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STATUS AND TRENDS IN WATER QUALITY AND LIVING RESOURCES IN THE VIRGINIA CHESAPEAKE BAY: YORK RIVER (1985-2003)

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Preface

This material in this report was produced for the Virginia Department of Environmental Quality in order to summarize patterns of status and trends in water quality, phytoplankton, primary productivity, zooplankton and benthos collected as part of the Virginia Chesapeake Bay Program. There are three reports, referred to as basin summaries, one each for the James River, the York River and the Rappahannock River. These basin summaries are intended to be electronic reports that will be periodically updated and they were intended for an audience already knowledgeable of the history and rationale of the program; design of the program; field and laboratory methods; specialized parameters, e.g. the Benthic Index of Biotic Integrity; status and trends analytical methods, etc.

In order to create a record of past patterns in status and trends and to make these data more widely available, a printed version of each basin summary was produced. To make the information more interpretable we have added an introduction and a methods section. However, this report is a data report and is not a comprehensive, interpretive report. Therefore, there is no discussion section to this report.

All three basin summaries and appendices are available at the Old Dominion University Chesapeake Bay Program website <www.chesapeakebay.odu.edu> under "Reports." The James River Report includes the Elizabeth River, the Chickahominy River and the Appomattox River. The York River Report includes the tidal Pamunkey River and Mattaponi River. The Rappahannock River Report includes the Corrotoman River. Also available at this website are appendices that include (1) tables of status for all parameters measured at all stations sampled by each program, (2) tables of all parameters and metrics for which there was a significant trend, and (3) scatter plots of all parameters over time. There are five appendices: water quality, phytoplankton, primary productivity, zooplankton and benthos.

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Summary of Status and Trends for the Chesapeake Bay and the James York and Rappahannock Rivers

The Virginia Chesapeake Bay and its tidal tributaries continue to show some environmental trends indicating progress toward restoration of a more balanced and healthy ecosystem. However, the Bay system remains degraded and some areas and indicators show continuing degradation. Progress in reducing nutrient inputs has made demonstrable improvements and we expect that continued progress toward nutrient reduction goals, along with appropriate fisheries management and chemical contaminant controls, will result in additional improvements to the Bay. Findings from the last 18 years of the monitoring programs are highlighted below.

In 1995, the Virginia DEQ instituted changes to its analytical techniques for determining nutrient concentrations in the tidal waters of Virginia. These changes resulted in step trends in the data for both the nitrogen and phosphorus parameters for which status and long-term trends were assessed. An appropriate statistical technique was employed to determine long-term trends for the entire period of record (1985-2003) and for trends that occurred during the pre-method change and post-method change periods. For the tidal waters of Virginia, all information presented in this summary concerning long-term trends in nutrient parameters refers only to trends detected for the entire period of record and focuses only on the James, Elizabeth, York and Rappahannock rivers.

- Nonpoint source loads (estimates of controllable and uncontrollable) of phosphorus, nitrogen, and sediment as calculated by the Bay Program Watershed Model, decreased by 13%,11%, and 12%, respectively, compared to the 1985 baseline loads (Table 1).

- Point source nutrient loads were reduced by 53% for phosphorus and 30% for nitrogen, compared to the 1985 baseline loads. This decrease in discharge may be partly due to ongoing drought conditions in Virginia (Table 1).

- Combined nutrient loads were reduced by 28% for phosphorus and 18% for nitrogen, compared to the 1985 baseline loads (Table 1).

- For nitrogen, there were improving trends at the river input stations of the James River, and the Rappahannock River along with a degrading trend in the Pamunkey River. For most segments, status of nitrogen parameters was either good or fair. Overall, there were four segments showing improving trends and six segments showing degrading trends. Five of the six degrading segment trends were in the York River. Three of the four improving segment trends were in the Elizabeth River and the James River and Rappahannock River.

- For phosphorus, there were improving trends in flow adjusted concentrations above the fall-line at the river input stations of the James River, Appomattox River, and Rapphannock River with a degrading trend in the Pamunkey River. Status in phosphorus parameters was typically poor in most segments except the tidal freshwater segments. Overall, there were nine improving segment trends and nine degrading segment trends in total phosphorus in the Virginia tributaries. All seven segments of the York River showed degrading phosphorus trends. Improving trends in phosphorus parameters were detected in nearly of the segments in the Elizabeth River.

- Chlorophyll *a* levels were high in just under half of the segments sampled but there was only one segment with a degrading trend in chlorophyll *a* and three showed an improving trend.

- Water clarity, a very important environmental parameter, was generally fair or poor in most segments throughout the tributaries. This is probably related to high and scattered increasing levels of suspended solids. These degrading conditions are a major impediment to restoration of submerged aquatic vegetation (SAV). No segments showed improving trends and seven segments showed degrading trends in water clarity.

- Levels of dissolved oxygen were good in the majority of areas in the tributaries and improving trends were detected in three segments.

- Phytoplankton populations are a major food source and oxygen producer in these waters, and represent a major indicator to the health status of these tributaries. Although dominated by favorable concentrations and long-term trends among the diatoms and chlorophytes within segments of these rivers, there are disturbing signs of increased concentrations of cyanobacteria throughout these estuaries, and blooms of dinoflagellates occur seasonally. These trends were enhanced at several locations by increased concentrations becoming more common since 1999. Among these taxa are species known to be toxin producers. Future attention will continue to be directed to any increased presence of these less favorable algal categories, and the environmental conditions that would favor their development over diatoms and chlorophytes.

- Benthic community patterns differed greatly between the rivers. In the James River there were strong improving trends upstream and continued good status down stream. In the Elizabeth River there was a strong improving trend although the status of the benthic communities remains poor. In the York River, community status was good in the down stream segments where communities continued to improve. In the Rappahannock River status was poor in the downstream segments of the river and degrading trends were detected at the middle station.

Table 1. Nutrient and Sediment Loads for Virginia (2001). Modified from data provided by the Virginia Department of Environmental Quality. Phosphorous and nitrogen loads are in kg/year and sediment loads are mtu/year. Percent change compares 2003 data to 1985 data. Nonpoint source loads are results based on the Year 2003 Progress Run of the Chesapeake Bay Watershed Model and calculated reductions for calendar year 2001 Best Management Practices (BMPs) as monitored by the Department of Conservation and Recreation. Values with a "*" were updated with the latest available point source data.

Non Point Source Loads

Tributary Basin	2003 Phosphorus Load (kg/yr)	% Change in Phosphorus	2003 Nitrogen Load(kg/yr)	% Change in Nitrogen	2003 Sediment Load (mtu/yr)	% Change in Sediment
Potomac	708,138	-15%	6,554,972	-6%	647,340	-14%
Rappahannock	396,540	-19%	3,263,308	-22%	301,575	-21%
York	273,596	-17%	2,914,234	-16%	114,097	-20%
James	1,864,703	-10%	9,934,493	-7%	1,058,367	-8%
Coastal	88,092	-14%	882,602	-11%	19,885	-6%
Totals	3,331,069	-13%	23,549,610	-11%	2,141,255	-12%

Point Source Loads and in parentheses the number of point sources

Tributary Basin	2003 Phosphorus Load (kg/yr)	% Change in Phosphorus	2003 Nitrogen Load (kg/yr)	% Change in Nitrogen
Potomac (39)	236,924	-32%	3,309,286	-33%
Rappahannock (18)	32,092	-63%	312,415	24%
York (10)	78,015	-62%	525,344	-17%
James (37)	782,495	-55%	7,731,942	-30%
Coastal Bays (5)	3,486	-81%	106,272	-18%
Totals	1,133,012	-53%	11,985,258	-30%

Total Loads

Tributary Basin	2003 Phosphorus Load	% Change in Phosphorus	2003 Nitrogen Load	% Change in Nitrogen	2003 Sediment Load (mtu/yr)	% Change in Sediment
Non Point Source	3,331,069	-13%	23,549,610	-11%	2,141,255	-12%
Point Source	1,133,012	-53%	11,985,258	-30%		
Combined	4,464,081	28%	35,534,868	18%	2,141,255	-12%

Chapter 1. Introduction

A marked decline in the water quality of the Chesapeake Bay has occurred over the past several decades. 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. 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, 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 this agreement, a long-term monitoring program in the Chesapeake Bay was established 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 practices on living resource communities.

Water quality and living resource monitoring in the Virginia Mainstem and tributaries began in 1985 and has continued for 19 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, 2002; Lane et al.,1998; Marshall, 1994,1996; Marshall and Burchardt, 1998, 2003, 2004a, 2004b; Marshall et al., 1998). An attempt was made to determine if there was concordance in current conditions of, and long-term changes, in water quality and living resources. The purpose of this project was to reassess the results of these studies by re-conducting the analyses after adding data collected during 2003. This report describes the status of water quality and living resource conditions for the Virginia Mainstem and tributaries, summarizes major long-term trends in water quality and measures of living resource community health.

Chapter 2. Chesapeake Bay Monitoring Program Descriptions

I. Water Quality

A. Sampling Locations and Procedures

As part of the U. S. Geological Survey's River Input Program, water quality data have been collected at five stations near the fall line and three stations above the fall line in Virginia. Samples were taken at base-flow twice a month and during high flows whenever possible between 1988 and 2003. Water quality data have also been collected by the Virginia Department of Environmental Quality (DEQ) at three additional stations upstream of these River Input sites (Figure 2-1). These stations had a minimum of three consecutive years of samples taken between 1985 and 1996 with sampling occurring on at least a monthly basis.

Water quality conditions were regularly monitored at 28 sites in the Bay Mainstem beginning in July, 1985. From 1985 until 1995 eight stations were sampled by Old Dominion University (ODU) and 20 stations were sampled by the Virginia Institute of Marine Science (VIMS). From 1995 through the present, Mainstem water quality monitoring was conducted by ODU. Tributary water quality monitoring was conducted by the Virginia DEQ at 27 sites in the James, York (including the Mattaponi and Pamunkey) and Rappahannock rivers (Figure 2). In addition, six permanent water quality monitoring sites were established in the Elizabeth River/Hampton Roads Harbor by ODU in February, 1989 (Figure 2-2). In August 1990, station LAF1 was dropped from the Elizabeth River Long Term Monitoring (ERLTM) Program.

The temporal sampling scheme for the water quality monitoring program changed several times over the 19 year period (varying from 20 to 12 sampling events per year) as a result of changes in the monitoring program budget. In general, Mainstem sampling cruises were conducted semi-monthly from March through October and monthly from November through February until 1996. Starting in 1996 Mainstem sampling cruises were conducted semi-monthly for July and August and monthly the rest of the year. Tributary sampling by the Virginia Department of Environmental Quality was conducted 20 times per year until 1994 when sampling was reduced to 12 times per year. The Elizabeth River stations were sampled monthly. Field sampling procedures used for ODU and VIMS water quality collections are described in detail by Alden et al. (1992a). Field sampling procedures for DEQ water quality collections are described in detail in DEQ's Quality Assurance Project Plan for the Chesapeake Bay Program (Donat and Doughten, 2002).

B. Laboratory Sample Processing

Descriptions of laboratory sample processing and standard operating procedures for all water quality parameters are found in the Chesapeake Bay Program Quality Assurance Project Plans (QAPjPs) prepared by each of the participating laboratories (Donat and Doughten, 2002). Copies of the QAPjPs can be obtained by contacting EPA's Chesapeake Bay Program Quality Assurance Officer.

II. Phytoplankton

A. Sampling Locations and Procedures

Seven stations were established in Chesapeake Bay in July 1985. These were CB6.1, CB6.4, CB7.3E, CB7.4, LE5.5, WE4.2, and LE3.6 (Figure 2-3). From July, 1985 through September, 1990, phytoplankton collections were taken from these stations twice a month from March through October, and monthly November through February. From October, 1990, monthly samples were taken at all Bay stations. Monthly sample collections and analysis in the James (TF5.5, RET5.2), York (RET4.1, RET4.3), and Rappahannock (TF3.3, RET3.1) rivers began in March, 1986. In March, 1987, station RET4.1 in the Pamunkey River was replaced by station TF4.2, and in February, 1989, monthly collections began at two stations (SBE2, SBE5) in the Elizabeth River. Picoplankton analysis was included at several trial stations in January, 1989, and was expanded to include all stations in July, 1989. Primary production analysis was added to all Bay and tributary stations in July 1989.

At each station, two vertical sets of three liter water samples were taken at five equidistant depths above the pycnocline and placed in two separate carboys. The process was repeated at five depths below the pycnocline. The water in each carboy was carefully mixed and replicate 500 ml sub-samples were removed from each carboy, and fixed with Lugol's solution. A second set of 125 ml sub-samples were also taken above and below the pycnocline, preserved with glutaraldehyde and placed in a cooler. These samples were taken to determine the concentrations of the autotrophic picoplankton population. An additional replicate set was also taken from the same carboy set taken above the pycnocline for primary productivity measurements.

B. Laboratory Sample Processing

Samples for phytoplankton analyses were passed through a series of settling and siphoning steps to produce a concentrate (or fraction of the concentrate) that was examined using a modified Utermöhl method with an inverted plankton microscope (Marshall and Alden, 1990). The analysis procedure attained an estimated precision of 85% (Venrick, 1978). The autotrophic picoplankton were processed through a protocol that included their collection on a 0.2 µ nucleopore filter, with subsequent analysis using an epifluorescent microscope, under oil at 1000x magnification, with "green" and “blue” filter sets (Marshall, 1995). Supplemental analysis with a scanning electron microscope was used in several of the species identifications. Methodology for the productivity measurements is given in Marshall and Nesius (1996). Appropriate quality assurance/quality control practices in sample collection, analysis, and data entry were employed throughout this period.

III. Benthos

A. Fixed Location Sampling

Sixteen stations in the lower Chesapeake Bay were sampled quarterly (March, June, September, December) from March 1985 through December 1995 as part of the Benthic Biological Monitoring Program of the Chesapeake Bay Program. Beginning in 1996 sampling at the fixed stations occurred only in June and September and a stratified random sampling element was added to the program. Power and robustness analyses indicated that sampling during June and September would be sufficient for detecting long-term trends at the fixed locations while at the same time, allow funding resources to be reallocated to the probability-based random sampling regime (Alden et al., 1997). Stations were located within the mainstem of the bay and the major tributaries - the James, York and Rappahannock rivers (Figure 2-3). In the tributaries, stations were located within the tidal freshwater zone (TF5.5, TF4.2, TF3.3), turbidity maximum (transitional) zone (RET5.2, RET4.3, RET3.1), lower estuarine mesohaline muds (LE5.2, LE4.1, LE3.2) and lower estuarine polyhaline silty-sands (LE5.4, LE4.3). The tidal freshwater station within the York River estuary was located in the Pamunkey River. In the Mainstem of the Bay three stations were located off the mouths of the major tributaries (CB8.1, CB6.4, CB6.1) and two stations in the deeper channels near the bay mouth (CB7.3E) and above the Rappahannock River near the Virginia-Maryland border (CB5.4).

In 1989, five additional stations were added to the program: two stations in the Southern Branch of the Elizabeth River (SBE2, SBE5) in regions exposed to contaminated sediments, a station in the transitional region of the James River (LE5.1), a station in the lower York River exposed to low dissolved oxygen events (LE4.3B), and a station in the lower Rappahannock River exposed to low dissolved oxygen events (LE3.4).

For the fixed point stations three replicate box core samples were collected for benthic community analysis. Each replicate had a surface area of 184 cm^2, a minimum depth of penetration to 25 cm within the sediment, was sieved on a 0.5 mm screen, relaxed in dilute isopropyl alcohol and preserved with a buffered formalin-rose bengal solution.

At each station on each collection date a 50g subsample of the surface sediment was taken for sediment analysis. Salinity and temperature were measured using a Beckman RS5-3 conductive salinometer and bottom dissolved oxygen was measured using a YSI Model 57 oxygen meter. For the original 16 stations see Dauer et al. (1992) for a summary of the pattern of bottom oxygen values, Dauer et al. (1993) for a summary of the distribution of contaminants in the sediments and Dauer (1993) for a summary of salinity, water depth, and sedimentary parameters.

B. Probability-Based Sampling

In 1996 a probability-based sampling program was added to estimate the area of the Virginia Chesapeake Bay and its tributaries that met the Benthic Restoration Goals as indicated by the B-IBI (Ranasinghe et al., 1994; Weisberg et al., 1997; Alden et al., 2002). Four strata were defined and each stratum was sampled by 25 randomly allocated sites. The four strata were: 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. Each year a new set of 25 random sites was selected for each stratum.

Probability-based sampling within strata supplements data collected at fixed-point stations. Sampling design and methods for probability-based sampling are based upon those developed by EPA's Environmental Monitoring and Assessment Program (EMAP, Weisberg et al., 1993) and allow unbiased comparisons of conditions between strata (e.g., tributaries) of the Chesapeake Bay within the same collection year and within tributaries for between different years. The consistency of sampling design and methodologies for probability-based sampling between the Virginia and Maryland benthic monitoring programs allows bay-wide characterizations of the condition of the benthos for the Chesapeake Bay (Dauer 1999; Dauer and Rodi 1998a, 1998b, 1999, 2001, 2002).

Within each probability-based stratum, 25 random locations were sampled using a 0.04 m^2 Young grab. At each station one grab sample was taken for macrobenthic community analysis and a second grab sample for sediment particle size analysis and the determination of total volatile solids. All sampling processing for probability-based sampling stations were identical to those for the fixed stations. Physical and chemical measurements were also made at the random locations.

C. Laboratory Sample Processing

In the laboratory, each replicate was sorted and all the individuals identified to the lowest possible taxon and enumerated. Biomass was estimated for each taxon as ash-free dry weight (AFDW) by drying to constant weight at 60 °C and ashing at 550 °C for four hours. Biomass was expressed as the difference between the dry and ashed weight.

The sand fraction of each sediment sample was dry sieved and the silt-clay fraction was quantified by a pipette analysis using the techniques of Folk (1974). Total volatile solids for each sediment sample was determined as the AFDW weight of the sediment divided by the dry weight of the sediment, expressed as a percentage.

IV. Statistical Analyses

In order 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 2-2). Status and trend analyses were conducted for different time periods or “seasons” as defined for each monitoring component in Table 2-1.

A. Status Assessments

For the tidal water quality stations, status analyses were conducted using surface and bottom water quality measurements for six parameters: total nitrogen, dissolved inorganic nitrogen, total phosphorus, dissolved inorganic phosphorus, chlorophyll *a*, and total suspended solids. Status analyses were also performed on secchi depth and bottom dissolved oxygen. All analyses were conducted using water quality data collected from all of the Chesapeake Bay Mainstem and tributary stations from the January 2001 through December of 2003 except for bottom dissolved oxygen for which analyses were conducted using data collected only during the summer months of June through September.

The relative status of each station and segment was determined by comparison to a benchmark data set comprised of all data collected from 1985 through1990 by both the Virginia and Maryland monitoring programs. Each station was rated as poor, fair, or good relative to the benchmark data. The ratings are obtained for data collected within each salinity zone with salinity zones being assigned using the Venice classification system (Symposium on the Classification of Brackish Waters, 1958). For each parameter in the benchmark data set, a transformation was chosen that yields a distribution that was symmetric and approximated by the logistic cumulative distribution function (CDF). In most cases, the logarithmic transformation was selected. A logistic CDF based on the mean and variance of each parameter of the benchmark data set was used to perform a probability integral transform on all data collected during the period of January, 2001 through December, 2003. This resulted in data in the interval (0,1) that follow a uniform distribution. The three year median of these transformed data was computed as an indicator of status for the period specified. The median of n observations taken from a uniform distribution follows a Beta distribution with parameters (m,m) where:

$$m = (n+1)/2$$

and n is the number of observations. The transformed three year medians were compared to the Beta density distribution and status was determined by the placement of the transformed medians along the distribution. If the median was in the upper third of the distribution (where upper is chosen as the end of the distribution that is ecologically desirable) then the status rating is good, while a median in the middle third was rated fair, and a median in the lower third was rated poor. In most cases, serial dependence of the raw data resulted in greater than expected variance in the Beta density of the medians. To adjust for this, the variance of the Beta density was increased by a function of the ratio of among station variance to within station variance.

Because sampling regimes between monitoring programs varied with respect to the number of collection events within a given month and the number of replicate samples collected at each station varied, a uniform calculation protocol was adopted for use by both states to insure that the calculations were not inadvertently biased by these discrepancies. First, replicate values were combined by calculating a median for each station date and layer combination. Median values for each station month and year combination were calculated to combine separate cruises per month.

Finally, median scores were calculated that were compared to the benchmark scale.

Water quality data were also assessed to determine if the SAV habitat requirements were met for the following parameters: chlorophyll *a*, total suspended solids, secchi depth, dissolved inorganic nitrogen, and dissolved inorganic phosphorus. Three year medians for the SAV growing season were compared to the SAV habitat requirement values (see Table 2-2) using a Mann-Whitney U-test. If the median values were significantly higher than the habitat requirement for that parameter then the parameter was considered to have failed to met the SAV habitat requirements and if the values were significantly lower (higher for secchi depth) than the habitat requirement then the parameter was to considered to have met the SAV habitat requirement. If there was no significant difference between the habitat requirements or there were insufficient data to conduct the analysis, the parameter was considered borderline.

