SUBMERGED AQUATIC VEGETATION IN TIDAL FRESHWATER REACHES OF THE PATUXENT RIVER

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QUANTITATIVE CHARACTERIZATION OF SUBMERGED AQUATIC VEGETATION SPECIES IN TIDAL FRESHWATER REACHES OF THE PATUXENT RIVER DRAINAGE BASIN

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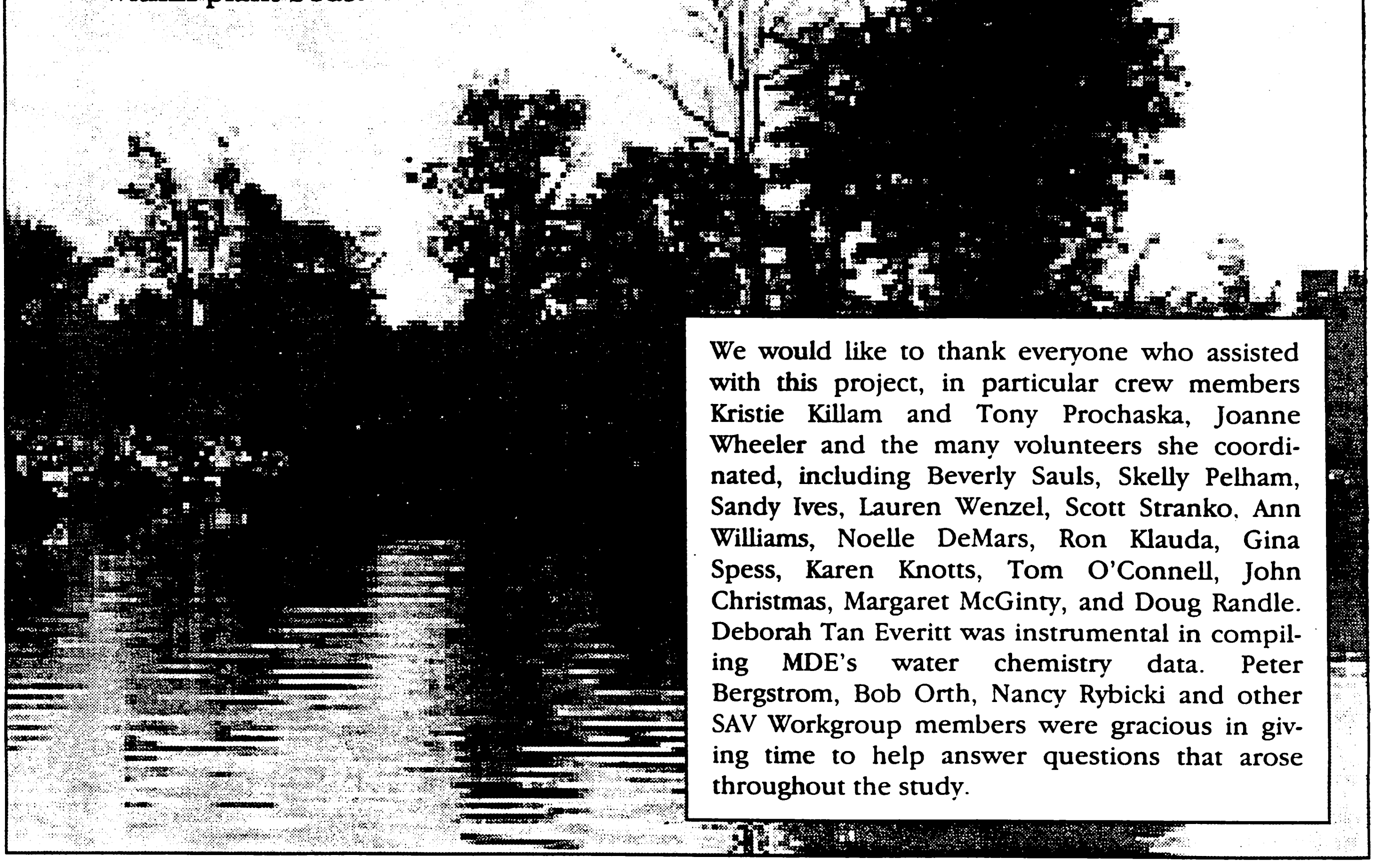
FOREWORD

This study is one component of the Patuxent River Demonstration Project, Phase II, and is funded by the Environmental Protection Agency Contract Number 563CMDE94 through an interagency agreement between Maryland Department of Natural Resources and Maryland Department of the Environment. The goal of the Patuxent Demonstration project is to investigate innovative ways of controlling non-point source water pollution in the Patuxent watershed. In Phase I, potential non-point pollution sources were investigated, and strategies to reduce these sources were developed. In Phase II, projects were developed and implemented.

One of the objectives for meeting the project goal was to establish mechanisms for monitoring the use and effectiveness of various management practices in protecting and restoring the Patuxent. This study, a part of the larger Patuxent Demonstration Project, presents a picture of water quality as reflected by the quantity and quality (as diversity) of Submerged Aquatic Vegetation (SAV). The status of SAV communities reflects the impacts of nutrient and sediment loadings to the Patuxent River. As restoration activities are implemented, the resultant increased growth of SAV will further act as pollution conttrol by sequestering nutrients in plant tissues and settling out sediments within plant beds.



We would like to thank everyone who assisted with this project, in particular crew members Kristie Killam and Tony Prochaska, Joanne Wheeler and the many volunteers she coordinated, including Beverly Sauls, Skelly Pelham, Sandy Ives, Lauren Wenzel, Scott Stranko, Ann Williams, Noelle DeMars, Ron Klauda, Gina Spess, Karen Knotts, Tom O'Connell, John Christmas, Margaret McGinty, and Doug Randle. Deborah Tan Everitt was instrumental in compiling MDE's water chemistry data. Peter Bergstrom, Bob Orth, Nancy Rybicki and other SAV Workgroup members were gracious in giving time to help answer questions that arose throughout the study.

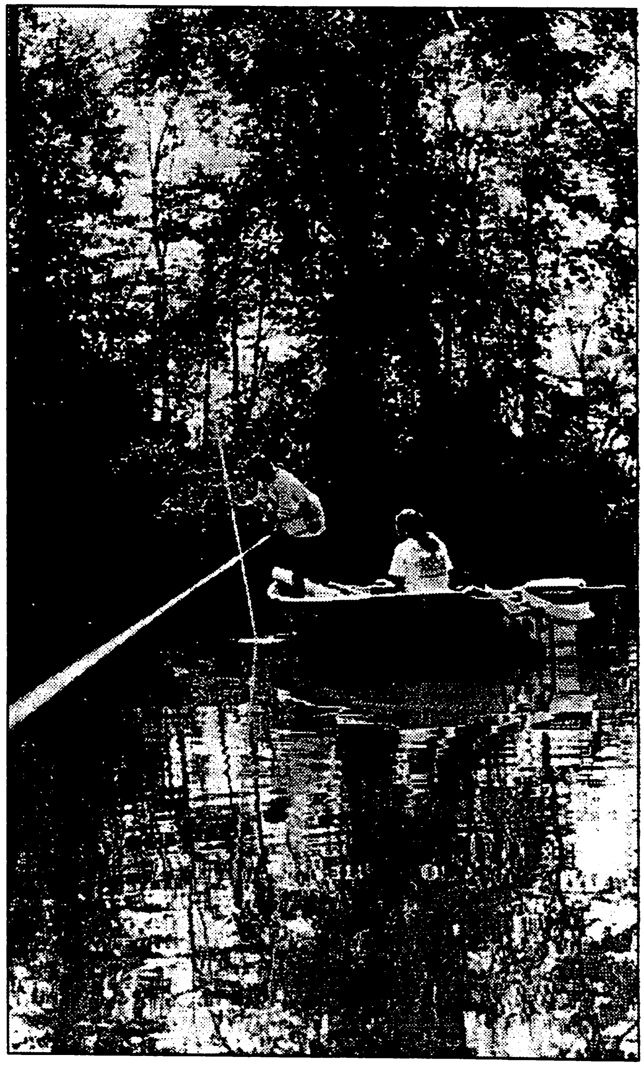
EXECUTIVE SUMMARY

Stratigraphic studies have revealed that the Patuxent River supported numerous Submerged Aquatic Vegetation (SAV) species from before the time of European colonization through the late 1960's when SAV populations all but disappeared. SAV re-appeared in the tidal, freshwater Patuxent River mainstem in 1993 in levels detectable by aerial photography. SAV coverage increased from 10 hectares in 1993 to 75 hectares in 1994. We sampled quadrats at line intercepts established systematically at 20 mainstem and 36 tributary stations in the tidal, freshwater reaches of the Patuxent River. All vegetation within each quadrat was removed, separated by species, and wet weighed. Sampling was conducted three times (early June, late July, and late September) to determine seasonal variations. Depth measurements were made at every quadrat to determine SAV presence and abundance by depth.

Eleven species of SAV were collected during this study. Species diversity in the mainstem was lower than in the tributaries, with two species representing 90% of the biomass in the mainstem as opposed to four species in the tributaries. Mean biomass was below 100 g wet weight per m^2 in both mainstem and tributaries, about one fifth the biomass found in the Potomac River during a similar resurgence. *Hydrilla verticillata*, an exotic species not found in the Patuxent River basin prior to 1993, was found in each sampling period during 1994. *Hydrilla* was the only species to increase as a percentage of total species biomass throughout the sampling periods, and in the location where *Hydrilla* was first discovered, late September sampling showed 98% of the total SAV biomass was *Hydrilla*.

Reduced nutrient inputs as a result of wastewater treatment plant upgrades over the past 4 years appear to have contributed to the SAV resurgence through reductions in epiphytic algae growth. Water quality data for the Patuxent show that light availability has not improved over the past 8 years, and light penetration appears to be a limiting factor in SAV abundance and distribution. The SAV increase has occurred despite the fact that minimum habitat requirements established by the Chesapeake Bay Program for dissolved inorganic nitrogen, total suspended solids, and light attenuation coefficient were not met at any measured station.

Prior to this study, the condition of SAV in the tidal, freshwater Patuxent river had not been quantified, and it was believed that transplanting might be a way to enhance the resource. Field work revealed a well established seed source in the freshwater tributaries from which mainstem populations may become established as water quality becomes suitable. Further investigation will be necessary to determine trends for SAV populations, refine the habitat requirements for SAV in the Patuxent, and to monitor the impact of *Hydrilla* on native SAV species, some of which occur in only a few locations and in very small quantities.

