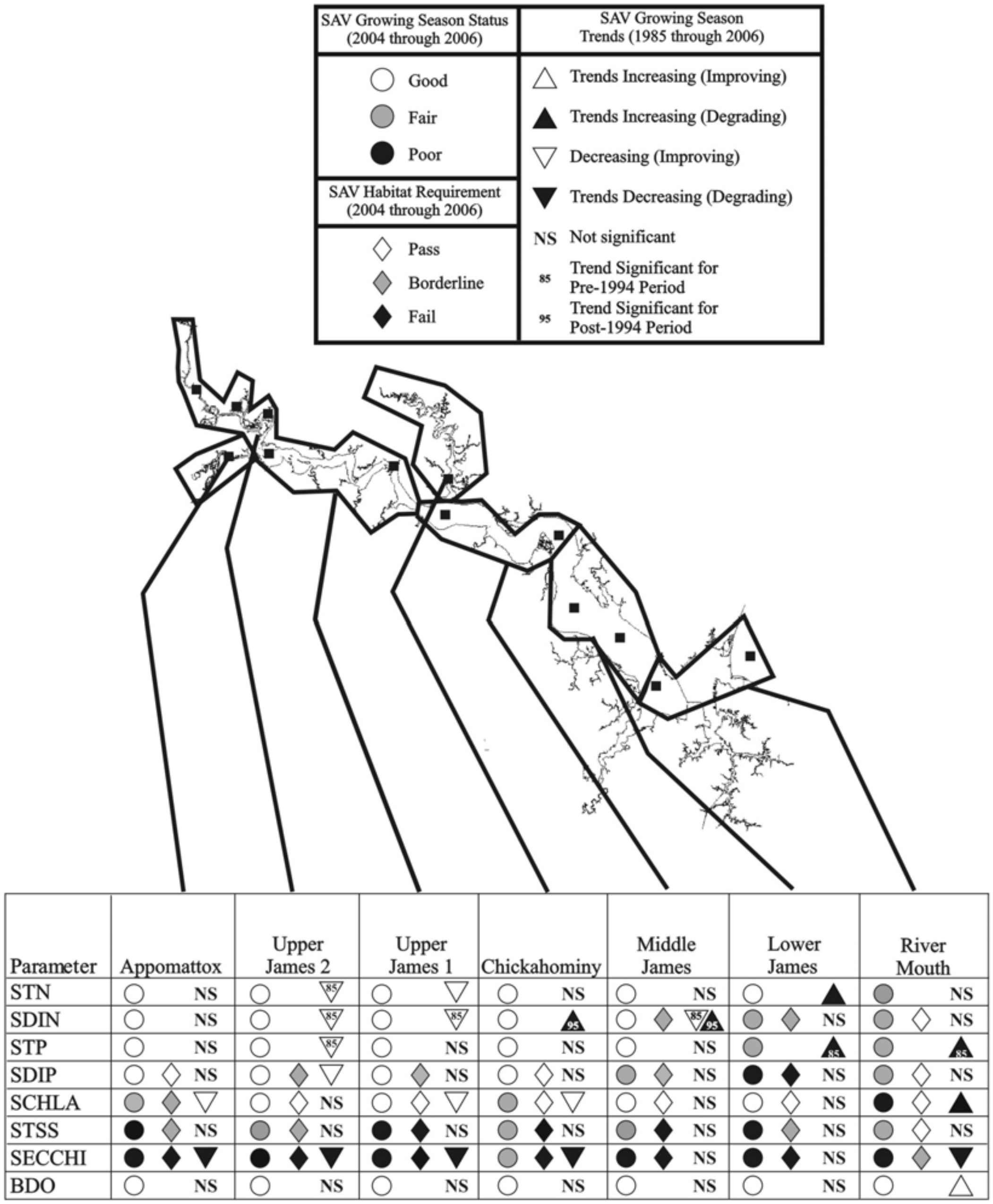
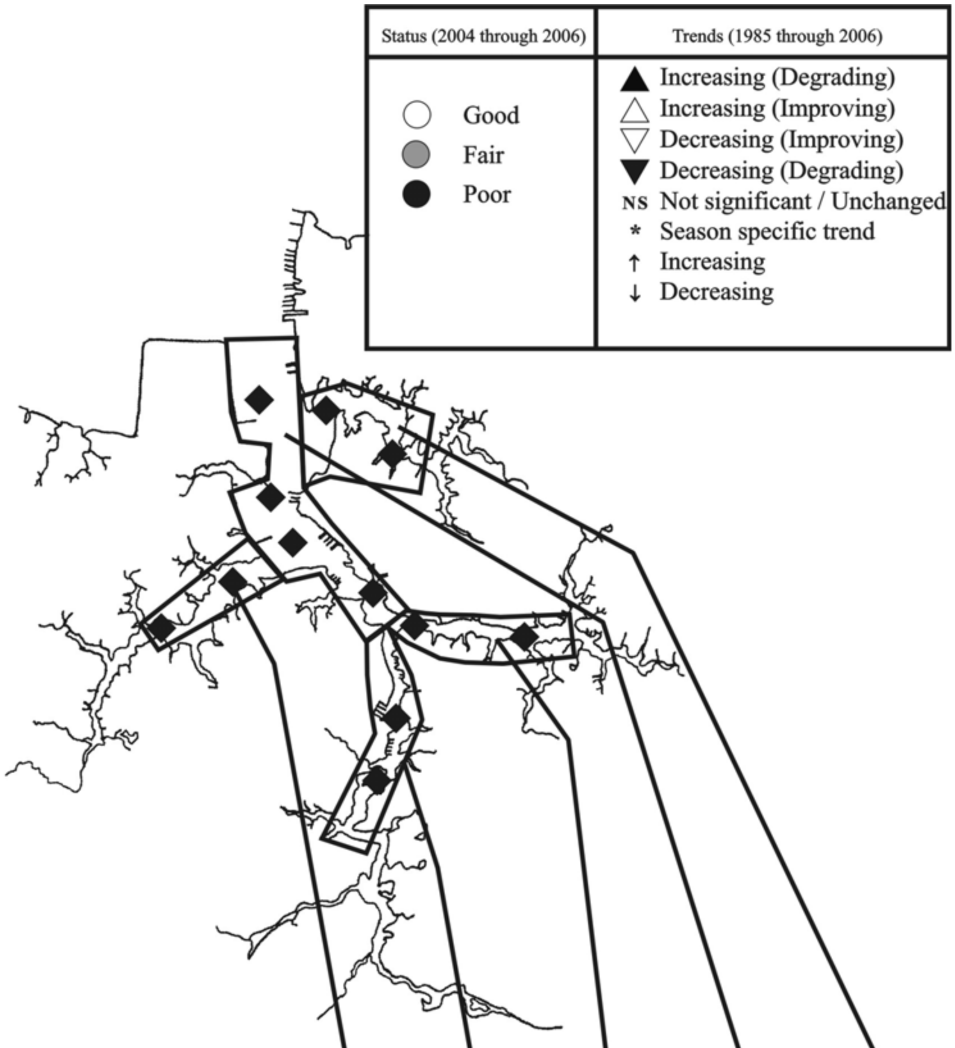
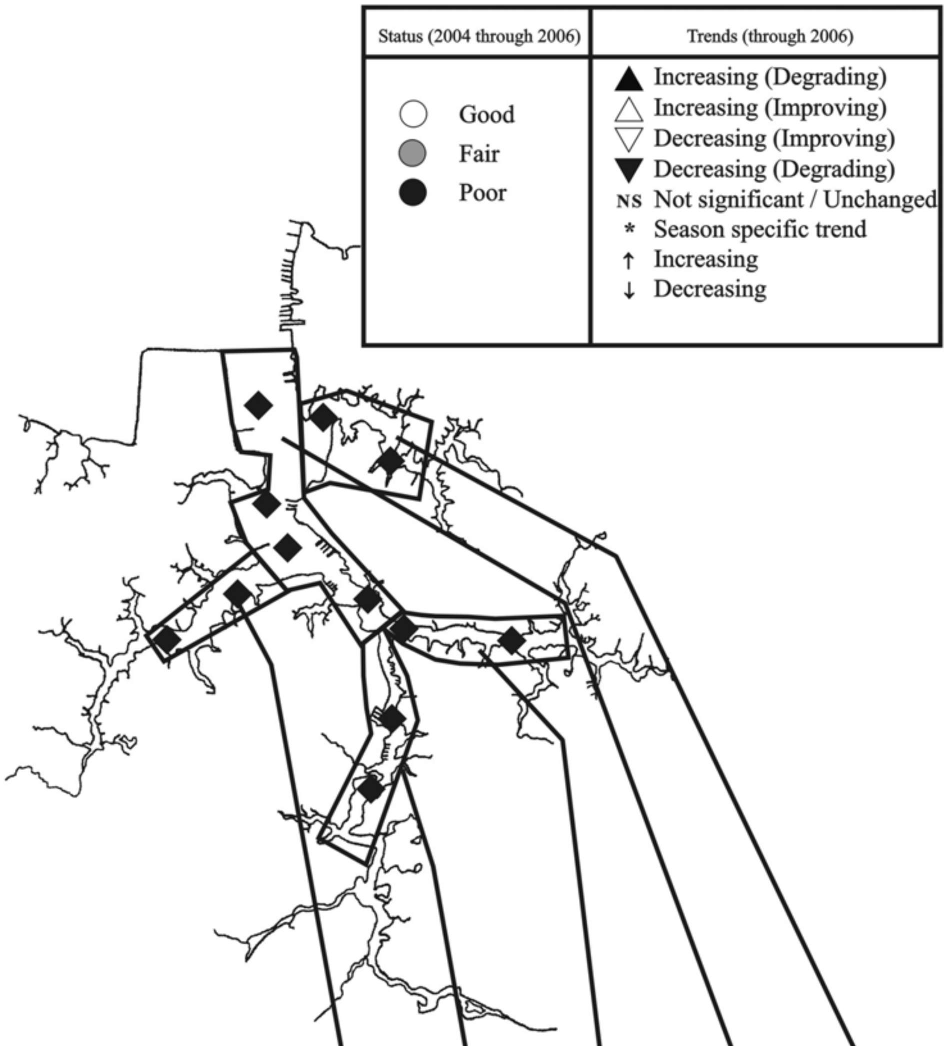


