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EPA

CHESAPEAKE BAY PROGRAM TECHNICAL STUDIES: A SYNTHESIS

SUMMARY

CONTENTS

FOREWORD

As part of the five year study plan for the EPA Chesapeake Bay Program (CBP), EPA staff, officials from Maryland and Virginia, and citizens identified 10 areas as foremost water quality problems of the Bay, and agreed upon three as most critical for intensive investigation: Nutrient Enrichment, Toxic Substances, and the Decline of Submerged Aquatic Vegetation. The EPA then initiated research to study intensively these three problem areas.

This summary describes a 600 page synthesis of the findings from research projects funded by the Chesapeake Bay Program in those three technical areas. The first section, Nutrient Enrichment, highlights findings from research on the enrichment problem in the Bay, processes that interact to sustain the problem, and what sources contribute nutrients to the estuary. The second section, Toxic Substances, covers major results from studies on sources, distribution, and concentrations of metals and organic compounds in the Bay's waters and sediments. The third part, Submerged Aquatic Vegetation (SAV) describes results of investigations into the distribution and abundance of SAV, the value of SAV to the Bay ecosystem, and reasons for its decline.

For more information on the complete report, _Chesapeake Bay Program Technical Studies: A Synthesis_, and its availability, contact the Chesapeake Bay Program, 2083 West St, Suite 5G, Annapolis, Maryland 21401, (301) 266-0077, FTS 922-3912.

NUTRIENT ENRICHMENT

Nutrients, both phosphorous (P) and nitrogen (N), are crucial to Bay life. Nutrient enrichment occurs when excessive additions of nitrogen and phosphorous compounds enter the water. Enrichment can lead to undesirable consequences such as phytoplankton blooms, depletion of oxygen, and changes in kinds of fish present. When an estuary, such as Chesapeake Bay, becomes nutrient-enriched, algae can thrive and accumulate in the water column. Their presence decreases light transparency, and, when they degrade, they use up dissolved oxygen that other plants and animals need.

Nutrient enrichment in Chesapeake Bay is evaluated by measuring a number of related factors including nutrient concentration and oxygen levels in the water, amounts of chlorophyll a, (a green pigment found in most algae), and transparency of the water (Secchi depth). Historical records of these measurements were gathered and analyzed during the Bay Program to look at trends in nutrients over the past 20 years. During this time, nutrient concentrations have increased, causing enrichment in some areas. Figure 1 shows areas of the Bay that are enriched. These include: most of the western tributaries such as the Patuxent, Potomac, and James; the northern and central main Bay; and some Eastern shore tributaries including the Chester and Choptank. These areas show high levels of nutrients and chlorophyll a, and reduced light transparency. The lower Bay, however, has remained relatively unaffected. An analysis that relates these trends to the health of fisheries in the Bay will be presented in the CBP report entitled "Characterization of Chesapeake Bay."

SOURCES OF NUTRIENTS

Phosphorus (P) and nitrogen (N) enter the Bay from several major sources or pathways: atmosphere, rivers, point sources, and sediments. The estimated percentage that each of the sources contributes to the Bay during a year is shown in Table 1.

TABLE 1. PERCENTAGE OF ANNUAL NUTRIENT LOADINGS FROM VARIOUS SOURCES(1)

Constituent	Atmospheric Sources	Riverine Sources	Point Sources	Sediment Sources
Total nitrogen	13	56	22	9
Total phosphorus	5	35	35	25

