OLD DOMINION UNIVERSITY

[1]Department of Biological Sciences
Old Dominion University, Norfolk, Virginia 23529

[2]Department of Chemistry and Biochemistry
Old Dominion University, Norfolk, Virginia 23529

[3]Chesapeake Bay Program Office
Virginia Department of Environmental Quality
Richmond, Virginia 23230

STATUS AND TRENDS IN WATER QUALITY AND LIVING RESOURCES IN THE VIRGINIA CHESAPEAKE BAY: YORK RIVER (1985-2004)

Prepared by

Principal Investigators:

Daniel M. Dauer[1]
Harold G. Marshall[1]
John R. Donat[2]
Michael F. Lane[1]
Peter L. Morton[2]
Suzanne C. Doughten[2]
Frederick A. Hoffman[3]

Submitted to:

Chesapeake Bay Program
Virginia Department of Environmental Quality
629 East Main Street
Richmond, Virginia 23230

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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 preiodically 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.

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 four sets of appendices: water quality, phytoplankton, primary productivity, and benthos.

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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 main stem and tributaries began in 1985 and has continued for 20 years. Detailed assessments of the status and long-term trends in water quality and living resources in Chesapeake Bay and its tributaries have been previously conducted (Alden et al., 1991,1992; Carpenter and Lane, 1998; Dauer, 1997; Dauer et al., 1998a,1998b, 2002b; Lane et al.,1998; Marshall, 1994,1996; Marshall and Burchardt, 1998, 2003, 2004a, 2004b; 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 2004. This report describes the status of water quality and living resource conditions for the Virginia main stem and tributaries, summarizes major long-term trends in water quality and measures of living resource community health and updates past basin summary reports (Dauer et al., 2003a, 2003b, 2003c).

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 2004. 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 main stem 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, main stem 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 20 year period (varying from 20 to 12 sampling events per year) as a result of changes in the monitoring program budget. In general, main stem sampling cruises were conducted semi-monthly from March through October and monthly from November through February until 1996. Starting in 1996 main stem 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 generally conducted 20 times per year until 1996 after which sample were conducted monthly. 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, 2003). Field sampling procedures for DEQ water quality collections are described in detail in DEQ's Quality Assurance Project Plan for the Chesapeake Bay Program (available from DEQ). QA Project plans and methodologies are also available on the internet (http://www.chesapeakebay.net/qatidal.htm).

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, 2003). 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. If no pycnocline is present, the composite series of samples are taken from the upper third and lower third regions of depth at the station. 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). Each sample is examined with specific protocols at 3 magnifications (125X, 300X, 600X) to determine species composition and abundance. 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). In 2004 the June cruise to fixed point stations was eliminated to support a special benthic study (Dauer and Lane 2005b) and to allow additional random benthic sampling in support of the National Coastal Assessment Program. Stations were located within the main stem 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 main stem 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 25 random sites were allocated to each stratum with a new set of 25 selected for each stratum for each year. 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 main stem of the Chesapeake Bay.

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 et al. 2005a, 2005b, 2005c; Dauer and Lane 2005a).

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. 303(d) Assessment Methods

To meet the requirements of the Clean Water Act, the States of Maryland and Virginia are using benthic biological criteria for reporting overall condition and identification of impaired waters in Chesapeake Bay. The Chesapeake Bay benthic index of biotic integrity (B-IBI) is the basis for these biological criteria. Previous work conducted by Versar and Old Dominion University had two objectives: to develop a methodology for the assessment of benthic community status for 303(d) impairment decisions and to produce an assessment for each of the Chesapeake Bay segments and sub-segments containing benthic community data. A statistical procedure was developed that tests whether the distribution of B-IBI scores from probability-based samples collected from a Bay segment is significantly different from the distribution of reference site scores (Llansó et al. 2003). This procedure, a stratified Wilcoxon rank sum test, was evaluated and applied to the 2003 assessment data. The assessment resulted in 26 segments considered impaired based upon benthic community condition. The Wilcoxon approach, however, was sensitive to small shifts in B-IBI scores relative to the reference condition and did not allow estimation of the magnitude of shift. It was recommended that alternative methods be evaluated, especially those that take into account magnitude of departure from reference conditions and whether this magnitude is above specific thresholds of protection that the States may wish to implement. For the 2006 303(d) report, a new method that quantifies magnitude of degradation (Llansó et al. 2005).

In addition, a benthic diagnostic tool has been developed that can be used to identify potential sources of stress affecting benthic community condition in the Chesapeake Bay (Dauer et al. 2002a, 2005d). The tool can distinguish stress due to contaminants versus stress due to other factors (e.g., low dissolved oxygen, or unknown). This screening tool was used to identify which impaired segments have a high probability of sediment contamination. These segments could then be targeted for additional sampling or evaluation. The B-IBI metric scores for abundance and biomass were also used to identify (1) insufficient abundance patterns consistent with a low dissolved oxygen effect and (2) excessive abundance patterns consistent with eutrophication effects.

D. 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 ºC and ashing at 550 ºC 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 main stem and tributary stations from the January 2001 through December of 2004 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 to 1990 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, 2004. 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.

The terms good, fair, and poor used in conjunction with water quality relative status are statistically determined classifications for comparison between 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 which have led to large areas of hypoxia as well as reductions in submerged aquatic vegetation and other effects on living resources. Given this, an absolute evaluation in relation to ideal conditions would indicate that most water quality parameters are currently poor throughout the whole Bay system. The Monitoring Subcommittee of the Federal-Interstate Chesapeake Bay Program continues to develop additional methodologies for absolute water quality status evaluations, which in the future will be used in conjunction with, or possibly in replacement of, the current methods.

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 (2002 through 2004) 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:

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

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

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

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 for some parameters at some stations. 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 2004) 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 combinations 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. <u>Living resources</u>

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 20 year period of 1985-2004. 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.

C. 303(d) Assessment Methods

The assessment data for the 2006 303(d) report consisted of random samples collected from 2000 to 2004 throughout the Chesapeake Bay. A total of 1,430 samples (single replicates) were used, including 750 samples collected by the Maryland Chesapeake Bay benthic monitoring program, 500 samples collected by the Virginia Chesapeake Bay benthic monitoring program, 150 samples collected by the Elizabeth River benthic biological monitoring program, and 10 samples collected for a gear comparison study in each of Mobjack Bay, the tidal fresh Mattaponi River, and the Nansemond River. All assessment samples were collected with a Young grab (440 cm^2 surface area, 0.5-mm screen).

Assessments were produced for each of 85 Chesapeake Bay Program segments and sub-segments containing benthic data. Segments (TMAW, 1999) are Chesapeake Bay regions having similar salinity and hydrographic characteristics. In Virginia, segments were sub-divided into smaller units by the Virginia Department of Environmental Quality. Sub-segments were produced for each of the main stems of rivers and bays (e.g., James River mesohaline) and for some of the smaller systems opening into the main stem (e.g., Pagan River). Assessment samples were assigned to segments and sub-segments using GIS software. Existing hydrographic data for each sample were used to assign each sample to one of seven habitat classes used in the calculation of the B-IBI. These are the same habitat classes used in the reference data set.

1. Bootstrap Method

The Bootstrap Method developed for the 2006 assessment was based on the confidence limit and bootstrap simulation concepts described in Alden et al. (2002). Specifically, bootstrap simulation (Efron and Tibshirani, 1998) was applied to incorporate uncertainty in reference conditions. Simulations were used because the reference data (by habitat) are based on a small number of samples and the B-IBI score corresponding to a particular percentile in the distribution is likely to vary if a different set of reference sites were sampled. Reference data are assumed to be representative sample from a "super population" of reference sites.

For each habitat, a threshold based on the 5th percentile B-IBI score of the reference data set for the good sites (or the maximum B-IBI score observed for the degraded sites, see below), was determined. This threshold was not intended to serve as a criterion for classifying individual B-IBI scores, rather it was used to categorize the segment as impaired or not based on the proportion of sites below the threshold and the variance associated with this estimate. The variance in the estimates of proportions for each segment was estimated by the simulations.

The B-IBI scores for the reference good and degraded sites had degrees of overlap that ranged from quite high in the tidal freshwater and oligohaline habitats to moderately low in the mesohaline and polyhaline habitats. An assessment sample is more likely to come from an impaired benthic community if the B-IBI score for this sample is within the range of scores observed for sites known to be degraded. Therefore, two criteria were established for determining the threshold: its score had to be within the lower bound of the good reference distribution (i.e., 5th percentile), and it had to be within the upper range of observed scores for known degraded sites (i.e., the reference degraded sites). If the 5th percentile score for a simulation run was not within the range of scores for the reference degraded sites, then the maximum B-IBI score for the reference degraded sites was selected as the threshold. Thus, in this study, sites with low B-IBI scores below thresholds were unlikely to have good sediment quality and were likely to be impaired.

In each simulation run, a subset of the reference good sites for each habitat was selected at random, and the B-IBI threshold for this subset was determined (i.e., the B-IBI score at the 5th percentile, or the maximum score for the reference degraded samples). The assessment B-IBI data for each habitat was then compared to the threshold to estimate the proportion of sites below the threshold. By repeating this process over and over again (5,000 runs) we were able to estimate the variance in the proportion of sites below the threshold from the bootstrap estimates. This variance reflects variability in the thresholds as well as sampling variability.

In the final step of the method, segments were declared impaired if the proportion of sites below the threshold was significantly higher than expected under the null hypothesis. Under the null hypothesis, a small number of sites (defined as 5% of the sites) would be expected to have low IBI scores even if all sites in a segment were in good condition (i.e., no low dissolved oxygen, contaminant, or nutrient enrichment problems). This is because of natural variability in the benthic communities, the effects of natural stressors, and sampling and methodological error. For a segment to be declared as impaired, the lower bound of the 95% confidence interval of the estimate had to higher than 5% (the expected proportion under the null hypothesis), with a minimum sample size of 10.

2. Wilcoxon Test

A stratified Wilcoxon rank sum test was applied as described in Llansó et al. (2003) using Proc-StatXact 5 software (ytel Software Corporation 2002). B-IBI scores were grouped into three ordered condition categories (1.0-2.0, 2.1-2.9, 3.0-5.0) and the distribution of scores within a segment was compared for each habitat to the distribution of scores for the reference condition. Under the null hypothesis (H_o) of no impairment, the two populations (segment and reference) were considered to have the same underlying multinomial distributions of samples among the ordered categories. The assessment of impairment was based on a one-sided exact test of H_o against the alternative hypothesis that the segment had a distribution shifted towards lower B-IBI scores than for the reference condition. The ranking was done separately by habitat, and then combined across habitats. Segments with a minimum of 10 samples for which the test was significant at the 1% alpha level and 90% power, were considered impaired under this method.

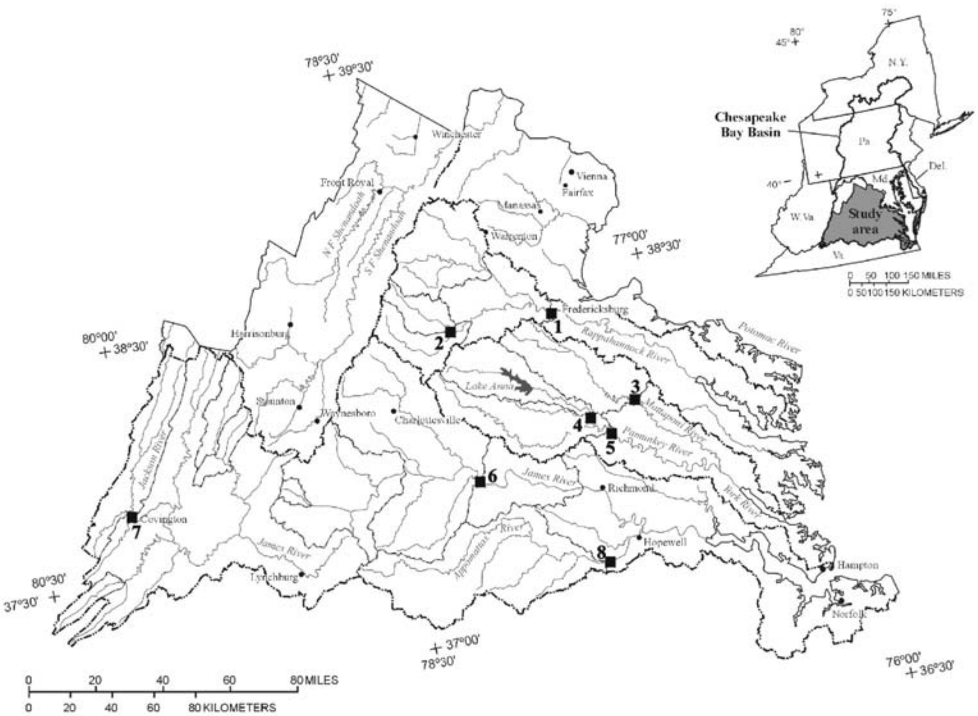
3. Benthic Diagnostic Tool

The benthic diagnostic tool allows environmental managers to identify potential sources of anthropogenic stress to benthic communities within Chesapeake Bay. The development and application of the tool was described in detail in Dauer et al. (2002a, 2005). The benthic diagnostic tool is based on a linear discriminant function that classifies sites in Chesapeake Bay identified as having degraded benthic communities into categories distinguished by the type of stress experienced by those communities. Presently, the function is capable of discriminating contaminated sites from sites affected by all other potential sources of stress in any of the seven benthic habitat types of Chesapeake Bay. The function was developed using a variety of metrics of benthic community structure, diversity, and function.

For this assessment, sites with B-IBI scores < 2.7 were defined as "degraded" for benthic diagnostic tool application purposes. This cutoff value may differ from the threshold used by the bootstrap method to determine proportion of sites with degraded benthic communities, but it should be very close to that threshold. Because cutoff values differ, diagnostic tool percentages should only be used as a general guide for identifying potential causes of degradation. For each "degraded" site, benthic metric values were submitted to the function and posterior probabilities of group membership calculated. Posterior probabilities for impaired segments were then used to identify the most likely source of stress affecting benthic communities in these segments.

4. Insufficient and Excess Abundance/Biomass Criteria

Insufficient and excess abundance or biomass was determined from the abundance and biomass metrics scores. In the B-IBI, a score of 1 is assigned to total species abundance and total biomass if the value of these metrics for the site being evaluated is below the 5th percentile or Below the 95th percentile of corresponding reference values. A score of 1 is assigned for both insufficient and excess abundance or biomass because abundance and biomass of organisms respond bimodally to pollution. An increase in abundance or biomass is expected at polluted sites when stress from pollution is moderate, such as at sites where there is organic enrichment of the sediment. Excess abundance and excess biomass are phenomena usually associated with eutrophic conditions. A decrease in abundance and biomass is expected at sites with high degrees of stress from pollution; for example, sites affected by low dissolved oxygen or toxic contamination. The insufficient and excess abundance or biomass criteria can then be used to determine the likelihood of contaminant or low dissolved oxygen problems versus eutrophic conditions for each of the Chesapeake Bay segments evaluated.



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.

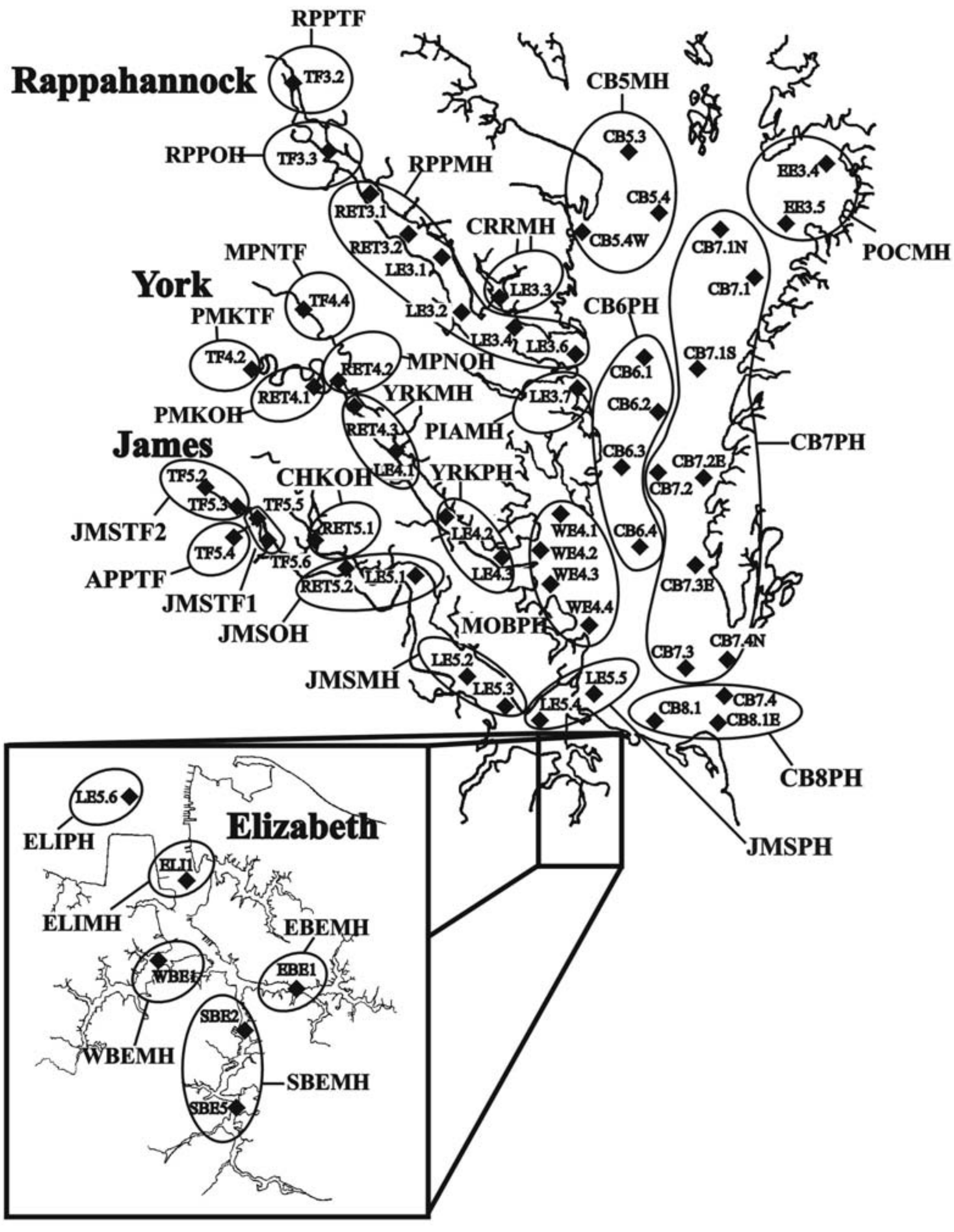


Figure 2-2. Map showing the locations of the water quality monitoring stations in the Virginia tributaries and the Lower Chesapeake Bay Mainstem used in the statistical analyses. Also shown are ellipses that delineate the Chesapeake Bay Program segmentation scheme.