Figure 8. Map of the James River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2006 for the SAV growing season. Abbreviations for each parameter are: TN=total nitrogen, SDIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus, CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=Secchi depth, DO=dissolved oxygen. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.



Parameter	Western Branch	Southern Branch	Eastern Branch	Elizabeth River Mainstem	Lafayette River
STN	◍ NS	● ▽	◍ NS	◍ NS	◍ NS
BTN	◍ NS	● NS	● ▽	● NS	◍ NS
SDIN	◍ NS	● ▽	● ▽	● NS	◍ NS
BDIN	◍ NS	● NS	● NS	● NS	◍ NS
STP	● NS	◍ ▽	◍ ▽	● NS	● NS
BTP	◍ NS	◍ ▽	◍ ▽	● NS	◍ NS
SDIP	● NS	● ▽	● NS	● NS	◍ NS
BDIP	◍ NS	● ▽	● ▽	● NS	◍ NS

Figure 9. Map of the Elizabeth River basin showing summaries of the status and trend analyses for each segment for the period of 1989 through 2006. Abbreviations for each parameter are: TN=total nitrogen, DIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP= dissolved inorganic phosphorus. The prefixes S and B refer to surface and bottom measurements, respectively.



Parameter	Western Branch	Southern Branch	Eastern Branch	Elizabeth River Mainstem	Lafayette River
SCHLA	● NS	○ NS	◍ NS	◍ NS	● NS
STSS	● NS	◍ ▽	◍ ▽	◍ ▽	● NS
BTSS	● NS	○ ▽	○ ▽	◍ ▽	● NS
SECCHI	● NS	● NS	● NS	● ▼	● NS
BDO	○ NS	◍ △	◍ △	○ NS	○ △
SSALIN	NS	NS	NS	NS	NS
BSALIN	NS	NS	NS	↓	NS
SWTEMP	NS	↑	NS	↑	NS
BWTEMP	↑	↑	↑	NS	NS

Figure 10. Map of the Elizabeth River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2006. Abbreviations for each parameter are: CHLA=chlorophyll a, TSS=total suspended solids, SECCHI=secchi depth, DO=dissolved oxygen, WTEMP=water temperature, SALIN=salinity. The prefixes S and B refer to surface and bottom measurements, respectively.

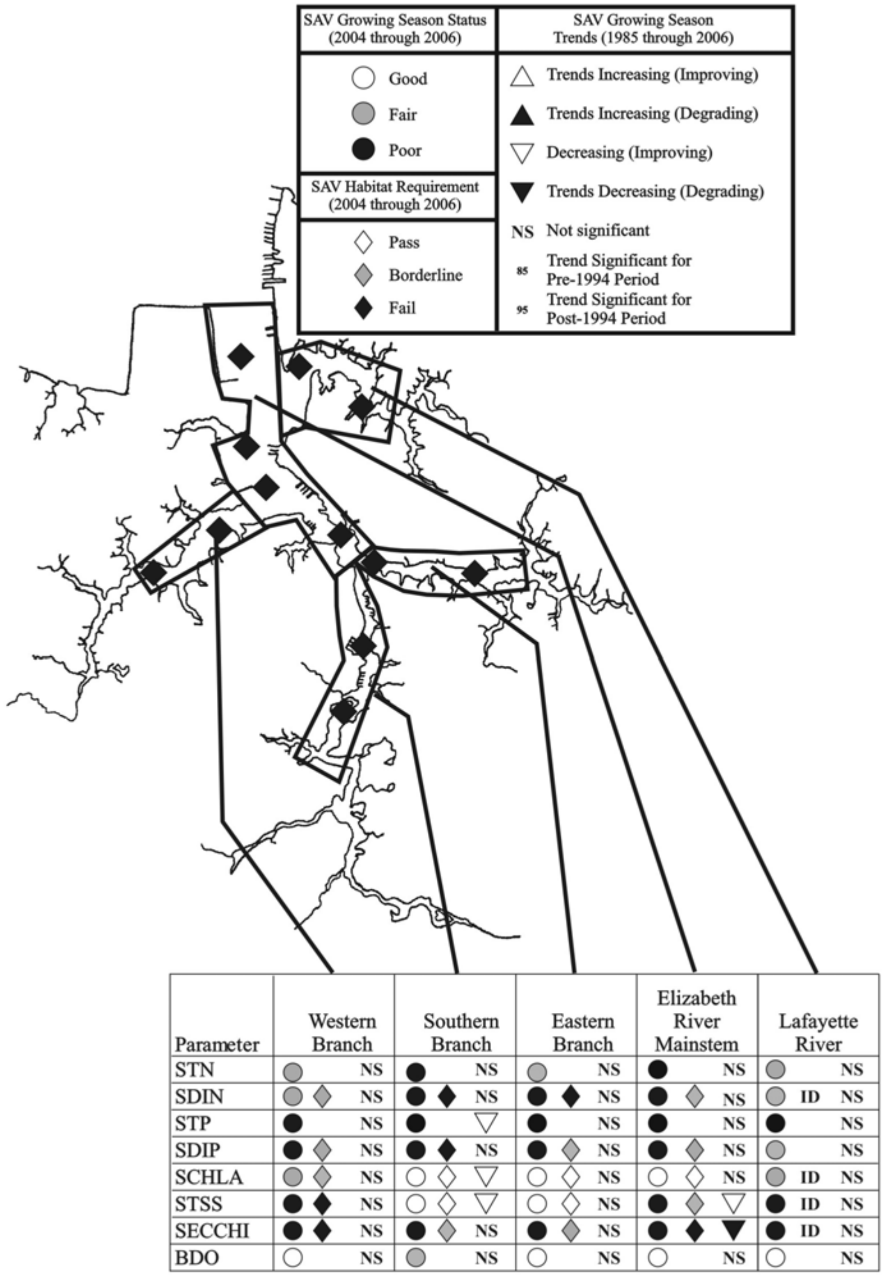
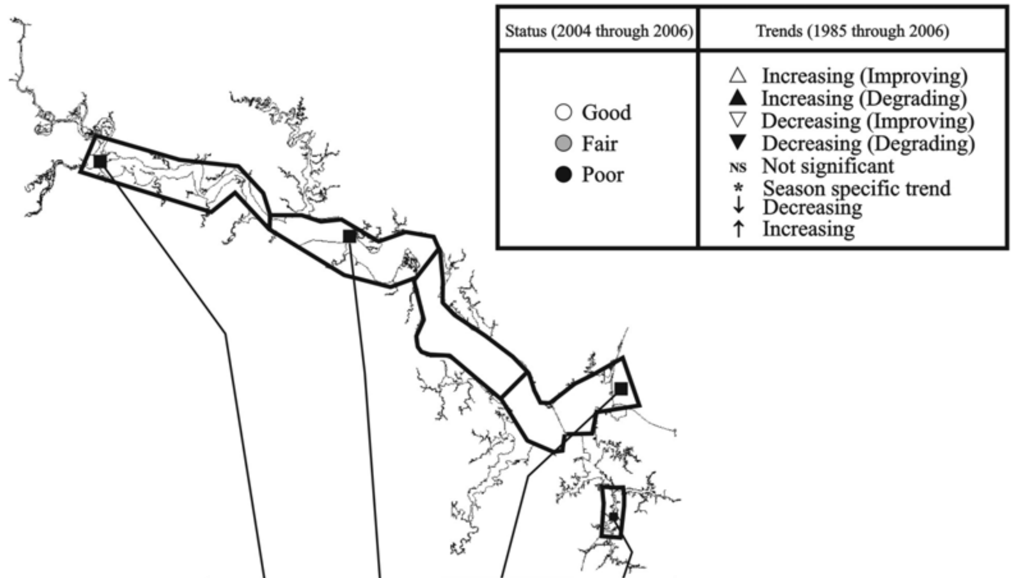
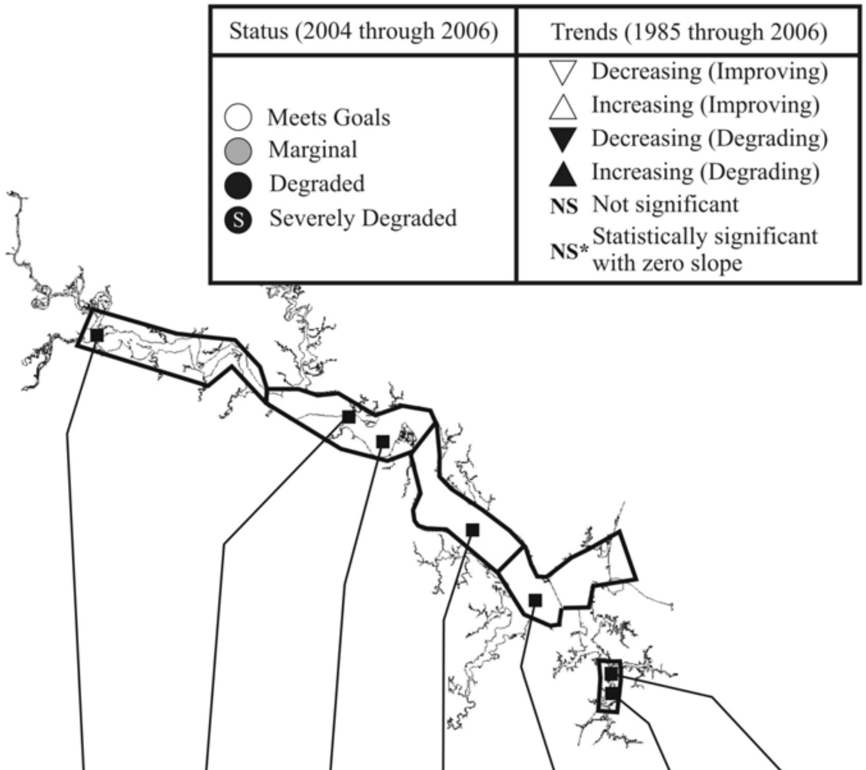


