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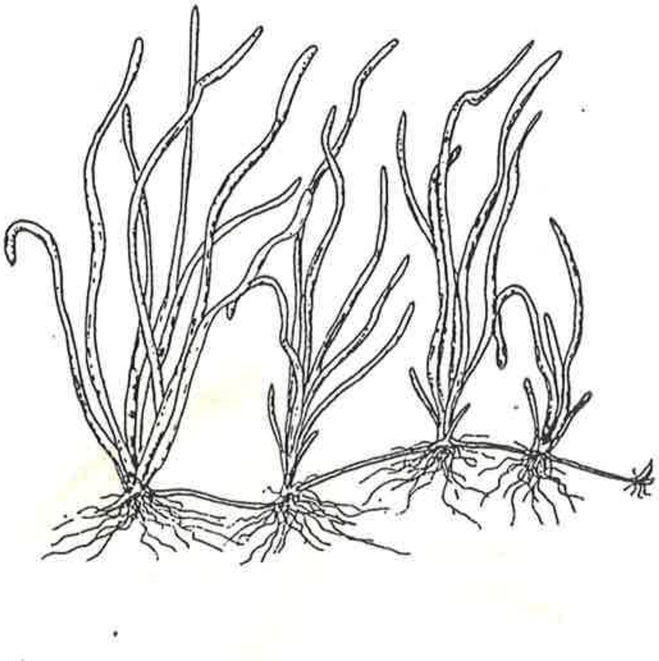
TRANSPLANT SUCCESS USING
VALLISNERIA AMERICANA (MICHX)
AND
WATER QUALITY MONITORING RESULTS
FROM THE
UPPER CHESAPEAKE BAY

FINAL REPORT

MARYLAND DEPARTMENT OF NATURAL RESOURCES
COASTAL RESOURCES DIVISION
TIDEWATER ADMINISTRATION



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INTRODUCTION

During the past 4 years, activities at this institution have focused on the transplanting and reintroduction of submersed aquatic vegetation (SAV) in the oligohaline waters of upper Chesapeake Bay. Throughout this period over 300,000 individual plants (mostly Vallisneria americana) have been introduced into 60 different recipient sites. In ideal circumstances, the plants should have established themselves, increased their areal extent vegetatively, and dispersed seeds to adjacent areas where new beds should have developed.

Of the 60 sites, 9 produced the ideal results, 6 were marginal and 45 were failures. While it is fair to say that most of the failures occurred during the first 2 years it is also noteworthy that several sites developed beautifully when planted during year 3 only to wane and disappear during year 4. In fact, success during the first year, followed by failure the second was fairly commonplace. For this reason, a bed must last in healthy condition for a minimum of two years in order to be called successful.

This paper will focus on the reasons for these triumphs or failures undertaken primarily during the past 2 years and will attempt to predict where transplanting might be positively executed in the future.

Methodologies

Between May and September of 1987 and 1988, mature Vallisneria americana plants were harvested from around Tydings Island, adjacent to Havre de Grace, Maryland and at the mouth of the Susquehanna River. This is one of the most prolific SAV beds in the upper Bay and has been able to tolerate plant removal with little or no apparant impact. Plants were removed and transplanted using previously described methods (13, 14, 15) and were replanted in recipient sites within several hours of harvest. Collected stock was replanted at densities of 200 individuals/m^2. Every other square meter was skipped so as to produce a checkerboard pattern which should have filled in as plants grew. All recipient sites this year were in the Sassafras or Elk Rivers and their tributaries. Growth and success rates were compared with similar data at former sites.

Twenty-four water quality sites were monitored monthly for temperature, pH, secchi depth, dissolved oxygen, salinity, nitrate-N, ammonia-N, ortho and total phosphate-P and chlorophyll a. Sites are indicated on Map I. These sites were selected to provide a spectrum of upper Bay water quality information in regions where transplants are being performed and for the purpose of comparing values inside and outside of SAV beds.

Dissolved oxygen and temperature readings were made *in situ* using a YSI model 51B D.O. meter while pH was determined using a Corning model 105 pH meter. Nutrient samples were collected at the .33 meter depth, immediately chilled and fixed as described in *Standard Methods for the Examination of Water and Wastewater* (16th Ed.).

Immediately upon returning to the lab, samples were analyzed. Ortho and total phosphorus were determined using acid hydrolysis and persulfate digestion with ascorbic acid as a colorimetric indicator. Absorption was determined using a Bausch and Lomb Spectronics 20 spectrophotometer. Nitrate and ammonia levels were determined using an Orion 407B lonalyzer with respective electrodes. Samples were checked frequently against known standards and the system was checked monthly against EPA standard samples.

All soil particle-size analyses were determined using Bouyoucos standard hydrometers. Organic matter was ascertained using high temperature oxidation.

Chlorophyll *a* samples were sent to the University of Maryland Wye Research Laboratory for analyses.

Results

TRANSPLANTS

During August of 1987 and from June through August of 1988, 20 sites in the Elk and Sassafras Rivers were utilized as recipient areas into which *Vallisneria americana* plants were introduced. These sites are indicated on Map I. The sites which outperformed all others for two years running were located in Elk Neck State Park, adjacent to existing beds of sago pondweed (*Potamogeton pectinatus*) and along a riprap stabilized shoreline area. Plot sizes here have increased from 1 m^2 to 2.25 m^2 over two growing seasons and are lush with vigorous new growth (see fig. 1). Other sites which performed well involved an unnamed cove on the north Elk shore, a marsh area on the south shore of the Sassafras (near Turner Creek), at Money Creek behind Ordinary Point and at an unnamed cove between Money Creek and

Grove Neck Wildlife Sanctuary on the north shore of the Sassafras. All sites which have performed acceptably are indicated with a star on Map I. Acceptable sites are defined as those which are still very healthy in appearance after two years and which have increased their numbers or areal extent. Sites which have performed marginally are indicated by a black dot while failed sites are marked with an ⊗. Marginal sites are defined as those which have maintained between 25% and 75% of their initial populations over a two year growing period. No sites were observed to remain the same after two growing seasons. They either improved, declined or disappeared. The beach area along Grove Neck Wildlife Sanctuary (N. Sassafras) is one such area. Transplants performed admirably here for one full growing season during 1987, more than doubling the planted population. By July of 1988, the populations had declined significantly, due apparently to depradation.

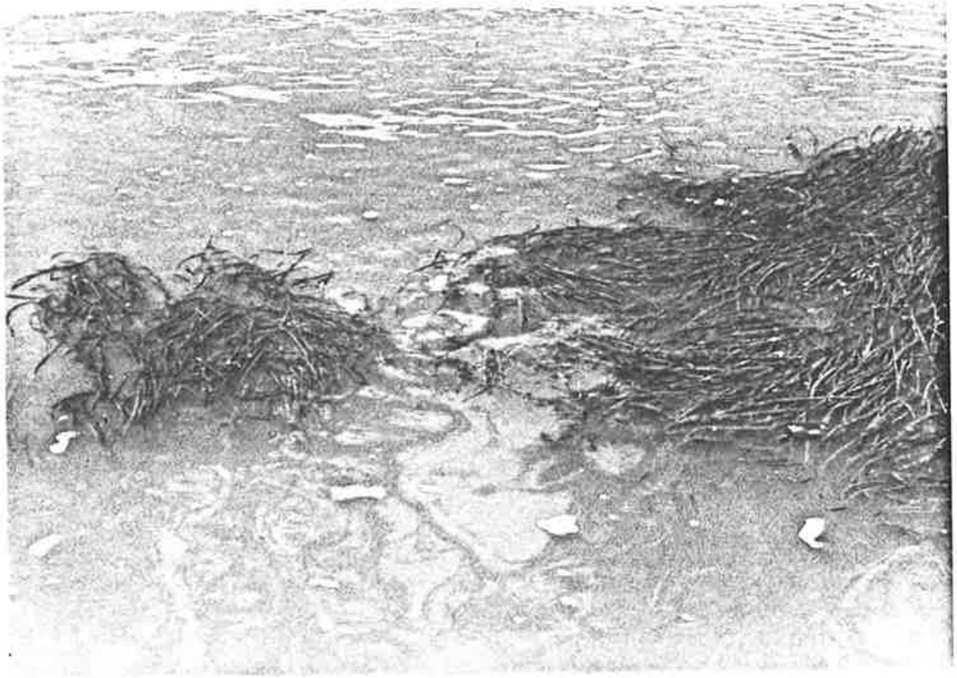


Fig. 1. Side-by-side transplant plots of *Vallisneria americana* in front of riprapped shoreline at Elk Neck State Park. Plot at right was planted in 1987 and plot at left in 1988. Initial size of each was one square meter. 1988 plot is now nearly 3.5 square meters.

Generally no sites on the Sassafras above Money Creek performed well and on the Elk only those sites previously mentioned exhibited significant growth.

WATER QUALITY

While it will be noted that average total phosphate levels outside of areas of successful growth were generally lower than 0.04 mg/l, the Elk Neck Site (#24) exhibited higher average levels, to .075 mg/l. Within beds, levels averaged just below .044 mg/l for T-PO$_4$-P and just below .025 mg/l -PO$_4$-P. These figures will be reiterated later. Dissolved oxygen and pH nearly always met water quality standards established by the State of Maryland. On one occassion (7/15/88) an abnormally low group of pH readings (5.2 - 5.5) was noted from the Bush River north to the Sassafras River. This was unique but has been described by others in that section of the Bay (21). Normally pH levels ran between 6.8 and 8.9. Dissolved oxygen readings were generally between 6 and 12 mg/l although on several occassions (see appendices) levels slipped below 6. Secchi depths were greatest at the mouth of the Susquehanna and Sassafras Rivers. They tended to decline with increasing distance up the Sassafras (See fig. 2) and in Cabin John Creek. Lowest values were noted during mid summer. The same trends were noted during both 1987 and 1988 with minor variations. The Bohemia River for example was more turbid last fall than during the fall of 1988 while the Elk Neck area showed the opposite trend.

With respect to chlorophyll a concentrations, they demonstrated the highest levels in the upper reaches of the Sassafras River, in Cabin John Creek and the central Bay areas, while the lowest levels were detected at the mouth of the Sassafras and in the Elk River. Chlorophyll a concentrations represented here (appendices) are from only late 1987 and early 1988 since analyses have not yet been completed.

	Nitrate-N	Ammonia-N	Total Phosphate-P	Ortho Phosphate-P	CHL a	Secchi
Upper Bay						
1987	1.20	.029	.060	.020	8.74	1.1
1988	2.03	.050	.067	.029	9.95	1.1
Sassafras River						
1987	1.74	.032	.073	.025	23.8	0.7
1988	2.04	.099	.048	.020	27.5	0.8
Elk River						
1987	2.45	.028	.049	.031	5.06	0.8
1988	2.59	.068	.060	.022	9.44	0.8

Table 1. Averages of all readings/year/area. Upper Bay includes sites 1-6, 17; Sassafras River includes sites 7-16; Elk River includes sites 18-24. 1987 includes Aug.-Oct.; 1988 includes May-Oct. All readings are in mg/l except chl a (ugm/l) and secchi depth (m).

Fig. 2

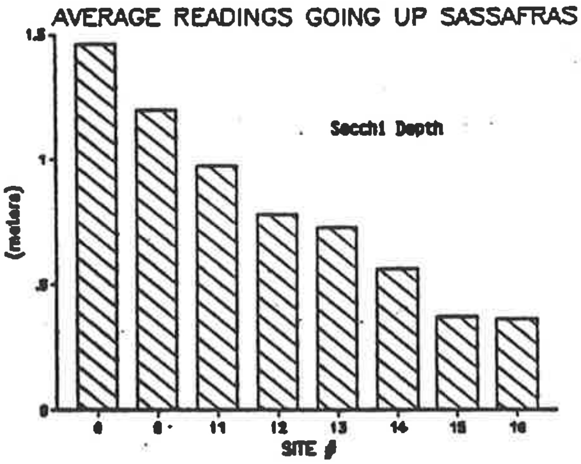
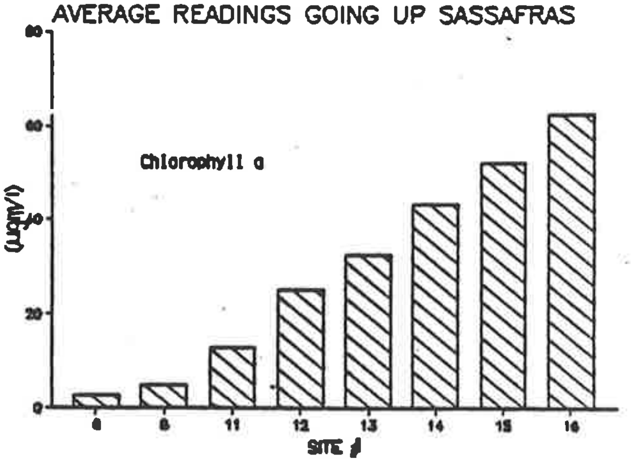
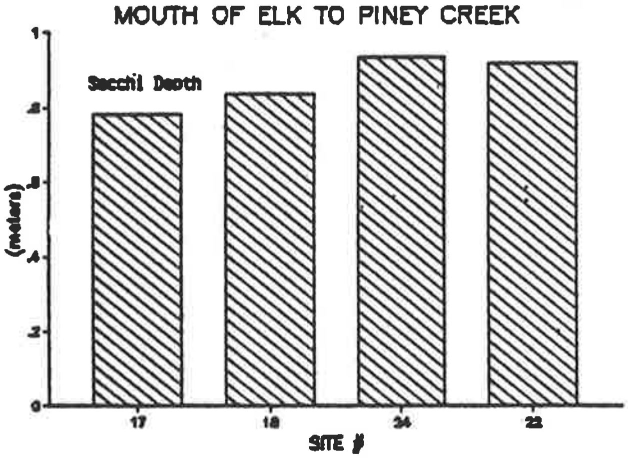


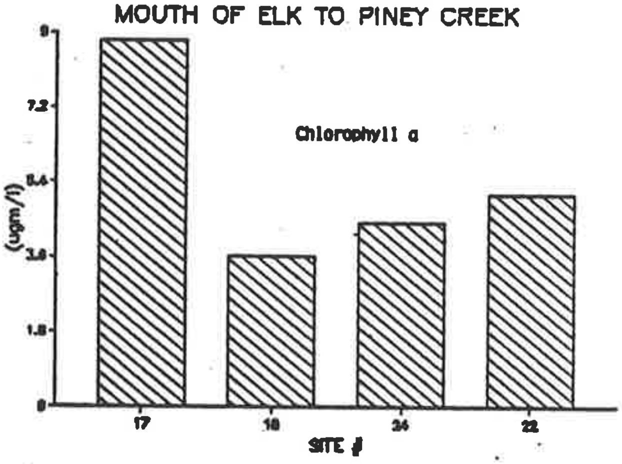
Fig. 3



2a



3a



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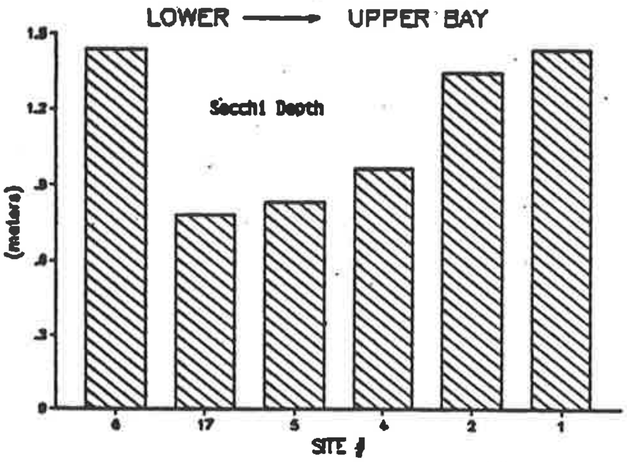

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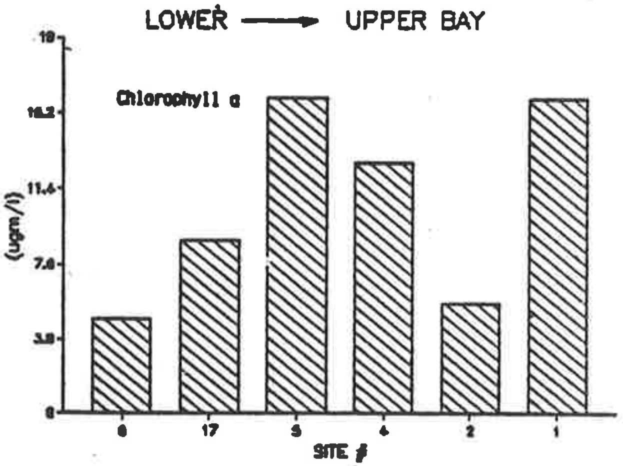


Averages of 1987-1988 readings taken in three watershed areas: Sassafras River, Elk River and Chesapeake Bay - Susquehanna River. See Map I for site locations.

