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Distribution and Abundance of Submerged Aquatic Vegetation in Chesapeake Bay

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DISTRIBUTION AND ABUNDANCE OF SUBMERGED AQUATIC VEGETATION IN CHESAPEAKE BAY: A SCIENTIFIC SUMMARY

by

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SECTION 1

INTRODUCTION

The Chesapeake Bay, with its extensive littoral zone and broad salinity regime of 0 to 25 ppt, supports many different species of submerged aquatic vegetation (SAV) (Anderson 1972, Stevenson and Confer 1978, Orth et al. 1979). Approximately ten species of submerged vascular plants are abundant in the Bay, with another ten species occurring less frequently. In many areas, more than one species is found in a particular bed of SAV because of the similarity in the physiological tolerances of some species. Between regions of the Bay, salinity appears to be the most important factor in controlling the species composition of an individual bed of SAV (Stevenson and Confer 1978), while sediment composition and light regime are important factors in controlling the distribution of SAV within regions of the Bay. All species, regardless of the salinity regime, are found in regions of the Bay's littoral zone and are located in water less than two to three meters deep (mean low water - MLW), primarily because of low levels of light that occur below these depths (Wetzel et al. 1981).

Three associations of SAV can be described in Chesapeake Bay based on their salinity tolerances as well as on their co-occurrence in mixed beds of SAV (Table 1) (Orth et al. 1979, Stevenson and Confer 1978). The first association, consisting of *Najas guadalupensis* (bushy pondweed), *Ceratophyllum demersum* (coontail), *Elodea canadensis* (waterweed), and *Vallisneria americana* (wildcelery), contains species that can tolerate fresh to slightly brackish water and are found in the upper reaches of the Bay and in the tidal freshwater areas of the Bay tributaries. The second association, including *Ruppia maritima* (widgeon grass), *Myriophyllum spicatum* (Eurasian watermilfoil), *Potamogeton pectinatus* (sago pondweed), *Potamogeton perfoliatus* (redhead grass), *Zannichellia palustris* (horned pondweed), and *Vallisneria americana* (wildcelery), is tolerant of slightly higher salinities than the first group. This group is found in the middle reaches of the Bay and its tributaries. The third group, consisting of *Zostera marina* (eelgrass) and *Ruppia maritima* (widgeon grass), is tolerant of the highest salinities in the Bay and is found in the lower sections of the Bay and its tributaries.

Since 1978 SAV has been the subject of an intensive research program funded by the U.S. Environmental Protection Agency's Chesapeake Bay Program (EPA/CBP). SAV was determined to be a high priority area of research in this program because of its high primary productivity; its important roles in the Chesapeake Bay ecosystem -- a food source for waterfowl, a habitat and nursery area for many species of commercially important fish and invertebrates, a shoreline erosion control mechanism, and a nutrient buffer. Most importantly, research was focused on SAV because of the dramatic, Bay-wide decline of these species in the late 1960's and 1970's.

Table 1. SPECIES ASSOCIATIONS OF SAV IN CHESAPEAKE BAY AND ITS TRIBUTARIES BASED ON THEIR SALINITY TOLERANCES AS WELL AS THEIR CO-OCCURRENCE WITH OTHER SPECIES (COMMON NAME OF EACH SPECIES GIVEN IN PARENTHESIS)

Group 1	Group 2	Group 3
Ceratophyllum demersum (coontail)	*Myriophyllum spicatum* (Eurasian watermilfoil)	*Ruppia maritima* (widgeon grass)
Elodea canadensis (common elodea)	*Potamogeton pectinatus* (sago pondweed)	*Zostera marina* (eelgrass)
Najas guadalupensis (southern naiad)	*Potamogeton perfoliatus* (redhead grass)	
Vallisneria americana (wildcelery)	*Ruppia maritima* (widgeon grass)	
	Vallisneria americana (wildcelery)	
	Zannichellia palustris (horned pondweed)	

One of the main elements of the SAV program was to examine the current distribution and abundance of submerged grasses in Chesapeake Bay using aerial photography to map the vegetation. In addition, the historical record of aerial photography was examined for recent evidence (less than 40 years) of alterations in SAV abundance, and a biostratigraphic analysis of sediment was performed to detect evidence of longer term (greater than 40 years) alterations in the abundance or species composition SAV beds in several locations within the Bay. A comparison was made to answer basic questions on the magnitude of the present decline of SAV as compared with documented historic declines, and to determine whether the curent decline was part of a natural cycle or a decline attributed to recent non-cyclic perturbations.

