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Ken Moore

Britt Anderson
Virginia Institute of Marine Science

Betty Neikirk
Virginia Institute of Marine Science

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RESTORATION OF SUBMERGED AQUATIC VEGETATION (SAV) IN THE TIDAL FRESHWATER JAMES RIVER: 2002-2003

Kenneth A. Moore, Britt Anderson and Betty Neikirk

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The Virginia Institute of Marine Science,
College of William and Mary
Gloucester Point, Virginia 23062

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EXECUTIVE SUMMARY

In 2002 wild celery (*Vallisneria americana*) was transplanted into four sites in the Hopewell region of the tidal James River. The SAV transplants were sampled by the Virginia Institute of Marine Science (VIMS) for survivorship and growth at bi-weekly to monthly intervals throughout the growing season. Concurrently, water quality sampling was conducted at bi-weekly intervals throughout the year for water column nutrients, chlorophyll a, suspended solids, water transparency and other chemical and physical constituents important for SAV growth. Objectives of the study were to: 1) expand the SAV transplanted plots within the study sites previously transplanted in 1999, 2000 and 2001; 2) conduct water quality sampling and periphyton monitoring at all sites in 2002; 3) evaluate the success of the different SAV species for restoration in this region; 4) evaluate the relationships between SAV transplant performance and water quality.

Wild celery originally transplanted at 1999 re-grew again in the spring of 2002 in the herbivory exclosures established at the Turkey Island transplant site. Approximately three growing seasons were necessary for the original bare-rooted transplants, planted at one-foot centers, to achieve 100% bottom cover. At the three other transplant sites wild celery transplants planted in the spring of 2001 also re-grew in 2002. Periphyton growth on the transplants was similar among all the sites and did not increase throughout the growing season. The periphyton consisted principally of inorganic sediment, by weight, with only 20-30% consisting of organic matter.

Transplants of wild celery planted in June 2002 became established after approximately 20-40% initial losses. These initial losses were similar to previous years' transplanting efforts. Water quality conditions in the late summer of 2002 were dominated by the highest salinities measured since 1999. These high salinities resulted in a dieback of all transplants at the three downriver transplant sites (Westover, Powell's Creek and Tar Bay) where salinities reached 5 psu or more during August and September of 2002. At the most upriver site (Turkey Island) the salinity intrusion was less pronounced (<1psu) and all transplanted beds survived and re-grew again in 2003. An interaction of high turbidity and high salinity resulted in conditions that were detrimental to wild celery transplants. Suspended sediment and turbidity levels in 2002 were comparable to 2001 even though freshwater inputs were greatly reduced. This suggests that turbidity in this region during the SAV growing season may not be directly related to freshwater inputs at that time and other factors including the re-working of existing sediments may be very important.

Bi-weekly fixed station water quality monitoring at all stations demonstrated decreasing chlorophyll concentrations throughout 2002 and into 2003. Water column nutrient levels were very low during the late summer of 2002 when river flow was low and increased in the fall and winter of 2002-2003 as river flow increased. Dissolved inorganic phosphorus (DIP), typically limiting for phytoplankton and epiphyte growth in freshwater regions, was generally at or below the SAV habitat requirement threshold of 0.02 mg/l at all times. High water column dissolved ammonium levels observed at all

sites during the 2001 growing season were not observed in 2003 and inorganic phosphorus levels were very low.

Continuous spatial mapping of water quality was undertaken along the axis of the tidal freshwater region of the James River during September 2003 using DATAFLOW technology. Results confirmed that the three stations downriver, where SAV survival was lowest, were subject to elevated salinity levels and high turbidity levels at his time. Phytoplankton levels demonstrated a general peak in abundance in the Hopewell region of the river, although several blooms extending for two miles or more were observed in areas upriver of this region. These bloom areas also corresponded to areas of highest concentrations of surface dissolved oxygen. The distribution of turbidity also was highest in the Hopewell region with additional peaks in the areas of the phytoplankton blooms. These continuous mapping data suggest that areas both upriver and downriver (using more saltwater tolerant species) may be very suitable for SAV restoration activities from a water clarity perspective.

1.0 INTRODUCTION

1.1 Background

Since 1999 a submerged aquatic vegetation (SAV) restoration and water quality monitoring project, funded by the Hopewell Regional Wastewater Treatment Facility (HRWTF) in partnership with the Chesapeake Bay Foundation (CBF), has been undertaken by the Virginia Institute of Marine Science (VIMS). The project was continued in 2002 and 2003 with the aid of a $5,000 grant from the Chesapeake Bay Restoration Fund. Objectives of this continuing project have been to:

1) Develop, evaluate and refine effective methodologies for the development, growth and transplantation of SAV propagules into the tidal freshwater James River ecosystem.
2) Evaluate if under current conditions, SAV transplants can survive in selected shallow water sites of the Hopewell region of the James River estuary and grow into self-perpetuating grass beds.
3) Determine if the response of the transplants is related to specific water quality conditions at the sites, site characteristics, and/or physical disturbance.

Beginning in 1999, four test sites (Powell's Creek, Tar Bay, Shirley Plantation and Turkey Island) were selected for test transplanting in the Hopewell region of the estuary. The sites chosen were based upon historical photographs showing previous SAV presence and appropriate water depths (Moore et al. 2000). A fifth shallow water site (Westover) was added in 2001 (Moore et al. 2002).

Replicated SAV transplants were undertaken at the various sites during the May-June periods of each of the years (Moore et al. 2000, 2001, 2002). To reduce herbivory of the plantings each of the transplanted plots was enclosed with a fence that extended from the sediment to above the high tide level. VIMS personnel monitored each site for growth and survival at bi-weekly to monthly intervals throughout the growing season, and HRWTF and VIMS personnel conducted biweekly water quality sampling throughout the year. In general, the results of the initial three-years of transplanting SAV in this region were successful. However only wild celery plants, among the six native species of SAV tested, appeared to be able to survive and reproduce from one year to the next. Little growth was observed outside of the exclosures. Water quality conditions did not appear to limit survival at transplanting depths of 0.5 m MLW or less, and periphyton fouling measured using artificial substrates was low. Herbivory appeared to be a major factor limiting initial transplant survival. Additionally, physical disruption by waves and currents at the transplant sites resulted in loss of canopy forming species such as sago pondweed and redhead grass. Reproduction from wild celery over-wintering tubers was evident in the spring of 2000, 2001 and 2002. Therefore establishing resident founder populations of wild celery in this region of the estuary appears very possible if the problems of herbivory can be overcome and water quality conditions remain stable or improve.

1.2 Objectives

The 2002 SAV restoration and water quality monitoring project was a continuation of the previous SAV transplanting studies. The specific objectives of the 2002-2003 study were:

1) Enlarge the SAV plots at the transplant sites to serve as habitat as well as a source of propagules for enhanced recovery of SAV in these areas.

2) Develop an additional site (Westover) in the tidal James River in the vicinity of Hopewell, VA. and work with the Alliance for the Chesapeake Bay (ACB), as well as the CBF to expand other restoration activities in this region of the river.
3) Monitor the transplant sites for water quality and SAV growth and survival as well as periphyton growth on the SAV shoots.
4) Relate the responses of the transplants to water quality conditions monitored at bi-weekly intervals in the shallows during the growing season to evaluate the cause/effect relationships between water quality and SAV habitat recovery.
5) Conduct continuous monitoring of surface water quality along the axis of the James River during one cruise to evaluate the spatial distribution of water quality in the James River tidal fresh segment.
6) Provide a hands-on educational experience in SAV propagation and restoration for Virginia secondary school students to supplement and enhance environmental training for educators as well as to expand the educational opportunities for the students.

2.0 METHODS

2.1 Study Sites

Five shallow water sites (Fig. 2-1) were used for SAV transplanting and/or water quality monitoring in the Hopewell region of the James River estuary in 2002-2003.

Turkey Island	Lat. 37.3826 N	Long. 77.2527 W
Shirley Cove	Lat. 37.3326 N	Long. 77.2631 W
Tar Bay	Lat. 37.3075 N	Long. 77.1902 W
Powell's Creek	Lat. 37.2929 N	Long. 77.1622 W

Westover Plantation Lat. 37.3105 N Long. 77.1558 W

Due to a dredge disposal operation at the Shirley Cove site, no transplants have been placed there in since 1999. However, water quality monitoring was continued in 2002-2003 to assess any long-term water changes at that location. In addition, technical assistance was provided to the Alliance for the Chesapeake Bay for the development of a restoration nursery area at this site in 2002. As a result of the success of CBF transplants at the Westover site and our review of previous water quality monitoring data at this site, SAV were transplanted by VIMS to that site in the spring of 2002 and the transplants were monitored for survival throughout 2002.

2.2 SAV Transplanting and Monitoring

The CBF program "Grasses in Classes" allows students the opportunity to participate in hands-on-restoration of underwater grasses. CBF provides the seed stock as well as all materials to grow wild celery in enclosed systems in the classroom. Training workshops were held by CBF in the spring of 2002, in the Hopewell, Richmond, and Hampton Roads areas of Virginia. Currently, approximately 550 classrooms participate in this program throughout Virginia, Maryland and Pennsylvania. Students maintain the systems for approximately 3 months, at which time the plants are mature enough for transplanting into the James River and elsewhere. Each system provided the project with up to 150 individual plants. Participating students and teachers are invited to assist with actual transplant efforts in the James River in early June. Most of these plants have been planted at the Westover site, located along the Charles City shoreline, under the supervision of CBF. Other wild celery plants obtained from CBF are planted at the other study site locations.

Technical assistance was also provided to other restoration efforts in the region. The Alliance for the Chesapeake Bay organized a SAV restoration workshop in the spring of 2002 in which VIMS and the CBF participated. Subsequently in June 2002 they conducted a pilot SAV restoration effort within a small lagoon near the Shirley Cove site after consultation with VIMS. A herbivory exclosure was constructed in June 2002 by VIMS and CBF at the Harrison Lake National Fish Hatchery in Charles City, Virginia, in collaboration with the U.S. Fish and Wildlife Service. Wild celery propagules were transplanted into one of their unused ponds to provide another source of SAV for restoration in the James River region.

Transplanting activities at all of the James River sites were undertaken in early June, 2002, after the wild celery donor plants had grown sufficiently to withstand transplanting into the tidal freshwater environment. Transplants were surveyed by diver at bi-weekly to monthly intervals throughout the growing season for percent survival and growth of planting units. Observations were also made on the relative condition of the transplants, including any evidence of herbivory. SAV transplant survival within the Harrison Lake Fish Hatchery was monitored only at the end of the 2002 growing season, and the ACB monitored their transplants at the Shirley site.

2.3 SAV Periphyton Monitoring

Previous work using artificial plastic strips to simulate SAV shoots and leaves (Moore et al. 2000) suggested that the fouling rates on SAV at the James River transplant sites should be low. The fouling of periphyton on SAV leaves can reduce the light available for plant photosynthesis and the rates of fouling can be greatest in regions of high nutrient and sediment concentrations. However, there has been little quantification of fouling on actual SAV in tidal freshwater systems such as the James River. Therefore to assess periphyton fouling, whole shoots of wild celery were collected from transplanted beds at the Turkey Island, Tar Bay, Westover and Powell's Creek transplant sites at monthly intervals from May to October 2002 and periphyton levels were determined. Three plants were arbitrarily collected at each site, stored in individual plastic bags, and transported to the laboratory on ice. The individual leaves were then separated from the roots, carefully scraped of all periphyton, and measured for leaf area using a Li-Cor 3100 area meter. The leaves and roots were dried at 60 θC and weighed separately. The removed periphyton material from each plant was placed into a solution with de-ionized water and well mixed. Replicate sub-samples of known volume were filtered through pre-weighed glass fiber filters, dried at 60 θC, weighed for total solids, and then heated at 550 θC for 5 hours and re-weighed for ashed weight. Organic weight was determined by difference.

2.4 Water Quality Monitoring

2.4.1 Fixed Station Monitoring

VIMS personnel conducted water quality sampling at bi-weekly intervals at each of the five James River restoration sites throughout from June 2002 to June 2003. This resulted in a continuous record of water quality conditions from previous monitoring. Water quality measurements included: air and water temperatures, turbidity (secchi depth), pH, conductivity, organic and inorganic nitrogen and phosphorus, chlorophyll, suspended solids, dissolved oxygen, total organic carbon and nitrogen. Samples were obtained at the shallow water transplant sites at water depths of approximate one meter. Water samples were obtained a depth of one-half meter below the surface.

2.4.2 Continuous Monitoring Using DATAFLOW Technology

DATAFLOW is a compact, self-contained surface water quality mapping system, suitable for use in a small boat operating at speeds of about 25 KT. The system collects water through a pipe ("ram") deployed on the transom of the vessel, pumps it through an array of water quality sensors, then discharges the water overboard. The entire system, from intake ram tube to the return hose, is shielded from light to negate any effect high intensity surface light might have on phytoplankton in the flow-through water that is being sampled. A blackened sample chamber is also used to minimize any effect of light on measurements by the fluorescence probe. The system records measurements once every 2-4 seconds. The resulting distance between samples is therefore a function of vessel speed. An average speed of 25 knots results in one observation collected every 40-60 m. Verification samples for DO and chlorophyll are sampled at regular intervals along the cruise track to insure accuracy of the sensor readings.