Fig. 4

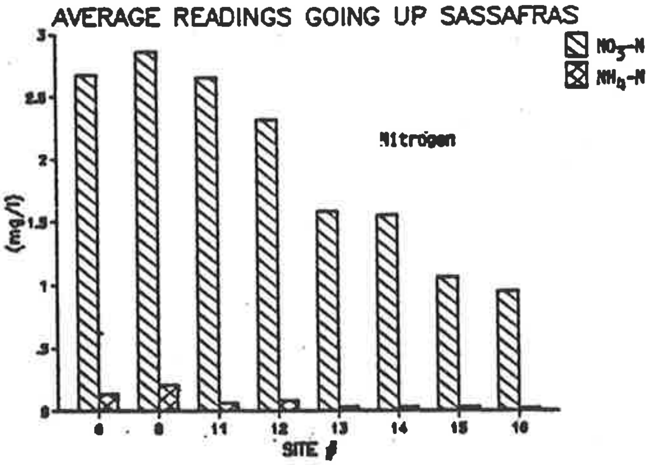
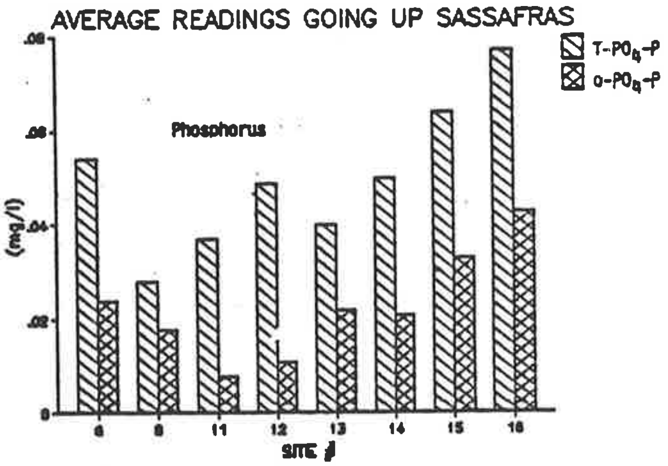


Fig. 5



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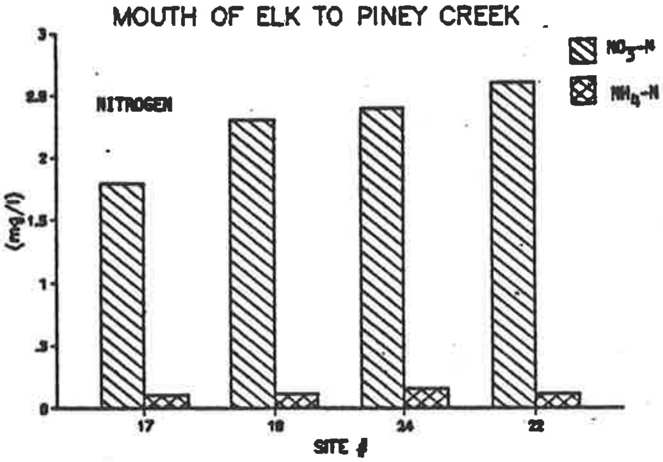
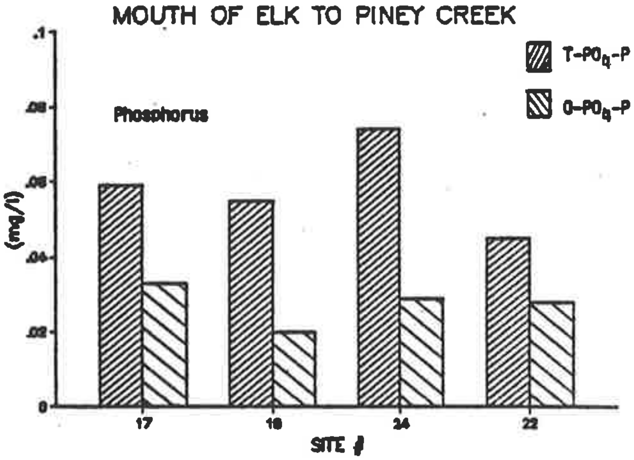


5a



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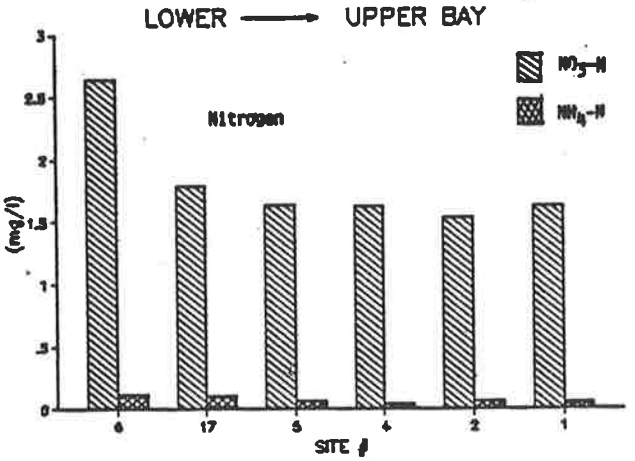

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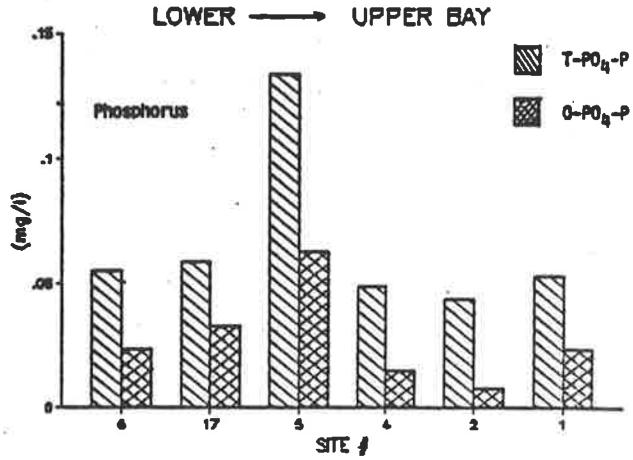


Averages of 1987-1988 readings taken in three watershed areas: Sassafras River, Elk River and Chesapeake Bay - Susquehanna River. See Map I for site locations.

NUTRIENTS

Nutrient levels are very important since they have been implicated in the decline of submersed plant populations throughout the Bay (4, 9, 11). In Neilson's rating system for estuaries (18), a level of 1-3.2 mg/l total nitrogen is considered to be eutrophic and marginal to not acceptable. Stevenson (U. of M. Horn Point Laboratories, personal communication) has indicated that when phosphorus levels were controlled to below .01 mg/l that DIN levels could rise to 1.4 mg/l. Carter (USGS-personal communication) indicated that 0.06 mg/l phosphorus was the threshold value beyond which SAV decline in the Potomac River. While our average TP levels (see table 1) approximate .06 mg/l, late summer 1987 and early summer 1988 levels were often considerably higher (figs. 37-60). Phosphorus pulses were particularly evident after heavy rainfall (6/88). Although we did not monitor total nitrogen, nitrate levels were for the most part very high throughout the upper Bay area (table 1) and all but the upper Bay '87 exceeded 1.4 mg/l NO_3-N. A general trend that can be noted is that as the year progresses, nitrate levels increase (figs.13-36) while phosphorus levels decline. These phenomena are likely drought related in that runoff carries phosphates and nitrates may be concentrated in surface waters when rainfall is limited. Ammonia -N levels, while higher than desirable, showed pulses primarily around marsh areas during the month of August (figs. 21, 22). Our monthly nutrient measurements are comensurate with values obtained by other investigations (22, 25).

Nutrients, water clarity, and chlorophyll <u>a</u> demonstrate obvious trends moving up the Sassafras River. From site six at the mouth to site sixteen near Wilsons Creek, average Secchi levels dropped from 1.5 meters to less than .4 meters (fig. 2). Over the same range, chlorophyll <u>a</u> concentrations increased from 4.85 ugm/l to over 60 ugm/l (fig. 3). The relationship between nitrogen and phosphorus is inverse. As NO_3-N drops from 2.75 mg/l to 1 mg/l (fig. 4) , T-PO_4-P rises from 0.025 mg/l to near 0.08 mg/l (fig. 5). This array of graphs depicts rather nicely how the limiting nutrient phosphorus enhances algae growth, thus reducing water clarity. The lower nitrate readings at the upper end of the river are likely due to uptake by large algae populations. As phosphorus levels drop, algae decline and nitrate absorption is reduced. All readings on figures 2-5 are 1987-88 averages.

Fig. 6

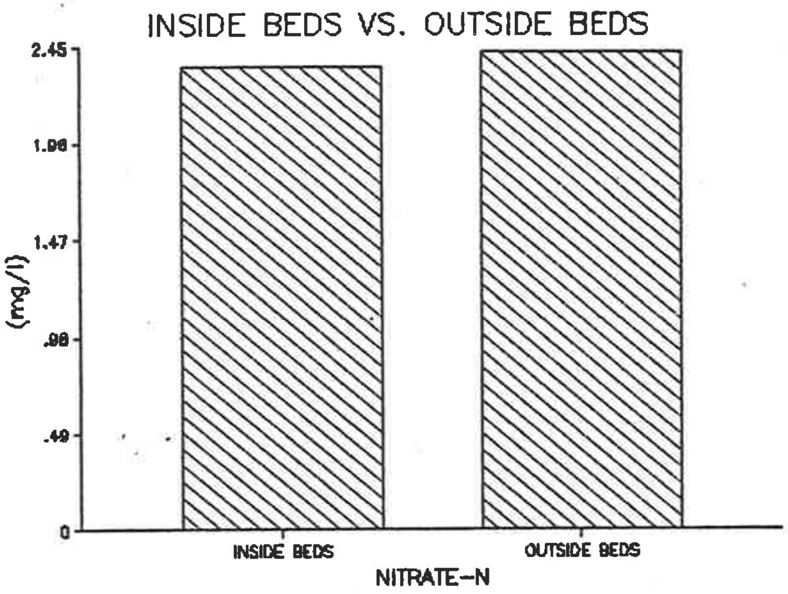


Fig. 7

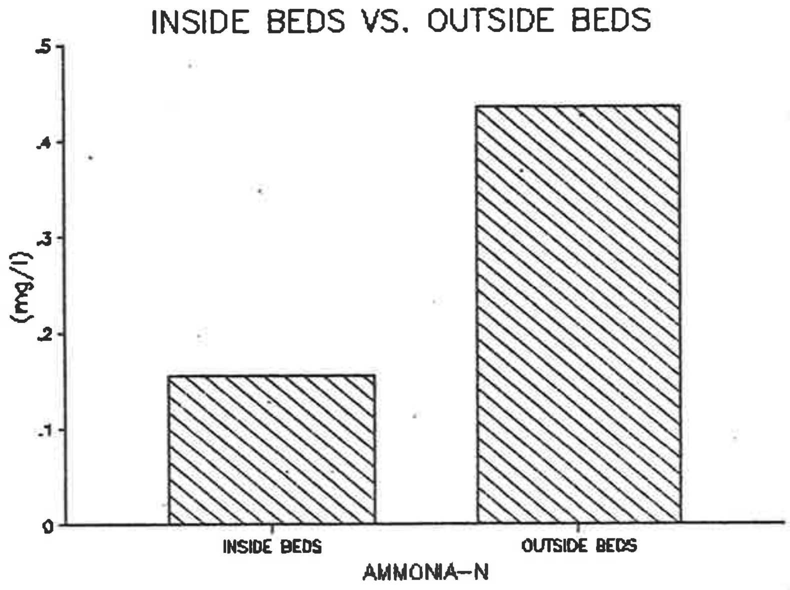


Fig. 8

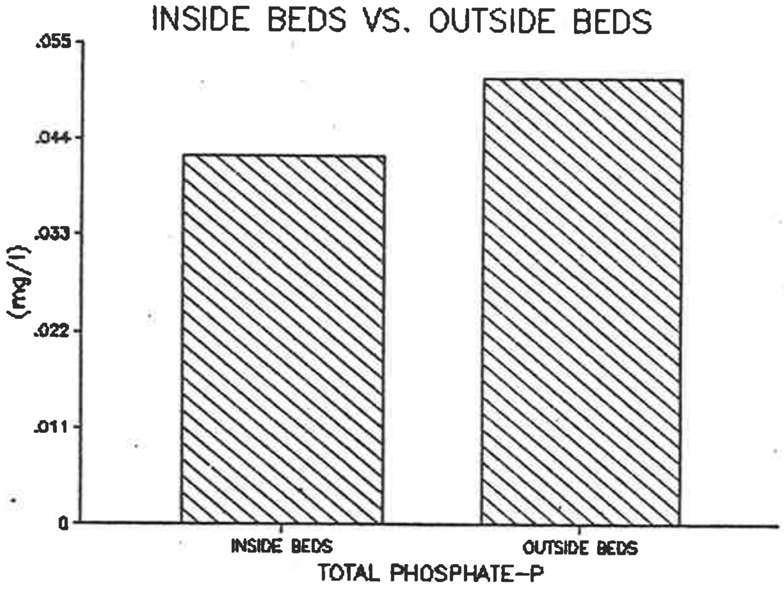
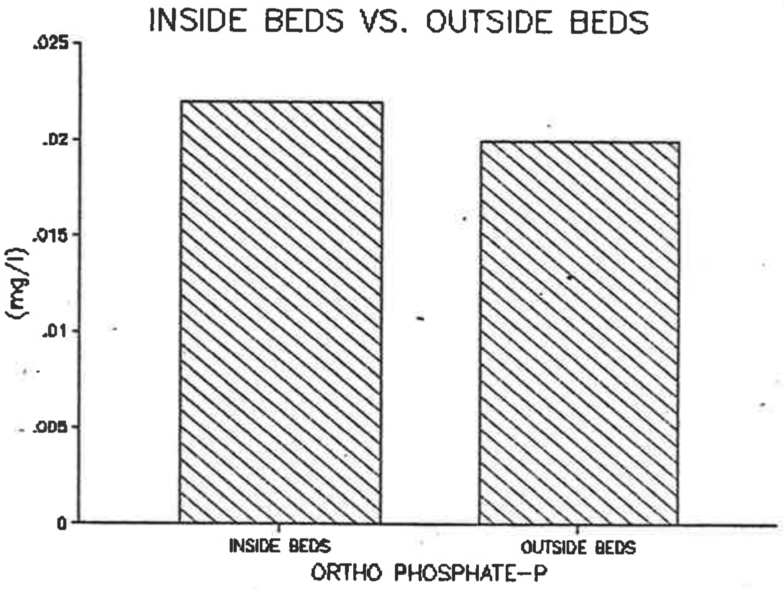


Fig. 9



Averages of 1987-1988 readings taken inside of and outside of SAV beds located at Elk Neck State Park, Sassafras Marsh and Sassafras Beds (near mouth). Health of Sassafras Beds declined significantly in 1988.