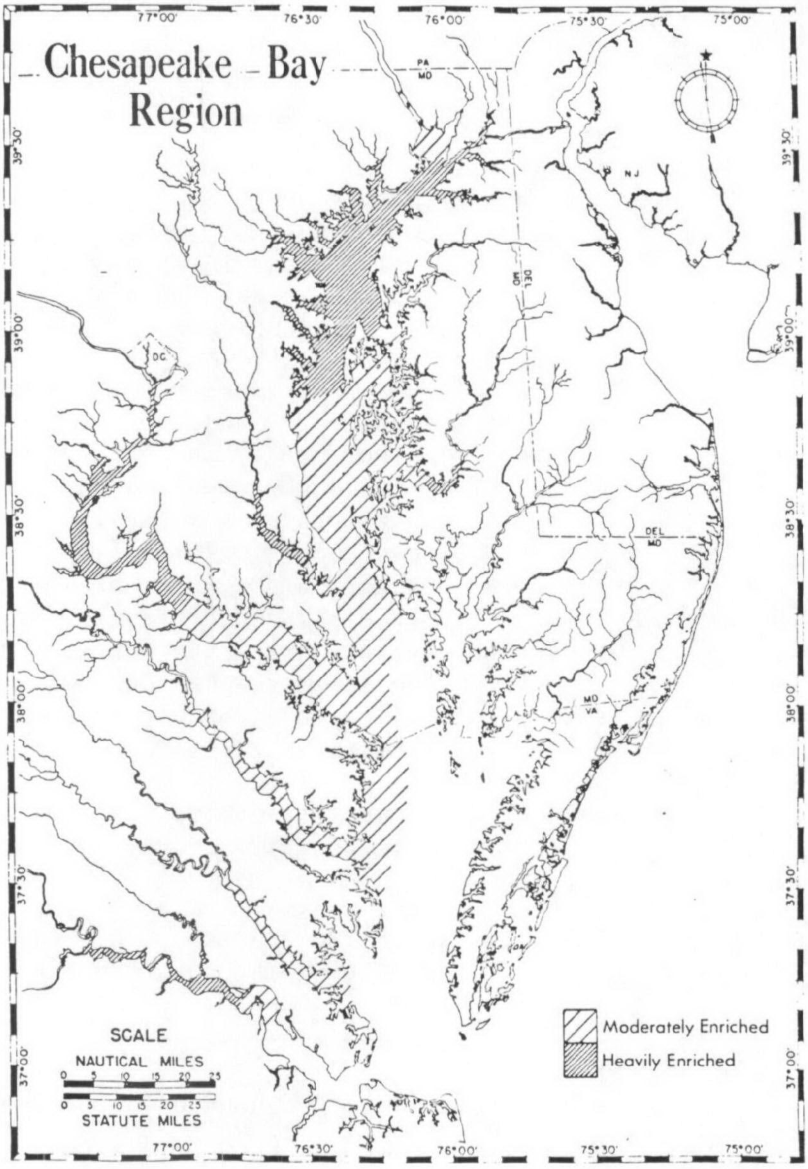

Figure 1. Map showing portions of Chesapeake Bay that are moderately or heavily enriched according to the criteria of Heinle et al. (1980).

(1) Definition of Terms

Atmosphere:	aerial input that directly lands on fluvial or tidal waters.
Riverine:	mass loadings of nutrients to Bay from above the head of tide.
Point sources:	nutrient loads from industry and municipalites below the head of tide.
Sediment sources:	nutrient releases or loads from the bottom sediment of Chesapeake Bay.

Riverine Sources

Riverine sources are a major contributor of N and P to the Bay; approximately 56 percent of the total nitrogen loading comes from these sources. This loading ranges from 39 percent in summer to 64 percent in spring when river flows are highest. Riverine source loads for P are about 35 percent of the total annual input and range from 12 percent in summer to 57 percent in spring.

Of all the river sources, the Susquehanna River is the major contributor of P and N, as shown in Table 2. The Susquehanna River has by far the largest drainage area and annual flow discharge among the river sources. This at least partly accounts for the relatively higher contribution of N and P from the Susquehanna. This river carries about 70 percent of the total nitrogen and 56 percent of the total phosphorus delivered to the Bay each year from riverine sources. Most of these loads enter during the winter and spring.

The Susquehanna produces only about 40 percent of annual sediment load, because the particulate matter is trapped in reservoirs located on the lower 60 miles of the main stem of the river. Only a large flow, above 400,000 cubic feet per second (cfs), will transport sediment through the reservoir and deliver them to the Bay. Such flows occur only one percent of the time.

TABLE 2. ESTIMATED PERCENTAGE OF TOTAL ANNUAL RIVERINE NUTRIENT AND SEDIMENT LOADS FROM CHESAPEAKE BAY TRIBUTARIES

Constituent	Susquehanna	Potomac	James	Other Tributaries
Total nitrogen	70	19	6	5
Total phosphorus	56	22	16	6
Sediment	40	33	16	11

Major land uses in the Chesapeake Bay basin and their estimated contribution to riverine nutrient loads are shown in Table 3.