Status for phytoplankton involved the calculation of relative status using the same technique as described for water quality relative status assessments. For phytoplankton communities the following indicators were assessed: total phytoplankton community abundance, total phytoplankton community biomass, diatom abundance, dinoflagellate abundance, cyanobacteria abundance, picoplankton abundance, and primary productivity (carbon fixation). Benchmarks for picoplankton abundance were made using data collected only in Virginia since sampling protocols for the Maryland program did not include counts of epifluorescent picoplankton.

Status of benthic communities at each station was characterized using the three-year mean value (2001 through 2003) of the B-IBI (Weisberg et al., 1997). The B-IBI indicates whether the macrobenthic community meets the restoration goals developed for benthic habitats of the Chesapeake Bay. An index value that exceeds or equals 3.0 indicates that the macrobenthic community meets or exceeds the restoration goals developed for that habitat type while a value below 3.0 indicates that the macrobenthic community does not meet the restoration goals. Status of the benthic community was classified into four levels based on the B-IBI. Values less than or equal to 2 were classified as severely degraded, values from 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 populated by benthos meeting the Chesapeake Bay Benthic Community Restoration Goals (Ranasinghe et al. 1994; Weisberg et al. 1997). This approach produces an estimate of the spatial extent and distribution of degraded benthic communities in Chesapeake Bay (Dauer and Llansó 2003; Llansó et al. 2003). To estimate the amount of area in the entire Bay that failed to meet the Chesapeake Bay Benthic Restoration Goals (P), we defined for every site *i* in stratum *h* a variable y_{hi} that had a value of 1 if the benthic community met the goals, and 0 otherwise. For each stratum, the estimated proportion of area meeting the goals, p_h, and its variance were calculated as the mean of the y_{hi}'s as follows:

$$p_h = \bar{y}_h = \sum_{i=1}^{n_h} \frac{y_{hi}}{n_h},$$

Variance for this estimate was calculated as:

$$\text{var }(p_h) = s_h^2 = \sum_{i=1}^{n_h} \frac{(y_{hi} - \bar{y}_h)^2}{n_h - 1}.$$

Estimates for strata were combined to achieve a statewide estimate as:

$$\hat{P}_{ps} = \bar{y}_{ps} = \sum_{h=1}^{10} W_h \bar{y}_h,$$

were the weighting factors, W_h, = A_h/A and A_h were the total area of the *h*th stratum. The variance of (3) was estimated as:

$$\text{var }(\hat{P}_{ps}) = V(\bar{y}_{ps}) = \sum_{h=1}^{10} W_h s_h^2 / n_h.$$

For combined strata, the 95% confidence intervals were estimated as the proportion plus or minus twice the standard error. For individual strata, the exact confidence interval was determined from tables.

B. Long-Term Trend Analyses

1. Non-tidal water quality

Trend analyses were conducted on data collected at nine stations at and above the fall-line in the Virginia tributaries. Concentrations of water-quality constituents are often correlated with streamflow. Removal of natural flow variability allows examination of changes in water quality resulting from human activities. Flow-adjusted concentration trends were determined with a non-parametric Kendall-Theil analysis. The trend slope was the overall median of the pairwise slopes of residuals from a log-linear-regression model incorporating flow and season terms. For data sets with greater than five percent censored data, a range in slope and magnitude was defined by twice computing the median slope - first, with censored data equal to zero and second, with censored data equal to the maximum detection limit. For data sets with greater than twenty percent censored data, no results were reported. A P value of 0.05 or less was considered significant for this analysis.

2. Tidal water quality

Trend analyses were conducted on the same suite of water quality parameters used for the status assessments, as well as, salinity and water temperature. Prior to the trend analyses, data were reduced to a single observation for each station month and layer combination by first calculating the median of all replicates for each layer by station and date and then calculating the median between all dates for a given station within each month. For all applicable water quality parameters, any values less then the highest detection limit were set to one half of the highest detection limit. For calculated parameters, each constituent parameter that was below the detection limit was set to one half of the detection limit and the parameter was then calculated.

Increasing trends in total nitrogen, dissolved inorganic nitrogen, total phosphorus, dissolved inorganic phosphorus, chlorophyll *a* and total suspended solids should indicate increased eutrophication and as a result positive slopes in these parameters indicate degrading conditions while negative slopes indicate improving water quality conditions. Increasing trends in secchi depth and bottom dissolved oxygen indicate increasing water clarity and reduced eutrophication, respectively and, as a result, indicate improving water quality conditions. Decreasing trends in these two parameters indicate degrading conditions.

In 1994, changes in laboratory analytical methods for estimating concentrations of total nitrogen, dissolved inorganic nitrogen, total phosphorus and dissolved inorganic phosphorus were implemented by the Department of Environmental Quality in order to improve the accuracy of concentration estimates. These changes resulted in step trends in these parameters. In order to compensate for the step trends, a “blocked” seasonal Kendall approach (Gilbert, 1987) was used to compare trends conducted between two separate time periods which in this case were the pre-method (1985 through 1993) and post-method change (1995 through 2003) time periods for these parameters. Note that 1994 was eliminated from the analyses because samples during this year were collected and processed by a laboratory that was different than the VADCLS. The “blocked” seasonal Kendall test was applied only to those segment/parameter combination for which a method change occurred. The statistical tests used for all other segment/parameter combinations were the seasonal Kendall test for monotonic trends and the Van Belle and Hughes tests for homogeneity of trends between stations, seasons, and station-season combinations (Gilbert, 1987).

A P value of 0.01 was chosen as the statistical test criterion for all water quality trend analyses. Recent studies on representative data sets from the Chesapeake Bay monitoring program have indicated that these tests are very powerful and robust, even when data violate most of the assumptions of parametric statistics (Alden et al., 1991; Alden et al., 1992b; Alden et al., 1994; Alden and Lane, 1996).

3. Living resources

Trend analyses for phytoplankton communities were conducted on the following phytoplankton community indices: the phytoplankton IBI, total phytoplankton abundance (excluding picoplankton); total phytoplankton biomass (excluding picoplankton); the Margalef species diversity index, and C^{14} productivity. In addition, trend analyses were conducted on abundance and biomass values for the following taxonomic groups: diatoms; dinoflagellates; cyanobacteria; cryptomonads; chlorophytes; bloom producing species; and toxic bloom producing species. A statistical test criterion for phytoplankton metrics was a P value of 0.05.

The Margalef species diversity index was calculated as follows:

$$D = \frac{S - 1}{\log_2 N}$$

where *S* is the number of taxa in the sample and *N* is the number of individuals (Margalef, 1958).

Trend analyses for benthic communities were conducted using the B-IBI (Ranasinghe et al., 1994; Weisberg et al., 1997) and on selected metrics of the B-IBI. Benthic restoration goals were developed for benthic habitats of the Chesapeake Bay based upon reference sites that were minimally impacted by low dissolved oxygen events and sediment contaminants. Goals were developed based upon data from an index period of July 15 through September 30. Therefore trends in the value of the B-IBI were based upon September cruise values for the 19 year period of 1985-2003. Selected benthic metrics were species diversity (H'), community abundance, community biomass, pollution-indicative species abundance, pollution-indicative species biomass, pollution-sensitive species abundance, and pollution-sensitive species biomass. See Weisberg et al. (1997) for a list of pollution-indicative and pollution-sensitive taxa.

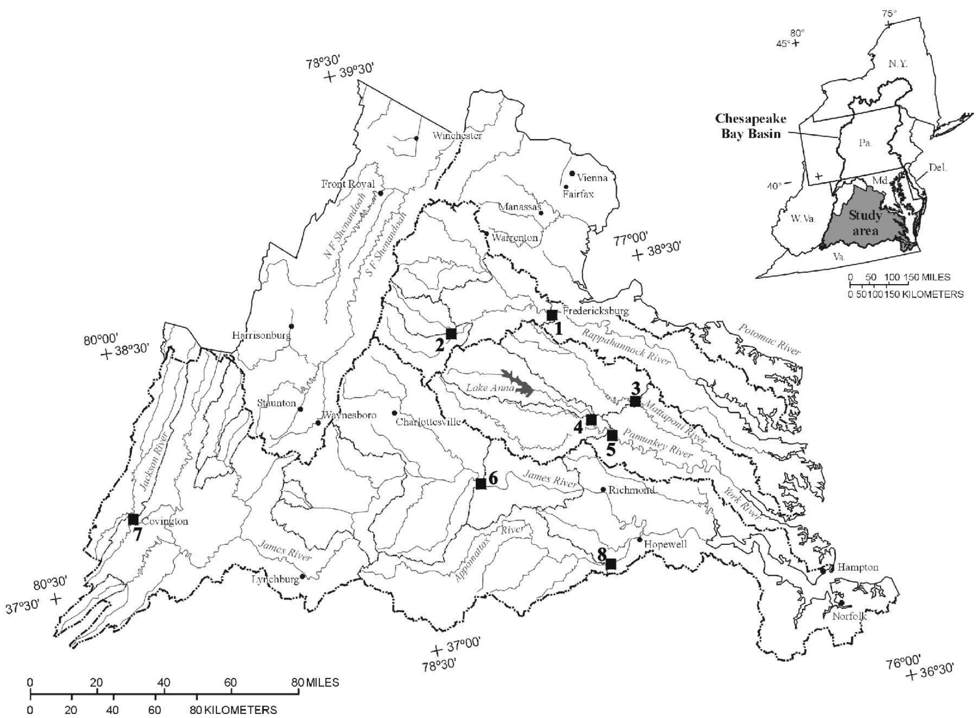
The statistical tests used for the living resources bioinidcators were the seasonal Kendall test for monotonic trends and the Van Belle and Hughes tests for homogeneity of trends between seasons (Gilbert, 1987). The statistical test criterion for the benthic bioindicators was a *P* value of 0.10.

Table 2-1. **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	x*	x*
Summer2	July through September	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 2-2. **Habitat requirements for growth and survival of SAV (from Batiuk et al., 1992; 2000).**

Salinity Regime	SAV Growth Season	Percent Light at Leaf	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



1 Station 01668000 - Rappahannock River near Fredericksburg
2 Station 01666500 - Robinson River
3 Station 01674500 - Mattaponi River near Beulahville
4 Station 01671020 - North Anna River near Doswell
5 Station 01673000 - Pamunkey River near Hanover
6 Station 02035000 - James River at Cartersville
7 Station 02013100 - Jackson River at Covington
8 Station 02041650 - Appomattox River

Figure 2-1. Locations of the USGS sampling stations at and above the fall-line in each of the Virginia tributaries.

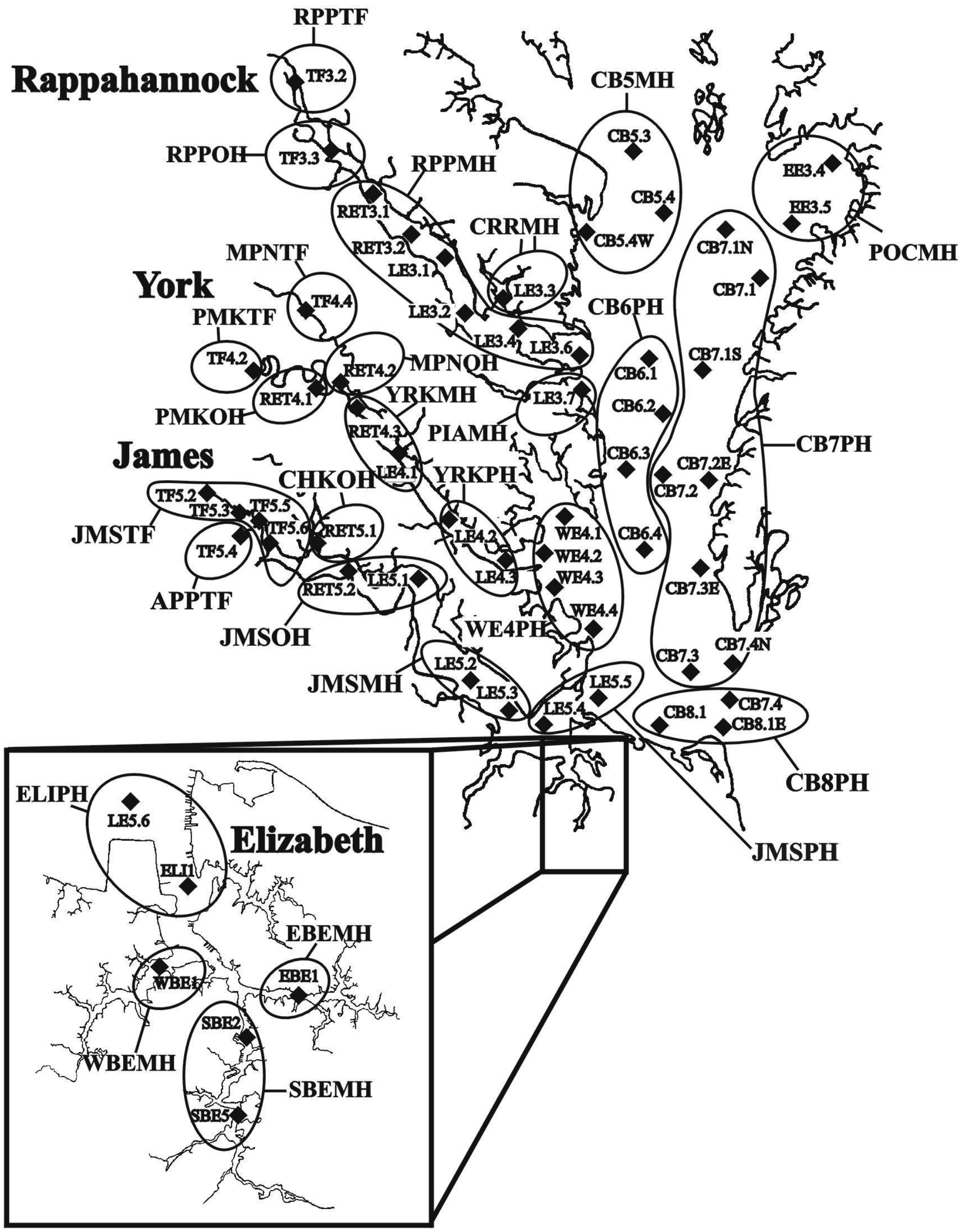


Figure 2-2. Map showing the locations of the water quality monitoring stations in the Virginia tributaries and the Lower Chesapeake Bay Mainstem used in the statistical analyses. Also shown are ellipses that delineate the Chesapeake Bay Program segmentation scheme.

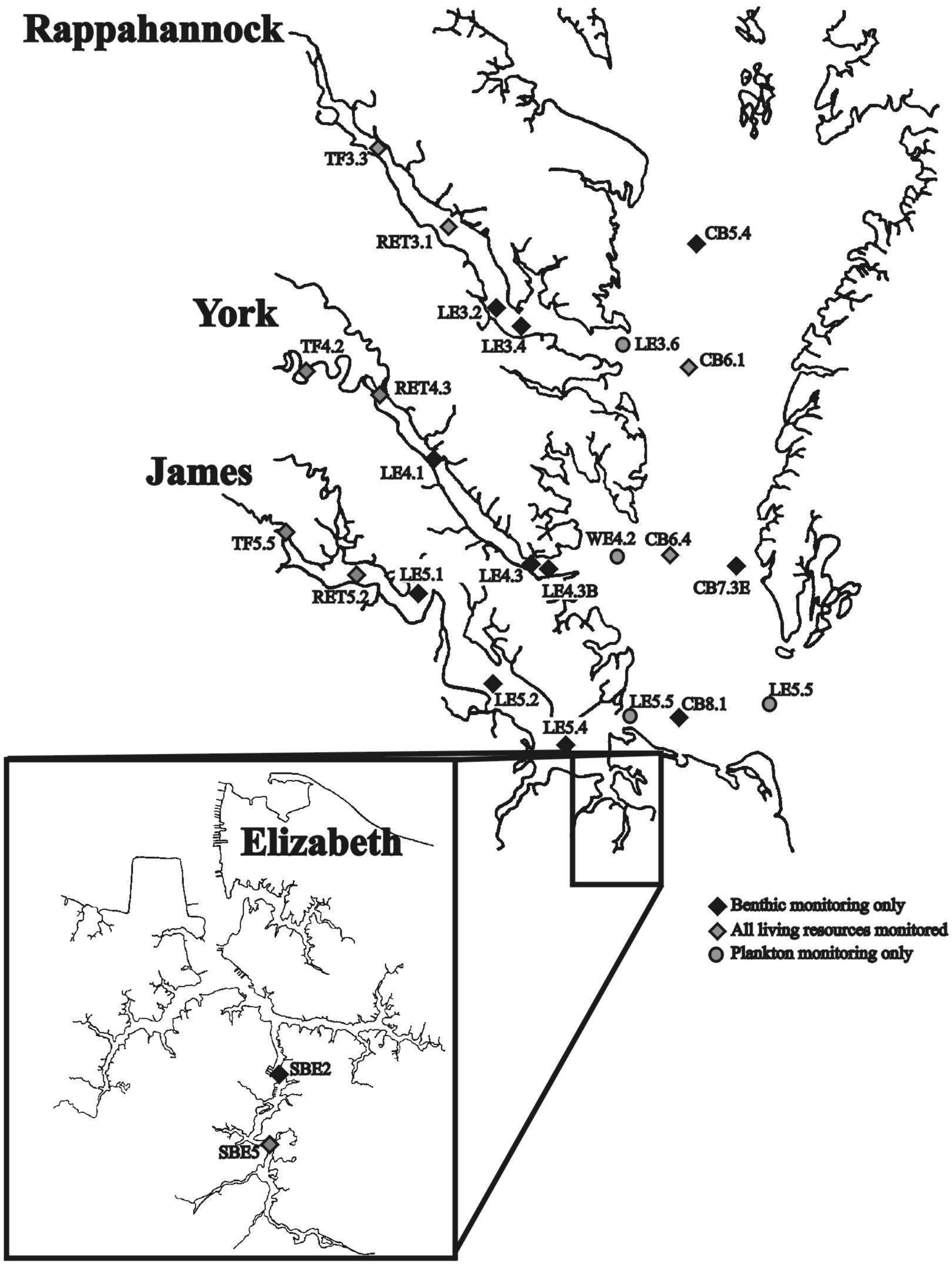


Figure 2-3. Location of living resource monitoring stations in the Virginia tributaries and the Lower Chesapeake Bay Mainstem.

Table 2-1. 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. Note that benthic status and trend analyses were conducted on data collected from June 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	x*	x*
Summer2	July through September	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 2-2. Habitat requirements for growth and survival of SAV (from Batuik el al., 1992; 2000).

Salinity Regime	SAV Growth Season	Percent Light at Leaf	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

Chapter 3. York River Basin

I. Executive Summary

A. Summary of Basin Characteristics

The York River watershed consists of approximately 8,468 km^2. Forested and agricultural lands are the most abundant in the watershed accounting for nearly 61% and 21% of the total land cover, respectively. All other land use types each account for less than 10% of the remaining land in the basin. Approximately 6,062 km of the over 16,117 km of streambanks and shoreline within the watershed have a 30 m minimum riparian forest buffer. The York River watershed has an estimated human population of 372,488 with an overall population density of 47.63 individuals per km^2. Major population centers within the watershed include Ashland, West Point, and Hampton.

In 2000, agricultural non-point sources accounted for 1,446,051 kg/yr (37%) of total nitrogen loadings to the York River, while urban non-point, mixed open non-point and point sources in combination account for 1,677,837 kg/yr (42%), in approximately equal proportions. Agricultural non-point sources accounted for 144,696 kg/yr (40%) of total phosphorus loadings, while mixed open and point sources accounted for 153,768 kg/yr (42%). In 2001, total point source loadings of total nitrogen and total phosphorus in the York River watershed were 502,801 kg/yr and 84,618 kg/yr, respectively.

Daily freshwater flow at the fall-line in the Mattaponi River ranged from a minimum of 0.01 m^3/sec to a maximum of 220.31 m^3/sec for the period of January 1, 1985 through December 31, 2002. Grand mean flow at the fall-line was 13.63 m^3/sec. Daily freshwater flow at the fall-line in the Pamunkey River was higher, ranging from a minimum of 0.68 m^3/sec to a maximum of 577.66 m^3/sec, with an grand mean flow of 26.71 m^3/sec. Figures 3-1 to 3-9 provide summary information of basin characteristics of the York River.

B. Summary of Status and Long Term Trends

Figures 3-10 and 3-11 provide summaries of water quality status and trend analyses for the York River. The terms *good*, *fair*, and *poor* used in conjunction with water quality conditions are statistically determined classifications for comparison among areas of similar salinity within the Chesapeake Bay system. Though useful in comparing current conditions among different areas of the Chesapeake Bay system, these terms are not absolute evaluations but only appraisals relative to other areas of a generally degraded system. Several major scientific studies have shown that the Chesapeake Bay system is currently nutrient enriched and has excessive and detrimental levels of nutrient and sediment pollution (USEPA, 1982; USEPA, 1983; Boynton et al., 1995; Harding and Perry, 1997; Bricker et al., 1999; USEPA 2001; Hagy et al., 2004). Given this, it is likely that an absolute evaluation in relation to ideal conditions would indicate that most water quality parameters are currently poor throughout the whole Bay system.