Fig. 10

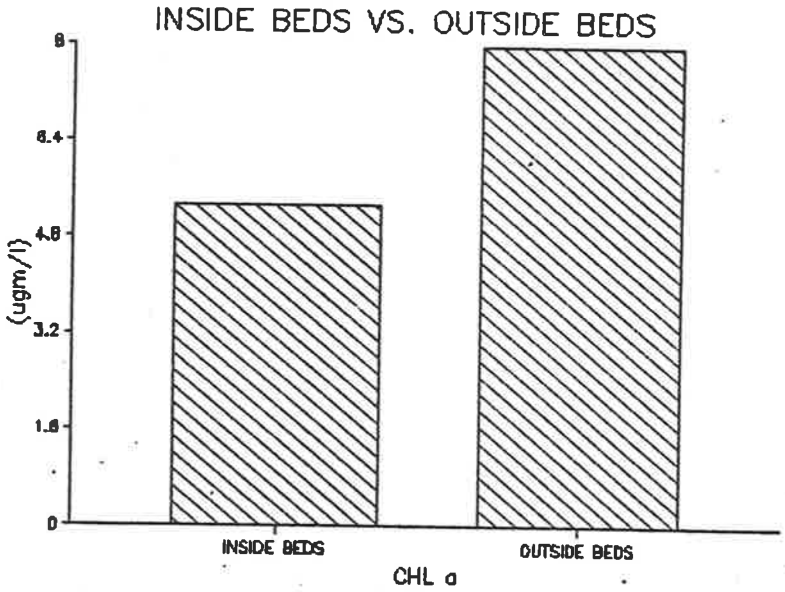


Fig. 11

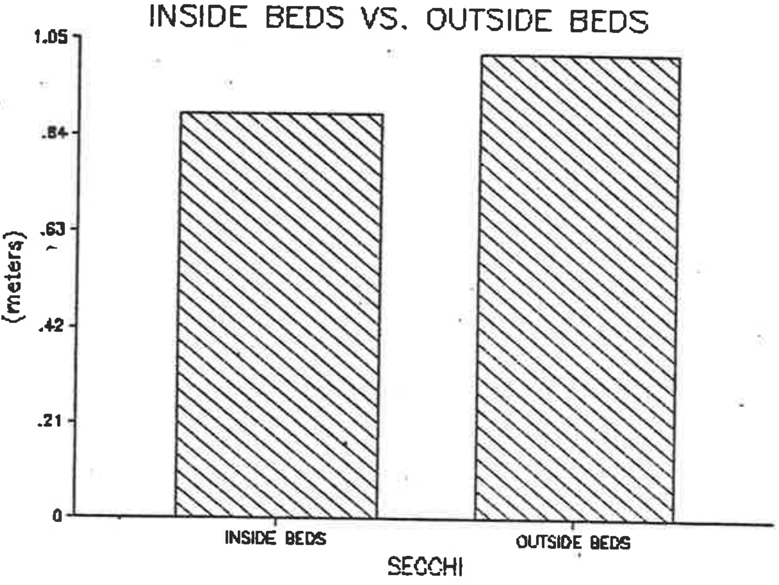
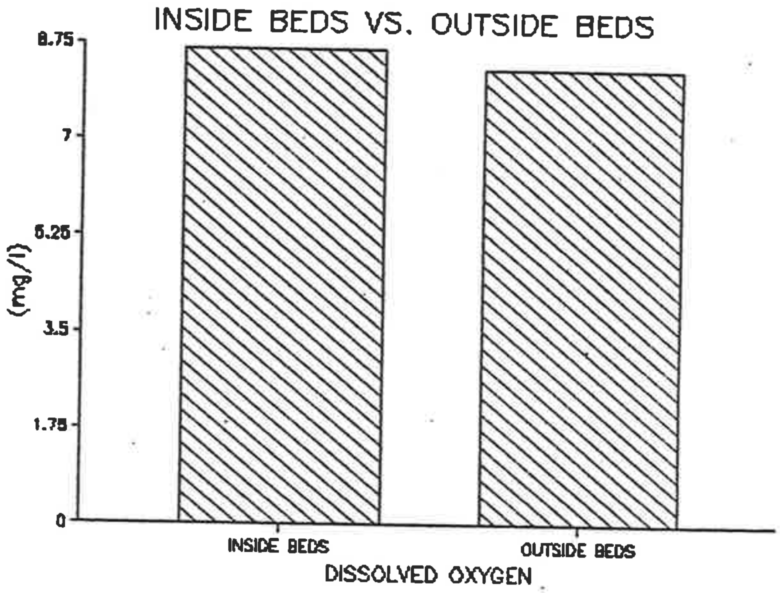


Fig. 12



Averages of 1987-1988 readings taken inside of and outside of SAV beds located at Elk Neck State Park, Sassafras Marsh and Sassafras Beds (near mouth). Health of Sassafras Beds declined significantly in 1988.

Figures 2a - 5a demonstrate water quality trends moving from the mouth of the Elk River (site 17 to the channel at Piney Creek- site 22). Although chlorophyll a is highest at the river mouth and nitrogen is lowest, the other trends are not quite as clear as those in the Sassafras. The chlorophyll a follows ortho-phosphate-P more closely that total phosphate-P, which is not unexpected since ortho phosphorus is the most available form.

Readings taken from the lower towards the upper Bay (figs. 2b - 5b) correlate fairly well in that chlorophyll a and secchi depths are inverse, and the highest phosphorus readings (site 5, central Bay) occurred with the highest chlorophyll a readings. The Sassafras mouth yielded the lowest phosphorus and chlorophyll a and highest secchi readings.

Figures 6-12 illustrate differences between readings taken inside of and outside of SAV beds. These readings may not in fact describe a perfect situation since one of the three beds declined during the testing period (Sassafras Beds declined while Elk Neck and Sassafras Marsh remained healthy) While nitrate-N averages (fig. 6) were not significantly different, ammonia-N averages (fig. 7) were less than half the values inside than they were outside. Ortho phosphate-P levels were not significantly different while total phosphate-P levels averaged just slightly greater outside of beds. Since most of the beds which we examined were along shorelines that were not well protected, resuspension of sediments and therefore phosphates was quite common. This is also why secchi readings (fig. 1) were not very different as has typically been described within SAV areas. Chlorophyll a levels averaged 8 ugm/liter outside of the beds and 5.3 ugm/l within beds. Dissolved oxygen levels were not significantly different.

Average water quality readings must be taken in perspective since several strong nutrient pulses during the growing season may be all it takes to disrupt the phenology and productivity of the plants. Monthly monitoring schedules may miss those critical pulses which can accompany high rainfall and runoff. The fact that some of our monitoring is incomplete will also deemphasize some of the data. Chlorophyll a averages on Table 1, for example are incomplete for 1988 and a portion of 1987 and there is not a good correlation between nutrients and chlorophyll a as there should be.

	% Sand	% Silt	% Clay	% org.	Type
1. Sass.-Freeman Cr.	89.7	6	4.3	0.6	Sand
2. Sass.-Marsh(ln) *	87.7	8	4.3	5.3	Sand
3. Sass.-Marsh(edge)	85.7	0	14.3	3.2	Sand
4. Sass.-Ordinary Pt. *	73.7	18	8.3	3.0	Sandy/silt
5. Sass.-Cove	91.7	0	8.3	0.2	Sand
6. Sass.-Beds	91.7	0	8.3	0.7	Sand
7. Lloyds Creek	95.7	0	4.3	0.3	Sand
8. Elk-Un. Cove *	90.4	6	3.6	1.1	Sand
9. Elk-Neck Pk-Sago *	24.4	72	3.6	3.3	Silt/Loam
10. Elk-Neck Pk-Waves *	88.4	8	3.6	0.9	Sand
11. Elk-Neck Pk-Waves	97.1	0	2.9	0.5	Sand
12. Elk-Piney Creek	94.4	2	3.6	0.8	Sand
13. Elk-Cabin John	93.1	33	3.6	0.9	Sand

Table 2. Particle Size Class distribution for attempted transplant sites. Successful sites have been asterisked. Note at least 6% silt and 1% organic matter at each successful site.

Site	%Sand	%Silt	%Clay	%Org. Matter
* Fishing Battery (0-5cm)	95.1	2.0	2.9	2.5
Fishing Battery (5-15cm)	90.7	6.0	3.2	4.1
* Log Pond (0-5cm)	78.8	15.3	5.9	2.5
Log Pond (5-15cm)	26.1	53.6	20.3	7.5

Table 3 - Sediment characteristics for former successful transplant site and productive source area.

Discussion

The crucial test of any transplant is longevity and it is obvious from our results that much of the upper Bay area is not yet ready for the reintroduction of wild celery (V. Americana), which was once so common (3, 5, 24). Reasons for the decline of SAV in the Bay have been ascribed mainly to nutrient levels (11) and sedimentation, both of which cloud or induce clouding of the water column. Maximum nutrient levels which will allow SAV to return have been variously defined, with DIN levels of 1.4 mg/l and DIP concentrations of 0.01 mg/l being the currently agreed upon values (26). Carter described the resurgence of SAV in the Potomac after phosphorus controls were installed at the Blue Plains Wastewater treatment plant and has indicated that 0.06 mg/l DIP was the threshold level in that system (personal communication). What we see in the Sassafras River is that no transplants make it that are exposed to average total phosphorus levels above 0.04 mg/l (fig. 5, Map I). Since many transplants are also lost below those levels, phosphorus is not the only critical parameter. Vallisneria has been described as being able to grow in substrates from peat to pebbles (10, 16). Barko, et al (2) have noted that with additions of silt to organic and sand substrates, that biomass can increase as much as 300 to 700 percent. Since most of the sediments of the lower Sassafras, where SAV growth might be expected are sand, there appears to be a critical relationship between water column nutrient levels and sediments. All of our transplant sites that survived for two or more years had at least 6% silt and 1% organic matter (table 2). Although grazing by carp has been described as an important element in the loss of SAV (7, 16, 17, 22) it may be that where silt is present that growth is enhanced enough for the plants t tolerate some degree of grazing pressure. Shelter has also been described as an important factor for the establishment of SAV (13, 14, 15) and all of the Sassfrass sites which lasted for 2 seasons were well sheltered. To expound, the pressures upon Vallisneria in the upper Bay due to pollution, grazing by rough fish and rising sea level are so great that only sites with very specific characteristics will manifest as being suitable. Vallisneria is a very durable species, tolerating very low light levels, wave action (23), high nutrient concentrations (8), and a variety of substrates (10, 16). It is thus only when too many factors are sub adequate that the species fails to survive.

Although it may be pushing the data somewhat, attempts will be made here to describe conditions in the upper Bay which will allow for SAV growth and transplant success. We can start with the criteria established in Habitat Requirements for Chesapeake Bay Living Resources (26).

Chlorophyll a and Secchi Depth - A maximum level of 15 ugm/l has been established and our averages in the vicinity of SAV beds are between 5 and 8 ugm/l (fig. 10). At the mouth of the Susquehanna River, where beds are the healthiest in the upper Bay, levels averaged 16 ugm/l and at Ordinary Point levels averaged near 25 ugm/l. At Elk Neck Park the levels were low at less than 5 ugm/l and at Fishing Battery they averaged 10 ugm/l. With the exception of Ordinary Point, the limit appears to be valid. What the Ordinary Point site has to its benefit is that it is well sheltered and has a sediment that is 18% silt. Average secchi depths where plants are growing and/or transplants have been successful, range from 0.7 m to 1.5 m, with most averaging near 0.8 m. Since Vallisneria can grow to depths of 3 times its secchi depth (10) an average minumum value of 0.8 m is not unreasonable.

Phosphorus - Average total phosphorus levels in and around SAV beds equal .045 mg/l and ortho phosphate levels are just over .02 mg/l. In the Sassafras River, SAV exposed to concentrations much above those levels showed no success. Very similar values are noted for vegetated sites at Fishing Battery, the mouth of the Susquehanna River and at Elk Neck State Park.

Conservatively, it could be stated that if other factors are acceptable total phosphorus-P levels of .04 mg/l and ortho phosphorus-P levels of .02 mg/l will allow for the growth of SAV. Recommended levels (26) are <.01 mg/l DIP (which approximates our $O\text{-}PO_4\text{-}P$).

↗ No, 0.14 mg/l (10 µM × 0.014)

Nitrogen - The established criteria call for DIN levels of not more than 1.4 mg/l. In most of the oligohaline waters of our area, both vegetated and unvegetated, averages of NO_3-N range between 1.5 and 3 mg/l and ammonia-N levels varied from zero to 2 mg/l. Ammonia-N levels demonstrated a significant rise during 1988 compared with 1987 throughout the upper Bay area, although the Sassafras River suffered the worst increases. (Table 1, appendices) Although these levels are high they are not inordinate for the upper Bay (25). High nitrogen levels throughout the area included vegetated sites and demonstrate that, submersed plants can tolerate higher nitrogen levels. It could very well be argued that the higher NH_4-N levels in 1988 contributed to the demise of the Sassafras transplant beds that performed so well during 1987. Irrespective, values of up to 2.5 mg/l NO_3-N might be considered tolerable if phosphorus levels are kept low.

Sediments - If there is any pattern that has repeated itself, it is that transplants survive best in sediments which contain at least 6% silt and 1% organic matter, and levels of silt to 50% have been noted as producing exceptional growth (Table 3). With respect to finding transplant sites in the upper Bay, this is not the most ideal situation since most of the eastern shore exhibits sand and pebbles in shallow water areas, and the central flats area which demonstrates finer textured sediments is below 1 meter of depth (Map II). Thus, while silts may improve such factors such as cation exchange capacity (C.E.C.) and can possibly counterbalance high water column nutrient impacts, they are not common in shallow water habitats.

Shelter - This factor has also influenced transplant success rates. Fishing Battery, Ordinary Point, and Sassafras Marsh all are areas sheltered by rock or land. Elk Neck State Park is sheltered by orientation away from the prevailing winds and by other SAV beds. One section (fig. 1) is immediately adjacent to a stone riprapped shoreline which may deter fish from grazing.

Fishing Battery is also protected by stone, although fish have access to the area. In the latter instance, the protected area probably allows finer sediments to drop out of the water column and diminishes turbulence.