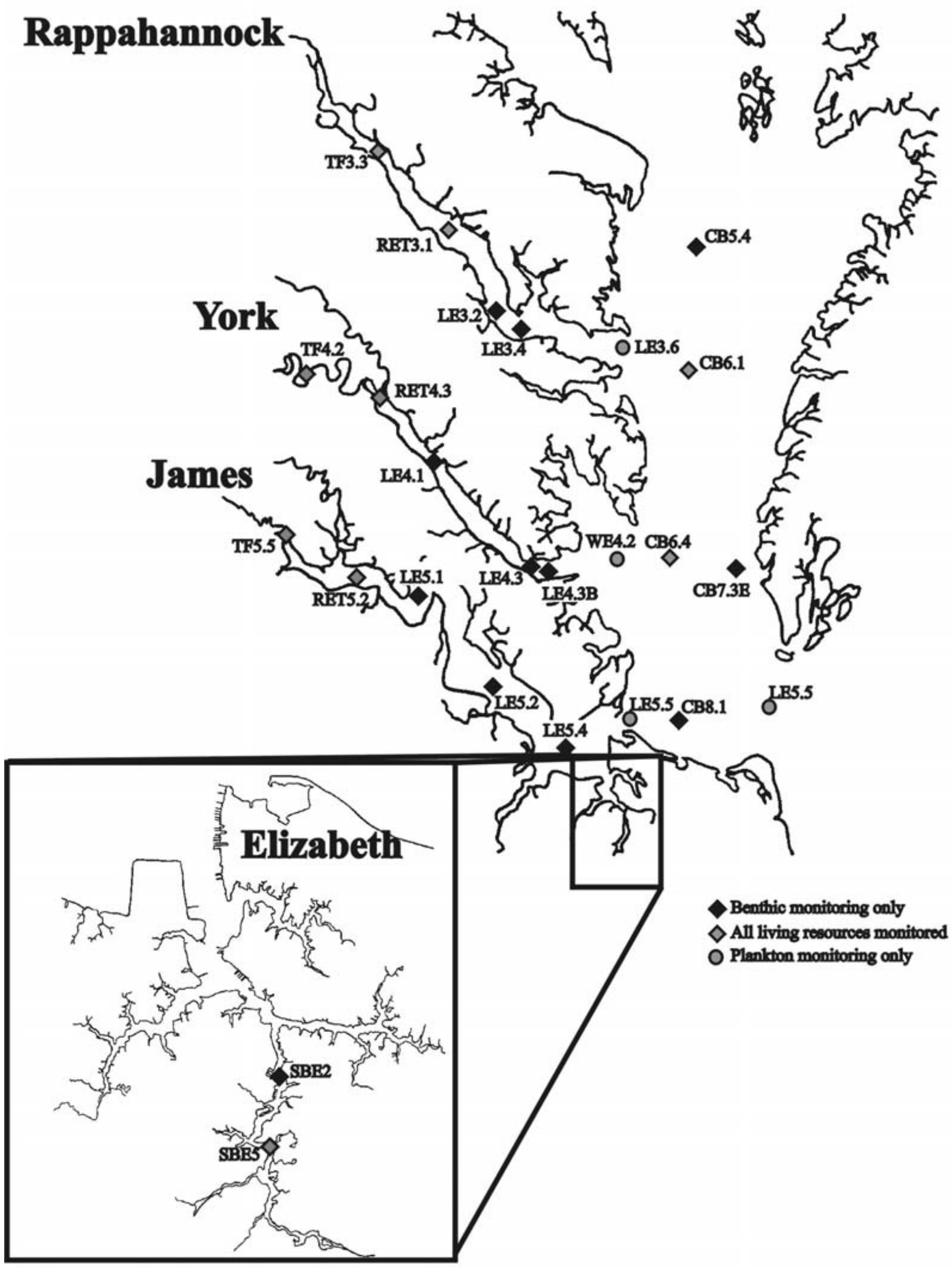


Figure 2-3. Location of living resource monitoring stations in the Virginia tributaries and the Lower Chesapeake Bay Mainstem.

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. 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

Chapter 3. York River Basin

I. Executive Summary

A. Basin Characteristics

- Although the York River watershed has the second highest total area and percentage of developed land and the second highest overall population density of all three of the Virginia tributaries, it is predominantly rural as indicated by the high percentages of forested and agricultural land with forested land accounting for over 60% of the total area. In addition, the York River has the highest percentages of open water and wetlands land of all of the Virginia tributaries, as well as, the highest percentage of shoreline with a riparian buffer.

- Non-point sources accounted for 82% of the approximately 3,446,000 kg/yr of the total nitrogen loadings to the York River. Although there has been an 18% reduction of non-point source loadings to the watershed due to the application of best management practices, point source loadings of total nitrogen increased by 1%.

- Non-point sources accounted for 78% of the nearly 340,000 kg/yr of total phosphorus loadings to the York River in 2004. Best management practices and the phosphate ban have resulted in an overall reduction of 19% and 63% in non-point and point source loadings to the river since 1985.

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

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

- In general, patterns in flow rates within the Mattaponi River reflected those in the Pamunkey River. There were no significant long-term trends in both rivers during the period of 1985 through 2004 although a four year dry period was observed from 1999 through 2002 when peak monthly mean flows and annual mean flows were generally lower than those in previous years.

B. Water Quality

- Water quality conditions above the fall-line in the Pamunkey River appear to be degrading as indicated by both the increasing trends in flow adjusted concentrations of nitrogen, phosphorus and suspended solids observed at the fall-line station at Hanover and the increasing trends in nitrogen and total suspended solids in the North Anna River.

- Water quality above the fall-line in the Mattaponi River appears to be improving as evidenced by decreasing trends in flow adjusted concentrations of both total nitrogen and total phosphorus at the fall-line station near Beulahville.

- Status of nitrogen parameters was generally fair or good in most segments although it was generally lower in downstream segments. Status of phosphorus parameters was good in the Upper Pamunkey River, the Upper Mattaponi River and Mobjack Bay but generally fair or poor in the lower segments of the Pamunkey and Mattaponi and the Middle and Lower York River.

- Degrading long-term or post 1994 trends in surface and/or bottom nitrogen parameters were detected in all segments except Mobjack Bay where improving trends in total nitrogen were detected. Degrading long term trends were detected in phosphorus parameters in the Lower Mattaponi River, and the Middle York River while in the Upper Pamunkey River and the Upper Mattaponi River both improving and degrading trends were observed in phosphorus parameters.

- Status of surface chlorophyll *a* was good in the Pamunkey River and Mattaponi River segments, but fair in remaining segments. Status of total suspended solids was poor in most segments except in the Upper Pamunkey River, the Upper Mattaponi Rivers and Mobjack Bay where it was fair or good. Status of secchi depth was poor in all segments of the York River except in the upper segments of the Pamunkey and Mattaponi rivers where it was fair and good, respectively. Status of Summer bottom dissolved oxygen was good or fair in all segments.

- Degrading trends were detected for surface chlorophyll *a* in the Upper Pamunkey River, bottom total suspended solids in in the Middle York River and secchi depth in the Upper Mattaponi River, the Lower York River and Mobjack Bay (MOBPH) while improving trends were detected in surface and bottom total suspended solids and Summer bottom dissolved oxygen in Mobjack Bay.

- Surface dissolved inorganic nitrogen was borderline in the Middle York River but met the SAV habitat requirements in the Lower York River and Mobjack Bay while surface dissolved inorganic phosphorus met the SAV requirements or was borderline in most segments except the Middle York River.

- During the SAV growing season degrading trends in nitrogen parameters were detected in all segments except the Lower York River and in Mobjack Bay where improving trends were detected. Degrading trends in phosphorus parameters were detected in the Upper Pamunkey River and the Middle York River while improving trends in phosphorus were detected in Mobjack Bay. Both improving and degrading trends in phosphorus parameters were detected in the Lower Pamunkey River.

- Surface chlorophyll *a* met the SAV habitat requirement in all segments while surface total suspended solids was borderline in the Upper Pamunkey River, failed to met the SAV habitat requirements in the Lower Pamunkey River, the Lower Mattaponi River, and the Middle York River but met the SAV requirements in the Lower Pamunkey River, the Lower York River and Mobjack Bay. The SAV requirements for secchi depth were either not met or secchi depth was borderline in all segments.

- Improving trends in surface chlorophyll *a* were detected in the upper segments of the Pamunkey and Mattaponi rivers while degrading trends in secchi depth were detected in the Upper Mattaponi River, the Lower York River and Mobjack Bay.

C. Living Resources

- Relative status of the majority of station/parameter combinations for phytoplankton was poor. The biomass to abundance ratio and Margalef diversity being poor throughout the York River. Productivity, cyanobacteria biomass, cyanobacteria abundance and picoplankton biomass were poor in the Middle York River and Mobjack Bay but fair in the Lower Pamunkey River while total biomass was poor in the Lower Pamunkey River and the Middle York River and fair in Mobjack Bay.

- Degrading trends in cyanobacteria abundance and biomass were detected at all stations of the York River while improving diatom biomass and chlorophyte biomass were detected at all stations.

- Benthic community status, as measured with the B-IBI, was good at all stations except TF4.2 and LE4.1 where it was severely degraded and degraded, respectively.

- An improving trend in the B-IBI was detected at station LE4.3B in the lower York River while a degrading trend in the B-IBI was detected at station LE4.1 in the Middle York River.

- Of the six segments in the York River with a sufficient sample size, four were classified as impaired with percentages degraded samples ranging from 36% in Mobjack Bay to 46% in the Lower Pamunkey River. Anthropogenic contamination, eutrophication and low dissolved oxygen adversely affect benthic communities in the York River.

- **D. Management Issues**

- Following a decline from 1985 through 1991, point source loadings of total phosphorus increased steadily during the next 12 years reaching nearly 57,300 kg/yr in 2003 above the fall-line in the Pamunkey River.

- Water quality in the non tidal portion of the Pamunkey River appears to be degrading as indicated by degrading trends observed in flow adjusted concentrations of both nitrogen and phosphorus parameters, as well as total suspended solids at the fall-line at Hanover and degrading trends in flow adjusted concentrations of total nitrogen and total suspended solids in the North Anna River.

- Despite the generally good relative status, increasing trends in both nitrogen and to a lesser degree phosphorus indicate that water quality in the tidal portion of the York River may be degrading although no readily apparent source of the problem has been identified.

- Poor water clarity is a persistent and widespread problem in the York River as indicated by the poor relative status and SAV habitat criterion violations throughout the estuary coupled with degrading trends in some segments. Source of the water clarity problem is unknown but probably tied to total suspended solids concentrations.

- Increasing long-term trends in abundance and biomass among the cyanobacteria are probably related to the increasing trends in nutrients observed and may adversely affect water clarity.

- Fixed point monitoring stations identified two areas of concern for the benthic communities: (1) the Upper Pamunkey as indicated by the severely degraded status of the B-IBI at station TF4.2, and the area near station LE4.1 in the Middle York River were benthic status was degraded and a degrading trend in the B-IBI was detected where stress may be caused by seabed mixing phenomena.

- Probability-based monitoring indicated that four out seven segments of the York River were impaired with percentages of degraded samples ranging from 36% in Mobjack Bay to 46% in the Lower Pamunkey River. Anthropogenic contamination appears to be the predominant source of stress to the benthos but eutrophication and low dissolved oxygen also play a role.

- The possibility that physical disturbance of the benthos caused by seabed mixing, a natural source of stress, may also be an important factor determining benthic community status in the York River .

II. Overview of Monitoring Results

A. Basin Characteristics

1. General

The York River is formed at West Point by the confluence of the Pamunkey and Mattaponi rivers and extends 225 km from the headwaters of these two tributaries to Yorktown where it empties into Chesapeake Bay. The Pamunkey and Mattaponi river watersheds comprise approximately 3,820 km^2 (45%) and 2,360 km^2 (28%) of the nearly 8,470 km^2 in the entire watershed. The length of the York River mainstem is just over 56 km and the tidal portions of the Pamunkey and Mattaponi rivers extend 90 km and 66 km upstream from West Point (Harrison and Fang, 1971). Both the Pamunkey River and Mattaponi River begin in the Blue Ridge and meander through the Piedmont while the York River main stem is located primarily in the Coastal Plain physiographic zone. Mean tidal range in the York River main stem ranges from 0.7 m at the mouth to 0.9 m at West Point (Sturm and Neilsen, 1977). Tidal range in the Pamunkey River is 0.6 m at about 29 km upstream from West Point and in the Mattaponi River is 1.2 m approximately 52 km upstream (Harrison and Fang, 1972). Climate in the area is characterized by hot summers and mild winters and can be classified as humid-subtropical (Harrison and Fang, 1972;Sturm and Neilsen, 1977) with an average annual precipitation of 114 cm (Sturm and Neilsen, 1977).

Major population centers within the watershed include Ashland, Gloucester Point, Hampton, and West Point. Predominant industries include agriculture (corn and soybeans), logging, and commercial fisheries of oysters (*Crassotrea virginica*), blue crabs (Callinectes sapidus) and pelagic fish. Heavy industry in the basin is limited to a pulp paper mill upstream at West Point and an oil refinery and coal/oil power plant at the mouth of the river (Sturm and Neilsen, 1977;Countway et al., 2003). Several military bases are also located in the lower portion of the river and much of the boat traffic in the river is a result of military shipping (Sturm and Neilsen, 1997).

2. Land Use

The York River has the second highest total area and percentage of developed land of the three tributaries exclusive to Virginia but forested and agricultural lands were the most abundant land-use types in the watershed accounting for nearly 61% and 21% of the total land cover in the basin overall, respectively. All other land use types each accounted for less than 10% of the remaining land in the basin. The York River has the highest percentages of open water and wetlands of the Virginia tributaries and the highest percentage of streambanks and shoreline with a 30 m minimum riparian forest buffer (Table 3-1A). Although it has the second highest overall at 44 individuals/km^2, the York River's population density is less than one half that of the James River. The human population in the watershed increased from 324,036 individuals in 1990 to 372,488 in and is projected to reach over 450,000 by 2020.

Both the total area and percentage of developed land in all sub-watersheds of the York River were relatively low being always less than 31 km^2 and 5%, respectively. Total areas and percentages of impervious surface were also low being typically less than 5 km^2 and always less than 3%, respectively. Percentages of agricultural land ranged from 12% in the Lower Tidal York River sub-watershed to 31% in the Upper Pamunkey River sub-watershed with both the percentage of agricultural land and total area being higher in the upstream and non-tidal portions of the Pamunkey and Mattaponi rivers than in the tidal portion of the York River. In general, forested land decreases substantially moving downstream from above the fall-line in the Pamunkey River to the Lower Tidal York River both in terms of total area and percent of the total area within the sub-watersheds. This pattern is similar moving downstream from above the fall-line in the Mattaponi River. The total number and percentage of kilometers with a riparian buffer was lower in those sub-watersheds in the tidal portion of the York River than those in the Pamunkey and Mattaponi rivers (Table 3-1B).

3. Nutrient and Sediment Loadings

Based on estimates provided by the Virginia DEQ, total point and non-point source loadings of nitrogen to the York River in 2004 were approximately 3,446,000 kg/yr with non-point sources accounting for 2,841,566 kg/yr or 82% of the total. Application of best management practices (BMPs) are estimated to have resulted in a 18% reduction of non-point source loadings to the watershed but point source loadings of total nitrogen increased by 1%. Non-point sources accounted for 78% of the nearly 340,000 kg/yr of total phosphorus to the York River in 2004 but BMPs have resulted in an overall reduction of 19% and 63% in non-point and point source loadings to the river since 1985. Total suspended sediments loadings in the York River was over 112,000 t/yr in 2004. BMPs have resulted in a reduction of 21% in total suspended solids loadings since 1985 (Table 3-2).

Point source loadings of total nitrogen above the fall-line in the Pamunkey River increased steadily from approximately 112,000 kg/yr in 1985 to just over 195,000 kg/yr but decreased substantially in subsequent years to just over 111,000 in 2003 (Figure 3-1A). In the Upper Mattaponi River (MPNTF), point source nitrogen loadings declined from approximately 617,000 kg/yr in 1985 to less then 300,000 in 1988. Total nitrogen loadings then increased to and remained above 500,000 kg/yr from 1989 through 1999 but dramatically declined thereafter ranging in values from approximately 236,000 in 2002 to just above 340,000 kg/yr in 2000 (Figure 3-1B). Following a substantial decline from nearly 620,000 in 1985 to approximately 238,000 kg/yr in 1987, point source loadings of total nitrogen in the Lower York River (YRKPH) have increased with some fluctuations over the last 16 years to reach nearly 757,000 kg/yr, an increase of nearly 18% since 1985 (Figure 3-1C). After an initial increase from just over 8000 kg/yr in 1985 to over 152,000 kg in 1993, point source total nitrogen loadings in Mobjack Bay (MOBPH), declined substantially reaching 2,325 kg/yr in 1993. Thereafter, point source loadings of total nitrogen remained below 2,700 and were generally less than 2,000 kg/yr (Figure 3-1D).

Point source loadings of total phosphorus above the fall-line in the Pamunkey River declined from about 40,000 kg/yr to just under 24,000 kg/yr in 1991 but have increased steadily during the next 12 years reaching nearly 57,300 kg/yr in 2003 (Figure 3-2A). In the Upper Mattaponi River

(MPNTF), point source loadings of total phosphorus declined from approximately 250,000 kg/yr in 1985 to just under 100,000 kg/yr in 1986. Following a slight increase in 1987, point source loadings of total nitrogen declined again to just over 48,000 kg/yr in 1990 and increased in 1990 to over 109,000 kg/yr in 1991. Phosphorus loadings then declined to nearly 78,000 kg/yr in 1992, rose again to over 103,000 in 1999 and have declined in recently to just under 51,000 kg/yr in 2003 (Figure 3-2B). In the Lower York River (YRKPH) an initial decline in total phosphorus loadings from nearly 154,000 kg/yr in 1985 to over 131,000 kg/yr in 1986 was followed by a peak in total phosphorus loadings to over 350,000 kg/yr in 1987 . Thereafter, point source loadings in total phosphorus dropped to just under 70,000 kg/yr in 1988 and have remained relatively stable ranging between just below 53,000 kg/yr to just over 73,000 kg/yr (Figure 3-2C). Point source loadings of total phosphorus in Mobjack Bay (MOBPH) showed a fairly steady decline from approximately 2,900 kg/yr in 1985 to just over 350 kg/yr in 1993 and subsequently remained at values below 300 kg/yr (Figure 3-2D).

4. Freshwater Flow

Daily freshwater flow at the fall-line in the Pamunkey ranged from a minimum of 0.65 m^3/sec to a maximum of 577.66 m^3/sec and with an grand mean flow of 28.97 m^3/sec. From 1985 through 1998, mean monthly flows in the Pamunkey River were characterized by peaks with values in excess of 50 m^3/sec that occurred one or two times per year except during 1992 and 1995. The largest peak occurring in spring of 1998 when monthly flow exceeded 200 m^3/sec. This was followed by a four years dry period from 1999 through 2002 during which monthly mean flow remained below 50 m^3/sec. The driest year was 2002 when monthly mean flow remained below 30 m^3/sec (Figure 3-3A). In subsequent years, monthly mean flow rates returned to more typical levels. From 1985 through 1998, annual mean flow rates for most years were either close to or higher than the grand mean flow rate. The highest annual mean flow occurred in 2003 following which annual mean flow declined to a level approaching the grand mean (Figure 3-3B). Flow rates in the Mattaponi River showed similar patterns to those observed in the Pamunkey River although the magnitude of flow rates in the Mattaponi River are generally lower (Figure 3-4A,B). Daily freshwater flow at the fall-line in the Mattaponi ranged from a minimum of 0.01 m^3/sec to a maximum of 220.30 m^3/sec with a grand mean of 14.99 m^3/sec. No significant trends in freshwater flow were detected in either the Pamunkey or Mattaponi rivers.