Figure 11. Map of the Elizabeth River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2006 for the SAV growing season. Abbreviations for each parameter are: TN=total nitrogen, SDIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus, CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=Secchi depth, DO=dissolved oxygen. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.



	TF5.5	RET5.2	LE5.5	SBE5
Total Abundance	NS	NS	↑	NS
Total Biomass	Poor ↑	Poor ↑	Poor ↑	Poor NS
Biomass to Abundance	Poor △	Poor △	Poor NS	Poor NS
Margalef Diversity Index	Poor NS	Poor ▼	Poor NS	Poor ▼
Productivity	Poor ▲	Poor ▽	Poor NS	Fair NS
Diatom Biomass	Fair △	Fair NS	Fair △	Poor NS
Dinoflagellate Biomass	Poor NS	Poor NS	Fair ▲	Fair NS
Cyanophyte Biomass	Poor ▲	Fair NS	Poor ▲	Fair ▲
Chlorophyte Biomass	Good △	Good △	Good NS	Good NS
Picoplankton Biomass	Fair ▽	Fair ▽	Good NS	Good NS
Cryptophyte Biomass	Good NS	Good ↑	Good NS	Good NS
Cyanophyte Abundance	Poor ▲	Fair NS	Poor ▲	Fair ▲

Figure 12. Map of the James River basin showing summaries of the status and trend analyses for phytoplankton bioindicators for each segment for the period of 1985 through 2006.



	TF5.5	RET5.2	LE5.1	LE5.2	LE5.4	SBE5	SBE2
Benthic IBI	● NS	◍ △	○ NS	◍ NS	○ NS	● △	● △
Total Abundance	NS	NS	NS	△	NS	NS	△
Total Biomass	NS	NS	NS	NS	▼	NS	NS
Pollution Sensitive Species Abundance (%)	△	△	NS	△	NS	△	△
Pollution Indicative Species Abundance (%)	△	NS	NS	NS	▽	▽	▽
Pollution Sensitive Species Biomass (%)	△	△	NS	NS	▼	△	△
Pollution Indicative Species Biomass (%)	△	NS	NS	NS	NS	▽	NS
Shannon-Weiner Diversity Index	NS	△	NS	NS	▼	NS	NS

Figure 13. Map of the James River basin showing summaries of the status and trend analyses for benthic bioindicators for each segment for the period of 1985 through 2006.

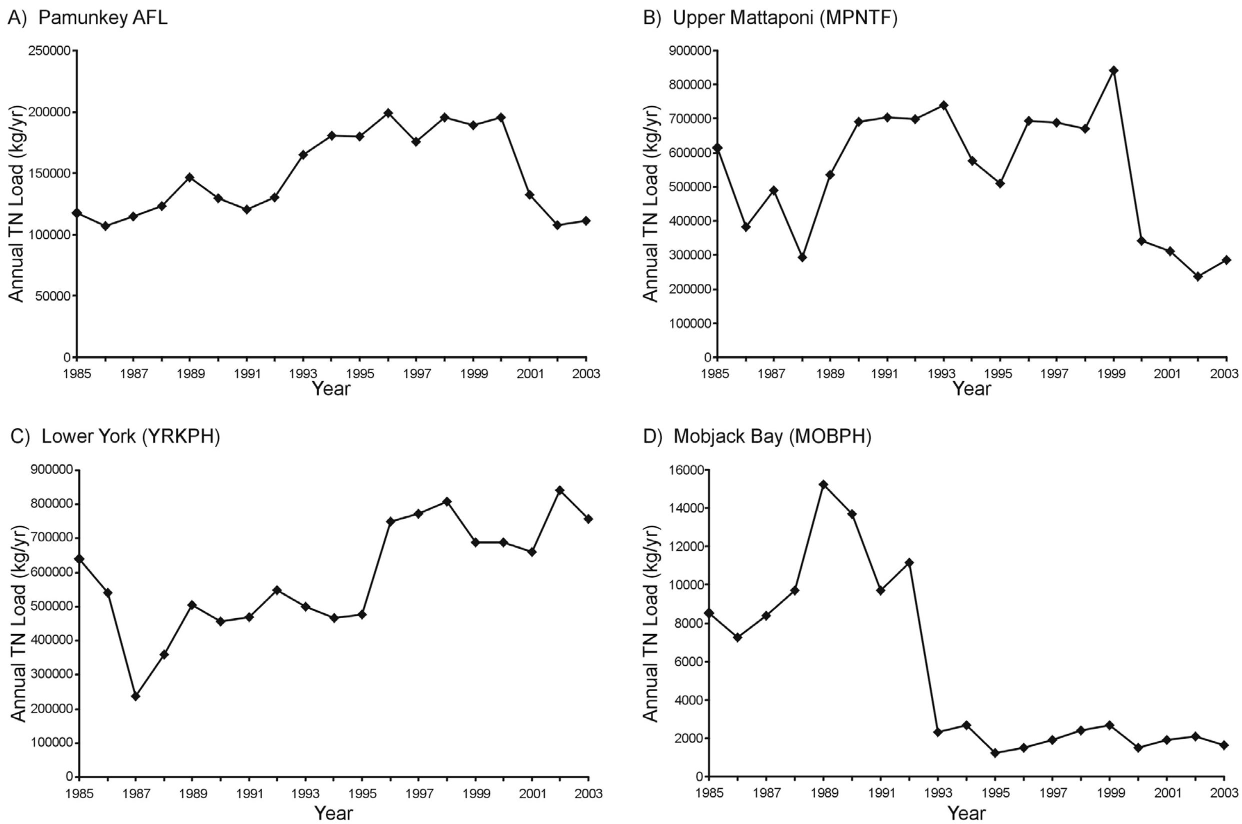


Figure 14. Long-term changes in point source total nitrogen loadings in the A) Pamunkey River Above the Fall-B) Upper Mattaponi (MPNTF), C) Lower York (YRKPH) and in D) Mobjack Bay (MOBPH) for 1985 through 2003.

