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# Restoration of Submerged Aquatic Vegetation (SAV) in the Tidal Freshwater James River: Year 2

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# RESTORATION OF SUBMERGED AQUATIC VEGETATION (SAV) IN THE TIDAL FRESHWATER JAMES RIVER: YEAR 2

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**HOPEWELL REGIONAL WASTEWATER TREATMENT FACILITY**
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**Hopewell, Virginia 23860**

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# EXECUTIVE SUMMARY

Submerged aquatic vegetation including wild celery (*Vallisneria americana*) and redhead grass (*Potamogeton perfoliatus*) supplied by the Chesapeake Bay Foundation and the USDA Plant Materials Center in Beltsville, MD, were transplanted in June and July 2000 to three areas in the Hopewell estuary region of the James River by the Virginia Institute of Marine Science. The three shallow water areas (<0.3m MLW) were locations of previous transplants in 1999 that were expanded with additional transplants in 2000. The SAV transplants were sampled by VIMS for survivorship and growth at bi-weekly to monthly intervals and, concurrently, water quality sampling was conducted at bi-weekly intervals by the Hopewell Regional Wastewater Treatment Facility for nutrients, chlorophyll a, suspended solids, water transparency and other chemical and physical constituents. Objectives of the study were to expand the SAV transplanted plots within the study areas, evaluate the use of different regional source stocks on transplant success, and relate the response of the transplants to water quality conditions in the shallows to evaluate the relationships between water quality and SAV habitat recovery.

Results demonstrated successful growth and survival of the wild celery transplants at each of the sites. Success rates of the Chesapeake Bay, Wisconsin, and Florida stocks were similar. Redhead grass transplants demonstrated poor success with complete loss within two months of transplanting. Significant re-growth of the wild celery from over wintering tubers from 2000 to 2001 was observed at the Turkey Island transplant site. This marked two complete years of SAV survival there. Loss of over-wintering tubers at the other sites was undetermined but may have been related to foraging activities at the sites.

Habitat conditions in 2000 were similar to 1999 at all the stations in spite of two to three times the river flow during the summer of 2000. Summertime water transparency, which is typically lowest at that time of the year, exceeded 0.4m in comparison to 1999 when levels were at 0.3m. Dissolved inorganic phosphorus concentrations were generally at or below the SAV habitat requirement threshold of 0.02 mg/l throughout the growing season. Transplants growth was successful in sediments with organic contents as high as 8%. This exceeds the recommended limit of 5% suggested for wild celery and indicates that restoration in many of the muddy shallow water sites that characterize this region of the James may be possible. In general, habitat conditions and SAV transplant in this region continue to suggest that SAV re-growth should be possible given SAV sufficient abundance to overcome the natural foraging activities of animals on the plants.

# INTRODUCTION

The James River tidal freshwater estuary is listed on the US EPA 303(d) TMDL Priority List as an impaired water body for aquatic life use attainment. Historic aerial photographs document the presence of submerged aquatic vegetation (SAV) in the tidal freshwater James during the 1940s. Since SAV abundance is one measure of the health of the river, its absence suggests that the water quality of the river is in question. However, despite high nutrient and chlorophyll levels at certain times of the year, the James River does not exhibit the typical signs of eutrophication that would be expected. In addition, while low dissolved oxygen levels have been recorded, the James does not exhibit the acute or chronic conditions reported in other estuaries.

The Commonwealth of Virginia Draft Tributary Strategy, "Goals for Nutrient and Sediment Reduction in the James River," identifies reduced light penetration preventing the growth of SAV as one of the key issues regarding water quality and living resource impacts. The strategy states, "Restoration of grass beds to the upper tidal river will greatly expand existing recreational fishing opportunities for largemouth bass and other tidal freshwater sport fish. Once grass beds gain a foothold, they will also begin to improve water quality themselves by stabilizing shorelines, minimizing re-suspension of sediments into the water due to wind and waves, and filtering nutrients out of the water." Since SAV is a vital resource that produces oxygen; provides a nursery habitat, food, and protection for a variety of aquatic organisms; and traps sediment, it serves as an important feature and crucial indicator of the health of the James River. Its distribution and abundance have been closely tied to water quality conditions (Batiuk et al. 1992). Therefore, restoration efforts must be closely tied to water quality and water quality improvements.

Analysis of historical aerial photographs and ground survey reports for SAV in the James River revealed evidence that shallow water areas of the James River near the City of Hopewell supported SAV growth until the mid-1940's. Since then SAV has been found only in scattered patches in a few small tributary creeks in this region of the tidal, freshwater James River (Moore et al. 1999). The current lack of re-growth of SAV in many of these shallow water areas may be related to a number of possible factors including (Batiuk et al. 1992):

- Poor water quality due to high turbidity and high nutrient levels,
- Poor sediment characteristics (high organic content),
- Physical limitation due to biological or physical disturbance,
- Limited SAV propagule supply.

Freshwater SAV are a potentially important component of the ecosystem because of their value to fish and waterfowl, and their recovery can be an important catalyst for positive ecosystem change throughout the James River region as they have been in the upper Potomac River. Chesapeake Bay Model evaluations of the continuing improvement to point source discharges in the region of the James suggest that water quality in many areas may be suitable for SAV growth. One way to assess the efficacy of the various hypotheses is to use SAV transplants to test the current suitability of the areas for SAV re-colonization. Using SAV plants directly can provide an integrated measure of habitat suitability that cannot be determined solely by discreet monitoring of physical and chemical habitat conditions. In addition, once established they can provide a local source of propagules to hasten recovery.

The EPA Water Quality Model provides an indication of how SAV are likely to respond to changes in water quality. Even at the limit of technology, the model predicts limited increases in SAV in the James River. The model has a number of factors that provide a conservative prediction on how living resources will respond to changes in water quality. In particular, the model does not:

- Contain a strong feedback mechanism to predict the localized water quality benefits that would results from SAV establishment,
- Estimate SAV growth at the one-meter contour level, yet most SAV re-establishment in the James River could be expected at the 0.5 meter level or less.
- Use a single species to predict response and that species only responds under fairly favorable conditions.

In 1999, the Hopewell Regional Wastewater Treatment Facility (HRWTF) began a submerged vegetation study in partnership with the Chesapeake Bay Foundation (CBF) and the Virginia Institute of Marine Science (VIMS) to transplant and introduce underwater grasses to the tidal freshwater James River and to study the relationships between SAV transplant survival and water quality and habitat conditions. Objectives of the initial project were to:

1) Develop and evaluate 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 sites of the Hopewell region of the James River estuary and grow into self-perpetuating underwater grass beds.
3) Determine if the response of the transplants is related to specific water quality conditions at the sites, site characteristics, or physical disturbance.

Results of the 1999 study (Moore et al. 2000) indicated that nursery-grown, bare-rooted, unanchored shoots of wild celery (*Vallisneria americana*) could be successfully transplanted in very shallow depths of less than 0.5m at mean low water (MLW). Initial tests with a second species of transplants of wild stock sago pondweed (*Potamogeton pectinatus*) were less successful as many of these canopy-forming plants were lost to dislodgement or breakage by tidal currents and waves. Water quality conditions among the three transplant sites were comparable throughout most of 1999. Levels of total suspended solids were typically highest in the spring and decreased to lowest levels in October, while chlorophyll concentrations were highest in July and August when they comprised their largest seasonal proportion (>20%) of total suspended particle load. Water transparency was lowest in the late summer with minimum secchi levels of 0.3m or less in August and September. Sediment organic content at the sites typically ranged from approximately 2.5% to 5%, which are within the range of conditions suitable for SAV growth.

SAV growing season habitat requirement for growth to 1m depths (Dennison et al. 1993) were not met in 1999 for light attenuation, secchi depth, and TSS concentration at any of the sites. Even though chlorophyll concentrations were high during the summer, overall reductions in chlorophyll alone, even to zero concentration, were predicted to be insufficient for SAV growth during 1999 at depths of one meter or greater due to the residual turbidity from the suspended sediments and dissolved organic matter. However, calculations of the growing season percent light through the water (PLW) and percent light to the leaf (PLL) to a depth of 0.3m using EPA's Technical Synthesis II Habitat quality Model (Batiuk et al. 2000) predicted SAV survival at only one of the transplant sites (Shirley Cove). The transplants did grow and expand at the planting depth of 0.3m at all the sites. This may have been due to rapid leaf growth and elongation that diminished the effective water column over the plant leaves and therefore increased the effective PLW. Additionally, the model predicted greater epiphyte fouling on the transplant leaves than was actually observed. This decreased the predicted PLL.

Protection of the transplanted SAV propagules from herbivory for at least the first growing season appears necessary for adequate survival. Observations from transplanting efforts with wild celery in the Potomac River, as well as other areas in the upper Chesapeake Bay in Maryland suggest that eventually, as the stands of SAV become established and more numerous in an area, the herbivory should decrease.

Until 1999 no transplants of SAV had been attempted in the tidal freshwater region of the James River. Although initial results indicated that SAV could grow and reproduce in the Hopewell estuarine region of the river, further studies were necessary and additional information needed during different years in order to better evaluate the cause/effect relationships between James River water quality conditions and SAV to determined if SAV can survive, reproduce, propagate, and succeed in the tidal freshwater James River.

### 1.1 Objectives

During 2000-2001 a second year restoration project in the Hopewell region of the James River was conducted. The objectives were to:

1) Enlarge the SAV plots at the three sites currently vegetated to serve as habitat as well as a source of propagules for enhanced recovery of SAV in these areas.
2) Monitor the sites for water quality and SAV growth and survival. Relate the response of the transplants to changing water quality conditions in the shallows during the growing season of different years to evaluate the cause/effect relationships between water quality and SAV habitat recovery, and to provide this information to assist in the development and implementation of tributary nutrient and sediment reduction strategies.
3) 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

Four shallow water sites (Fig. 2-1) were used for SAV transplanting and water quality monitoring in the Hopewell region of the James River estuary in 2000-2001:

| | | |
|---|---|---|
| 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 |

Due to dredge disposal operations at the Shirley Cove site, no transplants were placed there in 2000. However, water quality monitoring was continued from 1999 to assess any long-term water quality changes at that location.