SECTION 2

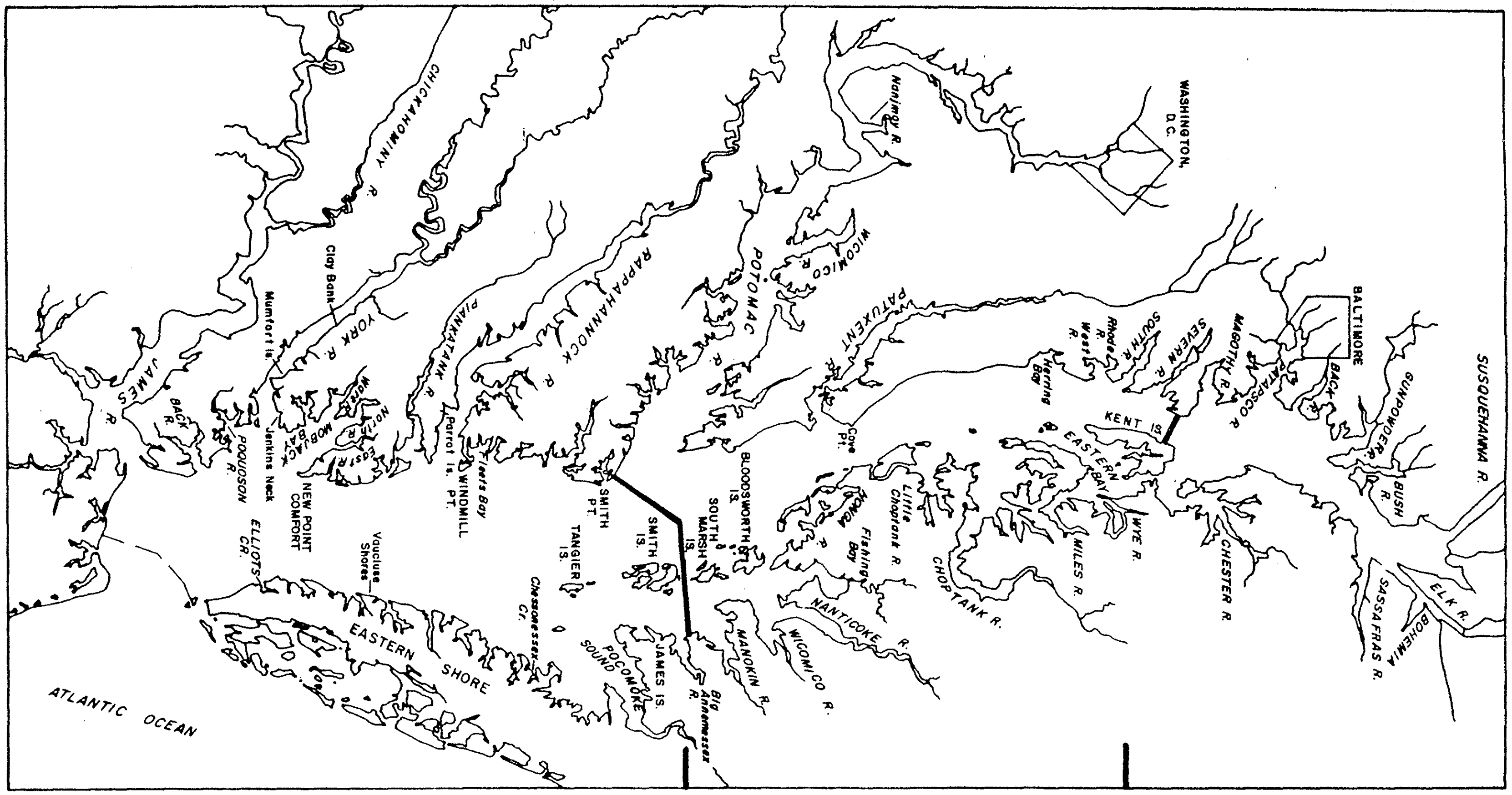
METHODS

The accurate delineation of SAV communities to analyze their distribution and abundance is difficult, especially when the areas of interest may incorporate hundreds of miles of shoreline that are subject to turbid water conditions. These communities are not static, but represent dynamic elements whose distribution and abundance can vary in both space and time. Distinct differences in SAV beds can be observed in time frames of less than two months. To avoid the problems associated with labor-intensive field surveys that provide only a limited view of SAV distribution, remote sensing techniques (aerial photographs) were used to acquire a synoptic view of the existing beds of SAV.

In 1978, the entire shoreline of Chesapeake Bay and its tributaries, from the Susquehanna Flats to the mouth of the Bay, was flown with light planes equipped with mapping cameras to acquire aerial photographs of all existing beds of SAV. Beds of SAV observed on the aerial film were mapped directly onto U.S.G.S. topographic quadrangles, and the areas of each bed were determined with an electronic planimeter (see Orth et al. 1979, and Anderson and Macomber 1980 for detailed information on methodologies used for this work). Field surveys of selected sites corroborated information observed on the aerial photographs and provided species information. Aerial photography comparable to that obtained in 1978 was acquired in 1980 and 1981 for Virginia's SAV only.

Data on the past distribution and abundance of SAV in the Bay were acquired from several sources: aerial photographs of the Bay's shoreline and near-shore zone dating back to 1937; reports of field surveys conducted by state and Federal laboratories, as well as by individual scientists throughout the Bay area; studies on the biostratigraphical analysis of estuarine sediments for seeds and pollen of SAV species (Brush et al. 1980, 1981); and anecdotal information supplied by watermen, landowners, and other interested citizens who had observed changes in the abundance of SAV in numerous areas of the Bay during the last 40 years.