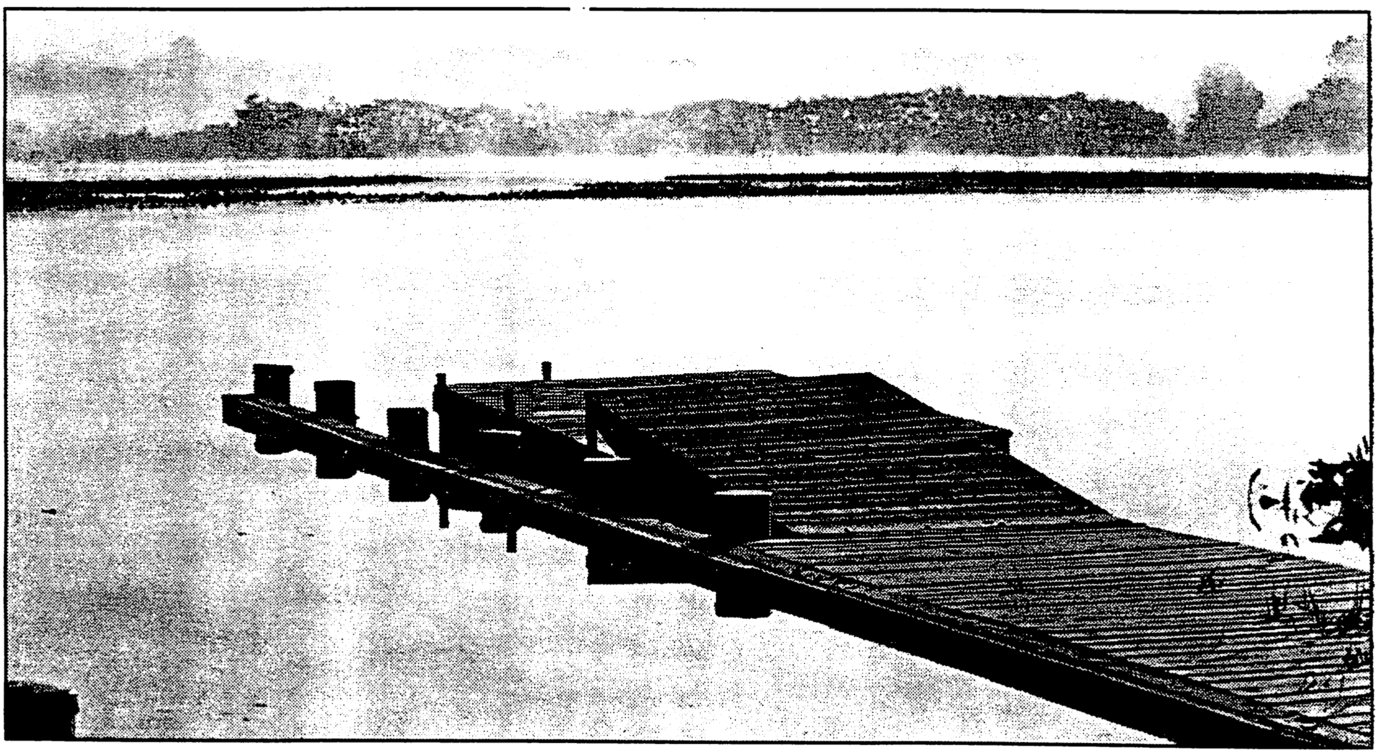


INTRODUCTION

Submerged aquatic vegetation (SAV) is widely recognized as a significant component of a healthy estuarine ecosystem (Batiuk *et al.* 1992). SAV provides food and shelter for fishes, food for waterfowl, and habitat for shellfish. SAV also positively affects nutrient cycling, water turbidity, and the stability of shorelines and sediments (McRoy and Helfferich 1977, Phillips and McRoy 1980). Stratigraphic studies have revealed that the Patuxent River supported numerous SAV species from before the time of European colonization through the late 1960's when SAV populations all but disappeared (Brush and Davis 1984). As point and nonpoint source mitigation efforts are expanded in the Patuxent watershed, improvements in water quality are expected to result in commensurate enhancements in estuarine living resources, particularly SAV.

Aerial surveys of SAV in Chesapeake Bay are conducted annually by the Virginia Institute of Marine Science, in collaboration with numerous researchers who perform ground surveys. The resultant publication, *Distribution of SAV in the Chesapeake Bay*, gives an overview of species diversity and large scale changes in SAV beds. The Patuxent River, particularly in the upper reaches, is too small to allow accurate photo interpretation of SAV. Although the ground truthing currently being conducted as a part of *Distribution of SAV in the Chesapeake Bay* may show the appearance or disappearance of a species, substantial changes in species abundance in the tidal freshwater portion of the Patuxent River could go undetected by the current aerial sampling methods.

This study was designed to provide a quantitative baseline characterization of SAV biomass and diversity in the tidal, freshwater reaches and tidal tributaries of the Patuxent River at several times during the growing season. As the relationship between SAV and water quality are relatively well known, this information will provide a basis for quantitatively evaluating future trends in water quality. To better understand the limiting factors, and to support understanding of the potential for SAV restoration and enhancement, selected physical and chemical parameters were measured as part of the project. The field portion of this study was conducted from 1 June to 3 October, 1994.



STUDY AREA

Study Area Selection

The freshwater portion of the Patuxent River was defined as all areas upstream of the 0.5 ppt salinity gradient (Greg Kerns, Patuxent River Park, pers. comm.). The tributary reaches under tidal influence were defined using the Chesapeake Bay Critical Areas Boundary map and the National Wetlands Inventory map. The study area consisted of the entire tidal, freshwater reach of the Patuxent River and the tidal reaches of all tributaries that empty into that reach of the river (Figure 1).

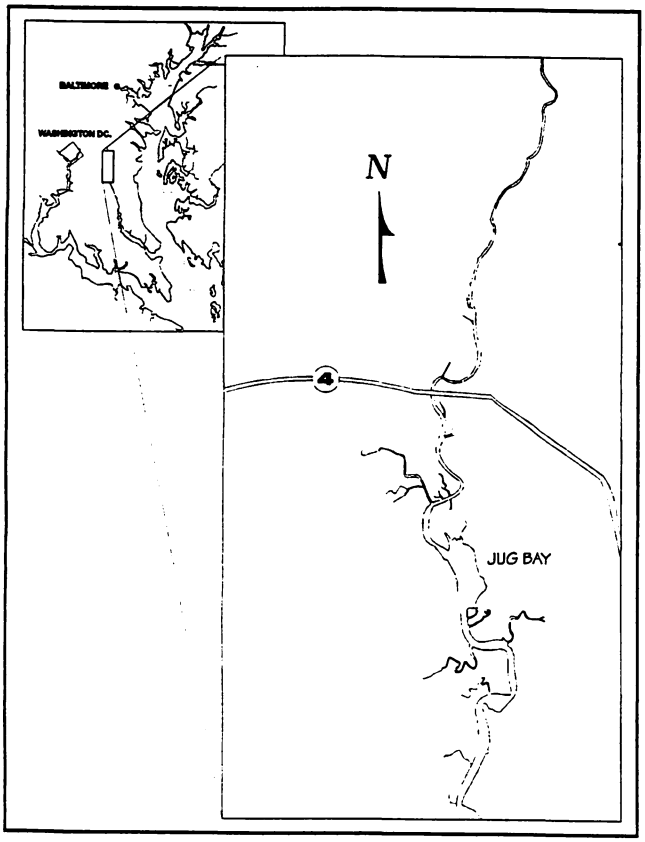


Figure 1. Location of study area in 1994.

Study Area Description

The Patuxent River drainage basin includes 1488 square kilometers in St. Mary's, Calvert, Charles, Anne Arundel, Prince Georges, Howard, Montgomery and Frederick counties. The study area included portions of Anne Arundel, Calvert and Prince George's counties and had a drainage area of approximately 896 square kilometers. The Patuxent drainage basin lies primarily in the coastal plain, with elevations ranging from sea level to 125 m. Most soils in the region are well drained, which can moderate runoff potential (USDA 1967, USDA 1973).

The climate in the study area is continental to semi-continental, with warm, moist summers, mild winters, and well defined seasons. The warmest part of the year is the second half of July, when Anne Arundel County has a mean daily maximum temperature of 32°C (USDA 1973). The mean annual precipitation is 102 to 112 cm, and is fairly evenly distributed throughout the year (USDA 1973).

Within the study area, the river ranged from 28 m wide and up to 1 m deep at station 2 to 420 m wide and over 10 m deep at station 20 (Figure 2). Tributary stations ranged from 1.5 m wide and 0.3 m deep at station 24 to 55 m wide and 1.4 m deep at station 57.

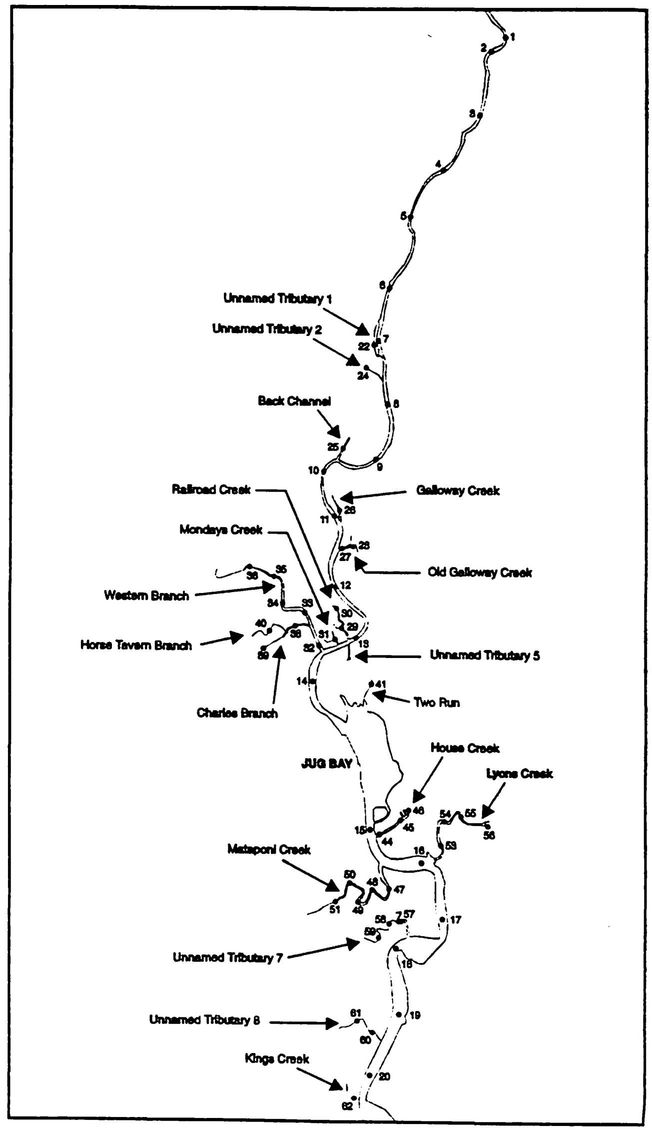


Figure 2. Location of sampling stations in tidal freshwater reaches of the Patuxent River in 1994.