B. Water Quality

1. Non-tidal

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. 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. Improving trends in flow adjusted concentrations of both total nitrogen and total phosporus were detected in the Mattaponi River near Beulahville (Table 3-3).

2. Tidal

Status of surface and bottom total nitrogen was good in most segments of the York River except for bottom total nitrogen in the Lower Pamunkey River (PMKOH) where it was fair and in the Middle and Lower York River (YRKMH and YRKPH) were it was poor. Status of surface and bottom dissolved inorganic nitrogen was good in all segments of the York River except in the Middle and Lower York River (YRKMH and YRKPH) where it was generally fair. Status of phosphorus parameters was mainly good in the Upper Pamunkey River (PMKTF), the Upper Mattaponi River (MPNTF) and Mobjack Bay (MOBPH). Status of phosphorus parameters was: (1) good in the upper Pamunkey and Mattaponi rivers (PMKTF and MPNTF) and Mobjack Bay (MOBPH), (2) fair or poor in the lower Pamunkey and Mattaponi rivers (PMKOH and MPNOH) and the Lower York River (YRKPH), and (3) poor in the Mddle York River (YRKMH) (Figure 3-5;Table 3-4).

Status of surface chlorophyll *a* was good in the Pamunkey River and Mattaponi River, but fair in the York River main stem segments and Mobjack Bay (MOBPH). Status for surface and bottom total suspended solids was poor in most segments in the York River except in the upper segments of the Pamunkey and Mattaponi rivers (segments PMKTF and MPNTF) where it was fair or good and in Mobjack Bay (MOBPH) where status of surface total suspended solids was good. Status of secchi depth was poor in all segments of the York River except in the upper segments of the Pamunkey and Mattaponi rivers (PMKTF and MPNTF) where it was fair and good, respectively. Status of Summer bottom dissolved oxygen was good or fair in all segments of the York River (Figure 3-6; Table 3-4).

Degrading long-term or post 1994 trends in bottom and/or surface total nitrogen were detected in all segments of the York River except Mobjack Bay (MOBPH) where improving trends were detected. Degrading post 1994 trends in bottom and/or surface dissolved inorganic nitrogen were detected in the Upper Pamunkey River and the Upper Mattaponi River (PMKTF and MPNTF). Degrading long term trends in surface and bottom dissolved inorganic nitrogen were detected in the Lower Mattaponi River (MPNTF). Degrading long term trends were detected in total phosphorus (surface or bottom or both) in the Upper Pamunkey River (PMKTF), the Upper and Lower Mattaponi River (MPNTF and MPNOH), and the Middle York River (YRKMH). Degrading long term trends in surface and bottom dissolved inorganic phosphorus were detected in the Middle York River (YRKMH) while improving long term or post 1994 trends were detected in the Upper Pamunkey River (PMKTF) and the Upper Mattaponi River (MPNTF) (Figure 3-5;Table 3-5).

A degrading long term trend in surface chlorophyll *a* was detected in the Upper Pamunkey River (PMKOH). A degrading trend in bottom total suspended solids was detected in the Middle York River (YRKMH). Degrading long term trends in secchi depth were detected in the Upper Mattaponi River (MPNTF), the Lower York River (YRKPH), and Mobjack Bay (MOBPH). Improving long term trends in surface and bottom total suspended solids and Summer bottom dissolved oxygen were detected in Mobjack Bay (MOBPH) (Figure 3-6;Table 3-6).

Surface dissolved inorganic nitrogen was borderline in the Middle York River (YRKMH) but met the SAV habitat requirements in the Lower York River (YRKPH) and Mobjack Bay (MOBPH).

Surface dissolved inorganic phosphorus met the SAV requirements or was borderline in most segments of the York River but failed to meet the SAV habitat criterion in the Middle York River (YRKMH). Surface chlorophyll *a* met the SAV habitat criterion in all segments. Surface total suspended solids was borderline in the Upper Pmaunkey River (PMKTF), failed to met the SAV habitat requirements in the Lower Pamunkey River, the Lower Mattaponi River, and the Middle York River but met the SAV requirements in the Lowere Pamunkey River (PMKOH), the Lower York River (YRKPH) and Mobjack Bay (MOBPH). The SAV requirements for secchi depth werre not met in the Lower Pamunkey River (PMKTF), the Lower Mattaponi River (MPNOH) and the Middle York River (YRKMH), but were met in Mobjack Bay (MOBPH) Secchi depth was borderline in all other segments (Figure 3-7;Table 3-7).

During the SAV growing season long-term or post 1994 degrading trends in surface total nitrogen and/or dissolved inorganic nitrogen were detected in all segments except the Lower York River (YRKPH) and Mobjack Bay (MOBPH). Improving long term trends in surface and bottom total nitrogen were detected in Mojack Bay (MOBPH). Although a long term degrading trend in surface total phosphorus was detected in the Upper Pamunkey River (PMKTF), improving long term trends in surface dissolved inorganic phosphorus were detected in this segment and in Mobjack Bay (MOBPH). Degrading long term trends in surface dissolved inorganic phosphorus were detected in the Lower Pamunkey River (PMKOH) and the Middle York River (YRKMH). Improving trends in surface chlorophyll *a* were detected in the upper segments of the Pamunkey and Mattaponi rivers. Degrading long term trends in secchi depth were detected in the Upper Mattaponi River (MPNTF), the Lower York River (YRKPH) and Mobjack Bay (MOBPH) (Figure 3-7;Table3-8 and 3-9).

C. Phytoplankton

The river was dominated by a diatom assemblage, in addition to increasing populations of chlorophytes and cryptomonads. There were increasing trends of total phytoplankton biomass and abundance in the Pamunkey and the upper York River stations. These trends were in the down stream York River station WE4.2. Phytoplankton community conditions in the York River appear to reflect water quality conditions. Status of several phytoplankton community metrics in the Upper Pamunkey River was poor or fair, with primary production status fair, but poor in the York. Several of the phytoplankton community parameters in the Middle York River (YRKMH) were poor or fair with the exception of diatoms, chlorophytes, and the cryptophytes whose 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 stations in the York River (Figure 3-8;Tables 3-10 and 3-11). 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 degrading trends in nutrients observed in the river. One of the more significant patterns associated with the trend analysis was the two increasing long term trends for cyanobacteria biomass and abundance. These algae are bloom producers and contain potentially harmful species.

Phytoplankton composition within the tidal freshwater region of the Pamunkey River is discussed in detail by Marshall and Burchardt (2005a) identifying the seasonally dominant flora and showing the monthly range of development over the monitoring period. Previous discussion regarding long term trends regarding phytoplankton components and water quality in this river were given by Marshall et al. (1998) and Marshall and Burchardt (2004a). Additional information regarding the phytoplankton composition within tributaries of the Chesapeake Bay estuarine complex is given in Marshall et al. (2005). These reports identify a diverse phytoplankton population within the Bay tributaries, primarily dominated by a diatom flora with a diverse complement of species coming from both freshwater and neritic coastal sources. Many of these taxa deserve continued monitoring in light of their potential deteriorating impact on the environmental status of these tributaries. Potentially harmful species are presented in Marshall et al. (2005).

D. Benthos

1. Fixed Point Monitoring

Benthic community status, as measured with the B-IBI, was good at all stations except TF4.2 and LE4.1 where status of this parameter was severely degraded and degraded, respectively. An improving trend in the B-IBI was detected at station LE4.3B in the lower York River accompanied by an improving trend in pollution indicative species abundance. A degrading trend in the B-IBI was detected, in the Middle York River (YRKMH) at station LE4.1 due to degrading trends in pollution sensitive species biomass, pollution indicative species biomass and the Shannon-Weiner diversity index. Although there was no trend in the B-IBI, improving trends in total abundance and the Shannon-Weiner diversity index along with degrading trends in pollution indicative species abundance and biomass were detected at station TF4.2 in the Upper Pamunkey River (PMKTF) (Figure 3-9;Tables 3-12 and 3-13).

2. Probability-Based Monitoring

All but one of the seven segments in the York River had a large enough sample size for assessment and four of these segments were classified as impaired with percentages of degraded samples ranging from 36% in Mobjack Bay (MOBPH) to 46% in the Lower Pamunkey River (PMKOH). Both segments of the Mattaponi River were classified as unimpaired although 25% of samples collected in the Upper Mattaponit River (MPNOH) were degraded. Although only four samples were collected in the Upper Pamunkey River (PMKTF), none were classified as degraded (Table 3-14). The percentage of samples below the threshold, decreases moving downstream from the Middle York River (YRKMH) to Mobjack Bay (MOBPH) and the extent of degradation in the Lower Pamunkey River (PMKOH) was similar (within 3%) to that in the Middle York River (YRKMH) (Table 3-14).

Within those segments classified as impaired, the predominant source of stress appears to be anthropogenic contamination. Percentages of degraded samples classified as contaminated ranged from 45% in the Lower York River (YRKPH) to 64% in the Middle York River (YRKMH) with average contaminant posterior probabilities ranged from 0.43 in the Lower York River (YRKMH) to 0.64 in the Middle York River (YRKMH) (Table 3-15). Eutrophication appears to be in part responsible for benthic community degradation in most segments of the York River. All segments except the Lower Pamunkey River (PMKOH) had from 9% to 12.5% of degraded samples classified as uncontaminated with excessive abundance and/or biomass. Low dissolved oxygen is also of source of stress to the benthos with from 12% to 27% of samples having insufficient abundance and/or biomass with the highest percentages occurring in the Lower York River (YRKPH) and Mobjack Bay (MOBPH) (Table 3-15). Overall, contaminants appear to be the predominant contributor to benthic community degradation in the York River particularly in the Lower Pamunkey River (PMKOH) and the middle York River (YRKMH) although both eutrophication and low dissolved oxygen may also effect benthic communities in most segments.

III. Management Issues

Water quality in the non tidal portion of the Pamunkey River appears to be degrading as indicated by degrading trends observed in flow adjusted concentrations of both nitrogen and phosphorus parameters, as well as total suspended solids at the fall-line at Hanover and degrading trends in flow adjusted concentrations of total nitrogen and total suspended solids in the North Anna River. Since the trends observed are flow adjusted, the source of degrading trends above the fall-line is presumably anthropogenic. The trends observed in nutrient concentrations may be in response to changes in point source loadings. Point source loadings in total nitrogen increased from 1985 through 2000 but declined in 2001 to levels similar to those observed in 1985. Degrading trends observed may be as a result of a lag in the response of nutrient concentrations to the change in loadings. Alternatively, the trends detected could be a statistical artifact caused by real trends in the data. Perhaps the reversal of trends caused by recent decreases in point source loadings is overshadowed by previous increasing trends in the data. The increase in point source loadings of total phosphorus may be responsible for the degrading trends in phosphorus parameters. Point source loadings above the fall-line have steadily increased since 1987.

With respect to nutrients, water quality throughout the tidal portions of the York River appears to be degrading. Although status of nitrogen parameters was typically good in most segments, long term or post 1994 degrading trends in nitrogen parameters were detected in all segments except Mobjack Bay where improving trends were detected. Status of phosphorus parameters decreased from good in the upper segments of the Pamunkey and Mattaponi rivers to fair in the lower segments of Pamunkey and Mattaponi river and to poor in the Middle York River and degrading trends in phosphorus parameters in several segments.

Water clarity also appears to be impacted in the York River and appears to be degrading in some segments as indicated by: (1) the poor relative status of secchi depth in all segments but Mobjack Bay, (2) the violation of the SAV requirements in the Lower Pamunkey River, the Lower Mattaponi River, and the Lower York River, and (3) degrading trends in the Lower Mattaponi River, the Lower York River and Mobjack Bay. Poor water clarity appears to be a persistent problem and widespread problem in the York River. Both poor relative status and SAV habitat requirement violations have been previously reported at the in most segments using data collected during previous Chesapeake Bay Program monitoring event in most segments (Dauer et al. 2002a;Dauer et al 2003a; Dauer et al. 2003c; Dauer et al. 2004). Results of the Mid-Atlantic Intergrated

Assessment program indicated that violations of the SAV habitat criterion (same as this study) for secchi depth occurred at 75% of stations in the York River (Kiddon et al., 2003).

The cause of the water clarity problems is uncertain but appears to be related to suspended solids since: (1) the relative status of secchi depth corresponds well to status in suspended solids; (2) violations of SAV criteria for secchi depth are coincidental for those with suspended solids, and (3) in general, degrading trends in secchi depth cooccur with degrading trends in suspended solids. The excessive concentrations of and degrading trends in total suspended solids do not appear to be related to changes in non-point source run-off since loadings of total suspended solids has decreased by 21% in the basin overall since 1985. However, a closer examination of spatial patterns in non-point source runoff may reveal specific areas that have experienced increases in sediment erosion. Other factors may influence water clarity within the York River. Recent studies indicate that the seabed in the York River is highly dynamic and experiences a continual cycle of erosion and deposition producing deep physical mixing ranging in depth from 40 cm to 100 cm (Dellapenna, 1998). Deep seabed mixing in concert with the long particle residence times observed in this estuary may significantly affect resuspension of particles and/or contaminations into the water column (Dellapenna, 1998). As such, seabed mixing as mediated by inter-annual changes in freshwater flow could be a dominant factor that influences trends in water clarity. The increasing trends in phytoplankton concentrations observed could also alter water clarity levels. Magnitudes of phytoplankton blooms have been demonstrated to affect water column light absorption and scattering coefficients in the Rhode River, a Chesapeake Bay tributary, both on a seasonal and inter-annual time scale (Gallegos et al., 2005). 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.

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 (Officer and Ryther, 1980), are associated with degrading water conditions, and also contain several potential bloom and toxin producers ((Marshall, 1995, 1996, 2003; Marshall and Burchardt, 2004)). Increased densities of cyanobacteria is may be due to the increasing trends in nutrients observed.

Based on the fixed point monitoring data, two regions of concern for the benthic communities were identified: the Upper Pamunkey as indicated by the severely degraded status of the B-IBI at station TF4.2 and the area near station LE4.1 in the Middle York River were benthic status was degraded and a degrading trend in the B-IBI was detected. Stress due to seabed mixing is known to adversely affect benthic communities in the Middle York River (Dellapenna et al., 2003); however, no clear source of stress to benthic communities in the Upper Pamunkey River can be readily identified.

Probability-based monitoring indicated that four out seven segments of the York River were impaired with percentages of degraded samples ranging from 36% in Mobjack Bay to 46% in the Lower Pamunkey River. Previous estimates of the areal extent benthic degradation in the York

River are similar (Kiddon et al., 2003). The predominant source of stress appears to be anthropogenic contamination although both eutrophication and low dissolved oxygen appear to play a role in some segments as well. There is no previous evidence of high concentrations of contaminants in York River sediments (USEPA, 1999;Hall et al., 2001); however, Kiddon et al. (2003) found at least one metal contaminant at concentrations above the Long et al. (1995) Effects Range Low concentrations in 100% of samples collected in the York River and PAHs and pesticides have been found in the water column of the estuary (Countway et al., 1999; Padma and Dickhut, 2002). Recent studies have noted the importance of sea bed mixing, a natural source of stress, in structuring estuarine benthic communities in the York River (Dellapenna, 1998;Dellapenna et al., 2003). These results indicated that the physically stressed portions of the York River had benthic communities characterized by small opportunistic species, a characteristic not unlike that observed for benthic communities stressed by contaminants. It is possible that the community signature of sediment contamination as characterized by the Contaminant Discriminant Tool (CDT) is similar to that of physical stress induced by seabed mixing so that samples collected in areas stressed by seabed mixing might be classified as contaminated by the CDT. A closer examination of the spatial distribution of samples classified as contaminated could reveal whether or not those samples occur in areas believed to experience physical disturbances.

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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.

Delivered load -the amount of point or non-point source nutrient loadings, expressed as a annual rate, that reaches the tidal portion of the estuary. In general, both point and non-point source nutrient loadings decrease as a result of the natural ability of a water body to assimilate and remove nutrients as they pass through it. Note that when calculating delivered loads to an estuary, both non-tidal point and non-point source nutrient loadings are adjusted for in-stream removal while point source loadings below the fall-line are given as discharged loads with no in-stream removal adjustment.

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.

Discharged load - the amount of point source nutrient loadings, expressed as a annual rate in kg/yr, that are directly input to a waterbody.

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 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 5th percentile and the 50th percentile (median) of the distribution of values at reference sites. Samples with metric values less than the lower 5th percentile are scored as a 1. Samples with values between the 5th and 50th metrics are scored as 3 and values greater than the 50th percentile are scored as 5. For abundance and biomass, values below the 5th and above the 95th percentile are scored as 1, values between the 5th and 25th and the 75th and 95th percentiles are scored as 3 and values between the 25th and 75th 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.

Figures

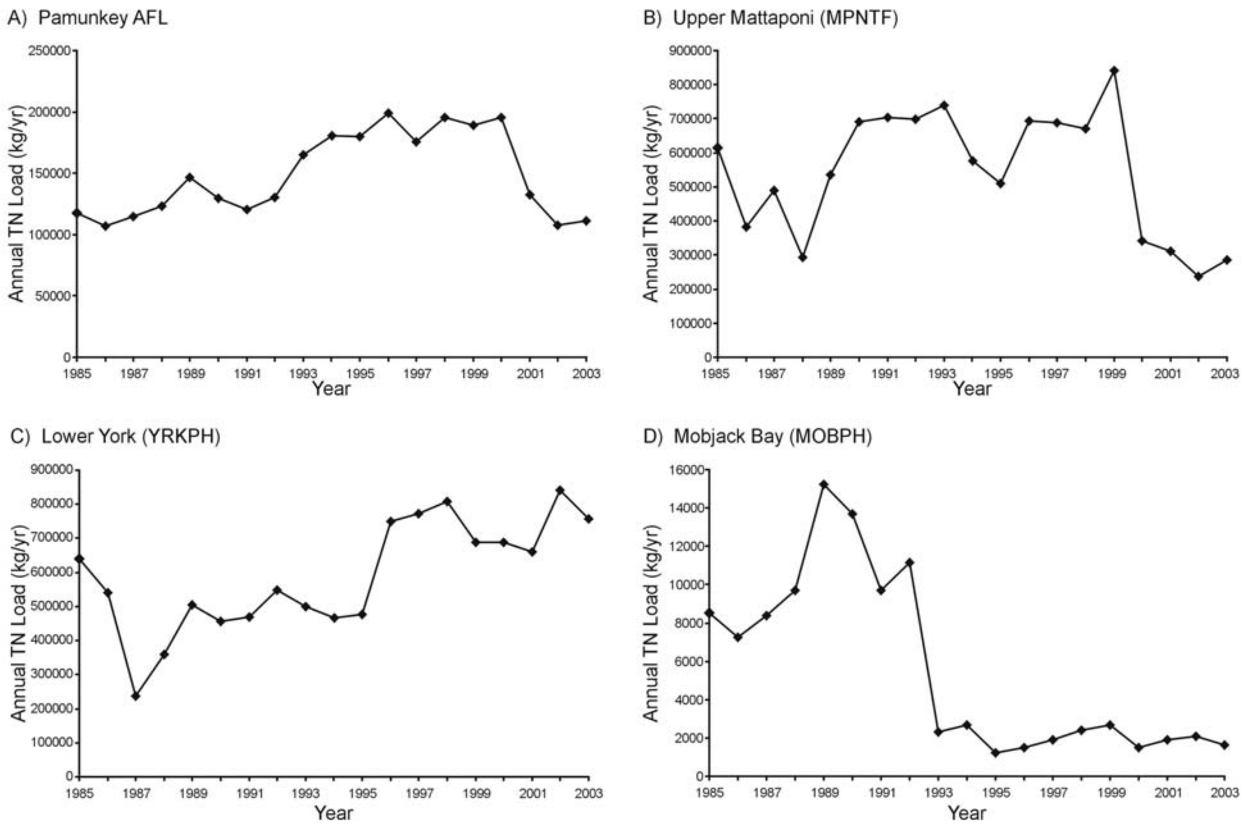


Figure 3-1. Long-term changes in discharged point source total nitrogen loadings in the A) Pamunkey River Above the Fall-B) Upper Mattaponi (MPNTF), C) Lower York (YRKPH) and in D) Mobjack Bay (MOBPH) for 1985 through 2003.