## 2.2 SAV Transplant Establishment

On April 7, 2000, two to four, 10m by 30m exclosures of staked, plastic poultry fencing were established at the Turkey Island, Tar Bay and Powell's Creek transplant sites. Subsequently on June 5, 2000, replicated 2m x 2m plots of wild celery planting units were established in each of the exclosures with assistance of CBF and HRWTF personnel as well as citizen and student volunteers. At each of the transplant sites 2m x 2m arrays of planting units were transplanted in unprotected areas adjacent to the exclosures to test for exclosure effect, especially relative to transplant loss by herbivory. The wild celery plants were supplied by CBF and consisted of nursery grown plants from native Chesapeake Bay (CB) stock. Additionally, at the Turkey Island site nursery grown varieties of wild celery originating from Wisconsin (W) and Florida (F) stocks were similarly planted in replicated arrays. Each array was sampled by divers for SAV planting unit survival, SAV relative abundance and plant vigor at semi-monthly to monthly intervals throughout the 2000 growing season. Transplants surviving from the 1999 restoration at the Turkey Island site were similarly monitored for survival.

Several test transplants of *Potamogeton perfoliatus* (red-head grass) were made at the Turkey Island, Tar Bay and Powell's Creek sites on June 5, 2000. The transplant material was obtained from the USDA National Plant Materials Center in Beltsville, MD. Transplants consisted of whole sods of shoots, root-rhizomes and sediments grown in approximately 2 sq. ft. flats. Redhead grass is a freswater/oligohaline canopy forming SAV species similar to *Potamogeton pectinatus* (sago pondweed) found in the upper Chesapeake Bay as well as in non-tidal lakes and ponds.

### 2.3 Sediment Characterization

Sediments in each of the transplant plots were characterized by use of replicate cores taken at each of two locations (shallow and deepest side) within each exclosure. The six-inch deep cores were mixed to provide a homogeneous sample, dried at 50 °C to a constant weight, weighed for dry weight, ashed for 5 hours at 550°C and weighed again. Organic content was determined by weight difference.

### 2.4 Water Quality Monitoring

Personnel of HRWTF conducted periodic water quality sampling at bi-weekly intervals. Water samples were collected at depths of 0.5m to 1.0m in the shallow littoral area immediately adjacent to the transplant locations. Parameters measured included air and water temperatures, secchi depth, pH, dissolved oxygen (DO), conductance, total Kjeldahl nitrogen (TKN), nitrate + nitrite ($NO_x$), ammonium, orthophosphate (DIP), total phosphorus (TP), total suspended solids (TSS), total organic carbon (TOC) and chlorophyll a (Chl a). Continuous monitoring (15 minute interval) of water quality was undertaken by HRWTF personnel for one to two week intervals at Turkey Island, Tar Bay and Turkey Island in June and October 2000. At each site pH, temperature, conductivity and turbidity (NTU) measurements were recorded by the use of YSI 6920 data logging sondes. Unfortunately the depths of placement at the sites allowed occasional inter-tidal exposure that confounded data recording. The results are therefore not included in this report.

# 3.0 RESULTS

## 3.1 Transplant Survival

Survival of the Year 1999 and Year 2000 wild celery transplants for the Powell's Creek (PC), Tar Bay (TB) and Turkey Island (TI) transplant sites are summarized in Figure 3-1, 3-2 and 3-3 respectively. Although approximately 60% to 80% of the Year 1999 transplants were present at the end of the 1999 growing season (Moore et al. 2000) significant re-growth was only evident at Turkey Island in the spring of 2000. Typically, over winter losses in below ground tubers necessary for re-growth the following spring can be related to waterfowl foraging and are unrelated to water quality or other environmental factors. However, approximately 50% of the Year 1999 planting units at Turkey Island (CB1999) re-sprouted in 2000 and continued new shoot cluster production throughout the 2000 growing season. In spite of the protective fences initial loss of the transplants was high within the first two weeks after transplanting and several of the plots at each of the sites were re-planted on June 19, 2000. Complete loss within approximately one month of all of the transplants that were placed outside of the exclosures indicates the strong grazing pressure exerted by resident fish, or turtles at the sites. After these initial losses the protective fences were reinforced with re-bar that was woven through the skirt of plastic mesh, which extended out across the bottom. This effectively reduced planting unit herbivory and those plots of transplants that were not initially grazed re-grew (e.g. PC1, TI1, TI2, TB1).

There were no noticeable differences in the growth of the Wisconsin (WI), Florida (FL), and Chesapeake Bay planting stocks. The FL stock re-grew quickly after the initial herbivory while the WI stock showed less recovery. The performances of both, however, were within the range of responses observed for the CB stock. By the end of the growing season in October when normal end-of-year die-back of shoot material occurred, 40% to 80% or more of the initial planting units remained at all the sites.

Transplants of the redhead grass showed little growth at the transplant sites, in contrast to the wild celery and no plants were evident by the end of August, approximately two months after transplanting.

Initial survival estimates in May 2001 revealed again significant re-growth of wild celery from over wintering tubers at the Turkey Island site only. Only a few shoots were observed at the other sites, indicating either significant over-wintering predation on belowground structures or poor production and survival of tubers at these locations. By July 2001 the wild celery transplants initially planted at Turkey Island had spread considerably and nearly filled one of the exclosures. This marked two continuous growing seasons of wild celery growth and survival at this site. Resident waterfowl had been noticed regularly in the vicinity of the Tar Bay and Powell's Creek transplant sites but none in the proximity of the Turkey Island site during sampling visits. This may be indicative of possibly higher predation at these locations but these observations are only speculative.

## 3.2 Habitat Conditions

### 3.2.1 Sediments

Sediments at most of the transplant sites (Figure 3-4) were similar to those levels found in 1999 (2% to 5% organic content). One objective of this year's transplanting project was to transplant into areas where the sediments were more organic-rich (i.e. >5%) to evaluate if there was any correspondence between SAV growth and survival and sediment type. Among the individual exclosures at the sites the highest organic matter sediment occurred in PC4 at Powell's Creek and TI2 and TI3 at Turkey Island. Quantitatively, there appeared to be little difference in the survival within sites that could be related to the sediment organic content although both PC4 and TI3, that had very high organic content sediments, had the poorest survival rates. Sediments at the Tar Bay site (TB1 and TB2) were quite soft and unconsolidated, however growth and survival throughout the 2000 growing season were quite good. These sediments appear representative of much of the shallow water substrate found in this region of the James River and growth and survival of the transplants there suggest that substrate conditions may not be limiting for SAV re-growth.

### 3.2.2 Water Quality

Water quality characterization at the sites was hampered to a degree by the lack of sampling during the months of June and July due to HRWTF sampling vessel repair. In comparison with the 1999 water quality measurements (Moore et al. 2000) summer water temperatures (Fig. 3-5) were slightly lower in 2000 compared to 1999 with maximums not exceeding 30 °C in 2000 compared to 30-34 °C in 1999. Conductivity (Fig. 3-6) was also lower, with annual fall maximums of 200-300 μmhos in 2000 compared to 500-900 μmhos in 1999. DO concentrations (Fig. 3-7) in the shallows were typically above 7 mg/l. The bi-modal pattern observed in 1999 of low daytime DO concentrations in the spring and early summer, high values in the summer and low values again in the fall could not be determined for 2000 due to the lack of sampling for June and July. Seasonal pH levels (Fig. 3-8) largely paralleled chlorophyll a concentrations, suggesting that pH in 2000 was controlled to some extent by primary production.

As in the 1999 growing season study, the Shirley Cove site had the lowest suspended particle concentrations (TSS). This site is located within an enclosed dredged basin and it is likely that suspended sediments are able to settle out. Overall, among all the transplant sites, TSS levels (Fig. 3-9) appeared to decline throughout the growing season as freshwater inputs decreased, although there was considerable day-to-day variability largely due to local current and wave conditions. As in 1999 the levels generally exceeded the 15 mg/l habitat requirement (Batiuk et al. 2000) associated with SAV restoration to 1m depths.

Chlorophyll levels (Fig. 3-10) demonstrated irregular spikes to high levels (>50 µg/l) throughout the growing season. Although consistently high levels were observed throughout the summer of 1999, lack of data from June and July of 2000 precluded a direct comparison between the years. Levels at the two upstream stations (Shirley Cove and Turkey Island) were quite low (<20 µg/l) on the August 2, 2000 sampling date however. This was not observed in 1999. Overall, levels were generally above the SAV habitat requirement of 15 µg/l for much of the year. During the spring of 1999 levels were quite low (<15 µg/l) but high during the summer. In contrast in 2000 it appeared that spring concentrations of phytoplankton were higher than 1999 but no real seasonal trends were evident. The latter may again be due to the lack of data for most of the summer of 2000. Phytoplankton as a component of TSS (Fig. 3-11) was highest in Shirley Cove, due in large part to generally lower TSS levels there. Chlorophyll levels were not much higher there than the other stations however. This may be significant in that it suggests that reductions in water column suspended sediments through watershed land use controls may not result in marked higher phytoplankton levels in this region of the river due to increased light availability.

Water transparencies measured as secchi depth (Fig. 3-12) demonstrated no real trends in 2000, in contrast to 1999 when there was a distinct decrease in secchi depth (reduced water transparency) during the summer. Overall secchi disk transparencies were greater in 2000 than 1999. Depths generally exceeded 0.4m in comparison to 1999 when minimum depths in August and September were 0.3m or less. These differences may be ecologically significant. Recovery of SAV in shallow tidal areas of the upper Patuxent River was first observed when secchi reading improved from 0.25m to 0.4m (M. Naylor, MDNR, unpublished). Small changes in water transparency can have marked changes in light availability for SAV growth in shallow water habitats.

TOC, TKN and TP (Fig. 3-13, 3-14 and 3-15) generally demonstrated slight increases throughout the growing season. TOC levels were markedly higher at the most upstream site (Turkey Island) in the spring. This may have been related to freshwater inputs as conductivity was slightly lower at this station compared to the others during this period. However, there was little seasonal relationship between conductivity (Fig. 3-6) and any of the total nutrient constituents (TOC, TKN and TP). This suggests that nutrient sources in 2000 may be more local than watershed based. Overall the ranges of values were similar to those observed in 1999.