TABLE 3. MAJOR LAND-USES ABOVE THE FALL LINE AND THEIR ESTIMATED CONTRIBUTION TO RIVERINE NUTRIENT LOADS

Land Use	Percent In Basin	Percent of Riverine Nutrient Loads	
		TN	TP
Cropland	15-20	45-70	60-85
Pasture	8-12	4-13	3- 8
Forest	60-65	9-30	4- 8
Urban	3- 5	2-12	4-12

Riverine loadings can vary considerably among land uses. The highest riverine loading rates come from cropland, and lowest from forest sites. Agricultural land appears to produce the largest fraction of the riverine loads by at least a factor of three for both nitrogen and phosphorus, due to the high unit-area loadings and large percentages of land used for agriculture in this area. The CBP's Bay-wide watershed model has estimated the relative contributions of nutrients from all nonpoint sources. These results will be presented in the CBP report "Management Strategies for Chesapeake Bay."

Point Sources

Most of the remaining nutrients in the Bay are contributed from point sources, such as sewage treatment plants and industries lying below the head of tide (see Table 1). These point sources account for about 22 percent of total nitrogen load and some 35 percent of total phosphorus input. The percentage of nutrient load from point sources ranges from 15 in spring to 29 in fall, while phosphorus percentages range from 59 percent in fall to 21 percent in summer.

Other sources include the atmosphere and bottom sediments. Atmospheric contribution constitutes about 13 percent of the total nitrogen and five percent of the annual phosphorus input, while bottom sediments make up about 10 percent of the annual nitrogen and 25 percent of the annual phosphorous load.

SEASONAL NATURE OF NUTRIENT LOADS

The largest portion of the annual nitrogen load enters the Bay during the winter and spring, while the highest portion of the annual phosphorus load enters during the spring and summer. These nutrient inputs support increases in algal standing crop. Since the relative abundance of nitrogen and phosphorus changes from spring to summer, so the potential limiting nutrient for the algal standing crop may change.

The limiting nutrient changes during the year in Chesapeake Bay as a result of three prominent events. The first is the substantial nitrate input with a spring runoff from the Susquehanna River. The second event occurs during mid-summer when very low oxygen concentrations in deeper Bay water permit release of phosphate from Bay sediments and accumulation of both phosphate and ammonium in the deep water. The third event is the fall nitrite maximum observed in both mid-Bay and in the lower Potomac River estuary. Thus, peak nitrogen availability occurs in spring, while peak phosphorus availability occurs in summer.

Consequently, phosphorus concentration is generally higher in deep water during summer. Addition of phosphorus during the other seasons could cause the standing crop of phytoplankton to increase, if nitrogen is available. Thus, phosphorous appears to be the biomass limiting, or regulating, nutrient for spring, fall, and winter. Nitrogen, however, is at its lowest levels and could be limiting in summer; additions at this time may cause phytoplankton to grow if phosphorous is available from the deep water due to recycling processes. An awareness of the response of phytoplankton to available nutrients is important when considering effects on Bay resources and how to control input. Because phytoplankton form the base of the Bay's food web, increases in their populations will create more food for other Bay inhabitants, to a point. Beyond this point (we feel that Figure 1 indicates what areas of the Bay are at this point) growth of phytoplankton can be detrimental to the Bay's water quality and its resources.

MANAGEMENT IMPLICATIONS

Management strategies to address the problem areas must take into account the seasonal patterns of nitrogen and phosphorous we have described and the degree to which each contributing source may be controlled, its relative costs to achieve this control, and trade-offs between point and nonpoint sources. The possible management strategies will be shown in the CBP report "Management Strategies for Chesapeake Bay".

TOXIC SUBSTANCES

Toxic substances constitute the second of three critical areas studied under the CBP. The research focused on determining the status of both metals and organic compounds in Chesapeake Bay, including their concentration in the water column, bed sediments, suspended sediments, and in some bivalves. Sources of metals and organic compounds were also investigated. A limited amount of research was performed on assessing the toxicity of point source effluents and Bay sediments.