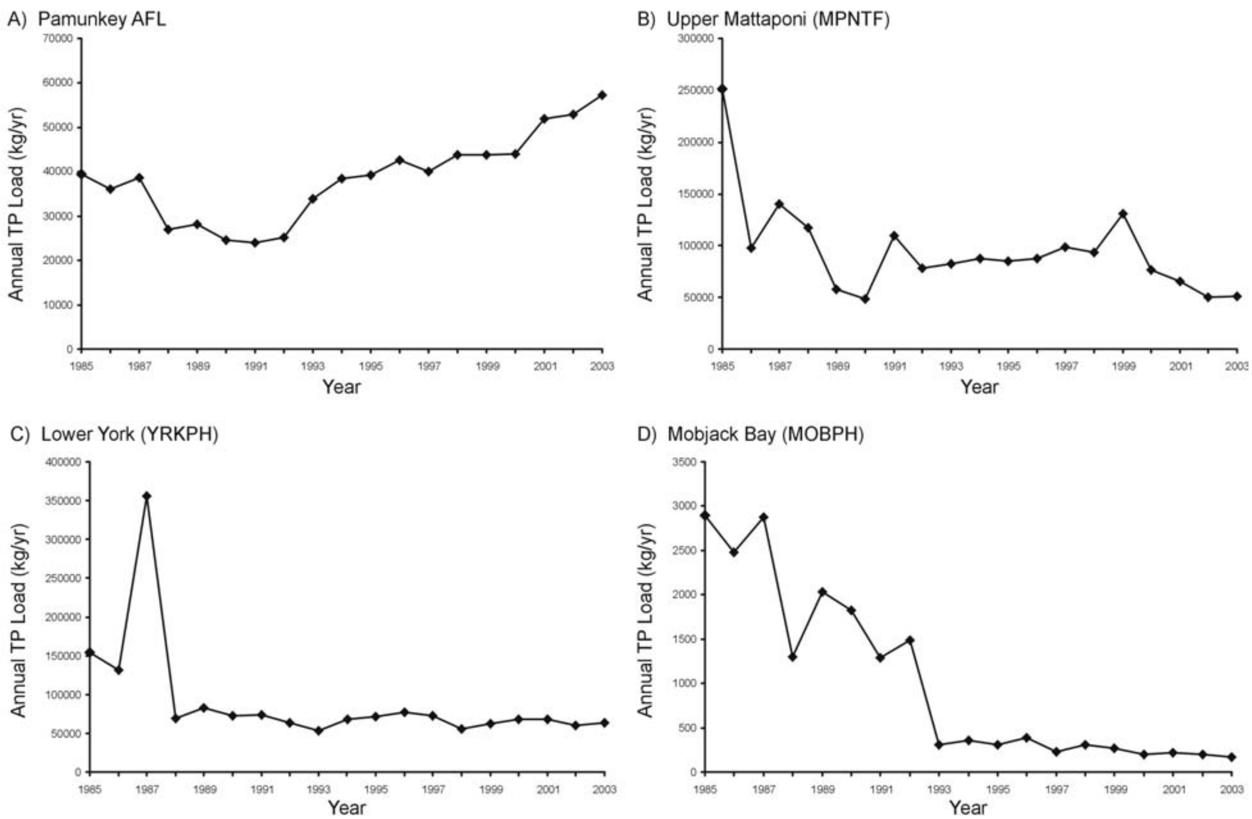


Figure 3-2. Long-term changes in discharged point source total phoshprus loadings in the A) Pamunkey River Above the Fall-B) Upper Mattaponi (MPNTF), C) Lower York (YRKPH) and in D) Mobjack Bay (MOBPH) for 1985 through 2003.

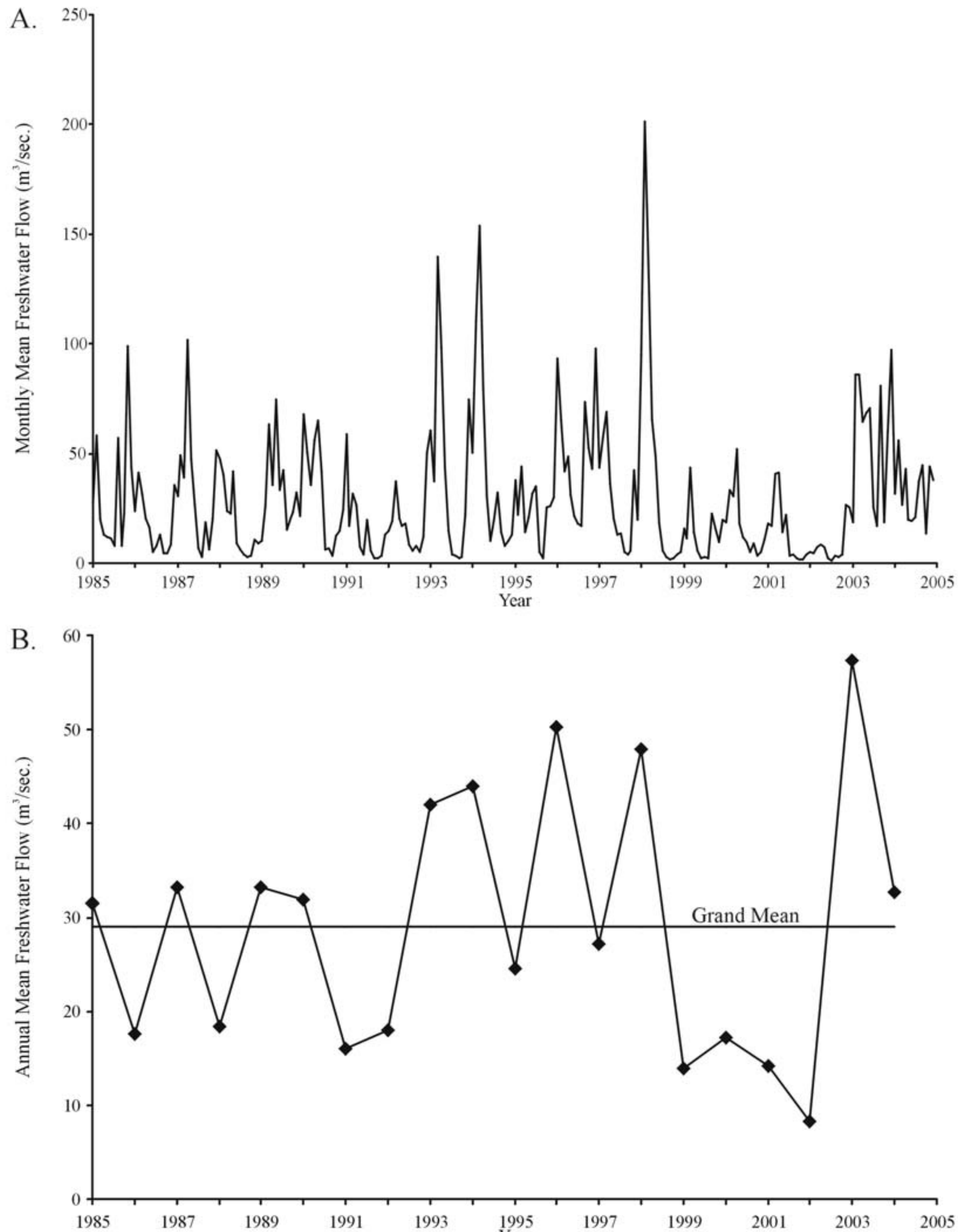


Figure 3-3. Plot of: A. monthly mean, and B. annual mean freshwater flow at the Pamunkey River fall-line for the period of 1985 through 2004.

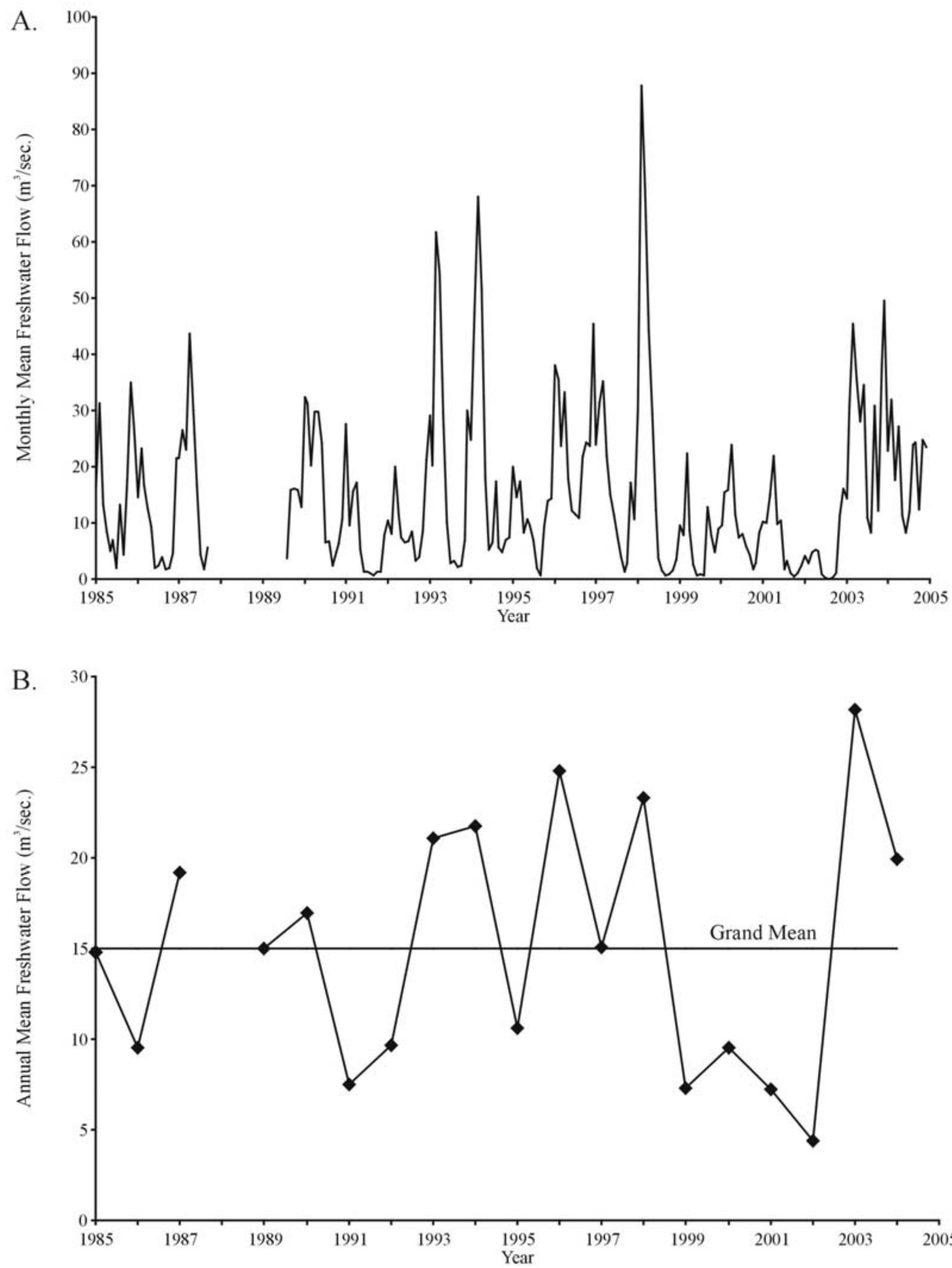
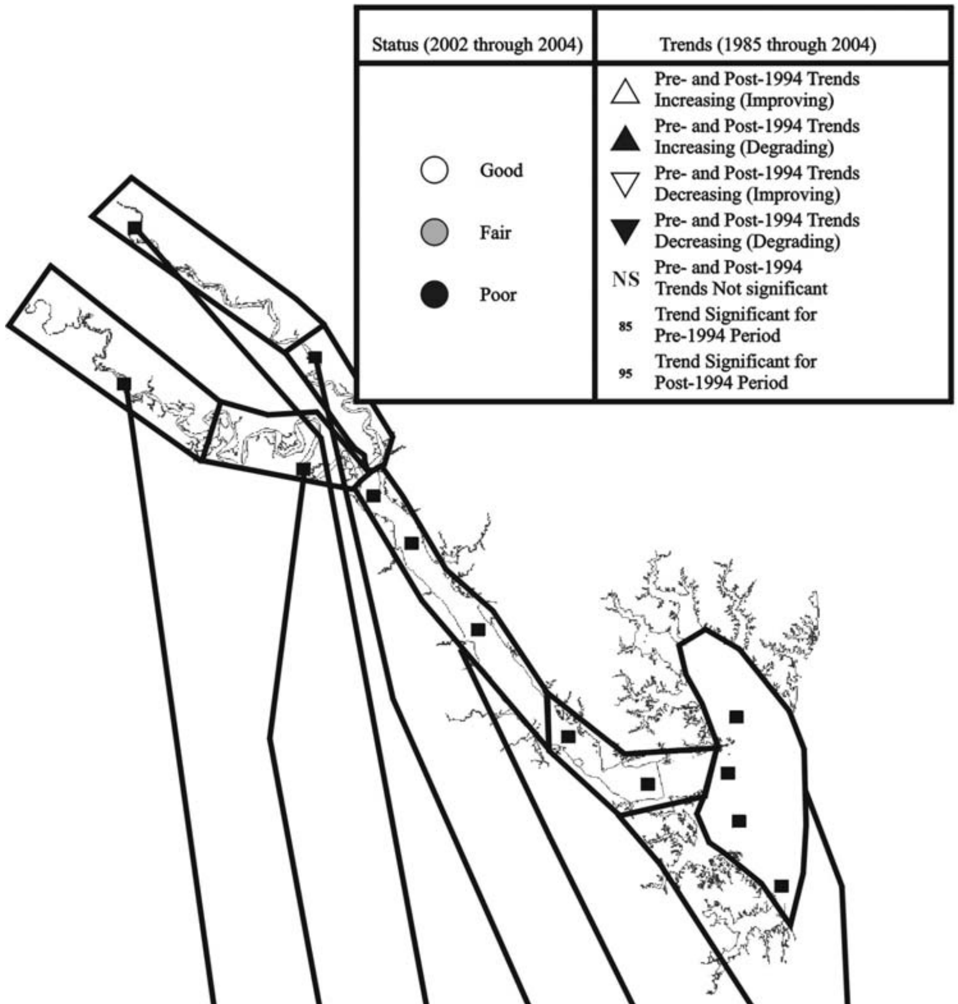
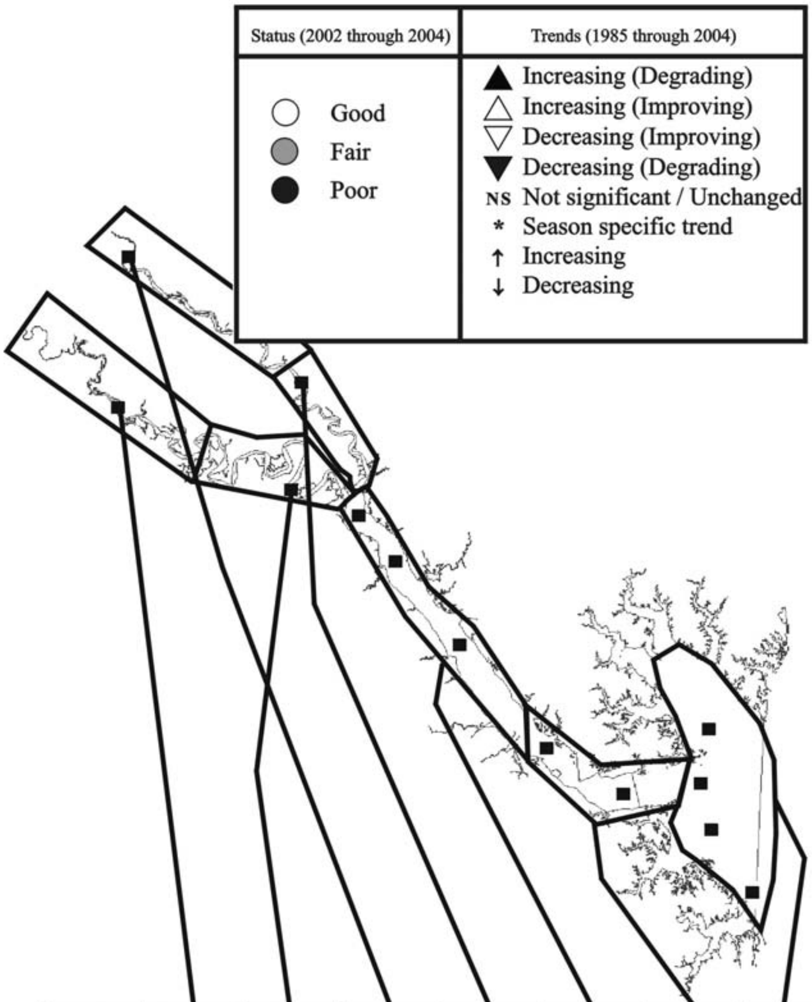


Figure 3-4. Plot of: A. monthly mean, and B. annual mean freshwater flow at the Mattaponi River fall-line for the period of 1985 through 2004.