Status of all nutrients was good in the Upper Pamunkey River (PMKTF) and the Upper Mattaponi River. Status of nitrogen in most of the remaining segments was either fair or good, but the status of the phosphorus parameters at most segments was poor. Status of surface chlorophyll *a* was good in all segments except the Middle York River (YRKMH), the Lower York River (YRKPH) and Mobjack Bay (MOBPH) where status for this parameter was poor. Status of surface and bottom total suspended solids was predominantly poor throughout the York River. Status of secchi depth was poor in all segments of the York River except the Upper Mattaponi River (MPNTF) where the status was fair. Status of Summer1 bottom dissolved oxygen was good or fair in all segments of the York River. Degrading trends that were consistent between the pre- and post-method change periods were detected for surface and bottom nitrogen in the Lower Pamunkey River (PMKOH), the Middle York River (YRKMH) and the Lower York River (YRKPH). A degrading trend in surface total nitrogen was detected in the Lower Mattaponi as well. At least one degrading trend in either total phosphorus or dissolved inorganic phosphorus was detected in all segments except Mobjack Bay (MOBPH). Improving trends in surface and bottom total nitrogen that were consistent between the pre- and post-method change periods were detected in Mobjack Bay (MOBPH). Improving trends for surface and bottom dissolved inorganic phosphorus were also detected in the Upper Pamunkey River (PMKTF).

Surface dissolved inorganic nitrogen was borderline or met the SAV habitat requirements in all applicable segments. Surface dissolved inorganic phosphorus was borderline or did not meet the SAV habitat requirement in all segments except Mobjack Bay (MOBPH). Surface chlorophyll *a* met the SAV habitat requirements in all segments in the York River. The SAV habitat requirement for surface total suspended solids was met in three segments, the Lower Mattaponi River (MPNOH), the Lower York River, and Mobjack Bay. Secchi depth was borderline or failed to meet the SAV habitat requirement in all segments. During the SAV growing season, long-term degrading trends for surface total nitrogen were detected in the Upper Pamunkey River (PMKTF) and the Middle York River (YRKMH). A long-term degrading trend in surface dissolved inorganic nitrogen was also detected in the Lower Mattaponi River (MPNOH). A long-term degrading trend in surface total phosphorus was detected in the Upper Pamunkey River (PMKTF), and long-term degrading trends in surface dissolved inorganic phosphorus were detected in the Lower Pamunkey River (PMKOH), the Lower Mattaponi River (MPNOH), and the Lower York River (YRKMH). A long-term improving trend in this parameter was detected in the Upper Pamunkey River (PMKTF).

Figures 3-12 and 3-13 provide summaries of living resource status and trend analyses for the York River. Phytoplankton communities appear to be degraded throughout the York River and are continuing to degrade. Status of total biomass, the biomass-to-abundance ratio, and Margalef Species Diversity was poor in all segments of the York. Status of dinoflagellate biomass, cyanophyte abundance and biomass, and picoplankton biomass were either poor or fair in all segments. Although improving trends in diatom biomass and chlorophyte biomass were detected throughout the York River, degrading trends in cyanophyte abundance and biomass were detected at all stations in the York River.

Benthic community status as measured with the B-IBI was good at all stations except RET4.3 and TF4.2 where status of this parameter was fair and poor, respectively. An improving trend in the B-IBI was detected at station LE4.3B in the lower York River accompanied by improving trends in pollution sensitive and pollution indicative species abundance and the Shannon-Weiner diversity index. Although no other trends in the B-IBI were detected, a degrading trend in pollution sensitive species biomass was detected in the Middle York River (RPPMH) and improving trends in total abundance and the Shannon-Weiner diversity index were detected in the Upper Pamunkey River (PMKTF).

C. Summary of Major Issues in the Basin

Although status of nitrogen parameters was typically good in most segments, degrading trends in surface and bottom total nitrogen observed throughout the York River are of concern. Status of phosphorus was poor in many segments of the York and degrading trends were detected in most segments. In addition, nutrients were either borderline or failed to meet the SAV habitat requirements for all segments except the Lower York River (YRKPH) and Mobjack Bay (MOBPH).

Water clarity also appears to be a widespread problem in the York River. Secchi depth status was poor in all segments of the York River except for the Upper Mattaponi River where it was fair. Status of surface and bottom total suspended solids was poor in most segments of the York. Status of surface chlorophyll *a* was poor only in the lower segments of the York River (YRKMH, YRKPH, and MOBPH). Secchi depth was either borderline or failed to met SAV habitat requirements for all segments except Mobjack Bay. The SAV habitat requirement for total suspended solids was violated in three of the seven segments in the York River

The major concerns within the phytoplankton community are increasing long-term trends in abundance and biomass among the cyanobacteria. These taxa are a less favorable food source within the water column, are associated with degrading water conditions, and also contain several potential bloom and toxin producers. The primary concern for the benthic communities was the poor status of the B-IBI in the Upper Pamunkey River (PMKTF) and the decreasing trend in Shannon-Weiner diversity at that segment.

II. Management Recommendations

The cause of the poor status and trends in phosphorus is uncertain. It seems likely that these problems are related, at least in part, to the increase in recent years of point source phosphorus loadings in both the Pamunkey and Mattaponi Rivers. The source of the water clarity problem is also unclear. It may be the result of increased sediment input from a variety of sources. Alternatively, the decrease in water clarity may be caused by an increase in the abundance of phytoplankton in the water column. At the CBP segment scale, chlorophyll *a* levels in the mesohaline York River are the highest of all Virginia's tidal waters. Degrading (increasing) trends in cyanobacterial abundance were detected at all stations monitored in the York River, and degrading trends in surface chlorophyll *a* concentrations were also detected in three segments of the

York River. The increases in point source nitrogen and phosphorus loads observed above the fall-line in the Pamunkey River could contribute to potential increases in phytoplankton. It is recommended that additional point source controls be initiated in this tributary to alleviate this potential problem.

Freshwater input to both the Pamunkey and Mattaponi rivers was lower from 1999 through 2001 than in previous years. Low flows could also adversely affect both nutrient levels and water clarity by reducing the flushing rates in the river such that nutrient, sediment and/or phytoplankton concentrations increase as a result.

A more thorough investigation of existing data sets may help to identify potential sources of the water clarity problems. An analysis of trends in both the fixed and volatile components of total suspended solids along with a statistical analysis of potential relationships between secchi depth and various environmental factors such as suspended solids concentrations, flow regime and phytoplankton concentrations is recommended. Continued monitoring of the status of the phytoplankton community is a prime concern to determine changes in the balance of favorable and non-favorable dominant taxa within the populations. Additional increases in the cyanobacteria or dinoflagellate populations should be documented in relation to location and water quality conditions.

With respect to benthic communities, the problem was located in the Middle York River (YRKMH). In the Middle York River benthic community status was marginal at both stations (RET4.3 and LE4.1) with a degrading trend in the B-IBI at Stations RET4.3. Additional information is required before conclusions regarding management actions related to the benthos can be made.

III. Overview of Basin Characteristics

The York River watershed consists of approximately 8,468 km^2 and extends 225 km from the headwaters of the Pamunkey and Mattaponi rivers in Orange and Louisa counties to Yorktown,Virginia where it empties into Chesapeake Bay. The human population in the York River watershed increased from 324,036 individuals in 1990 to 372,488 in 2000 (Figure 3-1a) and is projected to reach over 450,000 by 2020. Overall population density was 47.63 individuals per km^2. Population density within the York River watershed ranged from 20.59 individuals per km^2 within the Mattaponi sub-watersheds to over 500 individuals per km^2 in the Poquoson (lower portion of the York River) sub-watershed (Figure 3-1b). Major population centers within the watershed include Ashland, Gloucester Point, Hampton, and West Point.

Forested and agricultural lands are the most abundant land-use types in the watershed accounting for nearly 61% and 21% of the total land cover in the basin, respectively. All other land use types each account for less than 10% of the remaining land in the basin. Approximately 6,062 km of the over 16,117 km of streambanks and shoreline within the watershed has a 30 m minimum riparian forest buffer. Forested land decreases substantially moving downstream from the Pamunkey and Mattaponi rivers, both in terms of total area and percent of the total area within the sub-watersheds, while urban land increases downstream (Figures 3-2a-b).

In 2000, agricultural non-point sources accounted for 1,446,051 kg/yr (37%) of total nitrogen loadings to the York River while urban non-point, mixed open non-point and point sources in combination account for 1,677,837 kg/yr (42%) in approximately equal proportions (Figure 3-3a). Agricultural non-point sources accounted for 144,696 kg/yr (40%) of total phosphorus loadings while mixed open and point sources accounted for 153,768 kg/yr (42%) in nearly equal amounts (Figure 3-3b). The primary source of sediment loads to the York River is non-point run-off from agricultural and forest lands which account for 63,503,300 kg/yr (54%) and 29,937,270 kg/yr (25%) of the total load, respectively. The remaining sources of sediment loads contribute little to the total load (Figure 3-3c).

From 1985 through 1988, point source loadings of total nitrogen decreased substantially but during the following decade increased to levels above those observed in 1985. This increasing trend in point source nitrogen may be reversing as indicated by the drop in loadings during 2000 and 2001 (Figure 3-4a). Total phosphorus loadings substantially decreased immediately following the phosphate ban from over 200,000 kg/yr in 1985 to less than 70, 000 kg/yr in 1990. Although there appears to be a small increasing trend in the data point source loadings to the watershed have remained relatively stable at values less than 100,000 kg/yr (Figure 3-4b).

In 2001, point source loads of both total nitrogen and total phosphorus were concentrated above the fall-line in the Pamunkey River, and within the Mattaponi River,and Poquoson sub-watersheds. Point source loadings within other sub-watersheds are negligible (Figure 3-5a-b). Plots of annual point source total nitrogen loadings to these three sub-watersheds showed a fairly consistent increase in nitrogen loadings above the fall-line in the Pamunkey and in the Poquoson sub-watershed from 1985 through2001 (Figure 3-6). Following the phosphate ban, point source phosphorus loadings decreased substantially and have remained at consistently low levels in four of the five sub-watersheds of the York River (Figure 3-7). However, point source loadings of this nutrient are increasing above the fall-line in the Pamunkey River (Figure 3-7a).

Daily freshwater flow at the fall-line in the Mattaponi ranged from a minimum of 0.01 m^3/sec to a maximum of 220.31 m^3/sec for the period of January 1, 1985 through December 31, 2002. Grand mean flow at the fall-line was 13.63 m^3/sec. Daily freshwater flow at the fall-line in the Pamunkey was higher, ranging from a minimum of 0.68 m^3/sec to a maximum of 577.66 m^3/sec and with an grand mean flow of 26.71 m^3/sec. Peaks in monthly mean freshwater flow for the last four years in both the Pamunkey and Mattaponi rivers were generally less than those of previous years' peaks (Figure 8a-b). Annual mean flow during the last four years in both the Pamunkey and Mattaponi rivers was lower than the respective grand mean flow for each tributary (Figure 3-9a-b).

IV. Overview of Monitoring Results

Figures 3-10 and 3-11 depict the results of the status and trend analyses for water quality parameters for the Annual season. Status of surface and bottom total nitrogen was generally good or fair in the Pamunkey River and Mattoponi River segments (PMKTF, PMKOH, MPNTF and MPNOH) but fair and poor in the York River segments (YRKMH and YRKPH) and Mobjack Bay (MOBPH). Status of surface and bottom dissolved inorganic nitrogen was good in every segment of the York River. Status of phosphorus parameters was predominantly good in the Upper Pamunkey River (PMKTF), the Upper Mattaponi River (MPNTF) and Mobjack Bay (MOBPH). Status of phosphorus parameters was poor in the Lower Pamunkey River (PMKOH), Lower Mattaponi River (MPNOH), the Middle York River (YRKMH), the Lower York River (YRKPH) and Mobjack Bay (MOBPH). Status of surface chlorophyll *a* was good in the Pamunkey River and Mattaponi River segments, while status in the York River segments and Mobjack Bay (MOBPH) was poor. Status for surface and bottom total suspended solids was poor or fair in most segments in the York River except for bottom total suspended solids in the Upper Pamunkey River (PMKTF), surface and bottom total suspended solids in the Upper Mattaponi River (MPNTF), and bottom total suspended solids in Mobjack Bay (MOBPH) where status was good. Secchi depth status of was poor in all segments of the York River except in the Upper Mattaponi River where it was fair. Status of Summer1 bottom dissolved oxygen was good or fair in all segments of the York River.

Surface dissolved inorganic phosphorus was borderline or failed to meet the SAV habitat criterion in all segments except Mobjack Bay. However, surface chlorophyll *a* met the SAV habitat criterion in all segments. Where applicable, surface dissolved inorganic nitrogen was either borderline or met the SAV habitat requirement. Surface total suspended solids was borderline and met the SAV habitat requirement in the Upper Pamunkey River and Upper Mattaponi River, respectively. The SAV criteria were not met in the Lower Pamunkey River (PMKTF), the Lower Mattaponi River (MPNOH) and the Middle York River, but passed the SAV habitat requirement in the Lower York River (YRKPH) and Mobjack Bay (MOBPH) Secchi depth was borderline or failed to meet the SAV habitat requirement in all segments except Mobjack Bay (MOBPH) (Table 3-5).

Degrading trends in surface and bottom total nitrogen were detected in the Lower Pamunkey River (PMKOH), the Middle York River (YRKMH) and the Lower York River (YRKPH) which were consistent between the pre- and post-method change trends. A degrading trend in surface total nitrogen, which was consistent between the pre- and post-method periods, was also detected in the Lower Mattaponi River (MPNOH). A degrading trend in surface total nitrogen was also detected in the Upper Pamunkey River (PMKTF) during the post-method change period. Improving trends were detected in surface and bottom total nitrogen in Mobjack Bay (MOBPH). Degrading trends in bottom total phosphorus, which were consistent between the pre- and post-method change periods, were detected in all segments of the York River, except the Lower York River (YRKPH) and Mobjack Bay (MOBPH). Several degrading trends in surface and bottom total phosphorus were also detected during the pre-method change period. Long-term degrading trends in surface total phosphorus were also detected in the Upper Pamunkey River (PMKTF), the Upper Mattaponi River (MPNTF), and the Lower Mattaponi River (MPNOH). Degrading trends in surface and bottom dissolved inorganic phosphorus that were consistent between the pre- and post-method change periods were detected in the Middle York River (YRKMH) and the Lower York River (YRKPH), while long-term improving trends in surface and bottom dissolved inorganic phosphorus were detected in the Upper Pamunkey River (PMKTF) and in bottom dissolved inorganic phosphorus in the Upper Mattaponi River (MPNTF). An improving trend in bottom dissolved inorganic phosphorus was detected in the Upper Mattaponi River (MPNOH) during the post-method change period. An improving trend in surface total suspended solids was detected in Mobjack Bay (MOBPH) while a degrading trend in bottom total suspended solids was detected in the Upper Mattaponi River (MPNTF). Degrading trends in secchi depth were detected in the Upper Mattaponi River (MPNTF) and Mobjack Bay (MOBPH).

During the SAV growing season long-term degrading trends for surface total nitrogen were detected in the Upper Pamunkey River (PMKTF) and the Middle York River (YRKMH). A long-term degrading trend in surface dissolved inorganic nitrogen was also detected in the Lower Mattaponi River (MPNOH). A long-term degrading trend in surface total phosphorus was detected in the Upper Pamunkey River (PMKTF), and long-term degrading trends in surface dissolved inorganic phosphorus were detected in the Lower Pamunkey River (PMKOH), the Lower Mattaponi River (MPNOH) and the Lower York River (YRKMH). A long-term improving trend in this parameter was detected in the Upper Pamunkey River (PMKTF).

Figures 3-12 and 3-13 summarize the results of the status and trend analyses for living resources in the York River. Phytoplankton community conditions in the York River appear to reflect water quality conditions. Status of all phytoplankton community metrics in the Upper Pamunkey River was poor or fair except for primary production for which the status was good. All phytoplankton community parameters in the Middle York River (YRKMH) were poor except for primary productivity, diatom biomass and chlorophyte biomass for which the status was good. In Mobjack Bay, status of most phytoplankton parameters was poor or fair. Improving trends in diatom biomass and chlorophyte biomass and degrading trends in cyanophyte abundance and biomass were detected at all stations in the York River. An improving trend in primary productivity was also detected in Mobjack Bay.

Overall, the phytoplankton communities throughout the York River appear to be impacted probably due to the widespread poor status for many of the water quality parameters and the widespread degrading trends in nutrients observed in the river. Phytoplankton status in many categories is either poor or fair, with degrading trends identified in cyanobacteria abundance and biomass in all river segments where these parameters were measured.

Benthic community status, as measured with the B-IBI, was good at all stations except RET4.3 and TF4.2 where status of this parameter was fair and poor, respectively. An improving trend in the B-IBI was detected at station LE4.3B in the lower York River accompanied by improving trends in pollution sensitive and pollution indicative species abundance and the Shannon-Weiner diversity index. Although no other trends in the B-IBI were detected, a degrading trend in pollution sensitive species biomass was detected in the Middle York River (RPPMH) and improving trends in total abundance and the Shannon-Weiner diversity index were detected in the Upper Pamunkey River (PMKTF).

V. Detailed Overview of Status and Trends

A. Fall-Line

Above the fall-line of the North Anna River at Doswell, degrading trends in flow adjusted concentrations of total nitrogen and total suspended solids were detected along with improving trend in flow adjusted concentrations of total phopshorus. In the Pamunkey River at Hanover, degrading trends in flow adjusted concentrations of total nitrogen, nitrates-nitrites, total phosphorus, dissolved inorganic phosphorus, and total suspended solids were detected. No trends in flow adjusted concentrations for any parameters were detected in the Mattaponi River near Beulahville (Table 3-1).

B. Tidal Freshwater Pamunkey River (PMKTF - Upper Pamunkey)

1. Water quality for living resources

a) Nutrient parameters

Status of all nitrogen and phosphorus parameters was good in this segment (Figure 3-10;Table 3-2). There were no significant trends in nitrogen that were consistent between the pre- and post-method change periods but there was a significant degrading trend in surface total nitrogen during the post-method period. Significant degrading trends in surface and bottom total phosphorus were detected that were consistent between the pre- and post-method change periods. Significant improving trends in surface and bottom dissolved inorganic phosphorus were detected that were consistent between the pre- and post-method change periods (Figure 3-10;Table 3-3).

b) Non-nutrient parameters

Status of surface chlorophyll *a*, bottom total suspended solids and Summer1 bottom dissolved oxygen was good. Status of surface total suspended solids and secchi depth was poor (Figure 3-10;Table 3-2). No trends were detected in any of the non-nutrient parameters (Figure 3-10;Table 3-4).

2. Water quality for SAV

a) SAV habitat requirements

Although the SAV habitat requirements for surface dissolved inorganic phosphorus were met, all other parameters were borderline (Table 3-5).

b) Nutrient parameters

Degrading trends that were consistent between pre- and post-method change periods were detected for surface total nitrogen and surface total phosphorus. An improving trend in surface dissolved inorganic phosphorus was also detected that was consistent between pre- and post-method change periods (Table 3-6).

c) Non-nutrient parameters

No trends were detected in any of the non-nutrient parameters during the SAV growing season in this segment (Table 3-7).

3. Living resources

Long term trends in total phytoplankton abundance and biomass continue to be increasing. This development is associated with the increases in the diatom, chlorophyte, cryptophyte, and cyanobacteria categories. No significant change is noted for the dinoflagellates, although their status is poor, along with diatoms and total phytoplankton biomass (Figure 3-12, Appendix F). The increased trends in cyanobacteria abundance and biomass are a concern since these are a less desirable food source than the other flora, yet their current status is fair. Of note among these cyanobacteria are several potential toxin producers. No specific trends were present for species diversity (poor status), productivity (good status), or for the autotrophic picoplankton (fair status). The overall phytoplankton status was mainly fair to poor.

Benthic community status was good with improving trends in species diversity and total abundance (Figure 3-13). Values of the B-IBI generally remain above the B-IBI goal but occasionally dip below it, as they have during the last two years (Appendix L).

C. Oligohaline Pamunkey River (PMKOH - Lower Pamunkey)

1. Water quality for living resources

a) Nutrient parameters

Status of all nitrogen parameters was good except for bottom nitrogen for which the status was poor. Status of all phosphorus parameters was poor (Figure 3-10;Table 3-2). Significant degrading trends in surface and bottom total nitrogen and bottom total phosphorus were detected that were consistent between the pre- and post-method periods. A significant degrading trend was also detected in surface total phosphorus during the pre-method change period (Figure 3-10;Table 3-3).

b) Non-nutrient parameters

Status of surface chlorophyll *a* and Summer1 bottom dissolved oxygen was good while the status of surface and bottom total suspended solids and secchi depth was poor (Figure 3-11;Table 3-2). There were no trends in non-nutrient parameters in this segment (Figure 3-11;Table 3-4).

2. Water quality for SAV

a) SAV habitat requirements

All parameters except surface chlorophyll *a* failed to meet the SAV habitat criteria (Table 3-5).

b) Nutrient parameters

There were significant differences in trends between the pre- and post-method change periods for all parameters collected during the SAV growing season except for surface dissolved inorganic phosphorus for which the combined trend was degrading. Degrading trends were detected for surface total nitrogen and surface total phosphorus during the pre-method change period (Table 3-6).

c) Non-nutrient parameters

No trends were detected in any of the non-nutrient parameters during the SAV growing season in this segment (Table 3-7).

3. Living resources

Living resource monitoring is not conducted within this segment.