Toxic substances are usually defined as chemicals or chemical compounds that can harm living plants and animals, including humans, or impair physical or chemical processes. The two general classes of toxic substances studied were inorganic and organic compounds. Inorganic materials are metals such as arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), and zinc (Zn). Many of the organic compounds are products of human activities and include pesticides, phthalate esters, polynuclear aromatic hydrocarbons (PNA's), and other chlorinated hydrocarbon compounds (PCBs, etc.).

CURRENT STATUS

The highest concentrations of metals in Bay sediment occur in Baltimore Harbor and the Elizabeth River. In the main Bay, the highest metals concentrations in sediment occur in the northern Bay and particularly near the western shore where cadmium, cobalt, copper, manganese, nickel, lead, and zinc are enriched (elevated relative to natural levels) two to eight times above natural levels from the Susquehanna Flats to Baltimore Harbor region. At least half of the metal loads for chromium, cadmium, copper, and lead orginate from human sources.

Metals tend to partition with fine particulate matter such as detritus and silt. Consequently, highest concentrations of metals in suspended material (ug of metal per gram suspended material) occur in near-surface water in the central Bay where organic matter tends to be high. Cadmium, lead, copper, and zinc display the highest concentrations. Because this enriched zone is an area of high organic activity where organisms respire, reproduce, and grow, metals are available for uptake by phytoplankton and marine organisms. Once in the plankton, the metals can be passed through the food chain.

Like metals, organic compounds tend to cling to fine material that is suspended in the water. When this material settles, organic compounds will accumulate on the Bay floor. Concentrations of organic compounds in bottom sediments are highest in the northern Bay. They exhibit similar trends to metal enrichment, with highest concentrations occurring in the vicinity of Baltimore Harbor. Concentrations tend to increase up the Bay from the Potomac River mouth toward the Patapsco River. North of the Patapsco River, elevated concentrations are found to exist to the Susquehanna River mouth. It appears that many of these organic compounds may have entered from the Susquahanna River. In the southern Bay, the highest concentrations of organic compounds are found where the river estuaries enter the main Bay.

The sediments of the Patapsco River estuary show the highest concentrations of organic compounds. Highest levels occur near source locations. These sediments appear to be largely trapped within Baltimore Harbor.

Oysters collected from around the Bay and oyster-tissue extracts were examined for organic compound concentrations. These bivalves did accumulate some toxic compounds. There were 42 compounds detected whose individual concentrations exceeded 50 parts per billion. The mouth of the James River had 29 percent, and Baltimore Harbor 24 percent of these 42 compounds.

SOURCES

Riverine sources above the fall line, point sources below fall line, and atmospheric sources, contribute most of the metals to Chesapeake Bay as shown in Table 4. Of the three major rivers in which metal concentrations were measured (Susquahanna, Potomac, and James), the Susquahanna contributes the greatest amount of metals. These river loads include municipal, nonpoint, and industrial sources above the fall lines. The annual loadings of various metals of the three rivers are compared in Table 5. The concentration levels of metals in the three rivers are similar, however, the Susquehanna has greater loadings because of its higher flow. The Susquehanna River is also very significant to quality of water in the Bay proper, because the loads it delivers enter the Bay directly and are not trapped in the sub-estuaries like those from the James and Potomac.

Industrial and municipal input below the fall line are a major contributor of metals to the Bay (Table 4). For example, industrial loads account for 66 percent of total cadmium load. Municipal POTWs account for 19 percent of total chromium load. The distribution of these loadings for POTWs and industries below the fall line (Pennsylvania counties, thus, not included) by counties is shown in Table 6. The inputs of Cd, Cr, Cu, Fe, and Zn in Baltimore County and Baltimore City far exceed those from other counties. Substantial inputs from POTWs are also noted for Cr, Fe, and Zn in Richmond City; for Cr, Fe, and Zn from Norfolk City; and for Cr, Fe, and Zn at Hopewell City. The industrial load exceeds POTW loadings by two times. Loadings from urban runoff and atmospheric sources are also significant for several metals as shown in Table 4.