We have organized the discussion of SAV distribution into three zones (Figure 1). The area between the mouth of the Bay to a line stretching from the mouth of the Potomac River to just above Smith Island will be referred to as the lower Bay zone; the area between Smith Island and Chesapeake Bay Bridge at Kent Island will be referred to as the middle Bay zone; and the area between Chesapeake Bay Bridge and Susquehanna Flats will be referred to as the upper Bay zone. These zones have distinct salinity regimes that influence the type of SAV community that will grow within each area. The salinity within each zone roughly coincides with the major salinity zones of the estuaries: polyhaline (18-25 ppt), lower zone; mesohaline (5-18 ppt), middle zone; oligohaline (0.5-5.0 ppt), upper zone. Despite the fact that the major rivers (James, York, Rappahannock, Potomac, and Patuxent) as well as the smaller tributaries (for example, Choptank, Chester, and Piankatank) of the Bay have their own distinct salinity patterns, the distribution of the grasses in each river will be discussed within the zone where it connects to the Bay proper.



LOWER MIDDLE UPPER

Figure 1. Map of Chesapeake Bay showing the zonation of the Bay into the lower, middle and upper zones.

SECTION 3

PRESENT DISTRIBUTION

The results of the 1978 SAV aerial survey and mapping of the entire Bay and its tributaries documented the existence of significant stands of vegetation (Orth et al. 1979, Anderson and Macomber 1980). A total of 16,044 ha (39,629 acres) of bottom was found to be vegetated. Table 2 presents area values for major sections within each zone.

In the lower Bay zone (Figure 1) where salinities range from 16-18 ppt to 25 ppt, two species predominated: eelgrass (Z. marina) and widgeon grass (R. maritima). Horned pondweed (Z. palustris) was present, but occurred infrequently. In 1978, there were approximately 9400 ha (23,218 acres) of bottom covered with SAV in this zone. This included 46 ha (114 acres) of SAV that were found in the Chickahominy River, a fresh to brackish water tributary of James River. These areas ranged from very dense to very sparse in SAV coverage. The largest and most dense grass flats were concentrated in several main regions: (1) along the western shore of the Bay from just north of the James River to the Rappahannock River, especially in the region of Mobjack Bay; (2) behind protective sandbars along the Bay's eastern shore; and (3) in the shoal area between Tangier Island and Smith Island. The SAV bed between Tangier and Smith Island was the single, most extensive vegetated area in the entire Bay, with a total area coverage of 2394 ha (5912 acres) or 26 percent of the total vegetated bottom in the lower zone and 15 percent of the total vegetated bottom in the entire Bay. 1980 data for the upper Bay were not available.

Updated aerial photographs taken of the lower Bay in 1980 and 1981 indicate a decrease in abundance in 1980 followed by slight rebounding in 1981 (Table 3). The pattern of change determined for one section of the Mobjack Bay area since 1974 (Figure 2) illustrates a decrease in vegetation in the outer, generally deeper portions of the beds, a common pattern in areas where the vegetation has declined. It is significant to note that in one intensively sampled site in the York River a general increase in vegetation abundance was observed from 1978 to 1981. Examination of this site revealed that this increase was a result of a large number of seedlings, many with seed coats still evident, that were growing only in the most shallow areas of this location. Subsequent rapid growth and spreading of the seedlings are indicative of the potential importance of seeds to the reestablishment of the vegetation (Orth and Moore, in press).

In the middle zone of the Bay (Figure 1), SAV was found to shift from Zostera-Ruppia dominated beds to the lower salinity Potamogeton, Zannichellia, Vallisneria, and Myriophyllum beds. This zone contained 4,546 ha (11,229 acres) of bottom covered with SAV in 1978. The greatest concentration of vegetation (77 percent of 3500 ha) was located in the Little Choptank River to Eastern Bay area of the eastern shore (Table 2). Only five percent or 227 ha (561 acres) of the vegetation occurred between the Little Choptank River and Smith Island. An equally small amount [six percent or 273 ha (674 acres)] occurred along the western shore of the Bay