Dissolved inorganic nitrogen (DIN) and phosphorus (DIP) demonstrated different seasonal trends in 2000. DIP levels remained quite low throughout the year, except for a large spike in February. Phosphorus is generally considered the limiting nutrient for phytoplankton and epiphyte growth in freshwater tidal regions of the bay and its tributaries. As in 1999 DIP concentrations (Fig. 3-16) consistently met the SAV habitat requirement threshold of 0.02 mg/l throughout the growing season at all the sites. DIN concentrations (Fig. 3-17), which are composed largely of dissolved nitrate and nitrite ($NO_x$) in this region, demonstrated a consistent decline throughout the year. Ammonium levels were generally below detection (<0.05 mg/l). This decline in DIN indicates that uptake by the system (phytoplankton, algae and bacteria) generally exceed the inputs to the system during the warmer months. The depressions in $NO_x$ concentrations in April-May and again in August may be related to the higher phytoplankton (Chl a) levels observed during these periods.

### 3.2.3 Attainment of Conditions Suitable for SAV Growth

Model calculations of seasonal SAV habitat characteristics could not be determined due to the lack of water quality data for much of the 2000 growing season. However, qualitative comparison of water quality and turbidity levels between 2000 and 1999 suggest that in 2000 water quality conditions were at least as good as 1999. Surface conductivities were lower and therefore freshwater inputs were higher in 2000 than 1999 for most parameters. Mean monthly river flows in June, July and August of 2000 were approximately 2 to 3 times that of 1999 (USGS: Chesapeake Bay River Monitoring Program, 2000). However, habitat conditions for SAV growth in 2000 were generally equal to or better than 1999. This was reflected in the successful growth of SAV at all the sites throughout the 2000 growing season. Water clarity in the upper James River generally increases between Hopewell and Richmond. River-wide, a peak in turbidity has been typically observed in the Hopewell region with a second peak located further down river where the freshwater-saltwater mixing zone is more pronounced. The improvements in turbidity (higher secchi readings) observed in the study area in 2000 may be related to a slight downriver shift in this turbidity maximum due to increased river flow. Or, it may be related to potentially lower sediment inputs from the watershed as well as other factors such as reduced maintenance dredging of shipping channels with the resultant overboard disposal and tidal and wave reworking of these sediments.

## 4.0 CONCLUSIONS

Transplanting of wild celery into the Hopewell region of the James River was again successful in 2000 with survival at all of the sites throughout the 2000 growing season. Herbivory of the isolated transplants continues to be a problem although improvements to the exclosures, combined with regular maintenance appears adequate for protection. At the Turkey Island site survival and spreading of the transplants has continued for two growing seasons with a resulting dense bed of wild celery, the first in this region of the James in over 50 years. Over-winter survival at the other transplant sites remains problematic. Again, it is possible the losses are related to waterfowl or other organisms foraging during this period.

In spite of higher river flow during the summer of 2000 compared to 1999, SAV habitat conditions were again not limiting to growth at the shallow (0.3m) transplant depths used. Lack of water quality data during June and July precluded estimates of phytoplankton bloom intensity during the summer. However, regardless of the levels of phytoplankton during that period the documented survival of the transplants suggest water quality was suitable for growth once the wild celery became established.

Comparison of sediment types between the transplant locations indicates that wild celery will survive and grow in sediments with organic contents as high as 8% here. This observation is significant in that much of the potential shallow water habitat for SAV growth in the region of the James River appears to be of this higher organic content, muddy substrate. Because over winter survival was somewhat poorer in the exclosures with higher organic content substrate at Turkey island, the effect of substrate on long term SAV survival and growth in this region cannot be completely discounted.

Future investigations during 2001 should evaluate the propagule production to determine if any lack of re-growth during the subsequent year can be related to poor propagule production or tuber consumption by organisms. Additionally, transplantation of other SAV species other than Wild Celery should be continued. Extensive populations of SAV including *Elodea, Ceratophyllum and Hydrilla* are present in the upper Chickahominy River. Test transplants of these species should be attempted to determine their adequacy for restoration of SAV to the Hopewell region of the James.

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# APPENDIX OF FIGURES

Figure 2-1: Location of SAV Transplant and Water Quality Monitoring Sites

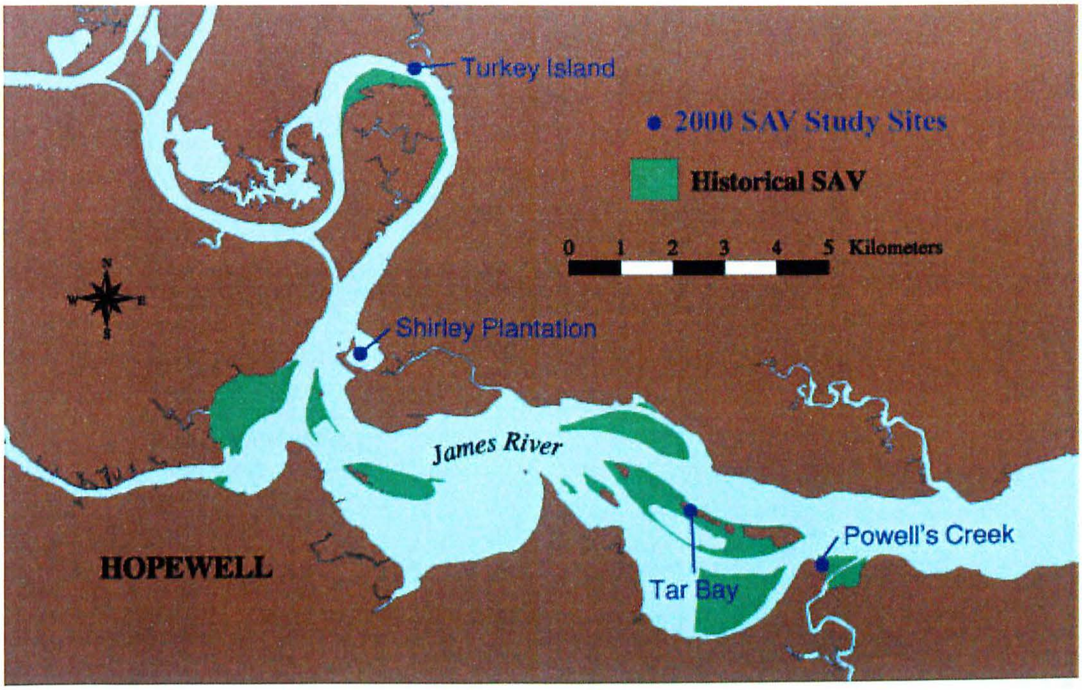


**Figure 3-1: Survival of Wild Celery and Redhead Grass Transplants at Powell's Creek.**
**(FL2000-2000 Florida Stock. WI2000-2000 Wisconsin Stock. RH2000-2000 Redhead Grass. CB2000-2000 Chesapeake Bay Stock. OUT-Located Outside Exclosure.)**

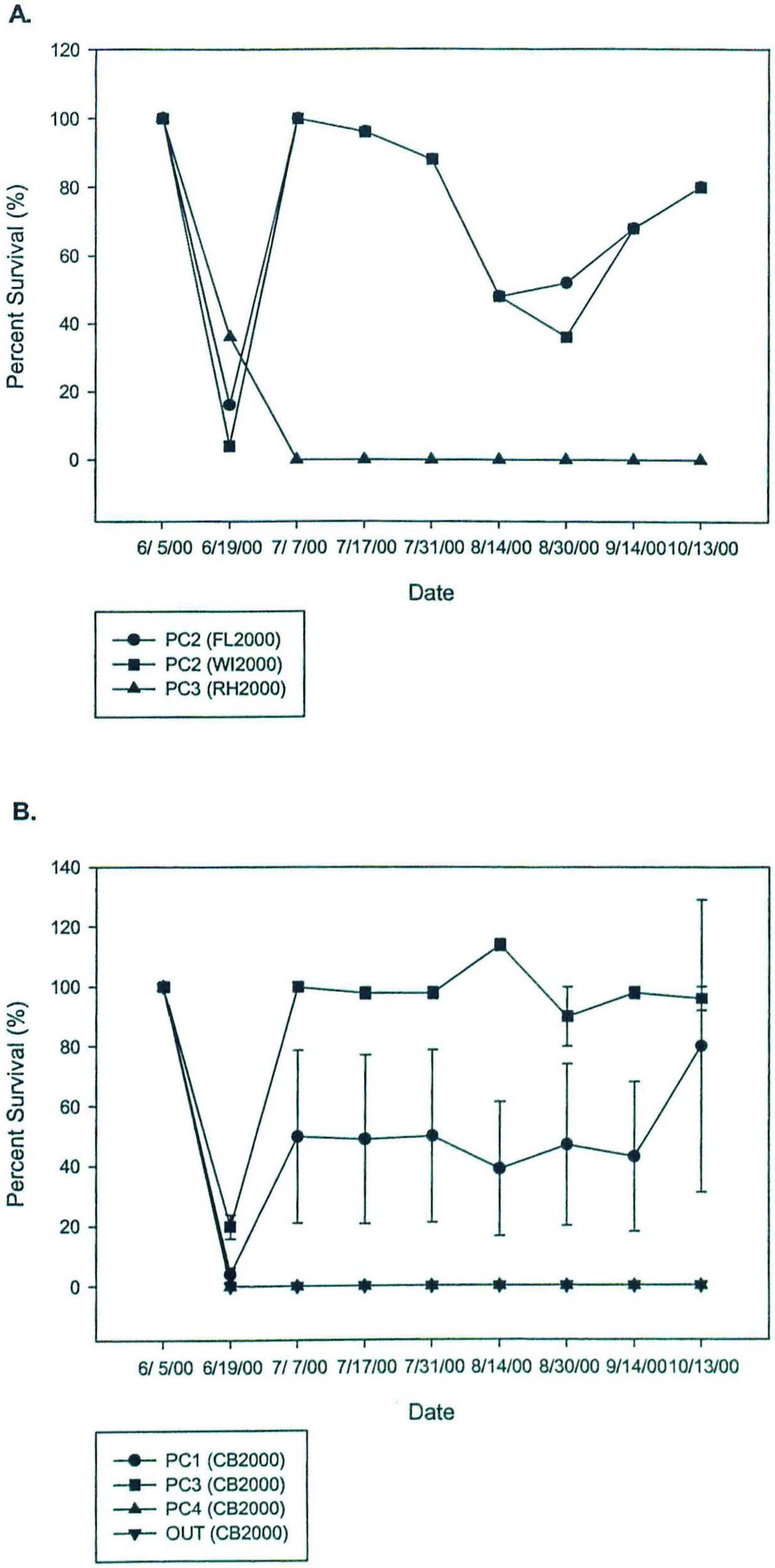


**Figure 3-2: Survival of Wild Celery Transplants at Tar Bay.**
**(CB2000-2000 Chesapeake Bay Stock. OUT-Located Outside Exclosure.)**