Results from the CBP show that sources of organic compounds to the Bay are human-related. In particular, organic compounds in northern-Bay sediments are probably from the Susquehanna River, and possibly some from the Patapsco. Concentrations of organic compounds in the Bay should be highest in areas of

TABLE 4. LOADINGS OF METALS FROM THE MAJOR SOURCES AND PATHWAYS TO CHESAPEAKE BAY (VALUES IN METRIC TONS/YEAR)

Source	Cr	Cd	Pb	Cu	Zn	Fe
Industry	200 (19)[1]	178 (66)	155 (22)	190 (22)	167 (6)	2,006 (1)
Municipal Wastewater	200 (19)	6 (2)	68 (10)	99 (12)	284 (10)	625 (1)
Atmospheric	---	3 (1)	34 (5)	28 (3)	825 (29)	87 (1)
Urban Runoff	10 (1)	7 (2)	111 (16)	9 (1)	63 (2)	977 (1)
Rivers	551 (53)	75 (28)	307 (43)	517 (59)	1444 (50)	199,682 (77)
Shore Erosion	83 (8)	1 (1)	28 (4)	29 (3)	96 (3)	57,200 (22)

[1]Values in parenthesis represent percent of total loading

TABLE 5. ESTIMATED AVERAGE ANNUAL LOADINGS FOR VARIOUS METALS FROM THE MAJOR TRIBUTARIES OF THE CHESAPEAKE BAY FOR 1979-1980 PERIOD* (VALUES IN METRIC TONS/YEAR) (FROM LANG AND GRASON 1980)

Parameter	Susquehanna @ Conowingo Dam	%	Potomac @ Chain Bridge	%	James @ Cartersville, Va.	%	Totals
Al-T	161,618	69	37,626	16	33,884	15	233,128
As-T	82	71	13	12	20	17	115
Cd-T	65	87	4	5	6	8	75
Co-T	59	40	39	27	48	33	146
Cr-T	383	70	105	19	63	11	551
Cu-T	390	75	86	17	41	8	517
Fe-D	1,844	57	839	26	567	17	3,250
Fe-S	192,422	65	76,227	26	27,783	9	296,432
Mn-T	14,469	77	1,933	10	2,327	13	18,729
Ni-T	229	57	109	27	64	16	402
Pb-T	174	57	102	33	31	10	307
Zn-T	837	58	322	22	285	20	1,444

*Values listed represent the mean of 1979 and 1980 calender year loadings. (Note: Percentages above are approximate numbers)

D - Dissolved
S - Suspended
T - Total

TABLE 6. POINT SOURCE LOADINGS OF METALS FROM INDUSTRIES[2] AND PUBLICLY OWNED TREATMENT WORKS (POTW'S)[1] IN COUNTIES BELOW THE FALL LINE FOR CR, CD, PB, CU, ZN, FE, IN METRIC PER YEAR