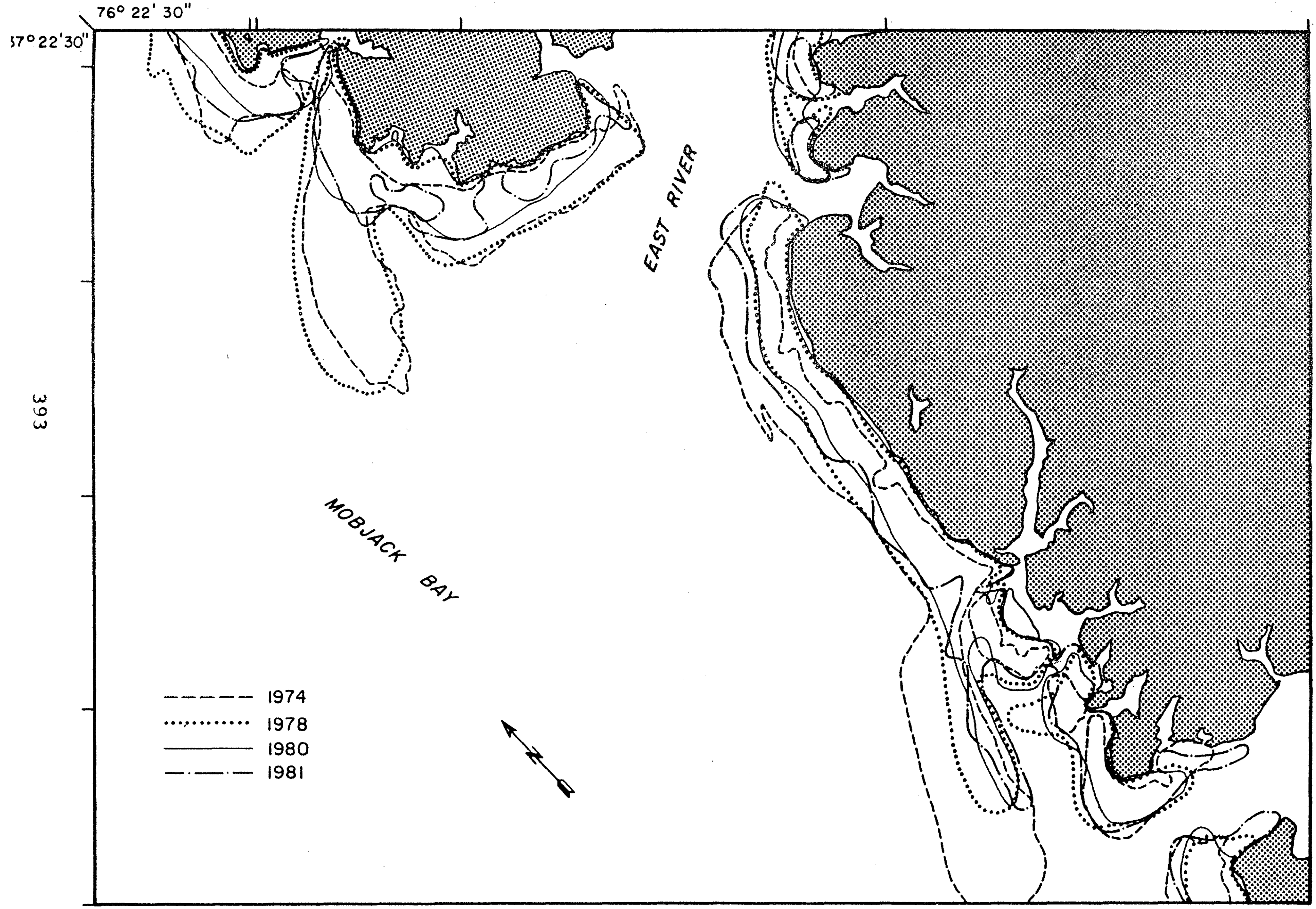


Figure 2. Map of mouth of East River and a portion of Mobjack Bay showing changes in SAV distribution from 1974 to 1981.

TABLE 2. NUMBERS OF HECTARES OF BOTTOM, COVERED WITH SUBMERGED AQUATIC VEGETATION IN 1978 FOR DIFFERENT SECTIONS WITHIN THE THREE ZONES IN THE CHESAPEAKE BAY (NUMBERS OF HECTARES ROUNDED OFF TO NEAREST WHOLE NUMBER)(DATA FROM ORTH et al. 1979, ANDERSON AND MACOMBER 1980)

Section	Hectares	Zone Totals
1. Susquehanna Flats	110	Upper
2. Upper Eastern Shore (Elk, Bohemia, and Sassafras Rivers)	29	
3. Upper Western Shore (Bush, Gunpowder, Middle, Back and Magothy Rivers, and Baltimore Harbor)	484	2098 hectares
4. Chester River	1475	
5. Central Western Shore (Severn, South, and West Rivers, and Herring Bay)	241	
6. Eastern Bay (Wye, East, and Miles Rivers)	1800	
7. Choptank River (Harris and Broad Creeks, Tred-Avon and Little Choptank Rivers, and Trippe Bay)	1740	Middle
8. Patuxent River	3	
9. Middle Western Shore (Herring Bay to mouth of Potomac River)	11	4546 hectares
10. Lower Potomac River Section (Nanjemoy Creek to mouth of Potomac)	541	
11. Middle Eastern Shore (Honga River to Smith Island and including Fishing Bay, Nanticoke, Wicomico, and Manokin Rivers)	210	
12. Tangier Island Complex (includes from Smith Island and Big Annemessex River to Chesconessex Creek)	3759	
13. Lower Eastern Shore (Chesconessex Creek to Elliots Creek)	1991	Lower
14. Reedville (includes area from Fleets Bay to Great Wicomico River)	364	
15. Rappahannock River (includes Rappahannock and Piankatank Rivers, and Milford Haven)	93	9354 hectares
16. New Point Comfort Region	271	
17. Mobjack Bay (includes East, North, Ware, and Severn Rivers)	1785	
18. York River (Clay Bank to mouth of York)	157	
19. Lower Western Shore (includes Poquoson and Back Rivers)	925	
20. James River (Hampton Roads area only)	9	