D. Tidal Freshwater Mattaponi River (MPNTF - Upper Mattaponi)

1. Water quality for living resources

a) Nutrient parameters

Status of all nutrient parameters was good (Figure 3-10;Table 3-2). Significant degrading trends in surface and bottom total phosphorus were detected that were consistent between the pre- and post-method change periods. A significant improving trend in bottom dissolved inorganic phosphorus was detected that was consistent between the pre- and post-method change periods. An improving trend in surface dissolved inorganic phosphorus was also detected during the post-method change period (Figure 3-10;Table 3-3).

b) Non-nutrient parameters

Status of all non-nutrient parameters was good except secchi depth for which the status was fair (Figure 3-11;Table 3-2). A degrading trend was detected in secchi depth in this segment accompanied by a decreasing trend in surface water temperature (Figure 3-11;Table 3-4).

2. Water quality for SAV

a) SAV habitat requirements

Although the SAV habitat requirements were met for surface chlorophyll a and surface total suspended solids, surface dissolved inorganic phosphorus and secchi depth were borderline (Table 3-5).

b) Nutrient parameters

A degrading trend in surface dissolved inorganic nitrogen was detected that was consistent between the pre- and post-method change periods. An improving trend was detected in surface dissolved inorganic phosphorus during the post-method change period (Table 3-6).

c) Non-nutrient parameters

No trends were detected for any of the non-nutrient parameters during the SAV season in this segment (Table 3-7).

3. Living resources

Living resource monitoring is not conducted within this segment.

E. Oligohaline Mattaponi River (MPNOH - Lower Mattaponi)

1. Water quality for living resources

a) Nutrient parameters

Status of all nitrogen parameters was good or fair while status of all phosphorus parameters was poor (Figure 3-10;Table 3-2). Significant degrading trends in surface total nitrogen and surface and bottom total phosphorus were detected that were consistent between the pre- and post-method change periods (Figure 3-10;Table 3-3).

b) Non-nutrient parameters

Status of surface chlorophyll *a* was good while status of total suspended solids and secchi depth was poor. Status of bottom dissolved oxygen was fair (Figure 3-11;Table 3-2). Increasing trends in surface and bottom salinity were detected in this segment (Figure 3-11;Table 3-4).

2. Water quality for SAV

a) SAV habitat requirements

Although surface chlorophyll *a* met the SAV habitat requirement, surface total suspended solids and secchi depth failed the SAV habitat requirement and surface dissolved inorganic phosphorus was borderline (Table 3-5).

b) Nutrient parameters

Significant degrading trends were detected in surface dissolved inorganic nitrogen and surface dissolved inorganic phosphorus that were consistent between the pre- and post-method changes periods. Degrading trends in surface total nitrogen and surface total phosphorus were also detected during the pre-method change period (Table 3-6).

c) Non-nutrient parameters

A degrading trend was detected in surface total suspended solids during the SAV growing season in this segment (Table 3-7).

3. Living resources

Living resource monitoring is not conducted within this segment.

F. Mesohaline York River (YRKMH - Middle York)

1. Water quality for living resources

a) Nutrient parameters

Status for surface and bottom total nitrogen was fair and poor while the status of surface and bottom dissolved inorganic nitrogen was good (Figure 3-10;Table 3-2). Status of all phosphorus parameters was poor. Significant trends in surface and bottom total nitrogen were detected that were consistent between the pre- and post-method change period. Significant degrading trends in bottom total and surface and bottom dissolved inorganic phosphorus were detected that were consistent between the pre- and post-method change periods. A degrading trend in surface total phosphorus was also detected during the pre-method time period (Figure 3-10;Table 3-3)

b) Non-nutrient parameters

The status of all non-nutrient parameters was poor except for Summer1 bottom dissolved oxygen for which the status was good (Figure 3-11;Table 3-2). A degrading trend in bottom total suspended solids was detected (Figure 3-11;Table 3-4).

2. Water quality for SAV

a) SAV habitat requirements

Although surface chlorophyll *a* met the SAV habitat requirements, all other parameters exceeded their respective criteria, or were borderline (Table 3-5).

b) Nutrient parameters

Degrading trends in surface total nitrogen and surface dissolved inorganic phosphorus were detected that were consistent between the pre- and post-method changes periods. A significant degrading trend in surface total phosphorus was also detected in pre-method change period (Table 3-6).

c) Non-nutrient parameters

No significant trends were detected in any non-nutrient parameters in this segment during the SAV growing season (Table 3-17).

3. Living resources

Total phytoplankton abundance and biomass had increasing trends, with poor status noted for total phytoplankton biomass. Also, increased favorable biomass trends were present for diatoms, chlorophytes, and cryptomonads. No significant trends were found for dinoflagellates (poor status), species diversity (poor status), or productivity (good status). Both cyanobacteria abundance and biomass had degrading trends, however, the picoplankton composed of mainly smaller cyanobacteria had poor status but showed a decreasing trend (Figure 3-12, Appendix F). Although degrading and improving trends were detected for multiple phytoplankton groups it is not clear that these trends will continue. The overall phytoplankton status of this region is mixed, but the majority of algal categories had poor status.

The B-IBI met the goal at station LE4.1, but was marginal at station RET4.3. No trends in benthic community parameters were detected at either station (Figure 3-13). In general, B-IBI values at station LE4.1 declined during the early 1990s to values below the B-IBI goal, and have increased during the last eight years to just above the B-IBI goal in 2003. B-IBI values at station RET4.3 were generally at, or slightly above, the B-IBI goal at this station (Appendix L).

G. Polyhaline York River (YRKPH- Lower York)

1. Water quality for living resources

a) Nutrient parameters

Status of all nitrogen parameters was good except bottom total nitrogen for which the status was poor. Status for surface and bottom total phosphorus was poor while the status for surface and bottom dissolved inorganic phosphorus was poor and fair, respectively (Figure 3-10;Table 3-3). Significant degrading trends in surface and bottom total nitrogen and in surface and bottom dissolved inorganic phosphorus were detected that were consistent between the pre- and post-method time periods. Degrading trends in surface and bottom total phosphorus were also detected but only during the pre-method change period (Figure 3-10;Table 3-3).

b) Non-nutrient parameters

Status of all non-nutrient parameters was either fair or poor (Figure 3-11;Table 3-2). No trends were detected for any of the non-nutrient parameters in this segment (Figure 3-11;Table 3-4).

2. Water quality for SAV

a) SAV habitat requirements

All parameters met the SAV habitat requirements except for surface dissolved inorganic phosphorus and secchi depth which were borderline (Table 3-5).

b) Nutrient parameters

No significant trends in nutrient parameters were detected that were consistent between pre- and post-method change periods. However a degrading trend in surface total phosphorus was detected during the pre-method change period (Table 3-6).

c) Non-nutrient parameters

A degrading trend was detected in secchi depth during the SAV growing season (Table 3-9).

3. Living resources

Phytoplankton monitoring is not conducted within this segment. Benthic community status was good at both stations LE4.3B and LE4.3 and an improving trend in the B-IBI was detected at station LE4.3B (Figure 3-13). Values of the B-IBI showed a steady increase from severely degraded conditions in 1990 to just above the B-IBI goal during the last three years (Appendix L).

H. Mobjack Bay (MOBPH)

1. Water quality for living resources

a) Nutrient parameters

Status was fair for surface and bottom total nitrogen and good for surface and bottom dissolved inorganic nitrogen. Status was good for all phosphorus parameters, except for surface total phosphorus for which the status was fair (Figure 3-10;Table 3-2). Significant improving trends in surface and bottom total nitrogen were detected that were consistent between the pre- and post-method change periods. No other nutrient trends were detected (Figure 3-10;Table 3-3).

b) Non-nutrient parameters

Status was poor for surface chlorophyll *a* and secchi depth, fair for surface total suspended solids and good for bottom total suspended solids and Summer1 bottom dissolved oxygen (Figure 3-11; Table 3-2). An improving trend was detected in surface total suspended solids, while a degrading trend was detected in secchi depth. (Figure 3-11;Table 3-4).

2. Water quality for SAV

a) SAV habitat requirements

All parameters meet the SAV habitat requirements (Table 3-5).

b) Nutrient parameters

Improving trends were detected in surface total nitrogen and surface dissolved inorganic nitrogen (Table 3-6).

c) Non-nutrient parameters

A significant degrading trend in secchi depth was detected in this segment during the SAV growing season (Table 3-5).

3. Living resources

Total phytoplankton biomass had an increasing long-term trend at this site, but with no significant trends in total phytoplankton abundance, in the biomass to abundance ratio, or species diversity, with each of these categories showing poor status. This increased biomass was accompanied by increasing biomass trends among the diatoms (good status), chlorophytes (good status), and cyanobacteria (poor status). Cyanobacteria abundance also had an increasing trend with poor status. The dinoflagellate biomass had fair status with no significant trends (Figure 3-12, Appendix F).

Sporadic blooms of dinoflagellates are common in this region from spring through early fall. The status results among the phytoplankton categories were generally poor, indicating an impacted area, and a decline in the overall phytoplankton community.

Benthic monitoring is not conducted within this segment and it is recommended that monitoring of benthic communities be conducted within this segment.

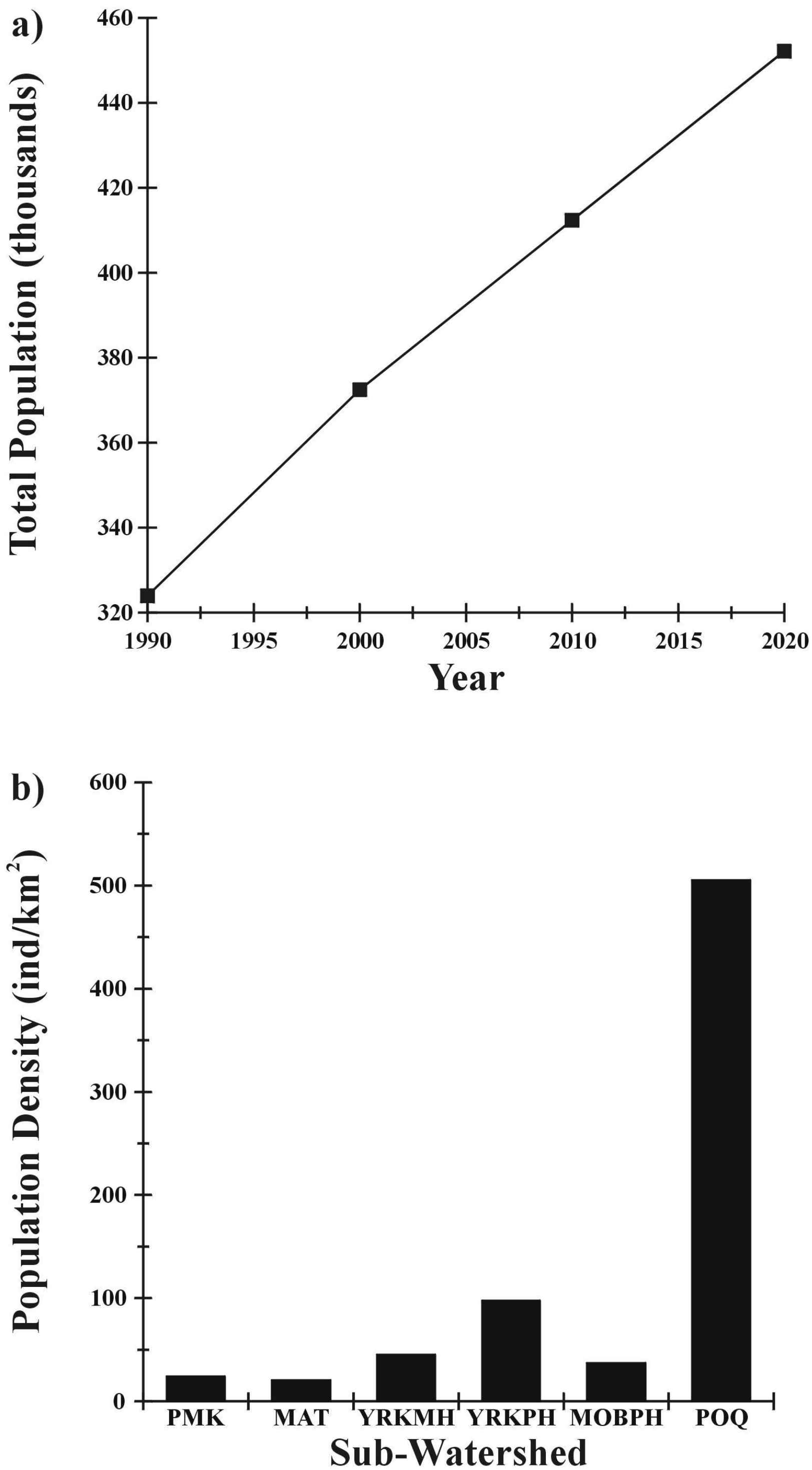


Figure 3-1. Patterns in: a) total and projected total watershed population over time, and b) population density between sub-watersheds within the York River basin.

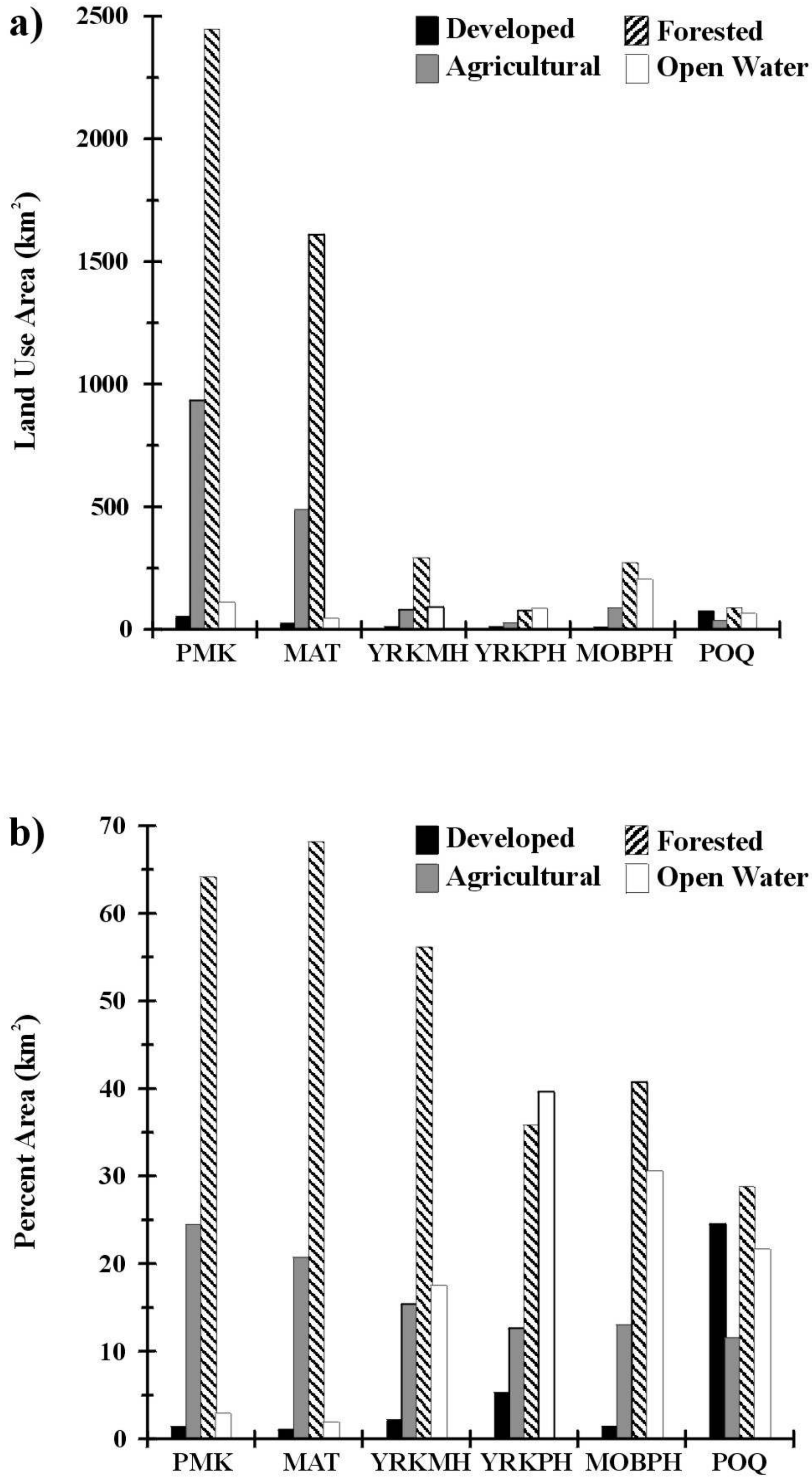


Figure 3-2. Differences in: a) total area, and b) percentages of land-use types between sub-watersheds of the York River for 1999. Data presented were provided by the USEPA, Chesapeake Bay Program Office.

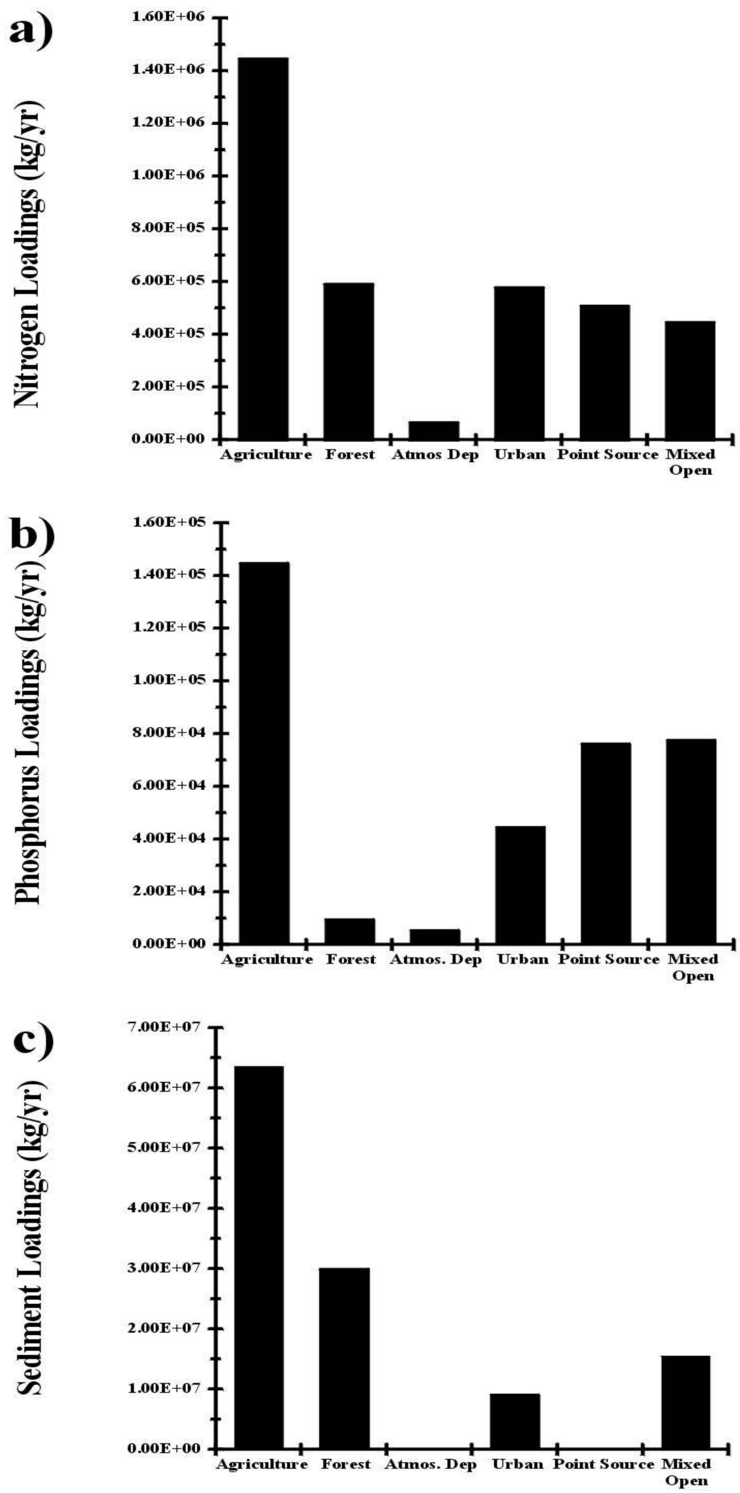
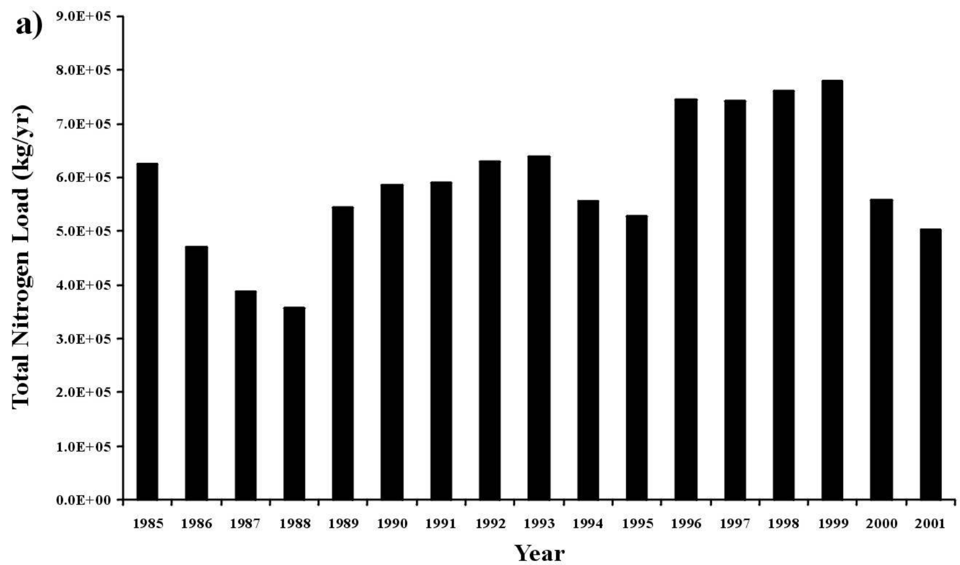


Figure 3-3. Non-point source loadings of: a) total nitrogen, b) total phosphorus, and c) sediments by source for the York River in 2000. Data generated using the USEPA Chesapeake Bay Watershed Model.