While the parameter limits outlined for SAV (26) are fairly solid, the purpose of discussions here is to ascertain where submersed plants will survive if transplanted there. Based upon observations, we will push the defined limits somewhat and introduce another factor. It appears that <u>Vallisneria americana</u> will survive in the upper Bay under the following average conditions:

Water Depth	$>$.3 M and $<$ 1.3 m low water
Secchi Depth	$>$ 0.8 M
Chl a	$<$ 15 ugm/l
Salinity	$<$ 5 ppt
$T\text{-}PO_4\text{-}P$	$<$ .04 mg/l
$O\text{-}PO_4\text{-}P$	$<$ .02 mg/l
$NO_3\text{-}N + NH_4\text{-}N$	$<$ 3 mg/l (1.5 = preferable max.)
Sediment	$>$ 6% Silt, $<$ 5% organic matter)
Shelter	Beneficial, avoid high energy shorelines

All factors are obviously not accounted for here. Wave action, grazing pressure, boating activity and storms can all influence growth and transplant success. Also, since we have observed plant growth where some of the above factors are higher than those indicated above there must be some method of accounting for that variance. For example, higher nutrient levels may be tolerated when more silt is present in the sediments or when stone breakwaters shelter the site. Although several attempts have been made to develop a formula which will yield an importance value, more work needs to be accomplished on this endeavor.

With conditions as they are in the upper Bay, it is clear that despite water column nutrients and chlorophyll <u>a</u> concentrations submersed plant populations still naturally occur and have been expanding somewhat (20). Areas of greatest population densities exist at the mouth of the Susquehanna River and where sandy silts and some sheltering influence predominate. Since we have already transplanted into most available known sites where water quality would permit SAV growth, there are three alternatives left for new transplants.

1) Wait for water quality to improve before progressing any further.

2) Plant in marsh areas directly adjacent to the Bay, where water quality is adequate (several possibilities exist around the

Elk and Sassafras Rivers).

3. Modify existing sediment or depth regimes or install some form of sheltering influence before performing new transplants.

While the first two factors are plausible, it is unknown at this time how much area within marshes which surround the Elk, Sassafras and Stillpond areas is suitable SAV habitat. We have found one area noted in this paper, near Turner Creek.

With respect to modification we have utilized time release fertilizers to enhance SAV growth (14, 15) as per Bob Orth (19) and we have used Heteranthera dubia and Myriophyllum spicatum to surround Vallisneria beds on the assumption that they would provide shelter because they are generally taller and grow in deeper water. These methods worked quite well for the first year, but if sediments were inappropriate (i.e. no silt), the plants generally did not perform well the second year. Two sites at which the plants did very well are Fishing Battery and Elk Neck State Park, along the riprapped shoreline. Whereas the Battery site is surrounded by stone, plants also did very nicely outside of, but immediately adjacent to the submersed stone breakwall. At Elk Neck, although plants did well throughout the area, they did exceptionally well along the riprap, very close to shore. The possibility exists that stone may have a deterent effect direct or indirect upon grazing by rough fish and this needs further investigation. The Elk Neck site has a number of other unique factors including spring water bleeding through the sediments at various locations. One other factor which we have not accounted for is the possible impact of drag nets on our transplant beds. At the Sassafras Beds site for example, and at several other open water sites, plants disappeared seemingly overnight after growing well for weeks or even for a full season. While rough fish may be responsible, even Myriophyllum and Heteranthera were impacted. At Sassafras Beds, the sites were easily visible in 1987 September overflights and were gone 2 weeks later. Myriophyllum and Heteranthera are both species which usually persit well into October before dying back. Although we have resisted the use of snow fence as a protective measure on the premise that the plants should be able to make it on their own in a particular area, the use of such measures will be employed next season. At two sites (Lloyds Creek and Cabin John Creek) boating activity significantly affected our plantings.

The final suggestion of this investigation is that some form of environmental modification be tested next season. The evidence is very strong that shelter and silty sediment have a lot to do with transplant survival in the upper Bay, despite degraded or marginal water quality. As uncommon as healthy SAV beds are, it behooves us to ascertain just how effective different measures can be. Riprap, sediment alteration, artificial shoals, snow fences, and use of dredge overboarding are all possibilities that should be tested. As sea level continues to rise, modification may prove to be a valuable tool for replacement, establishment or enhancement of SAV beds in the upper Chesapeake Bay.

Conclusions

Water quality monitoring of the Susquehanna Flats, Elk and Sassafras Rivers has demonstrated that for the most part nutrient levels and chlorophyll a concentrations are beyond these levels established as being limiting for SAV growth (26). While submersed grasses are typically not found where the parameters are beyond those established levels and transplants have generally failed when attempted, there are exceptions. These exceptions have generally occurred where sediments contain favorable amounts of silt (>6%) and often where shelter is evident. Since much of the upper Bay area with adequate depth profiles has sandier sediments or else organic muds (also unfavorable) it will prove beneficial to locate those microcosms with ideal sediments and to transplant with at least snow fence as a shelter. The other possibility is modify existing silt/shelter regimes to test the feasibility of such activities.

Acknowledgements

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Fig. 13

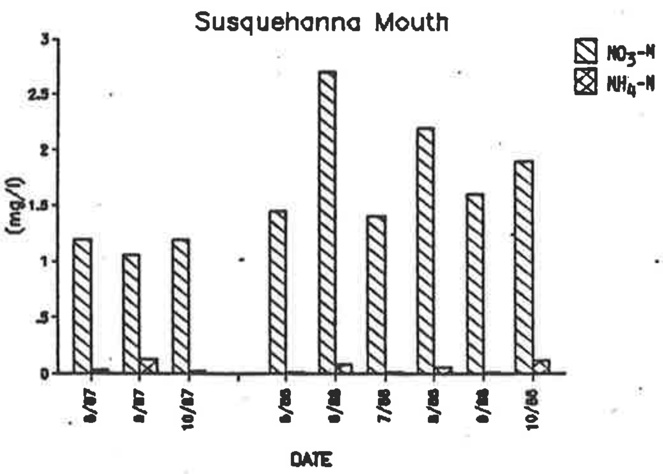


Fig. 14

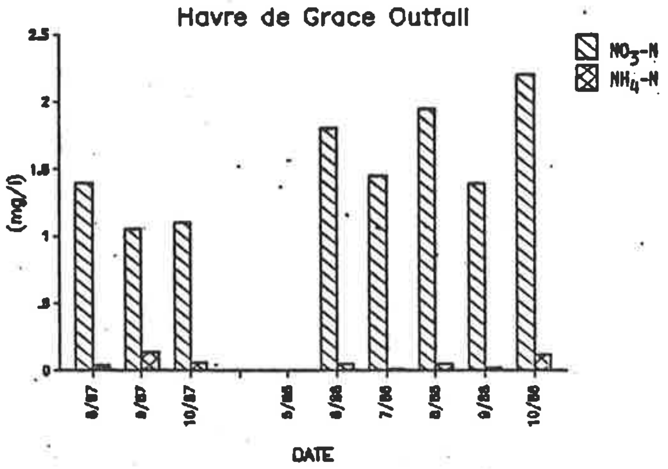


Fig. 15

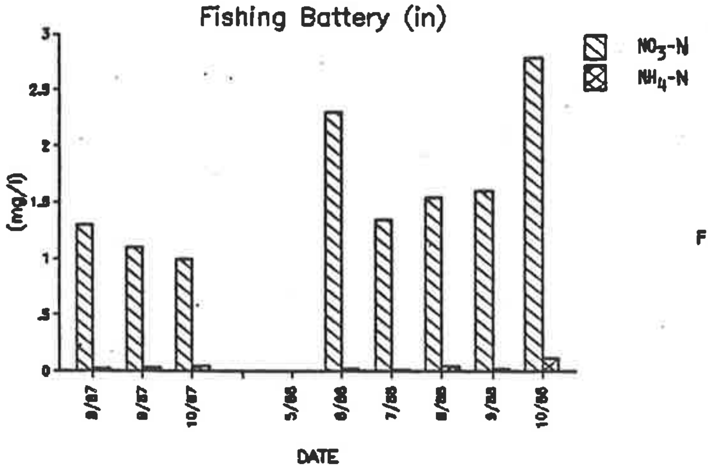


Fig. 16

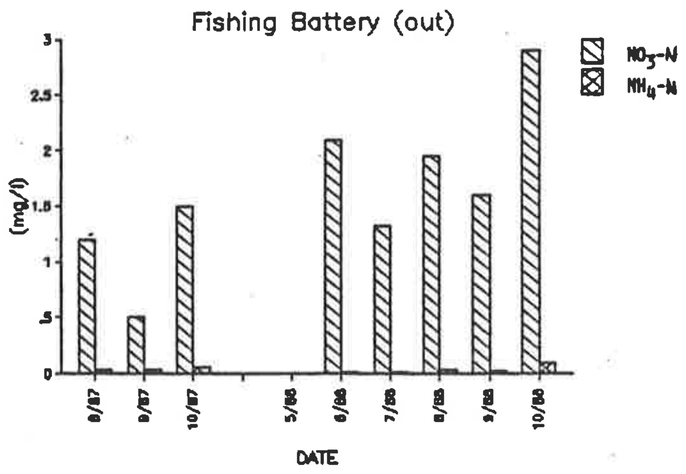
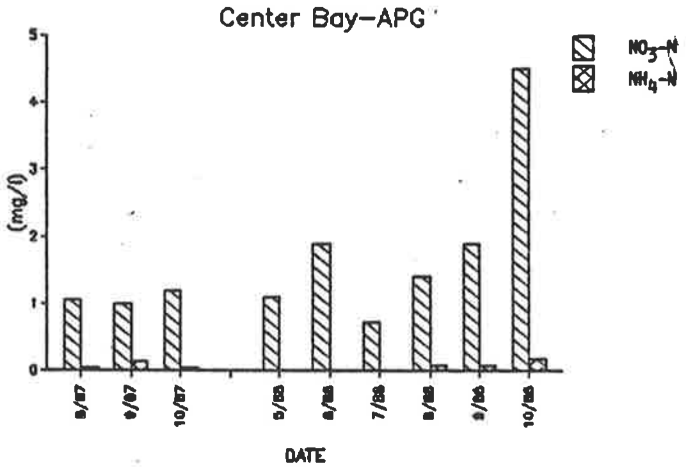


Fig. 17



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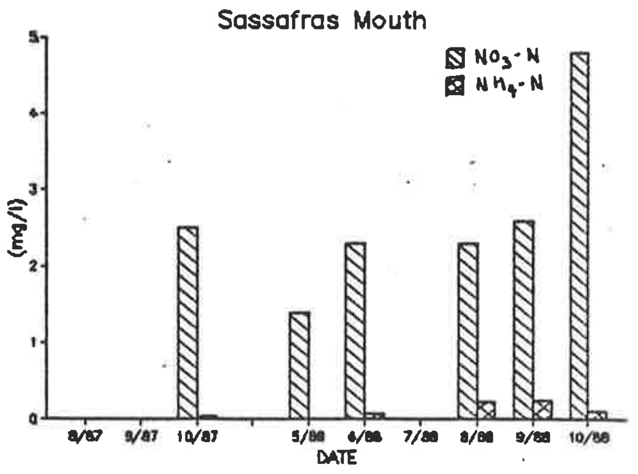


Monthly Nitrate-N and Ammonia-N readings at indicated sites.

Fig. 19

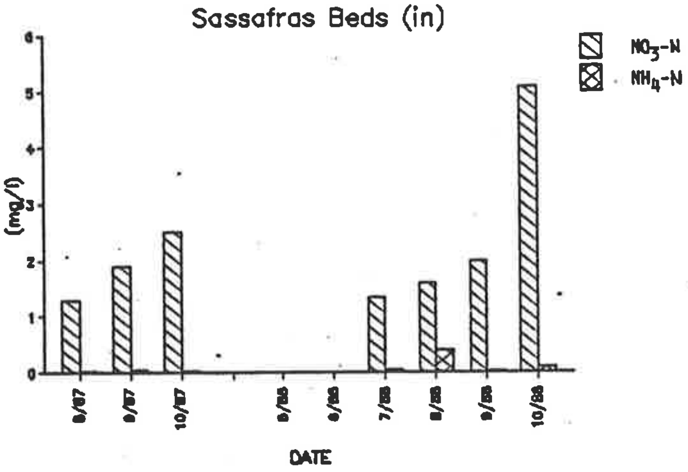


Fig. 22

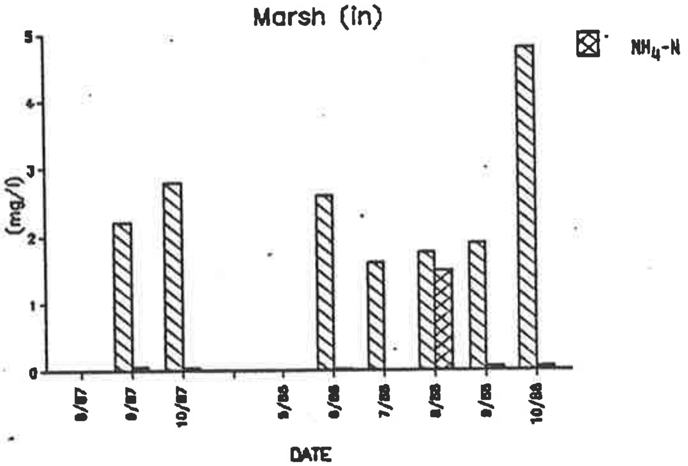
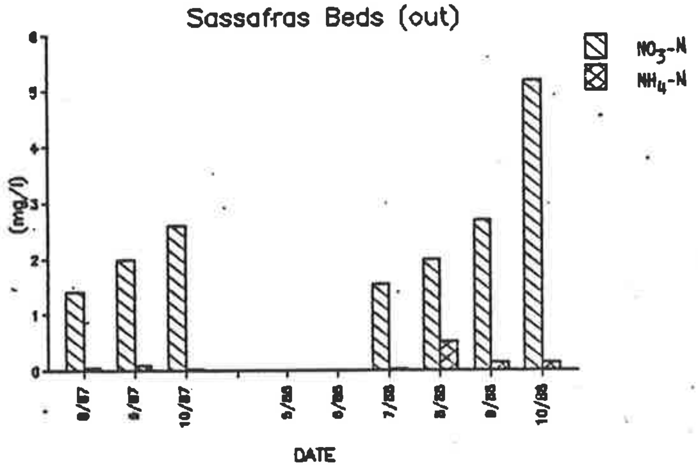


Fig. 20



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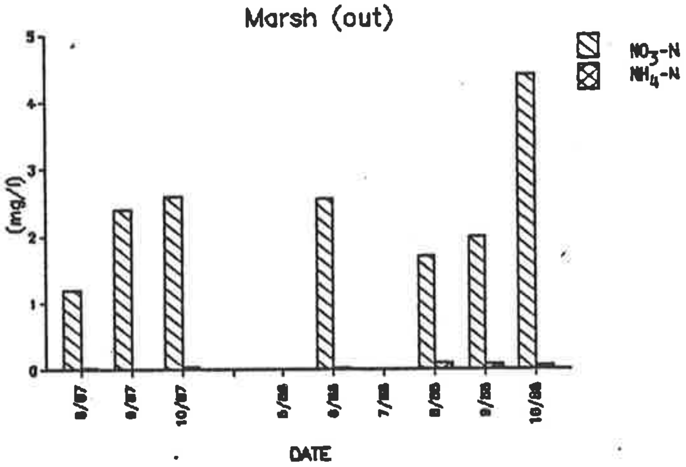