TABLE 3. NUMBERS OF HECTARES OF BOTTOM, COVERED WITH SUBMERGED AQUATIC VEGETATION IN 1971, 1974, 1978, 1980, AND 1981 FOR DIFFERENT SECTIONS IN THE LOWER BAY ZONE (NUMBERS OF HECTARES ROUNDED OFF TO NEAREST WHOLE NUMBER)(* INDICATES SECTIONS THAT WERE NOT MAPPED THAT YEAR) (DATA FROM ORTH AND GORDON 1975, ORTH et al. 1979, AND UNPUBLISHED DATA)

	Year				
Section	1971	1974	1978	1980	1981
Tangier Island Complex (Includes from MD-VA border to Chesconessex Creek)	*	*	2814	2420	2794
Lower Eastern Shore (Chesconessex Creek to Elliots Creek)	*	*	1991	1370	1691
Reedville (Includes area from Windmill Pt. to Smith Pt.)	*	*	364	31	133
Rappahannock River (Includes Rappahannock and Piankatank Rivers, and Milford Haven)	1273	68	93	3	43
New Point Comfort Region	168	233	271	182	207
Mobjack Bay (Includes East, North, Ware, and Severn Rivers)	1294	1593	1785	1317	1275
York River (Clay Bank to mouth of York)	493	141	157	135	142
Lower Western Shore (Includes Poquoson and Back Rivers)	1620	1069	925	1002	996
James River (Hampton Roads area only)	*	7	9	0	0
TOTAL FOR LOWER BAY ZONE			8,409	6,460	7281

from the mouth of the Potomac River to Chesapeake Bay Bridge, including the South, Severn, Rhode, and West Rivers. The Patuxent River had virtually no vegetation with only three ha (7.4 acres) being observed along the entire length of the river. A small amount [12 percent or 545 ha (1346 acres)] of the total vegetation in this zone was found in the Potomac River in the vicinity of Nanjemoy Creek, Port Tobacco River, Mathias Point Neck, and Mattox and Machodoc Creeks, at a distance of 50 to 100 km from the river's mouth. These beds fringe the shoreline on the lower portions of the creeks and the Potomac River proper, near U.S. 301 bridge, and are dominated by P. perfoliatus and V. americana. This was the only vegetation found along the entire length of the Potomac River, except for small pockets of SAV that existed at the heads of several small marsh creeks (Carter and Haramis 1980, Carter et al. 1980). In addition, this is the only area of comparable vegetation found along any of the Bay's major western tributaries (James, York, Rappahannock, Potomac, and Patuxent Rivers). Less intensive surveys in 1979 showed only slight decreases from the 1978 distributional patterns to those in 1979, but considerable declines in 1981 were observed throughout the middle zone of the Bay (personal information from unmapped data).

The upper zone of the Bay (Figure 1) contained 2098 ha (5182 acres) of substrate covered with SAV in 1978 (Table 2), with the species association shifting from Group 2 to Group 1 (Table 1). Susquehanna Flats had 110 ha (272 acres) of vegetation in 1978, most of which occurred in scattered beds. This was a very small area when compared to abundance of SAV in the late 1960s and early 1970s. Only two species were present on the Flats in 1978, Eurasian watermilfoil (M. spicatum) and wildcelery (V. americana); eleven species were found by researchers in 1971 (Bayley et al. 1978). Approximately 23 percent of the total bottom area covered with SAV in this zone was in the Gunpowder, Middle, Bush, and Magothy Rivers located along the western shore, whereas almost no vegetation was present in the Elk, Bohemia, and Sassafras Rivers on the eastern shore. About 70 percent [1469 ha (3628 acres)] of the total bottom area covered with vegetation was present in the Chester River and Eastern Neck area. The Chester River area contained a diverse assemblage of SAV, with seven species recorded during the 1978 survey. Less intensive surveys in 1979 show little change in distribution patterns from 1978, but surveys in 1981 indicate considerable declines in this zone.

In summary, the survey of SAV in the Bay in 1978 indicated the presence of many apparently healthy beds in various sections of the Bay. There were, however, large sections devoid of almost all vegetation where, in earlier years (1965-1970), luxuriant beds persisted (see Figure 5). Tributaries with major reductions of SAV included portions of the York, Rappahannock, Potomac, Patuxent, Choptank, Chester, and Piankatank Rivers. SAV populations in other areas along the main stem of the Bay, including Susquehanna Flats, the area between Smith Point on the Potomac River, and Windmill Point on the Rappahannock River, and an area between Smith Island and Eastern Bay, which includes many smaller rivers, have also significantly declined. More recent evidence from ground truth surveys and aerial photographs taken from 1978 to 1981 indicate that this decline has continued in certain areas. This suggests a widespread but complex pattern of recent major decline, involving the entire spectrum of SAV communities found in the Bay, from the mouth of the Bay to Susquehanna Flats at the head of the Bay.