Water quality in the study area from 1991 to 1993 was described as "fair to good" in the Maryland Department of the Environment (MDE) Water Quality Inventory (1994). The waters in the study area remain highly nutrient enriched despite significant (30 - 40%) decreases in dissolved inorganic phosphorous (DIP as PO_4) over the past decade. Dissolved inorganic nitrogen (DIN as NO_2, NO_3, and NH_4) levels during the growing season remain high (> 0.7 mg/L) despite recent declines. High bacterial, nutrient, and suspended sediment levels were observed at several stations from 1991 to 1993, and elevated chlorophyll levels reflected algal bloom conditions. Oxygen levels were observed to decline in summer, but did not fall below 5 mg/l (MDE 1994).

Historical Abundance of SAV in the Patuxent River

Stratigraphic evidence revealed numerous SAV species from prior to European settlement through the late 1960's (Brush and Davis 1984). Six species occurred continuously, including *Vallisneria americana, Elodea canadensis, Najas gracillima, N. flexilis,* and *N. guadalupensis*. After 1972, all native species disappeared from the seed record. The decline is believed to be the result of both chronic (increased population density) and acute (Hurricane Agnes) sediment and nutrient loading, with possible contributions from herbicides and chlorine (Brush and Davis 1984, CRC 1976). Aerial photography of the Patuxent mainstem for the 1986-1993 annual reports on *Distribution of SAV in the Chesapeake Bay* showed very little SAV in tidal freshwater reaches, although ground surveys conducted each year found up to 12 species occurring primarily in the tributaries of the Patuxent upstream from Jug Bay (Orth et.al. 1994).

METHODS AND MATERIALS

Experimental Design

The study area was stratified into 1) the tidal freshwater portion of the mainstem Patuxent River and 2) the tidal reaches of all tributaries that empty into the tidal freshwater mainstem. Stations were established in systematic fashion (Cochran 1977, Simonson *et al.* 1994, APHA 1990), beginning a random distance from the upstream extent of the sampling area. Twenty mainstem and 42 tributary stations were established with a map wheel on USGS Topographical maps (1:24,000). Mainstem stations were established every 1.22 km, and tributary stations were established every 0.58 km (Figure 2). Each station was sampled three times over the course of the SAV growing season: 2 June- 21 June, 25 July- 10 August, and 20 September- 5 October.

Latitude and longitude for each station were derived from a USGS topographical map that had been scanned into GIS and overlaid with a coordinate grid. Stations were located using GPS receivers and marked with flagging. Transect lines were established from bank to bank perpendicular to the flow of the river at each sampling station. As no SAV was expected to grow below 1 m water depth (mlw), the portions of the transect line extending from each bank that were less than 2 m deep (twice the expected depth for SAV growth in the Patuxent) were identified, and only those areas were sampled. The transect line was moved upstream 3 m between sampling periods to preclude sampling previously disturbed areas. All data pertaining to each station were collected at the transect line.

Five tributary stations selected for sampling were not sampled: Stations 42 and 43 in Black Walnut Creek, Station 52 in Mataponi Creek, and Station 61 in unnamed tributary #8 were inaccessible, and Station 23 in unnamed tributary #1 contained no water. Rock Branch (Station 21) was sampled, but proved to be non-tidal and therefore was not included in any calculations.

Five to ten evenly spaced 1 m^2 quadrats were sampled along each transect line, with the first quadrat placed at a random distance from shore. Two-digit random numbers were generated with a scientific calculator, and the first quadrat was placed at twice the sample interval multiplied by the random number as a decimal. Water depths were corrected to mean low tide following National Ocean Service guidelines (1987), assuming a linear range of tide from 0 m at station 1 to 0.8 m at Jacksons Landing and extrapolated in linear fashion to station 20. Sample intervals were calculated based on the distance along the transect line of less than 2 m water depth. At least 5 quadrats were placed at each station, and for distances of 50 m or less, at least 20% of the stream bottom was sampled at each station. Stations with greater than 50 m of < 2 m water depth were sampled using 10 quadrats.

At each quadrat, substrate type (as sand, silt, clay, or gravel), water depth, and degree of siltation (as none, <50%, >50%, or complete) on the SAV were recorded. All SAV within each quadrat was collected by hand using snorkeling gear, separated by species, spun in a plastic mesh bag for one minute, and wet weighed. For analysis, SAV biomass (wet weight) was examined by species, depth category, and sampling period.

Five sampling stations were randomly selected for replication during each sampling period. At each of these stations, a second transect line was sampled one meter above the first to determine intra-station variance.

Physical and Chemical Characterization

To characterize the water quality in the study area, temperature, dissolved oxygen, and pH were measured near the surface at several mainstem stations and at the downstream end of each tributary before and after each sampling period. Water quality measurements were made using a Hydrolab Surveyor II, or a combination of Orion 250A pH meters and YSI models 51B and 58 dissolved oxygen meters. All water quality instruments were calibrated daily prior to use. Secchi depth was recorded when water quality measurements were taken and also at each station on the dates it was sampled. Additional water quality data from MDE and Jug Bay Wetlands Sanctuary were used to quantify nutrient concentrations, total suspended solids, and Secchi depths (MDE 1994 and unpublished data).

RESULTS

SAV was found in the mainstem upstream from station 10 at only three stations during the sampling periods, and the total measured biomass was less than 10 g. To provide a more representative picture of the downstream portion of the study area where SAV was more common, all mainstem SAV abundance calculations included only mainstem stations 10 to 20 (Figure 2). SAV distribution by species is presented in graphic form in Appendix A, while species distribution by station and sampling period is presented in Appendix B.

SAV was present in one or more quadrats at 80% of mainstem stations in June (Figure 3). During July and September, percent occurrence decreased to 73% and 64%, respectively. Variation was greater in the tributaries, ranging from 62% occurrence in July to 38% in September (Figure 4).

The number of individual quadrats with SAV declined between each sampling period in both mainstem and tributary stations. SAV was present in 27% of the mainstem station quadrats sampled in June. By July, percent occurrence decreased to 23%, and further decreased to 15% in September. In the tributary quadrats, presence of SAV declined from 32 -34% in June and July to 22% in September.

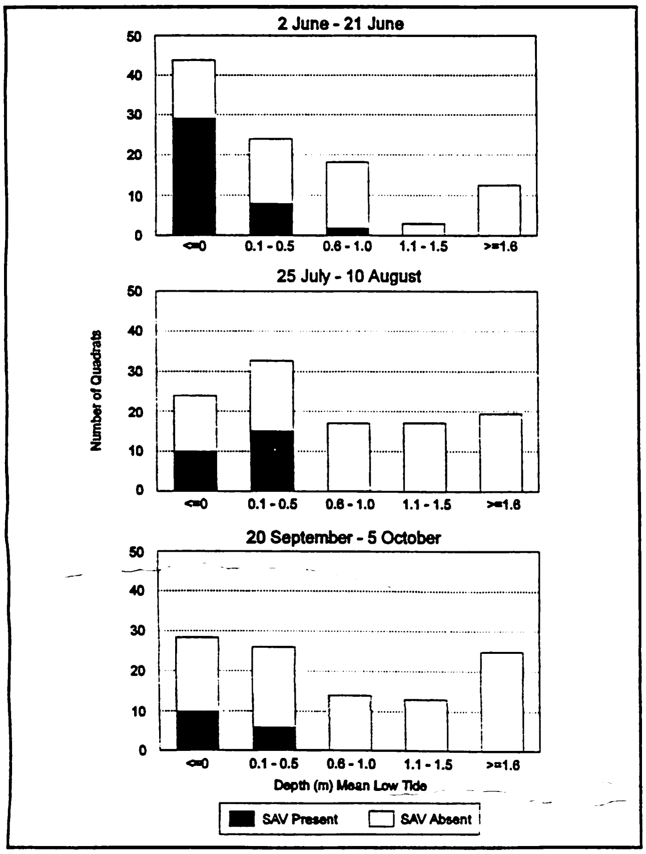


Figure 3. Presence/absence of SAV in quadrants by depth in tidal freshwater reaches of the Patuxent River in 1994-mainstem stations 10-20.

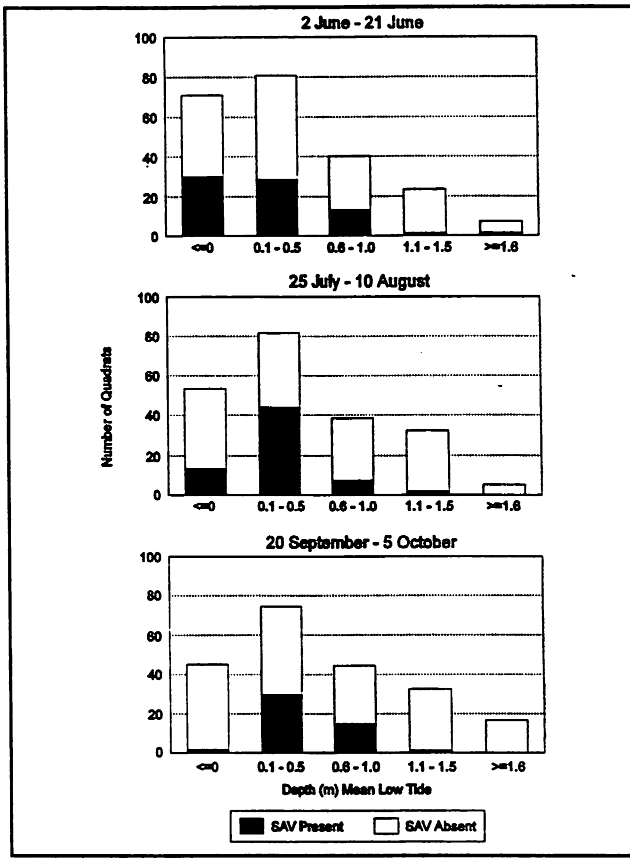


Figure 4. Presence/absence of SAV in quadrants by depth in tidal freshwater reaches of the Patuxent River in 1994-tributary stations.