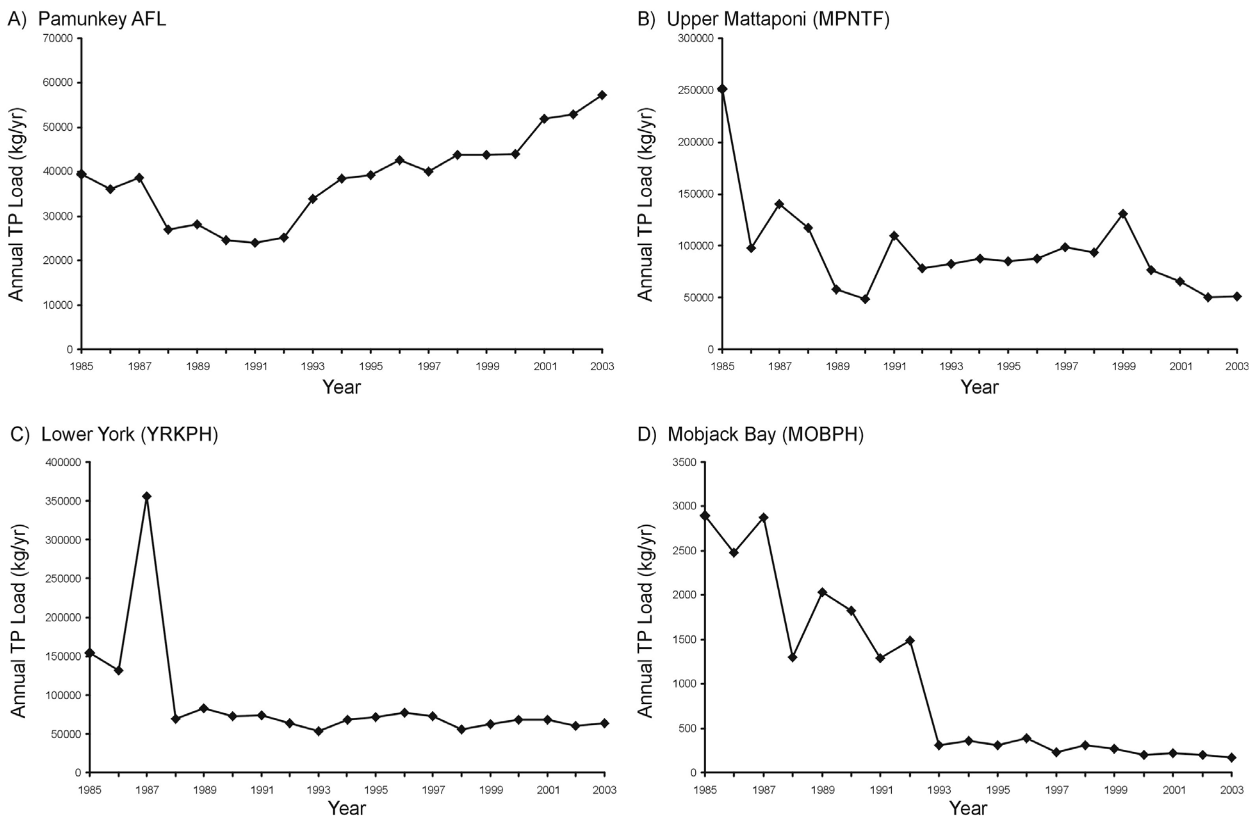


Figure 15. Long-term changes in point source total phosphorus loadings in the A) Pamunkey River Above the Fall-B) Upper Mattaponi (MPNTF), C) Lower York (YRKPH) and in D) Mobjack Bay (MOBPH) for 1985 through 2003.