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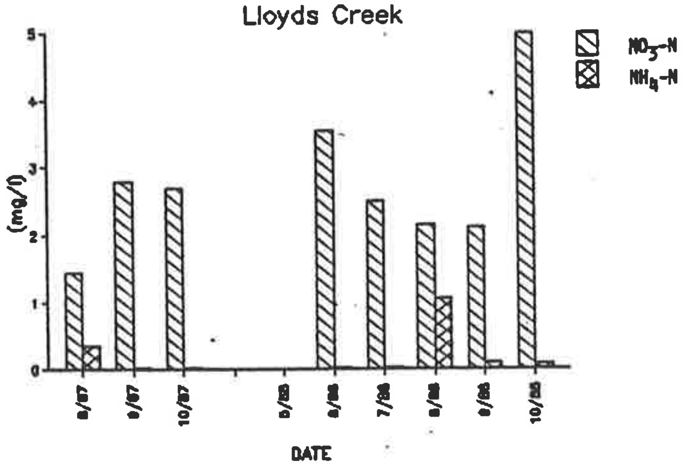
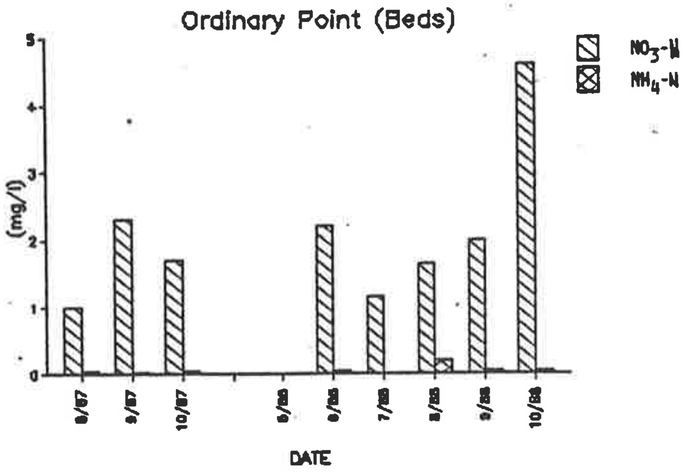


Fig. 24



Monthly Nitrate-N and Ammonia-N readings at indicated sites.

Fig. 25

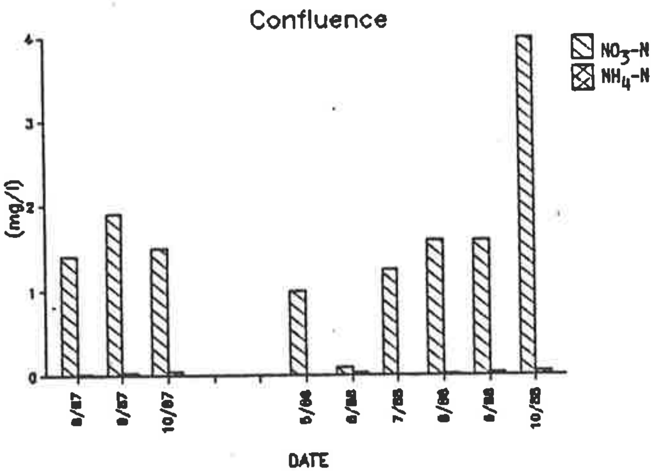


Fig. 26

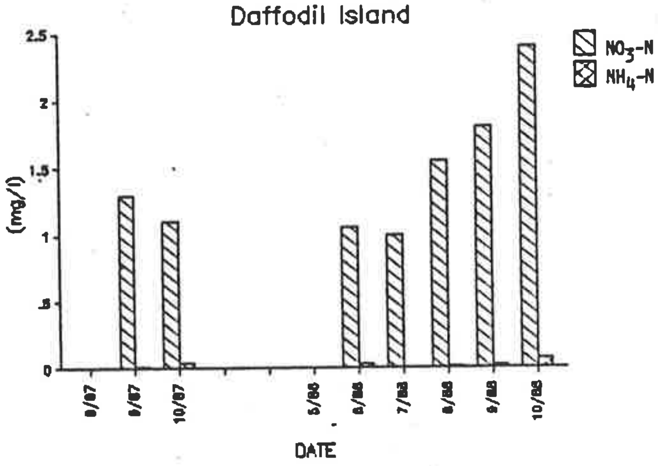
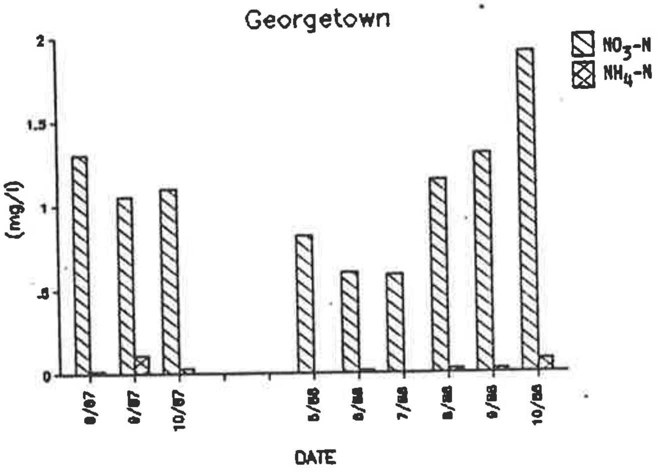


Fig. 27



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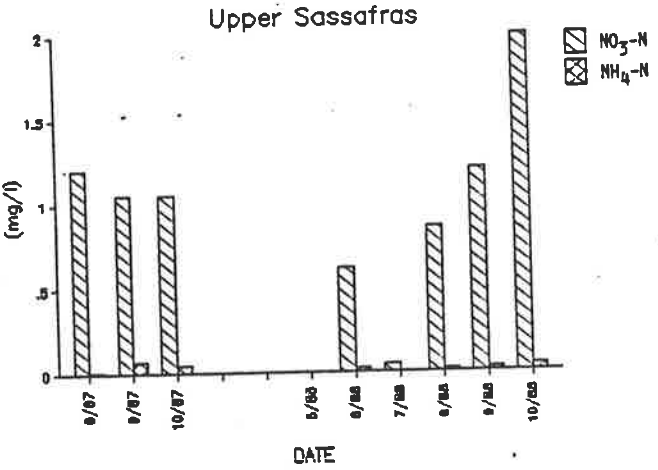

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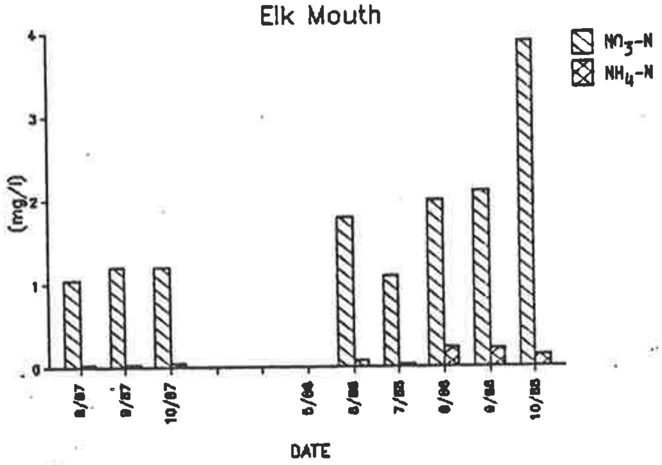

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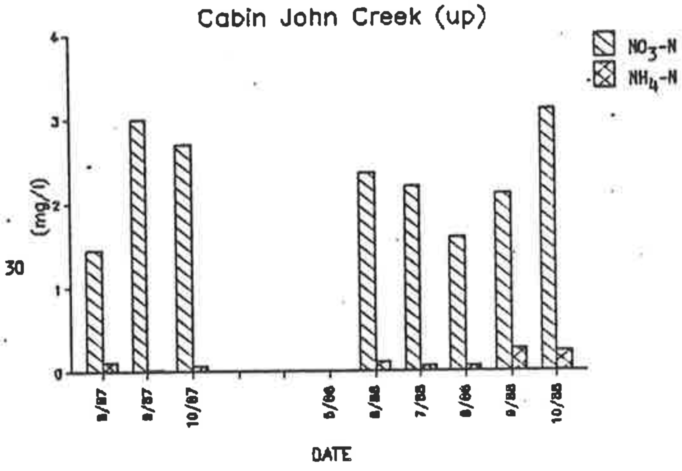


Monthly Nitrate-N and Ammonia-N readings at indicated sites.

Fig. 31

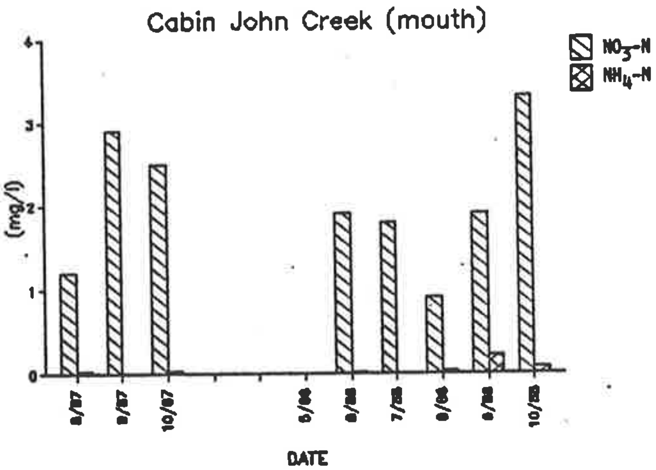

Cabin John Creek (mouth)

Fig. 32

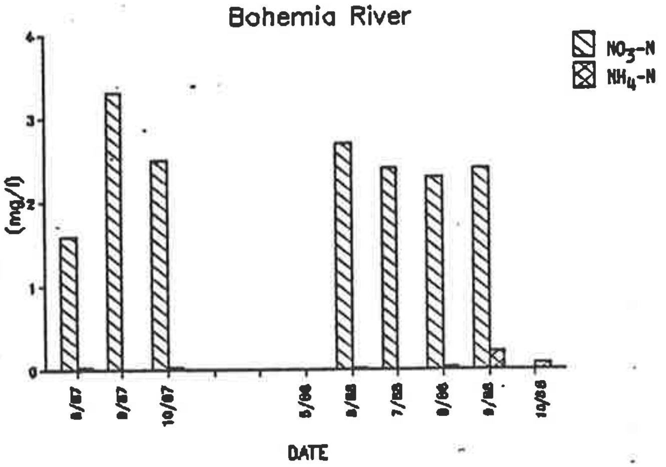

Bohemia River

Fig. 33

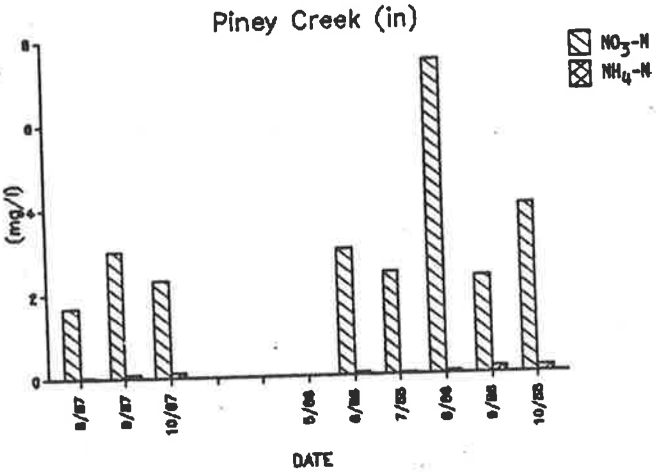

Piney Creek (in)

Fig. 34

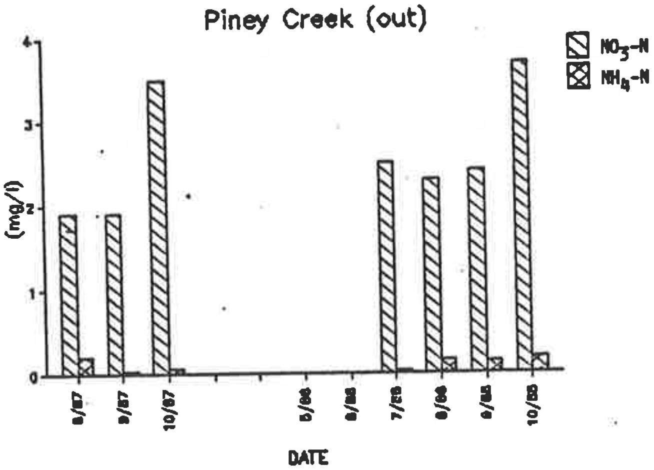

Piney Creek (out)

Fig. 35

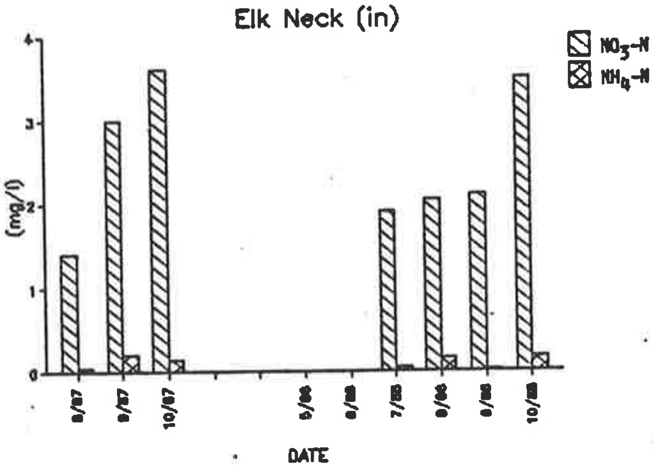
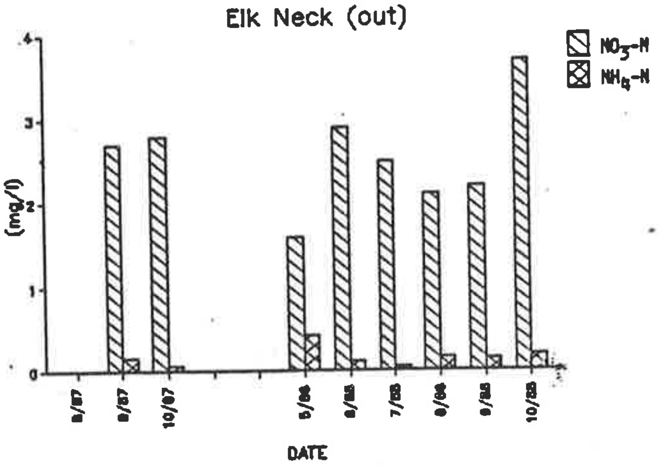

Elk Neck (in)

Fig. 36


Elk Neck (out)

Monthly Nitrate-N and Ammonia-N readings at indicated sites.