The DATAFLOW system has a YSI 6600 sonde equipped with a flow-through chamber. The sensors include a Clark-type 6562 DO probe, a 6561 pH probe, a 6560 conductivity/temperature probe, a 6026 turbidity probe, and a 6025 chlorophyll probe. The sonde transmits data collected from the sensors directly to a laptop computer using a data acquisition system created with LabView software (National Instruments, Inc.). Custom software written in the Labview environment provides for data acquisition, display, control, and storage. Real-time graphs and indicators provide feedback to the operator in the field, ensuring quality data is being collected. All calibrations and maintenance on the YSI 6600 sondes are completed in accordance with the YSI, Inc.

operating manual methods (YSI 6-series Environmental Monitoring Systems Manual; YSI, Inc. Yellow Springs, OH).

The system is also equipped with a Garmin GPSMAP 168 Sounder. This unit serves several functions including chart plotting, position information, and depth. The unit is WAAS (Wide Area Augmentation System) enabled providing a position accuracy of better than three meters 95 percent of the time.

The continuous DATAFLOW sampling was undertaken on a single cruise conducted on September 3, 2002. The cruise track was run along the center axis of the estuary from the mouth of the Chickahominy River to the upper limit of tidal water in Richmond from approximately 10:00 am to 3:00 pm.

3.0 RESULTS

3.1 Transplant Survival

As in previous years SAV transplanted to the Turkey Island site continued to have the greatest survival and growth of all the restoration areas. Survival of the 1999, 2001 and 2002 wild celery transplants is summarized in Fig. 3-1. Transplants in exclosure TI 1 that had been planted with wild celery during the spring of 1999, re-grew for the third year in the spring of 2002. The 1999 transplants had gradually expanded throughout the 2000 and 2001 growing seasons, reaching nearly 100% cover of the bottom by October, 2001. They continued at this density throughout 2002. This suggests that approximately three growing seasons are required in this region for normal density to be achieved by wild celery propagules originally planted at 1 ft. centers. As the density of the plants increased, their capacity to trap sediments was evident and bottom depths in the exclosure increased 5-10 cm relative to the adjacent, unvegetated bottom outside of the exclosure.

Exclosure TI 3, which was planted in June of 2001 with wild celery, experienced approximately 60% survival by the end of the 2001 growing season (Figure 3-1). Approximately this same number re-sprouted after the 2001-2002 winter and SAV coverage increased to approximately 80% by October of 2002. Exclosure TI 4, which was planted in June of 2002 experienced some initial loss of plants. However, approximately 70-80% of the planting units survived and spread throughout 2002. No evidence of herbivory was observed within the exclosures, however no growth outside of the exclosures was observed. The shallowness of the site and the build up of sediments resulted in some of the plants being completely exposed at extremely low tides. This caused some of the plants within the exclosures to dieback, but most survived the infrequent exposure.

Wild celery planted at Tar Bay in June 2001 in exclosure TB 1 re-grew in the spring of 2002 and approximately 50-60% of the initial planting units were found throughout the spring and early summer of 2002. Transplants planted in exclosure TB 2 in 2002 experienced some initial losses but approximately 60-70% of the transplants survived through the summer of 2002. Between July 29 and September 10, 2002, however, a complete loss of all planting units occurred in both of the exclosures. There was no evidence of herbivory, suggesting that habitat conditions had changed significantly and the plants had simply died.

At the Powell's Creek site transplants in exclosure PC 2 planted in June of 2001 survived through 2001 and approximately 40% re-grew in the spring of 2002 and survived throughout 2002 until August (Fig. 3-1). Approximately 60% of the transplants planted in exclosure PC 1 in June 2002 survived and spread throughout the summer of

2002. During August 2002, all of the plants died out in a manner similar to those at Tar Bay.

Spring 2002 transplants at the Westover site followed a similar survival pattern in 2002 to the transplants at the Tar Bay and Powell's Creek sites (Fig. 3-1). This site experienced initial losses of planting units, followed by stabilization and spreading during June and July of 2002, then complete loss during August 2002 unrelated to herbivory. The rapid losses during August at the three most downriver sites suggest that the onset of limiting conditions there were quite rapid. These limiting conditions did not occur at the upriver Turkey Island location.

3.2 Periphyton Monitoring

Periphyton accumulation on the wild celery transplant leaves demonstrated no consistent trends throughout the growing season and accumulations on the transplants at the different sites were similar (Fig. 3-2). There was no significant relationship between periphyton levels and survival. Accumulations of periphyton on shoots at the Turkey Island site, which had the greatest survival, were similar to Westover and Powell's Creek, which had the poorest survival. There was no evidence of increased periphyton accumulation immediately preceeding transplant dieout. Most of the periphyton weight consisted of inorganic sediment (Fig. 3-3). Only 20-30% was organic, and this ratio was consistent throughout the growing season.

3.3 Water Quality Monitoring

3.3.1 Fixed Station Monitoring

Results of water quality measurements are presented for all years of shallow water SAV habitat monitoring. Sampling was initiated at Westover Plantation on April 10,

2001. Water temperatures (Fig. 3-4) demonstrated similar annual patterns over the 1999-2003 sampling period at all the stations with daytime minimums ranging from approximately 5 °C to maximums of 30-32 °C. During the winter of 2002-2003 however, water temperatures were near zero on one occasion. Conductivity (Fig. 3-5) demonstrated marked differences among the years reflecting differences in river discharge rates and low summertime freshwater inputs in 2001 and 2002. Conductivities were generally in the range of 100-300 Πmhos (0 psu salinity) throughout most of the year at all sites. These increased to nearly 1000 Πmhos (0.5 psu salinity) in the fall of 1999, 2000 Πmhos (1.0 psu salinity) in the fall of 2001 and 3500 Πmhos during the late summer and fall of 2002 (>6.0 psu salinity). Typically salinities of 3-5 psu are required to stress growth and reproduction of wild celery (French and Moore, in press), however other freshwater species can be more sensitive to elevated salinity levels. When salinity levels increased in the fall of 1999, 2001 and 2002, highest levels were reached at the most downstream stations of Westover Plantation, Powell's and Tar Bay. At other times there were no differences among the stations. Generally, the very high salinity levels did not reach the upriver Turkey Island site where transplant survival was highest.

Daytime dissolved oxygen (DO) concentrations (Fig. 3-6) followed somewhat similar annual patterns over all years with lowest levels in the late spring (May-June), another decrease in the late summer, and highest levels in the winter (12-16 mg/l) as temperatures decreased. Typically, daytime DO levels at the transplant sites did not fall below 5 mg/l. DO levels remained consistent (8-11 mg/l) during the summer of 2002 even as salinity (measured as conductivity) increased to highest levels. Dissolved oxygen increased rapidly as river flow increased in October. Water column pH levels (Fig. 3-7) paralleled changing DO levels to some extent from 1999-2003. However pH is affected by many factors including the buffering capacity of the water, which is related to salinity. The highest salinities observed here typically buffer pH between 7.5 and 8.0. pH dropped markedly in the fall of 2002 as river flow increased and levels were unusually low at Westover during the winter of 2002.

Suspended particle loads (TSS) were consistently lowest at the Shirley Cove station (Fig. 3-8). Very high levels (>50 mg/l) likely reflected wind or wave re-suspensions of bottom sediments. The Westover and Tar Bay sites had the greatest proportion of short-term increases in TSS. These were likely due to both the exposure of the Tar Bay site to prevailing winds and the adjacency of the Westover site to the shipping channel. Overall, concentrations at all the restoration sites were generally higher in the late winter and early spring (Feb-Apr) and lowest in summer. Year-to-year differences in salinity were not generally reflected in the suspended sediment concentrations, although the increased river flow in October 2002 was accompanied by several peaks in TSS to over 100 mg/l. High salinities in the fall of 2001 and 2002 were not accompanied by concomitant decreases in turbidities.

The pattern of high salinity in 2002 was associated with decreasing phytoplankton levels throughout 2002 and into 2003 (Fig. 3-9). Levels throughout the spring of 2003 were similar to conditions in 1999. All stations usually followed the same temporal patterns indicating generally similar phytoplankton levels throughout this region of the river. However, the variability in chlorophyll levels among the various stations from sampling date to sampling date suggests a patchiness in the bloom events. A pattern of generally increasing chlorophyll levels from initiation of the monitoring in 1999 through mid 2002 with a decrease after that time is evident. Overall, seasonal chlorophyll medians were below the habitat requirement of 15 Πg/l for freshwater regions in 1999, in spite of the high levels during the summer, but were above the requirement for 2001 and 2002. In spite of this, wild celery survival and growth during the growing season was similar during all years.

Water transparencies measured as secchi depth (Fig. 3-10) demonstrated generally greater depths (clearer water) during the higher flow years of 2000 and 2002 than the lower flow years of 1999 and 2000. This may be related to a shifting in the turbidity maximum to a region slightly downriver during wet years and slightly upriver during dry years. Generally, secchi depths were always greatest (i.e. clearer water) at the Shirley Cove site. This site is located off the main section of the river. It is more sheltered from wave and current action than the other sites and TSS levels were usually lowest.

Total organic carbon (TOC), total kjeldahl nitrogen (TKN) and total phosphorus (TP) levels (Figs. 3-11, 3-12, 3-13) were relatively consistent among the years. TKN concentrations were below detection limits for many sampling periods but occasional increases were not related to decreases in conductivity, suggesting a source unrelated to watershed inputs. Concentrations were usually, but not always, highest during the summers but increased in the fall of 2001 and again in the fall of 2002 as salinity levels rose and river flow decreased. TOC levels were lowest at Shirley Cove and usually highest at Turkey Island, the most upstream site. Periodic, high concentrations at Westover may reflect patterns of greater re-suspension at this relatively more exposed site. There was generally a pattern of increasing levels throughout 2001-2002 followed by a decrease in the fall of 2002 as freshwater input increased. Again, this suggests that much of the TOC was unrelated to river freshwater inputs. Generally TP followed TSS patterns as much of the total phosphorus load is bound to suspended sediments. In this regard, levels were consistently lowest at Shirley Cove.

Dissolved inorganic nitrogen constituents (nitrate, nitrite and ammonium), in contrast to dissolved inorganic phosphorus (DIP), generally are not limiting for phytoplankton and epiphyte growth in tidal freshwater regions. In low salinity regions, however, total dissolved inorganic nitrogen levels (nitrate + nitrite + ammonium) above 0.15 mg/l have been found to be associated with SAV declines and lack of recovery. Throughout the study period nitrate + nitrite levels (Fig. 3-14) have been quite variable, both over time and among stations. Nitrate and nitrite generally represent "new" nitrogen entering the system through the watershed. Concentrations were generally highest in the winter and lowest in the summer. Nitrate + nitrite levels were very low in the summer of 2002 and increased markedly in the fall of 2002 as river flow increased. A marked increase in dissolved ammonium concentrations (Fig. 3-15) was observed for all stations during the fall of 2001 when salinity levels increased following reduced river flow. The marked increase in the fall of 2001, that was unrelated to river flow, may have reflected greater inputs of point source ammonium, or less dilution of ammonium due to reduced freshwater input. However during 2002 when drought conditions were even greater than 2001 and salinity levels higher, there was no corresponding increase in ammonium. By the spring of 2003 levels were at or below detection at all stations.

Typically, dissolved inorganic phosphorus (DIP) concentrations (Fig. 3-16) remained at or below the SAV habitat requirement threshold of 0.02 mg/l for all years of study. These low levels suggest there is the potential that epiphyte growth on SAV shoots may be nutrient-limited to some degree for much of the time. Elevated levels of DIP accompanied the reduced salinities beginning in the fall of 2002 and continuing into 2003. Phytoplankton, reported as chlorophyll a, generally did not follow the pattern of DIP suggesting that some other factor(s) may be affecting year-to-year differences in phytoplankton growth in this region.

3.3.2 Continuous Monitoring Using DATAFLOW Technology

Continuous mapping of the James River system from the mouth of the Chickahominy River to the fall line at Richmond in early September 2003 (Fig. 3-17), provided an overall pattern of the distribution of water clarity (turbidity), chlorophyll (phytoploankton) and dissolved oxygen in the tidal fresh segment of the James River (JMSTF) at that time. The pattern of salinity (Fig. 3-18) suggests that the lower transplant sites (Westover, Powell's Creek and Tar Bay were subject to saline water during this period, while the Shirley Plantation and Turkey Island sites remained in fresh water. This salinity gradient will vary over time as a function of river flow and tidal stage. The maximum salinity intrusion would have likely occurred approximately one month later as indicated by the fixed station monitoring (Fig. 3-5). These spatially intensive data suggest a strong correlation between salinity intrusion and SAV transplant declines. Dissolved oxygen levels (Fig. 3-19) generally exceeded 6 mg/l throughout the region with several areas of high DO observed. Chlorophyll concentrations (Fig. 3-20) demonstrated a general increase in distance upriver with a maximum at the Hopewell region of the James. Highest levels were observed in the SAV transplant region (Westover to Turkey Island) with several peaks or blooms of phytoplankton extending for distances of two mile or more were observed in areas upriver of this region. These blooms corresponded directly to the regions of high DO (Fig. 3-19) suggesting high daytime oxygen concentrations in these areas were related to phytoplankton photosynthesis. The distribution of turbidity demonstrated a general increase from downriver areas upriver to the Hopewell region and then a decrease continuing upriver to the fall line (Fig. 3-21). Several of the highest regions of turbidity were also associated with the highest regions of chlorophyll indicating the significant contribution of phytoplankton to overall turbidity in these areas.