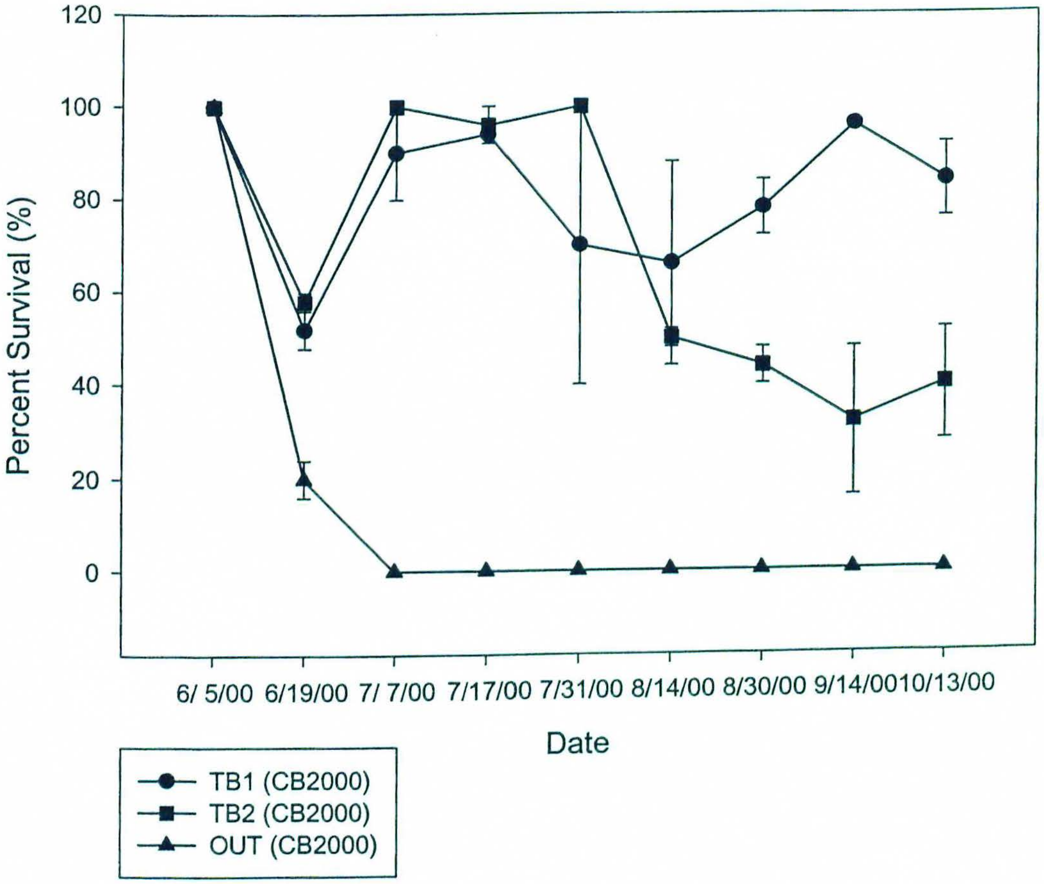


**Figure 3-3: Survival of Wild Celery Transplants at Turkey Island.**
**(FL2000-2000 Florida Stock. WI2000-2000 Wisconsin Stock. CB2000-2000 Chesapeake Bay Stock. CB1999-1999 Chesapeake Bay Stock. OUT-Located Outside Exclosures.)**

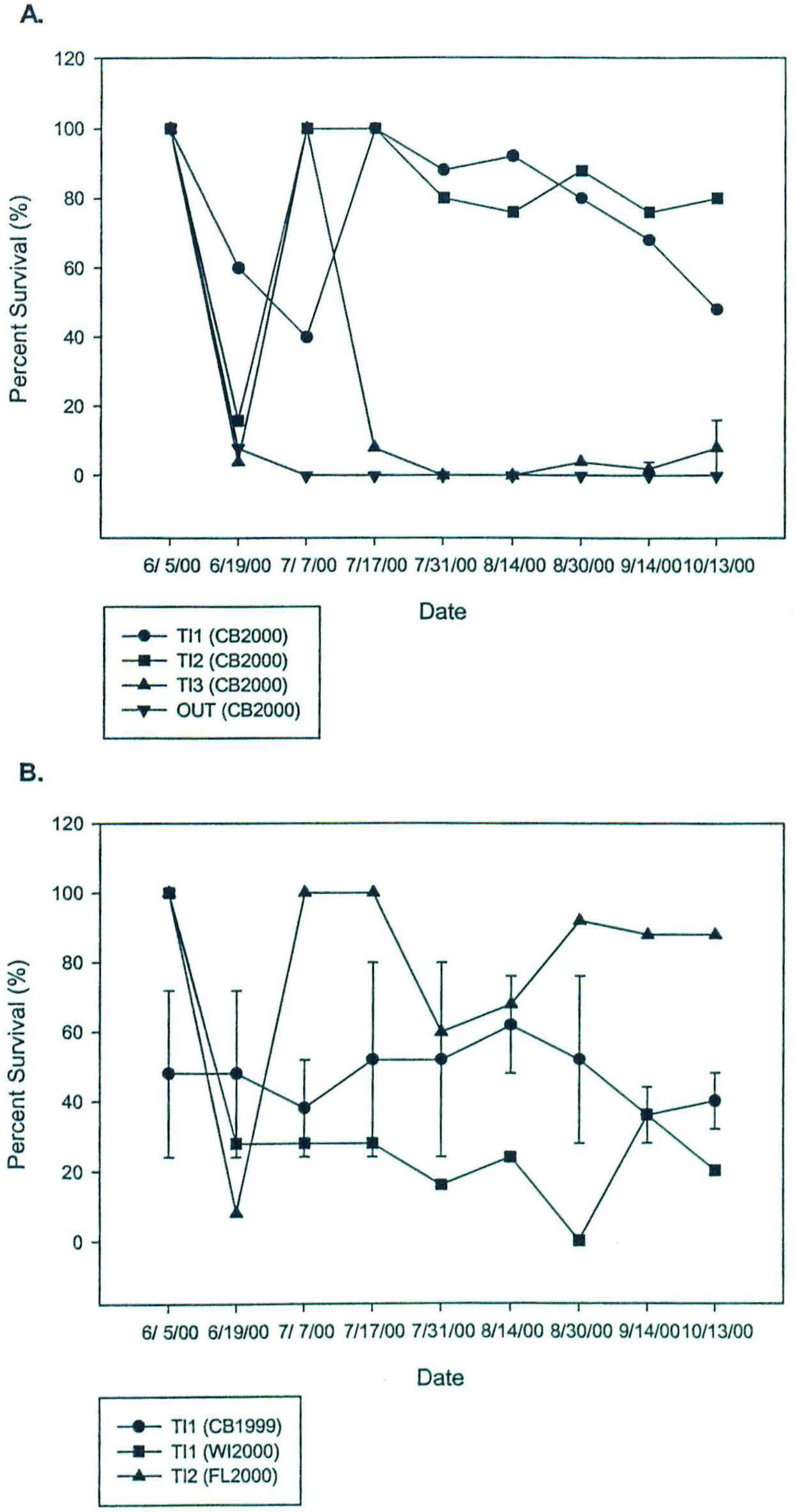
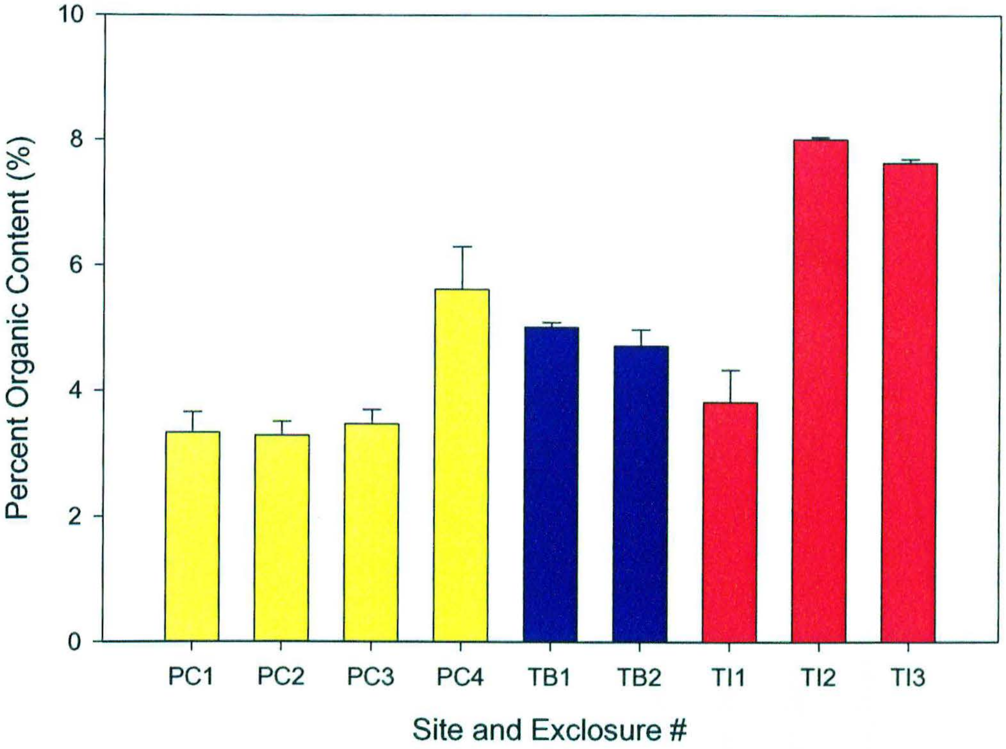
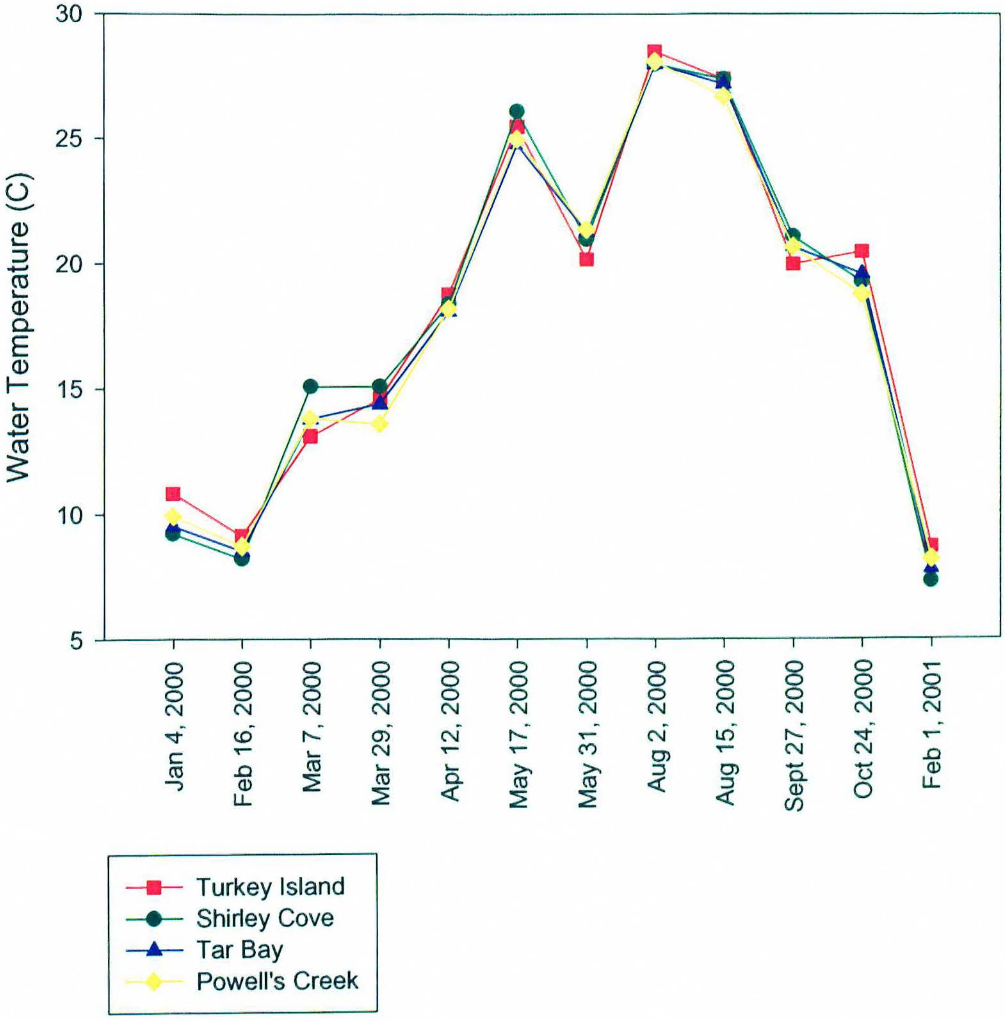