	Metal											
	Cr		Cd		Pb		Cu		Zn		Fe	
	POTW	I[3]	POTW	I	POTW	I	POTW	I	POTW	I	POTW	I
Arundel	7.3	0.7	0.2	0.2	2.4	3.1	3.4	2.4	9.9	1.3	21.8	9.4
Baltimore		59.5		24.1		17.5		88.5		59.1		225.1
Baltimore City	78.9	47.2	1.8	142.3	25.5	9.9	37.1	20.7	106.8	45.5	234.4	1729.6
Calvert		3.8		-		8.9		1.9		-		-
Caroline		0.0		0.0		0.0		0.0		0.0		0.0
Cecil	0.6	0.0	0.0	0.0	0.2	0.0	0.3	0.0	0.9	0.0		0.0
Charles		0.0		0.0		0.0		0.0		0.0		0.0
Dorchester	4.9	0.6	0.1	0.1	1.6	0.2	2.3	0.4	6.6	0.4	14.4	-
Harford	2.2	0.8	0.1	0.2	0.7	0.1	1.0	0.6	2.9	0.6	6.5	-
Howard		0.0		0.0		0.0		0.0		0.0		0.0
Kent	0.2	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.0	0.7	-
Prince Georges	12.8	1.8	0.3	0.0	4.1	4.1	6.0	0.9	17.3	0.0	37.9	0.1
Saint Mary's	0.0	0.0	0.9	0.0	0.3	0.0	0.4	0.0	1.2	0.0	2.6	-
Wicomico	1.8	0.1	0.0	0.0	0.6	0.0	0.9	0.0	2.5	0.1	5.4	0.1
Alexandria City	10.2	2.2	0.2	-	3.3	5.1	4.8	1.1	13.7	-	30.2	-
Chesterfield	2.5	9.6	0.1	0.1	0.8	17.5	1.2	4.0	3.3	2.4	7.3	0.3
Henrico		1.1		0.0		0.4		0.2		1.9		0.0
Hopewell City	14.6	7.6	0.3	0.3	4.7	2.9	6.9	1.4	19.7	13.9	43.3	-
Louisa		22.7		-		53.0		11.4		-		-
Newport News City	12.8	9.6	0.3	3.9	4.2	2.7	6.0	13.9	17.4	9.3	38.1	36.7
Norfolk City	16.7	2.0	0.4	0.9	5.4	0.4	7.8	3.0	22.6	2.0	49.5	5.9
Northampton		0.0		0.0		0.2		0.0		0.0		0.7
Portsmouth City	5.2	14.4	0.1	5.9	1.7	3.1	2.5	20.8	7.0	14.9	15.5	-
Prince William	13.4	2.0	0.3	-	4.3	4.7	6.3	1.0	18.1	-	39.7	-
Richmond City	22.6	1.1	0.5	0.6	7.3	2.5	10.6	12.8	30.5	6.7	67.1	-
Spotsylvania	0.2	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.0	0.6	-
Westmoreland	0.3	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.4	0.1	0.9	0.2
Williamsburg City	2.3	0.1	0.1	0.0	0.7	0.0	1.1	0.0	3.1	0.1	6.8	-
York		12.1		0.2		18.7		4.5		8.9		-
TOTAL	199.5	199.1	5.7	178.8	68.1	155.0	98.9	189.6	284.4	167.3	624.6	2008.2

[1] POTW loadings were calculated for facilities where flows were 0.5 MGD.

[2] Loadings computed from approximately 122 industrial dischargers.

[3] I = Industry

sedimentation near industrial regions and high population areas. The CBP is further investigating sources of toxic substances and will present the results in CBP report "Management Strategies for Chesapeake Bay".

In certain areas, present levels of toxic substances could threaten the health of organisms. Bioassay tests on bottom sediments from the Bay show that sediments from the Patapsco and Elizabeth Rivers and northern Bay are potentially more toxic than elsewhere. This toxicity is probably produced by a combination of high metal content and large loads of organic compounds. These tests on bottom sediments found concentrations that cause mortality. The highest mortalities occurred on samples from the upper reach of the Patapsco and Elizabeth Rivers, and the northern Bay. Tests performed on effluent from industrial plants around the Bay area revealed that up to half of effluents sampled killed test fish and invertebrates. The significance of these results and their relationship to Bay resources will be discussed in CBP report "Characterization of Chesapeake Bay".

MANAGEMENT IMPLICATIONS

Managing toxic substances requires a priority, or ranking, framework that evaluates toxic material for its greatest potential to affect human and environmental health. As with nutrients, areas where environmental quality is severely degraded should be established, based on all available environmental quality data (sediment, biota, and water) and should be top priority for cleanup. The priority areas will be examined in the CBP report "Characterization of Chesapeake Bay".

SUBMERGED AQUATIC VEGETATION

PATTERN OF DECLINE

Submerged aquatic vegetation (SAV) has, in the past, been very abundant throughout Chesapeake Bay. Our current evidence indicates a pattern of SAV decline that includes all species in all sections of the Bay. A marked decline has occurred throughout the estuary since the mid-1960's. Present abundance of Bay grasses is at its lowest level in recorded history.

Historical analysis of sediments on Bay-grass seeds and pollen indicates a continuous presence of Bay grasses from the 17th century. In the last 50 years, there have been several distinct periods and patterns where Bay grasses have undergone major changes. An outbreak of eelgrass wasting disease occurred in 1930's and reduced SAV populations, as did a watermilfoil outbreak in the late 1950's and early 1960's. However, a far more dramatic and Bay-wide decrease in SAV populations occurred in the 1960's and 1970's where, unlike the eelgrass and milfoil events, all species in almost all areas of the Bay were affected. The change is not attributable to disease.