Eleven species of SAV were found over the course of the study. Ten species of SAV were found in June (Appendix B-1), eleven species were found in July (Appendix B-2), and eight species were found in September (Appendix B-3). As many as eight species were found at a single station, and up to six species were found in a single quadrat. Only three species of SAV were collected in the Patuxent mainstem stations downstream of Mataponi Creek (Figure 2). In early June, dominant species in both the tributaries and mainstem were *Elodea canadensis* and *Zannichellia palustris* (Figure 5 and 6). Dominant species in late July were *Najas gracillima* and *E. canadensis* in the mainstem and *N. gracillima*, *Hydrilla verticillata*, and *E. canadensis* in the tributaries. In late September, dominant species were *E. canadensis* in the mainstem and *H. verticillata* and *E. canadensis* in the tributaries.

In June, SAV was found up to 1.0 m deep (mean low water) in the mainstem, and up to 2.0 m deep in the tributaries (Figure 7 and 8). In July and September, SAV was only found up to 0.5 m deep in the mainstem and 1.5 m deep in the tributaries. Mean biomass was highest in the ≤ 0 m depth category (i.e., dewatered at low tide) for both tributary and mainstem stations in early June. In late July, mean biomass was highest in the 0.1 - 0.5 m depth category

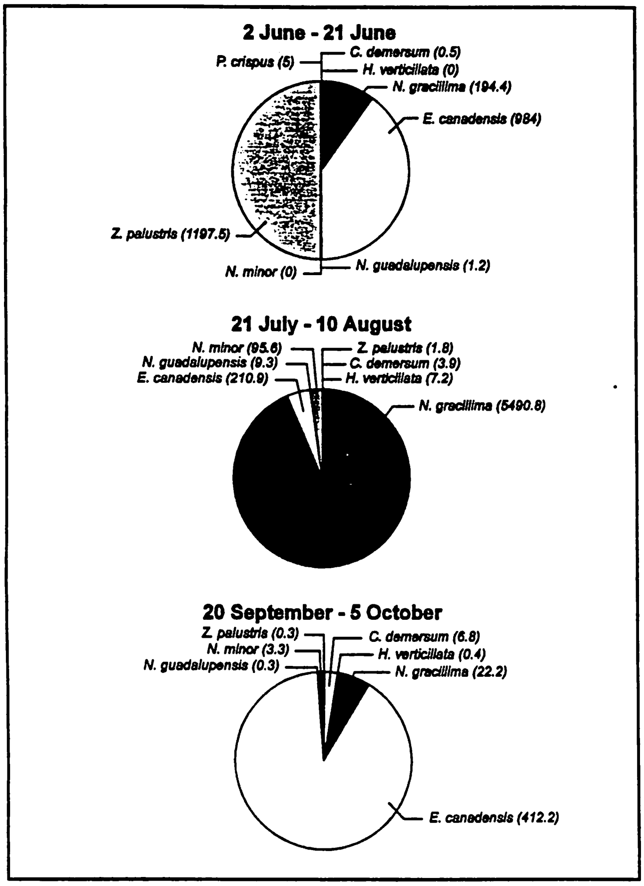


Figure 5. SAV biomass (g) by species in tidal freshwater reaches of the Patuxent River in 1994-mainstem stations 10-20.

for both tributary and mainstem stations. In September, mean biomass was highest in the ≤ 0 m depth category for mainstem stations and 0.6 - 1.0 m depth category for tributary stations. The highest biomass observed at a quadrat in the tributaries during the study was 2361 g wwt/m^2, while the highest biomass observed at a mainstem quadrat was 2001 g wwt/m^2. Both peak biomass levels occurred in the 0.1-0.5 m depth category during the 25 July- 10 August sampling period.

Replicate sampling revealed that when SAV was present, it was always present in both transect lines and was always present in the same number of quadrats (Table 1). However, species composition

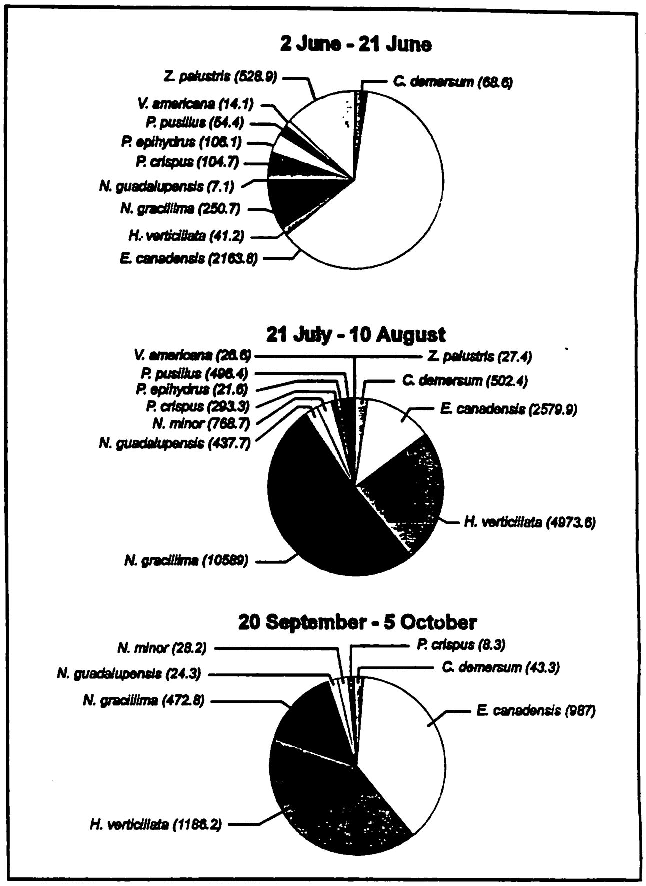


Figure 6. SAV biomass (g) by species in tidal freshwater reaches of the Patuxent River in 1994-tributary stations.

was variable, with only one station having an identical species list at both transects. Intra-station biomass was often different by more than an order of magnitude; for this reason biomass data are not reported by station.

H. verticillata (*Hydrilla*), a non-indigenous species not found in the Patuxent River basin prior to a 1993 survey conducted by Maryland National Capital Parks and Planning Commission- Patuxent River Park (Orth et.al. 1993), was found in all sampling periods during 1994. Back Channel and Mill Creek, the locations where *Hydrilla* was first discovered by MNCPPC-PRP personnel in 1993, appear to have been the focal points for downstream distribution.

Hydrilla was the only species to increase as a percentage of total species biomass throughout the sampling period. *Hydrilla* biomass increased from 1% of all species in June to 25% in July to 43% in September (Figure 6). In Back Channel, *Hydrilla* increased from 20% of total biomass in June to 88% in July and 98% in September (Figure 9). Over the course of the study, *Hydrilla* was collected at 10 of the 30 stations with SAV (Appendix A-1).

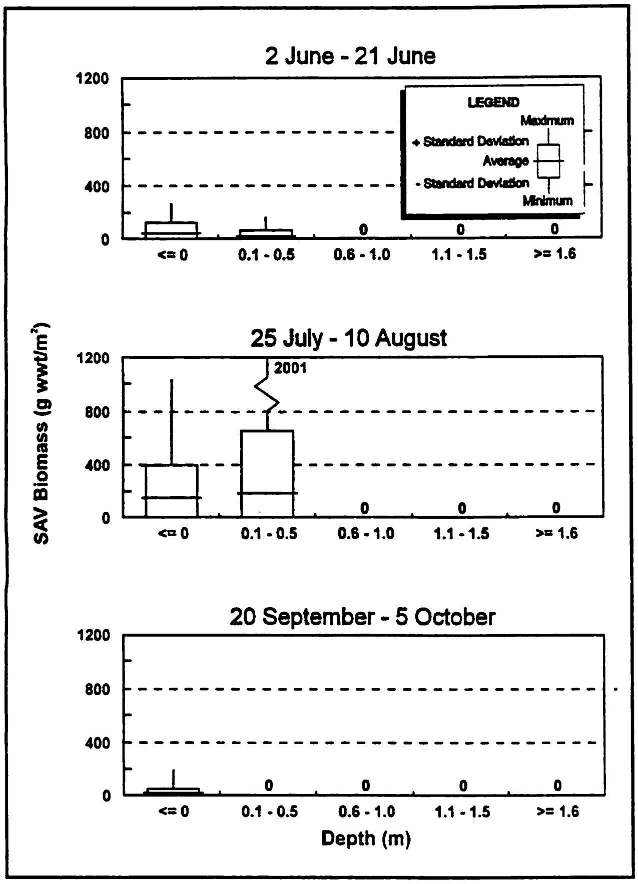


Figure 7. SAV biomass by depth category in tidal freshwater reaches of the Patuxent River in 1994-mainstem stations 10-20.