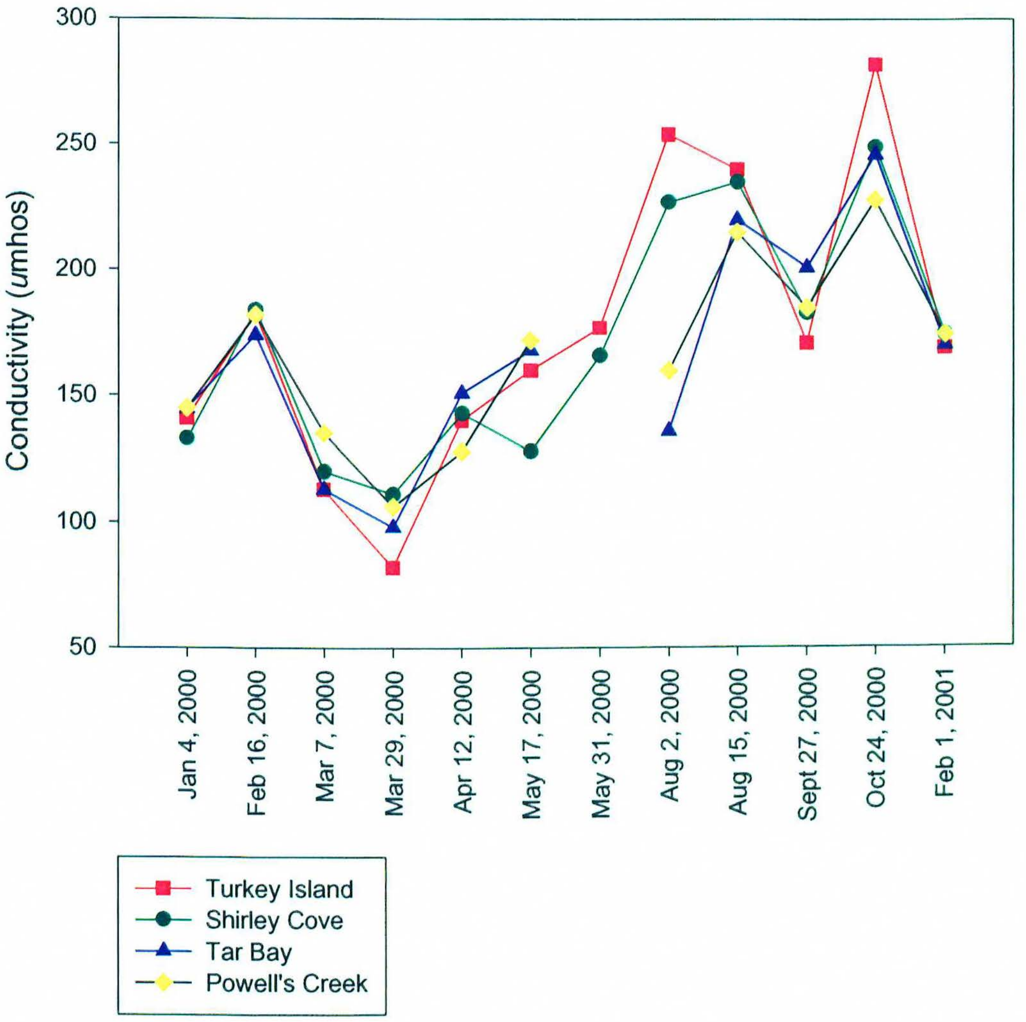
Figure 3-4: Percent Organic Content of Sediments in Exclosures. (PC-Powell's Creek. TB-Tar Bay. TI-Turkey Island.)