Parameter	Upper Pamunkey	Lower Pamunkey	Upper Mattaponi	Lower Mattaponi	Middle York	Lower York	Mobjack Bay
STN	○ ▲95	○ ▲	○ ▲95	○ ▲	○ ▲	○ ▲	○ ▽
BTN	○ ▲95	◐ ▲	○ ▲95	○ NS	● ▲	● ▲	○ ▽
SDIN	○ ▲95	○ NS	○ ▲95	○ ▲	◐ NS	○ NS	○ NS
BDIN	○ NS	○ NS	○ ▲95	○ ▲	◐ NS	◐ NS	○ NS
STP	○ ▲	◐ ▲85	○ ▲	◐ ▲	● ▲85	◐ ▲85	○ NS
BTP	○ ▲	● NS	○ NS	◐ ▲	● ▲	● ▲85	○ NS
SDIP	○ ▽	◐ NS	○ ▽95	◐ NS	● ▲	◐ NS	○ NS
BDIP	○ ▽	◐ NS	○ ▽95	◐ NS	● ▲	◐ NS	○ NS

Figure 3-5. Map of the York River basin showing summaries of the status and trend analyses for each segment for the period of 1985 to 2004. Abbreviations for each parameter are: TN=total nitrogen, DIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus. The prefixes S and B refer to surface and bottom measurements, respectively. 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 1994 change result.



Parameter	Upper Pamunkey	Lower Pamunkey	Upper Mattaponi	Lower Mattaponi	Middle York	Lower York	Mobjack Bay
SCHLA	○ ▲	○ NS	○ NS	○ NS	◍ NS	◍ NS	◍ NS
STSS	◍ NS	● NS	○ NS	● NS	● NS	◍ NS	◍ ▽
BTSS	○ NS	● NS	○ NS	● NS	● ▲	● NS	○ ▽
SECCHI	◍ NS	● NS	○ ▼	● NS	● NS	● ▼	● ▼
BDO	○ NS	○ NS	○ NS	◍ NS	○ NS	◍ NS	○ △
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 3-6. Map of the York River basin showing summaries of the status and trend analyses for each segment for the period of 1985 to 2004. Abbreviations for each parameter are: CHLA=chlorophyll a, TSS=total suspended solids, SECCHI=secchi depth, DO=dissolved oxygen, WTEMP=water temperature, SALIN=salinity. The prefixes S and B refer to surface and bottom measurements, respectively.

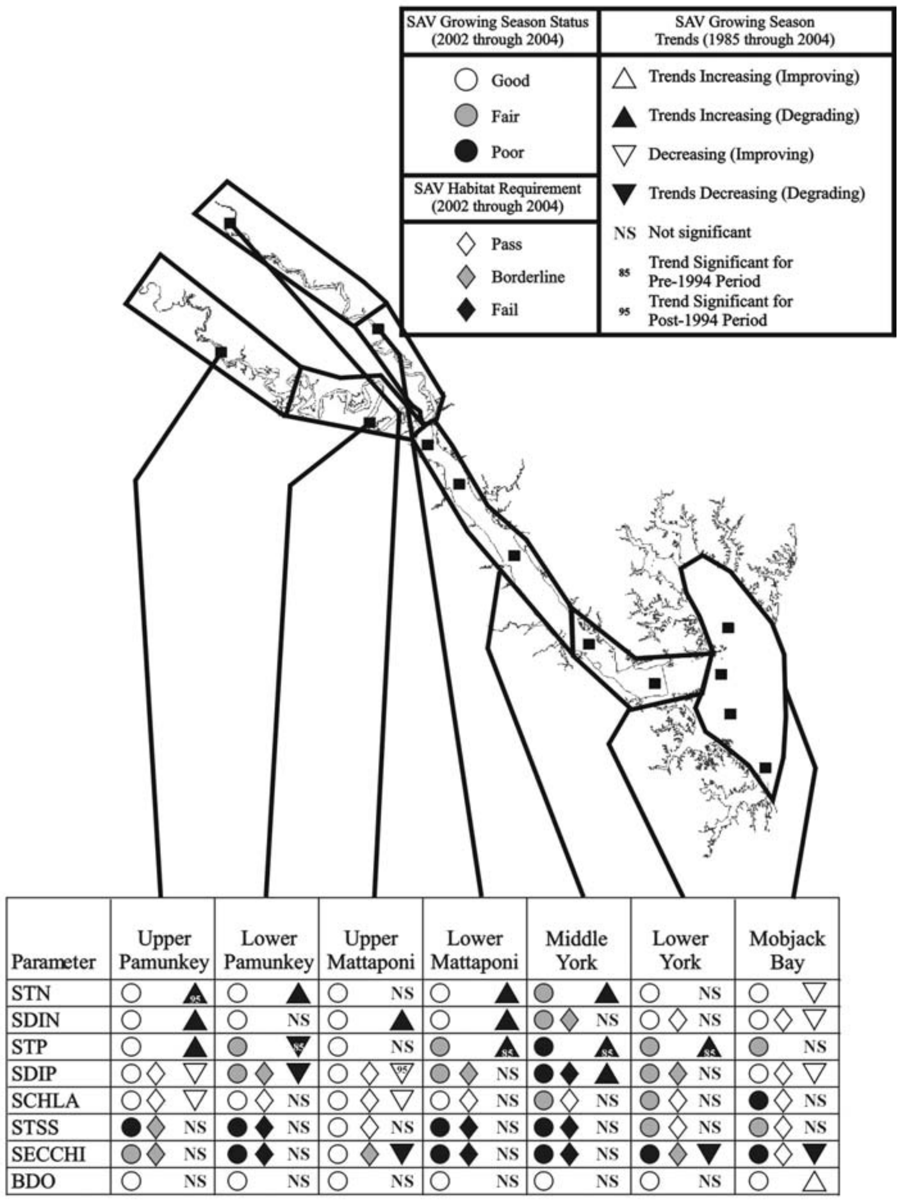


Figure 3-7. Map of the York River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2004 for the SAV growing season. Abbreviations for each parameter are: TN=total nitrogen, SDIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus, CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=Secchi depth, DO=dissolved oxygen. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post 1994 change result.

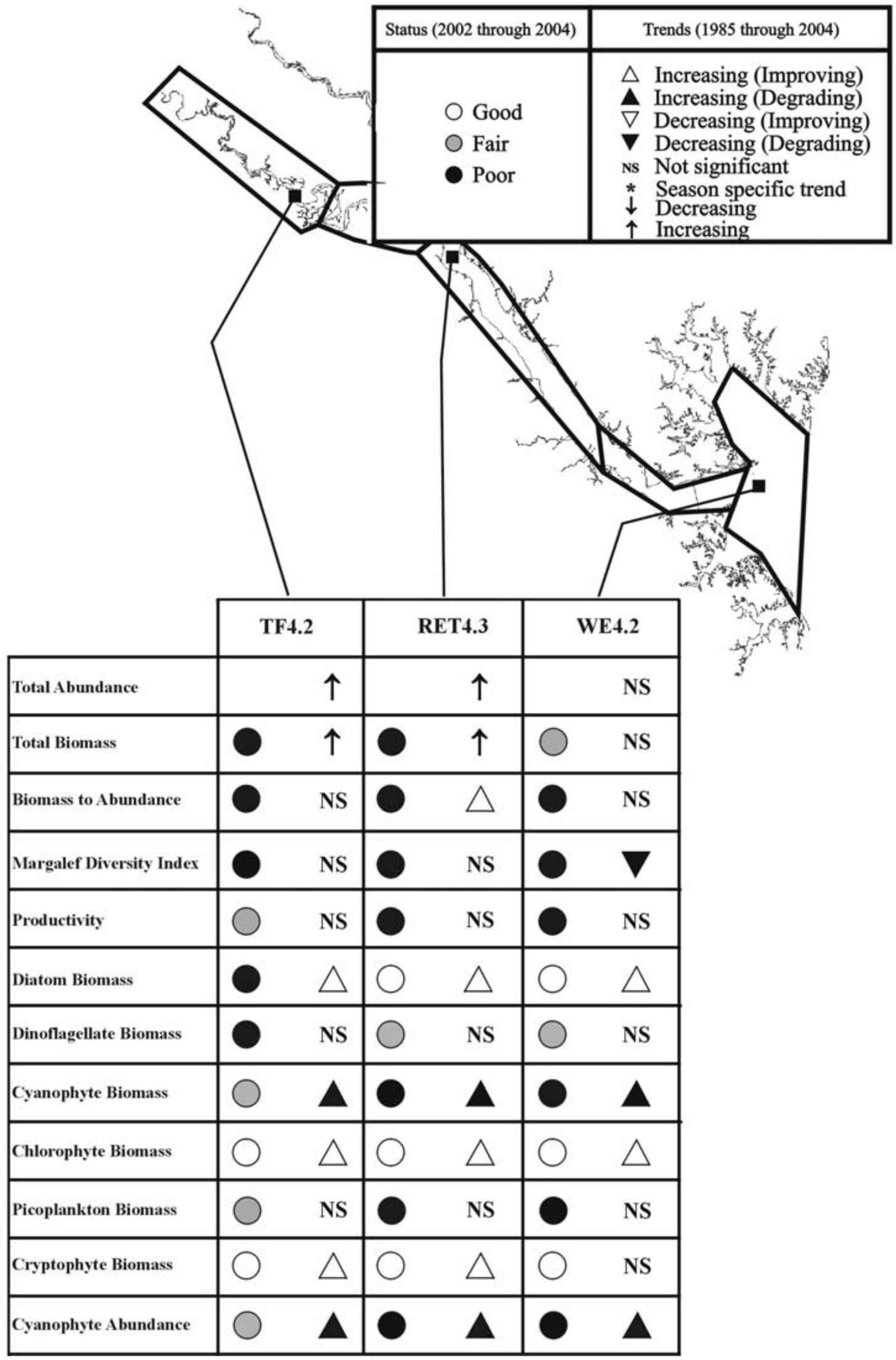
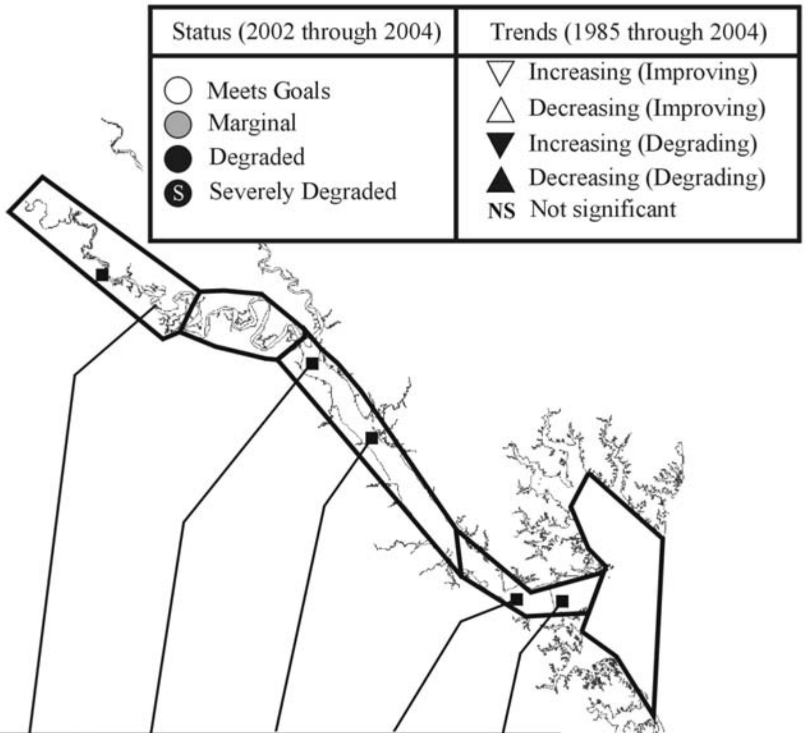


Figure 3-8. Map of the York River basin showing summaries of the status and trend analyses for phytoplankton bioindicators for each segment for the period of 1985 to 2004.



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

Figure 3-9. Map of the York River basin showing summaries of the status and trend analyses for benthic bioindicators for each segment for the period of 1985 to 2004.

Tables

Table 3-1. Land use and population patterns in the York River watershed in comparison to A. Watersheds of the Virginia portion of Chesapeake Bay, and within B. Sub-watersheds of the York River. Land use values are expressed as the total area in km2 within each watershed or sub-watershed and in parentheses as percentages of the total area within the watershed or sub-watershed. Note that Impervious Surfaces are a portion of the Developed land use type. Riparian buffers are measured in km of shoreline with a 30 m riparian buffer. Population values are provided as both total number per watershed or sub-watershed and densities expressed in the number of individuals per km^2. All land use and population data presented were provided by and/or modified from data available from the USEPA's Chesapeake Bay Program Watershed Profiles website: http://www.chesapeakebay.net/wspv31/.

A. Watersheds of the Virginia portion of Chesapeake Bay

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

B. Sub-watersheds of the James River

	Land Use Area in km^2 (percent of total)									
Sub-watershed	Total Area	Developed	Agriculture	Forested	Open Water	Wetland	Barren	Impervious Surfaces	Riparian Buffers (%)	Pop. Number/ Density(#/km^2)
Above Fall-Line Pamunkey	2748	31(1.1)	645(23.5)	1870(68.0)	67(2.5)	75(2.7)	62(2.3)	5(0.4)	1720(65)	55111(20)
Upper Pamunkey	785	21(2.6)	243(31.0)	425(54.1)	13(1.7)	67(8.6)	13(1.7)	3(0.8)	686(74)	33911(43)
Lower Pamunkey	282	3(0.9)	44(15.6)	150(53.2)	31(11.0)	49(17.4)	5(1.8)	1(0.5)	189(38)	3696(13)
Above Fall-Line Mattaponi	1023	16(1.5)	199(19.5)	717(70.1)	10(1.0)	52(5.1)	23(2.3)	5(1.3)	816(81)	32564(32)
Upper Mattaponi	805	3(0.3)	179(22.2)	541(67.2)	10(1.3)	54(6.8)	16(1.9)	1(0.3)	774(87)	8430(10)
Lower Mattaponi	534	5(1.0)	111(20.9)	350(65.5)	23(4.4)	47(8.7)	3(0.5)	1(0.4)	482(67)	7577(14)
Upper Tidal York	523	10(2.0)	80(15.3)	293(55.9)	91(17.3)	47(8.9)	3(0.5)	2(1.0)	376(53)	23676(45)
Lower Tidal York	215	10(4.8)	26(12.0)	78(36.1)	85(39.8)	13(6.0)	0(0)	2(2.2)	91(31)	21072(98)
Mobjack Bay	671	10(1.5)	88(13.1)	272(40.5)	205(30.5)	93(13.9)	5(0.8)	2(0.7)	270(27)	24929(37)

Table 3-2. Nutrient and Sediment A. Non-point Source and B. Point Source and C Total Loadings for Virginia tributaries for 2004, modified from data provided by the Virginia Department of Environmental Quality. Phosphorous and nitrogen loads are in kg/yr and sediment loads are metric tonnes per year (t/yr). Percent changes compare 2004 data to 1985 data. Non-point source loads are results based on the Year 2005 Progress Run of the Chesapeake Bay Watershed Model and calculated reductions for calendar year 2005 Best Management Practices (BMPs) as monitored by the Department of Conservation and Recreation and are expressed as delivered loads. Point source loadings are expressed as delivered loads. Number of major point sources for each watershed are provided in parentheses to the right of the watershed name.

A. Non-point Source

Tributary	2004 Phosphorus Load (kg/yr)	% Change in Phosphorus	2004 Nitrogen Load (kg/yr)	% Change in Nitrogen	2004 Sediment Load (t/yr)	% Change in Sediment
James	1,752,035	-0.15	9,676,183	-0.09	1,014,036	-0.12
York	268,239	-0.19	2,841,566	-0.18	112,347	-0.21
Rappahannock	383,145	-0.22	3,155,383	-0.25	290,692	-0.23
Potomac	696,186	-0.17	6,661,144	-0.05	623,163	-0.17
Coastal	86,828	-0.15	871,116	-0.12	19,722	-0.08
Totals	3,187,342	-0.17	23,206,301	-0.12	2,061,532	-0.16

B. Point Source

Tributary	2004 Phosphorus Load (kg/yr)	% Change in Phosphorus	2004 Nitrogen Load (kg/yr)	% Change in Nitrogen
James (37)	769,391	-0.61	7,426,636	-0.31
York (10)	71,424	-0.63	604,317	0.01
Rappahannock (18)	27,862	-0.67	231,831	0.02
Potomac (39)	120,817	-0.51	2,186,824	-0.46
Coastal Bays (5)	3,040	-0.84	87,379	-0.34
Totals	989,494	-0.6	10,449,608	-0.33

C. Total Loads

Tributary	2004 Phosphorus Load (kg/yr)	2004 Nitrogen Load (kg/yr)	2004 Sediment Load (t/yr)
James	2,521,426	17,102,819	1,014,036
York	339,663	3,445,883	112,347
Rappahannock	411,007	3,387,214	290,692
Potomac	817,003	8,847,968	623,163
Coastal Bays	89,868	958,495	19,722
Totals	4,176,836	33,655,909	2,061,532

Table 3-3. Trends in flow adjusted concentrations (FAC) of water quality parameters at the York 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 2004.

Station Name	Parameter	Beta-T	p-value	% Change	Direction
Pamunkey River near Hanover	TN	0.1514	0.0024	16.3	Degrading
Pamunkey River near Hanover	DNO23	0.3726	<0.0001	45.1	Degrading
Pamunkey River near Hanover	TP	0.6395	<0.0001	89.6	Degrading
Pamunkey River near Hanover	DIP	0.8521	<0.0001	134.5	Degrading
Pamunkey River near Hanover	TSS	0.4925	0.0004	63.6	Degrading
Mattaponi River near Beulahville	TN	-0.0879	0.0349	-8.4	Improving
Mattaponi River near Beulahville	DNO23	-0.1192	0.1816	-11.2	No trend
Mattaponi River near Beulahville	TP	-0.1441	0.03	-13.4	Improving
Mattaponi River near Beulahville	DIP	0.1193	0.1817	12.7	No trend
Mattaponi River near Beulahville	TSS	0.1434	0.2149	15.4	No trend
North Anna River near Doswell	TN	0.1724	0.0175	18.8	Degrading
North Anna River near Doswell	TP	-1.5842	<0.0001	-79.5	Improving
North Anna River near Doswell	TSS	0.8673	0.0033	138.1	Degrading

Table 3-4. Annual and Summer (DO only) season water quality status in the Pamunkey River, Mattaponi River and York River for the period of 2002 through 2004 (presented are median values with Secchi depth in meters, chlorophyll *a* in µg/l, and all other parameters in mg/l).