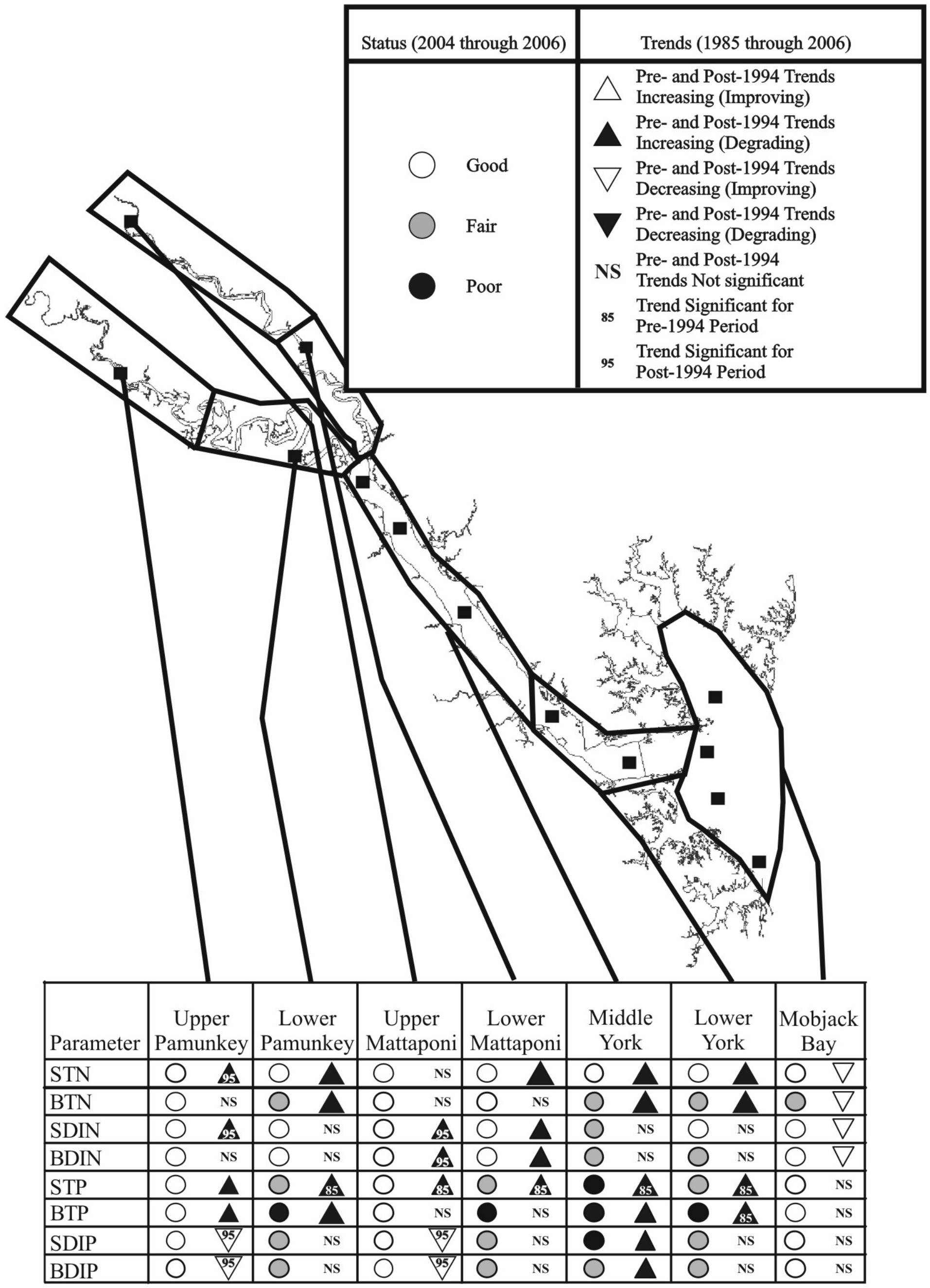
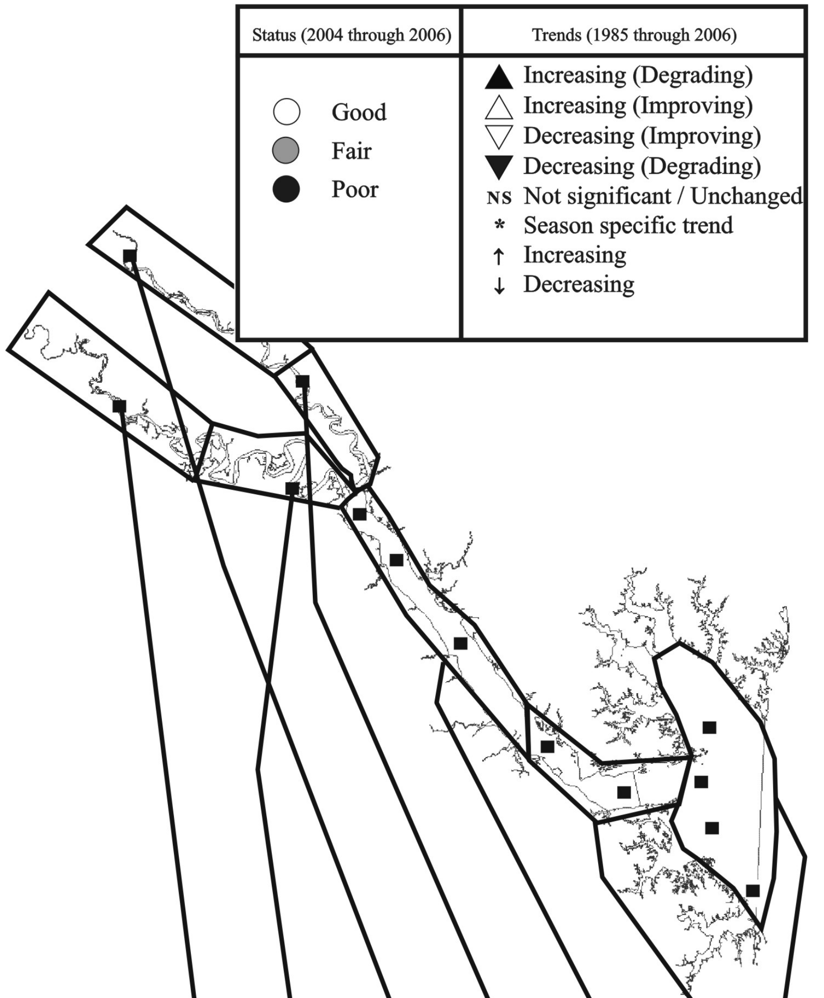
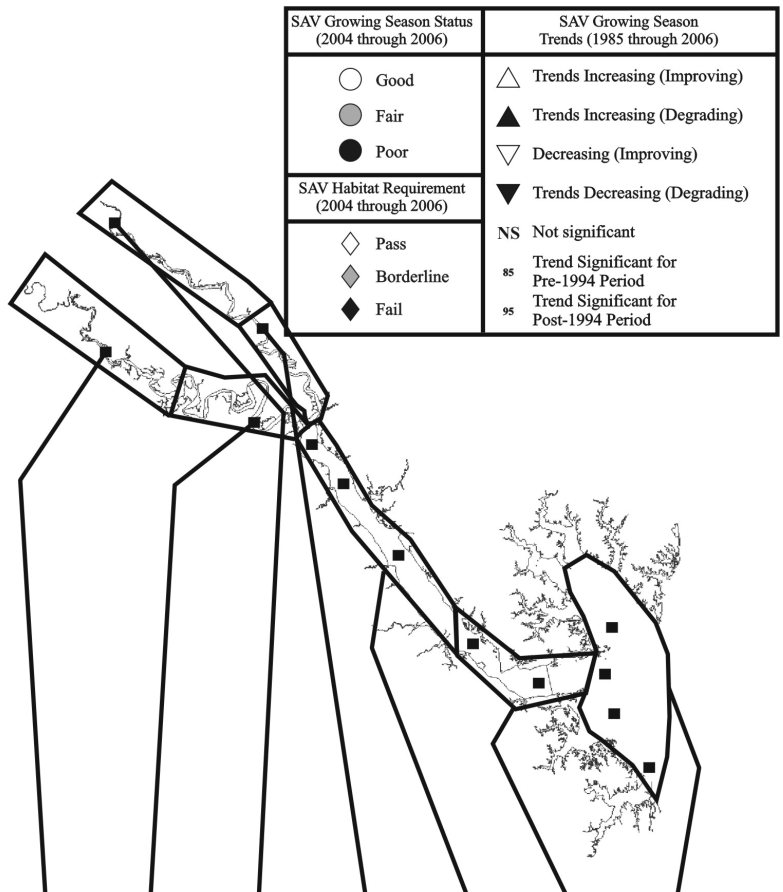


Figure 16. Map of the York River basin showing summaries of the status and trend analyses for each segment for the period of 1985 to 2006. Abbreviations for each parameter are: TN=total nitrogen, DIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.



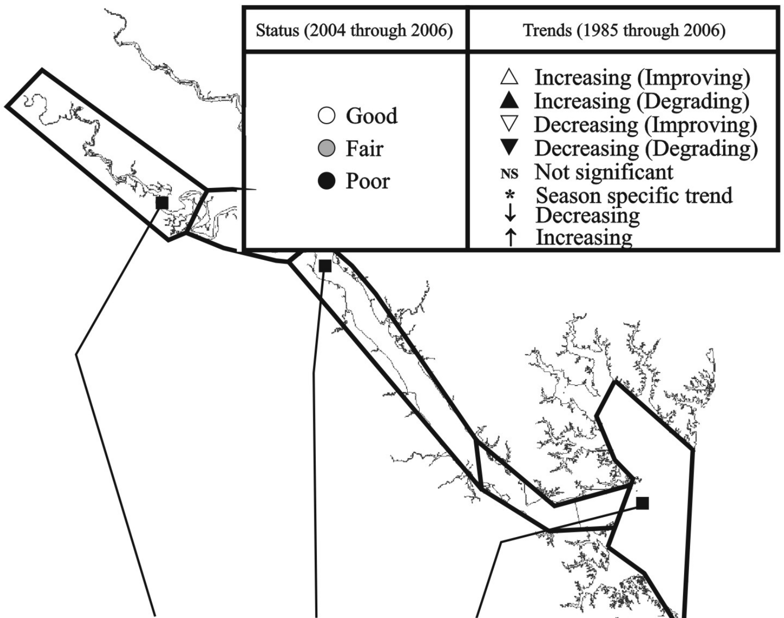
Parameter	Upper Pamunkey	Lower Pamunkey	Upper Mattaponi	Lower Mattaponi	Middle York	Lower York	Mobjack Bay
SCHLA	○ NS	○ NS	○ NS	○ NS	◐ NS	◐ ▲	◐ NS
STSS	◐ NS	● NS	○ NS	● NS	● NS	◐ NS	◐ ▽
BTSS	○ NS	● NS	○ NS	● NS	● ▲	● ▲	○ ▽
SECCHI	◐ ▼	● NS	○ ▼	● NS	● NS	● ▼	● ▼
BDO	○ NS	◐ NS	○ NS	◐ NS	◐ NS	◐ NS	○ △
SSALIN	NS	NS	NS	↑	NS	↓	↓
BSALIN	NS	NS	NS	NS	NS	NS	↓
SWTEMP	NS	NS	NS	NS	NS	NS	NS
BWTEMP	NS	NS	NS	NS	NS	NS	NS

Figure 17. Map of the York River basin showing summaries of the status and trend analyses for each segment for the period of 1985 to 2006. Abbreviations for each parameter are: CHLA=chlorophyll a, TSS=total suspended solids, SECCHI=secchi depth, DO=dissolved oxygen, WTEMP=water temperature, SALIN=salinity. The prefixes S and B refer to surface and bottom measurements, respectively.