Fig. 37

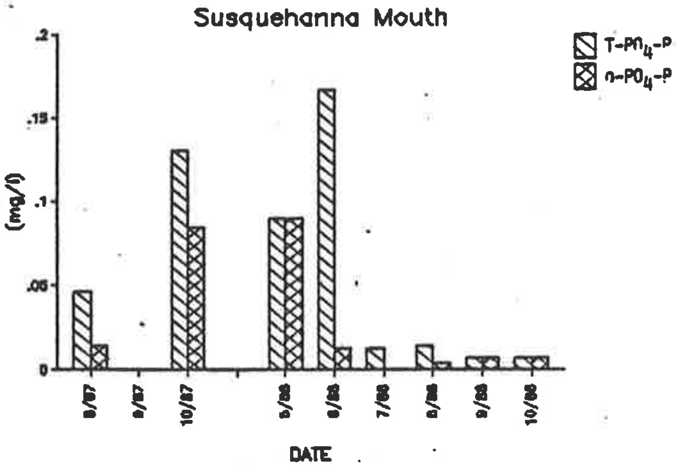
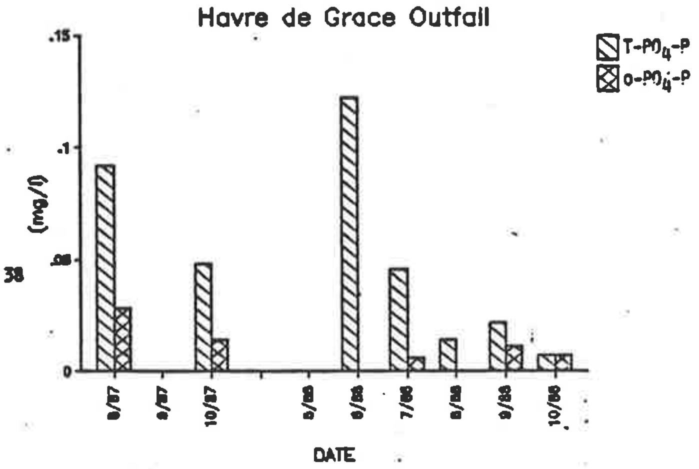


Fig. 38



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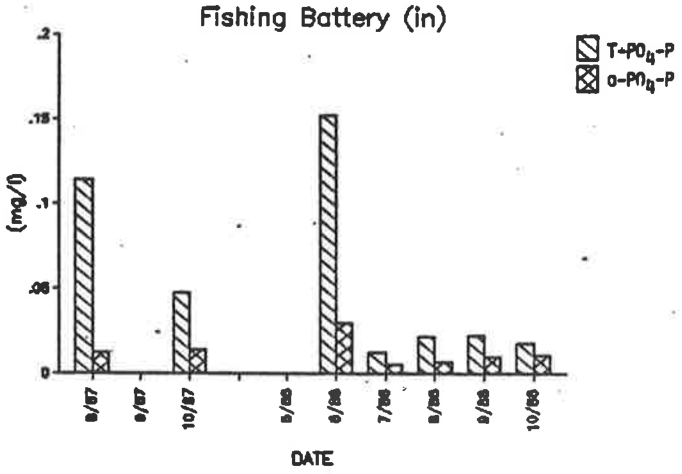

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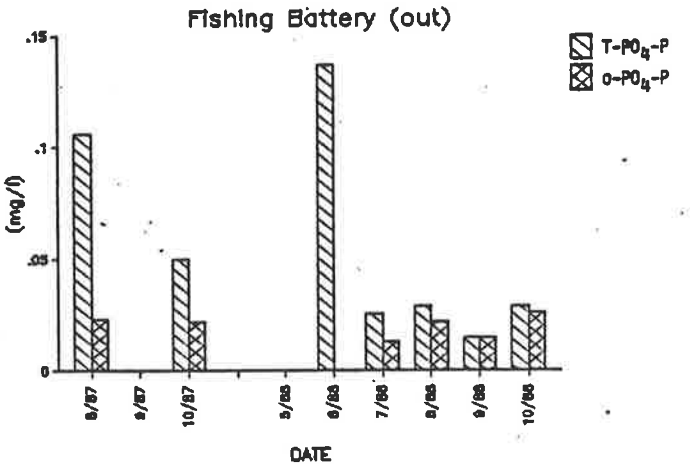

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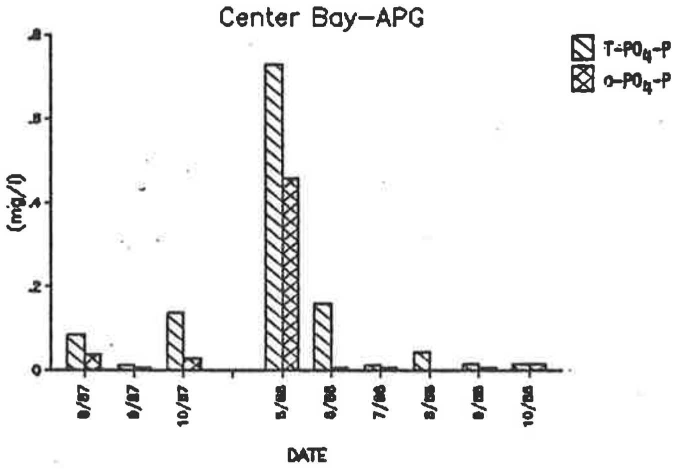

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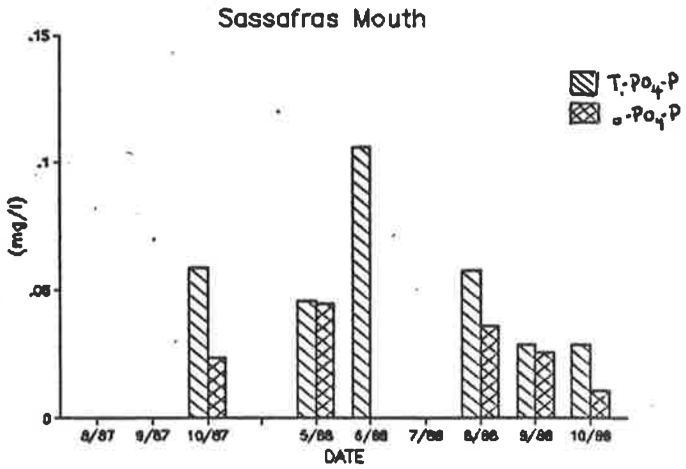


Monthly total and ortho phosphate-P readings at indicated sites.

Fig. 43

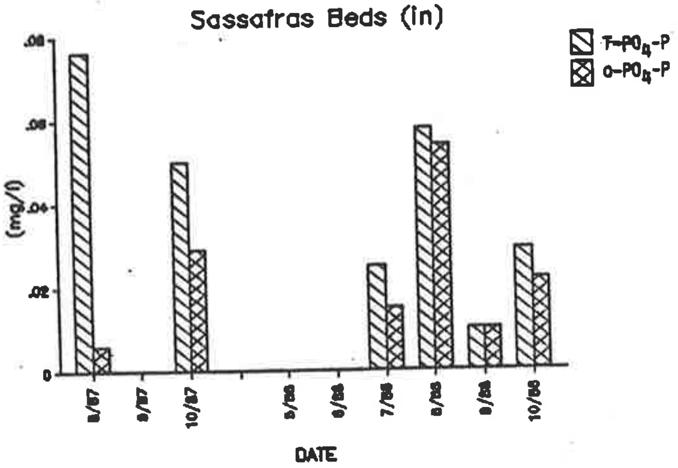
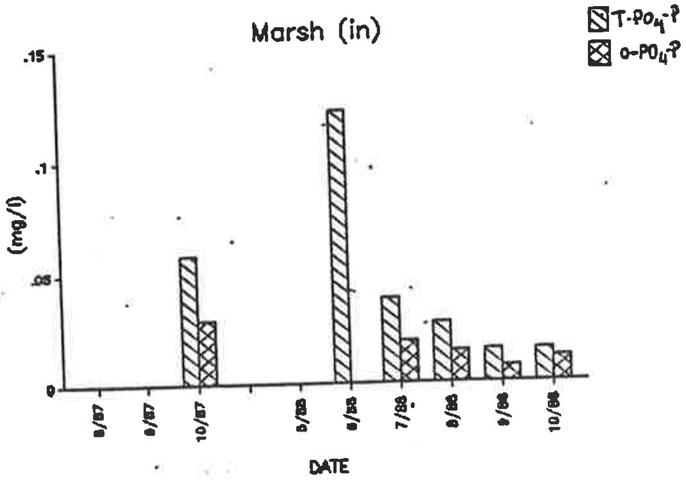


Fig. 46



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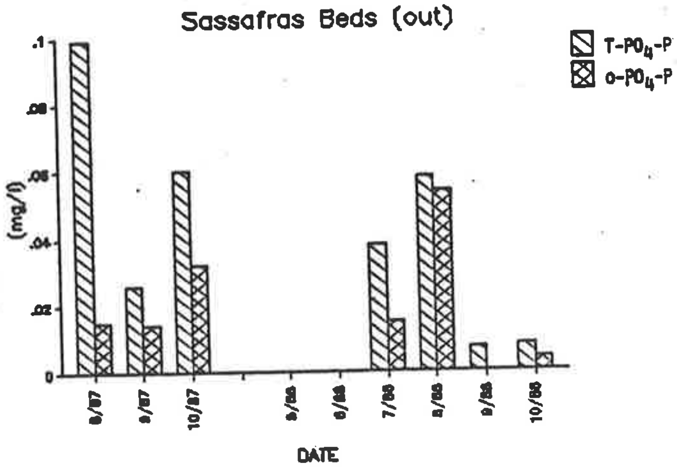

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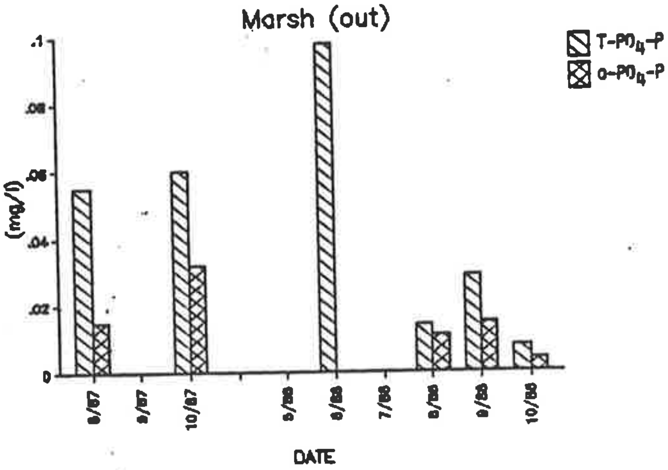

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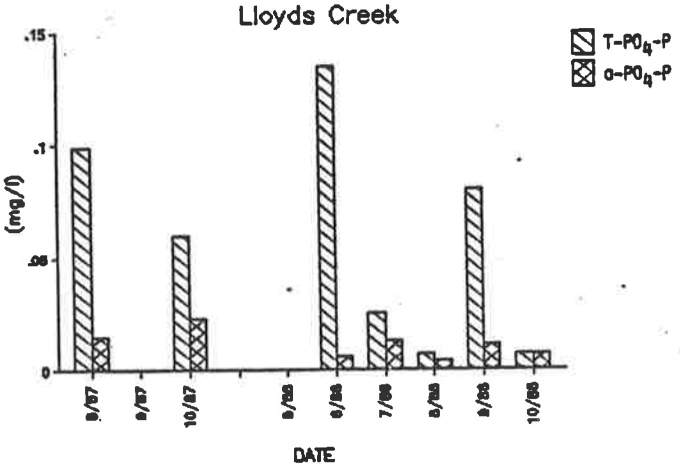

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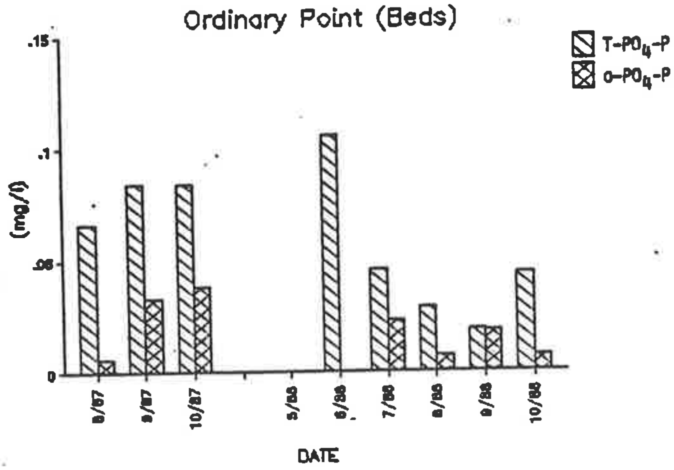


Monthly total and ortho phosphate-P readings at indicated sites.

Fig. 49

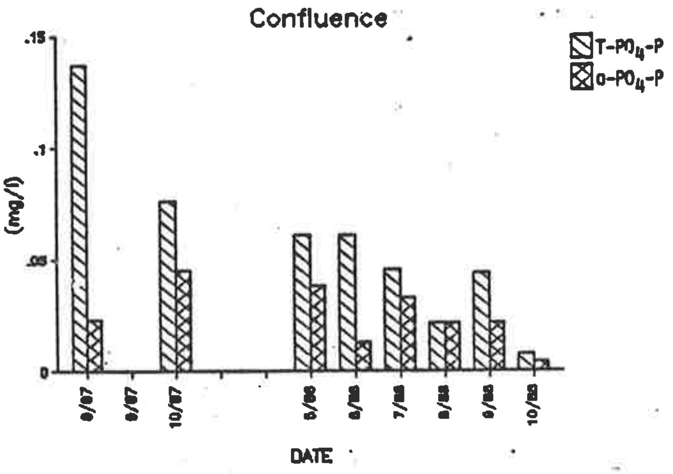


Fig. 50

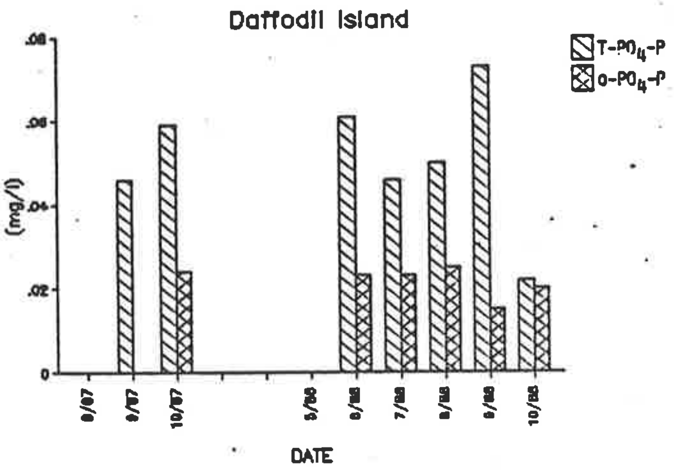
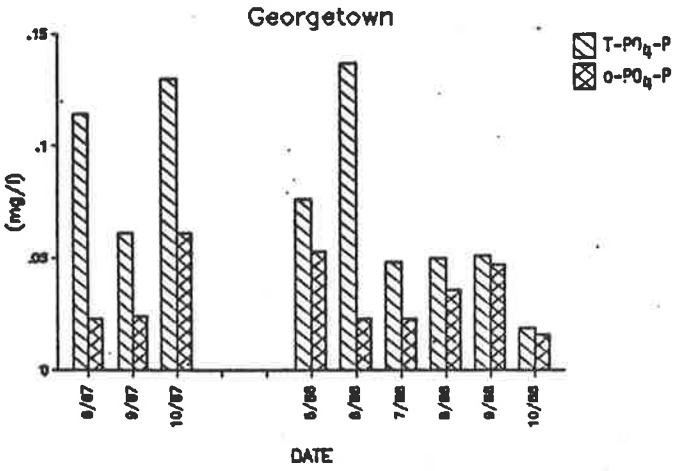