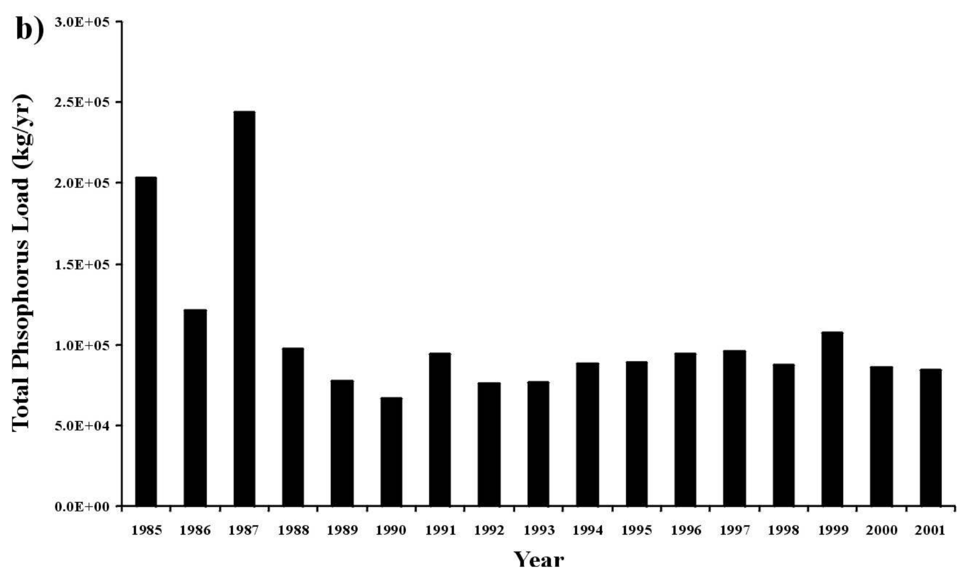


Figure 3-4. Long-term trends in point source: a) total nitrogen loadings, and b) total phosphorus loadings in the York River from 1985 through 2001.

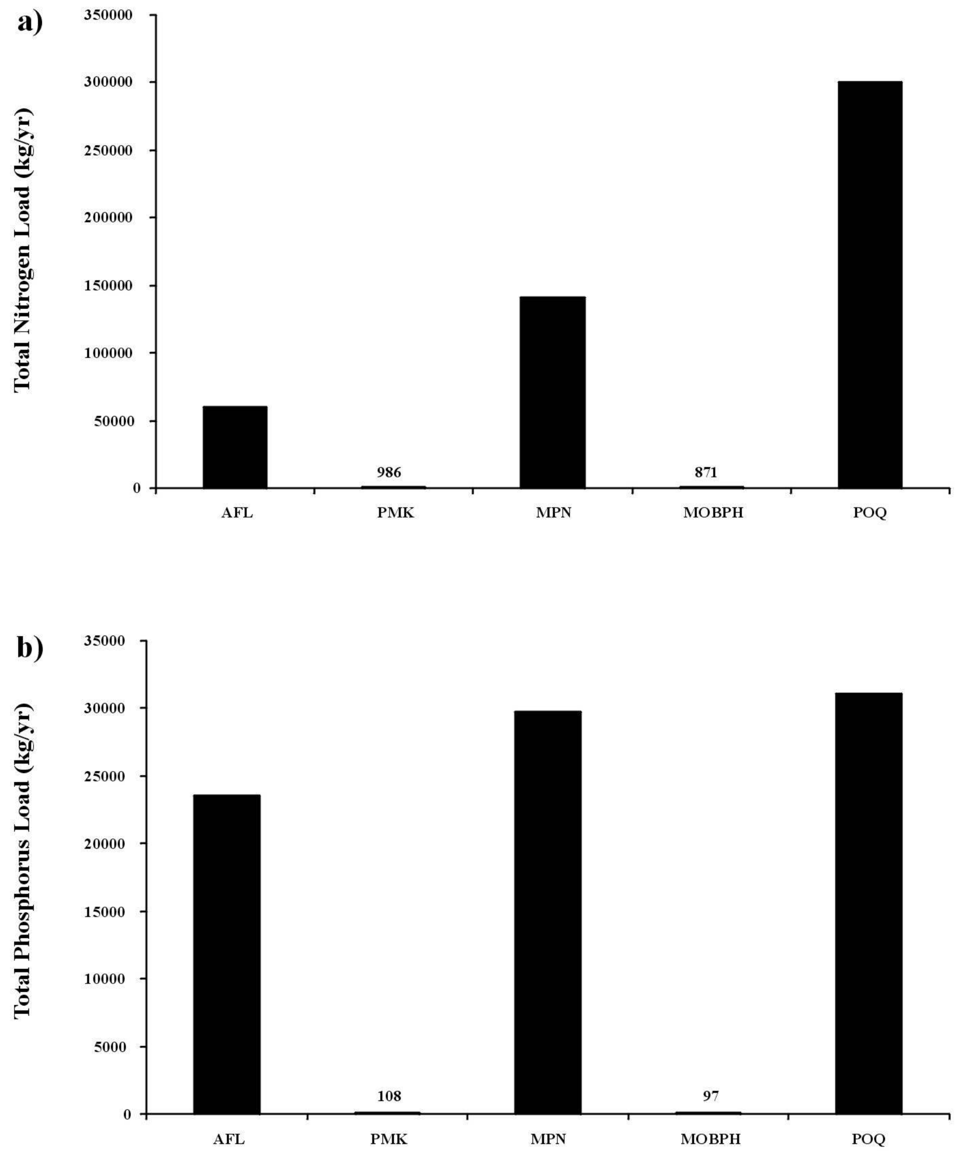


Figure 3-5. Spatial patterns in point source: a) total nitrogen, and b) total phosphorus loadings in the York River for 2001. AFL=Above the Fall-line (Pamunkey River), PMK=Pamunkey (PMKOH only), MPN=Mattaponi (MPNTF and MPNOH), MOBPH=Mobjack Bay and , POQ=Poquoson Bay sub-watersheds.

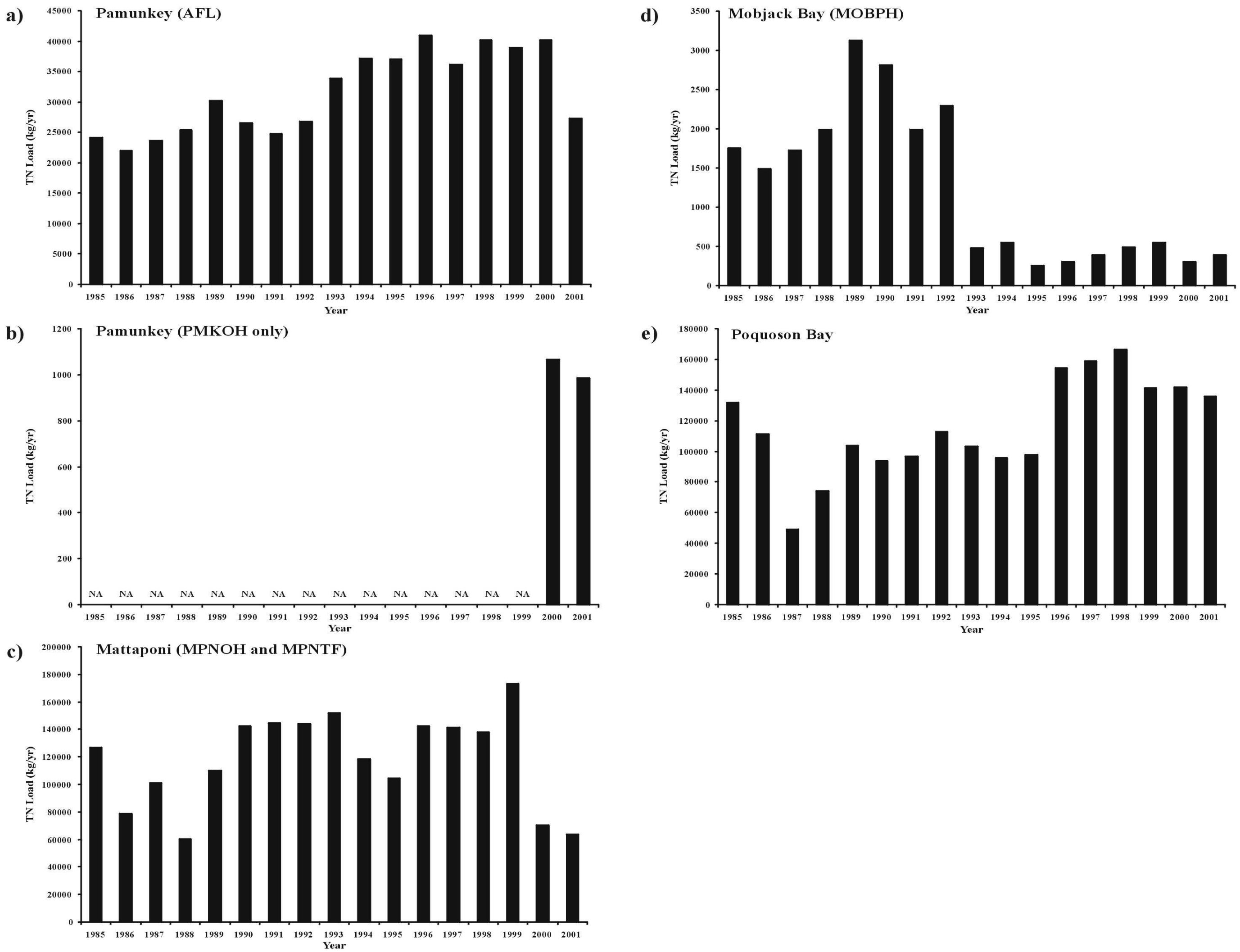


Figure 3-6 Change in point source total nitrogen in the: a) Pamunkey River (AFL=Above the Fall-line), b) Pamunkey River (PMKOH only), c) Mattaponi River (MPNOH and MPNTF), d) Mobjack Bay (MOBPH), and e) Poquoson Bay sub-watersheds of the York River from 1985 through 2001.

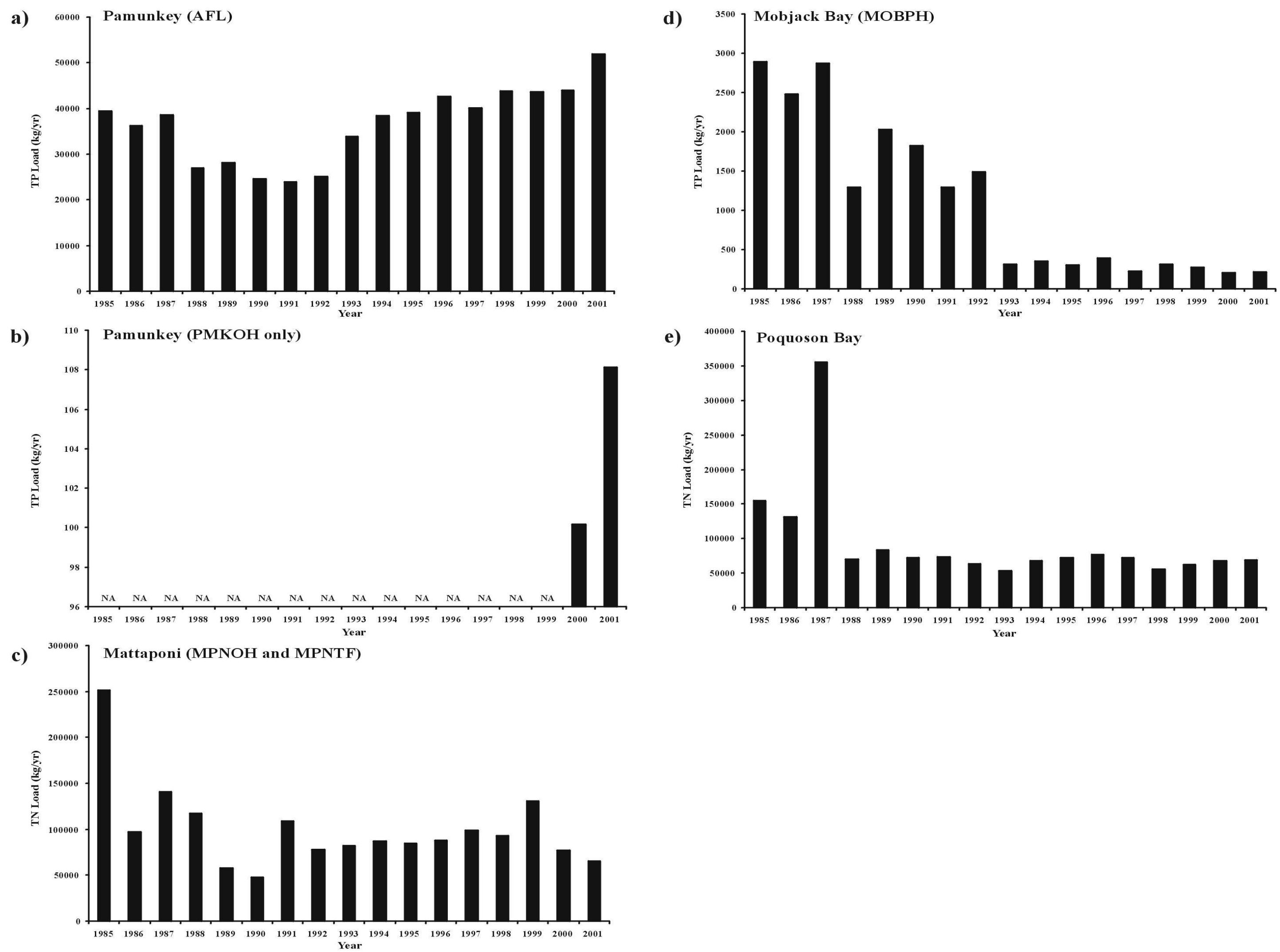


Figure 3-7. Change in point source total phosphorus in the: a) Pamunkey River (AFL=Above the Fall-line), b) Pamunkey River (PMKOH only), c) Mattaponi River (MPNOH and MPNTF), d) Mobjack Bay (MOBPH), and e) Poquoson Bay sub-watersheds of the York River from 1985 through 2001.

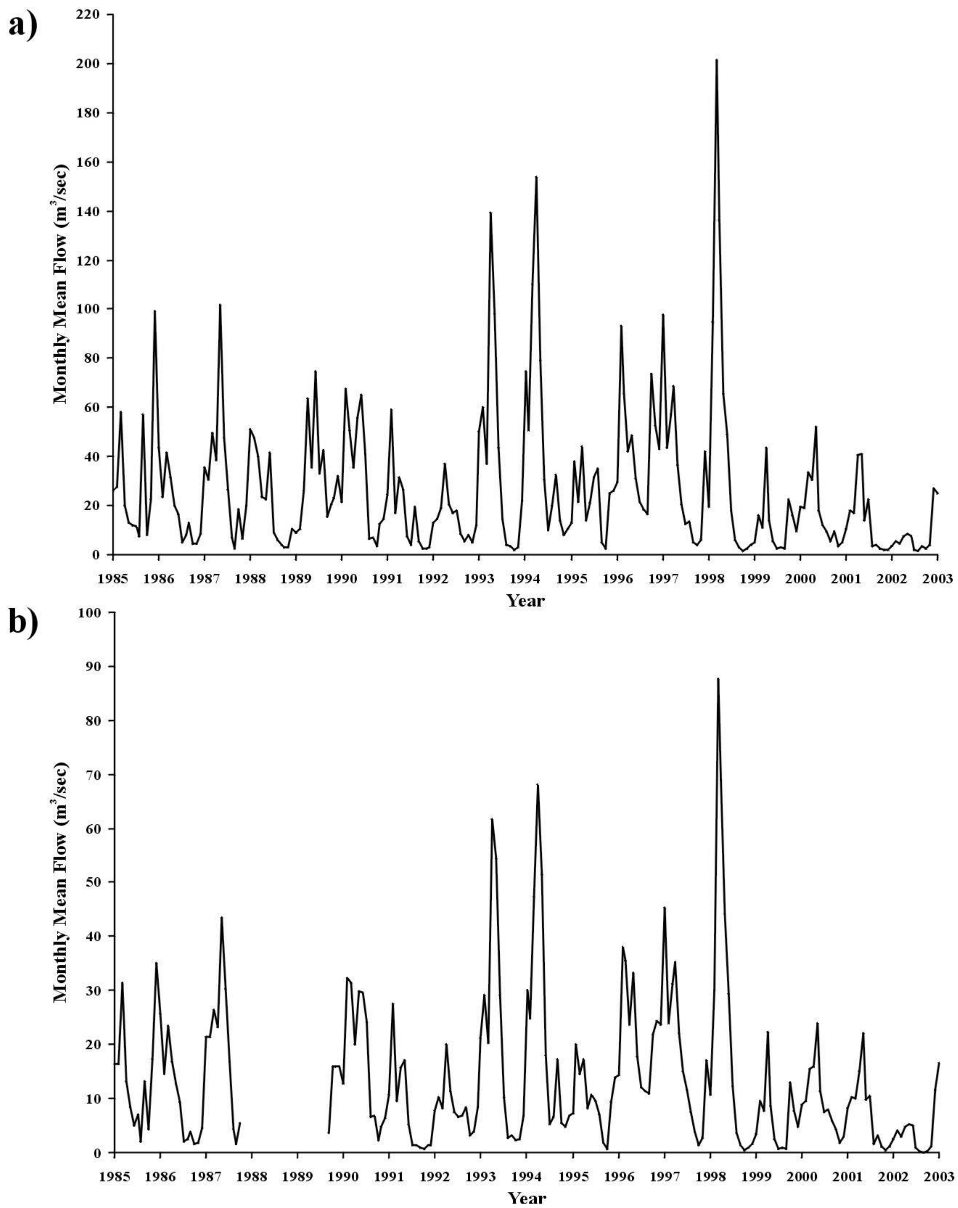
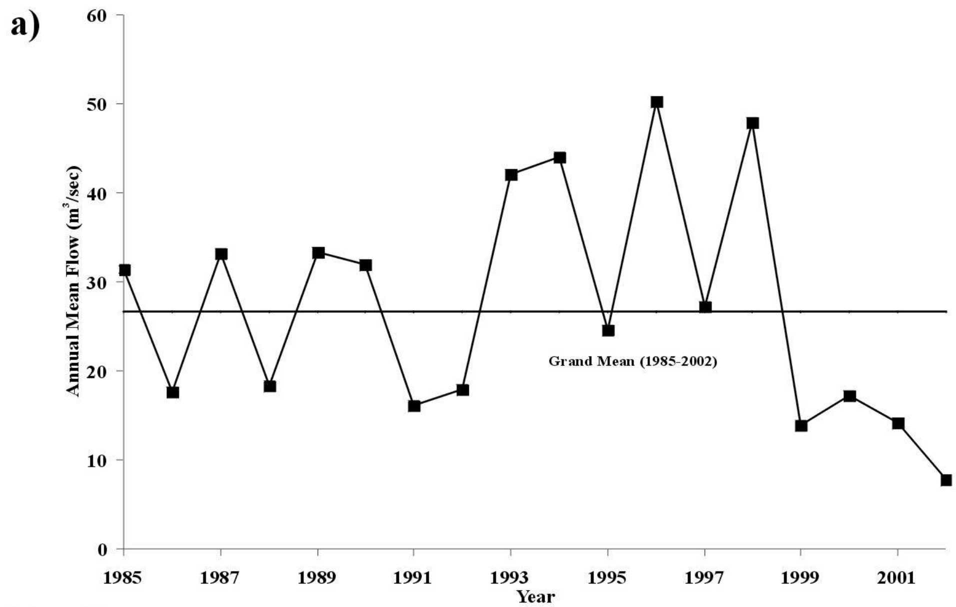


Figure 3-8. Plot of monthly mean flow at the: a) Pamunkey River fall-line, and b) the Mattaponi River fall-line for the period 1985 to 2002.