Because there has not been a significant change in SAV distribution along the east coast of the United States comparable to the Chesapeake Bay decline, it is most likely that water quality problems affecting the distribution of grasses in Bay are regional and specific to the Bay, its tributaries, and their drainage basin. Recent international studies have found that SAV declines in other countries are highly correlated with changing water-quality conditions, such as decreasing water clarity resulting from increased eutrophication, as sewage, agricultural runoff, and suspended sediment inputs increase. CBP work suggests that sediment composition and light availability are the most important factors controlling the distribution of SAV within regions of the Bay. In addition, SAV decline parallels historical increases in nutrients and chlorophyll a concentrations in the upper Bay and major tributaries that occurred first in freshwater parts and have now moved "down-river".

VALUE

The severity of the decline is heightened by the importance of SAV to the vitality of the Bay. The Bay grasses are vitally important to the Bay because of their value as large primary producers, food sources for waterfowl, habitat and nursery areas for many commercially important fish, controls for shoreline erosion, and mechanisms to buffer negative effects of excessive nutrients.

Numerous studies have shown that the primary productivity of SAV communities is among the highest recorded for any aquatic systems. However, trends in SAV biomass production follows those of its distribution and abundance. The average

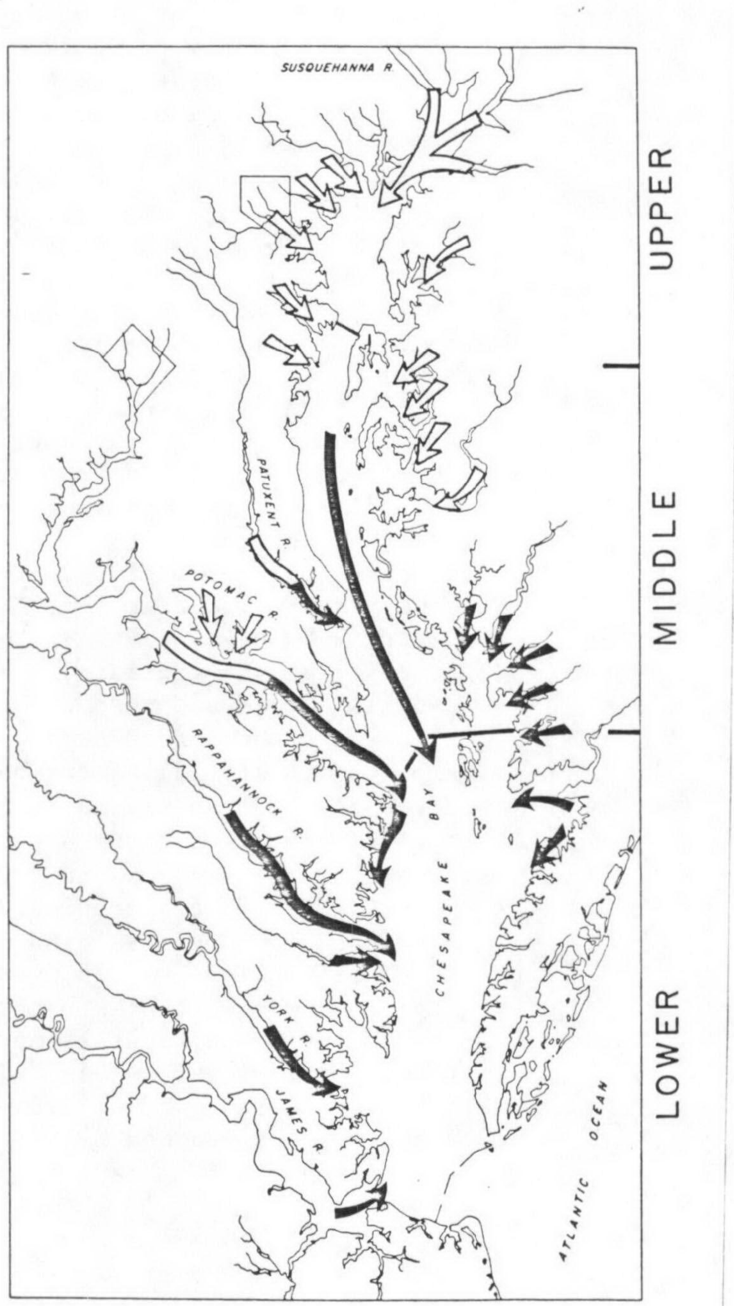

Figure 2. Pattern of recent changes in the distribution of SAV in Chesapeake Bay. Arrows indicate former to present limits. Solid arrows indicate areas where eelgrass (Zostera marina) dominated. Open arrows indicate other SAV species. (Orth et al. 1982)

biomass estimates for SAV in the Bay are low relative to other communities. For example, we have estimated that some 40 percent of primary production in Bay was attributable to SAV in 1963 while only six percent is attributable to SAV in 1975. These trends along with other results are indicative of stressed plants, particularly in the upper Bay.

SAV provides food and habitat for many species of birds and animals. The most definitive linkage is between SAV and waterfowl. Some types of SAV are excellent food for waterfowl. In recent years, the most important waterfowl wintering areas have also been the most abundantly vegetated areas. Waterfowl have adapted to the SAV decline primarily by wintering elsewhere in the Atlantic Flyway.

SAV beds in Chesapeake Bay support larger populations of most animals than nearby unvegetated bottoms, and provide significant protection from predators. Fish abundance in SAV communities in the upper Bay are among the highest ever recorded, indicating that SAV are sources of food either directly, or indirectly, to important Bay species. Few commercially-important finfish use SAV beds as significant nursery habitats. However, lower Bay beds do serve as a primary blue crab nursery, supporting a very large number of juvenile blue crabs throughout the year.