Segment	Parameter	Season	Surface Median	Surface Score	Surface Status	Bottom Median	Bottom Score	Bottom Status
PMKTF	TN	Annual	0.87	14.48	Good	0.87	11.96	Good
PMKTF	DIN	Annual	0.45	22.78	Good	0.43	20.13	Good
PMKTF	STP	Annual	0.08	29.31	Good	0.07	21.93	Good
PMKTF	PO4F	Annual	0.02	30.73	Good	0.01	34.24	Good
PMKTF	CHLA	Annual	1.98	9.13	Good	-	-	-
PMKTF	TSS	Annual	18.00	56.40	Fair	19.00	25.09	Good
PMKTF	SECCHI	Annual	0.50	36.37	Fair	-	-	-
PMKTF	DO	Summer1	-	-	-	5.30	-	Good
PMKOH	TN	Annual	0.80	20.67	Good	1.00	37.55	Fair
PMKOH	DIN	Annual	0.27	23.04	Good	0.24	26.38	Good
PMKOH	STP	Annual	0.09	54.99	Fair	0.15	70.98	Poor
PMKOH	PO4F	Annual	0.02	60.02	Fair	0.02	54.96	Fair
PMKOH	CHLA	Annual	5.80	20.56	Good	-	-	-
PMKOH	TSS	Annual	36.00	90.26	Poor	89.00	92.69	Poor
PMKOH	SECCHI	Annual	0.40	10.60	Poor	-	-	-
PMKOH	DO	Summer1	-	-	-	4.57	-	Fair
MPNTF	TN	Annual	0.69	8.85	Good	0.68	6.29	Good
MPNTF	DIN	Annual	0.31	15.18	Good	0.31	14.15	Good
MPNTF	STP	Annual	0.06	20.16	Good	0.06	16.89	Good
MPNTF	PO4F	Annual	0.01	25.18	Good	0.01	29.39	Good
MPNTF	CHLA	Annual	1.28	5.79	Good	-	-	-
MPNTF	TSS	Annual	9.00	20.01	Good	11.00	8.41	Good
MPNTF	SECCHI	Annual	0.70	69.36	Good	-	-	-
MPNTF	DO	Summer1	-	-	-	5.74	-	Good
MPNOH	TN	Annual	0.76	18.14	Good	0.86	18.94	Good
MPNOH	DIN	Annual	0.24	25.25	Good	0.22	20.79	Good
MPNOH	STP	Annual	0.10	48.94	Fair	0.11	58.55	Fair
MPNOH	PO4F	Annual	0.02	52.26	Fair	0.02	44.64	Fair
MPNOH	CHLA	Annual	3.25	11.16	Good	-	-	-
MPNOH	TSS	Annual	37.00	92.41	Poor	52.50	86.12	Poor
MPNOH	SECCHI	Annual	0.40	12.26	Poor	-	-	-
MPNOH	DO	Summer1	-	-	-	4.69	-	Fair
YRKMH	TN	Annual	0.72	33.40	Good	0.87	69.52	Poor
YRKMH	DIN	Annual	0.21	45.00	Fair	0.21	41.70	Fair
YRKMH	STP	Annual	0.07	66.68	Poor	0.13	95.00	Poor
YRKMH	PO4F	Annual	0.02	74.06	Poor	0.02	64.83	Poor
YRKMH	CHLA	Annual	13.11	51.50	Fair	-	-	-
YRKMH	TSS	Annual	25.50	90.26	Poor	81.00	97.43	Poor
YRKMH	SECCHI	Annual	0.60	7.31	Poor	-	-	-
YRKMH	DO	Summer1	-	-	-	4.41	-	Fair
YRKPH	TN	Annual	0.52	22.79	Good	0.59	68.56	Poor
YRKPH	DIN	Annual	0.10	30.95	Good	0.10	57.25	Fair
YRKPH	STP	Annual	0.05	46.17	Fair	0.07	74.62	Poor
YRKPH	PO4F	Annual	0.01	59.25	Fair	0.01	49.39	Fair
YRKPH	CHLA	Annual	9.27	42.78	Fair	-	-	-
YRKPH	TSS	Annual	9.00	50.48	Fair	26.50	76.37	Poor
YRKPH	SECCHI	Annual	1.05	32.30	Poor	-	-	-
YRKPH	DO	Summer1	-	-	-	3.81	-	Fair
MOBPH	TN	Annual	0.45	17.03	Good	0.46	27.53	Good
MOBPH	DIN	Annual	0.02	19.55	Good	0.03	15.47	Good
MOBPH	STP	Annual	0.03	29.57	Good	0.03	26.09	Good
MOBPH	PO4F	Annual	0.00	23.50	Good	0.00	20.37	Good
MOBPH	CHLA	Annual	10.01	60.55	Fair	-	-	-
MOBPH	TSS	Annual	10.03	50.33	Fair	11.75	32.99	Good
MOBPH	SECCHI	Annual	1.10	25.33	Poor	-	-	-
MOBPH	DO	Summer1	-	-	-	6.13	-	Good

Table 3-5. Annual and Summer (DO only) season trends in nutrient parameters in the Pamunkey River, Mattaponi River, and York River for the period of 1985 through 2004.

A) Seasonal Kendall

Segment	Season	Parameter	% BDL	P value	Slope	Baseline	% Change	Direction
MOBPH	Annual	STN	0.00	0.0000	-0.005	0.482	-19.80	Improving
MOBPH	Annual	BTN	0.00	0.0000	-0.007	0.521	-25.13	Improving
MOBPH	Annual	SDIN	96.34	0.0000	-0.001	0.044	-	High BDLs
MOBPH	Annual	BDIN	92.01	0.0000	-0.001	0.062	-	High BDLs
MOBPH	Annual	STP	18.36	0.5227	0.000	0.028	-	No trend
MOBPH	Annual	BTP	12.99	0.0643	0.000	0.034	-9.34	No trend
MOBPH	Annual	SPO4F	86.75	0.0000	0.000	0.010	-	High BDLs
MOBPH	Annual	BPO4F	79.38	0.0000	0.000	0.010	-	High BDLs

B) Blocked Seasonal Kendall

Segment	Parameter	'93 Trend P value	'93 Slope	'93 Trend Direction	'04 Trend P value	'04 Slope	'04 Trend Direction	Trend Comparison P value	Trend Comparison	Combined Trend P value	Combined Trend Direction
PMKTF	STN	0.9500	0.000	No Trend	0.0000	0.033	Degrading	0.0000	Different	0.0000	-
PMKTF	BTN	0.4911	-0.005	No Trend	0.0000	0.023	Degrading	0.0004	Different	0.0119	-
PMKTF	SDIN	0.7301	-0.003	No Trend	0.0000	0.020	Degrading	0.0002	Different	0.0010	-
PMKTF	BDIN	0.8440	-0.002	No Trend	0.0039	0.017	Degrading	0.0204	Same	0.0439	No Trend
PMKTF	STP	0.0005	0.003	Degrading	0.0015	0.002	Degrading	0.9483	Same	0.0000	Degrading
PMKTF	BTP	0.0000	0.004	Degrading	0.0787	0.002	No Trend	0.0691	Same	0.0000	Degrading
PMKTF	SPO4F	0.0042	0.000	High BDLs	0.0001	-0.001	Improving	0.1570	Same	0.0000	Improving
PMKTF	BPO4F	0.0041	0.000	High BDLs	0.0000	-0.001	Improving	0.1284	Same	0.0000	Improving
PMKOH	STN	0.0012	0.028	Degrading	0.2370	0.006	No Trend	0.1575	Same	0.0018	Degrading
PMKOH	BTN	0.0005	0.050	Degrading	0.0774	0.021	No Trend	0.2924	Same	0.0002	Degrading
PMKOH	SDIN	0.5354	-0.001	No Trend	0.0185	0.009	No Trend	0.0310	Same	0.2082	No Trend
PMKOH	BDIN	0.8888	0.000	No Trend	0.0063	0.010	Degrading	0.0500	Same	0.0287	No Trend
PMKOH	STP	0.0005	0.006	Degrading	0.2417	-0.001	No Trend	0.0010	Different	0.1092	-
PMKOH	BTP	0.0003	0.018	Degrading	0.9264	0.000	No Trend	0.0166	Same	0.0114	No Trend
PMKOH	SPO4F	0.0116	0.000	No Trend	0.5836	0.000	No Trend	0.0405	Same	0.2291	No Trend
PMKOH	BPO4F	0.1884	0.000	No Trend	0.7737	0.000	No Trend	0.2936	Same	0.5527	No Trend
MPNTF	STN	0.8507	0.001	No Trend	0.0002	0.020	Degrading	0.0099	Different	0.0040	-
MPNTF	BTN	0.0156	-0.013	No Trend	0.0002	0.017	Degrading	0.0000	Different	0.2877	-
MPNTF	SDIN	0.5936	0.002	No Trend	0.0000	0.015	Degrading	0.0007	Different	0.0000	-
MPNTF	BDIN	0.7114	0.001	No Trend	0.0000	0.012	Degrading	0.0033	Different	0.0005	-
MPNTF	STP	0.0002	0.002	Degrading	0.4363	0.001	No Trend	0.0556	Same	0.0021	Degrading
MPNTF	BTP	0.0211	0.001	No Trend	0.4057	0.001	No Trend	0.3382	Same	0.0286	No Trend
MPNTF	SPO4F	1.0000	0.000	High BDLs	0.0000	-0.002	Improving	0.0000	Different	0.0000	-
MPNTF	BPO4F	0.0287	0.000	High BDLs	0.0000	-0.002	Improving	0.0076	Different	0.0000	-
MPNOH	STN	0.0000	0.025	Degrading	0.0110	0.017	No Trend	0.2141	Same	0.0000	Degrading
MPNOH	BTN	0.0211	0.022	No Trend	0.7699	-0.004	No Trend	0.0672	Same	0.1591	No Trend
MPNOH	SDIN	0.3547	0.002	No Trend	0.0006	0.012	Degrading	0.0685	Same	0.0017	Degrading
MPNOH	BDIN	0.3570	0.002	No Trend	0.0021	0.011	Degrading	0.0924	Same	0.0033	Degrading
MPNOH	STP	0.0000	0.006	Degrading	0.4482	0.002	No Trend	0.0121	Same	0.0003	Degrading
MPNOH	BTP	0.0012	0.006	Degrading	0.4737	0.001	No Trend	0.0968	Same	0.0065	Degrading
MPNOH	SPO4F	0.0603	0.000	High BDLs	0.4378	0.000	No Trend	0.0706	Same	0.5467	No Trend
MPNOH	BPO4F	0.0943	0.000	High BDLs	0.2364	0.000	No Trend	0.0458	Same	0.8723	No Trend
YRKMH	STN	0.0122	0.020	No Trend	0.0011	0.012	Degrading	0.4659	Same	0.0000	Degrading
YRKMH	BTN	0.0010	0.027	Degrading	0.0345	0.016	No Trend	0.6152	Same	0.0002	Degrading
YRKMH	SDIN	0.3716	-0.002	No Trend	0.0256	0.009	No Trend	0.0233	Same	0.3122	No Trend
YRKMH	BDIN	0.5417	-0.001	No Trend	0.0160	0.010	No Trend	0.0237	Same	0.1525	No Trend
YRKMH	STP	0.0000	0.005	Degrading	0.6867	0.000	No Trend	0.0000	Different	0.0002	-
YRKMH	BTP	0.0000	0.008	Degrading	0.1205	0.003	No Trend	0.0531	Same	0.0000	Degrading
YRKMH	SPO4F	0.0000	0.001	Degrading	0.1339	0.000	No Trend	0.1335	Same	0.0001	Degrading
YRKMH	BPO4F	0.0000	0.001	Degrading	0.0045	0.001	Degrading	0.7390	Same	0.0000	Degrading

Table 3-5. Continued.

Segment	Parameter	‘93 Trend P value	‘93 Slope	‘93 Trend Direction	‘04 Trend P value	‘04 Slope	‘04 Trend Direction	Trend Comparison P value	Trend Comparison	Combined Trend P value	Combined Trend Direction
YRKPH	STN	0.0035	0.018	Degrading	0.0044	0.008	Degrading	0.7670	Same	0.0000	Degrading
YRKPH	BTN	0.0000	0.033	Degrading	0.0916	0.007	No Trend	0.1867	Same	0.0001	Degrading
YRKPH	SDIN	0.1261	-0.001	No Trend	0.1365	0.002	No Trend	0.0316	Same	0.9060	No Trend
YRKPH	BDIN	0.5912	0.000	No Trend	0.2949	0.001	No Trend	0.6163	Same	0.2362	No Trend
YRKPH	STP	0.0000	0.003	Degrading	0.4056	0.000	No Trend	0.0023	Different	0.0000	-
YRKPH	BTP	0.0000	0.004	Degrading	0.7342	0.000	No Trend	0.0003	Different	0.0000	-
YRKPH	SPO4F	0.0037	0.000	High BDLs	0.3733	0.000	No Trend	0.3115	Same	0.0142	No Trend
YRKPH	BPO4F	0.0104	0.000	No Trend	0.4538	0.000	No Trend	0.3763	Same	0.0349	No Trend

Table 3-6. Annual season trends in non-nutrient parameters in the Pamunkey River, Mattaponi River, and York River for the period of 1985 through 2004.

Segment	Season	Parameter	% BDLs	P value	Slope	Baseline	% Change	Direction
PMKTF	Annual	SCHLA	33.33	0.0000	-0.033	3.100	-	Improving
PMKTF	Annual	STSS	1.70	0.1509	0.182	14.000	22.08	No trend
PMKTF	Annual	BTSS	0.87	0.0263	-0.357	20.500	-29.62	No trend
PMKTF	Annual	SECCHI	0.00	0.0146	0.000	0.700	0.00	No trend
PMKTF	Annual	BDO	0.00	0.3081	0.011	6.825	3.35	No trend
PMKTF	Summer1	BDO	0.00	0.1705	0.017	5.350	6.53	No trend
PMKTF	Annual	SSALIN	0.00	0.0000	0.000	0.010	0.00	No trend
PMKTF	Annual	BSALIN	0.00	0.0000	0.000	0.010	0.00	No trend
PMKTF	Annual	BWTEMP	0.00	0.1135	0.041	19.100	4.30	No trend
PMKTF	Annual	SWTEMP	0.00	0.1048	0.040	18.000	4.44	No trend
PMKOH	Annual	SCHLA	14.95	0.4923	0.000	6.383	0.00	No trend
PMKOH	Annual	STSS	0.38	0.0604	-0.538	48.000	-22.44	No trend
PMKOH	Annual	BTSS	0.44	0.0657	-2.000	102.000	-33.33	No trend
PMKOH	Annual	SECCHI	0.00	0.0049	0.000	0.300	0.00	No trend
PMKOH	Annual	BDO	0.00	0.9427	0.000	6.200	0.00	No trend
PMKOH	Summer1	BDO	0.00	1.0000	0.000	4.775	0.00	No trend
PMKOH	Annual	SSALIN	0.00	0.1213	0.023	3.490	12.89	No trend
PMKOH	Annual	BSALIN	0.00	0.1887	0.030	4.310	13.92	No trend
PMKOH	Annual	BWTEMP	0.00	0.9279	0.000	20.525	0.00	No trend
PMKOH	Annual	SWTEMP	0.00	0.8635	-0.003	20.550	-0.32	No trend
MPNTF	Annual	SCHLA	38.81	0.0000	0.000	3.100	-	No trend
MPNTF	Annual	STSS	11.34	0.0535	0.100	6.375	26.67	No trend
MPNTF	Annual	BTSS	6.87	0.4709	0.000	8.250	0.00	No trend
MPNTF	Annual	SECCHI	0.00	0.0000	-0.017	1.000	-33.33	Degrading
MPNTF	Annual	BDO	0.00	0.6008	0.005	6.975	1.37	No trend
MPNTF	Summer1	BDO	0.00	0.4888	0.008	5.850	2.63	No trend
MPNTF	Annual	SSALIN	0.00	0.0005	0.000	0.010	0.00	No trend
MPNTF	Annual	BSALIN	0.00	0.0005	0.000	0.010	0.00	No trend
MPNTF	Annual	BWTEMP	0.00	0.0310	0.064	18.575	6.87	No trend
MPNTF	Annual	SWTEMP	0.00	0.0091	0.080	17.500	9.14	Increasing
MPNOH	Annual	SCHLA	21.40	0.9334	0.000	4.245	-	No trend
MPNOH	Annual	STSS	0.75	0.5482	0.125	26.000	9.62	No trend
MPNOH	Annual	BTSS	0.44	0.8232	0.125	44.000	5.68	No trend
MPNOH	Annual	SECCHI	0.00	0.4608	0.000	0.475	0.00	No trend
MPNOH	Annual	BDO	0.00	0.4134	0.007	6.075	2.47	No trend
MPNOH	Summer1	BDO	0.00	0.4412	0.009	4.975	3.80	No trend
MPNOH	Annual	SSALIN	0.00	0.0173	0.080	3.380	47.34	No trend
MPNOH	Annual	BSALIN	0.00	0.0333	0.086	4.310	40.02	No trend
MPNOH	Annual	BWTEMP	0.00	0.2275	0.022	20.325	2.19	No trend
MPNOH	Annual	SWTEMP	0.00	0.1256	0.025	20.500	2.44	No trend

Table 3-6. Continued.

Segment	Season	Parameter	% BDLs	P value	Slope	Baseline	% Change	Direction
YRKMH	Annual	SCHLA	5.78	0.0866	0.117	9.590	24.43	No trend
YRKMH	Annual	STSS	0.00	0.1211	-0.267	27.000	-16.83	No trend
YRKMH	Annual	BTSS	0.43	0.0054	1.525	39.000	66.47	Degrading
YRKMH	Annual	SECCHI	0.00	0.1672	0.000	0.600	0.00	No trend
YRKMH	Annual	BDO	0.00	0.5459	-0.006	6.300	-1.76	No trend
YRKMH	Summer1	BDO	0.00	0.8135	0.001	5.175	0.35	No trend
YRKMH	Annual	SSALIN	0.00	0.7985	-0.010	12.430	-1.61	No trend
YRKMH	Annual	BSALIN	0.00	0.6304	-0.022	13.580	-3.27	No trend
YRKMH	Annual	BWTEMP	0.00	0.7325	0.006	19.900	0.63	No trend
YRKMH	Annual	SWTEMP	0.00	0.8299	-0.008	20.050	-0.75	No trend
YRKPH	Annual	SCHLA	7.89	0.0156	0.086	7.998	21.62	No trend
YRKPH	Annual	STSS	7.62	0.4898	0.050	6.000	16.67	No trend
YRKPH	Annual	BTSS	2.15	0.0100	0.500	17.750	47.89	No trend
YRKPH	Annual	SECCHI	0.00	0.0031	-0.010	1.200	-16.67	Degrading
YRKPH	Annual	BDO	0.00	0.0888	-0.025	6.875	-7.27	No trend
YRKPH	Summer1	BDO	0.00	0.3999	-0.025	4.750	-10.53	No trend
YRKPH	Annual	SSALIN	0.00	0.0292	-0.075	20.645	-7.27	No trend
YRKPH	Annual	BSALIN	0.00	0.7845	-0.009	22.055	-0.78	No trend
YRKPH	Annual	BWTEMP	0.00	0.4723	-0.018	18.725	-1.92	No trend
YRKPH	Annual	SWTEMP	0.00	0.3638	-0.017	19.025	-1.81	No trend
MOBPH	Annual	SCHLA	12.14	0.0844	0.073	5.620	26.14	No trend
MOBPH	Annual	STSS	3.12	0.0003	-0.215	9.900	-43.43	Improving
MOBPH	Annual	BTSS	1.52	0.0007	-0.250	15.000	-33.33	Improving
MOBPH	Annual	SECCHI	0.00	0.0000	-0.017	1.450	-22.99	Degrading
MOBPH	Summer1	BDO	0.00	0.0002	0.056	5.950	18.88	Improving
MOBPH	Annual	BDO	0.00	0.0000	0.062	7.675	16.07	Improving
MOBPH	Annual	SSALIN	0.00	0.0041	-0.093	22.215	-8.33	Decreasing
MOBPH	Annual	BSALIN	0.00	0.0006	-0.098	22.885	-8.55	Decreasing
MOBPH	Annual	BWTEMP	0.00	0.2564	0.019	17.625	2.17	No trend
MOBPH	Annual	SWTEMP	0.00	0.4399	0.017	18.450	1.81	No trend

Table 3-7. SAV season water quality status in the Pamunkey River, Mattaponi River and York River for the period of 2002 through 2004 (presented are median values with Secchi depth in meters, chlorophyll *a* in µg/l, and all other parameters in mg/l).