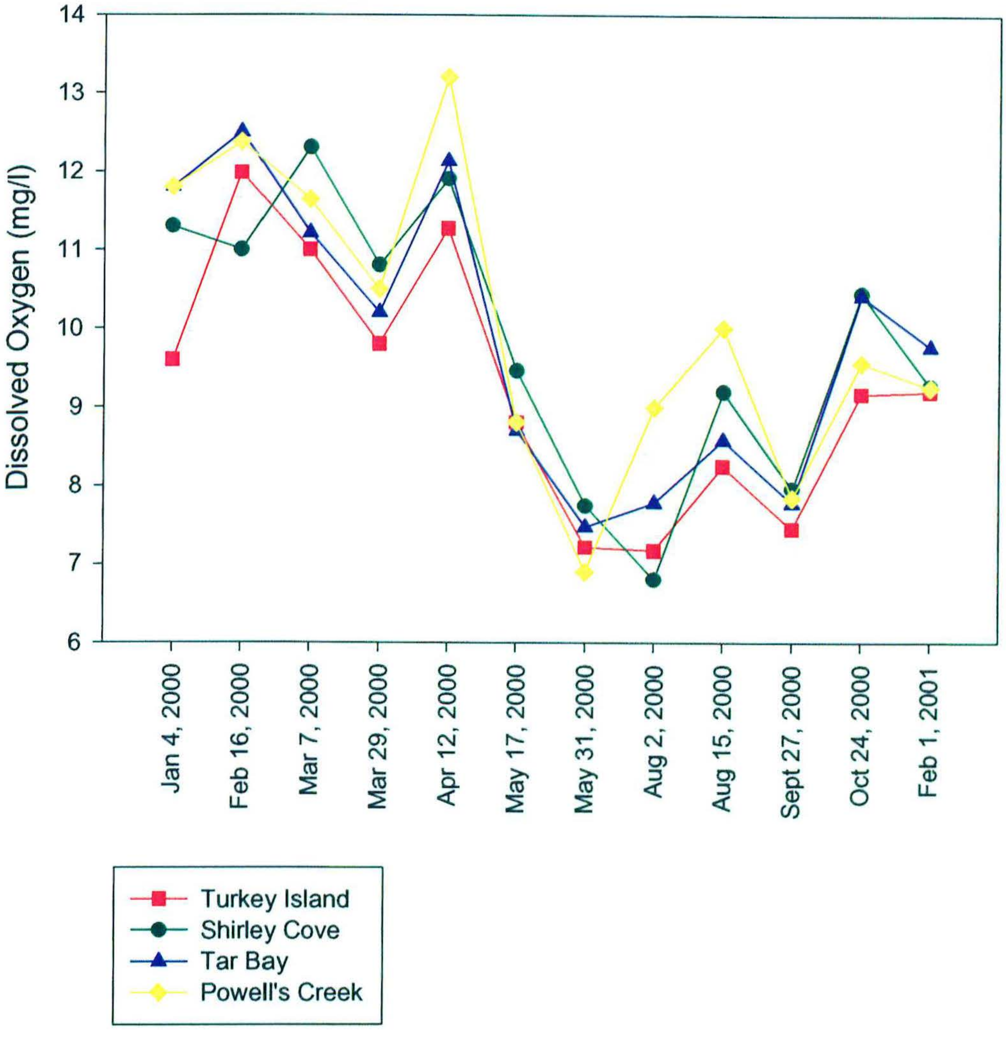
## Figure 3-5: Water Temperature



## Figure 3-6: Surface Conductivity



## Figure 3-7: Surface Dissolved Oxygen



## Figure 3-8: Water Column pH

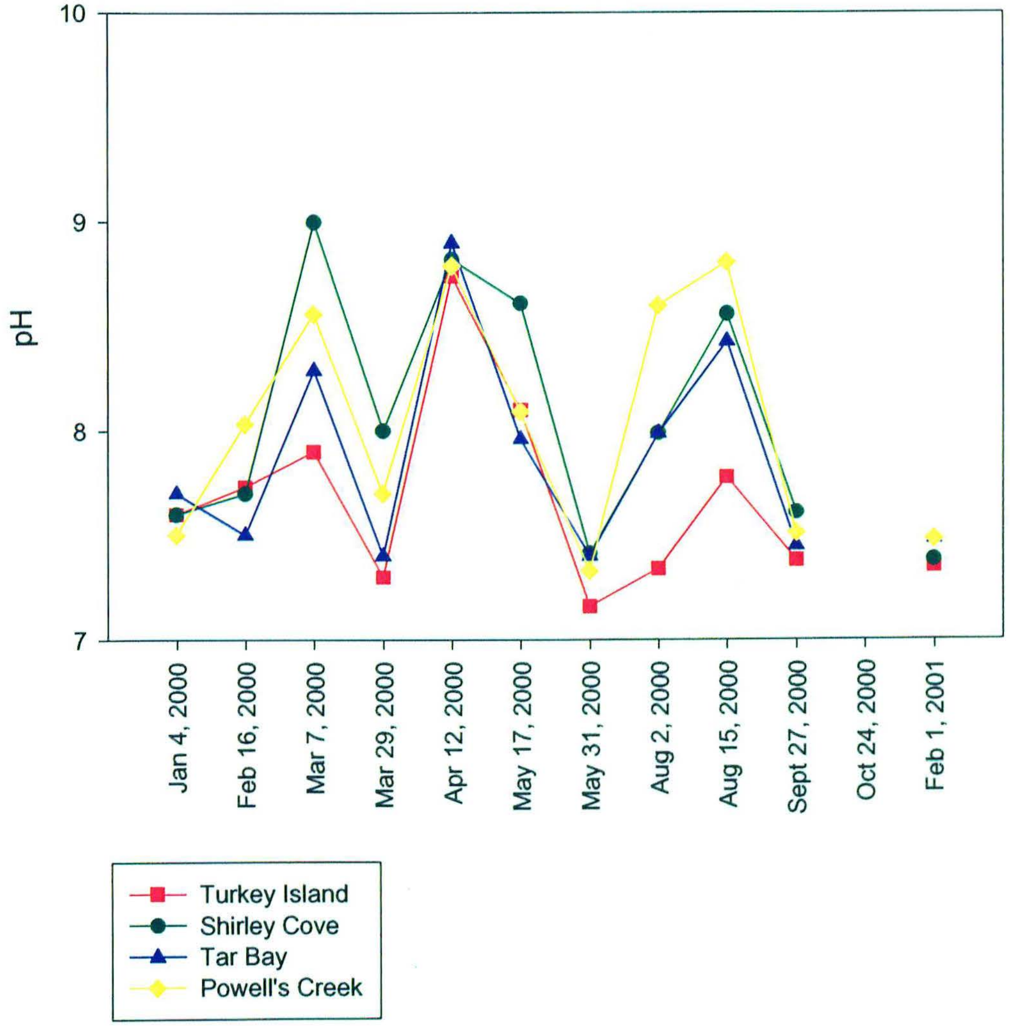
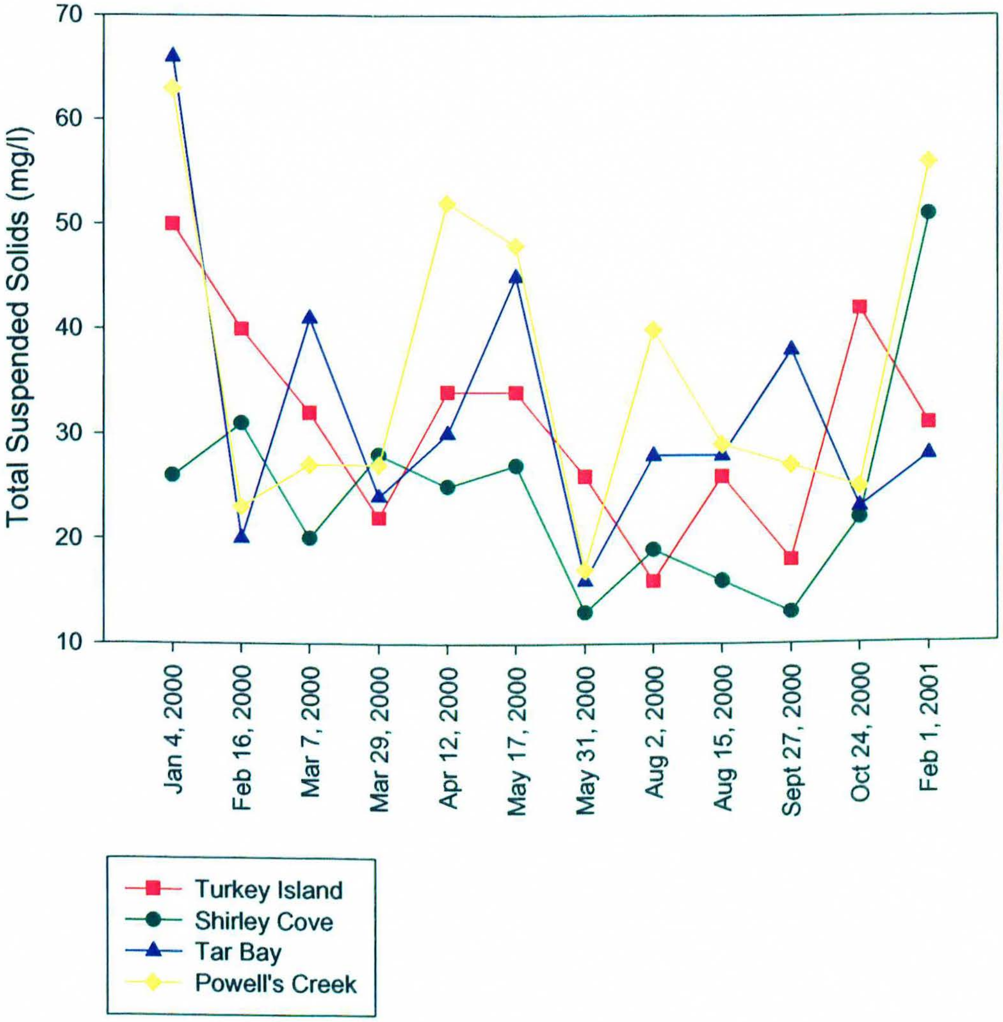
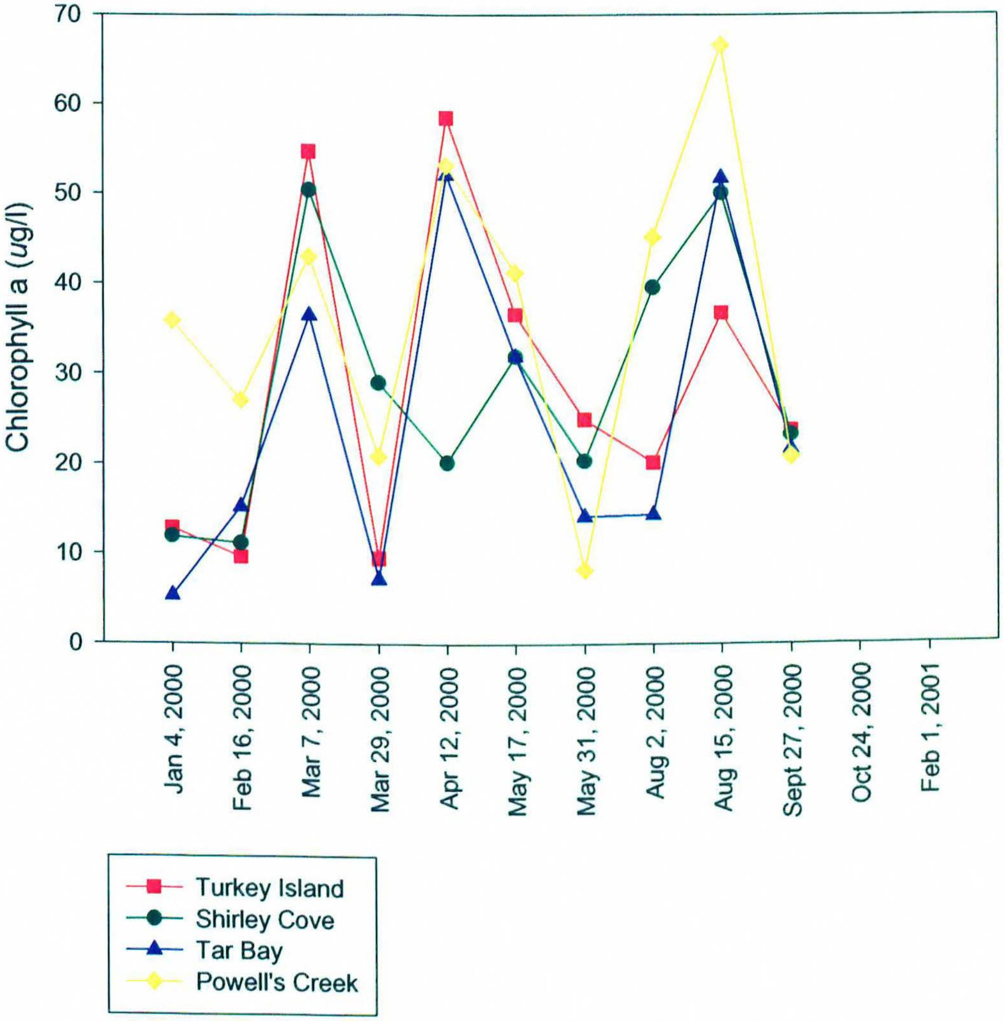