4.0 DISCUSSION AND CONCLUSIONS

Comparison of the different 1999-2002 periods of monitoring presented in this study reveals the effects of climatic conditions and river flow in this region of the estuary on water quality conditions and subsequently SAV response. In 2002, very dry conditions during the summer resulted in significantly increased salinities at three downriver transplant sites (Westover, Powell's Creek and Tar Bay) which were directly related to SAV transplant declines. This was in contrast to previous growing seasons where the salinity intrusion was less pronounced. The fact that water clarity conditions did not improve with this influx of more saline water in 2002 resulted in a combination of conditions that were limiting to the SAV vegetation. Research on the interactions of salinity and turbidity to wild celery (French and Moore in press) indicates that as salinity levels increase to approximately 5 psu the light requirements of the underwater vegetation for growth and survival increase 50% or more. If no additional light is available to compensate for this salinity stress, then the plants will grow poorly. At levels above 5 psu growth will cease. Salinity conditions at the lower three transplant sites (Westover, Powell's Creek and Tar Bay) all exceeded 5 psu during the period when the dieback occurred.

Large, established beds of wild celery should have a greater capacity to withstand periodic increases in salinity or other stresses such as those found in 2002 compared to small transplanted founder beds. Propagules and seed banks in established beds would assist SAV recovery in subsequent years. Additionally, since established freshwater tidal SAV beds are generally composed of a variety of species (Moore et al. 2000), some of which are more tolerant to periodic periods of elevated salinity than wild celery (Stevenson and Confer 1972), overall bed stability is greater. Since historical photography and other records indicate that SAV beds were present in the Hopewell region prior the 1950s (Moore et al. 1998), it is likely that a variety of species were present historically, so that periodic extremes in environmental conditions would not be limiting. Declines in wild celery SAV transplants similar to those observed in the James River were also observed in other regions of the Chesapeake Bay in Maryland where salinity intrusions occurred in 2002 (Orth et al. in press). This suggests that the changes in SAV observed here were part of larger regional responses to climatic conditions and not to conditions specific only to the James River.

In response to the low river inflow evident in 2002, phytoplankton levels were low in 2002 and the first six months of 2003 compared to other years when river flow conditions were greater (ie. 2000-2001). This highlights the relatively strong relationship between phytoplankton bloom conditions and non-point source inputs from the watershed. Since turbidity levels were not so responsive it suggests that much of the turbidity in the region is related to reworking of material in this region of the river. The correlation observed between areas of phytoplankton blooms and elevated turbidities using spatially intensive monitoring (Dataflow) illustrates the additional light reductions that phytoplankton can add to the system above that of that provided by the suspended sediments. Thus, implementation of strategies to reduce nutrient inputs to lower phytoplankton levels and reduce sediment inputs to decrease suspended sediment levels may be required to improve light conditions for SAV growth to greater depths than those transplanted here. Additionally, given the lack of strong relationships between year-to-year differences in river flow and suspended sediment levels, factors that contribute to the reworking of sediments may need to be addressed and studied further. Overboard disposal of dredged material from maintenance of navigation channels may be one contributing factor. Alternatives such as the use of containment islands, or the creation of emergent marsh areas where the material may be stored for longer periods of time should be investigated.

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APPENDIX OF FIGURES

Figure 2-1. Location of SAV Transplant Sites

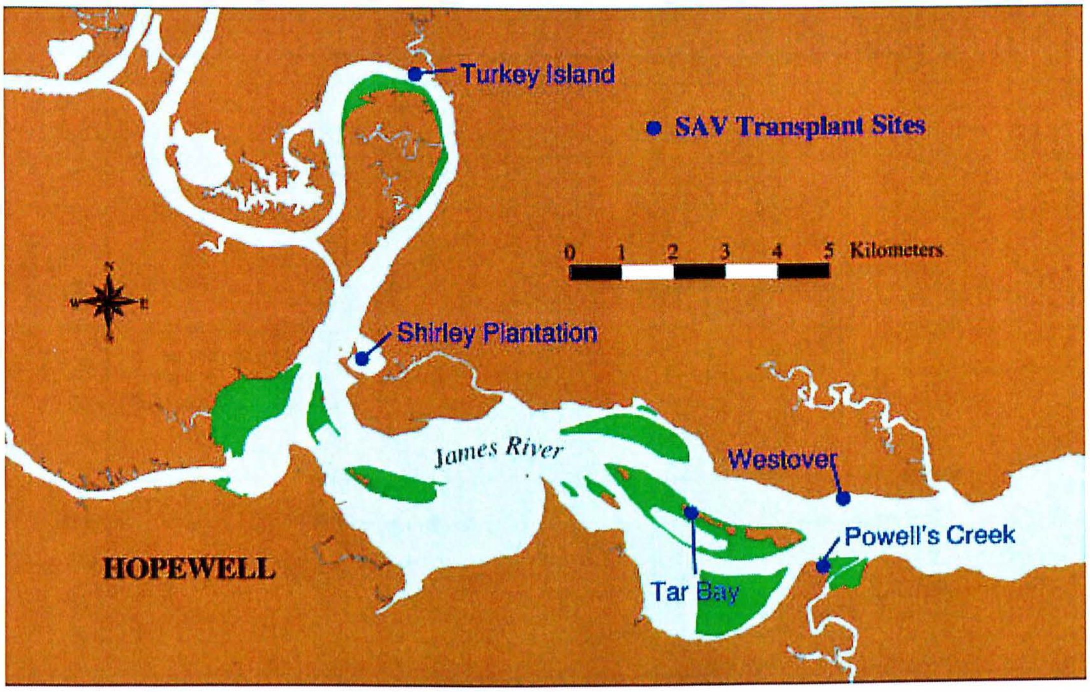


Figure 3-1. James River Wild Celery Transplant Survival
(CB1999, CB2001, CB2002 = 1999, 2001, 2001 Chesapeake Bay Stock)
(WP- Westover, PC - Powell's Creek, TB - Tar Bay, TI - Turkey Island)