Work in the upper Chesapeake Bay has shown that SAV is important in stablizing suspended sediments. As turbid water enters SAV beds on rising tides, sediments are effectively removed, and light transparency increases. Sediment resuspension is reduced in proportion to SAV biomass.

SAV also reduces nutrient levels in the water. Our studies show that, at moderate loading rates, nutrient concentrations are consistently lower in SAV communities than in unvegetated sites. Ammonium concentrations were one to 10 times lower, nitrate two to 10 times lower, and orthophosphate generally two to four times lower in the SAV community than in deeper, offshore waters. When loading rates and nutrient concentrations reached high levels, SAV was no longer effective in reducing nutrient levels.

CAUSE OF THE DECLINE

During the Bay program, investigators looked at light reduction as a major cause of SAV decline. Overall, factors governing light energy availability to submerged aquatic vegetation are the principal control for growth and survival. Bay grasses are currently living in a marginal light environment, and water quality problems, such as increases in nutrients and chlorophyll _a_ concentrations in major tributaries and the main stem of the Chesapeake Bay over the past several decades, are seriously affecting the distribution and abundance of grasses in the Bay region. Epiphyte communities, those organisms that directly attach to submerged aquatic plant blades, can also limit light availability.

Another important factor contributing to the stress of SAV in the Bay is the input of herbicides to the ecosystem. Our laboratory and field experiments indicate that herbicides are not generally available to SAV in toxic levels, and their presence alone probably did not cause the SAV decline. However, herbicide-induced impacts could, in concert with the other major stresses (such as those from light limitation), create intolerable conditions for SAV existence.

In summary, the SAV decline parallels a general increase in nutrients, chlorophyll a concentrations, and turbidity in the upper Bay and major tributaries. This decline first ocurred in freshwater portions, and has moved down-river. The upper-Bay, western-shore, and lower-Bay communities have been the most severely impacted. Light, restricted by organic and inorganic suspended particles from runoff and nutrient loads, and by changes in physical-chemical regimes (salinity and temperature), is the principal factor controlling Bay-grass growth and survival. Bay grasses are now living in a marginal light environment and will be adversely stressed if water quality in the Bay declines further. Management programs that minimize sediment and nutrient loads will have to be improved and expanded if SAV is to flourish again throughout the Bay.

The "Characterization" report will address relationships between SAV, other natural resources, and water quality trends; the "Management Strategies" report will suggest ways to protect and/or enhance these resources.