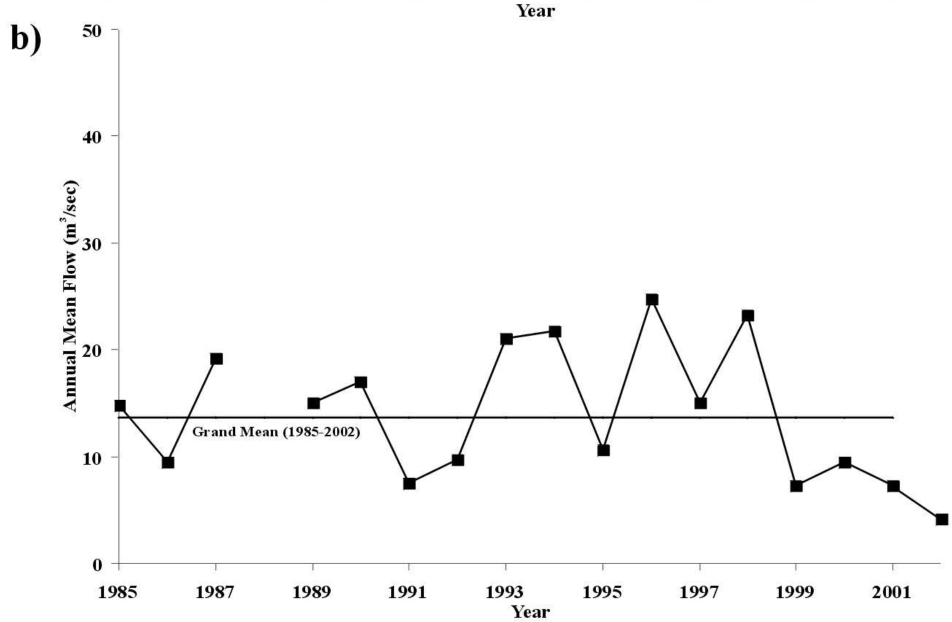


Figure 3-9. Plot of annual mean flow at the: a) Pamunkey River fall-line, and b) the Mattaponi River fall-line for the period 1985 to 2002.

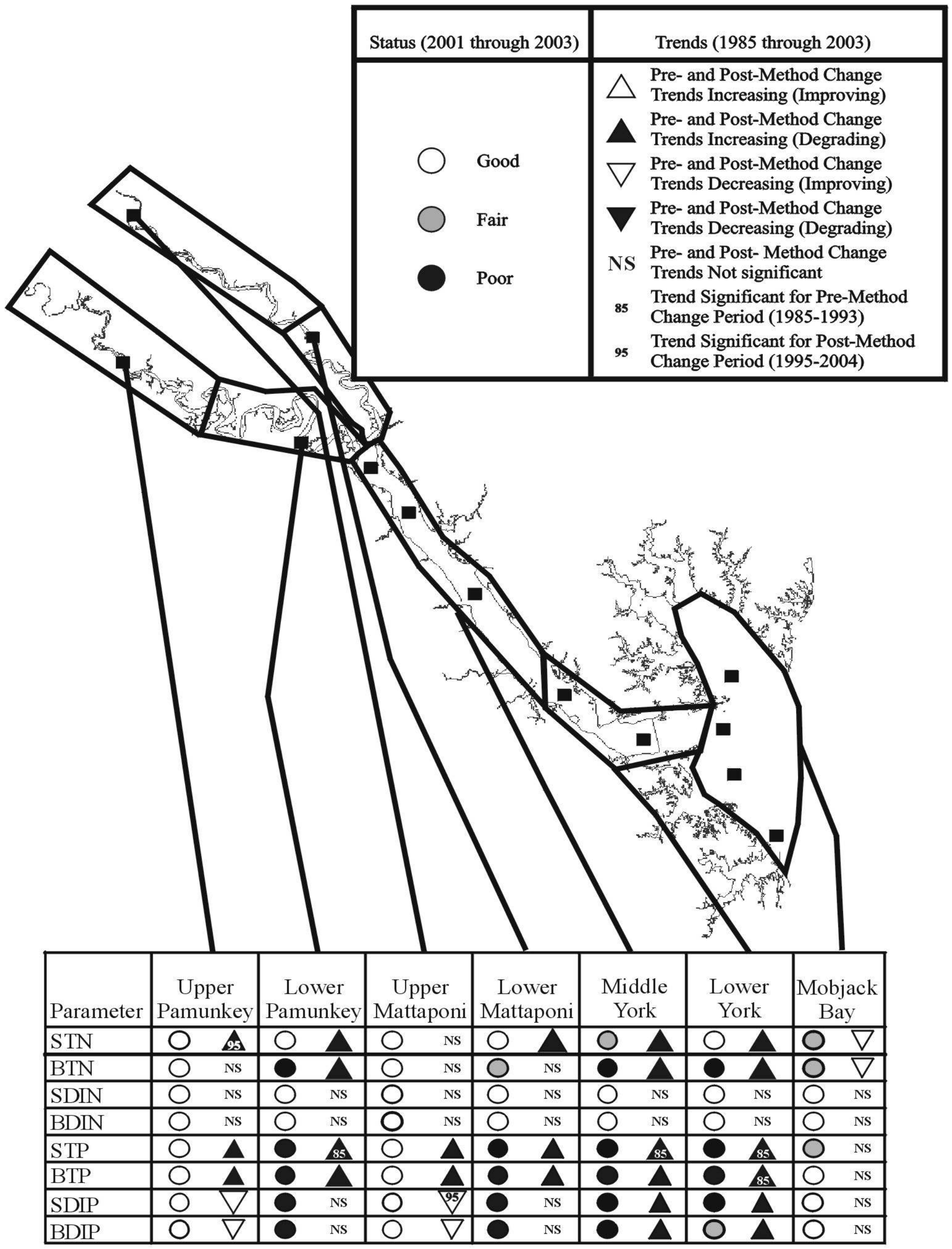
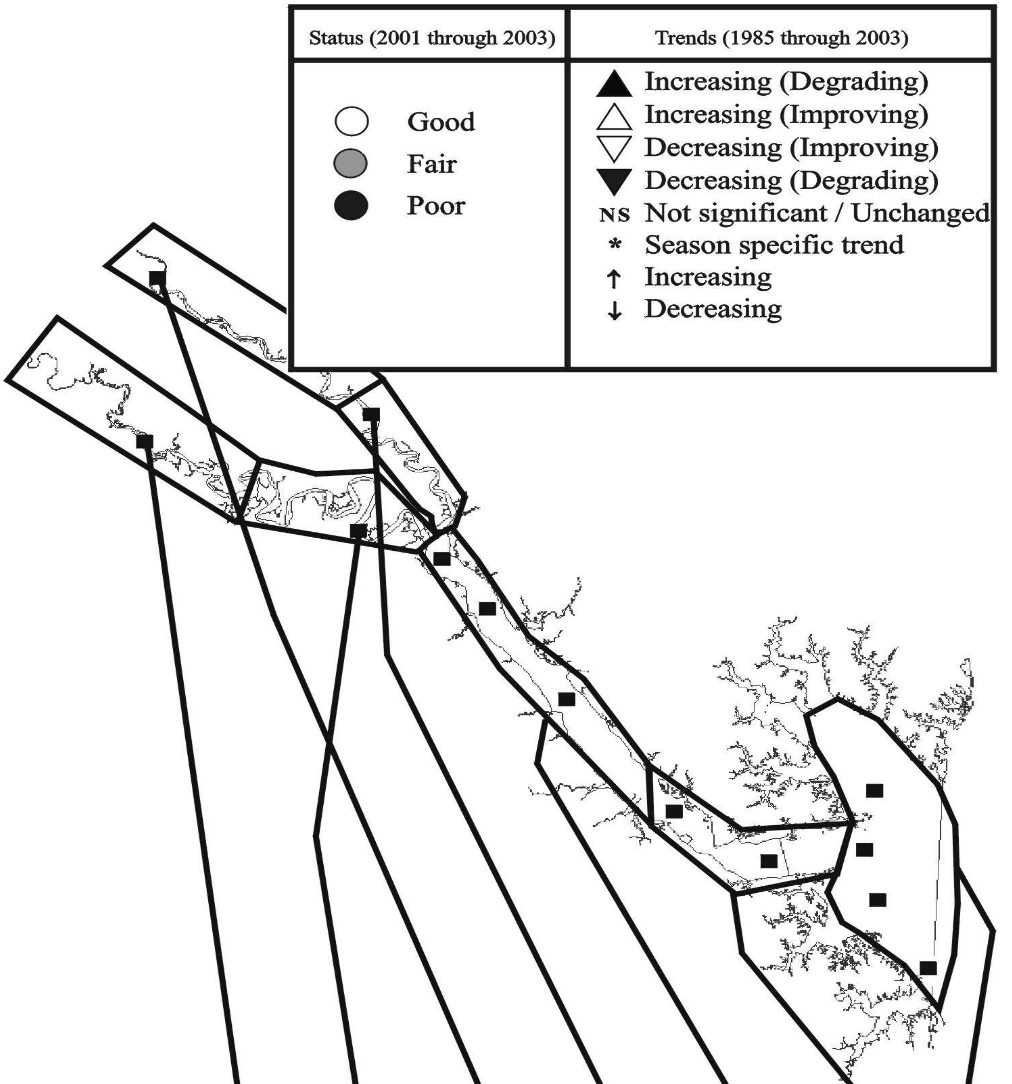
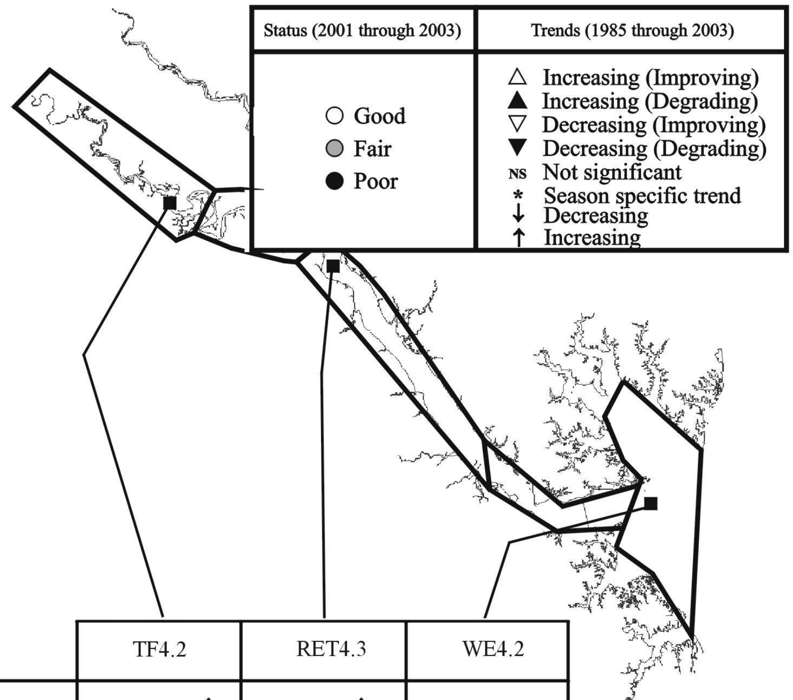


Figure 3-10. Map of the York River basin showing summaries of the status and trend analyses for each segment for the period 1985 through 2003. Abbreviations for each parameter are: TN=total nitrogen, DIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus. The prefixes 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.



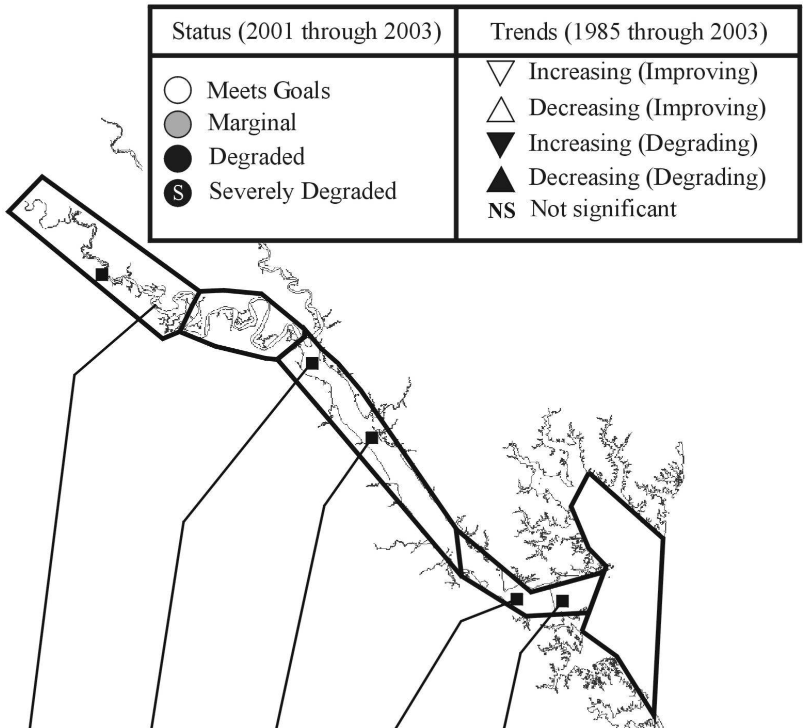
Parameter	Upper Pamunkey		Lower Pamunkey		Upper Mattaponi		Lower Mattaponi		Middle York		Lower York		Mobjack Bay	
SCHLA	Good	NS	Good	NS	Good	NS	Good	NS	Poor	NS	Poor	NS	Poor	NS
STSS	Poor	NS	Poor	NS	Good	NS	Poor	NS	Poor	NS	Fair	NS	Fair	▽
BTSS	Good	NS	Poor	NS	Good	NS	Poor	NS	Poor	▲	Poor	NS	Good	NS
SECCHI	Poor	NS	Poor	NS	Fair	▼	Poor	NS	Poor	NS	Poor	NS	Poor	▼
BDO	Good	NS	Good	NS	Good	NS	Fair	NS	Good	NS	Fair	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		NS

Figure 3-11. Map of the York River basin showing summaries of the status and trend analyses for each segment for the period 1985 through 2003. 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.



	TF4.2		RET4.3		WE4.2	
Total Abundance		↑		↑		NS
Total Biomass	●	↑	●	↑	●	↑
Biomass to Abundance	●	NS	●	△	●	NS
Margalef Diversity Index	●	NS	●	NS	●	NS
Productivity	○	NS	○	NS	◍	▽
Diatom Biomass	●	△	○	△	○	△
Dinoflagellate Biomass	●	NS	●	NS	◍	NS
Cyanophyte Biomass	◍	▲	●	▲	●	▲
Chlorophyte Biomass	◍	△	○	△	○	△
Picoplankton Biomass	◍	NS	●	▽	●	NS
Cryptophyte Biomass		△		△		NS
Cyanobacteria Abundance	◍	▲	●	▲	●	▲

Figure 3-12. Map of the York River basin showing summaries of the status and trend analyses for phytoplankton bioindicators for each segment for the period 1985 through 2002.



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

Figure 3-13. Map of the York River basin showing summaries of the status and trend analyses for benthic bioindicators for each segment for the period 1985 through 2002.

Table 3-1. Trends in flow adjusted concentrations (FAC) of water quality parameters at the James River watershed RIM stations located in the North Anna River near Doswell, at the Pamunkey River fall-line at Hanover and at the Mattaponi River fall-line at Belulahville for the period 1985 through 2003.

Station	Data Type	Parameter	t-stat	p-value	slope	Direction
North Anna River near Doswell	FAC	TN	4.7790	0.0014	0.0360	Degrading
North Anna River near Doswell	FAC	TKN	0.9799	0.3558	0.0082	No Trend
North Anna River near Doswell	FAC	NH4	-0.4963	0.6330	-0.0157	No Trend
North Anna River near Doswell	FAC	NO23	2.2080	0.0583	0.0229	No Trend
North Anna River near Doswell	FAC	TP	-9.3484	0.0000	-0.0977	Improving
North Anna River near Doswell	FAC	TSS	3.2329	0.0120	0.0442	Degrading
Pamunkey River at Hanover	FAC	TN	4.4052	0.0023	0.0141	Degrading
Pamunkey River at Hanover	FAC	NO23	3.1461	0.0137	0.0122	Degrading
Pamunkey River at Hanover	FAC	TP	5.9381	0.0003	0.0344	Degrading
Pamunkey River at Hanover	FAC	DIP	11.8583	0.0000	0.0590	Degrading
Pamunkey River at Hanover	FAC	TSS	2.7669	0.0244	0.0292	Degrading
Mattaponi River at Belulahville	FAC	TN	1.3949	0.2006	0.0006	No Trend
Mattaponi River at Belulahville	FAC	NO23	-0.4517	0.6635	-0.0069	No Trend
Mattaponi River at Belulahville	FAC	TP	-1.1927	0.2672	-0.0071	No Trend
Mattaponi River at Belulahville	FAC	DIP	-1.7313	0.1216	-0.0052	No Trend
Mattaponi River at Belulahville	FAC	TSS	1.2734	0.2386	0.0090	No Trend

Table 3-2. Annual season water quality status in the York River for the period 2001 through 2003 (values presented are median concentrations with secchi depth in meters, chlorophyll *a* in µg/l, all other parameters in mg/l).

Segment	Parameter	Surface Median	Surface Score	Surface Status	Bottom Median	Bottom Score	Bottom Status
PMKTF	TN	0.8460	25.09	**Good**	0.8115	14.32	**Good**
PMKTF	DIN	0.3925	26.61	**Good**	0.3750	21.55	**Good**
PMKTF	TP	0.0800	35.52	**Good**	0.0777	28.99	**Good**
PMKTF	PO4F	0.0165	32.91	**Good**	0.0150	34.42	**Good**
PMKTF	CHLA	2.91	14.68	**Good**	-	-	-
PMKTF	TSS	19.00	67.11	**Poor**	25.00	40.30	**Good**
PMKTF	SECCHI	0.50	27.92	**Poor**	-	-	-
PMKOH	TN	0.7945	32.98	**Good**	1.0320	82.21	**Poor**
PMKOH	DIN	0.2190	24.78	**Good**	0.2103	29.26	**Good**
PMKOH	TP	0.0967	90.00	**Poor**	0.1675	97.79	**Poor**
PMKOH	PO4F	0.0220	75.18	**Poor**	0.0210	63.65	**Poor**
PMKOH	CHLA	6.09	34.56	**Good**	-	-	-
PMKOH	TSS	37.00	93.89	**Poor**	103.00	96.47	**Poor**
PMKOH	SECCHI	0.40	6.08	**Poor**	-	-	-
MPNTF	TN	0.6670	12.15	**Good**	0.6495	6.59	**Good**
MPNTF	DIN	0.2520	14.47	**Good**	0.2340	11.05	**Good**
MPNTF	TP	0.0671	28.70	**Good**	0.0700	25.62	**Good**
MPNTF	PO4F	0.0129	29.60	**Good**	0.0135	33.69	**Good**
MPNTF	CHLA	1.92	9.11	**Good**	-	-	-
MPNTF	TSS	8.00	21.00	**Good**	10.50	16.89	**Good**
MPNTF	SECCHI	0.70	52.65	**Fair**	-	-	-
MPNOH	TN	0.7593	36.72	**Good**	0.8620	48.27	**Fair**
MPNOH	DIN	0.1945	30.42	**Good**	0.1780	27.86	**Good**
MPNOH	TP	0.1002	90.71	**Poor**	0.1200	92.54	**Poor**
MPNOH	PO4F	0.0215	71.42	**Poor**	0.0210	62.27	**Poor**
MPNOH	CHLA	6.07	29.83	**Good**	-	-	-
MPNOH	TSS	37.00	96.62	**Poor**	55.00	92.06	**Poor**
MPNOH	SECCHI	0.40	4.11	**Poor**	-	-	-
YRKMH	TN	0.7203	47.15	**Fair**	0.8395	80.86	**Poor**
YRKMH	DIN	0.1455	32.72	**Good**	0.1275	31.74	**Good**
YRKMH	TP	0.0860	94.10	**Poor**	0.1243	97.84	**Poor**
YRKMH	PO4F	0.0190	84.76	**Poor**	0.0220	71.17	**Poor**
YRKMH	CHLA	12.40	66.93	**Poor**	-	-	-
YRKMH	TSS	25.50	93.42	**Poor**	59.50	96.47	**Poor**
YRKMH	SECCHI	0.55	4.11	**Poor**	-	-	-
YRKPH	TN	0.4770	31.63	**Good**	0.5188	62.94	**Poor**
YRKPH	DIN	0.0435	24.51	**Good**	0.0835	36.73	**Good**
YRKPH	TP	0.0500	77.74	**Poor**	0.0750	84.16	**Poor**
YRKPH	PO4F	0.0140	65.33	**Poor**	0.0153	55.96	**Fair**
YRKPH	CHLA	9.14	57.52	**Poor**	-	-	-
YRKPH	TSS	10.25	54.40	**Fair**	25.50	76.53	**Poor**
YRKPH	SECCHI	1.18	17.55	**Poor**	-	-	-
MOBPH	TN	0.4130	38.8	**Fair**	0.4150	44.20	**Fair**
MOBPH	DIN	0.0180	19.0	**Good**	0.0260	16.20	**Good**
MOBPH	TP	0.0260	40.06	**Fair**	0.0270	24.30	**Good**
MOBPH	PO4F	0.001	9.90	**Good**	0.002	7.3	**Good**
MOBPH	CHLA	8.10	60.4	**Poor**	-	-	-
MOBPH	TSS	8.90	51.10	**Fair**	12.80	26.00	**Good**
MOBPH	SECCHI	1.35	24.4	Poor	-	-	-

Table 3-3. Trends in nutrient parameters in the York River for the Annual season for the period 1985 through 2003.