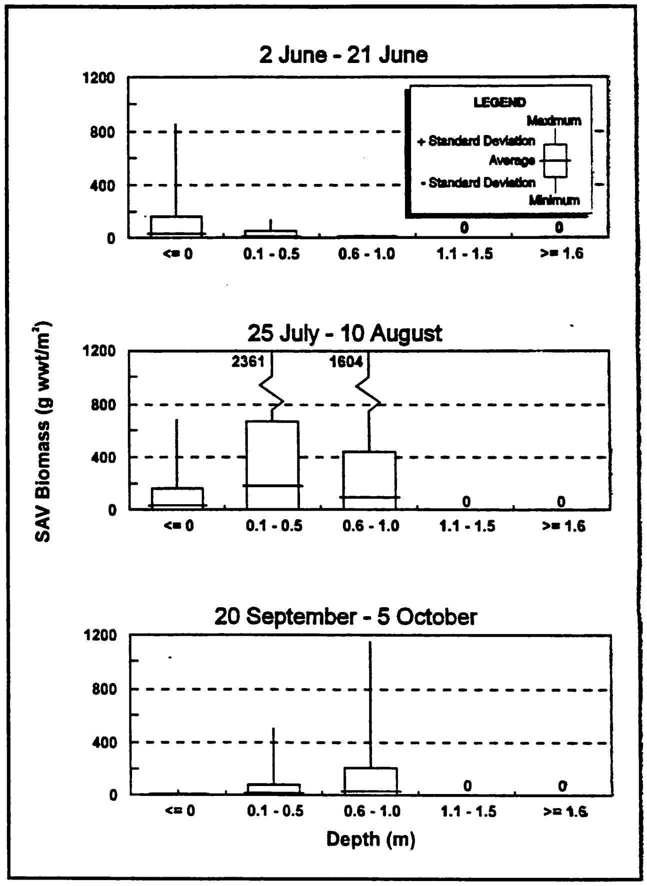
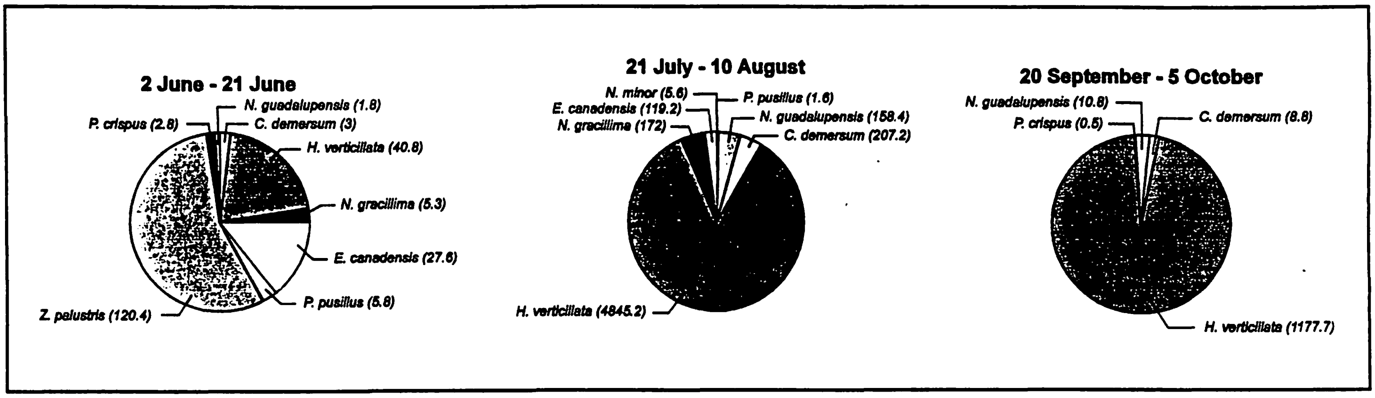


Figure 8. SAV biomass by depth category in tidal freshwater reaches of the Patuxent River in 1994-tributary stations.

Table 1. Results of replicate sampling in tidal freshwater reaches of the Patuxent River in 1994.

Station	Date	Replicate	Number of Species	Number of Quadrats with SAV	Biomass g wwt/m^2
24	3-Jun	A,B	0	0	0
3	2-Jun	A,B	0	0	0
53	15-Jun	A,B	0	0	0
38	14-Jun	A,B	0	0	0
58	16-Jun	A,B	0	0	0
7	3-Aug	A,B	0	0	0
27	10-Aug	A	6	2	189.7
27	10-Aug	B	6	2	263.0
51	4-Aug	A	4	2	432.6
51	4-Aug	B	2	2	6.3
34	9-Aug	A,B	0	0	0
7	30-Sep	A,B	0	0	0
27	28-Sep	A	4	3	6.1
27	28-Sep	B	3	3	3.3
41	3-Oct	A,B	0	0	0
51	3-Oct	A	4	1	16.1
51	3-Oct	B	1	1	1.8
34	21-Sep	A,B	0	0	0

Figure 9. SAV biomass by species in tidal freshwater reaches of the Patuxent River in 1994-station 25.



Water quality parameters measured for MDE in 1994 (growing season averages) did not meet any of the habitat requirements for SAV growth, with the exception of dissolved inorganic phosphorous (MDE 1994, Batiuk, *et al.* 1992). Dissolved inorganic nitrogen values ranged from 10 to 100 times the recommended levels, and total suspended solids ranged from 1.5 to 2.5 times the recommended levels. *At all stations*, values from surface samples for pH ranged from 6.3 to 8.7, dissolved oxygen ranged from 4.6 to 14.0 mg/l, and temperatures ranged from 13.5 to 30.1°C (Appendix C).

DISCUSSION

As a result of this study, a quantitative baseline dataset has been established for SAV in the tidal freshwater portion of the Patuxent River. As changes in water quality occur in the Patuxent basin, repeating this study will provide a means to document changes in the SAV community. This documentation could provide tangible evidence that efforts to improve water quality in the Patuxent River basin have had a positive impact on the living resources of Chesapeake Bay.

A direct comparison of the current status of the Patuxent River SAV community with SAV in other river systems such as the Potomac River (where a significant SAV recovery dominated by *Hydrilla* occurred in the late 1980's) is not possible due to differences in collection and quantification techniques. However, gross examination of data from Rybicki *et al.* (1988) indicate that current biomass of SAV in the Patuxent River mainstem is markedly lower than SAV biomass in the Potomac River. Biomass values as high as 1632 g/m² dry weight have been recorded in the Potomac (Rybicki *et al.* 1988). As SAV is 90 - 95% water (APHA 1991), this dry biomass translates into wet weights on the order of 16,000- 32,000 g/m², eight to sixteen times the maximum wet weight biomass found in the Patuxent in 1994. Mean SAV biomass in the Potomac in the late 1980's for several stations was approximately 2000 g/m² wet weight over the growing season (Rybicki *et al.* 1988). In contrast, mean biomass in the Patuxent, including the tributaries, was less than 100 g/m² wet weight in 1994.

SAV diversity in the Patuxent mainstem was low, with one or two species representing more than 90% of the total biomass in all three sampling periods. Diversity was higher in tributaries to the Patuxent River, with eleven species represented and 90% of the biomass composed of at least four species. Several species occurred in relict populations. For example, *V. americana* and *Potamogeton epihydrus* occurred at only two and one stations, respectively, and in very small quantities at both locations.

Strong temporal variations were observed for *Z. palustris*, which was the second most abundant species in early June and practically nonexistent in the other sampling periods. Annual ground truthing for the *Distribution of SAV in the Chesapeake Bay* reports does not show the great abundance of *Z. palustris* early in the growing season. Using ground truthing data alone, it would appear that *Z. palustris* is most abundant in the lower Patuxent downstream of our sampling area. The data from our study suggest that the reason for this distribution pattern is temporal, not spatial, and can be predicted by the sampling dates. The Benedict quadrangle stations are sampled by citizen volunteers primarily in June or early July, whereas all other Patuxent stations are sampled by Patuxent River Park personnel between early July and late August. Our data revealed that *Z. palustris* was present at 16 stations in early June but only three stations in late July.

Light availability has proven to be a major factor in SAV distribution (Carter and Rybicki, 1990, Kemp *et al.* 1993). SAV presence in the tidal, freshwater reaches of the Potomac declined when Secchi depths fell below 0.65 m during the growing season (Carter, *et al.* 1994). In the Patuxent River, virtually no SAV currently grows in areas deeper than 0.5 and 1.0 m mean low tide depth in the mainstem and tributaries, respectively. The maximum depth at which SAV grew corresponded to the Secchi depth averages of 0.5 m for mainstem stations 10 - 20, but did not appear to correspond to the mean Secchi depth average of 0.6 m in the tributaries. This may be due to the great variation in water clarity between tributaries, ranging from 0.9 m in Western Branch to 0.5 m in Lyons Creek.

Light levels currently limit the available habitat for SAV in the Patuxent, and growth of SAV was generally limited to areas where water depth was less than the Secchi depth. Secchi depth measurements have been collected weekly in the Patuxent River near Jackson's Landing since 1986 by Jug Bay Wetlands Sanctuary personnel and volunteers. Mean Secchi depth measurements from June through the first week in October ranged from 0.32 m in 1990 to 0.45 m in 1988 (Swarth and Peters 1993 and unpublished data). As mean Secchi depth in the Patuxent in 1994 was 0.37 m, the resurgence of SAV cannot be attributed to changes in light availability. Total suspended solids (TSS) levels in the study area in 1994 were also very similar to the nine year average (MDE 1994).

Studies under controlled conditions have shown the reduction or elimination of aquatic macrophytes in response to nitrogen and phosphorus loading (Twilley *et al.* 1985, Phillips *et al.* 1978). Dramatic increases of SAV in the Potomac River in the early 1980's are believed to have been a response to substantial reductions in point source loadings of phosphorus, nitrogen, and suspended solids (Carter and Rybicki 1986). The impacts of nutrient loading on SAV are generally indirect, resulting from decreased water clarity and increased epiphytic growth that result in decreased light availability to SAV. Stratigraphic evidence suggests that algal shading has played a role in the decline of SAV in the upper Patuxent River (Brush and Davis 1984). As light availability in the water column remains unchanged over the past 8 years (Swarth and Peters 1993 and unpublished data), the SAV increases we observed in the Patuxent River in 1994 are probably due to decreased epiphytic growth.

From 1991 to 1994, more than $190 million were spent upgrading eight wastewater treatment plants that discharge into the Patuxent River in Anne Arundel, Howard, Prince Georges, and Montgomery counties. The upgrades decreased nutrient levels in plant effluents, undoubtedly helping to effect the 30 to 40% decrease in nitrogen and phosphorus levels observed in the tidal Patuxent from 1988 to 1993 (MDE 1994). Until the summer of 1994, no dense stands of SAV had been observed in the Patuxent basin since the late 1960's (Orth *et al.* 1994, Brush and Davis 1984). During 1994, SAV was detected for the first time in the freshwater Patuxent mainstem downstream of Jug Bay by routine aerial SAV surveys that have been conducted since 1986 (Bob Orth pers. comm). If the resurgence of SAV in the Patuxent parallels what has occurred in the Potomac, the total coverage of SAV in the Patuxent should continue to increase, although the specific areas covered may change unpredictably.

The near absence of SAV in the upper reaches of the mainstem in 1994 did not appear to be due to water quality. Temperatures were slightly lower in the upper mainstem than in the lower mainstem stations. DIN values were marginally higher in upper mainstem stations based on 9 year averages (MDE 1994). The lack of SAV is probably due to the combination of dense tree cover along both banks of the narrow stream channel reducing available light in areas of <1 m water depth due to shading (Simonson *et al.* 1994), and unsuitable substrates (far more gravel and sand than in lower reaches). The lack of suitable substrates is substantiated by the fact that *C. demersum*, a species that does not need to be rooted at any point of its life cycle, was the only species found on more than one occasion upstream of Station 10.