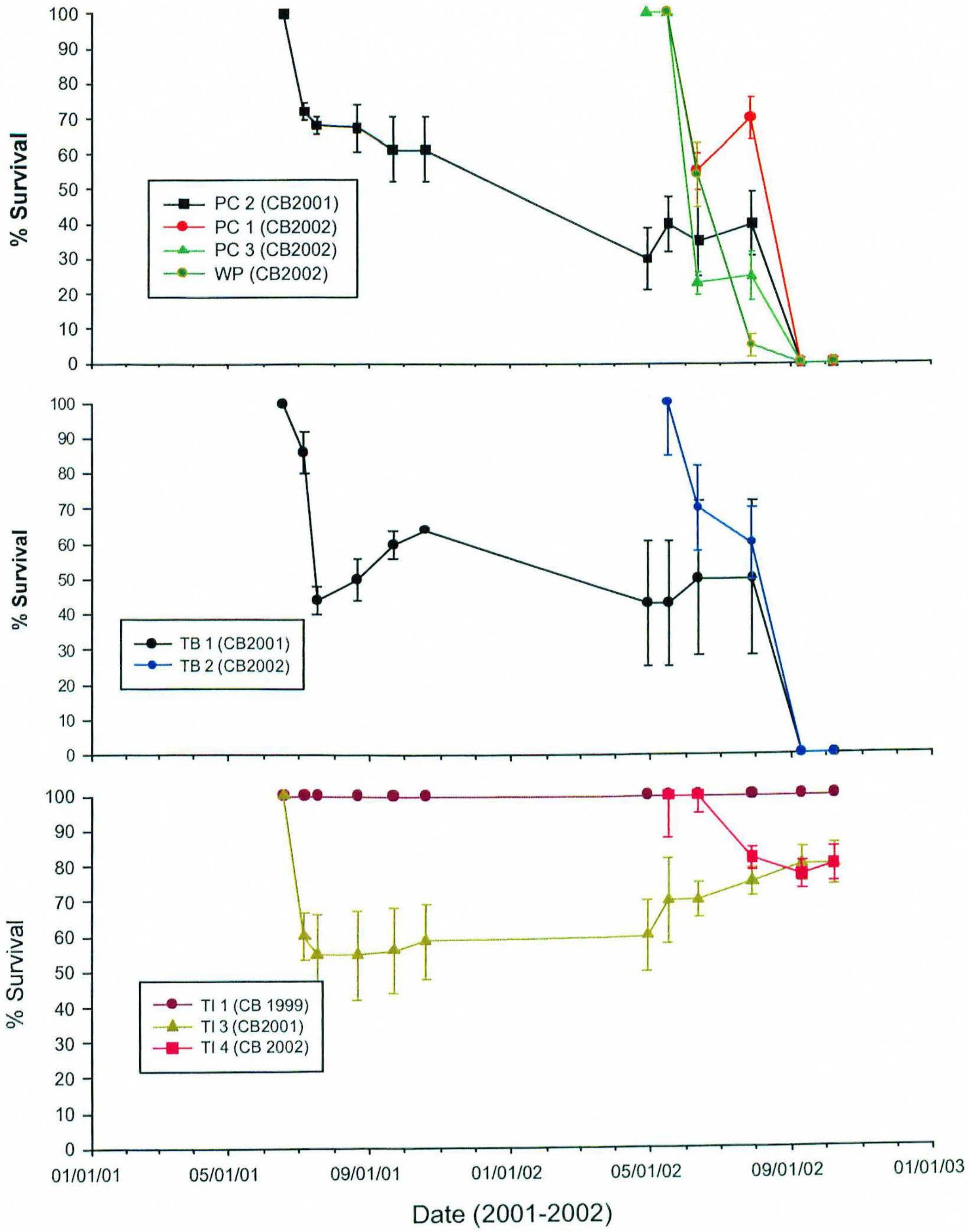


Fig. 3-2. Periphyton Dry Weight

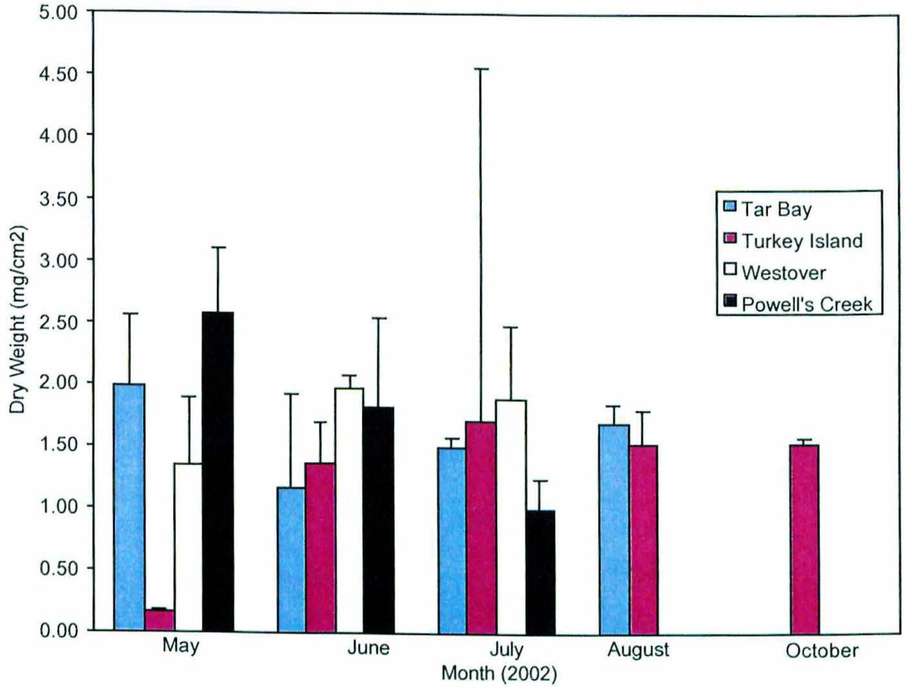


Fig. 3-3. Percent Organic Periphyton Material

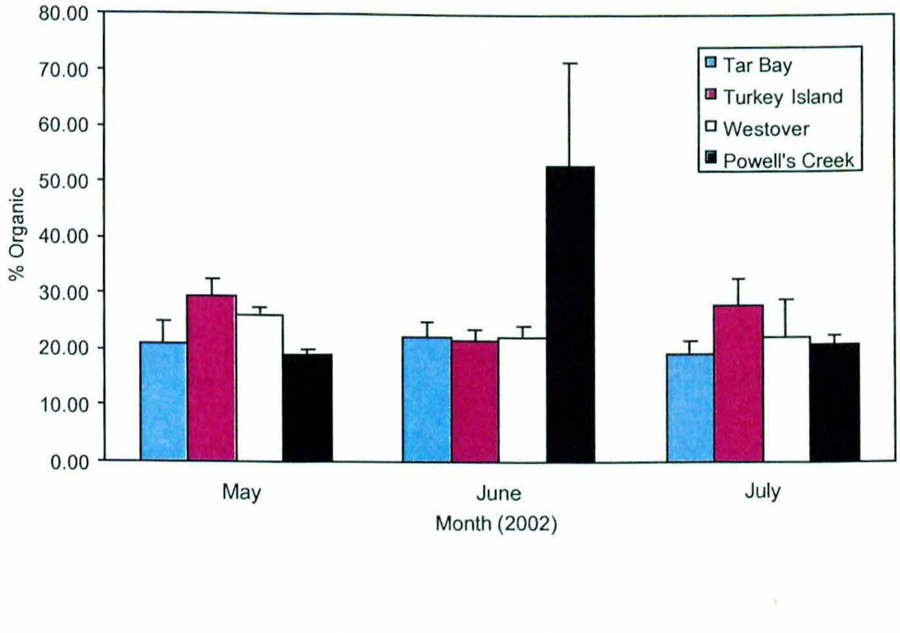


Figure 3-4: Water Temperature

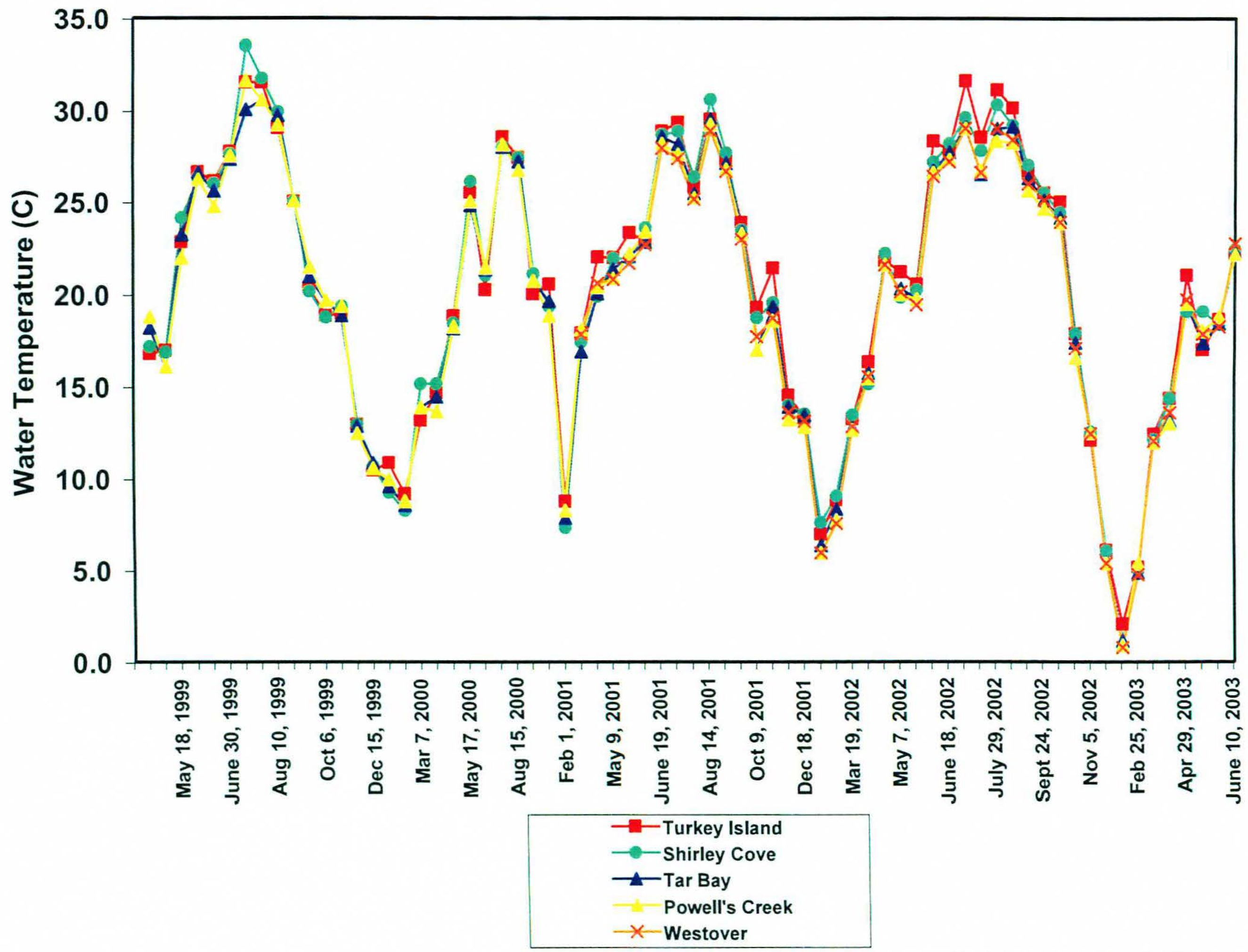


Figure 3-5: Conductivity

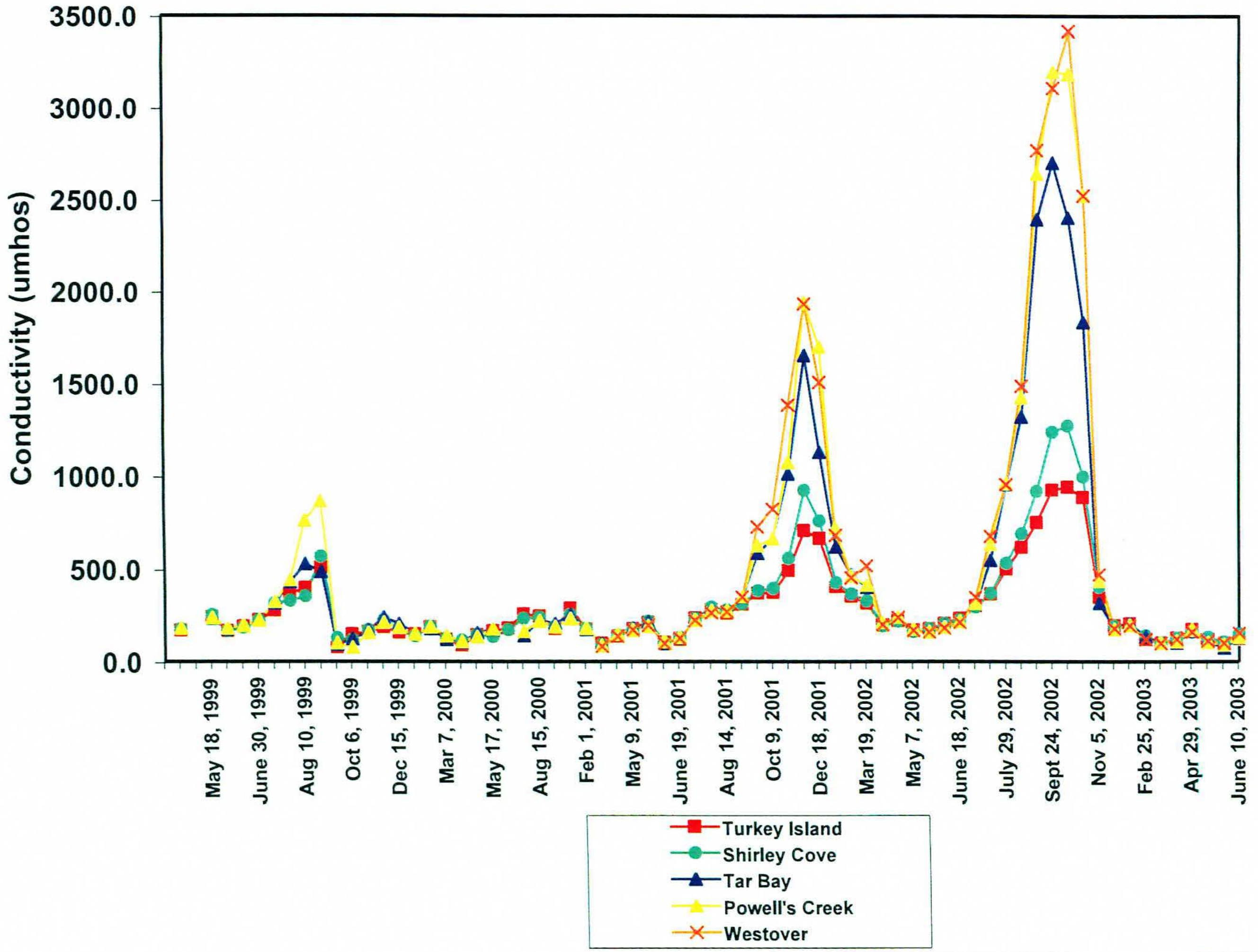


Figure 3-6: Dissolved Oxygen