Segment	Parameter	'93 Trend P value	'93 Slope	'93 Trend Direction	'03 Trend P value	'03 Slope	'03 Trend Direction	Trend Comparison P value	Trend Comparison	Combined Trend P value	Combined Trend Direction
PMKTF	STN	0.9500	0.0000	No Trend	0.0000	0.0288	Degrading	0.0024	Different	0.0015	-
PMKTF	BTN	0.4911	-0.0050	No Trend	0.0045	0.0219	Degrading	0.0157	Same	0.1833	No Trend
PMKTF	SDIN	0.7301	-0.0032	No Trend	0.0057	0.0107	Degrading	0.0285	Same	0.0993	No Trend
PMKTF	BDIN	0.8440	-0.0020	No Trend	0.4137	0.0041	No Trend	0.4639	Same	0.6879	No Trend
PMKTF	STP	0.0005	0.0025	Degrading	0.0053	0.0020	Degrading	0.4955	Same	0.0000	Degrading
PMKTF	BTP	0.0000	0.0043	Degrading	0.0480	0.0023	No Trend	0.0454	Same	0.0000	Degrading
PMKTF	SPO4F	0.0042	0.0000	High BDLs	0.0013	-0.0010	Improving	0.6033	Same	0.0000	Improving
PMKTF	BPO4F	0.0041	0.0000	High BDLs	0.0016	-0.0010	Improving	0.7033	Same	0.0000	Improving
PMKOH	STN	0.0012	0.0275	Degrading	0.3181	0.0059	No Trend	0.0794	Same	0.0018	Degrading
PMKOH	BTN	0.0005	0.0500	Degrading	0.0295	0.0370	No Trend	0.2948	Same	0.0000	Degrading
PMKOH	SDIN	0.5354	-0.0008	No Trend	0.4390	0.0042	No Trend	0.3166	Same	0.9805	No Trend
PMKOH	BDIN	0.8888	0.0000	No Trend	0.3024	0.0046	No Trend	0.5495	Same	0.3966	No Trend
PMKOH	STP	0.0005	0.0063	Degrading	0.3799	-0.0010	No Trend	0.0012	Different	0.0424	-
PMKOH	BTP	0.0003	0.0175	Degrading	0.7421	0.0010	No Trend	0.0158	Same	0.0036	Degrading
PMKOH	SPO4F	0.0116	0.0000	No Trend	0.7334	0.0000	No Trend	0.1362	Same	0.0426	No Trend
PMKOH	BPO4F	0.1884	0.0000	No Trend	0.5419	0.0003	No Trend	0.6872	Same	0.1742	No Trend
MPNTF	STN	0.8507	0.0005	No Trend	0.0131	0.0185	No Trend	0.1389	Same	0.0705	No Trend
MPNTF	BTN	0.0156	-0.0130	No Trend	0.0152	0.0127	No Trend	0.0006	Different	0.8603	-
MPNTF	SDIN	0.5936	0.0023	No Trend	0.0020	0.0083	Degrading	0.0819	Same	0.0107	No Trend
MPNTF	BDIN	0.7114	0.0008	No Trend	0.0294	0.0063	No Trend	0.2188	Same	0.0705	No Trend
MPNTF	STP	0.0002	0.0017	Degrading	0.2338	0.0014	No Trend	0.0642	Same	0.0004	Degrading
MPNTF	BTP	0.0211	0.0013	No Trend	0.1539	0.0019	No Trend	0.4862	Same	0.0072	Degrading
MPNTF	SPO4F	1.0000	0.0000	High BDLs	0.0001	-0.0015	Improving	0.0031	Different	0.0037	-
MPNTF	BPO4F	0.0287	0.0000	High BDLs	0.0002	-0.0013	Improving	0.2155	Same	0.0000	Improving
MPNOH	STN	0.0000	0.0246	Degrading	0.0025	0.0210	Degrading	0.1937	Same	0.0000	Degrading
MPNOH	BTN	0.0211	0.0218	No Trend	0.9690	-0.0005	No Trend	0.0737	Same	0.0918	No Trend
MPNOH	SDIN	0.3547	0.0015	No Trend	0.0238	0.0100	No Trend	0.4314	Same	0.0266	No Trend
MPNOH	BDIN	0.3570	0.0025	No Trend	0.0778	0.0089	No Trend	0.5896	Same	0.0558	No Trend
MPNOH	STP	0.0000	0.0058	Degrading	0.2554	0.0027	No Trend	0.0119	Same	0.0000	Degrading
MPNOH	BTP	0.0012	0.0061	Degrading	0.3768	0.0024	No Trend	0.0823	Same	0.0028	Degrading
MPNOH	SPO4F	0.0603	0.0000	High BDLs	0.2640	0.0004	No Trend	0.6418	Same	0.0332	No Trend
MPNOH	BPO4F	0.0943	0.0000	High BDLs	0.4630	0.0002	No Trend	0.5453	Same	0.0866	No Trend
YRKMH	STN	0.0122	0.0200	No Trend	0.0008	0.0164	Degrading	0.6648	Same	0.0000	Degrading
YRKMH	BTN	0.0010	0.0270	Degrading	0.0570	0.0165	No Trend	0.3539	Same	0.0002	Degrading
YRKMH	SDIN	0.3716	-0.0017	No Trend	0.3837	0.0046	No Trend	0.2035	Same	0.9610	No Trend
YRKMH	BDIN	0.5417	-0.0006	No Trend	0.3534	0.0048	No Trend	0.2654	Same	0.8395	No Trend
YRKMH	STP	0.0000	0.0050	Degrading	0.4145	0.0007	No Trend	0.0001	Different	0.0000	-
YRKMH	BTP	0.0000	0.0075	Degrading	0.0492	0.0032	No Trend	0.0490	Same	0.0000	Degrading
YRKMH	SPO4F	0.0000	0.0008	Degrading	0.0033	0.0008	Degrading	0.4596	Same	0.0000	Degrading
YRKMH	BPO4F	0.0000	0.0010	Degrading	0.0001	0.0010	Degrading	0.9415	Same	0.0000	Degrading
YRKPH	STN	0.0035	0.0179	Degrading	0.0853	0.0062	No Trend	0.4239	Same	0.0010	Degrading
YRKPH	BTN	0.0000	0.0333	Degrading	0.4323	0.0035	No Trend	0.0223	Same	0.0005	Degrading
YRKPH	SDIN	0.1261	-0.0013	No Trend	0.8827	0.0001	No Trend	0.2231	Same	0.3375	No Trend
YRKPH	BDIN	0.5912	0.0000	No Trend	0.5713	-0.0009	No Trend	0.4209	Same	0.9599	No Trend
YRKPH	STP	0.0000	0.0029	Degrading	0.1874	0.0011	No Trend	0.0024	Different	0.0000	-
YRKPH	BTP	0.0000	0.0036	Degrading	0.3687	0.0007	No Trend	0.0004	Different	0.0000	-
YRKPH	SPO4F	0.0037	0.0000	High BDLs	0.0464	0.0005	No Trend	0.7282	Same	0.0006	Degrading
YRKPH	BPO4F	0.0104	0.0000	No Trend	0.0471	0.0005	No Trend	0.9400	Same	0.0014	Degrading

Table 3-3. Trends in nutrient parameters in the York River for the Annual season for the period 1985 through 2003.

Segment	Season	Parameter	% BDLs	P value	Slope	Baseline	% Change	Direction
MOBPH	Annual	STN	0.00	0.0000	-0.0040	0.4460	-17.60	Improving
MOBPH	Annual	BTN	0.00	0.0000	-0.0050	0.4930	-19.30	Improving
MOBPH	Annual	SDIN	35.00	0.1900	0.0000	0.0200	0.00	No Trend
MOBPH	Annual	BDIN	32.00	0.1570	0.0000	0.0300	0.00	No Trend
MOBPH	Annual	STP	2.00	0.3090	0.0000	0.0280	0.00	No Trend
MOBPH	Annual	BTP	1.00	0.5830	0.0000	0.0330	0.00	No Trend
MOBPH	Annual	SDIP	64.00	0.0000	0.0000	0.0050	0.00	High BDLs
MOBPH	Annual	BDIP	56.00	0.0060	0.0000	0.0050	0.00	High BDLs

Table 3-4. Trends in non-nutrient parameters in York River for the Annual season for the period 1985 through 2003.

Segment	Season	Parameter	% BDLs	P value	Slope	Baseline	% Change	Direction
PMKTF	Annual	SCHLA	65.76	0.0000	-0.0070	3.10	0.00	High BDLs
PMKTF	Annual	STSS	1.64	0.0636	0.2500	14.00	28.57	No Trend
PMKTF	Annual	BTSS	1.28	0.0697	-0.3333	20.50	-26.02	No Trend
PMKTF	Annual	SECCHI	0.00	0.0340	0.0000	0.70	0.00	No Trend
PMKTF	Summer1	BDO	0.00	0.0434	0.0300	5.35	10.65	No Trend
PMKTF	Annual	SSALINITY	0.00	0.0000	0.0000	0.01	0.00	Unchanged
PMKTF	Annual	BSALINITY	0.00	0.0000	0.0000	0.01	0.00	Unchanged
PMKTF	Annual	BWTEMP	0.00	0.0722	0.0523	19.10	5.20	No Trend
PMKTF	Annual	SWTEMP	0.00	0.0644	0.0492	18.00	5.19	No Trend
PMKOH	Annual	SCHLA	29.36	0.7013	0.0000	6.38	0.00	No Trend
PMKOH	Annual	STSS	0.77	0.1174	-0.5000	48.00	-19.79	No Trend
PMKOH	Annual	BTSS	0.45	0.1802	-1.8625	102.00	-29.22	No Trend
PMKOH	Annual	SECCHI	0.00	0.0122	0.0000	0.30	0.00	No Trend
PMKOH	Summer1	BDO	0.00	0.3839	0.0167	4.78	6.63	No Trend
PMKOH	Annual	SSALINITY	0.00	0.0164	0.0633	3.49	34.48	No Trend
PMKOH	Annual	BSALINITY	0.00	0.0297	0.0683	4.31	30.12	No Trend
PMKOH	Annual	BWTEMP	0.00	0.7196	0.0046	20.53	0.42	No Trend
PMKOH	Annual	SWTEMP	0.00	0.9389	0.0000	20.55	0.00	No Trend
MPNTF	Annual	SCHLA	71.04	0.0000	0.0000	3.10	0.00	High BDLs
MPNTF	Annual	STSS	24.38	0.0277	0.1250	6.38	0.00	No Trend
MPNTF	Annual	BTSS	16.38	0.3489	0.0528	8.25	0.00	No Trend
MPNTF	Annual	SECCHI	0.00	0.0008	-0.0143	1.00	-27.14	Degrading
MPNTF	Summer1	BDO	0.00	0.5772	0.0066	5.85	2.13	No Trend
MPNTF	Annual	SSALINITY	0.00	0.0001	0.0000	0.01	0.00	Unchanged
MPNTF	Annual	BSALINITY	0.00	0.0001	0.0000	0.01	0.00	Unchanged
MPNTF	Annual	BWTEMP	0.00	0.0160	0.0871	18.58	8.91	No Trend
MPNTF	Annual	SWTEMP	0.00	0.0067	0.0915	17.50	9.94	Increasing
MPNOH	Annual	SCHLA	38.48	0.3539	0.0000	4.25	0.00	High BDLs
MPNOH	Annual	STSS	1.15	0.2665	0.2000	26.00	14.62	No Trend
MPNOH	Annual	BTSS	0.45	0.5830	0.2500	44.00	10.80	No Trend
MPNOH	Annual	SECCHI	0.00	0.3038	0.0000	0.48	0.00	No Trend
MPNOH	Summer1	BDO	0.00	0.0880	0.0250	4.98	9.55	No Trend
MPNOH	Annual	SSALINITY	0.00	0.0011	0.1185	3.38	66.61	Increasing
MPNOH	Annual	BSALINITY	0.00	0.0031	0.1410	4.31	62.18	Increasing
MPNOH	Annual	BWTEMP	0.00	0.2580	0.0219	20.33	2.04	No Trend
MPNOH	Annual	SWTEMP	0.00	0.1626	0.0243	20.50	2.25	No Trend
YRKMH	Annual	SCHLA	12.84	0.1322	0.1148	9.59	22.75	No Trend
YRKMH	Annual	STSS	0.00	0.3721	-0.2000	27.00	-11.85	No Trend
YRKMH	Annual	BTSS	0.43	0.0053	1.5714	39.00	64.47	Degrading
YRKMH	Annual	SECCHI	0.00	0.3461	0.0000	0.60	0.00	No Trend
YRKMH	Summer1	BDO	0.00	0.2157	0.0185	5.18	6.78	No Trend
YRKMH	Annual	SSALINITY	0.00	0.5957	0.0357	12.43	5.46	No Trend
YRKMH	Annual	BSALINITY	0.00	0.7582	0.0175	13.58	2.45	No Trend
YRKMH	Annual	BWTEMP	0.00	0.7197	0.0067	19.90	0.64	No Trend
YRKMH	Annual	SWTEMP	0.00	0.9916	0.0000	20.05	0.00	No Trend
YRKPH	Annual	SCHLA	14.42	0.1081	0.0590	8.00	14.02	No Trend
YRKPH	Annual	STSS	20.40	0.5825	0.0413	6.00	0.00	No Trend
YRKPH	Annual	BTSS	4.76	0.0186	0.5139	17.75	46.32	No Trend
YRKPH	Annual	SECCHI	0.00	0.0162	-0.0080	1.20	-12.69	No Trend
YRKPH	Summer1	BDO	0.00	0.3826	-0.0300	4.75	-12.00	No Trend
YRKPH	Annual	SSALINITY	0.00	0.2884	-0.0417	20.65	-3.83	No Trend
YRKPH	Annual	BSALINITY	0.00	0.8576	0.0043	22.06	0.37	No Trend
YRKPH	Annual	BWTEMP	0.00	0.4499	-0.0183	18.73	-1.86	No Trend
YRKPH	Annual	SWTEMP	0.00	0.4731	-0.0155	19.03	-1.54	No Trend

Table 3-4. Trends in non-nutrient parameters in York River for the Annual season for the period 1985 through 2003.

Segment	Season	Parameter	% BDLs	P value	Slope	Baseline	% Change	Direction
MOBPH	Annual	SCHLA	0.00	0.4900	0.0260	5.6000	0.00	No Trend
MOBPH	Annual	STSS	0.00	0.0030	-0.2040	10.0000	-39.20	Improving
MOBPH	Annual	BTSS	0.00	0.0180	-0.1890	15.0000	-24.00	No Trend
MOBPH	Annual	SECCHI	0.00	0.0010	-0.0140	1.5000	-18.10	Degrading
MOBPH	Annual	BDO	0.00	0.0010	0.0500	6.0000	15.80	Improving
MOBPH	Annual	SSALINITY	0.00	0.0980	-0.0530	22.1000	0.00	No Trend
MOBPH	Annual	BSALINITY	0.00	0.0390	-0.0670	22.6000	-5.70	No Trend
MOBPH	Annual	SWTEMP	0.00	0.4160	0.0160	18.5000	0.00	No Trend
MOBPH	Annual	BWTEMP	0.00	0.4160	0.0160	17.6000	0.00	No Trend

Table 3-5. SAV season water quality status in in the York River for the period 2001 through 2003 (values presented are median concentrations with secchi depth in meters, chlorophyll *a* in µg/l, all other parameters in mg/l).

Segment	Parameter	Season	Layer	Median	Score	Status	Habitat Requirement
PMKTF	STN	SAV	S	0.8455	28.22	**Good**	**-**
PMKTF	SDIN	SAV	S	0.3803	27.09	**Good**	**-**
PMKTF	STP	SAV	S	0.0733	34.56	**Good**	**-**
PMKTF	SPO4F	SAV	S	0.0175	34.46	**Good**	**Borderline**
PMKTF	SCHLA	SAV	S	2.76	10.67	**Good**	**Pass**
PMKTF	STSS	SAV	S	19.00	64.48	**Poor**	**Borderline**
PMKTF	SECCHI	SAV	S	0.55	30.67	**Poor**	**Borderline**
PMKOH	STN	SAV	S	0.8080	36.92	**Good**	**-**
PMKOH	SDIN	SAV	S	0.2105	25.44	**Good**	**-**
PMKOH	STP	SAV	S	0.1156	86.70	**Poor**	**-**
PMKOH	SPO4F	SAV	S	0.0225	71.66	**Poor**	**Fail**
PMKOH	SCHLA	SAV	S	5.71	29.02	**Good**	**Pass**
PMKOH	STSS	SAV	S	40.50	91.74	**Poor**	**Fail**
PMKOH	SECCHI	SAV	S	0.38	5.92	**Poor**	**Fail**
MPNTF	STN	SAV	S	0.6425	13.33	**Good**	**-**
MPNTF	SDIN	SAV	S	0.2095	12.95	**Good**	**-**
MPNTF	STP	SAV	S	0.0586	27.03	**Good**	**-**
MPNTF	SPO4F	SAV	S	0.0129	31.47	**Good**	**Borderline**
MPNTF	SCHLA	SAV	S	2.04	8.12	**Good**	**Pass**
MPNTF	STSS	SAV	S	8.00	17.48	**Good**	**Pass**
MPNTF	SECCHI	SAV	S	0.85	65.35	**Good**	**Borderline**
MPNOH	STN	SAV	S	0.7630	35.56	**Good**	**-**
MPNOH	SDIN	SAV	S	0.1865	22.97	**Good**	**-**
MPNOH	STP	SAV	S	0.1084	94.94	**Poor**	**-**
MPNOH	SPO4F	SAV	S	0.0235	68.48	**Poor**	**Borderline**
MPNOH	SCHLA	SAV	S	6.07	28.50	**Good**	**Pass**
MPNOH	STSS	SAV	S	46.50	96.50	**Poor**	**Fail**
MPNOH	SECCHI	SAV	S	0.40	4.04	**Poor**	**Fail**
YRKMH	STN	SAV	S	0.6990	44.66	**Fair**	**-**
YRKMH	SDIN	SAV	S	0.1973	31.28	**Good**	**Borderline**
YRKMH	STP	SAV	S	0.0948	96.52	**Poor**	**-**
YRKMH	SPO4F	SAV	S	0.0225	90.05	**Poor**	**Fail**
YRKMH	SCHLA	SAV	S	9.67	61.99	**Poor**	**Pass**
YRKMH	STSS	SAV	S	34.25	94.93	**Poor**	**Fail**
YRKMH	SECCHI	SAV	S	0.50	4.04	**Poor**	**Fail**
YRKPH	STN	SAV	S	0.5063	34.99	**Good**	**-**
YRKPH	SDIN	SAV	S	0.0640	32.54	**Good**	**Pass**
YRKPH	STP	SAV	S	0.0592	76.07	**Poor**	**-**
YRKPH	SPO4F	SAV	S	0.0150	74.14	**Poor**	**Borderline**
YRKPH	SCHLA	SAV	S	9.93	66.49	**Poor**	**Pass**
YRKPH	STSS	SAV	S	11.00	57.43	**Fair**	**Pass**
YRKPH	SECCHI	SAV	S	0.95	11.65	**Poor**	**Borderline**
MOBPH	STN	SAV	S	0.4725	36.95	**Good**	**-**
MOBPH	SDIN	SAV	S	0.0233	25.23	**Good**	**Pass**
MOBPH	STP	SAV	S	0.0365	53.52	**Fair**	**-**
MOBPH	SPO4F	SAV	S	0.0181	54.77	**Fair**	**Pass**
MOBPH	SCHLA	SAV	S	10.15	68.03	**Poor**	**Pass**
MOBPH	STSS	SAV	S	11.26	63.51	**Poor**	**Pass**
MOBPH	SECCHI	SAV	S	1.10	13.73	**Poor**	**Pass**

Table 3-6. Trends in nutrient parameters in the York River for the SAV season for the period 1985 through 2003.

a) Blocked seasonal Kendall trends

Segment	Parameter	'93 Trend P value	'93 Slope	'93 Trend Direction	'03 Trend P value	'03 Slope	'03 Trend Direction	Trend Comparison P value	Trend Comparison	Combined Trend P value	Combined Trend Direction
PMKTF	STN	0.7822	0.0017	No Trend	0.0001	0.0377	Degrading	0.0191	Same	0.0048	Degrading
PMKTF	SDIN	0.3432	0.0043	No Trend	0.0164	0.0152	No Trend	0.3566	Same	0.0182	No Trend
PMKTF	STP	0.0132	0.0025	No Trend	0.1743	0.0013	No Trend	0.3529	Same	0.0053	Degrading
PMKTF	SPO4F	0.0041	0.0000	High BDLs	0.0039	-0.0010	Improving	0.9512	Same	0.0000	Improving
PMKOH	STN	0.0001	0.0350	Degrading	0.8222	0.0018	No Trend	0.0069	Different	0.0022	-
PMKOH	SDIN	0.3295	0.0050	No Trend	0.1205	0.0096	No Trend	0.8057	Same	0.0745	No Trend
PMKOH	STP	0.0023	0.0063	Degrading	0.2343	-0.0015	No Trend	0.0020	Different	0.1486	-
PMKOH	SPO4F	0.0002	0.0017	Degrading	0.1740	0.0008	No Trend	0.0911	Same	0.0002	Degrading
MPNTF	STN	0.8123	-0.0016	No Trend	0.2714	0.0162	No Trend	0.3603	Same	0.6257	No Trend
MPNTF	SDIN	0.0966	0.0050	No Trend	0.0318	0.0100	No Trend	0.8176	Same	0.0067	Degrading
MPNTF	STP	0.0129	0.0014	No Trend	0.8202	0.0003	No Trend	0.0950	Same	0.0420	No Trend
MPNTF	SPO4F	0.6734	0.0000	High BDLs	0.0005	-0.0022	Improving	0.0055	Different	0.0342	-
MPNOH	STN	0.0000	0.0355	Degrading	0.0330	0.0184	No Trend	0.0092	Different	0.0000	-
MPNOH	SDIN	0.0356	0.0073	No Trend	0.1442	0.0086	No Trend	0.5396	Same	0.0100	Degrading
MPNOH	STP	0.0000	0.0067	Degrading	0.9639	0.0003	No Trend	0.0003	Different	0.0002	-
MPNOH	SPO4F	0.0163	0.0008	High BDLs	0.2237	0.0007	No Trend	0.3846	Same	0.0091	Degrading
YRKMH	STN	0.0002	0.0329	Degrading	0.0066	0.0225	Degrading	0.4561	Same	0.0000	Degrading
YRKMH	SDIN	0.3622	-0.0017	No Trend	0.1002	0.0113	No Trend	0.0716	Same	0.7093	No Trend
YRKMH	STP	0.0000	0.0063	Degrading	0.7672	0.0003	No Trend	0.0019	Different	0.0004	-
YRKMH	SPO4F	0.0001	0.0013	Degrading	0.0069	0.0009	Degrading	0.4962	Same	0.0000	Degrading
YRKPH	STN	0.0483	0.0137	No Trend	0.5409	0.0047	No Trend	0.3641	Same	0.0648	No Trend
YRKPH	SDIN	0.1691	-0.0042	No Trend	0.8133	0.0003	No Trend	0.2363	Same	0.4298	No Trend
YRKPH	STP	0.0000	0.0029	Degrading	1.0000	0.0000	No Trend	0.0009	Different	0.0009	-
YRKPH	SPO4F	0.7589	0.0000	High BDLs	0.0757	0.0003	No Trend	0.2212	Same	0.0979	No Trend

a) Seasonal Kendall trends

Segment	Season	Parameter	% BDLs	P value	Slope	Baseline	% Change	Direction
MOBPH	SAV	STN	0.00	0.0000	-0.0040	0.4630	-20.00	Improving
MOBPH	SAV	SDIN	25.00	0.0000	-0.0010	0.0880	-21.70	Improving
MOBPH	SAV	STP	1.00	0.7640	0.0000	0.0300	0.00	No Trend
MOBPH	SAV	SDIP	59.00	0.0460	0.0000	0.0080	0.00	No Trend
MOBPH	SAV	SCHLA	0.00	0.6480	0.0160	4.3000	0.00	No Trend

Table 3-7. Trends in non-nutrient parameters in the York River for the SAV growing season for the period 1985 through 2003.