Fig. 51



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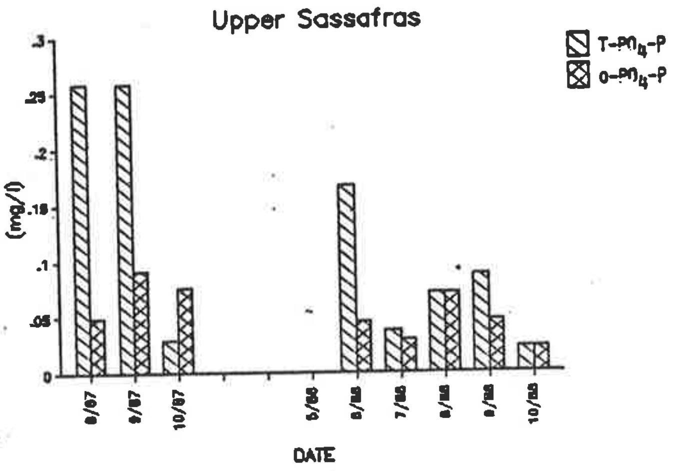


Fig. 53

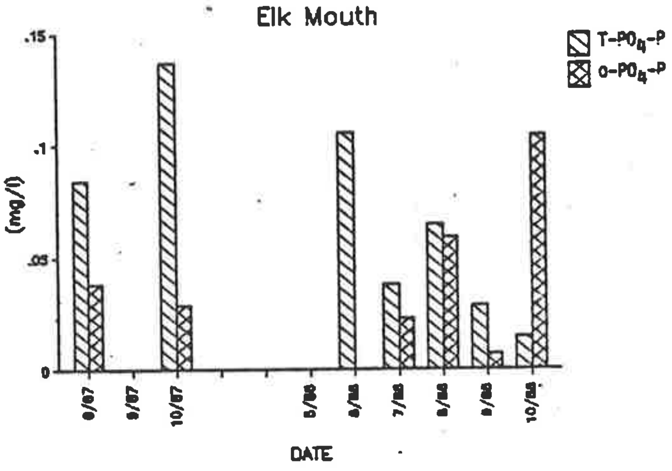
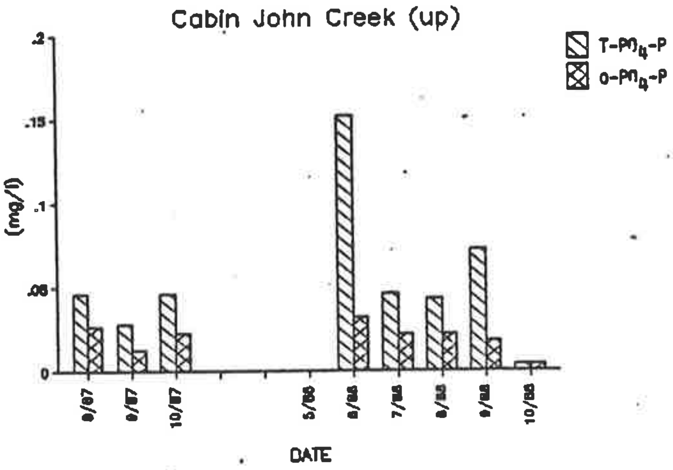


Fig. 54



Monthly total and ortho phosphate-P readings at indicated sites.

Fig. 55

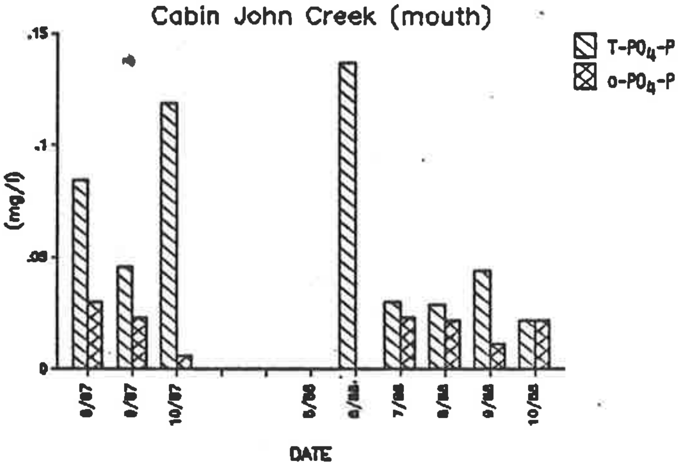


Fig. 58

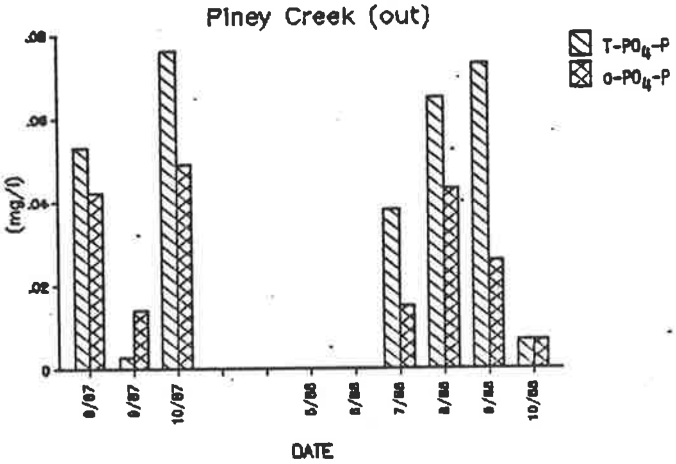


Fig. 56

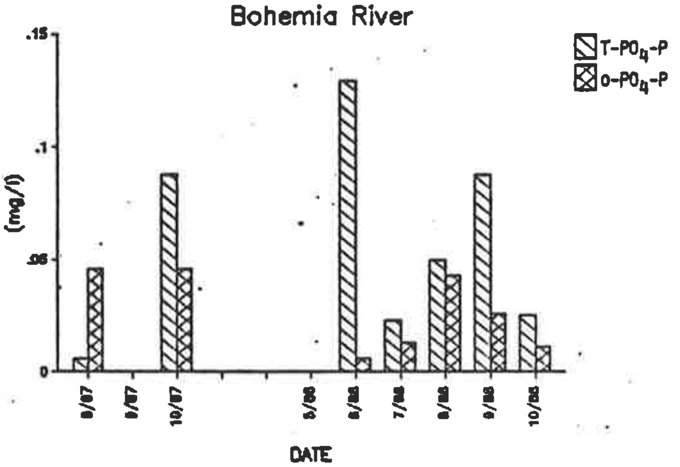


Fig. 59

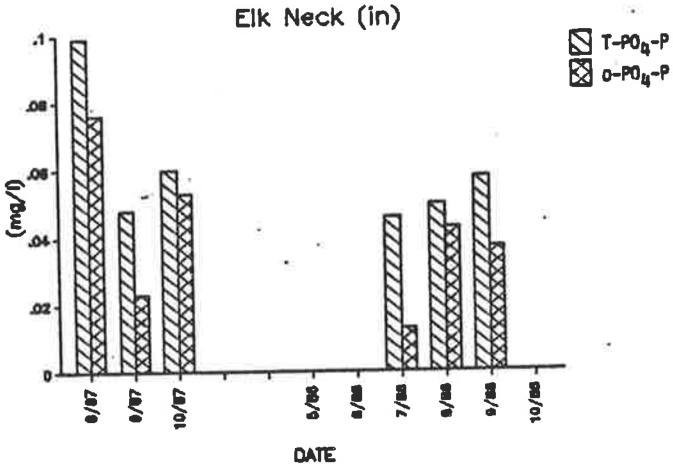


Fig. 57

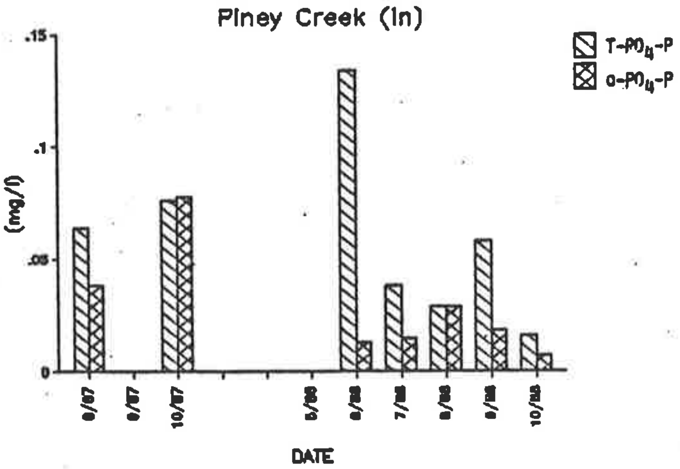
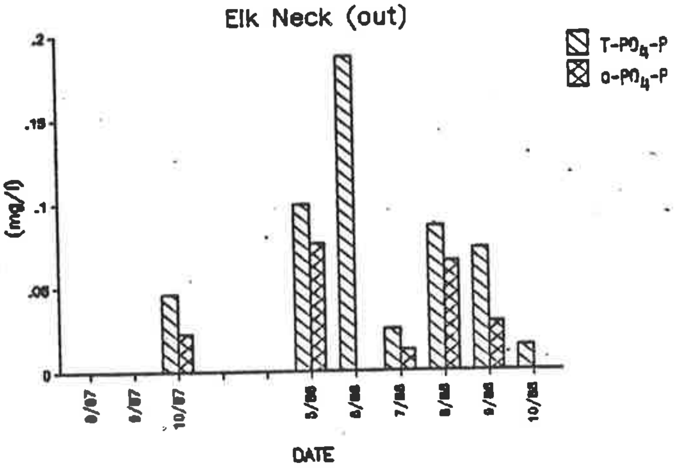


Fig. 60



Monthly total and ortho phosphate-P readings at indiated sites.

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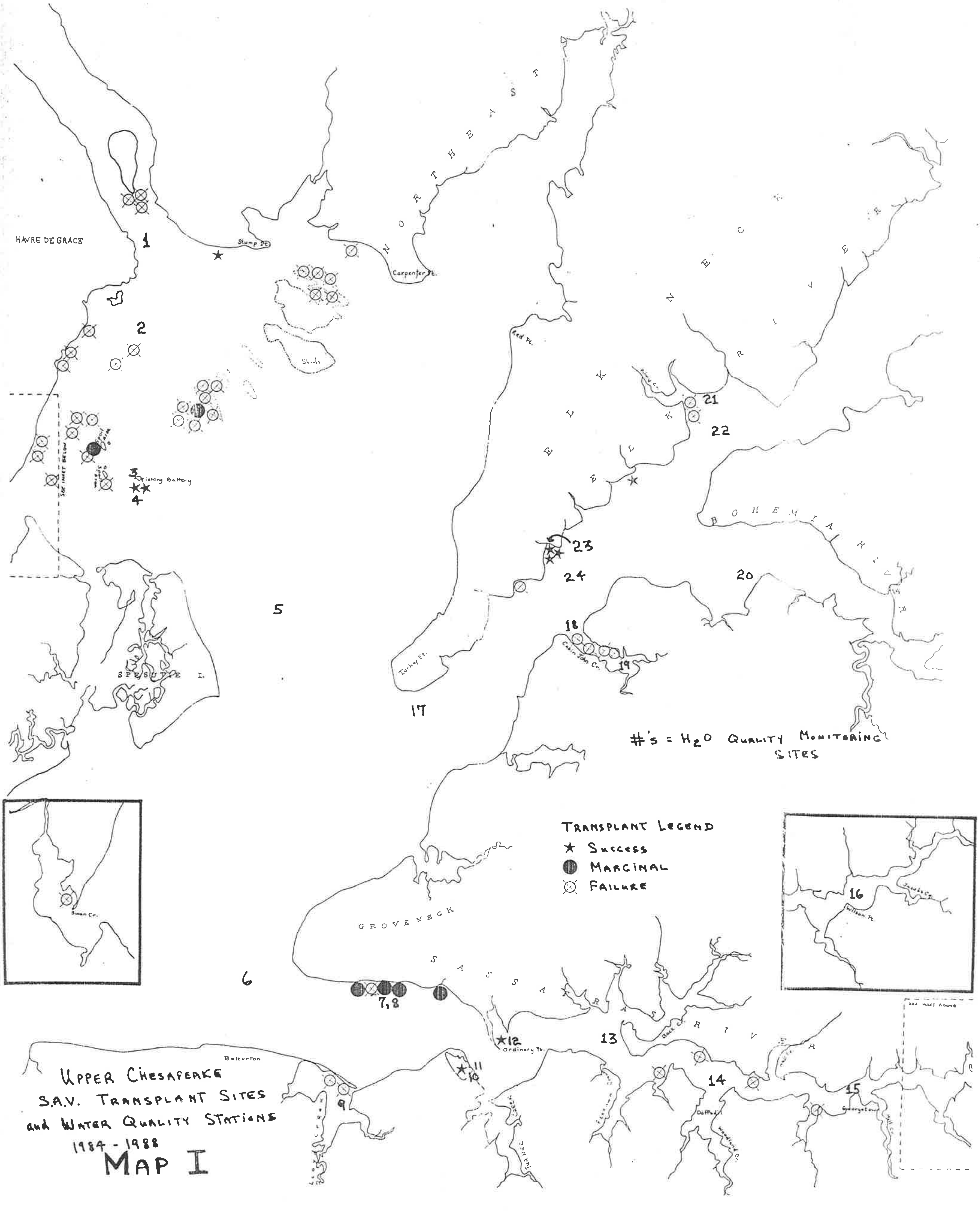
APPENDICES