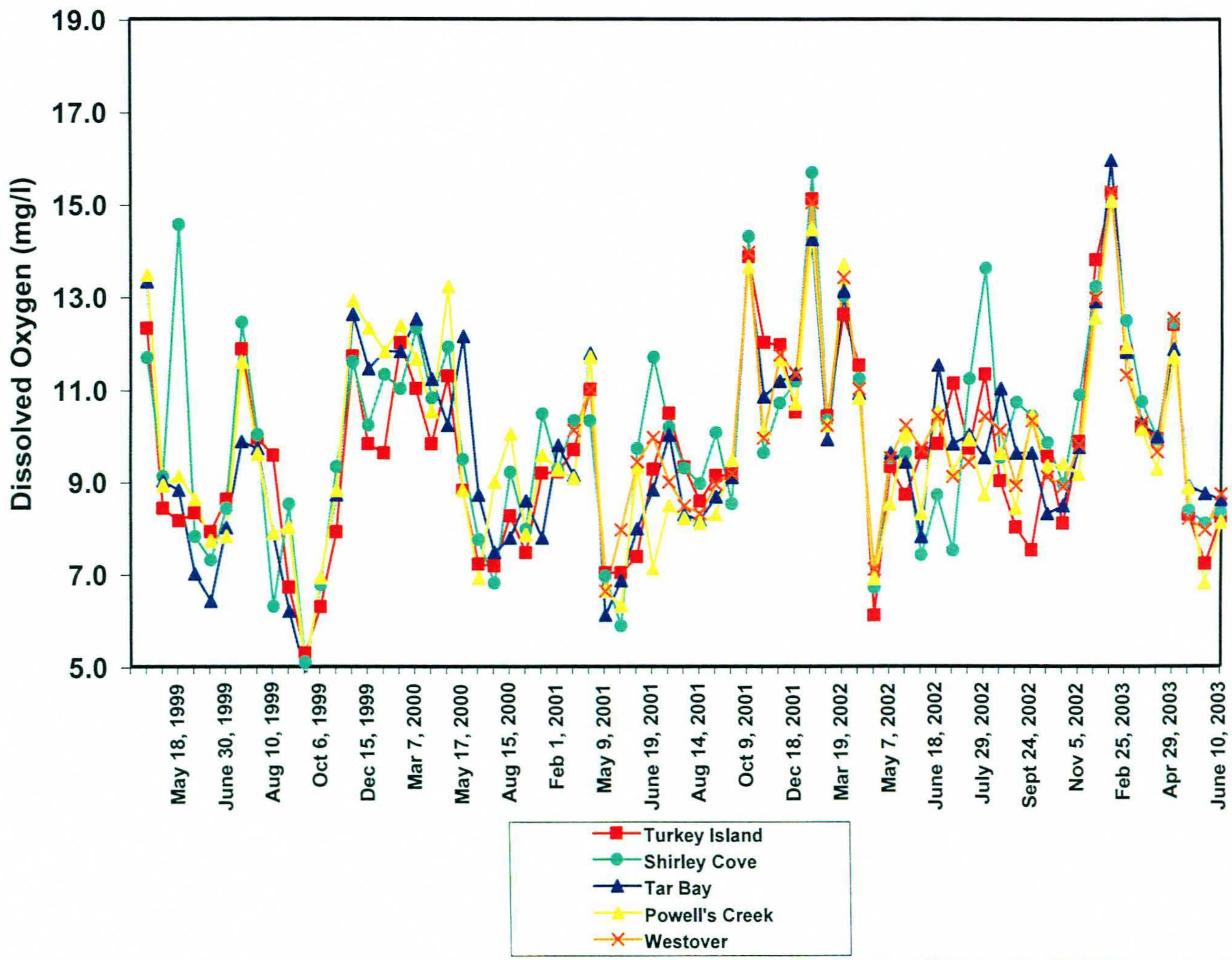


Figure 3-7: Water Column pH

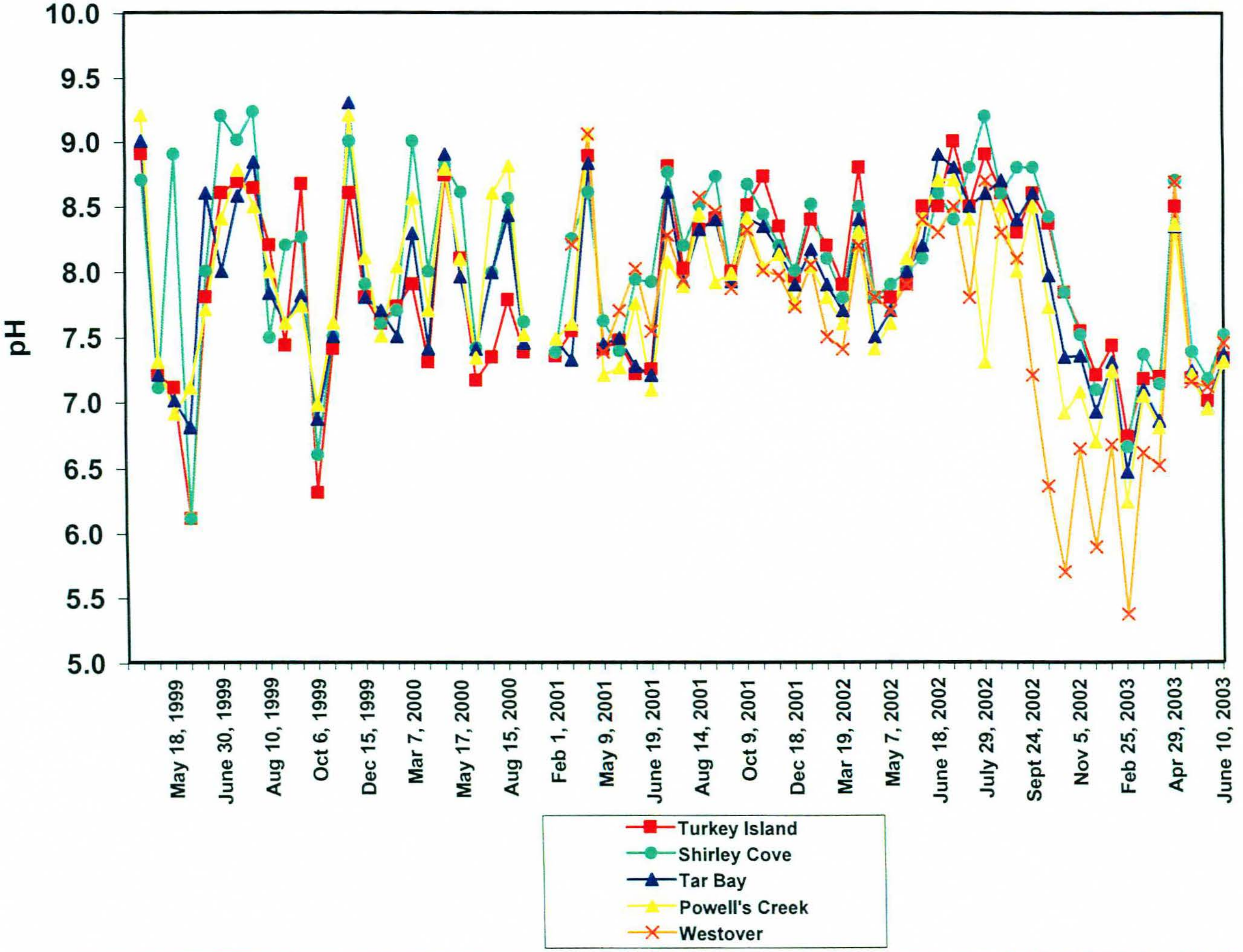


Figure 3-8: Total Suspended Solids (TSS)

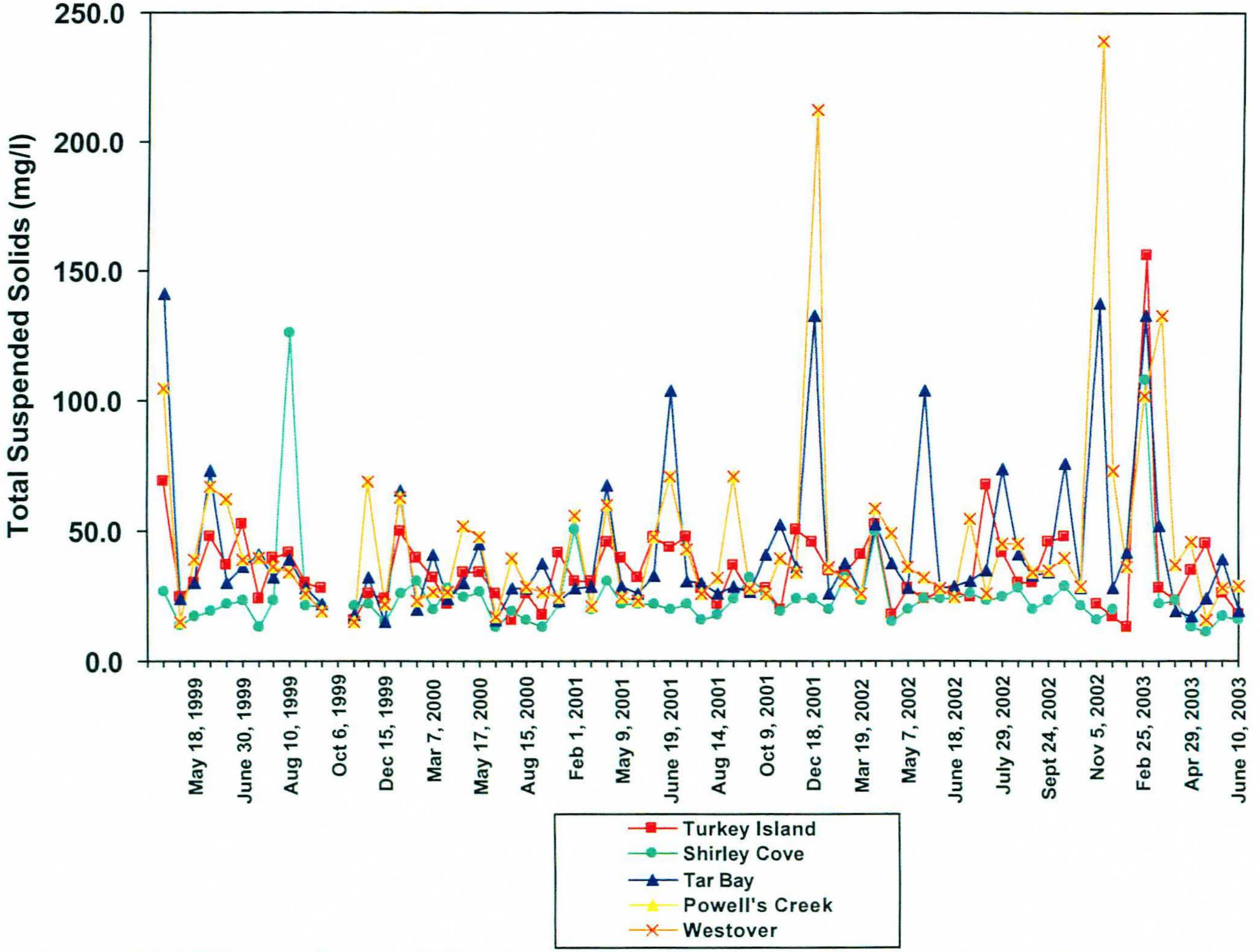


Figure 3-9: Phytoplankton as Chlorophyll a

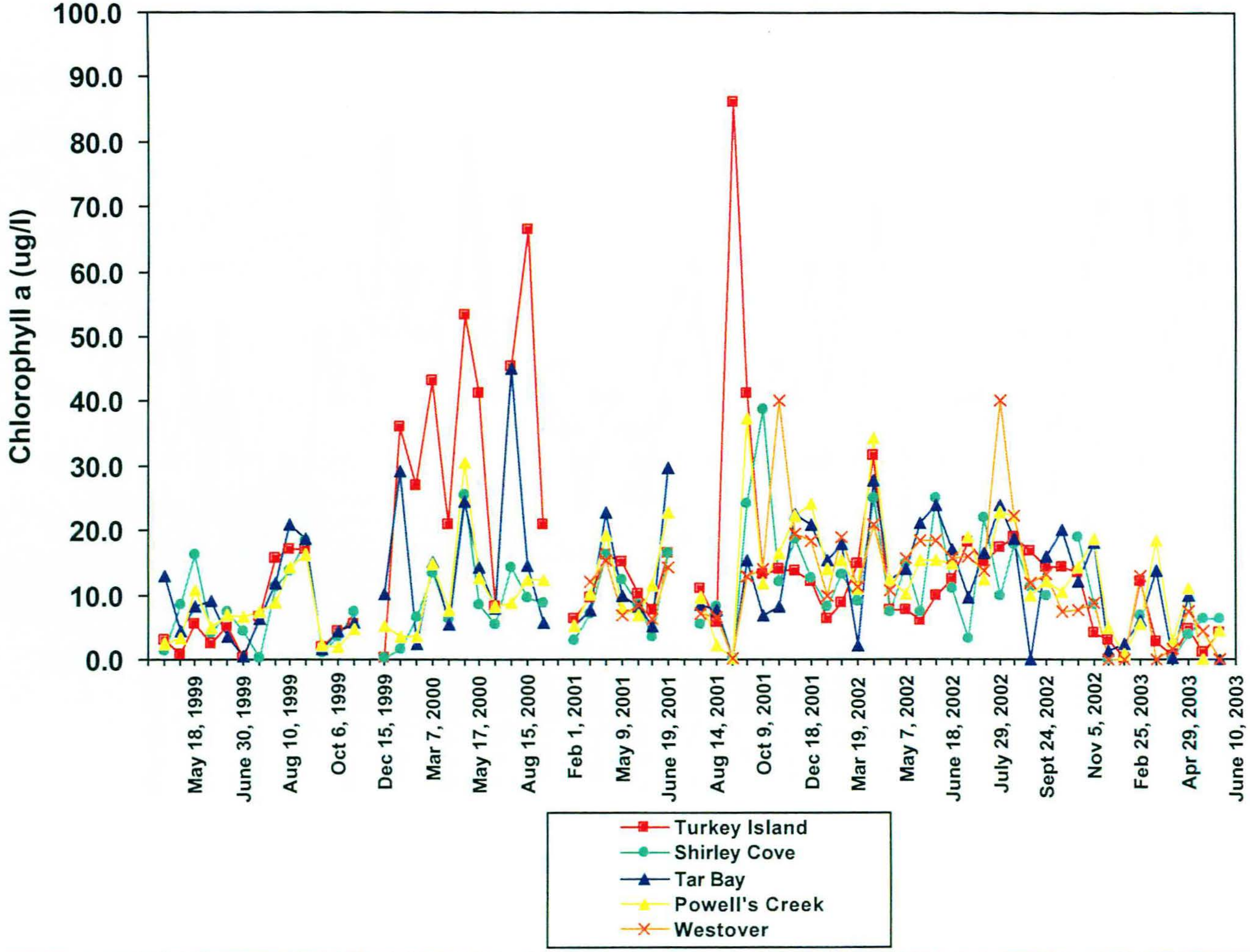


Figure 3-10: Secchi Depth

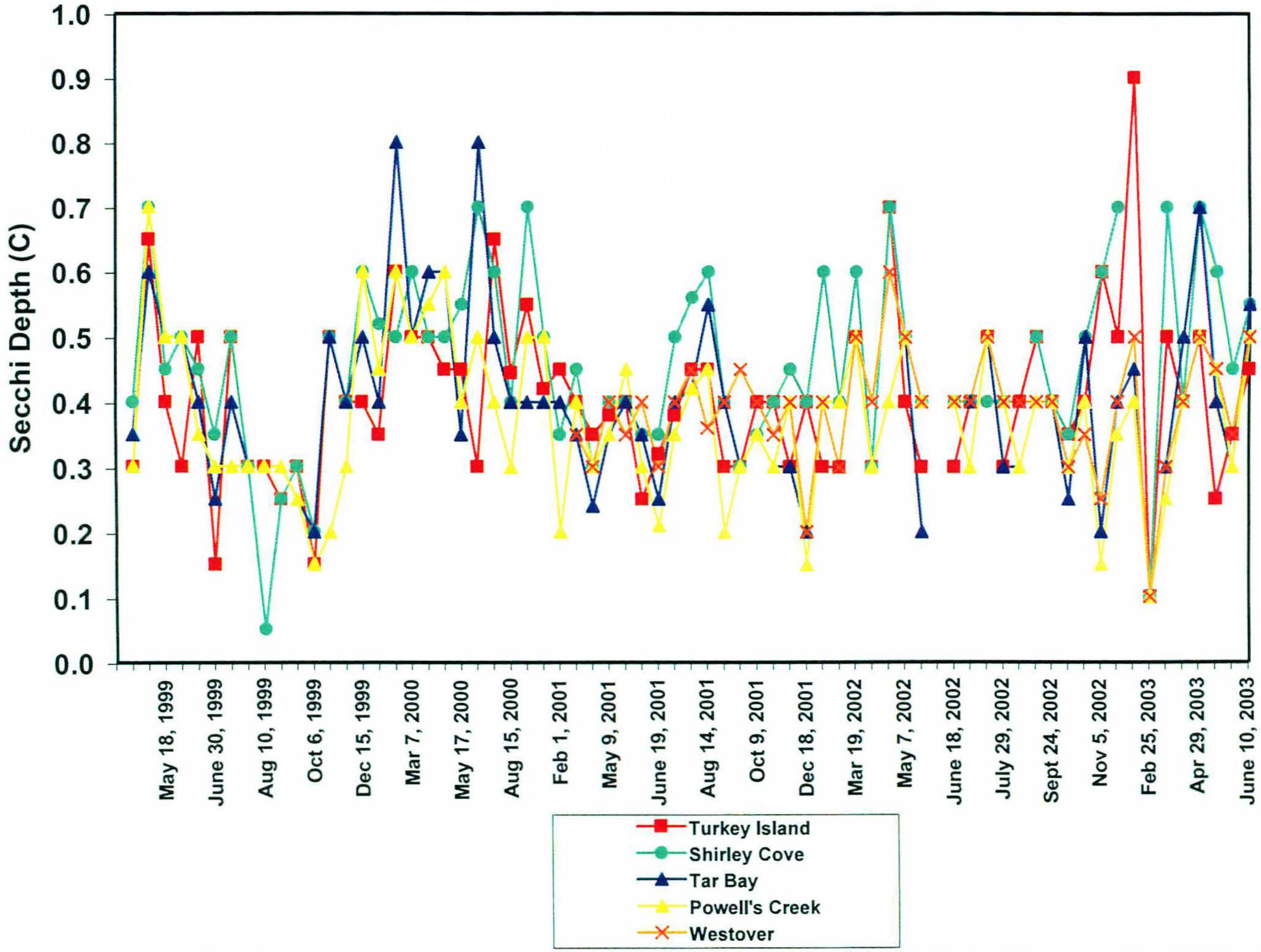


Figure 3-11: Total Organic Carbon (TOC)