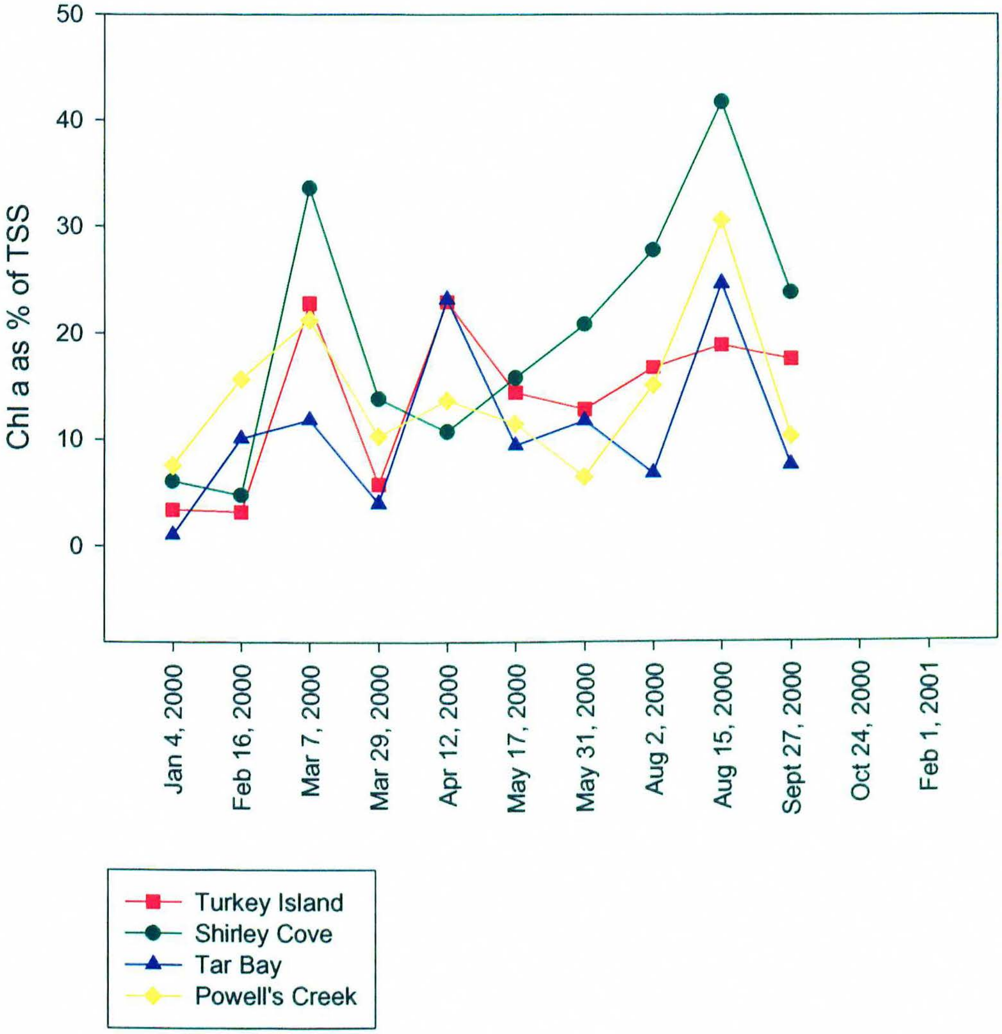
Figure 3-9: Total Suspended Solids (TSS)



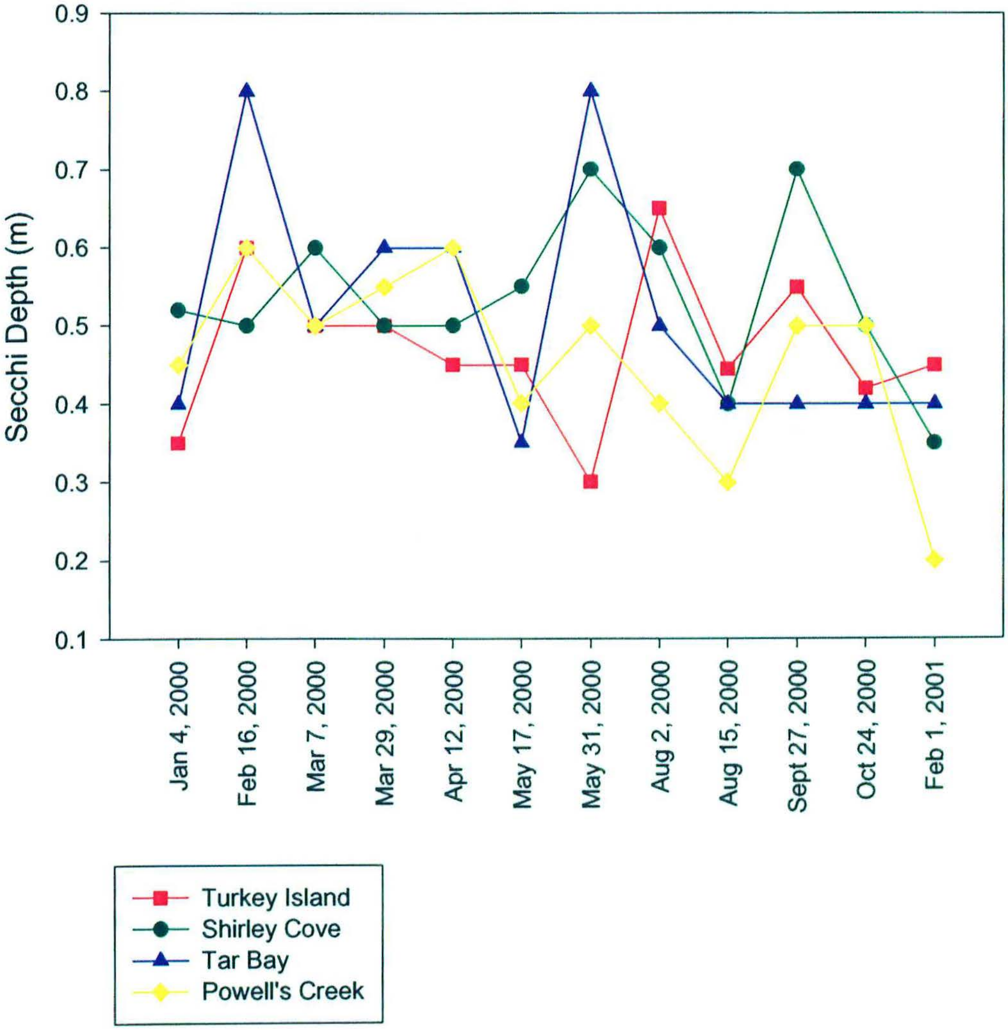
## Figure 3-10: Phytoplankton as Chlorophyll a



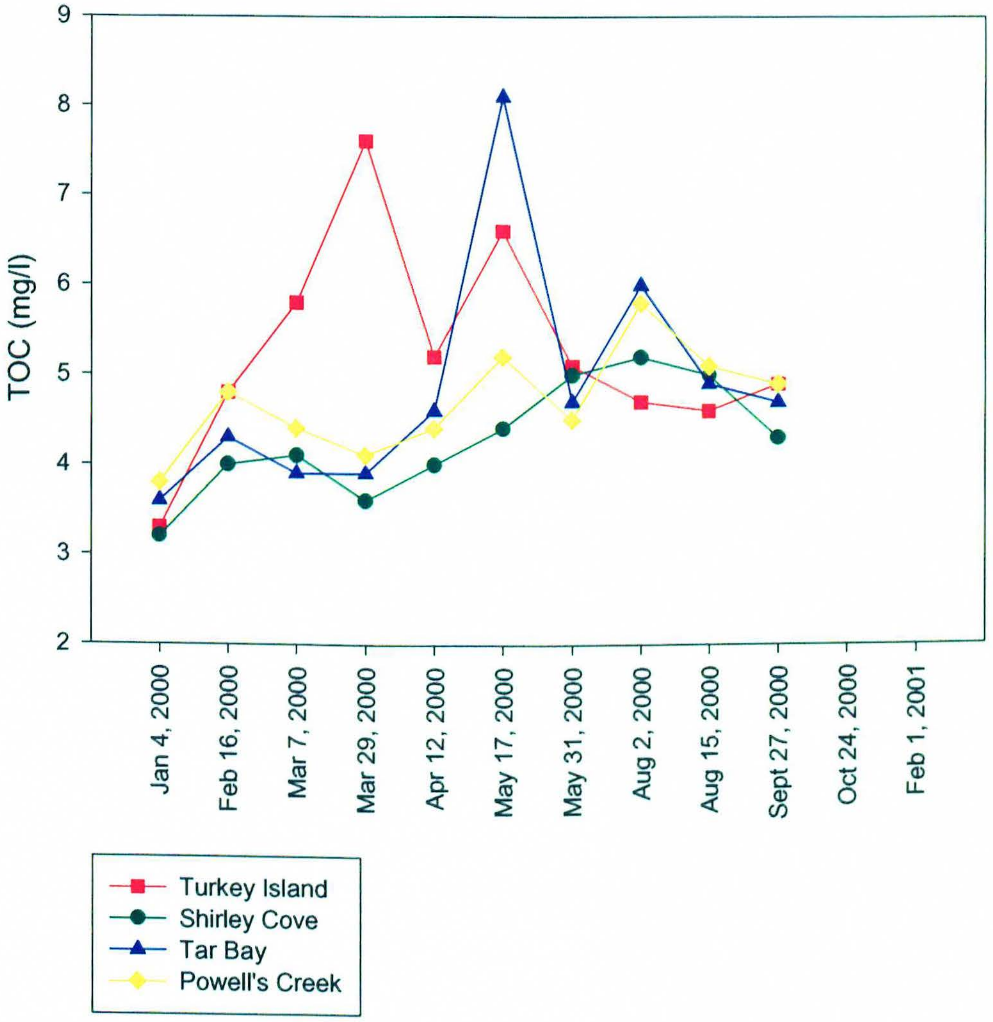
# Figure 3-11: Phytoplankton Component of TSS