The appearance of *Hydrilla* could have a dramatic impact on many features of the Patuxent River. Following a decline of native SAV before World War II, *Hydrilla* first appeared in the Potomac River along with the resurgence of some native species in 1983 (Stevenson *et al.* 1989). Although *Hydrilla* beds are capable of supporting a rich assemblage of fish (Morgan *et al.* 1988) and have been shown to reduce suspended particulate, chlorophyll a, and phosphorus levels, the beds themselves can present such a nuisance to boating and other recreation that mechanical removal is required (Carter *et al.* 1988, Stevenson *et al.* 1989).

Hydrilla was not identified at any location in the tidal Patuxent River during surveys conducted annually from 1986 to 1992. In July 1993, *Hydrilla* was found by MNCPPC-PRP personnel in Back Channel and Mill Creek. During our 1994 study, *Hydrilla* distribution increased from two stations in early June to seven stations in late July. Late September sampling also showed *Hydrilla* at seven stations, but two were further downriver than in July. The location where *Hydrilla* was most abundant (Back Channel) is the location where it was first discovered in 1993 and seems to have been a focal point for distribution.

Hydrilla was the only species to increase (as a percentage of total species biomass) throughout the sampling period. In September, *Hydrilla* accounted for 43% of the total SAV biomass at all stations despite the fact that *Hydrilla* was collected at only 7 of the 22 stations with SAV. In Back Channel, the location where *Hydrilla* was first discovered, it accounted for 98% of the total SAV biomass in September. As *Hydrilla* continues to increase at other stations, species diversity throughout the Patuxent River may become similar to Back Channel.

Based on habitat requirements, *Hydrilla* could potentially grow in all the areas currently occupied by *N. gracillima*, although saltwater intrusion during low flow years may limit its downstream distribution more than the naiad. As *Hydrilla* has a higher net productivity than native species (Staver and Stevenson 1994) and is a canopy forming species, it may become an obstacle to boaters, particularly in the tidal tributaries.

In light of the apparent SAV resurgence documented by our 1994 study, restoration (i.e. transplanting) of aquatic macrophytes in the Patuxent is not currently necessary. A sufficient source of seed and propagules exists in the tributaries to supply the mainstem. The SAV resource would be enhanced by further reductions in sediment and nutrient loadings. Several rainfall events during the summer resulted in such dramatic water discoloration that visibility was reduced to near zero for several days. Weekly Secchi depth readings near Jackson's Landing (our Station 14) have shown numerous Secchi depths of 0.1 m, presumably following runoff events, and TSS levels in 1994 were as high as 120 mg/L, eight times the recommended levels for SAV success.

Based on a combination of scientific and anecdotal evidence, the abundance of SAV in the Patuxent River in 1994 was greater than in the past twenty years. Having established a quantitative SAV baseline, the logical next step would be to repeat the study after an appropriate interval of time. Repeating the study would allow us to compare changes in SAV abundance and diversity to trends in water quality between the periods, and would allow for refinement of minimum habitat requirements for SAV. As the sampling area is heavily used for many activities including recreational and commercial fishing, pleasure boating, and waterfowl hunting, future studies may also prove valuable as a way to monitor the spread of *Hydrilla* in order to better anticipate navigational problems.

It would also be valuable to look at this study in relationship to the annual *SAV in the Chesapeake Bay* report. By comparing data from these two studies, the SAV densities required for aerial detectability could be established and biomass estimates could be made for each aerially determined density class. This would assist in determining the acreage of SAV in the Chesapeake Bay that is not detected by aerial photography, thus allowing a better estimate of the total quantity of SAV in the Chesapeake Bay.

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APPENDIX A

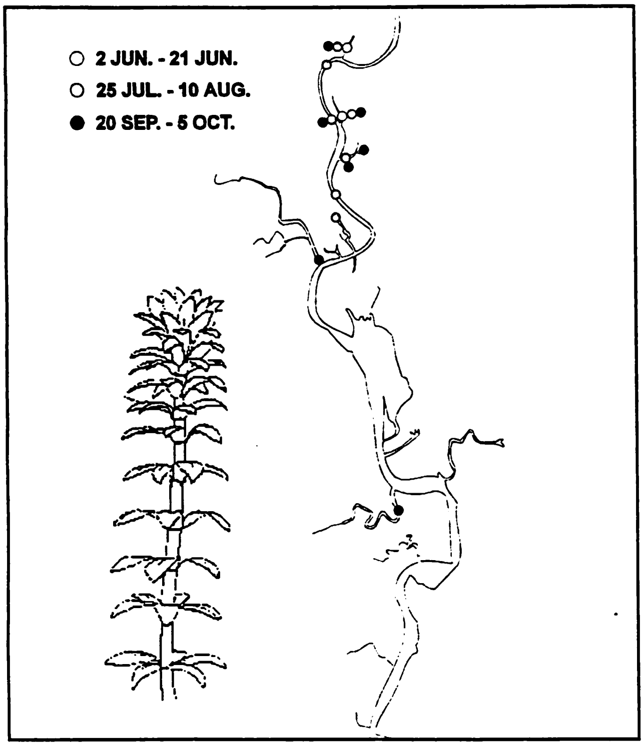

Figure A-1. Distribution of *Hydrilla verticillata* in tidal freshwater reaches of the Patuxent River in 1994.

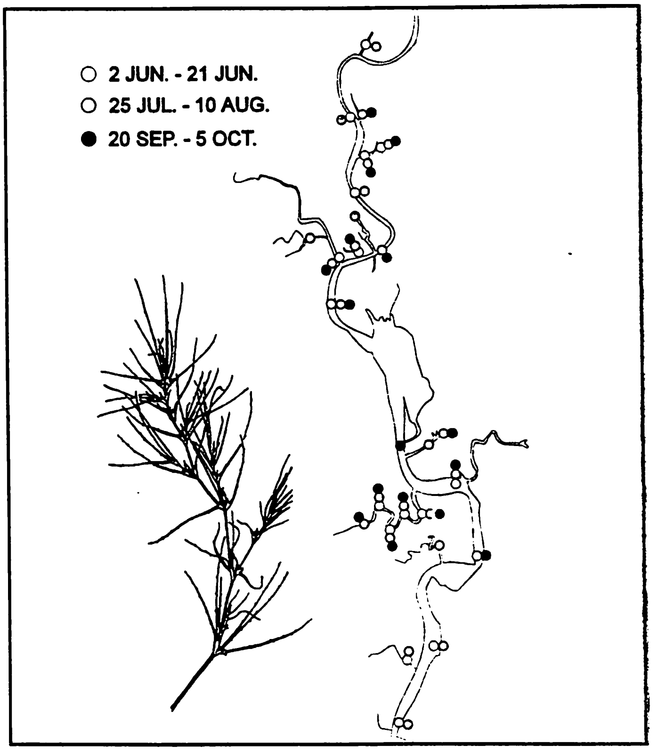

Figure A-3. Distribution of *Najas gracillima* in tidal freshwater reaches of the Patuxent River in 1994.

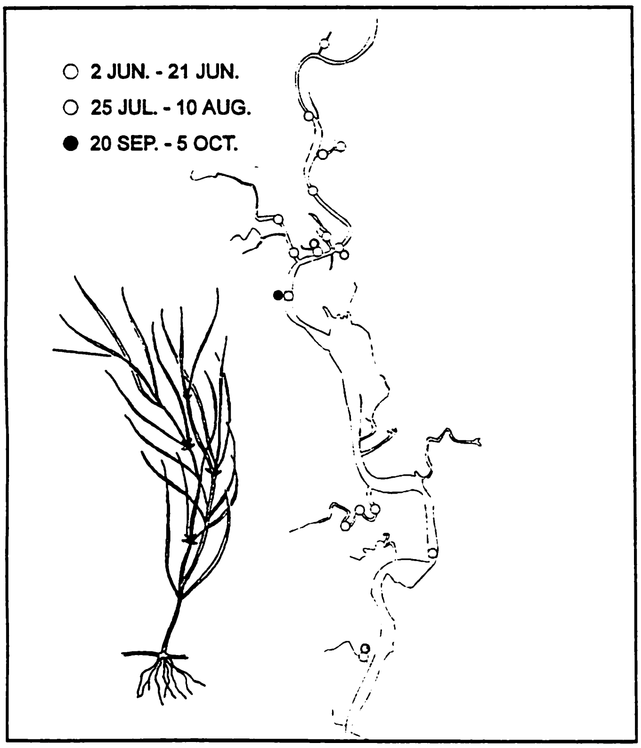

Figure A-2. Distribution of *Zannichellia palustris* in tidal freshwater reaches of the Patuxent River in 1994.

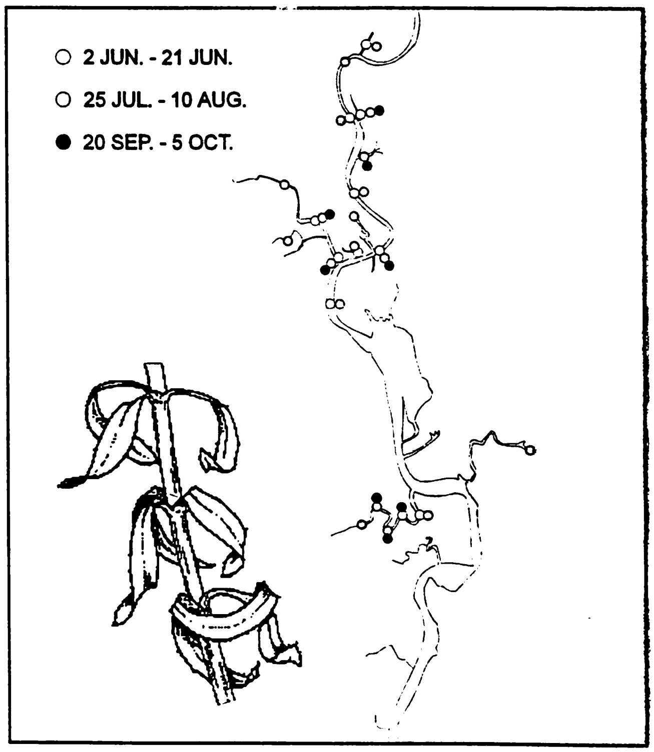

Figure A-4. Distribution of *Elodea canadensis* in tidal freshwater reaches of the Patuxent River in 1994.