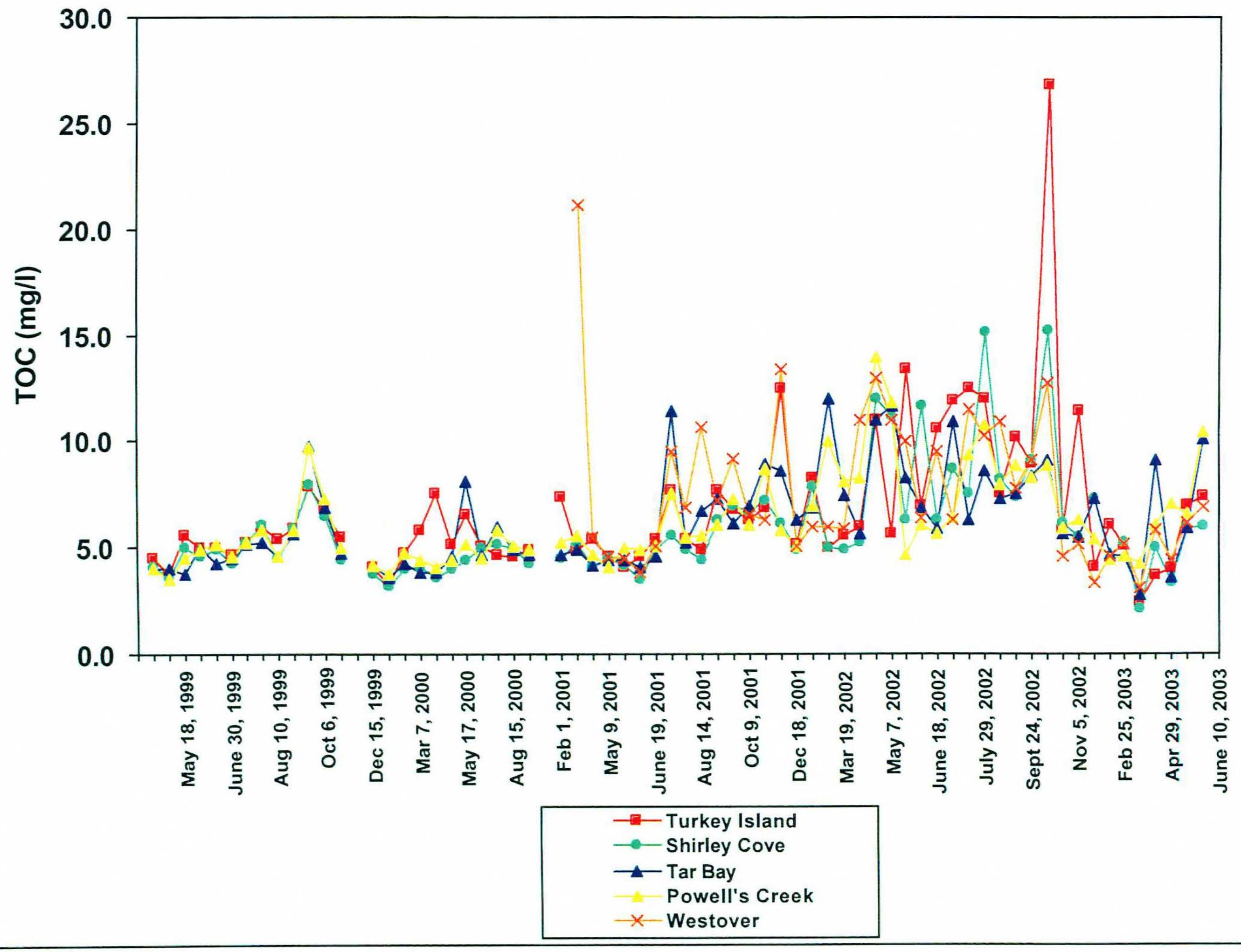
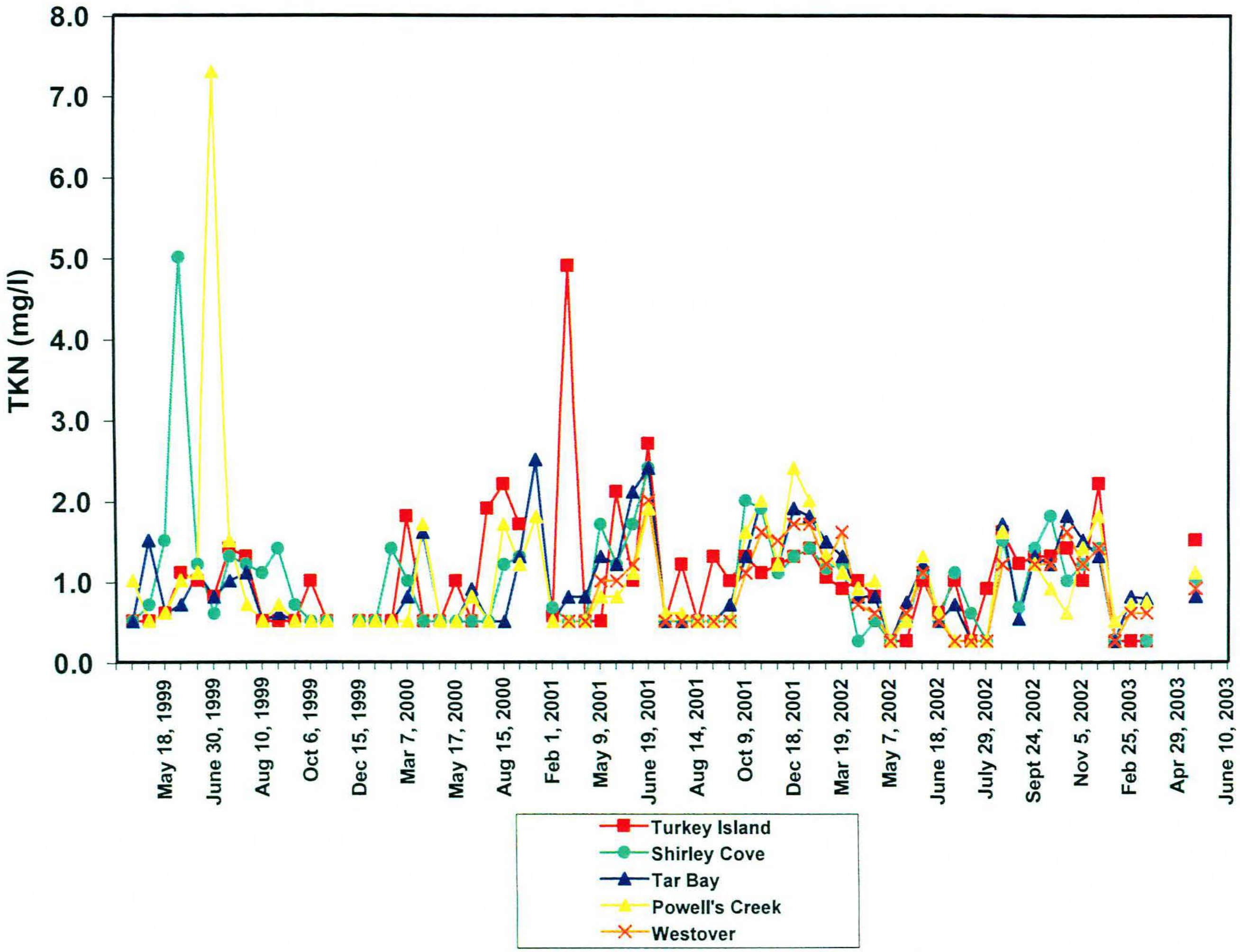


Figure 3-12: Total Kjeldahl Nitrogen (TKN)



Fiugre 3-13: Total Phosphorus (TP)