SECTION 4

PAST DISTRIBUTION

A detailed discussion of past trends of SAV distribution and abundance is hindered by the lack of adequate data for many sites over a long period of time. A review of the available historical information indicates that SAV has generally, in the past, been very abundant throughout the Bay. In the last 50 years, however, there have been several distinct periods where SAV, in some large portions of the Bay, has undergone major fluctuations, although SAV populations have been known to undergo erratic oscillations within small areas (Stevenson and Confer 1978).

HISTORICAL TRENDS (1700-1930)

The pattern of SAV distribution and abundance in the Bay during this period was determined primarily from indirect evidence, pollen and seed analysis, and qualitative observations. Aerial photography can usually provide good evidence for the presence of SAV, but was not generally available until the late 1930s. If it can be assumed that less urbanization during this period resulted in better water quality throughout the Bay and its tributaries (Heinle et al. 1980), conditions may have been more favorable for the growth of SAV.

Biostratigraphical analysis of sediments for SAV seeds and pollen from Furnace Bay (Brush et al. 1980), a small embayment off Susquehanna Flats, indicates the continuous presence of SAV seeds from the 17th century. However, there appear to have been some changes in species of SAV (for example, declines of Najas spp.) corresponding to changes in land use, such as deforestation. Increased erosion and sedimentation from these practices possibly resulted in more turbid water conditions and, thus, the eventual decline of species less adapted to low light levels.

The Potomac River, the largest tidal tributary in the Bay, historically contained numerous species of SAV that were very abundant. Several species (wild celery, coontail, naiad, and elodea) were reported in the vicinity of Washington, D.C. in one of the earliest accounts (Seaman 1875). Cumming et al. (1916) provided a map of the Potomac River below Washington, DC that showed the river having a narrow channel and wide shallow margins that he reported to be extensively vegetated with curly pondweed (P. crispus), wildcelery (V. americana), and coontail (C. demersum). Many other pondweed species were reported at mouths of tributaries below Washington, D.C. (Hitchcock and Standley 1919), indicating the widespread presence of SAV species in the tidal portion of the Potomac River.

Eelgrass (Z. marina) apparently underwent some decline in Chesapeake Bay area in the late 19th century, although the magnitude of the decline was never quantified. Cottam (1934, 1935) states that a guide from the Honga River Gunning Club reported on the decline of eelgrass in Dorchester County, Maryland in 1893-1894. Cottam also reports an interview with a member of the Maryland Game Commission who commented on the decline of eelgrass in Chesapeake Bay in 1889 (at the time of the Johnstown Flood) and stated that it was 25 years before eelgrass fully recovered. Cottam documents other declines of eelgrass along the east coast of the U.S. -- one as early as 1854. From these accounts, it appears that eelgrass has undergone several fluctuations during this period (1700-1930), suggesting some irregular, though undefined, perturbations on the system.

In summary, evidence suggests that in the Bay: (1) SAV was apparently much more widespread from 1700 to 1930 than it is today; (2) SAV had been a persistent feature of shallow water habitats, although there may have been some localized shifts in species composition of the beds; and (3) abundance of eelgrass has apparently undergone changes several times.

RECENT PAST (1930-1980)

With an increased awareness of the value of SAV as a food source for waterfowl wintering in the Bay and observations of major fluctuations in the Bay and elsewhere, researchers placed more focus on the distribution and abundance of SAV during this period. This research led to the availability of more quantitative information; as a result, a much greater perspective can be obtained. During these last 50 years, there have been two distinct events in which significant changes occurred within individual species of SAV: (1) the eelgrass wasting disease in the 1930's; and (2) the watermilfoil (M. spicatum) problem in the late 1950's and early 1960's. Even far more dramatic are the changes in SAV populations in the Bay in the 1960's and 1970's, when, unlike the eelgrass and milfoil events, all species in almost all areas of the Bay were affected to some degree. The following three sections discuss each of these periods.

The Eelgrass Wasting Disease (1931-1932)

The most documented decline of a species in the Bay was that of eelgrass in the early 1930's. This decline was recorded not only in the Bay area, but also along the entire east coast of the U.S. and the west coast of Europe (Cottam 1934, 1935; den Hartog 1970; Rasmussen 1977). Cottam (1934) comments, based on information from his surveys of historical records and personal inquiries of fishermen, watermen, and scientists, that "in the memory of man there has been no period of scarcity at all comparable to the present one (1931-1932 compared to other past periods)." The extent of the decline in Chesapeake Bay was never quantified, but aerial photographs taken in 1937, five to six years after the height of the decline, are available for almost all of the shoreline in the lower Bay. A review of many areas in the lower Bay and subsequent mapping of six sites (Orth et al. 1979) shows areas of bottom in shallow water covered with large amounts of submerged vegetation (it was assumed to be eelgrass based on knowledge of present day patterns and anecdotal information from long-time residents of these areas). All six areas showed subsequent increases in later years up to 1972. Although quantitative information is lacking prior to the wasting disease, we assume that the vegetation present in 1937 represented partial recovery from the height of the decline in 1931-1932. Cottam (1935) confirmed our conclusions from aerial photographs when he reported that Chesapeake Bay eelgrass was showing "an encouraging change, with a few localized areas fast approaching the normal."