Parameter	Upper Pamunkey	Lower Pamunkey	Upper Mattaponi	Lower Mattaponi	Middle York	Lower York	Mobjack Bay
STN	○ NS	○ ▲85	○ NS	○ ▲85	○ ▲	○ ▲	◍ ▽
SDIN	○ ▲	○ ◈ NS	○ ▲	○ ◈ NS	○ ◇ NS	○ ◇ NS	○ ◇ NS
STP	○ NS	◍ ▽85	○ NS	◍ ▲85	● ▲85	◍ ▲85	◍ NS
SDIP	○ ◇ ▽	◍ ◈ NS	○ ◇ ▽95	◍ ◈ NS	● ◆ NS	◍ ◈ NS	○ ◇ NS
SCHLA	○ ◇ NS	○ ◇ NS	○ ◇ NS	○ ◇ NS	○ ◇ NS	◍ ◇ ▲	◍ ◇ NS
STSS	◍ ◈ NS	● ◆ NS	○ ◇ NS	● ◆ NS	● ◆ NS	● ◈ NS	◍ ◇ NS
SECCHI	◍ ◈ NS	● ◆ NS	○ ◈ ▼	● ◆ NS	● ◆ NS	● ◆ ▼	● ◆ ▼
BDO	○ △	○ NS	○ NS	○ NS	○ NS	○ NS	○ △

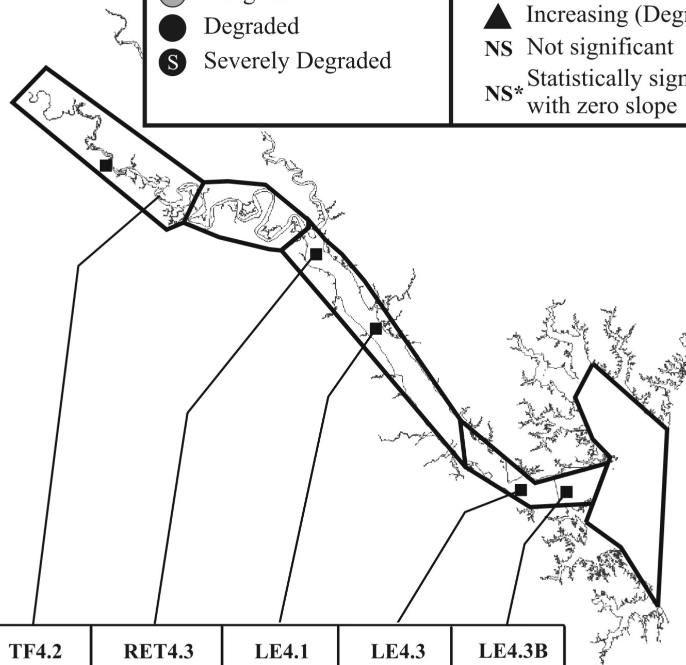
Figure 18. Map of the York River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2006 for the SAV growing season. Abbreviations for each parameter are: TN=total nitrogen, SDIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus, CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=Secchi depth, DO=dissolved oxygen. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.



	TF4.2		RET4.3		WE4.2	
Total Abundance		↑		NS		NS
Total Biomass	Poor	↑	Poor	↑	Poor	NS
Biomass to Abundance	Poor	NS	Poor	NS	Poor	NS
Margalef Diversity Index	Poor	NS	Poor	NS	Poor	▼
Productivity	Fair	NS	Poor	NS	Poor	▲
Diatom Biomass	Poor	NS	Fair	NS	Fair	NS
Dinoflagellate Biomass	Poor	NS	Fair	NS	Fair	NS
Cyanophyte Biomass	Good	▲	Fair	▲	Poor	▲
Chlorophyte Biomass	Fair	△	Good	△	Good	NS
Picoplankton Biomass	Fair	NS	Poor	NS	Good	NS
Cryptophyte Biomass	Good	↑	Good	NS	Fair	↓
Cyanophyte Abundance	Good	▲	Fair	▲	Poor	▲

Figure 19. Map of the York River basin showing summaries of the status and trend analyses for phytoplankton bioindicators for each segment for the period of 1985 to 2006.

Status (2004 through 2006)	Trends (1985 through 2006)
○ Meets Goals ◍ Marginal ● Degraded Ⓢ Severely Degraded	▽ Decreasing (Improving) △ Increasing (Improving) ▼ Decreasing (Degrading) ▲ Increasing (Degrading) **NS** Not significant **NS*** Statistically significant with zero slope



	TF4.2	**RET4.3**	**LE4.1**	**LE4.3**	**LE4.3B**
Benthic IBI	● **NS**	● **NS**	Ⓢ **NS**	○ **NS**	● △
Total Abundance	△	△	**NS**	**NS**	**NS**
Total Biomass	**NS**	**NS**	**NS**	**NS**	**NS**
Pollution Sensitive Species Abundance (%)	**NS**	**NS**	**NS**	**NS**	**NS**
Pollution Indicative Species Abundance (%)	**NS**	**NS**	**NS**	**NS**	▽
Pollution Sensitive Species Biomass (%)	**NS**	**NS**	▼	**NS**	**NS**
Pollution Indicative Species Biomass (%)	**NS**	**NS**	▲	**NS**	**NS**
Shannon-Weiner Diversity Index	△	**NS**	▼	**NS**	**NS**

Figure 20. Map of the York River basin showing summaries of the status and trend analyses for benthic bioindicators for each segment for the period of 1985 to 2006.