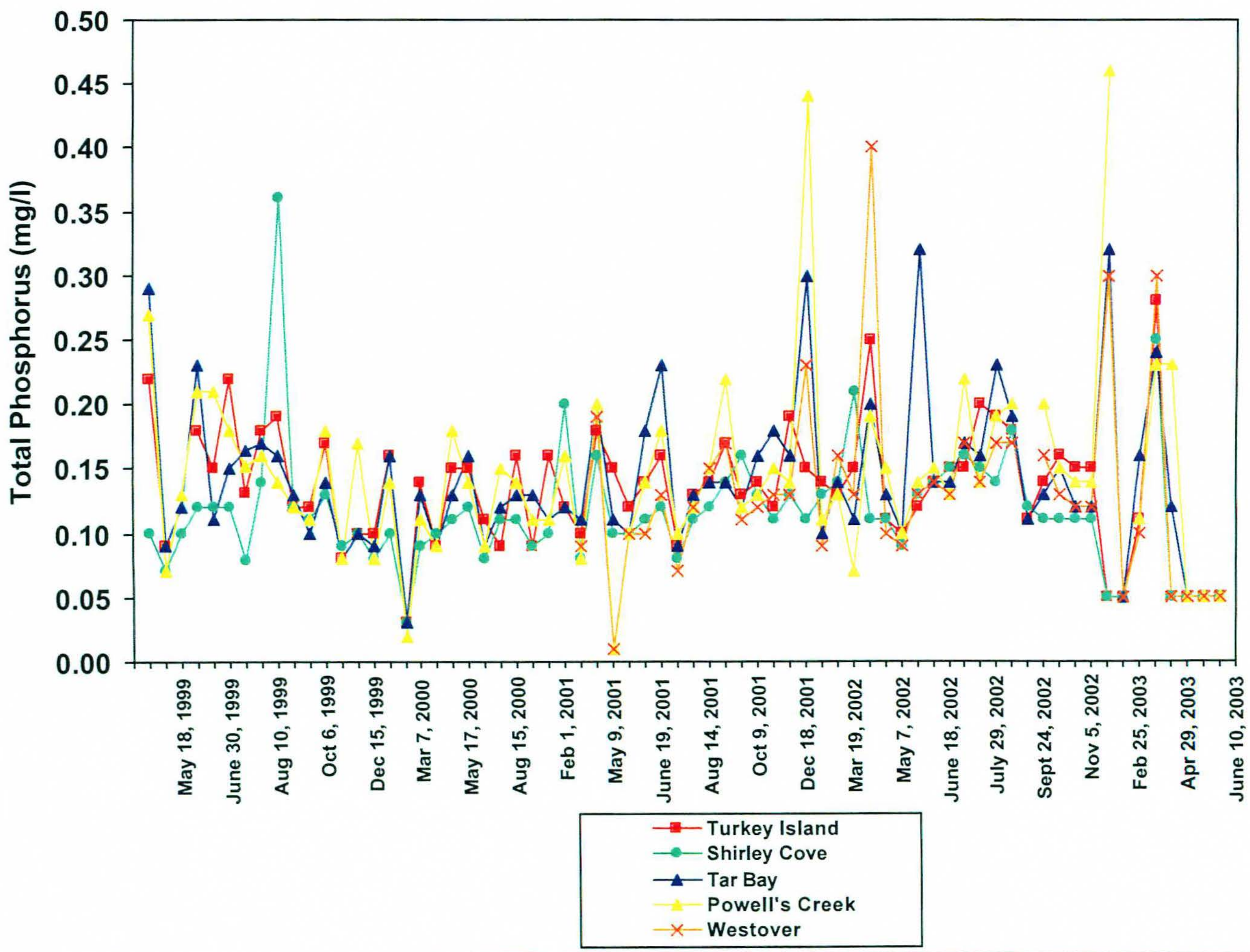


Figure 3-14: Dissolved Nitrate + Nitrite

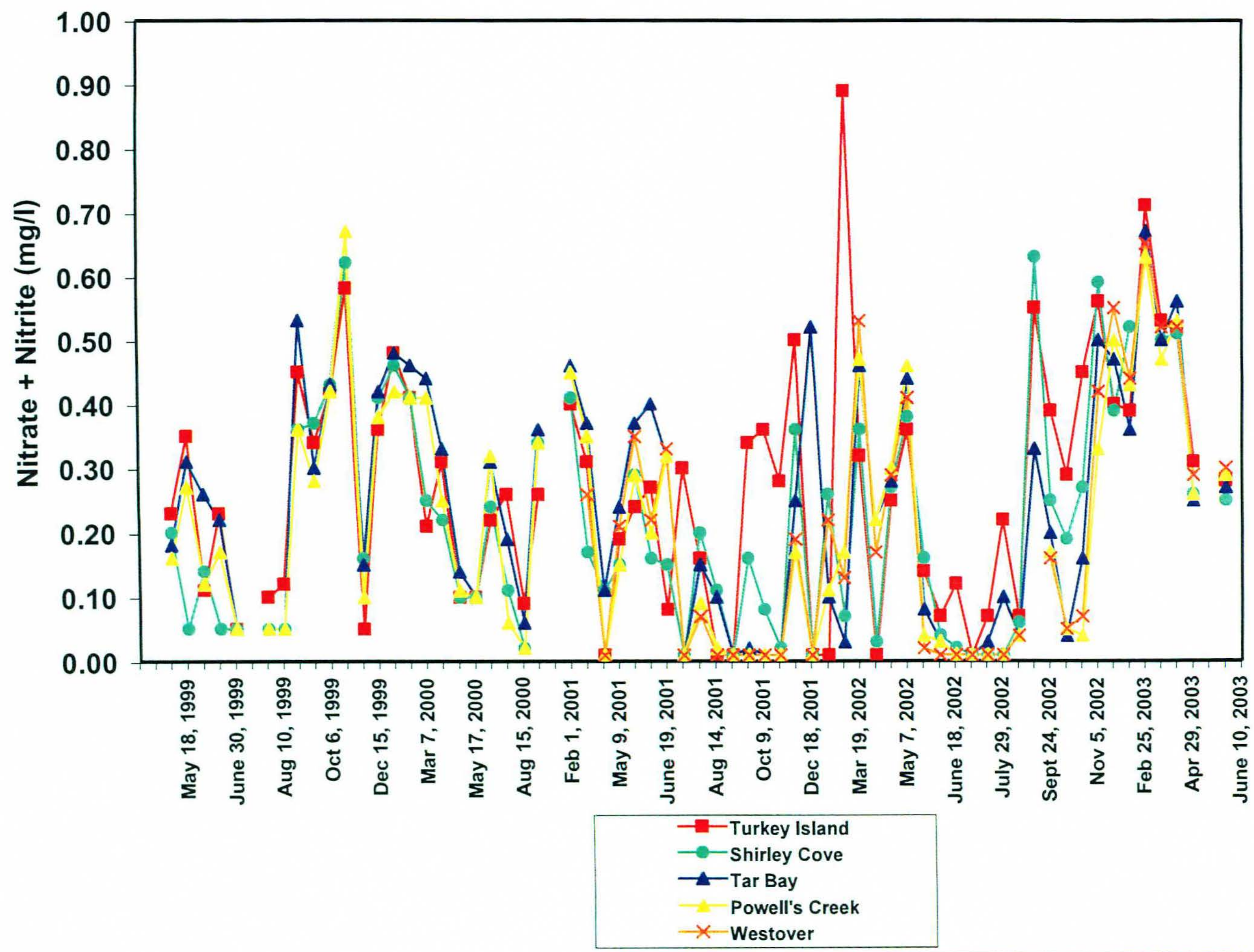


Figure 3-15: Dissolved Ammonium

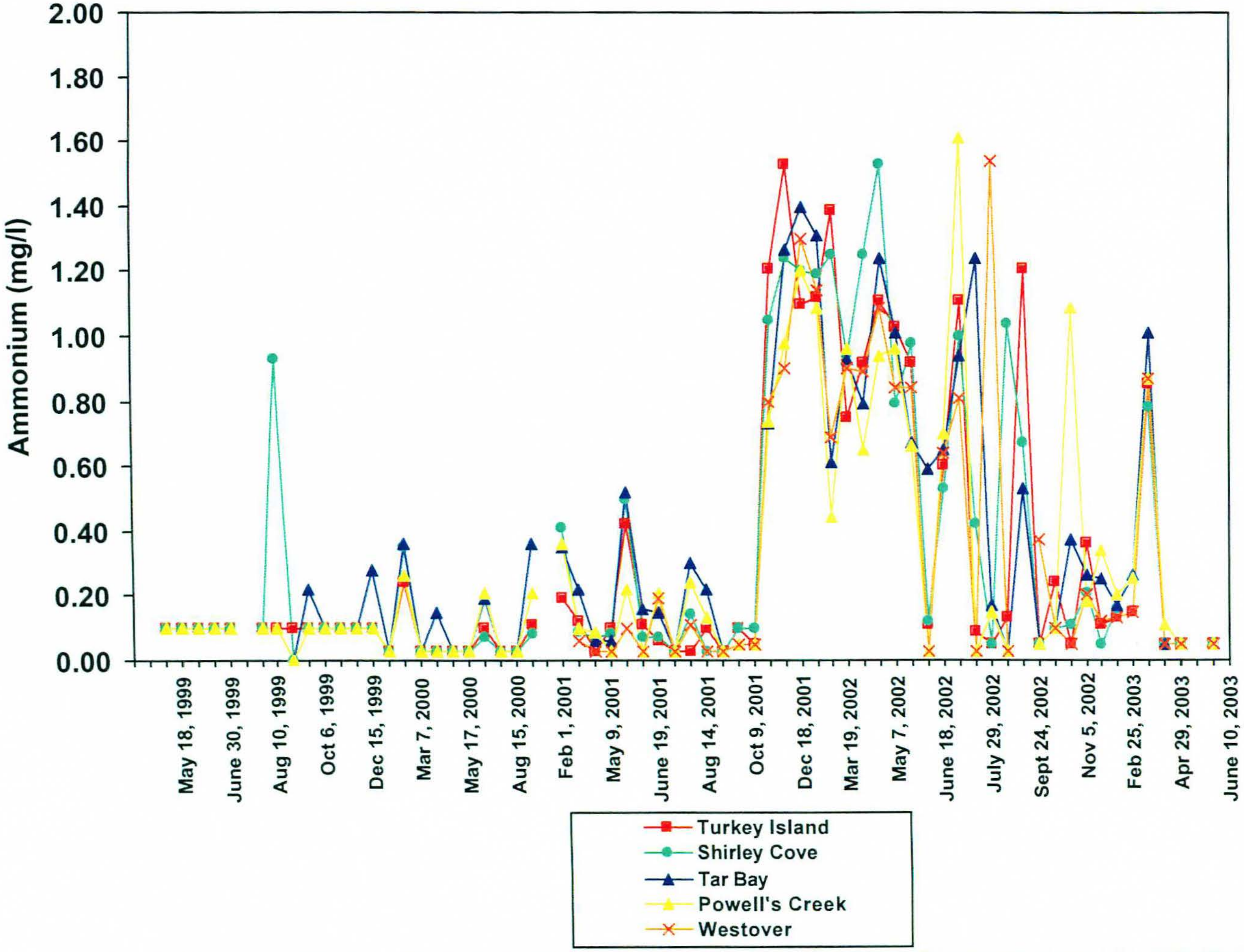


Figure 3-16: Dissolved Inorganic Phosphate (DIP)