Segment	Season	Parameter	% BDLs	P value	Slope	Baseline	% Change	Direction
PMKTF	SAV	SCHLA	77.59	0.0028	-0.0750	4.23	0.00	High BDLs
PMKTF	SAV	STSS	1.59	0.0304	0.3889	12.25	50.79	No Trend
PMKTF	SAV	SECCHI	0.00	0.2428	0.0000	0.70	0.00	No Trend
PMKTF	SAV	SSALINITY	0.00	0.0000	0.0000	0.01	0.00	Unchanged
PMKTF	SAV	SWTEMP	0.00	0.1103	0.0478	22.88	3.97	No Trend
PMKOH	SAV	SCHLA	27.81	0.6914	0.0200	7.54	0.00	No Trend
PMKOH	SAV	STSS	0.76	0.1992	-0.5385	45.00	-22.74	No Trend
PMKOH	SAV	SECCHI	0.00	0.1544	0.0000	0.45	0.00	No Trend
PMKOH	SAV	SSALINITY	0.00	0.2802	0.0224	5.03	8.45	No Trend
PMKOH	SAV	SWTEMP	0.00	0.7357	-0.0074	24.43	-0.57	No Trend
MPNTF	SAV	SCHLA	80.46	0.0004	-0.0659	4.59	0.00	High BDLs
MPNTF	SAV	STSS	25.60	0.1298	0.0962	5.63	0.00	No Trend
MPNTF	SAV	SECCHI	0.00	0.0578	-0.0065	1.00	-12.27	No Trend
MPNTF	SAV	SSALINITY	0.00	0.0071	0.0000	0.01	0.00	Unchanged
MPNTF	SAV	SWTEMP	0.00	0.0110	0.1043	23.38	8.48	No Trend
MPNOH	SAV	SCHLA	40.46	0.5929	0.0000	7.42	0.00	High BDLs
MPNOH	SAV	STSS	1.47	0.0084	0.6000	19.00	60.00	Degrading
MPNOH	SAV	SECCHI	0.00	0.3805	0.0000	0.53	0.00	No Trend
MPNOH	SAV	SSALINITY	0.00	0.0738	0.0892	4.27	39.65	No Trend
MPNOH	SAV	SWTEMP	0.00	0.2962	0.0200	24.50	1.55	No Trend
YRKMH	SAV	SCHLA	10.50	0.4397	0.0763	9.59	15.12	No Trend
YRKMH	SAV	STSS	0.00	0.3064	-0.2500	32.75	-12.21	No Trend
YRKMH	SAV	BTSS	0.00	0.1275	1.2500	44.50	44.94	No Trend
YRKMH	SAV	SECCHI	0.00	0.5192	0.0000	0.50	0.00	No Trend
YRKMH	SAV	SSALINITY	0.00	0.2731	-0.0657	13.61	-9.18	No Trend
YRKMH	SAV	SWTEMP	0.00	0.7995	-0.0100	24.28	-0.78	No Trend
YRKPH	SAV	SCHLA	9.46	0.7297	0.0157	7.97	3.75	No Trend
YRKPH	SAV	STSS	15.92	0.3166	0.1250	8.50	0.00	No Trend
YRKPH	SAV	SECCHI	0.00	0.0072	-0.0100	1.03	-18.54	Degrading
YRKPH	SAV	SSALINITY	0.00	0.5201	-0.0417	18.42	-4.30	No Trend
YRKPH	SAV	SWTEMP	0.00	0.1702	-0.0373	17.18	-4.13	No Trend
MOBPH	SAV	STSS	0.00	0.0420	-0.1180	9.0000	-25.00	No Trend
MOBPH	SAV	SECCHI	0.00	0.0000	-0.0200	1.8000	-21.10	Degrading
MOBPH	SAV	SSALINITY	0.00	0.2780	-0.0380	20.6000	0.00	No Trend
MOBPH	SAV	SWTEMP	0.00	0.6580	0.0120	17.6000	0.00	No Trend

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Glossary of Important Terms

Anoxic - condition in which the water column is characterized by a complete absence of oxygen. Anoxic conditions typically result from excessive decomposition of organic material by bacteria, high respiration by phytoplankton, stratification of the water column due to salinity or temperature effects or a combination of these factors. Anoxic conditions can result in fish kills or localized extinction of benthic communities.

Anthropogenic - resulting from or generated by human activities.

Benthos - refers to organisms that dwell on or within the bottom. Includes both hard substratum habitats (e.g. oyster reefs) and sedimentary habitats (sand and mud bottoms).

B-IBI - the benthic index of biotic integrity of Weisberg et al. (1997). The B-IBI is a multi-metric index that compares the condition of a benthic community to reference conditions.

Biological Nutrient Removal (BNR) - a temperature dependent process in which the ammonia nitrogen present in wastewater is converted by bacteria first to nitrate nitrogen and then to nitrogen gas. This technique is used to reduce the concentration of nitrogen in sewage treatment plant effluents.

Biomass - a quantitative estimate of the total mass of organisms for a particular population or community within a given area at a given time. Biomass for phytoplankton is measured as the total carbon within a liter of water. Biomass for the benthos is measured as the total ash-free dry weight per square meter of sediment habitat.

Chlorophyll *a* - a green pigment found in plant cells that functions as the receptor for energy in the form of sunlight. This energy is used in the production of cellular materials for growth and reproduction in plants. Chlorophyll *a* concentrations are measured in µg/L and are used as estimate of the total biomass of phytoplankton cells in the water column. In general, high levels of chlorophyll *a* concentrations are believed to be indicative of excessive growth of phytoplankton resulting from excess nutrients such as nitrogen and phosphorus in the water column.

Calanoid copepod - crustaceans of the subclass Copepoda and order Calanoida that are the dominant group of the mesozooplankton in marine systems. Copepods in this group (e.g. *Acartia tonsa*) are one of the most important consumers of phytoplankton in estuarine systems.

Chlorophytes - algae belonging to the division Chlorophyta often referred to as true "green algae." Chlorophytes occur in unicellular, colonial and filamentous forms and are generally more common in tidal freshwater and oligohaline portions of estuaries.

Cladocerans - crustaceans of the class Branchipoda and class Cladocera commonly referred to as "water fleas." Although cladocerans are primarily found in tidal freshwater areas in estuaries, blooms of marine cladocerans periodically occur in higher salinity areas. Some smaller species such as *Bosmina longirostris* are believed to be indicators of poor water quality conditions.

Cryptomonads -algae belonging to the division Cryptophyta that have accessory pigments in addition to chlorophyll *a* which give these small flagellated cells a red, brown or yellow color.

Cyanobacteria - algae belonging to the division Cyanophycea that are procaryotic and that occur in single-celled, filamentous and colonial forms. In general, high concentrations of cyanobacteria are considered to be indicative of poor water quality.

Cyclopoid copepod - crustaceans of the subclass Copepoda and order Cyclopoida that are the dominant group of the mesozooplankton in marine systems. Copepods in this group (e.g. *Mesocyclops edax*) are one of the most important consumers of phytoplankton in estuarine systems.

Diatoms - algae belonging to the division Bacillariophyta that have a cell wall that is composed primarily of silica and that consists of two separate halves. Most diatoms are single-celled but some are colonial and filamentous forms. Diatoms are generally considered to be indicative of good water quality and are considered to be appropriate food for many zooplankton.

Dinoflagellates - biflagellated, predominately unicellular protists which are capable of performing photosynthesis. Many dinoflagellates are covered with cellulose plates or with a series of membranes. Some dinoflagellates periodically reproduce in large numbers causing blooms that are often referred to as "red tides." Certain species produce toxins and blooms of these forms have been implicated in fish kills. High concentrations of dinoflagellates are generally considered to be indicative of poor water quality.

Dissolved oxygen (DO) - the concentration of oxygen in solution in the water column, measured in mg/L. Most organisms rely on oxygen for cellular metabolism and as a result low levels of dissolved oxygen adversely affect important living resources such as fish and the benthos. In general, dissolved oxygen levels decrease with increasing pollution.

Dissolved inorganic nitrogen (DIN) - the concentration of inorganic nitrogen compounds including ammonia (NH_4), nitrates (NO_3) and nitrites (NO_2) in the water column measured in mg/L. These dissolved inorganic forms of nitrogen are directly available for uptake by phytoplankton by diffusion without first undergoing the process of decomposition. High concentrations of dissolved inorganic nitrogen can result in excessive growth of phytoplankton which in turn can adversely effect other living resources.

Dissolved inorganic phosphorus (PO4F) - the concentration of inorganic phosphorus compounds consisting primarily of orthophosphates (PO_4), The dissolved inorganic forms of phosphorus are directly available for uptake by phytoplankton by diffusion without first undergoing the process of decomposition. High concentrations of dissolved inorganic phosphorus can result in excessive growth of phytoplankton which in turn can adversely effect other living resources.

Estuary - a semi-enclosed body of water that has a free connection with the open sea and within which seawater is diluted measurably with freshwater derived from land drainage.

Eucaryote - organisms the cells of which have discrete organelles and a nucleus separated from the cytoplasm by a membrane.

Fall-line - location of the maximum upstream extent of tidal influence in an estuary typically characterized by a waterfall.

Fixed Point Stations - stations for long-term trend analysis whose location is unchanged over time.

Flow adjusted concentration (FAC) - concentration value which has been recalculated to remove the variation caused by freshwater flow into a stream. By removing variation caused by flow, the effects of other factors such as nutrient management strategies can be assessed.

Holoplankton - zooplankton such as copepods or cladocerans that spend their entire life cycle within the water column.

Habitat - a local environment that has a community distinct from other such habitat types. For the B-IBI of Chesapeake Bay seven habitat types were defined as combinations of salinity and sedimentary types - tidal freshwater, oligohaline, low mesohaline, high mesohaline sand, high mesohaline mud, polyhaline sand and polyhaline mud.

Hypoxic - condition in which the water column is characterized by dissolved oxygen concentrations less than 2 mg/L but greater than 0 mg/L. Hypoxic conditions typically result from excessive decomposition of organic material by bacteria, high respiration by phytoplankton, stratification of the water column due to salinity or temperature effects or a combination of these factors. Hypoxic conditions can result in fish kills or localized extinction of benthic communities.

Light attenuation (KD) - absorption, scattering, or reflection of light by dissolved or suspended material in the water column expressed as the change in light extinction per meter of depth. Light attenuation reduces the amount of light available to submerged aquatic vegetation.

Loading - the total mass of contaminant or nutrient added to a stream or river generally expressed in lbs/yr.

Macrobenthos - a size category of benthic organisms that are retained on a mesh of 0.5 mm.

Meroplankton - temporary zooplankton consisting of the larval stages of organisms whose adult stages are not planktonic.

Mesohaline - refers to waters with salinity values ranging between 0.5 and 18.0 ppt.

Mesozooplankton - zooplankton with a maximum dimension ranging between 63 µm and 2000 µm. This size category consists primarily of adults stages of copepods, cladocerans, mysid shrimp, and chaetognaths, as well as, the larval stages of a variety of invertebrates and fish.

Metric - a parameter or measurement of community structure (e.g., abundance, biomass, species diversity).

Microzooplankton - zooplankton with a maximum dimension ranging between 2 µm and 63 µm. This size category consists primarily of single-celled protozoans, rotifers and the larval stages of copepods, cladocerans and other invertebrates.

Nauplii - earliest crustacean larval stage characterized by a single simple eye and three pairs of appendages.

Non-point source - a source of pollution that is distributed widely across the landscape surrounding a water body instead of being at a fixed location (e.g. run-off from residential and agricultural land).

Oligohaline - refers to waters with salinity values ranging between 0.5 and 5.0 ppt.

Oligotrich - protists of the phylum Ciliophora and order Oligotricha. These ciliates are important predators of small phytoplankton in marine systems.

Percent of light at the leaf surface (PLL) - the percentage of light at the surface of the water column that reaches the surface of the leaves of submerged aquatic vegetation generally estimated for depths of 0.5 m and 1.0 m. Without sufficient light at the leaf surface, submerged aquatic plants cannot perform photosynthesis and hence cannot grow or reproduce.

Phytoplankton - that portion of the plankton capable of producing its own food by photosynthesis. Typical members of the phytoplankton include diatoms, dinoflagellates and chlorophytes.

Picoplankton - phytoplankton with a diameter between 0.2 and 2.0 µm in diameter. Picoplankton consists primarily of cyanobacteria and high concentrations of picoplankton are generally considered to be indicative of poor water quality conditions.

Pielou's evenness - an estimate of the distribution of proportional abundances of individual species within a community. Evenness (J) is calculated as follows: $J=H'/\ln S$ where H' is the Shannon - Weiner diversity index and S is the number of species.

Plankton - aquatic organisms that drift within and that are incapable of movement against water currents. Some plankton have limited locomotor ability that allows them to change their vertical position in the water column.

Point source - a source of pollution that is concentrated at a specific location such as the outfall of a sewage treatment plant or factory.

Polyhaline - refers to waters with salinity values ranging between 18.0 and 30 ppt.

Primary productivity - the rate of production of living material through the process of photosynthesis that for phytoplankton is typically expressed in grams of carbon per liter of water per hour. High rates of primary productivity are generally considered to be related to excessive concentrations of nutrients such as nitrogen and phosphorus in the water column.

Probability based sampling - all locations within a stratum have an equal chance of being sampled. Allows estimation of the percent of the stratum meeting or failing the benthic restoration goals.

Procaryote - organisms the cells of which do not have discrete organelles or a nucleus (e.g. Cyanobacteria).

Pycnocline - a rapid change in salinity in the water column indicating stratification of water with depth resulting from either changes in salinity or water temperature.

Random Station - a station selected randomly within a stratum. In every succeeding sampling event new random locations are selected.

Recruitment - the successful dispersal settlement and development of larval forms of plants or animal to a reproducing adult.

Reference condition - the structure of benthic communities at reference sites.

Reference sites - sites determined to be minimally impacted by anthropogenic stress. Conditions at theses sites are considered to represent goals for restoration of impacted benthic communities. Reference sites were selected by Weisberg et al. (1997) as those outside highly developed watersheds, distant from any point-source discharge, with no sediment contaminant effect, with no low dissolved oxygen effect and with a low level of organic matter in the sediment.

Restoration Goal - refers to obtaining an average B-IBI value of 3.0 for a benthic community indicating that values for metrics approximate the reference condition.

Riparian Buffer - an area of trees and shrubs a minium of 100 feet wide located up gradient, adjacent, and parallel to the edge of a water feature which serves to: 1) reduce excess amounts of sediment, organic matter, nutrients, and other pollutants in surface runoff, 2) reduce soluble pollutants in shallow ground water flow, 3) create shade along water bodies to lower aquatic temperatures, 4) provide a source of detritus and large woody debris aquatic organisms, 5) provide riparian habitat and corridors for wildlife, and 6) reduce erosion of streambanks and shorelines

Rotifer - small multicellular planktonic animal of phylum Rotifera. These organisms are a major component of the microzooplankton and are major consumers of phytoplankton. High densities of rotifers are believed to be indicative of high densities of small phytoplankton such as cyanobacteria and as such are believed to be indicative of poor water quality.

Salinity - the concentration of dissolved salts in the water column measured in mg/L, ppt or psu. The composition and distribution of plant and animal communities is directly affected by salinity in estuarine systems. The effects of salinity on living resources must be taken into consideration when interpreting the potential effects of human activities on living resources.

Sarcodinians - single celled protists of the subphylum Sarcodina which includes amoeba and similar forms, characterized by possession of pseudopodia. Planktonic forms of sarcodinians typically have a external shell or test constructed of detrital or sedimentary particles and are important consumers of phytoplankton.

Secchi depth - the depth of light penetration expressed in meters as measured using a secchi disk. Light penetration depth directly affects the growth and recruitment of submerge aquatic vegetation.

Shannon Weiner diversity index - a measure of the number of species within a community and the relative abundances of each species. The Shannon Weiner index is calculated as follows:

$$H' = -\sum_{i=1}^{S} p_i \log_2 p_i$$

where p_i is the proportion of the ith species and S is the number of species.

Stratum - a geographic region of unique ecological condition or managerial interest.

Submerged aquatic vegetation (SAV) - rooted vascular plants (e.g. eelgrass, widgeon grass, sago pondweed) that grow in shallow water areas . SAV are important in marine environments because they serve as a major food source, provide refuge for juvenile crabs and fish, stabilize sediments preventing shoreline erosion and excessive suspended materials in the water column, and produce oxygen in the water column.

Threshold - a value of a metric that determines the B-IBI scoring. For all metrics except abundance and biomass, two thresholds are used - the lower 5^{th} percentile and the 50^{th} percentile (median) of the distribution of values at reference sites. Samples with metric values less than the lower 5^{th} percentile are scored as a 1. Samples with values between the 5^{th} and 50^{th} metrics are scored as 3 and values greater than the 50^{th} percentile are scored as 5. For abundance and biomass, values below the 5^{th} and above the 95^{th} percentile are scored as 1, values between the 5^{th} and 25^{th} and the 75^{th} and 95^{th} percentiles are scored as 3 and values between the 25^{th} and 75^{th} percentiles are scored as 5.

Tidal freshwater - refers to waters with salinity values ranging between 0 and 0.5 ppt which are located in the upper reaches of the estuary at or just below the maximum upstream extent of tidal influence.

Tintinnid - protists of phylum Ciliophora and order Oligotricha. These ciliates are important predators of small phytoplankton in marine systems. Tintinnids are distinguished from other members of this group because they create an exoskeleton or test made of foreign particles that have been cemented together.

Total nitrogen (TN) - the concentration of both inorganic and organic compounds in the water column which contain nitrogen measured in mg/L. Nitrogen is a required nutrient for protein synthesis. Inorganic forms of nitrogen are directly available for uptake by phytoplankton while organic compounds must first be decomposed by bacteria prior to being available for use for other organisms. High levels of total nitrogen are considered to be detrimental to living resources either as a source of nutrients for excessive phytoplankton growth or as a source of excessive bacterial decomposition that can increase the incidence and extent of anoxic or hypoxic events.

Total phosphorus (TP) - the concentration of both inorganic and organic compounds in the water column which contain phosphorus measured in mg/L. Phosphorus is a required nutrient for cellular metabolism and for the production of cell membranes. Inorganic forms of phosphorus are directly available for uptake by phytoplankton while organic compounds must first be decomposed by bacteria prior to being available for use for other organisms. High levels of total nitrogen are considered to be detrimental to living resources either as a source of nutrients for excessive phytoplankton growth or as a source of excessive bacterial decomposition that can increase the incidence and extent of anoxic or hypoxic events.

Total suspended solids (TSS) - the concentration of suspended particles in the water column, measured in mg/L. The composition of total suspended solids includes both inorganic (fixed) and organic (volatile) compounds. The fixed suspended solids component is comprised of sediment particles while the volatile suspended solids component is comprised of detrital particles and planktonic organisms. The concentration of total suspended solids directly affects water clarity which in turn affects the development and growth of submerged aquatic vegetation.

Zoea - last planktonic larval stage of crustaceans such as crabs and shrimp. Numbers of crab zoea may reflect the recruitment success of adult crabs.

Zooplankton - the animal component of the plankton which typically includes copepods, cladocerans, jellyfish and many other forms.