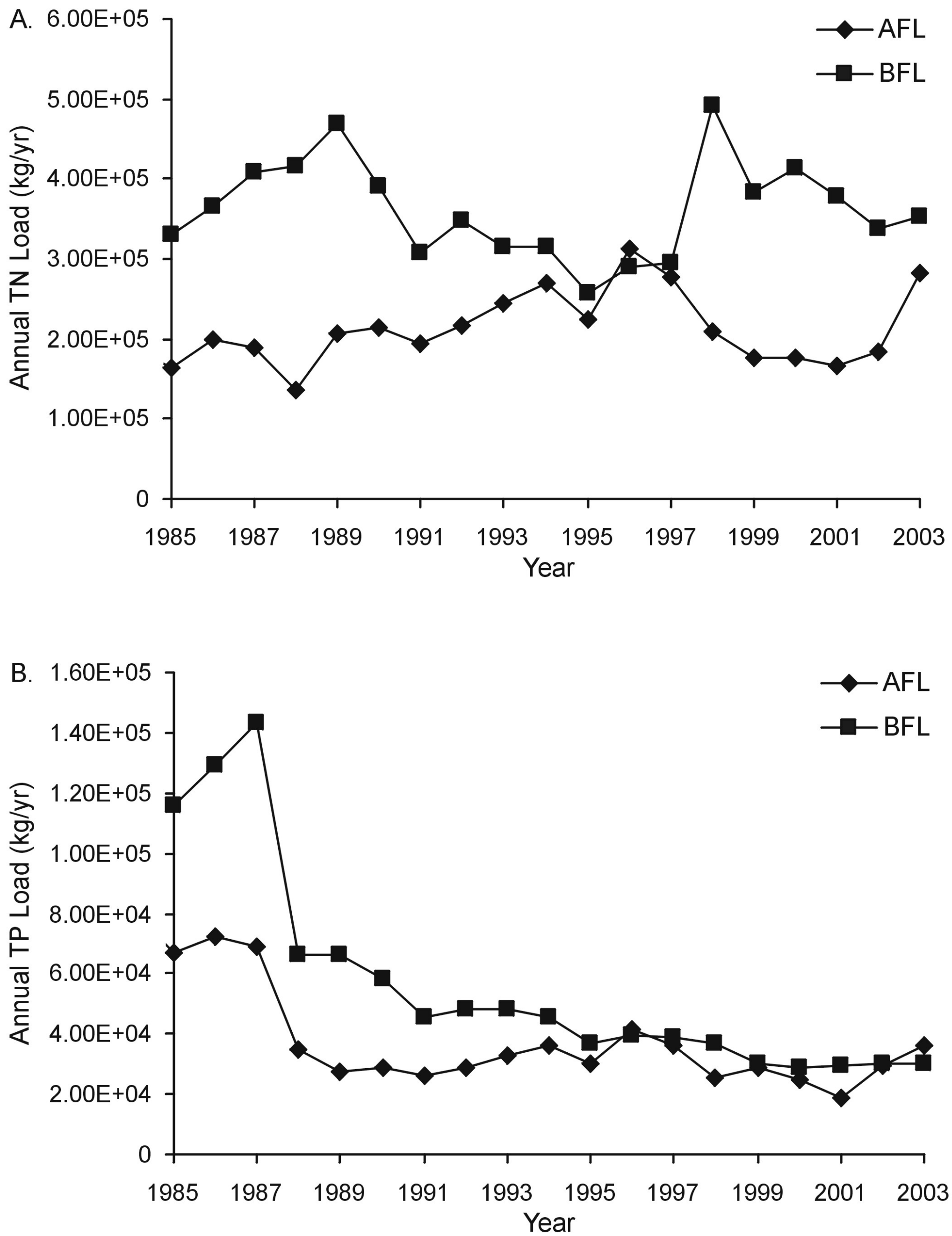
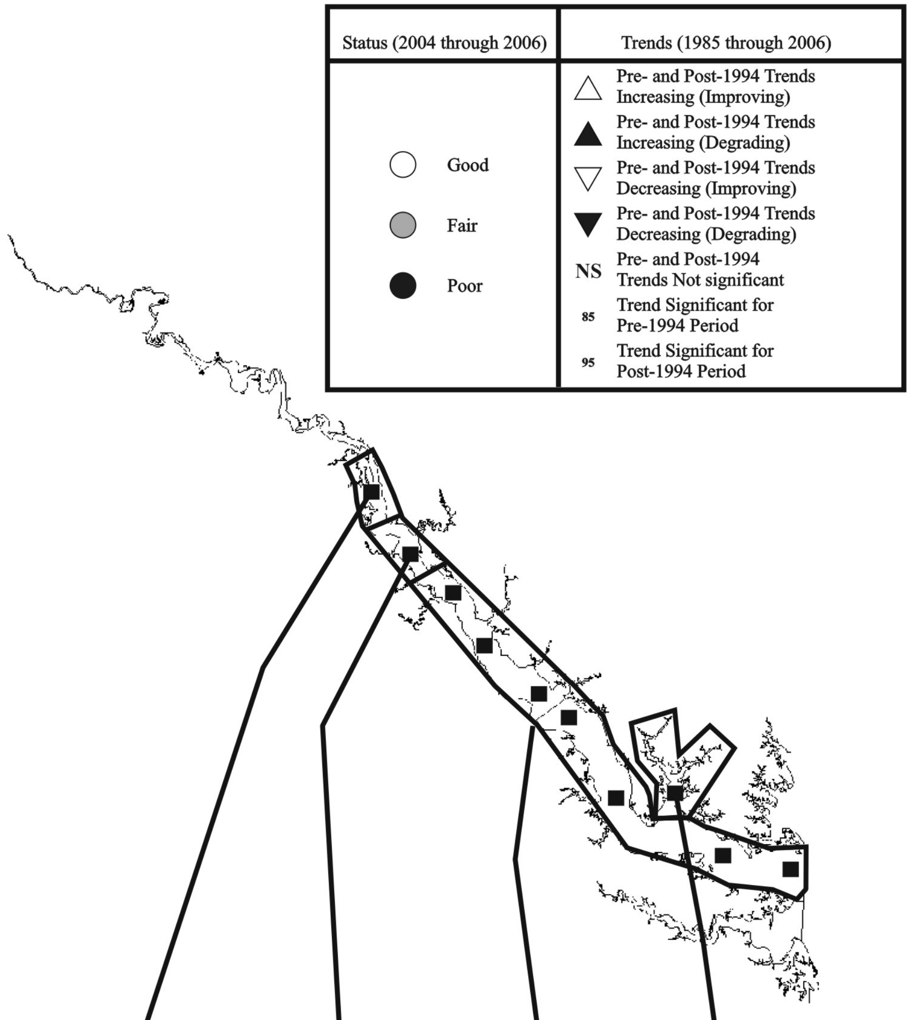


Figure 21. Long-term changes in above fall-line (AFL) and below fall-line (BFL) point source A. Total Nitrogen Loadings, and B. Total Phosphorus Loadings in the Rappahannock River for 1985 through 2003.



Parameter	Upper Rappahannock	Middle Rappahannock	Lower Rappahannock	Corottoman River
STN	○ NS	○ NS	○ NS	○ NS
BTN	○ NS	○ ▲	○ NS	○ NS
SDIN	○ ▲	○ NS	○ ▽85	○ ▽
BDIN	○ ▲	○ NS	○ NS	○ NS
STP	○ NS	○ NS	○ ▲85	○ ▲
BTP	○ NS	◐ ▲	○ ▲85	○ ▲85
SDIP	○ ▽95	○ NS	○ NS	○ NS
BDIP	○ ▽95	○ ▽	○ NS	○ NS

Figure 22. Map of the Rappahannock River basin showing summaries of the status and trend analyses for each segment for the period 1985 through 2006. Abbreviations for each parameter are: TN=total nitrogen, DIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.

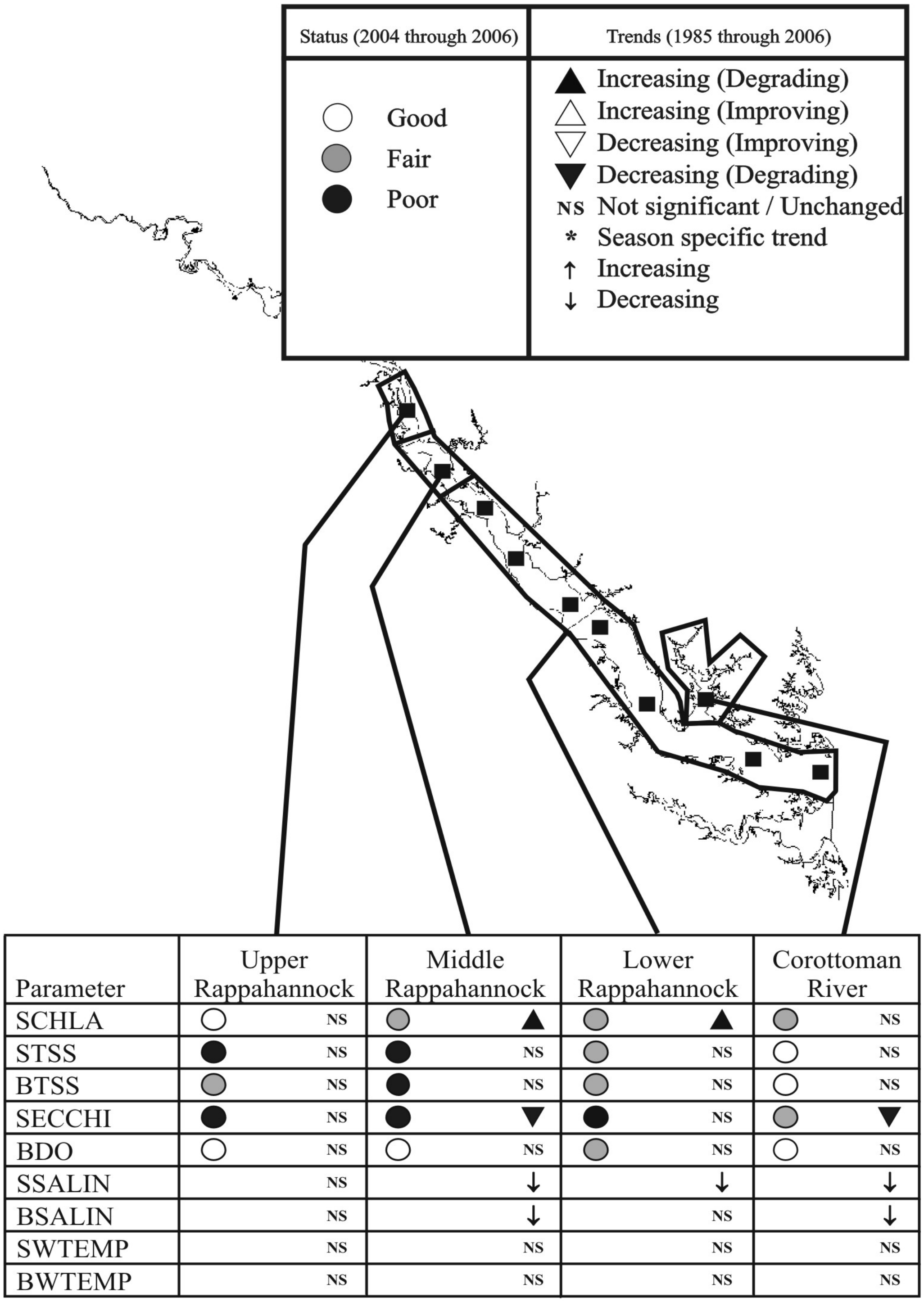
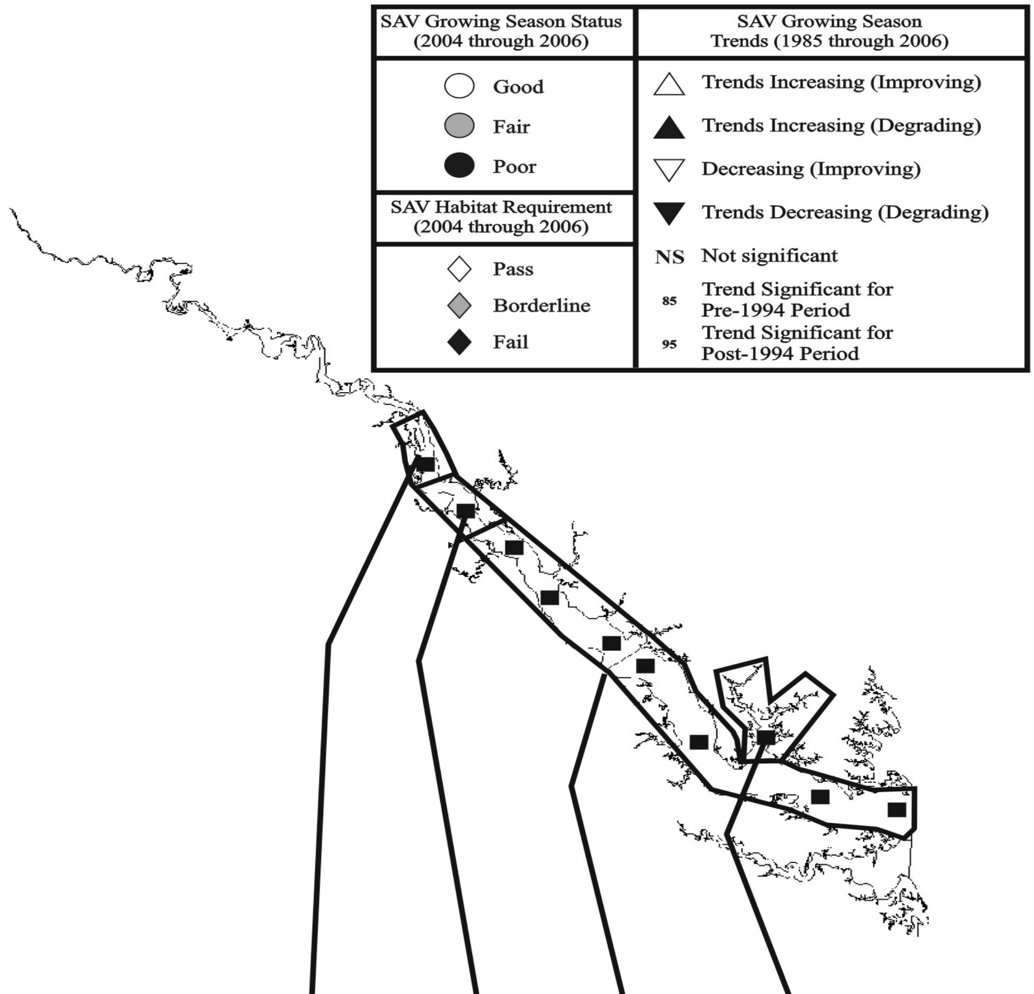