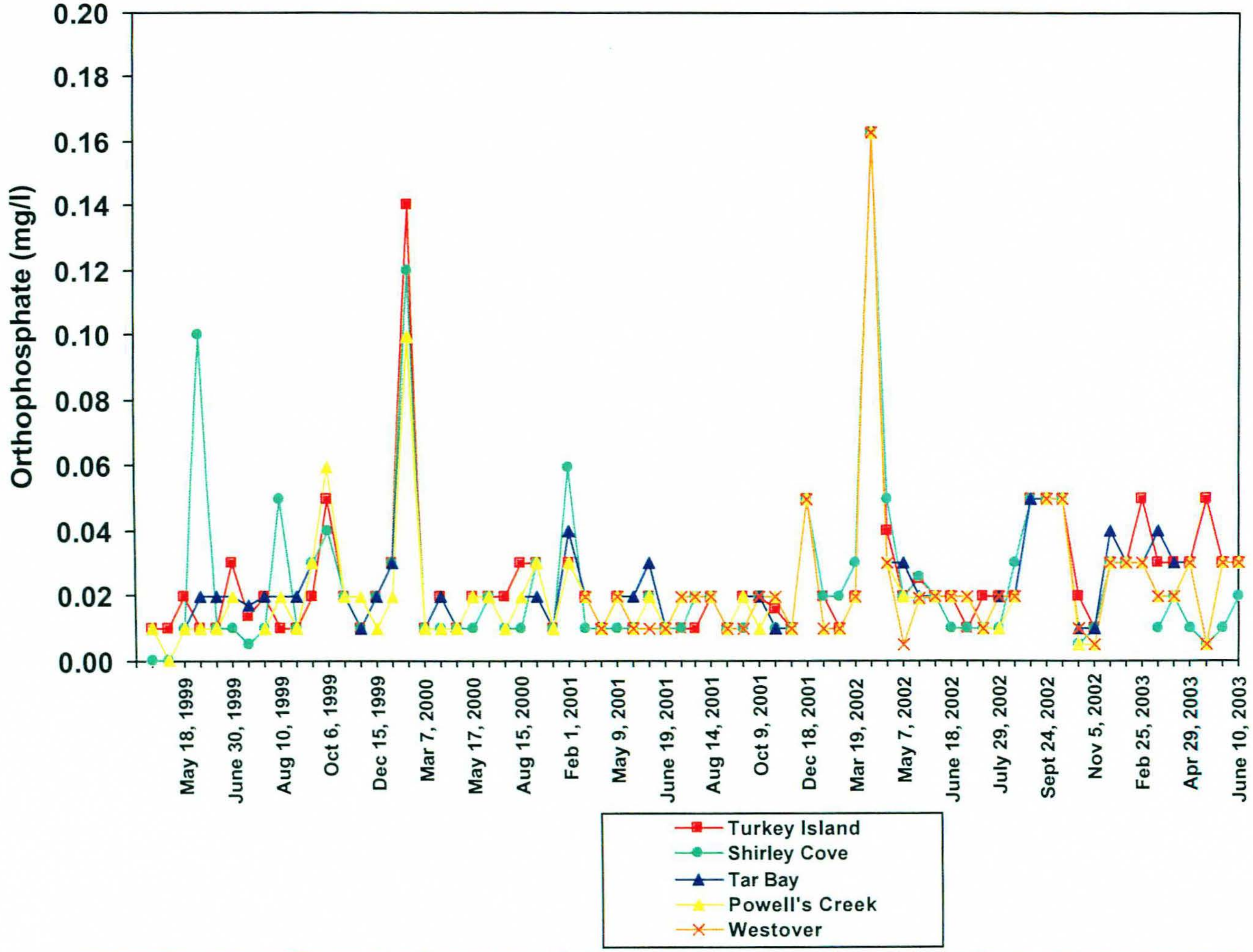


Figure 3-17 Upper James River Dataflow Cruise Sept. 3, 2002

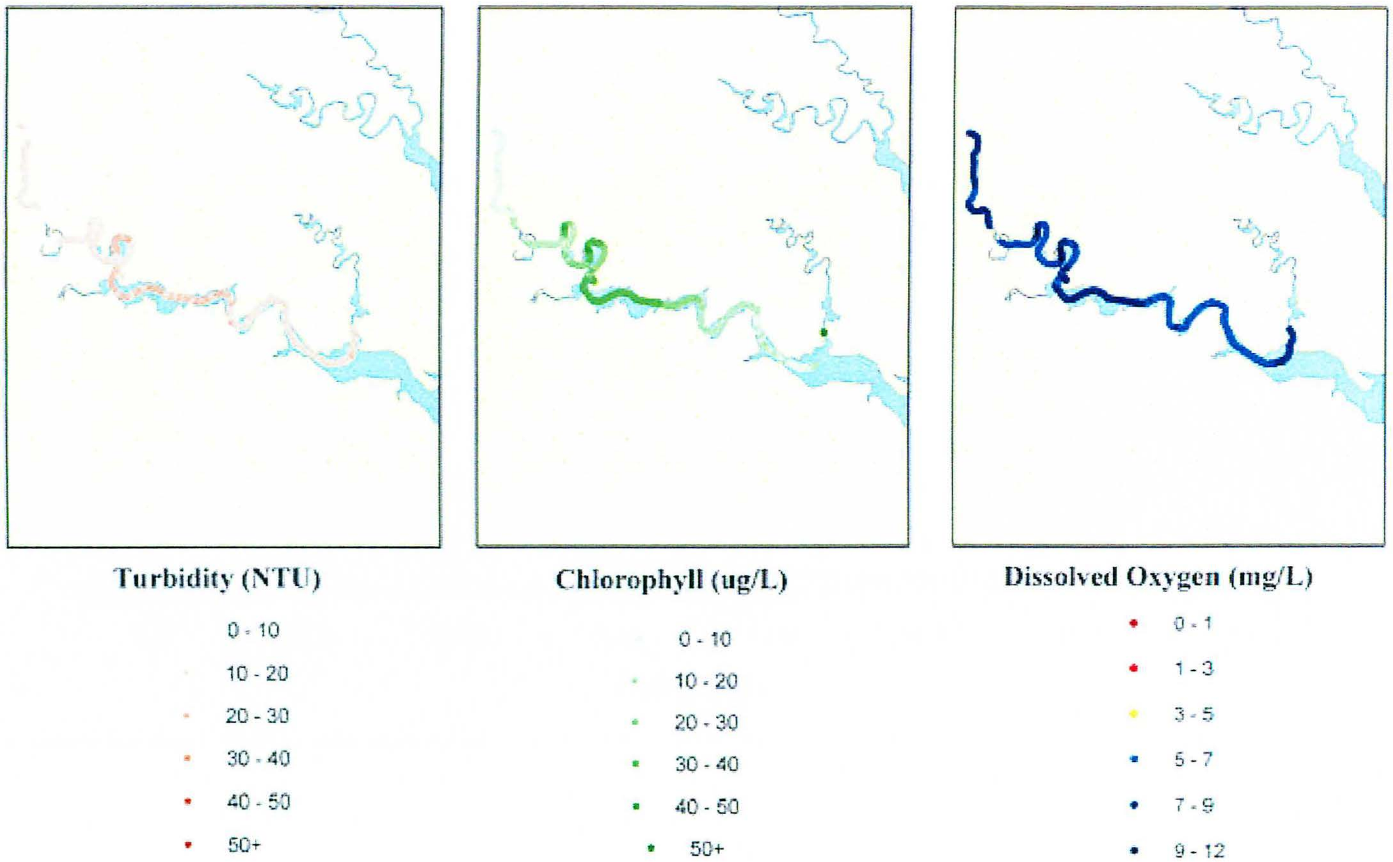
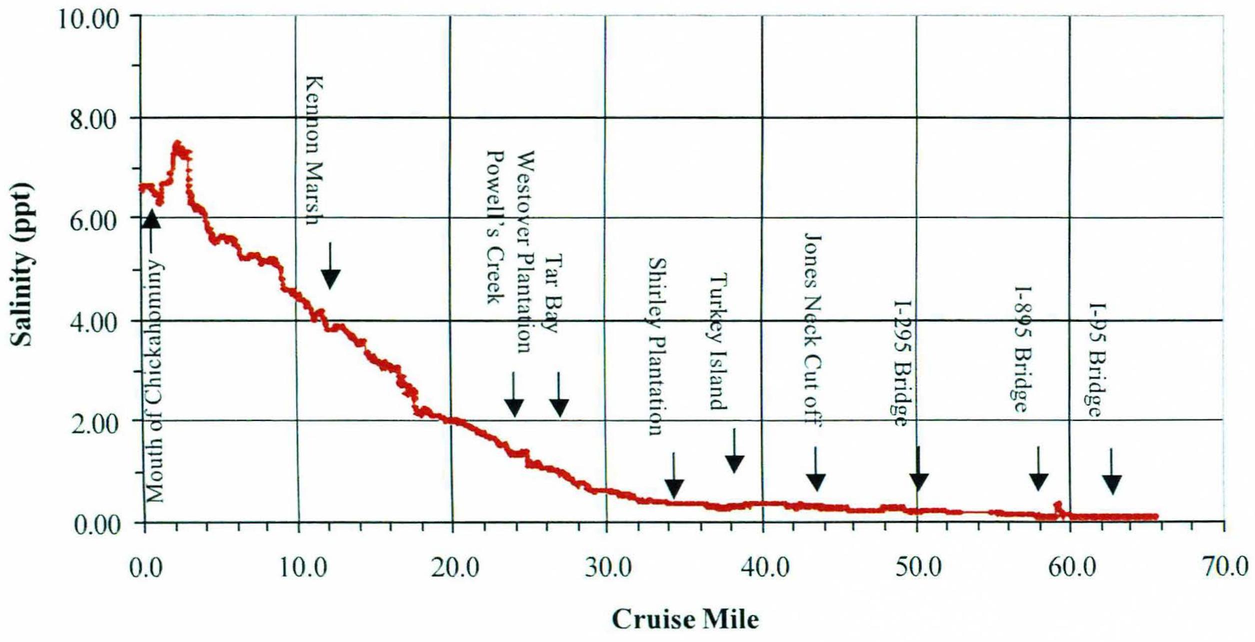


Figure 3-18 Upper James River Dataflow Cruise - Sept. 3, 2002
Salinity (ppt)



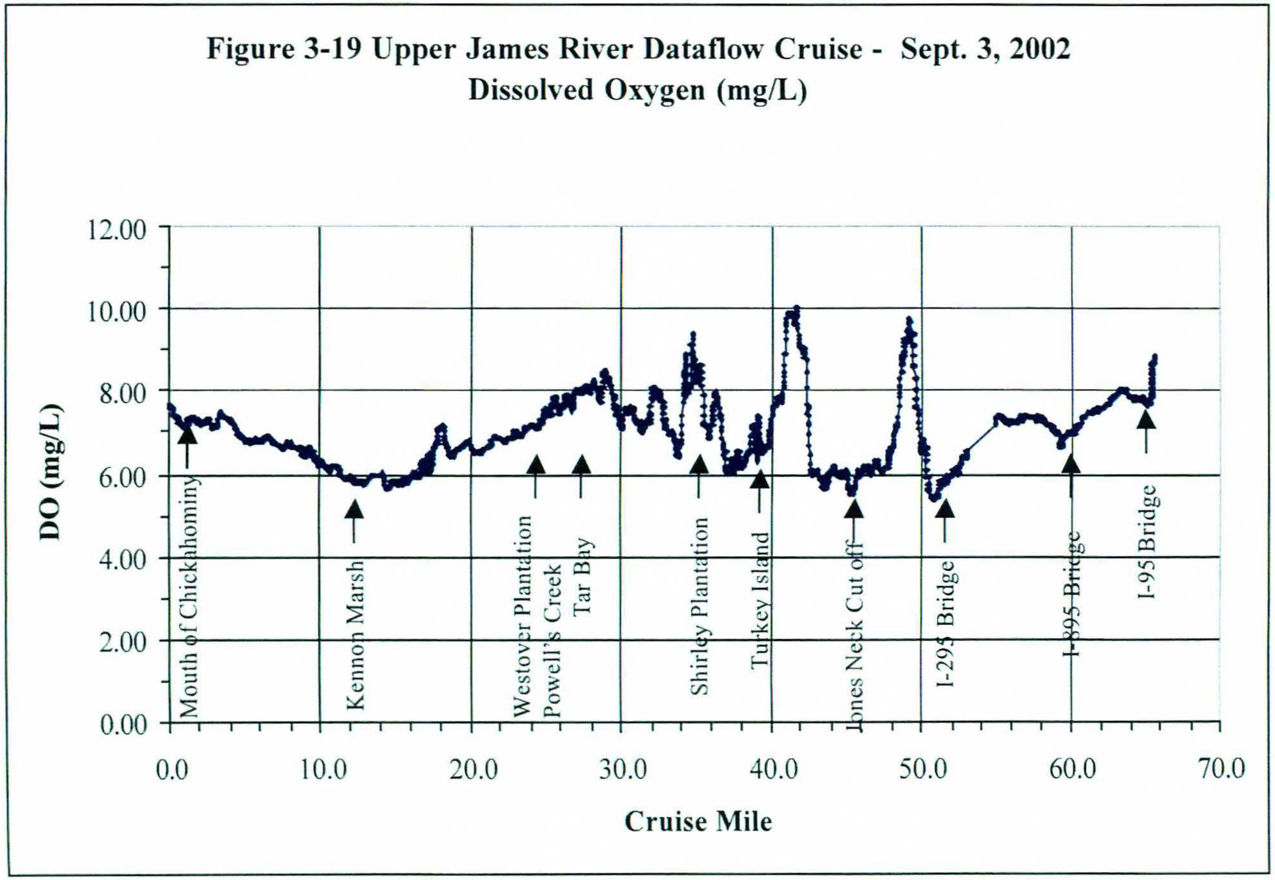


Figure 3-19 Upper James River Dataflow Cruise - Sept. 3, 2002
Dissolved Oxygen (mg/L)
DO (mg/L)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
Cruise Mile
Mouth of Chickahominy
Kennon Marsh
Westover Plantation
Powell's Creek
Tar Bay
Shirley Plantation
Turkey Island
Jones Neck Cut off
I-295 Bridge
I-895 Bridge
I-95 Bridge

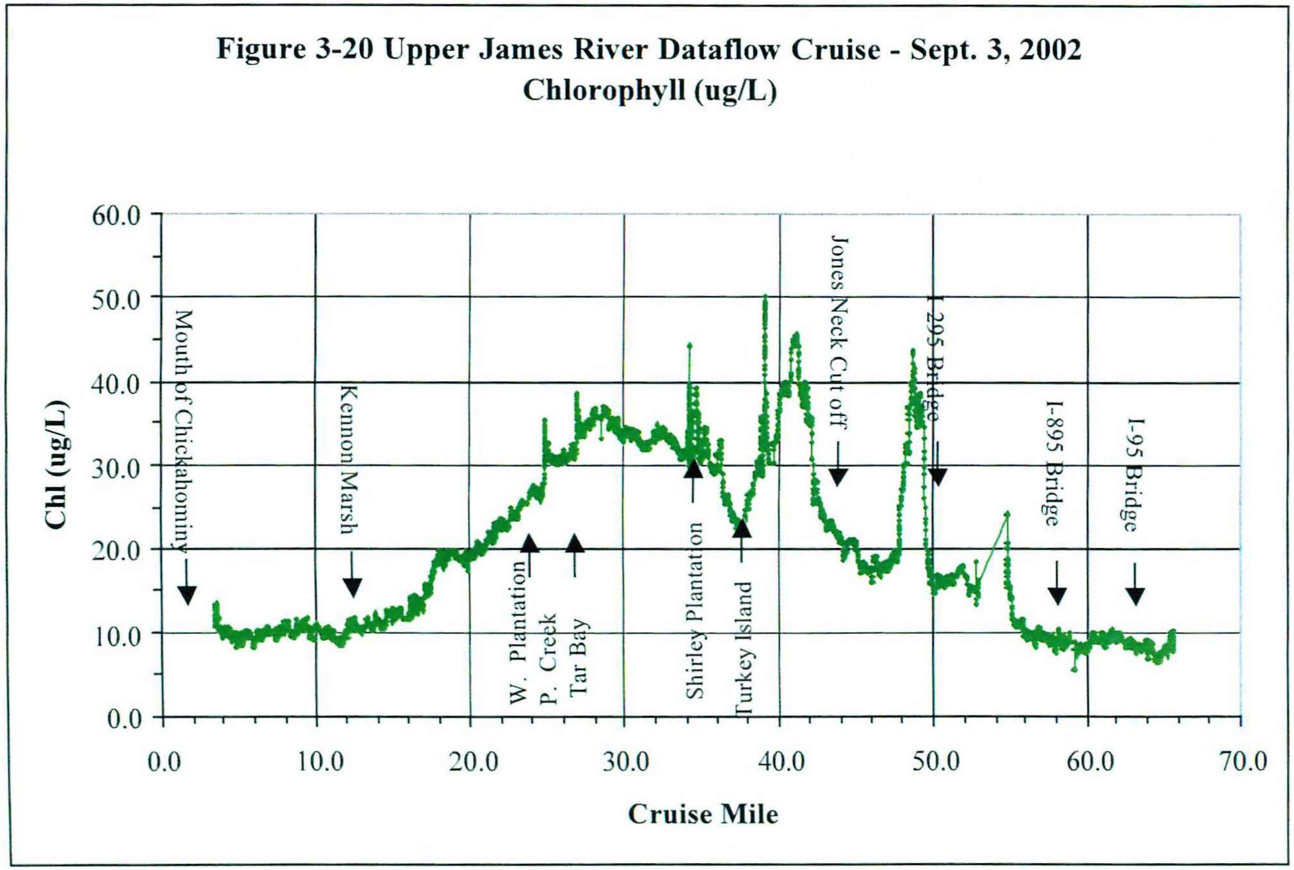


Figure 3-20 Upper James River Dataflow Cruise - Sept. 3, 2002
Chlorophyll (ug/L)
Chl (ug/L)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
Cruise Mile
Mouth of Chickahominy
Kennon Marsh
W. Plantation
P. Creek
Tar Bay
Shirley Plantation
Turkey Island
Jones Neck Cut off
I-295 Bridge
I-895 Bridge
I-95 Bridge

Figure 3-21 Upper James River Dataflow Cruise - Sept. 3, 2002
Turbidity (NTU)