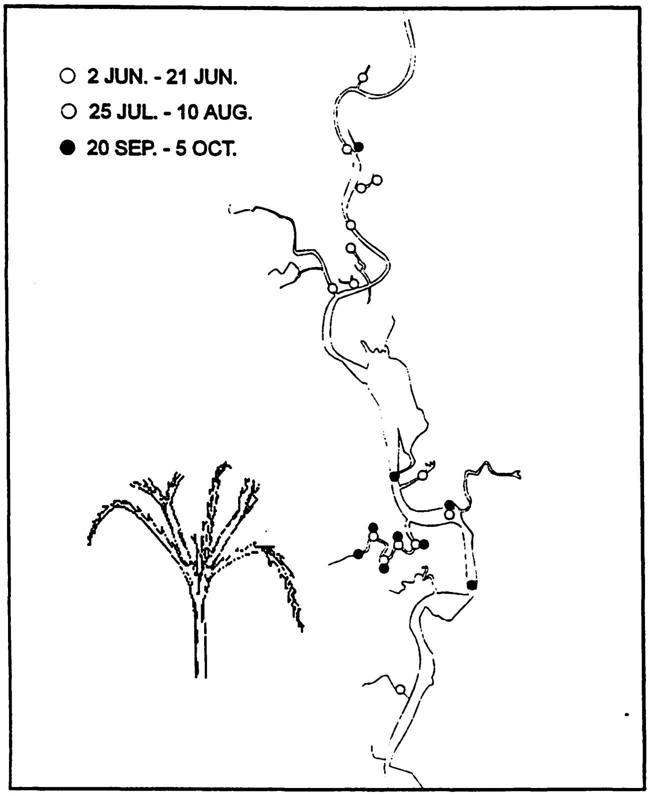

Figure A-5. Distribution of *Najas minor* in tidal freshwater reaches of the Patuxent River in 1994.

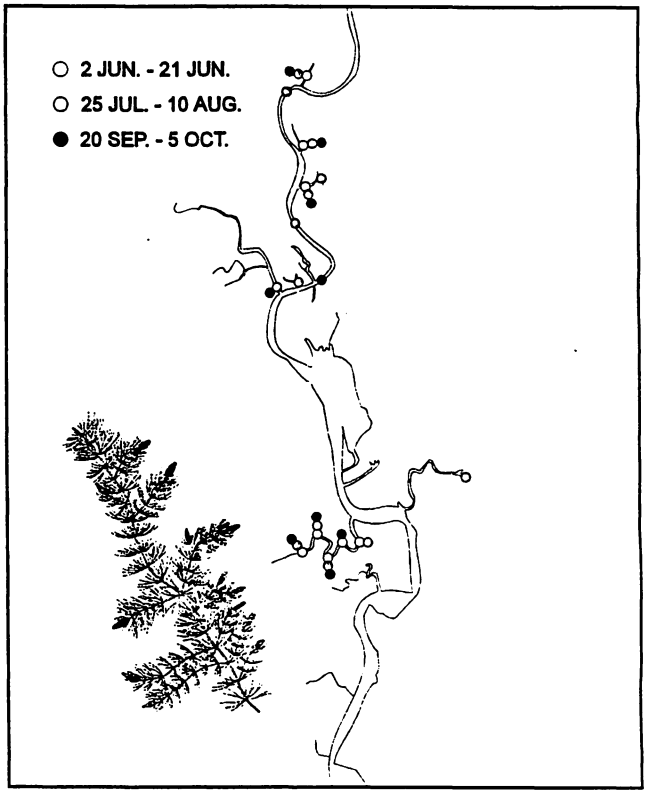

Figure A-7. Distribution of *Ceratophyllum demersum* in tidal freshwater reaches of the Patuxent River in 1994.

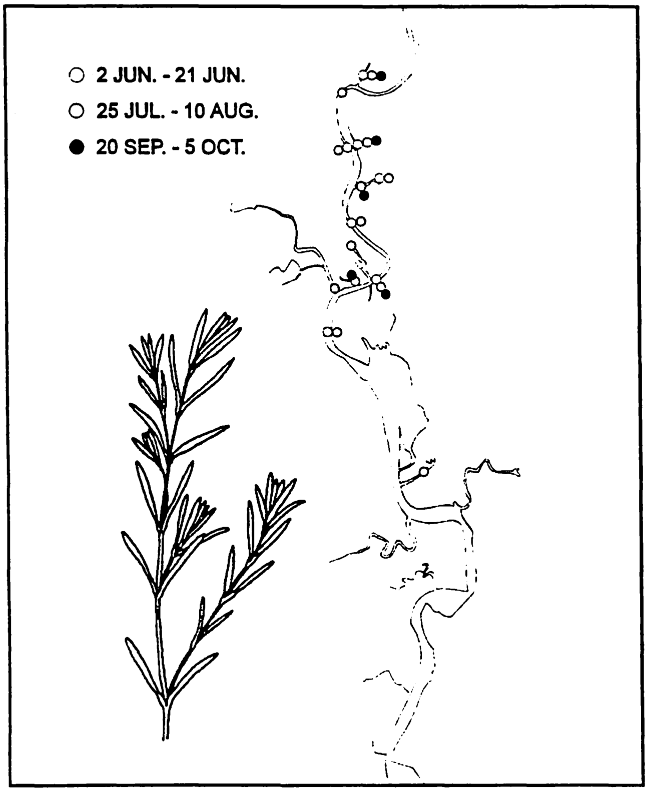

Figure A-6. Distribution of *Najas guadalupensis* in tidal freshwater reaches of the Patuxent River in 1994.

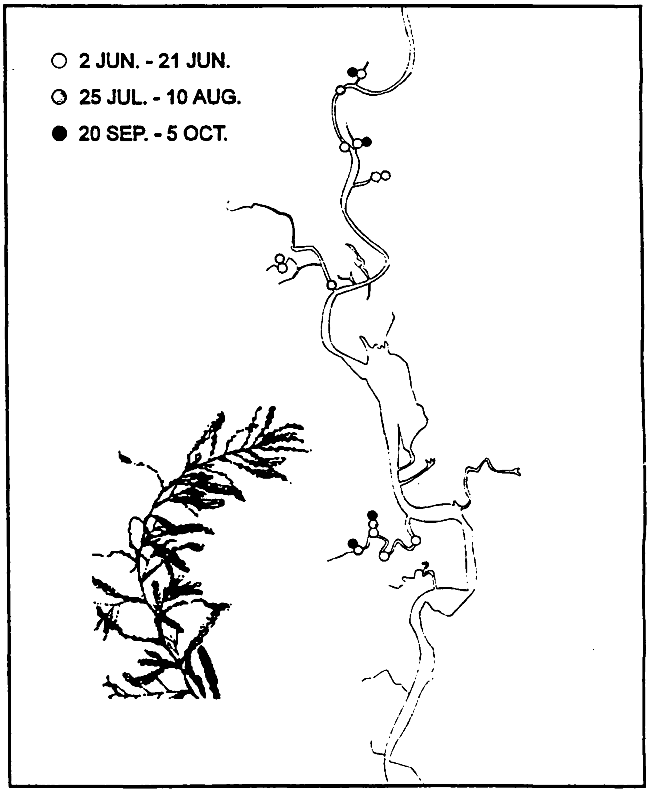

Figure A-8. Distribution of *Potamogeton crispus* in tidal freshwater reaches of the Patuxent River in 1994.

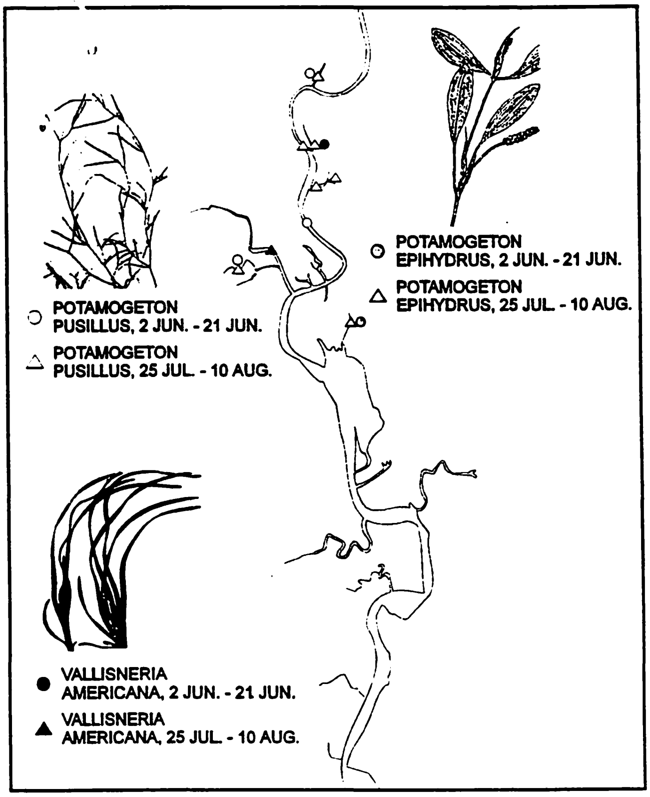

Figure A-9. Distribution of *Potamogeton epihydrus*, *Vallisneria americana*, and *Potamogeton pusillus* in tidal freshwater reaches of the Patuxent River in 1994.

APPENDIX B

Table B-1. SAV species list in tidal freshwater reaches of the Patuxent River in 1994, 2 June - 21 June.

Station	C. dem	E. can	H. ver	N. gra	N. gua	N. min	P. cri	P. epi	P. pus	V. ame	Z. pal
5		X									
11		X		X	X		X		X		X
12		X		X	X						X
13		X			X						X
14		X		X	X						X
16				X							
17				X							X
19				X							
20				X							X
22		X									
25	X	X	X	X	X		X		X		X
26	X	X	X		X		X		X		
27	X			X					X		X
28				X	X		X		X		X
29											X
31		X		X							X
32		X		X							X
33		X								X	X
40							X		X		
41								X			
47	X	X		X			X				X
48	X	X		X							X
49	X			X			X				X
50	X			X			X				
51	X										
60				X							

Table B-2. SAV species list in tidal freshwater reaches of the Patuxent River in 1994, 25 July - 10 August.