Segment	Parameter	Season	Layer	Median	Score	Status	Habitat Requirement
PMKTF	STN	SAV1	S	0.866	15.80	Good	-
PMKTF	SDIN	SAV1	S	0.442	20.92	Good	-
PMKTF	STP	SAV1	S	0.064	25.10	Good	-
PMKTF	SPO4F	SAV1	S	0.016	32.33	Good	Pass
PMKTF	SCHLA	SAV1	S	1.550	7.84	Good	Pass
PMKTF	STSS	SAV1	S	19.000	62.21	Poor	Borderline
PMKTF	SECCHI	SAV1	S	0.500	40.36	Fair	Borderline
PMKOH	STN	SAV1	S	0.813	18.47	Good	-
PMKOH	SDIN	SAV1	S	0.224	18.46	Good	-
PMKOH	STP	SAV1	S	0.113	59.63	Fair	-
PMKOH	SPO4F	SAV1	S	0.020	60.49	Fair	Borderline
PMKOH	SCHLA	SAV1	S	5.260	19.40	Good	Pass
PMKOH	STSS	SAV1	S	41.000	90.46	Poor	Fail
PMKOH	SECCHI	SAV1	S	0.325	16.68	Poor	Fail
MPNTF	STN	SAV1	S	0.668	9.24	Good	-
MPNTF	SDIN	SAV1	S	0.294	13.72	Good	-
MPNTF	STP	SAV1	S	0.050	18.71	Good	-
MPNTF	SPO4F	SAV1	S	0.008	27.00	Good	Pass
MPNTF	SCHLA	SAV1	S	1.195	6.01	Good	Pass
MPNTF	STSS	SAV1	S	7.500	14.74	Good	Pass
MPNTF	SECCHI	SAV1	S	0.800	78.56	Good	Borderline
MPNOH	STN	SAV1	S	0.742	14.56	Good	-
MPNOH	SDIN	SAV1	S	0.216	16.14	Good	-
MPNOH	STP	SAV1	S	0.097	52.22	Fair	-
MPNOH	SPO4F	SAV1	S	0.017	53.49	Fair	Borderline
MPNOH	SCHLA	SAV1	S	3.670	17.25	Good	Pass
MPNOH	STSS	SAV1	S	42.000	94.79	Poor	Fail
MPNOH	SECCHI	SAV1	S	0.400	16.23	Poor	Fail
YRKMH	STN	SAV1	S	0.750	38.95	Fair	-
YRKMH	SDIN	SAV1	S	0.221	38.76	Fair	Borderline
YRKMH	STP	SAV1	S	0.079	82.81	Poor	-
YRKMH	SPO4F	SAV1	S	0.023	86.50	Poor	Fail
YRKMH	SCHLA	SAV1	S	10.668	50.22	Fair	Pass
YRKMH	STSS	SAV1	S	34.250	95.20	Poor	Fail
YRKMH	SECCHI	SAV1	S	0.575	5.87	Poor	Fail
YRKPH	STN	SAV2	S	0.545	24.08	Good	-
YRKPH	SDIN	SAV2	S	0.099	34.87	Good	Pass
YRKPH	STP	SAV2	S	0.053	48.79	Fair	-
YRKPH	SPO4F	SAV2	S	0.015	65.27	Fair	Borderline
YRKPH	SCHLA	SAV2	S	10.715	50.71	Fair	Pass
YRKPH	STSS	SAV2	S	10.500	50.05	Fair	Pass
YRKPH	SECCHI	SAV2	S	0.900	19.27	Poor	Borderline
MOBPH	STN	SAV2	S	0.489	30.03	Good	-
MOBPH	SDIN	SAV2	S	0.020	21.34	Good	Pass
MOBPH	STP	SAV2	S	0.033	36.39	Fair	-
MOBPH	SPO4F	SAV2	S	0.001	23.28	Good	Pass
MOBPH	SCHLA	SAV2	S	10.235	66.44	Poor	Pass
MOBPH	STSS	SAV2	S	11.040	57.74	Fair	Pass
MOBPH	SECCHI	SAV2	S	1.000	20.45	Poor	Pass

Table 3-8. SAV growing season trends in nutrient parameters in the Pamunkey River, Mattaponi River, and York River for the period of 1985 through 2004.

A) Seasonal Kendall

Segment	Season	Layer	Parameter	% BDL	P value	Slope	Baseline	% Change	Direction
MOBPH	SAV2	S	STN	0.00	0.0000	-0.006	0.517	-24.51	Improving
MOBPH	SAV2	B	BTN	0.00	0.0000	-0.007	0.542	-26.94	Improving
MOBPH	SAV2	S	SDIN	96.39	0.0045	-0.002	0.103	-29.45	Improving
MOBPH	SAV2	B	BDIN	89.72	0.0081	-0.001	0.113	-26.38	Improving
MOBPH	SAV2	S	STP	8.48	0.0867	0.000	0.033	-10.26	No trend
MOBPH	SAV2	B	BTP	4.73	0.1302	0.000	0.035	-10.18	No trend
MOBPH	SAV2	S	SPO4F	86.21	0.0001	0.000	0.011	-29.30	Improving
MOBPH	SAV2	B	BPO4F	75.30	0.0004	0.000	0.011	-25.56	Improving

B) Blocked Seasonal Kendall

Segment	Season	Parameter	'93 Trend P value	'93 Slope	'93 Trend Direction	'04 Trend P value	'04 Slope	'04 Trend Direction	Trend Comparison P value	Trend Comparison	Combined Trend P value	Combined Trend Direction
PMKTF	SAV1	STN	0.7822	0.0017	No Trend	0.0000	0.0361	Degrading	0.0021	Different	0.0004	-
PMKTF	SAV1	BTN	0.8128	0.0025	No Trend	0.0028	0.0220	Degrading	0.0608	Same	0.0230	No Trend
PMKTF	SAV1	SDIN	0.3432	0.0043	No Trend	0.0003	0.0203	Degrading	0.0408	Same	0.0007	Degrading
PMKTF	SAV1	BDIN	0.3636	0.0053	No Trend	0.0356	0.0173	No Trend	0.3840	Same	0.0295	No Trend
PMKTF	SAV1	STP	0.0132	0.0025	No Trend	0.0175	0.0018	No Trend	0.9779	Same	0.0005	Degrading
PMKTF	SAV1	BTP	0.0003	0.0046	Degrading	0.6947	0.0006	No Trend	0.0204	Same	0.0040	Degrading
PMKTF	SAV1	SPO4F	0.0041	0.0000	High BDLs	0.0012	-0.0010	Improving	0.5194	Same	0.0000	Improving
PMKTF	SAV1	BPO4F	0.0753	0.0000	No Trend	0.0005	-0.0010	Improving	0.1541	Same	0.0001	Improving
PMKOH	SAV1	STN	0.0001	0.0350	Degrading	0.5174	0.0030	No Trend	0.0268	Same	0.0016	Degrading
PMKOH	SAV1	BTN	0.0026	0.0441	Degrading	0.1685	0.0215	No Trend	0.2865	Same	0.0020	Degrading
PMKOH	SAV1	SDIN	0.3295	0.0050	No Trend	0.0138	0.0106	No Trend	0.2933	Same	0.0135	No Trend
PMKOH	SAV1	BDIN	0.3415	0.0050	No Trend	0.0046	0.0120	Degrading	0.1550	Same	0.0058	Degrading
PMKOH	SAV1	STP	0.0023	0.0063	Degrading	0.2951	-0.0014	No Trend	0.0039	Different	0.1737	-
PMKOH	SAV1	BTP	0.0014	0.0185	Degrading	0.9696	-0.0004	No Trend	0.0248	Same	0.0286	No Trend
PMKOH	SAV1	SPO4F	0.0002	0.0017	Degrading	0.8055	0.0001	No Trend	0.0214	Same	0.0075	Degrading
PMKOH	SAV1	BPO4F	0.0403	0.0003	No Trend	0.8053	0.0000	No Trend	0.2612	Same	0.1318	No Trend
MPNTF	SAV1	STN	0.8123	-0.0016	No Trend	0.0438	0.0186	No Trend	0.1074	Same	0.2246	No Trend
MPNTF	SAV1	BTN	0.0110	-0.0185	No Trend	0.0197	0.0132	No Trend	0.0005	Different	0.8167	-
MPNTF	SAV1	SDIN	0.0966	0.0050	No Trend	0.0004	0.0136	Degrading	0.1437	Same	0.0002	Degrading
MPNTF	SAV1	BDIN	0.2934	0.0027	No Trend	0.0056	0.0100	Degrading	0.1969	Same	0.0056	Degrading
MPNTF	SAV1	STP	0.0129	0.0014	No Trend	0.9693	0.0001	No Trend	0.0880	Same	0.0781	No Trend
MPNTF	SAV1	BTP	0.6206	0.0000	No Trend	0.7837	-0.0004	No Trend	0.5697	Same	0.8646	No Trend
MPNTF	SAV1	SPO4F	0.6734	0.0000	No Trend	0.0000	-0.0022	Improving	0.0002	Different	0.0022	-
MPNTF	SAV1	BPO4F	0.0695	0.0000	No Trend	0.0001	-0.0023	Improving	0.0698	Same	0.0000	Improving
MPNOH	SAV1	STN	0.0000	0.0355	Degrading	0.0948	0.0127	No Trend	0.0108	Same	0.0000	Degrading
MPNOH	SAV1	BTN	0.0292	0.0345	No Trend	0.2789	-0.0090	No Trend	0.0192	Same	0.4125	No Trend
MPNOH	SAV1	SDIN	0.0356	0.0073	No Trend	0.0353	0.0100	No Trend	1.0000	Same	0.0027	Degrading
MPNOH	SAV1	BDIN	0.1485	0.0071	No Trend	0.0361	0.0103	No Trend	0.5947	Same	0.0108	No Trend
MPNOH	SAV1	STP	0.0000	0.0067	Degrading	0.9086	0.0002	No Trend	0.0008	Different	0.0004	-
MPNOH	SAV1	BTP	0.0122	0.0065	No Trend	0.9086	-0.0008	No Trend	0.0666	Same	0.0954	No Trend
MPNOH	SAV1	SPO4F	0.0163	0.0008	No Trend	0.6848	-0.0003	No Trend	0.0538	Same	0.1860	No Trend
MPNOH	SAV1	BPO4F	0.0141	0.0009	No Trend	0.5242	-0.0004	No Trend	0.0330	Same	0.2387	No Trend
YRKMH	SAV1	STN	0.0002	0.0329	Degrading	0.0059	0.0128	Degrading	0.6809	Same	0.0000	Degrading
YRKMH	SAV1	BTN	0.0012	0.0300	Degrading	0.3398	0.0142	No Trend	0.1499	Same	0.0040	Degrading
YRKMH	SAV1	SDIN	0.3622	-0.0017	No Trend	0.0156	0.0118	No Trend	0.0161	Same	0.2765	No Trend
YRKMH	SAV1	BDIN	0.6708	0.0000	No Trend	0.0443	0.0107	No Trend	0.0715	Same	0.2408	No Trend
YRKMH	SAV1	STP	0.0000	0.0063	Degrading	0.7188	-0.0003	No Trend	0.0008	Different	0.0046	-
YRKMH	SAV1	BTP	0.0011	0.0075	Degrading	0.2815	0.0027	No Trend	0.1698	Same	0.0028	Degrading
YRKMH	SAV1	SPO4F	0.0001	0.0013	Degrading	0.2546	0.0003	No Trend	0.1105	Same	0.0007	Degrading
YRKMH	SAV1	BPO4F	0.0005	0.0013	Degrading	0.0077	0.0006	Degrading	0.9564	Same	0.0000	Degrading

Table 3-8. Continued.

Segment	Season	Parameter	'93 Trend P value	'93 Slope	'93 Trend Direction	'04 Trend P value	'04 Slope	'04 Trend Direction	Trend Comparison P value	Trend Comparison	Combined Trend P value	Combined Trend Direction
YRKPH	SAV2	STN	0.0483	0.0137	No Trend	0.1349	0.0062	No Trend	0.8858	Same	0.0147	No Trend
YRKPH	SAV2	BTN	0.0212	0.0176	No Trend	0.1257	0.0073	No Trend	0.7717	Same	0.0076	Degrading
YRKPH	SAV2	SDIN	0.1691	-0.0042	No Trend	0.1726	0.0017	No Trend	0.0497	Same	0.9278	No Trend
YRKPH	SAV2	BDIN	0.7788	0.0000	No Trend	0.2229	0.0024	No Trend	0.2492	Same	0.4601	No Trend
YRKPH	SAV2	STP	0.0000	0.0029	Degrading	0.4672	-0.0002	No Trend	0.0003	Different	0.0118	-
YRKPH	SAV2	BTP	0.0000	0.0033	Degrading	0.7306	-0.0002	No Trend	0.0030	Different	0.0143	-
YRKPH	SAV2	SPO4F	0.7589	0.0000	No Trend	0.8804	0.0000	No Trend	0.9489	Same	0.7485	No Trend
YRKPH	SAV2	BPO4F	0.8539	0.0000	No Trend	1.0000	0.0000	No Trend	0.8981	Same	0.8981	No Trend

Table 3-9. SAV growing season trends in non-nutrient parameters in the Pamunkey River, Mattaponi River, and York River for the period of 1985 through 2004.

Segment	Season	Layer	Parameter	% BDL	P value	Slope	Baseline	% Change	Direction
PMKTF	SAV1	S	SCHLA	45.14	0.0002	-0.092	4.230	-43.42	Improving
PMKTF	SAV1	S	STSS	1.67	0.0339	0.333	12.250	46.26	No trend
PMKTF	SAV1	B	BTSS	1.68	0.1111	-0.333	19.000	-29.82	No trend
PMKTF	SAV1	S	SECCHI	0.00	0.0783	0.000	0.700	0.00	No trend
PMKTF	SAV1	B	BDO	0.00	0.1337	0.017	5.800	5.75	No trend
PMKTF	SAV1	S	SSALINITY	0.00	0.0000	0.000	0.010	0.00	Unchanged
PMKTF	SAV1	B	BSALINITY	0.00	0.0000	0.000	0.010	0.00	Unchanged
PMKTF	SAV1	B	BWTEMP	0.00	0.3380	0.025	22.875	2.19	No trend
PMKTF	SAV1	S	SWTEMP	0.00	0.2106	0.033	22.875	2.86	No trend
PMKOH	SAV1	S	SCHLA	14.29	0.4702	0.051	7.540	13.64	No trend
PMKOH	SAV1	S	STSS	0.00	0.2202	-0.500	45.000	-22.22	No trend
PMKOH	SAV1	B	BTSS	0.00	0.2537	-1.917	148.500	-21.94	No trend
PMKOH	SAV1	S	SECCHI	0.00	0.1392	0.000	0.450	0.00	No trend
PMKOH	SAV1	B	BDO	0.00	0.5824	0.007	5.575	2.47	No trend
PMKOH	SAV1	S	SSALINITY	0.00	0.7135	0.006	5.028	2.31	No trend
PMKOH	SAV1	B	BSALINITY	0.00	0.9501	0.000	5.328	0.00	No trend
PMKOH	SAV1	B	BWTEMP	0.00	0.6554	-0.010	24.450	-0.82	No trend
PMKOH	SAV1	S	SWTEMP	0.00	0.3881	-0.017	24.425	-1.36	No trend
MPNTF	SAV1	S	SCHLA	49.32	0.0000	-0.091	4.588	-39.75	Improving
MPNTF	SAV1	S	STSS	9.76	0.2412	0.060	5.625	18.16	No trend
MPNTF	SAV1	B	BTSS	6.67	0.6175	0.000	8.750	0.00	No trend
MPNTF	SAV1	S	SECCHI	0.00	0.0032	-0.013	1.000	-25.00	Degrading
MPNTF	SAV1	B	BDO	0.00	0.2688	0.010	6.350	3.15	No trend
MPNTF	SAV1	S	SSALINITY	0.00	0.0206	0.000	0.010	0.00	No trend
MPNTF	SAV1	B	BSALINITY	0.00	0.0207	0.000	0.010	0.00	No trend
MPNTF	SAV1	B	BWTEMP	0.00	0.0795	0.067	23.000	5.80	No trend
MPNTF	SAV1	S	SWTEMP	0.00	0.0163	0.093	23.375	7.98	No trend
MPNOH	SAV1	S	SCHLA	24.32	0.7691	0.000	7.415	0.00	No trend
MPNOH	SAV1	S	STSS	0.74	0.0501	0.483	19.000	50.88	No trend
MPNOH	SAV1	B	BTSS	0.86	0.3874	0.611	44.000	27.78	No trend
MPNOH	SAV1	S	SECCHI	0.00	0.2700	0.000	0.525	0.00	No trend
MPNOH	SAV1	B	BDO	0.00	0.1494	0.013	5.325	4.69	No trend
MPNOH	SAV1	S	SSALINITY	0.00	0.3445	0.030	4.273	13.93	No trend
MPNOH	SAV1	B	BSALINITY	0.00	0.3487	0.032	5.023	12.61	No trend
MPNOH	SAV1	B	BWTEMP	0.00	0.6543	0.011	24.375	0.91	No trend
MPNOH	SAV1	S	SWTEMP	0.00	0.3026	0.020	24.500	1.67	No trend

Table 3-9. Continued.