SITE #	SITE NAME	DATE	TEMPERATURE (degrees C)	DISSOLVED OXYGEN (mg/l)	SECCHI DEPTH (meters)	CHL a (ugm/l)	pH	NITRATE-N (mg/l)	AMMONIA-N (mg/l)	TOTAL PHOSPHATE-P (mg/l)	ORTHO PHOSPHATE-P (mg/l)
13	Confluence										
		8/87	28	8.2	.5		7.7	1.4	.021	.137	.023
		9/87	24.5	9	.66	29.05	8.9	1.9	.031	0	0
		10/87	15	11.3	.5	13.53	9.2	1.5	.053	.076	.045
		5/88	14.5	10.1	.66	21.25	7.9	1		.061	.038
		6/88	28.5	9	.7	24.19	6.7	.1	.039	.061	.013
		7/88	28	11.2	.6	52.52	8.96	1.25		.046	.033
		8/88	26	8	.6		7.35	1.6	.016	.022	.022
		9/88	23.5	9.3	.8		8.11	1.6	.034	.044	.022
		10/88	11.5	10.8	1		7.51	4	.057	.008	.004
14	Daffodil Island										
		8/87									
		9/87	24.5	8.6	.5	47.43	8.5	1.3	.015	.046	0
		10/87	15	11.4	.33	37.78	9.4	1.1	.04	.059	.024
		5/88									
		6/88	29.5	9.2	.5	29.65	8.35	1.05	.033	.061	.023
		7/88	28	11.4	.5	57.17	9.8	1		.046	.023
		8/88	25.5	8.8	.5		8.29	1.55	.0165	.05	.025
		9/88	23	8.8	.5		8,39	1.8	.024	.073	.015
		10/88	11.5	11.4	.8		7.29	2.4	.074	.022	.02
15	Georgetown										
		8/87	29	8.6	.33		8.6	1.3	.015	.114	.023
		9/87	24.5	9.8	.33	61.76	8.9	1.05	.11	.061	.024
		10/87	15.5	11.3	.33	45.64	9.3	1.1	.03	.13	.061
		5/88	15	10.2	.33	56.2	8.4	.82		.076	.053
		6/88	30	8.6	.3	36.82	8.17	.6	.018	.137	.023
		7/88	28	9.2	.3	63.18	9.48	.59		.048	.023
		8/88	25	7.6	.3		6.87	1.15	.024	.05	.036
		9/88	23	8.4	.5		8.22	1.3	.025	.051	.047
		10/88	11.5	11	.5		7.55	1.9	.078	.019	.016
16	Upper Sassafras										
		8/87	30	10.8	.33		9.3	1.2	.01	.258	.049
		9/87	24.5	7.8	.25	66.19	9.2	1.05	.071	.258	.091
		10/87	15.5	13.6	.33	37.46	9.7	1.05	.052	.03	.076
		5/88									
		6/88	31	8.6	.3	43.22	8.48	.62	.023	.167	.046
		7/88	28	10.6	.3	81.98	9.5	.046		.038	.03
		8/88	24	9.4	.2		8.51	.86	.015	.072	.072
		9/88	24	8.9	.5		8.91	1.2	.023	.008	.047
		10/88	11.5	11.4	.5		7.54	2	.041	.022	.022
17	Elk Mouth										
		8/87	28	7.9	.6		8.1	1.05	.04	.084	.038
		9/87	23	8.8	.9	12.05	8.6	1.2	.035	0	0
		10/87	15	12.4	.66	6.03	8.9	1.2	.045	.137	.029
		5/88									
		6/88	28.5	7.5	.6	12.64	6.89	1.8	.079	.106	0
		7/88	24.5	6.9	.5	4.48	6.88	1.1	.042	.038	.023
		8/88	25	6.2	1		6.76	2	.235	.065	.059
		9/88	23	6.8	1.4		6.93	2.1	.23	.029	.007
		10/88	11.5	9.8	.6		6.78	3.9	.145	.015	.105
18	Cabin John Creek (up)										
		8/87	31	7	.5		7.7	1.45	.11	.046	.027
		9/87	24.5	9.5	.5	4.17	8.2	3	.016	.028	.013
		10/87	16	8.6	.25	3.57	8.6	2.7	.061	.046	.023
		5/88									
		6/88	30	6.2	.6	3.92	6.73	2.35	.12	.152	.032
		7/88	27	6.7	1.1	2.81	7.4	2.2	.067	.046	.022
		8/88	24.5	8.3	.5		7.14	1.6	.063	.043	.022
		9/88	23	7.6	1		6.9	2.1	.265	.073	.018
		10/88	11	10.6	1.2		7.05	3.1	.235	.004	.004
19	Cabin John Creek (mouth)										
		8/87	31	10	.33		9.1	1.2	.034	.084	.03
		9/87	24.5	10.2	.33	5.28	9.2	2.9	.01	.046	.023
		10/87	17	11.8	.33	7	8.9	2.5	.037	.119	.006
		5/88									
		6/88	30	9.8	.2	29.07	7.75	1.9	.026	.137	0
		7/88	28.5	11.7	.5	33.91	8.68	1.8	.011	.03	.023
		8/88	25	9.9	.3		8.7	.91	.029	.029	.022
		9/88	23	8.6	1		6.87	1.9	.22	.044	.011
		10/88	10.5	10	.8		7.24	3.3	.082	.022	.022
20	Bohemia River										
		8/87	30.5	6.9	.33		8.9	1.6	.041	.006	.046
		9/87	24	10.8	.6	18.48	8.7	3.3	.01	0	0
		10/87	15.5	9	.33	17.96	8.3	2.5	.033	.088	.046
		5/88									
		6/88	28.5	6	.8	4.2	6.77	2.7	.1	.129	.006
		7/88	26.5	6.6	1	2.87	6.47	2.4	.061	.023	.013
		8/88	25.5	5.9	.5		6.82	2.3	.12	.05	.043
		9/88	23	7.4	1.8		6.73	2.4	.195	.088	.026
		10/88	11.5	10.6	1.2		7.1	3.6	.175	.025	.011
21	Piney Creek (in)										
		8/87	31	13.2	.6		7.6	1.7	.043	.064	.038
		9/87	24	6.9	1.66	.94	7.4	3	.11	0	0
		10/87	16.5	7.8	.66	1.73	7.5	2.3	.14	.076	.078
		5/88									
		6/88	30.5	6.8	.4	7.21	6.64	3	.075	.134	.013
		7/88	27	8.1	.5	8.77	6.71	2.45	.04	.038	.015
		8/88	25	7.8	.5		6.85	7.45	.066	.029	.029
		9/88	23.5	8.4	1		6.82	2.3	.155	.058	.018
		10/88	11	11	1.1		7.08	4	.17	.016	.007
22	Piney Creek (out)										
		8/87	30.5	5.4	1		7	1.9	.2	.053	.042
		9/87	24	7.8	.8	1.39	8	1.9	.042	.003	.014
		10/87	15.5	8.2	1.32	1.79	7.5	3.5	.069	.076	.049
		5/88									
		6/88									
		7/88	26.5	6.9	.5	12.1	6.7	2.5	.04	.038	.015
		8/88	25.5	6.8	.8		6.8	2.3	.16	.065	.043
		9/88	23.5	9.4	.6		6.68	2.4	.145	.073	.026
		10/88	11.5	11	1.7		7.07	3.7	.19	.007	.007
23	Elk Neck (in)										
		8/87	31	5.7	.5		7	1.4	.053	.099	.076
		9/87	28	8.6	.33	1.35	7.9	3	.2	.048	.023
		10/87	18	9.1	1.66	1.47	7.6	3.6	.15	.06	.053
		5/88									
		6/88									
		7/88	27	6.8	.5	1.4	6.71	1.9	.058	.046	.013
		8/88	26	6.4	.8		6.7	2.05	.155	.05	.043
		9/88	23	6.8	.8		6.84	2.1	.02	.058	.037
		10/88	12	10.7	1.2		7.31	3.5	.18	0	0
24	Elk Neck (out)										
		8/87									
		9/87	24	6.7	1.33	4.91	7.1	2.7	.16	0	0
		10/87	15.5	8.2	1.56	.74	8.3	2.8	.065	.046	.023
		5/88	14	9.7	.66	8.88	6.8	1.6	.42	.099	.076
		6/88	28	6.3	.9	4.82	6.94	2.9	.11	.187	0
		7/88	26	6.7	.8	2.75	6.66	2.5	.054	.025	.013
		8/88	26	6.8	.5		6.69	2.1	.16	.086	.065
		9/88	23	7.2	.6		6.85	2.2	.145	.073	.029

SITE #	SITE NAME	DATE	TEMPERATURE (degrees C)	DISSOLVED OXYGEN (mg/l)	SECCHI DEPTH (meters)	CHL a (ugm/l)	pH	NITRATE-N (mg/l)	AMMONIA-N (mg/l)	TOTAL PHOSPHATE-P (mg/l)	ORTHO PHOSPHATE-P (mg/l)
1	Susquehanna Mouth										
		8/87	28	8.2	1.7		7.8	1.2	.035	.046	.014
		9/87	24.5	8.2	1.9	5.24	7.7	1.05	.13	0	0
		10/87	14.5	11.6	1.66	3.51	7.9	1.2	.032	.13	.084
		5/88	13	10.2	1	15.31	7.19	1.45	.012	.09	.09
		6/88	27	7.1	1.2	4.27	6.66	2.7	.082	.167	.013
		7/88	26	9.8	1.5	10.87	8.3	1.4	.016	.013	0
		8/88	26	7.6	1.5		6.88	2.2	.059	.014	.004
		9/88	23	8.4	1.2		7.15	1.6	.017	.007	.007
		10/88	13	9.8	1.2		7.22	1.9	.125	.007	.007
2	Havre de Grace Outfall										
		8/87	28	7.5	1.5		7.8	1.4	.04	.092	.028
		9/87	24	6.9	1.66	7.54	6.8	1.05	.14	0	0
		10/87	14.5	10	1	4.35	8	1.1	.061	.048	.014
		5/88									
		6/88	26.5	7.6	1.2	5.32	6.62	1.8	.048	.122	0
		7/88	26	9.5	1.6	5.41	8.26	1.45	.016	.046	.006
		8/88	25	9.8	1.1		7.76	1.95	.056	.014	0
		9/88	22	9.5	1.2		7.59	1.4	.018	.022	.011
		10/88	12.5	10	2		7.12	2.2	.115	.007	.007
3	Fishing Battery (in)										
		8/87	30	7.8	1.5		7.8	1.3	.025	.114	.013
		9/87	23	9	1	5.61	7.7	1.1	.035	0	0
		10/87	15.5	12.2	1	3.11	9.1	1	.045	.048	.014
		5/88									
		6/88	27	7.1	1	13.2	6.4	2.3	.027	.152	.03
		7/88	26	8.4	.8	8.43	7.72	1.35	.013	.013	.006
		8/88	23.5	8.8	1		8.11	1.55	.045	.022	.007
		9/88	21	9.6	1		8.18	1.6	.021	.023	.01
		10/88	12	12	1		7.59	2.8	.12	.018	.011
4	Fishing Battery (out)										
		8/87	28	8	1		8	1.2	.04	.106	.023
		9/87	23	7.8	1.25	12.71	7.7	.5	.043	0	0
		10/87	15	12.2	1	6.54	9	1.5	.062	.05	.022
		5/88									
		6/88	27	11	.6	16.26	8.27	2.1	.017	.137	0
		7/88	25.8	8.2	.8	15.26	7.95	1.32	.0125	.025	.013
		8/88	24	8.5	1		7.5	1.95	.034	.029	.022
		9/88	22	9	1.1		8.32	1.6	.026	.015	.015
		10/88	11.5	11	1		7.58	2.9	.093	.029	.026
5	Center Bay-APG										
		8/87	28	8	1.6		8	1.05	.04	.084	.038
		9/87	23	8.4	.66	23.08	8.1	1	.15	.012	.006
		10/87	15	12.4	.66	15.2	8.9	1.2	.045	.137	.029
		5/88	13	10.3	.5	7.82	7.1	1.1	.014	.73	.46
		6/88	27	8.5	.5	17.59	7.7	1.9	.012	.159	.006
		7/88	25	8.6	.8	16.37	8.1	.72	.014	.013	.006
		8/88	24	8	1.1		7.79	1.4	.078	.043	0
		9/88	21.5	9	1.2		7.11	1.9	.082	.015	.007
		10/88	11	14	1.5		7.11	4.5	.185	.015	.015
6	Sassafras Mouth										
		8/87	28								
		9/87									
		10/87	16	12.4	1.33	8.62	8.7	2.5	.033	.059	.024
		5/88	14	10	1.2	4.64	7.05	1.4	.011	.046	.045
		6/88	29	8	2	1.29	6.57	2.3	.081	.106	0
		7/88									
		8/88	25.5	8.6	1.5		6.48	2.3	.225	.058	.036
		9/88	22	8	1.4		6.83	2.6	.25	.029	.026
		10/88	-11.5	11	1.2		7.48	4.8	.105	.029	.011
7	Sassafras Beds (in)										
		8/87	30	7.4	1.2		7.2	1.3	.028	.076	.006
		9/87	24	8.6	1	5.61	6.9	1.9	.042	0	0
		10/87	16	11.6	.66	.55	8.6	2.5	.027	.05	.029
		5/88									
		6/88	29	7.4	1	3.98	6.74				
		7/88	27.5	8.6	1	1.76	6.45	1.35	.042	.025	.015
		8/88	25	7.4	.5		6.43	1.6	.401	.058	.054
		9/88	22	9	1.6		6	2	.02	.01	.01
		10/88	11.5	10.8	1		7.25	5.1	.105	.029	.022
8	Sassafras Beds (out)										
		8/87	30	6.8	1.2		7.1	1.4	.045	.099	.015
		9/87	24	6.6	.33		6.7	2	.09	.026	.014
		10/87	16	11.6	.66	8.98	8.6	2.6	.037	.06	.032
		5/88									
		6/88									
		7/88	26	7.8	1	5.11	7.21	1.55	.029	.038	.015
		8/88	25	8	.6		6.9	2	.51	.058	.054
		9/88	22.5	7.7	2		6.66	2.7	.145	.007	0
		10/88	11.5	10.6	1.2		7.12	5.2	.155	.008	.004
9	Lloyds Creek										
		8/87	30	7.4	.6		7.2	1.45	.35	.099	.015
		9/87	24.5	8.8	1	14.6	7.6	2.8	.016	0	0
		10/87	15.5	13.4	.66	3.19	9	2.7	.027	.06	.023
		5/88									
		6/88	28.5	8.1	.8	15.09	7.17	3.55	.023	.135	.006
		7/88	27	9	1	8.04	6.84	2.5	.018	.025	.013
		8/88	25	9.4	.8		6.94	2.15	1.05	.007	.004
		9/88	22.5	8.9	1.4		6.97	2.1	.096	.08	.011
		10/88	11.5	10.8	1.2		7.37	5	.093	.007	.007
10	Marsh (in)										
		8/87									
		9/87	26.5	6.4		5.7	7.8	2.2	.064	0	0
		10/87	18	13	.5	5.7	8.7	2.8	.042	.058	.029
		5/88									
		6/88	30	7.4	.6	11.82	7.5	2.6	.026	.122	0
		7/88	28	7.6	.5	23.19	7.58	1.6	.01	.038	.019
		8/88	25	8.7	1		6.79	1.75	1.49	.027	.014
		9/88	23	10.6	.8		6.84	1.9	.06	.015	.007
		10/88	11.5	11.6	1		7.26	4.8	.066	.015	.011
11	Marsh (out)										
		8/87	31	9	.5		8.5	1.2	.025	.055	.015
		9/87	25	8.1	.5		8.1	2.4	.014	0	0
		10/87	16	9.8	1	12	8.7	2.6	.037	.06	.032
		5/88									
		6/88	29.5	8.6	.8	12.78	7.73	2.55	.023	.098	0
		7/88									
		8/88	25	8.7	.8		7.09	1.7	.099	.014	.011
		9/88	23	7.4	1.1		6.74	2	.081	.029	.015
		10/88	11.5	11.8	1.2		7.42	4.4	.057	.008	.004
12	Ordinary Point (Beds)										
		8/87	30	9.2	.66		7.5	1	.035	.066	.006
		9/87	24.5	9.6	.33	18.87	8.2	2.3	.021	.084	.033
		10/87	17	11.8	.66	13.99	9.1	1.7	.039	.084	.038
		5/88									
		6/88	28.5	7.7	.6	15.59	6.64	2.2	.044	.106	0
		7/88	27	8.2	.6	35.08	8.8	1.15		.046	.023
		8/88	25.5	7.7	.8		6.74	1.65	.205	.029	.007
		9/88	23.5	9.7	.8		7.58	2	.042	.019	.018
		10/88	11.5	11.2	1.1		7.39	4.6	.054	.044	.007



UPPER CHESAPEAKE
S.A.V. TRANSPLANT SITES
and WATER QUALITY STATIONS
1984 - 1988
MAP I

UPPER CHESAPEAKE
SHORELINE SEDIMENT PROFILES

MAP II.