Station	C. dem	E. can	H. ver	N. gra	N. gua	N. min	P. cri	P. epi	P. pus	V. ame	Z. pal
1	X										
10	X	X	X		X	X					
11		X	X	X	X	X					
12	X	X	X	X	X	X			X		
13		X		X	X						X
14		X		X	X						
16				X		X					
19				X							
20				X							
25	X	X	X	X	X	X			X		
26	X	X	X	X	X					X	
27	X	X	X	X	X	X					
28	X			X	X	X	X				
30		X	X	X	X	X					
31	X	X		X	X	X					X
32	X	X		X	X	X	X				
33		X									
35		X									
38				X							
40		X					X		X		
41								X			
45				X	X	X					
46				X							
47	X	X		X		X					
48				X		X					
49	X	X		X		X					
50	X	X		X		X	X				
51	X	X		X			X				
56	X	X									
57				X							
60				X		X					X

Table B-3. SAV species list in tidal freshwater reaches of the Patuxent River in 1994, 25 July - 10 August.

Station	C. dem	E. can	H. ver	N. gra	N. gua	N. min	P. cri	P. epi	P. pus	V. ame	Z. pal
1	X										
10											
11			X								
13	X	X		X	X						
14				X							X
15				X		X					
16				X		X					
17				X		X					
22		X									
25	X		X		X		X				
26	X	X	X	X	X	X	X				
27	X	X	X	X	X						
28			X	X							
31				X	X						
32	X	X	X	X							
33		X									
46				X							
47			X	X		X					
48	X	X		X		X					
49	X	X		X		X					
50	X	X		X		X	X				
51	X			X		X	X				

APPENDIX C

Table C-1. Water chemistry data in tidal freshwater reaches of the Patuxent River in 1994 during sampling period 1.

		Secchi (m)		Temp (C)		pH		DO (mg/L)	
Mainstem Station	**Stn**	**1-2 June**	**22 June**	**1-2 June**	**22 June**	**1-2 June**	**22 June**	**1-2 June**	**22 June**
PAT-6	6	1.07	0.53	21.1	24.3	7.17	7.43	7.80	6.10
PAT-7	7	1.01	0.53	20.5	25.0	7.08	7.45	6.66	6.00
PAT-8	8	0.85	0.55	19.7	25.1	6.92	7.42	6.86	5.90
PAT-9	9	0.74	0.49	19.7	25.6	6.83	7.44	6.75	6.10
PAT-10	10	0.63	0.49	19.6	25.9	6.30	7.40	6.52	6.40
PAT-11	11	0.69	0.60	21.7	26.4	7.14	7.37	7.15	6.30
PAT-12	12	0.57		22.1		7.11		7.14	
PAT-13	13	0.61		22.5		7.19		8.15	
PAT-14	14	0.53		22.8		7.34		9.28	
PAT-15	15	0.44		24.8		8.18		10.65	
PAT-16	16	0.51		24.2		7.69		9.37	
PAT-17	17	0.68		24.1		7.22		7.68	
PAT-18	18	0.68		24.5		7.13		7.48	
PAT-19	19	0.58		24.0		7.18		7.53	
PAT-20	20	0.57		23.5		7.10		7.26	
Averages		**0.68**	**0.53**	**22.3**	**25.4**	**7.00**	**7.42**	**7.75**	**6.13**
Tributary Station									
Back Channel	25	0.56	0.42	19.9	26.7	6.71	7.06	6.28	5.60
Mill Creek	26	0.46	0.47	24.8	26.2	6.70	7.30	8.28	6.30
Galloways Creek	27	0.63		24.6		6.91		7.18	
Railroad Creek	29	0.39		24.7		7.14		8.90	
Western Branch	32	0.53		22.6		7.07		7.54	
House Creek	44	0.49		25.1		6.94		7.35	
Mataponi Creek	47	0.46		24.5		7.29		10.11	
Lyons Creek	53	0.48		23.9		6.95		8.11	
Kings Creek	62	0.49		23.6		7.11		6.75	
Averages		**0.50**	**0.45**	**23.7**	**26.5**	**6.94**	**7.16**	**7.83**	**5.95**
Average (All)		**0.61**	**0.51**	**22.9**	**25.7**	**6.98**	**7.34**	**7.78**	**6.09**

Table C-2. Water chemistry data in tidal freshwater reaches of the Patuxent River in 1994 during sampling period 2.

Mainstem Station	Stn	Secchi (m) 25 - 26 Jul	Secchi (m) 11 Aug	Temp (C) 25 - 26 Jul	Temp (C) 11 Aug	pH 25 - 26 Jul	pH 11 Aug	DO (mg/L) 25 - 26 Jul	DO (mg/L) 11 Aug
PAT-6	6	0.26		24.2	22.8	7.28	7.51	6.05	9.10
PAT-7	7	0.27	0.56	24.3	23.2	7.30	7.72	6.12	9.50
PAT-8	8	0.36	0.73	25.1	23.2	7.44	7.59	6.33	8.95
PAT-9	9	0.40	0.70	25.2	23.3	7.46	7.61	6.35	8.90
PAT-10	10	0.48	0.65	25.3	23.6	7.40	7.55	6.05	8.69
PAT-11	11	0.43	0.61	28.6	23.9	7.04	7.51	6.50	8.40
PAT-12	12	0.44	0.68	28.9	24.8	7.04	7.43	7.09	7.99
PAT-13	13	0.53	0.69	28.7	25.0		7.33	7.17	7.49
PAT-14	14	0.56	0.60	27.9	25.0	6.97	7.19	6.69	6.80
PAT-15	15	0.47	0.55	29.6	27.0	7.43	7.77	9.65	10.90
PAT-16	16	0.43	0.55	29.4	26.4	7.50	7.59	9.80	9.60
PAT-17	17	0.43	0.51	29.3	26.3	7.41	7.41	9.17	9.15
PAT-18	18	0.41	0.52	29.4	26.2	7.36	7.35	8.60	8.23
PAT-19	19	0.38	0.51	29.6	26.2	7.42	7.35	8.70	7.82
PAT-20	20	0.52	0.49	29.3	26.4	7.25	7.31	7.96	7.76
Averages		**0.42**	**0.60**	**27.7**	**24.9**	**7.27**	**7.45**	**7.48**	**8.62**
Tributary Station									
Back Channel	25	0.98		26.9	27.4	7.18	7.53	5.78	11.40
Mill Creek	26	0.50		30.8	28.2	6.85	7.07	10.55	9.37
Galloways Creek	27	0.64	0.85	31.0	27.0	6.95	7.13	8.77	8.55
Railroad Creek	29	0.50	0.41	30.8	27.6	6.90	7.01	7.61	4.78
Western Branch	32	0.62	0.78	27.3	25.5	7.03	7.41	7.65	8.60
House Creek	44	0.44	0.66	29.2	27.3	6.61	6.85	4.70	5.10
Mataponi Creek	47	0.55	0.83	29.6	27.6	7.05	7.07	9.59	7.90
Lyons Creek	53	0.50	0.48	30.1	27.0	6.97	6.97	9.04	6.76
Kings Creek	62			27.2	25.3	6.32	6.68	4.63	5.01
Averages		**0.59**	**0.67**	**29.2**	**27.0**	**6.79**	**7.02**	**7.59**	**7.50**
Average (All)		**0.48**	**0.62**	**28.2**	**25.7**	**7.02**	**7.24**	**7.52**	**8.20**

Table C-3. Water chemistry data in tidal freshwater reaches of the Patuxent River in 1994 during sampling period 3.

		Secchi (m)		Temp (C)		pH		DO (mg/L)	
Mainstem Station	**Stn**	**20 Sept**	**5 Oct**	**20 Sept**	**5 Oct**	**20 Sept**	**5 Oct**	**20 Sept**	**5 Oct**
PAT-6	6	0.79		20.1	14.8	7.59	7.43	7.65	8.87
PAT-7	7	0.86		20.3	14.7	7.66	7.38	7.75	8.66
PAT-8	8	0.79		19.8	14.5	7.72	7.35	7.43	8.30
PAT-9	9	0.62	0.80	20.0	15.0	7.71	7.30	7.70	8.12
PAT-10	10	0.56	0.92	20.3	15.0	7.79	7.27	8.06	7.93
PAT-11	11	0.49	0.81	20.8	15.0	8.21	7.16	10.16	7.84
PAT-12	12	0.59	0.77	21.4	15.1	8.45	7.24	11.00	7.75
PAT-13	13	0.44	0.64	21.3	15.2	8.34	7.13	10.92	7.06
PAT-14	14	0.49	0.66	21.0	15.9	7.59	7.03	8.43	6.70
PAT-15	15	0.36	0.45	22.1	15.6	7.97	6.94	9.71	8.00
PAT-16	16	0.47	0.52	22.2	15.7	7.61	6.93	8.05	7.98
PAT-17	17	0.50	0.43	22.3	15.9	7.53	6.94	7.76	8.00
PAT-18	18	0.43	0.43	22.3	16.1	7.31	6.96	7.17	8.06
PAT-19	19	0.50	0.43	22.7	16.5	7.25	7.02	7.00	8.51
PAT-20	20	0.52	0.47	22.8	16.4	7.09	6.80	6.85	7.98
Averages		**0.56**	**0.61**	**21.3**	**15.4**	**7.58**	**7.09**	**8.38**	**7.98**
Tributary Station									
Back Channel	25	0.50	1.04	21.5	14.5	8.67	7.16	14.02	6.27
Mill Creek	26	0.41	0.40	22.0	16.1	8.69	7.00	16.60	7.13
Galloways Creek	27	0.34	0.76	21.5	14.4	8.74	7.15	13.70	6.32
Railroad Creek	29	0.40	0.58	21.5	14.9	8.20	7.12	12.30	6.97
Western Branch	32	0.69	0.93	21.5	17.2	7.39	6.99	7.37	7.83
House Creek	44	0.49	0.57	19.8	14.4	7.17	6.83	6.23	6.04
Mataponi Creek	47	0.48	0.67	21.5	14.8	7.40	6.98	7.44	7.25
Lyons Creek	53	0.44	0.64	20.7	14.1	7.31	6.81	7.25	6.81
Kings Creek	62			17.5	13.5	6.57	6.43	3.47	5.15
Averages		**0.47**	**0.70**	**20.8**	**14.9**	**7.27**	**6.88**	**9.82**	**6.64**
Average (All)		**0.53**	**0.65**	**21.1**	**15.2**	**7.43**	**6.99**	**8.92**	**7.48**