One indication of the magnitude and severity of the decline of eelgrass, experienced not only in Chesapeake Bay but also along the east coast of the U.S. and the west coast of Europe, was found in the coastal lagoons on Virginia's seaside. These areas contained dense beds of eelgrass that supported a large bay scallop industry. The post-veliger larvae of the scallop require eelgrass as a setting substrate (Gutsell 1930). Without eelgrass, there can be no scallops because a scallop lives, at the longest, two years, and a change or disappearance of eelgrass results in rapid shifts of the scallop population. Indeed, this is what happened (Table 4). The commercial fishery that resulted in a harvest of over 14,000 kg per year in the late 1920s and early 1930s completely declined in 1933, over a span of just two years. Eelgrass has never recovered in the seaside bays as compared with Chesapeake Bay and many other areas where it had substantially declined (Cottam and Munro 1954), nor has the scallop industry ever returned.

TABLE 4. CHANGES IN AMOUNT OF SCALLOPS (SHUCKED MEAT) HARVESTED FROM THE DELMARVA PENINSULA FROM 1928-1975 (COLLATED FROM U.S. FISHERIES DIGEST)

Year	Harvested scallops (kg shucked meat)
1928	5,050
1929	16,038
1930	25,549
1931	17,170
1932	9,220
1933	0
1934	0
//	//
1981	0

<u>The Milfoil Problem (1959-1965)</u>

A second major period of extensive SAV fluctuation in the Bay was the large increase in Eurasian watermilfoil (<u>M. spicatum</u>) in the late 1950's and early 1960's (Stennis 1970, Bayley et al. 1978, Stevenson and Confer 1978b). The area affected by the milfoil was restricted to the upper Bay area and a large section of the Potomac River (Figure 3). The intolerance of milfoil to high salinity water limited its downward expansion in the Bay, but reasons for its sudden expansion in abundance during this period are not well understood. Until 1955, milfoil was found only sporadically in the Bay, apparently introduced from Europe to the U.S. between 1880 and 1900 (Rawls 1978). Biostratigraphic evidence substantiated its recent arrival to Chesapeake Bay (Brush et al. 1980). Milfoil seeds were found in sections of sediment cores from Furnace Bay near Susquehanna Flats and dated only to approximately 1935, though sediments from the cores had recorded events, including the presence of other SAV species, to 1770.