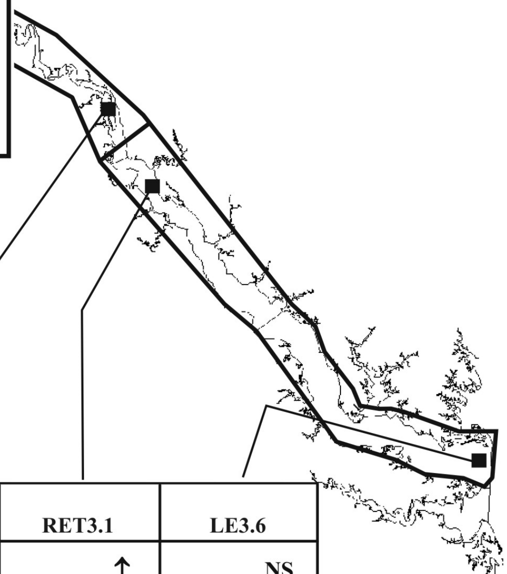
Figure 23. Map of the Rappahannock River basin showing summaries of the status and trend analyses for each segment for the period 1985 through 2006. Abbreviations for each parameter are: CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=secchi depth, DO=dissolved oxygen, WTEMP=water temperature, SALIN=salinity. The prefixes S and B refer to surface and bottom measurements, respectively.



Parameter	Upper Rappahannock	Middle Rappahannock	Lower Rappahannock	Corottoman River
STN	○ NS	○ NS	○ NS	○ NS
SDIN	○ NS	○ NS	○ ◇ NS	○ ◇ ▽
STP	○ NS	○ NS	○ ▲85	○ NS
SDIP	○ ◇ NS	○ ◇ NS	○ ◇ NS	○ ◇ NS
SCHLA	○ ◈ NS	● ◈ ▲	◐ ◇ ▲	◐ ◇ NS
STSS	● ◆ NS	● ◆ NS	◐ ◇ NS	○ ◇ NS
SECCHI	● ◆ NS	● ◆ ▼	● ◈ ▼	◐ ◇ ▼
BDO	○ NS	○ NS	○ NS	○ NS

Figure 24. Map of the Rappahannock River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2006 for the SAV growing season. Abbreviations for each parameter are: TN=total nitrogen, SDIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus, CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=Secchi depth, DO=dissolved oxygen. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.

Status (2004 through 2006)	Trends (1985 through 2006)
○ Good Fair ● Poor	△ Increasing (Improving) ▲ Increasing (Degrading) ▽ Decreasing (Improving) ▼ Decreasing (Degrading) NS Not significant * Season specific trend ↓ Decreasing ↑ Increasing



	TF3.3		RET3.1		LE3.6	
Total Abundance		↑		↑		NS
Total Biomass	Poor	↑	Poor	↑	Poor	NS
Biomass to Abundance	Poor	△	Poor	NS	Poor	NS
Margalef Diversity Index	Poor	NS	Poor	NS	Fair	▼
Productivity	Poor	▲	Poor	▲	Poor	▲
Diatom Biomass	Fair	△	Fair	△	Fair	NS
Dinoflagellate Biomass	Poor	NS	Fair	NS	Poor	▲
Cyanophyte Biomass	Poor	▲	Poor	▲	Fair	▲
Chlorophyte Biomass	Good	△	Good	△	Fair	NS
Picoplankton Biomass	Fair	NS	Poor	NS	Poor	▽
Cryptophyte Biomass	Good	NS	Good	NS	Good	NS
Cyanophyte Abundance	Poor	▲	Poor	▲	Fair	▲

Figure 25. Map of the Rappahannock River basin showing summaries of the status and trend analyses for phytoplankton bioindicators for each segment for the period 1985 through 2006.

Status (2004 through 2006)	Trends (1985 through 2006)
○ Meets Goals ◍ Marginal ● Degraded Ⓢ Severely Degraded	▽ Decreasing (Improving) △ Increasing (Improving) ▼ Decreasing (Degrading) ▲ Increasing (Degrading) **NS** Not significant **NS*** Statistically significant with zero slope

	TF3.3	**RET3.1**	**LE3.2**	**LE3.4**
Benthic IBI	○ **NS**	◍ ▼	Ⓢ **NS**	Ⓢ **NS**
Total Abundance	**NS**	**NS**	**NS**	**NS**
Total Biomass	▼	▼	**NS**	**NS**
Pollution Sensitive Species Abundance (%)	**NS**	▼	**NS**	**NS**
Pollution Indicative Species Abundance (%)	**NS**	**NS**	**NS**	**NS**
Pollution Sensitive Species Biomass (%)	▼	▼	**NS**	**NS**
Pollution Indicative Species Biomass (%)	**NS**	**NS**	**NS**	**NS**
Shannon-Weiner Diversity Index	**NS**	**NS**	**NS**	**NS**

Figure 26. Map of the Rappahannock River basin showing summaries of the status and trend analyses for benthic bioindicators for each segment for the period of 1985 through 2006.