Segment	Season	Layer	Parameter	% BDL	P value	Slope	Baseline	% Change	Direction
YRKMH	SAV1	S	SCHLA	5.41	0.2665	0.095	9.590	19.81	No trend
YRKMH	SAV1	S	STSS	0.00	0.1365	-0.300	32.750	-15.57	No trend
YRKMH	SAV1	B	BTSS	0.42	0.1126	1.367	44.500	52.21	No trend
YRKMH	SAV1	S	SECCHI	0.00	0.3184	0.000	0.500	0.00	No trend
YRKMH	SAV1	B	BDO	0.00	0.9798	0.000	5.525	0.00	No trend
YRKMH	SAV1	S	SSALINITY	0.00	0.1185	-0.087	13.605	-12.86	No trend
YRKMH	SAV1	B	BSALINITY	0.00	0.0580	-0.081	15.308	-10.62	No trend
YRKMH	SAV1	B	BWTEMP	0.00	0.8915	-0.005	24.400	-0.37	No trend
YRKMH	SAV1	S	SWTEMP	0.00	0.5114	-0.021	24.275	-1.77	No trend
YRKPH	SAV2	S	SCHLA	6.70	0.0849	0.056	6.783	16.51	No trend
YRKPH	SAV2	S	STSS	5.75	0.7575	0.013	9.188	2.72	No trend
YRKPH	SAV2	B	BTSS	1.02	0.9879	0.000	9.688	0.00	No trend
YRKPH	SAV2	S	SECCHI	0.00	0.0013	-0.015	1.350	-22.51	Degrading
YRKPH	SAV2	B	BDO	0.00	0.0424	0.025	7.400	6.71	No trend
YRKPH	SAV2	S	SSALINITY	0.00	0.0581	-0.073	19.925	-7.33	No trend
YRKPH	SAV2	B	BSALINITY	0.00	0.4662	-0.024	20.585	-2.35	No trend
YRKPH	SAV2	B	BWTEMP	0.00	0.0170	-0.053	17.300	-6.17	No trend
YRKPH	SAV2	S	SWTEMP	0.00	0.0153	-0.057	17.425	-6.59	No trend
MOBPH	SAV2	S	SCHLA	8.44	0.1344	0.047	4.530	20.55	No trend
MOBPH	SAV2	S	STSS	2.18	0.0713	-0.159	9.650	-32.90	No trend
MOBPH	SAV2	B	BTSS	1.31	0.3603	-0.083	11.250	-14.74	No trend
MOBPH	SAV2	S	SECCHI	0.00	0.0002	-0.018	1.500	-23.81	Degrading
MOBPH	SAV2	B	BDO	0.00	0.0000	0.046	7.675	12.06	Improving
MOBPH	SAV2	S	SSALINITY	0.00	0.0329	-0.094	20.085	-9.36	No trend
MOBPH	SAV2	B	BSALINITY	0.00	0.0388	-0.085	20.085	-8.47	No trend
MOBPH	SAV2	B	BWTEMP	0.00	0.7404	-0.011	17.000	-1.24	No trend
MOBPH	SAV2	S	SWTEMP	0.00	0.9577	0.000	17.600	-0.04	No trend

Table 3-10. Annual season status in phytoplankton bioindicators in the Pamunkey River and York River for the period of 2002 through 2004.

Station	Season	Parameter	Above Pycnocline Median	Above Pycnocline Score	Above Pycnocline Score
TF4.2	Annual	Total Biomass	3.50E+08	25.15	Poor
TF4.2	Annual	Biomass to Abundance Ratio	44.09	23.69	Poor
TF4.2	Annual	Margalef Diversity Index	1.45	10.92	Poor
TF4.2	Annual	Diatom Biomass	1.63E+08	35.63	Poor
TF4.2	Annual	Dinoflagellate Biomass	7.97E+04	72.69	Poor
TF4.2	Annual	Cyanobacteria Biomass	3.95E+06	50.17	Fair
TF4.2	Annual	Chlorophyte Biomass	4.67E+07	64.57	Good
TF4.2	Annual	Primary Productivity	22.80	42.90	Fair
TF4.2	Annual	Cryphtophyte Biomass	1.81E+07	90.55	Good
TF4.2	Annual	Cyanobacteria Abundance	5.32E+05	45.49	Fair
RET4.3	Annual	Total Biomass	5.25E+08	27.16	Poor
RET4.3	Annual	Biomass to Abundance Ratio	37.45	14.09	Poor
RET4.3	Annual	Margalef Diversity Index	1.63	40.64	Poor
RET4.3	Annual	Diatom Biomass	4.09E+08	57.99	Good
RET4.3	Annual	Dinoflagellate Biomass	2.27E+07	56.38	Fair
RET4.3	Annual	Cyanobacteria Biomass	1.03E+07	60.52	Poor
RET4.3	Annual	Chlorophyte Biomass	1.61E+07	89.08	Good
RET4.3	Annual	Primary Productivity	63.59	64.69	Poor
RET4.3	Annual	Cryphtophyte Biomass	2.52E+07	98.75	Good
RET4.3	Annual	Cyanobacteria Abundance	8.05E+05	62.03	Poor
WE4.2	Annual	Biomass to Abundance Ratio	54.78	17.15	Poor
WE4.2	Annual	Margalef Diversity Index	2.00	14.60	Poor
WE4.2	Annual	Diatom Biomass	3.41E+08	60.31	Good
WE4.2	Annual	Dinoflagellate Biomass	5.45E+07	52.71	Fair
WE4.2	Annual	Cyanobacteria Biomass	1.74E+06	79.75	Poor
WE4.2	Annual	Chlorophyte Biomass	5.79E+04	74.79	Good
WE4.2	Annual	Primary Productivity	64.70	85.41	Poor
WE4.2	Annual	Cryphtophyte Biomass	2.18E+07	69.45	Good
WE4.2	Annual	Cyanobacteria Abundance	2.70E+05	82.43	Poor

Table 3-11. Annual season trends in phytoplankton bioindicators in the Pamunkey River and York River for the period of 1985 through 2004. "N.E." in the Percent Change column indicates "No Estimate" was made for the percent change due to a zero value for the parameter baseline.

Station	Season	Layer	Parameter	P value	Slope	Baseline	Percent Change	Direction	Homogeneity test P value
TF4.2	Annual	AP	Total Abundance	0.0000	1.77E+05	3.32E+06	95.95	Increasing	0.8285
TF4.2	Annual	AP	Total Biomass	0.0000	8.05E+06	1.00E+08	144.78	Increasing	0.8037
TF4.2	Annual	AP	Biomass to Abundance Ratio	0.2151	0.493	32.22	27.53	No Trend	0.9487
TF4.2	Annual	AP	Margalef Diversity Index	0.2244	-0.010	1.85	-9.30	No Trend	0.3267
TF4.2	Annual	AP	Diatom Biomass	0.0067	3.34E+06	8.67E+07	69.47	Improving	0.9356
TF4.2	Annual	AP	Dinoflagellate Biomass	0.9696	0	1.55E+05	0.00	No Trend	0.1125
TF4.2	Annual	AP	Cyanobacteria Biomass	0.0000	1.52E+05	3.65E+05	748.33	Degrading	0.0276
TF4.2	Annual	AP	Chlorophyte Biomass	0.0000	5.76E+05	8.71E+05	1190.51	Improving	0.8132
TF4.2	Annual	AP	Primary Productivity	0.6874	-0.05	10.29	-0.83	-8.10	0.3866
TF4.2	Annual	AP	Cryptophyte Biomass	0.0000	8.46E+05	8.55E+06	178.08	Increasing	0.9613
TF4.2	Annual	AP	Cyanobacteria Abundance	0.0000	2.60E+04	5.84E+04	800.61	Degrading	0.0239
RET4.3	Annual	AP	Total Abundance	0.0000	3.60E+05	7.86E+06	87.17	Increasing	0.8056
RET4.3	Annual	AP	Total Biomass	0.0000	1.61E+07	3.30E+08	93.02	Increasing	0.9462
RET4.3	Annual	AP	Biomass to Abundance Ratio	0.0077	0.554	31.87	33.03	Improving	0.8504
RET4.3	Annual	AP	Margalef Diversity Index	0.4600	-0.004	1.61	-5.26	No Trend	0.0652
RET4.3	Annual	AP	Diatom Biomass	0.0000	1.12E+07	1.85E+08	114.86	Improving	0.5583
RET4.3	Annual	AP	Dinoflagellate Biomass	0.4200	1.26E+05	1.99E+07	11.97	No Trend	0.5668
RET4.3	Annual	AP	Cyanobacteria Biomass	0.0000	3.27E+05	9.01E+05	688.46	Degrading	0.6587
RET4.3	Annual	AP	Chlorophyte Biomass	0.0000	6.30E+05	1.40E+03	852879.12	Improving	0.7615
RET4.3	Annual	AP	Primary Productivity	0.9260	0.01	34.81	0.22	0.64	0.8215
RET4.3	Annual	AP	Cryptophyte Biomass	0.0001	1.20E+06	1.93E+07	118.30	Increasing	0.3023
RET4.3	Annual	AP	Cyanobacteria Abundance	0.0000	4.76E+04	1.94E+05	465.08	Degrading	0.8648
WE4.2	Annual	AP	Total Abundance	0.0629	7.21E+04	6.09E+06	23.67	No Trend	0.7988
WE4.2	Annual	AP	Total Biomass	0.0238	6.95E+06	3.59E+08	38.72	No Trend	0.3864
WE4.2	Annual	AP	Biomass to Abundance Ratio	0.4840	0.214	45.34	9.43	No Trend	0.5364
WE4.2	Annual	AP	Margalef Diversity Index	0.0065	-0.023	2.61	-17.72	Degrading	0.5223
WE4.2	Annual	AP	Diatom Biomass	0.0003	7.73E+06	1.83E+08	84.31	Improving	0.3325
WE4.2	Annual	AP	Dinoflagellate Biomass	0.1010	8.51E+05	5.18E+07	32.85	No Trend	0.6918
WE4.2	Annual	AP	Cyanobacteria Biomass	0.0000	4.83E+04	0	n.e.	Degrading	0.6345
WE4.2	Annual	AP	Chlorophyte Biomass	0.0002	2.28E+03	7.14E+04	63.88	Improving	0.8455
WE4.2	Annual	AP	Primary Productivity	0.8500	-0.09	50.54	-1.40	-2.77	0.2640
WE4.2	Annual	AP	Cryptophyte Biomass	0.2937	-1.69E+05	2.33E+07	-14.50	No Trend	0.3212
WE4.2	Annual	AP	Cyanobacteria Abundance	0.0000	6.68E+03	1.54E+03	8699.51	Degrading	0.6796

Table 3-12. Annual status in benthic community condition based on the B-IBI in the Pamunkey River and York River for the period of 2002 through 2004.

Station	Score	Status
TF4.2	2.0	Severely degraded
RET4.3	3.2	Meets Goals
LE4.1	2.5	Degraded
LE4.3	3.6	Meets Goals
LE4.3B	3.3	Meets Goals

Table 3-13. Annual season term trends in the benthic IBI and its component metrics in the Pamunkey River and York River for the period of 1985 through 2004.

Station	Parameter	P value	Slope	Baseline	% Change	Direction
TF4.2	Benthic Index of Biotic Integrity	0.6547	-0.02	3.00	-12.96	No Trend
TF4.2	Total Abundance per square meter	0.0899	83.29	410.22	406.08	Improving
TF4.2	Total Biomass per square meter	0.5606	0.01	0.15	103.57	No Trend
TF4.2	Shannon-Weiner Diversity Index	0.0322	0.04	0.96	75.44	Improving
TF4.2	Pollution Sensitive Species Abundance	0.2277	0.55	12.50	88.19	No Trend
TF4.2	Pollution Indicative Species Abundance	0.0438	0.69	4.17	329.24	Degrading
TF4.2	Pollution Sensitive Species Biomass	0.8934	-0.14	19.44	-14.40	No Trend
TF4.2	Pollution Indicative Species Biomass	0.0314	1.26	11.11	227.37	Degrading
RET4.3	Benthic Index of Biotic Integrity	0.1951	-0.03	3.70	-17.12	No Trend
RET4.3	Total Abundance per square meter	0.0742	151.28	1030.32	293.67	Improving
RET4.3	Total Biomass per square meter	0.4213	-0.25	4.43	-114.12	No Trend
RET4.3	Shannon-Weiner Diversity Index	0.1081	-0.04	2.74	-27.28	No Trend
RET4.3	Pollution Sensitive Species Abundance	0.2841	-0.97	40.89	-47.54	No Trend
RET4.3	Pollution Indicative Species Abundance	0.5922	-0.12	12.91	-18.69	No Trend
RET4.3	Pollution Sensitive Species Biomass	0.8583	0.05	83.08	1.13	No Trend
RET4.3	Pollution Indicative Species Biomass	0.8583	0.03	3.23	15.94	No Trend
LE4.1	Benthic Index of Biotic Integrity	0.0598	-0.05	3.10	-34.95	Degrading
LE4.1	Total Abundance per square meter	0.5919	-16.76	1535.94	-21.82	No Trend
LE4.1	Total Biomass per square meter	0.1291	-0.97	27.51	-70.55	No Trend
LE4.1	Shannon-Weiner Diversity Index	0.0322	-0.02	2.54	-19.30	Degrading
LE4.1	Pollution Sensitive Species Abundance	0.7889	-0.30	37.56	-15.74	No Trend
LE4.1	Pollution Indicative Species Abundance	0.3481	0.55	23.71	46.47	No Trend
LE4.1	Pollution Sensitive Species Biomass	0.0124	-3.16	82.49	-76.55	Degrading
LE4.1	Pollution Indicative Species Biomass	0.0670	0.93	8.28	224.31	Degrading
LE4.3	Benthic Index of Biotic Integrity	0.1824	0.02	2.95	11.30	No Trend
LE4.3	Total Abundance per square meter	0.9672	-2.12	3138.66	-1.35	No Trend
LE4.3	Total Biomass per square meter	0.9020	0.15	6.32	48.34	No Trend
LE4.3	Shannon-Weiner Diversity Index	0.2675	0.03	2.47	25.78	No Trend
LE4.3	Pollution Sensitive Species Abundance	0.7738	-0.11	56.44	-4.05	No Trend
LE4.3	Pollution Indicative Species Abundance	0.5379	-0.24	15.73	-29.92	No Trend
LE4.3	Pollution Sensitive Species Biomass	0.9020	0.11	72.97	2.96	No Trend
LE4.3	Pollution Indicative Species Biomass	0.9672	0.01	4.14	5.62	No Trend
LE4.3B	Benthic Index of Biotic Integrity	0.0500	0.10	2.62	64.14	Improving
LE4.3B	Total Abundance per square meter	0.4459	52.87	2766.60	32.49	No Trend
LE4.3B	Total Biomass per square meter	0.8276	0.02	3.28	9.88	No Trend
LE4.3B	Shannon-Weiner Diversity Index	0.1274	0.07	2.44	49.13	No Trend
LE4.3B	Pollution Sensitive Species Abundance	0.1274	1.33	18.36	123.34	No Trend
LE4.3B	Pollution Indicative Species Abundance	0.0385	-2.09	41.44	-85.59	Improving
LE4.3B	Pollution Sensitive Species Biomass	0.6631	0.31	54.16	9.73	No Trend
LE4.3B	Pollution Indicative Species Biomass	0.5861	-0.40	14.87	-45.42	No Trend

Table 3-14. Bootstrap and Wilcoxon rank sum test results for the York River segments and sub-segments for the period 2000-2004. Shown is sample size, proportion of sites in segment below threshold (P), proportion of sites below threshold under the null hypothesis (P_o), difference between P and P_o, lower 95% confidence limit bound for the difference (CL-L), upper 95% confidence limit bound for the difference (CL-U), power and p-values for the Wilcoxon test, impaired segments by the bootstrap method (lower 95% confidence bound for the difference > 0), impaired segments for the Wilcoxon test (reference and segment B-IBI score distributions differ, with lower scores in segment than in reference), mean B-IBI value, number of sites in segment with B-IBI scores equal to or greater than 2.7, number of sites in segment with B-IBI scores equal to or greater than 3.0, percent of sites in segment with B-IBI scores equal to or grater than 2.7, and percent of sites in segment with B-IBI scores equal to or greater than 3.0. $P-P_o$ confidence limits for segments with small sample size (<10) were not calculated.

		Bootstrap Results					Wilcoxon Results		Impaired						
Segment	Sample Size	P	Po	P-Po	CL- L (P-Po)	CL-U (P-Po)	Power	p-value	Bootstrap	Wilcoxon	mean B-IBI	N >=2.7	N >=3.0	% >=2.7	% >=3.0
PMKTFa	4	0.00	0.05	-0.05	-	-	0.94	0.2105	-	-	3.9	4	4	100	100
PMKOHa	11	0.46	0.05	0.41	0.07	0.75	1.00	0.0009	Yes	Yes	2.6	4	4	36	36
MPNTFa	13	0.00	0.05	-0.05	-0.17	0.07	1.00	0.2139	No	No	3.5	10	10	77	77
MPNOHa	11	0.25	0.05	0.20	-0.11	0.52	1.00	0.0212	No	No	2.6	6	6	55	55
YRKMHa	64	0.43	0.05	0.38	0.15	0.61	1.00	<0.0001	Yes	Yes	2.5	31	20	48	31
YRKPHa	29	0.38	0.05	0.33	0.11	0.56	1.00	<0.0001	Yes	Yes	3.0	18	14	62	48
MOBPHa	20	0.36	0.05	0.31	0.06	0.56	1.00	<0.0001	Yes	Yes	3.0	12	11	60	55

Table 3-15. Diagnostic assessment of benthic community degradation for random sites sampled within the York River segments and sub-segments for the period 2000-2004. Presented is the mean B-IBI score in each segment, the total number of samples collected, the mean posterior probability of membership in the Contaminant group (Cont. Post. Prob.), and the total number, percentage of degraded, and percentage of the total samples for the following: (1) samples with posterior probability of contaminant group membership >=0.50, (2) degraded samples with excessive abundance or biomass, and (3) degraded samples with insufficient abundance or biomass. w/o Cont. = Percentage of samples (of degraded or total) not classified in the contaminant group. Segments in bold were classified as impaired by the bootstrap analysis. Additional segments listed are as follows: YRKPHd=Sarah Creek, YRKPHe=Timberneck Creek, MOBPHa=Mobjack Bay, MOBPHe=Severn Creek, MOBPHf=Ware River, MOBPHg=North River, MOBPHh=East River.

				Samples with Contaminant Posterior Prob >=0.50			Degraded Samples with Excessive Abundance/Biomass				Degraded Samples with Insufficient Abundance/Biomass			
SUBSEG	B-IBI	Total Count	Cont. Post. Prob.	Total #	% of Degraded	% of Total	Total #	% of Degraded	% of Degraded w/o Cont.	% of Total w/o Cont.	Total #	% of Degraded	% of Degraded w/o Cont	% of Total w/o Cont
PMKTFa	3.9	4	-	0	-	0.00	0	-	-	0.00	0	-	-	0.00
PMKOHa	2.6	11	0.6200	4	57.14	36.36	3	42.86	0.00	0.00	1	14.29	14.29	9.09
MPNTFa	3.5	13	0.6501	2	66.67	15.38	0	0.00	0.00	0.00	0	0.00	0.00	0.00
MPNOHa	2.6	11	0.8684	4	80.00	36.36	2	40.00	0.00	0.00	2	40.00	0.00	0.00
YRKMHa	2.5	64	0.6433	21	63.64	32.81	17	51.52	9.09	4.69	10	30.30	12.12	6.25
YRKMHb	1.7	1	0.0937	0	0.00	0.00	1	100.00	100.00	100.00	0	0.00	0.00	0.00
YRKPHa	3.0	29	0.4256	5	45.45	17.24	1	9.09	9.09	3.45	4	36.36	27.27	10.34
YRKPHd	1.3	1	0.8476	1	100.00	100.00	0	0.00	0.00	0.00	1	100.00	0.00	0.00
YRKPHe	2.7	1	-	0	-	0.00	0	-	-	0.00	0	-	-	0.00
MOBPHa	3.0	20	0.5545	4	50.00	20.00	1	12.50	12.50	5.00	6	75.00	25.00	10.00
MOBPHe	2.7	1	-	0	-	0.00	0	-	-	0.00	0	-	-	0.00
MOBPHf	1.3	1	0.5064	1	100.00	100.00	0	0.00	0.00	0.00	1	100.00	0.00	0.00
MOBPHg	1.7	1	0.5968	1	100.00	100.00	0	0.00	0.00	0.00	1	100.00	0.00	0.00
MOBPHh	2.7	2	-	0	-	0.00	0	-	-	0.00	0	-	-	0.00