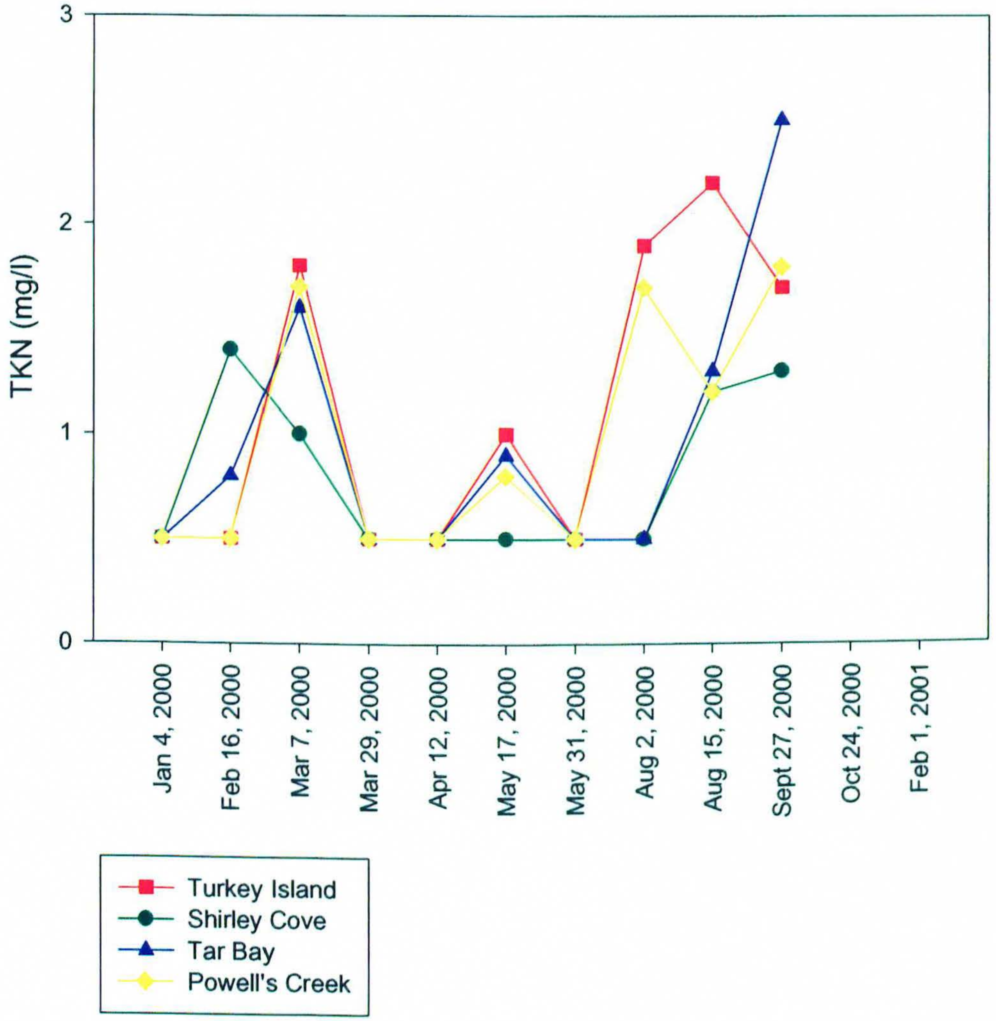
## Figure 3-12: Secchi Depth



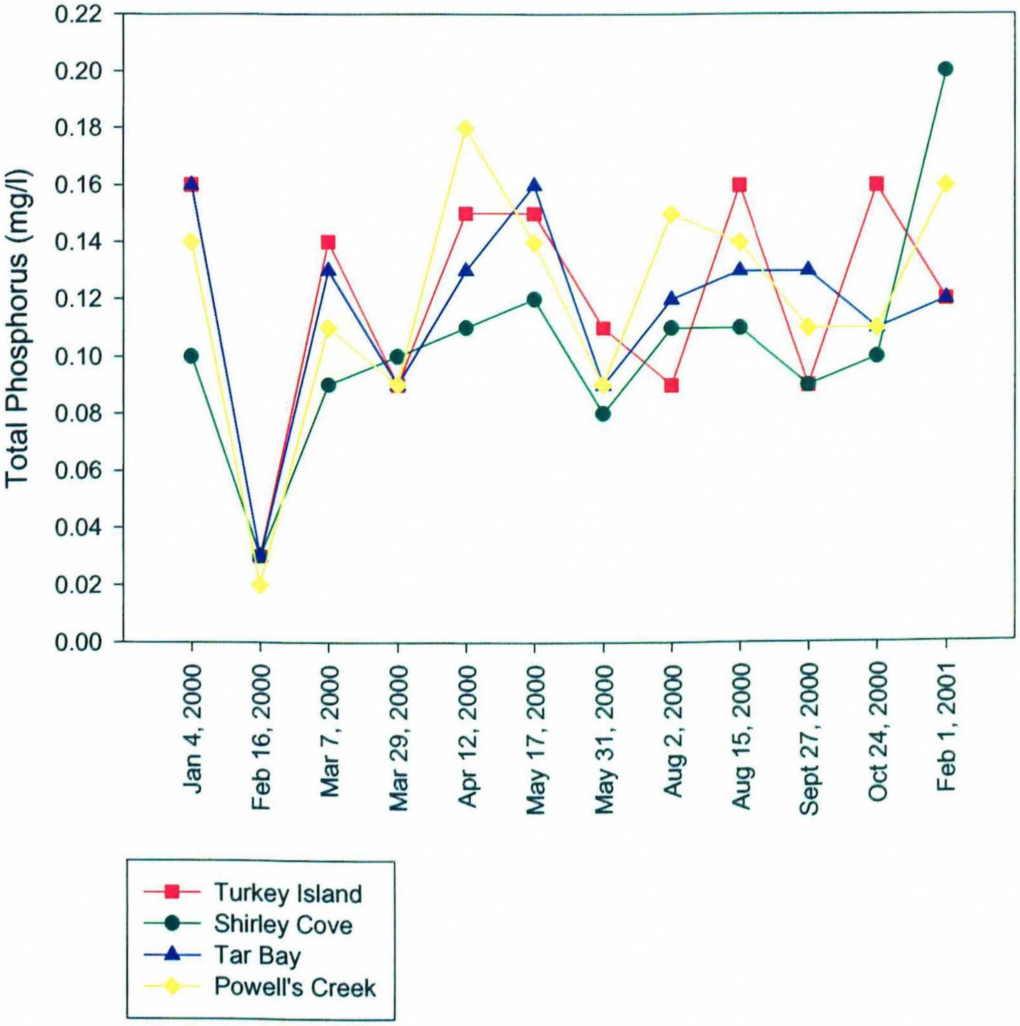
## Figure 3-13: Total Organic Carbon (TOC)



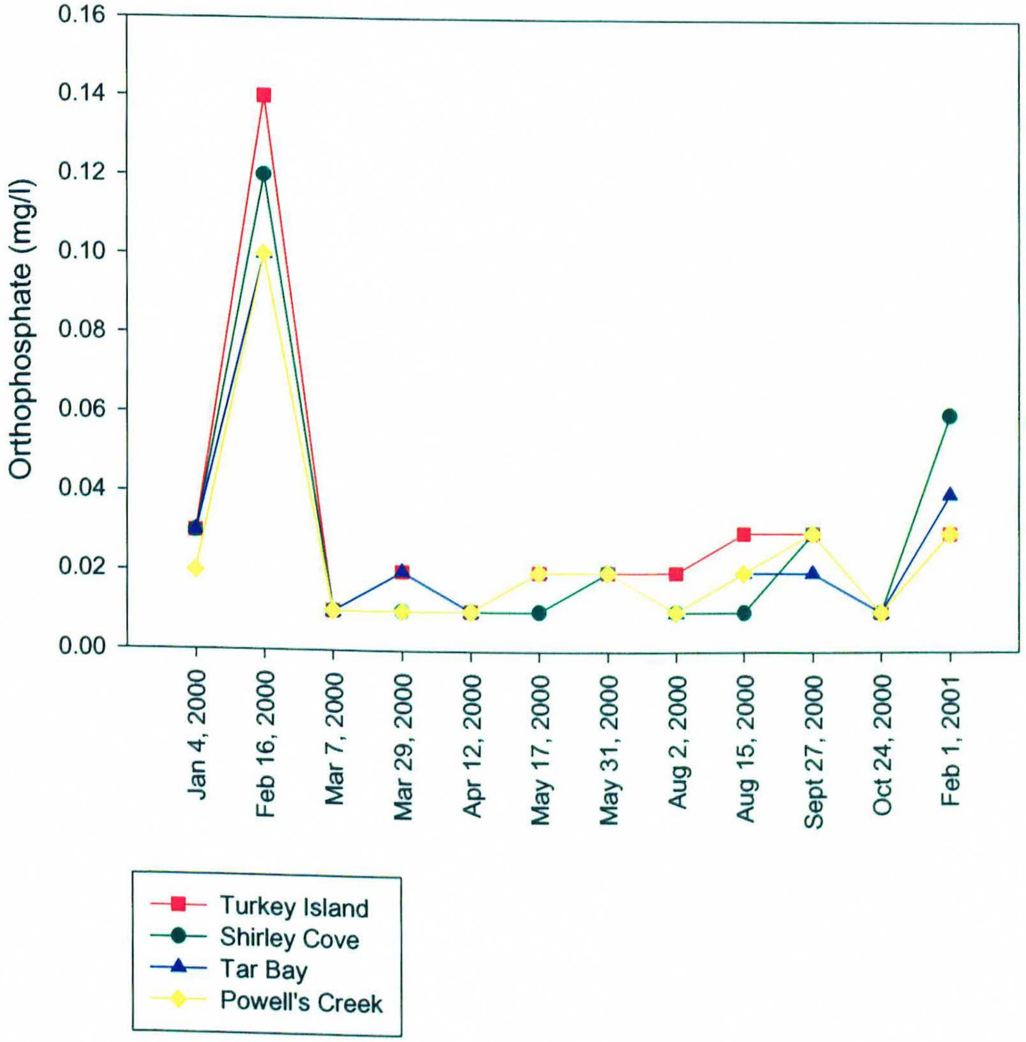
## Figure 3-14: Total Kjeldahl Nitrogen (TKN)



## Figure 3-15: Total Phosphorus (TP)



## Figure 3-16: Dissolved Inorganic Phosphate (DIP)



## Figure 3-17: Dissolved Nitrate + Nitrite