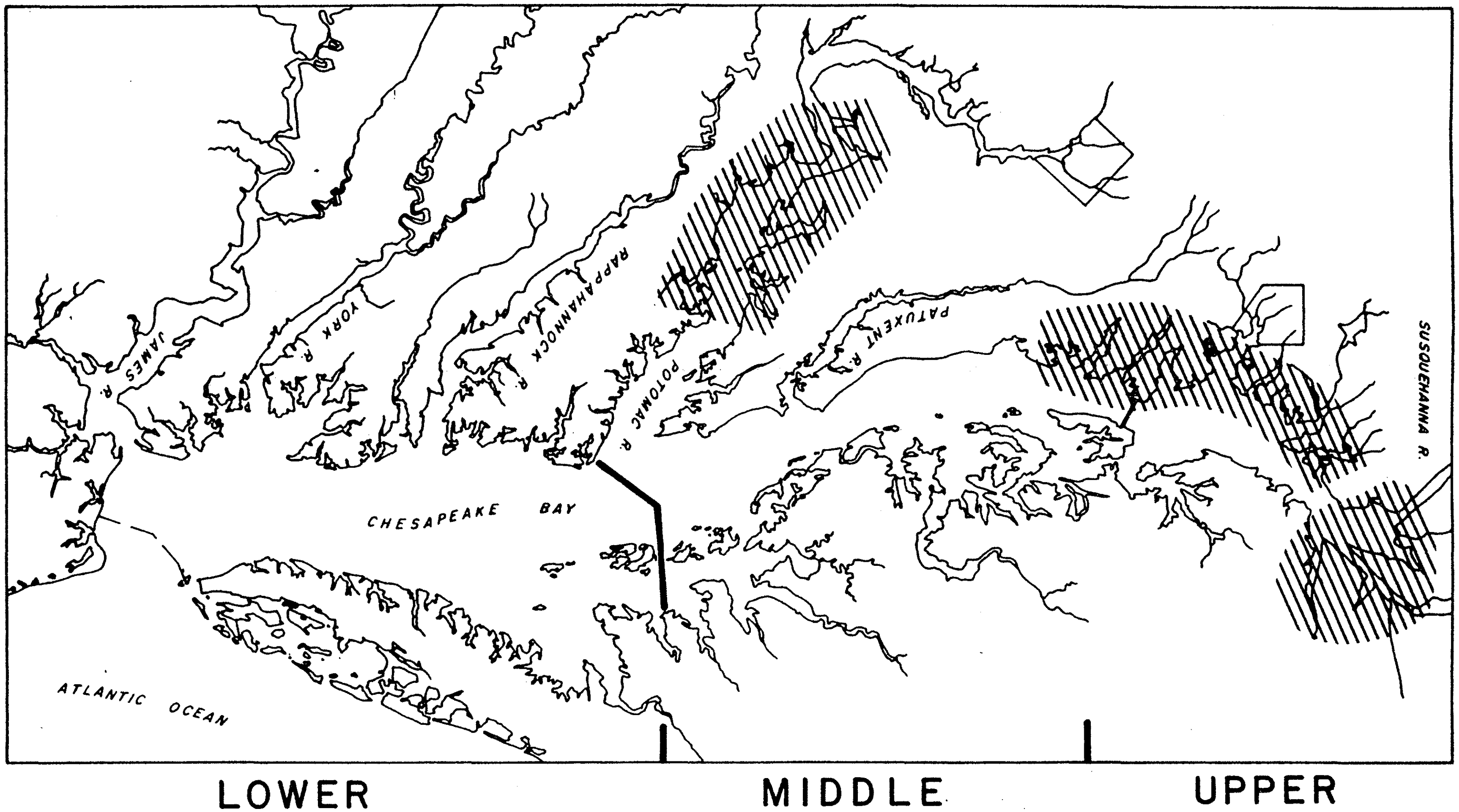


Figure 3. Location of regions (cross-hatching) in the Bay area which were considered to be severely impacted by the growth of Eurasian watermilfoil from 1959-1963.

Milfoil increased Bay-wide from 20,200 ha (49,894 acres) in 1960 to 40,500 ha (100,035 acres) in 1961 (Rawls 1978). In contrast, the 1978 baywide SAV survey found that only 16,000 ha (39,525 acres) of bottom were covered by all SAV species combined. In creeks along the Potomac River, the milfoil reached densities so high that it was considered a nuisance, and attempts to eradicate it with applications of 2-4 D were initiated (Rawls 1978).

The Susquehanna Flats area typifies the changes noted during the rapid expansion of milfoil. In 1957, a survey conducted of SAV found that milfoil did not occur at any sampling stations. Subsequently, it was found in one percent of these stations in 1958, 47 percent in 1959, 82 percent in 1960, and 89 percent in 1961 and 1962. After 1962, milfoil declined in the Flats, with slight increases in 1966 and 1967. The most serious effect associated with the rapid increase in milfoil was a decline in other native species such as common elodea (E. canadensis), naiad (N. guadalupensis), and wildcelery (V. americana). The decline of native species is shown in Figure 4. For example, this graph shows that in 1963 abundance of native plant material was below 50, while abundance of watermilfoil was over 200. Bayley et al. (1978) suggest that the decline of native species was due to competitive exclusion by milfoil. As milfoil declined, these native species returned, but were found at a lower density and covered less area than prior to the milfoil expansion (Bayley et al. 1978).

The Bay-wide Problem (1960-1980)

In the 1960's and 1970's a number of field surveys and aerial surveys were conducted to estimate the distribution and abundance of SAV in the Bay. These estimates, when considered with the results of the SAV distribution projects funded by the Bay Program, reveal dramatic results. The combined data show a pattern of vegetation decline that includes all species in all sections of the Bay and a present abundance of vegetation that may be at its lowest level in recorded history.

The results of this recent decline were first evident in changes in diving duck populations in the Bay (Perry et al. 1981). Two species, in particular, the canvasback (Aythya valisineria) and the redhead (Aythya americana), have shown significant population declines in the last 10 years in the Bay despite increases in the overall North American and Atlantic flyway populations. These two duck species have traditionally used SAV as food (Stewart 1962). The decline in their preferred food source presumably led to the decline in the total number of ducks found in the Bay. Since the SAV decline, canvasbacks have altered their feeding habits to include clams, and redheads still feed predominantly on vegetation.

To illustrate the major changes of SAV populations that have occurred in the Bay area in the last 20 years, we have delineated SAV distribution on a Bay-wide basis at five-year intervals beginning in 1965 and subsequently in 1970, 1975, and 1980 (Figures 5, 6, 7, and 12). 1965 was chosen as a starting point because of the lack of complete information for Bay-wide determination prior to 1965; the compounding problem of the explosion in the late 1950's of Eurasian watermilfoil, which declined by 1965; and the relatively abundant Bay-wide distribution of SAV during this time, apparent from archival photographs and anecdotal information. Though the scale of the map is small in relation to the generally small size of

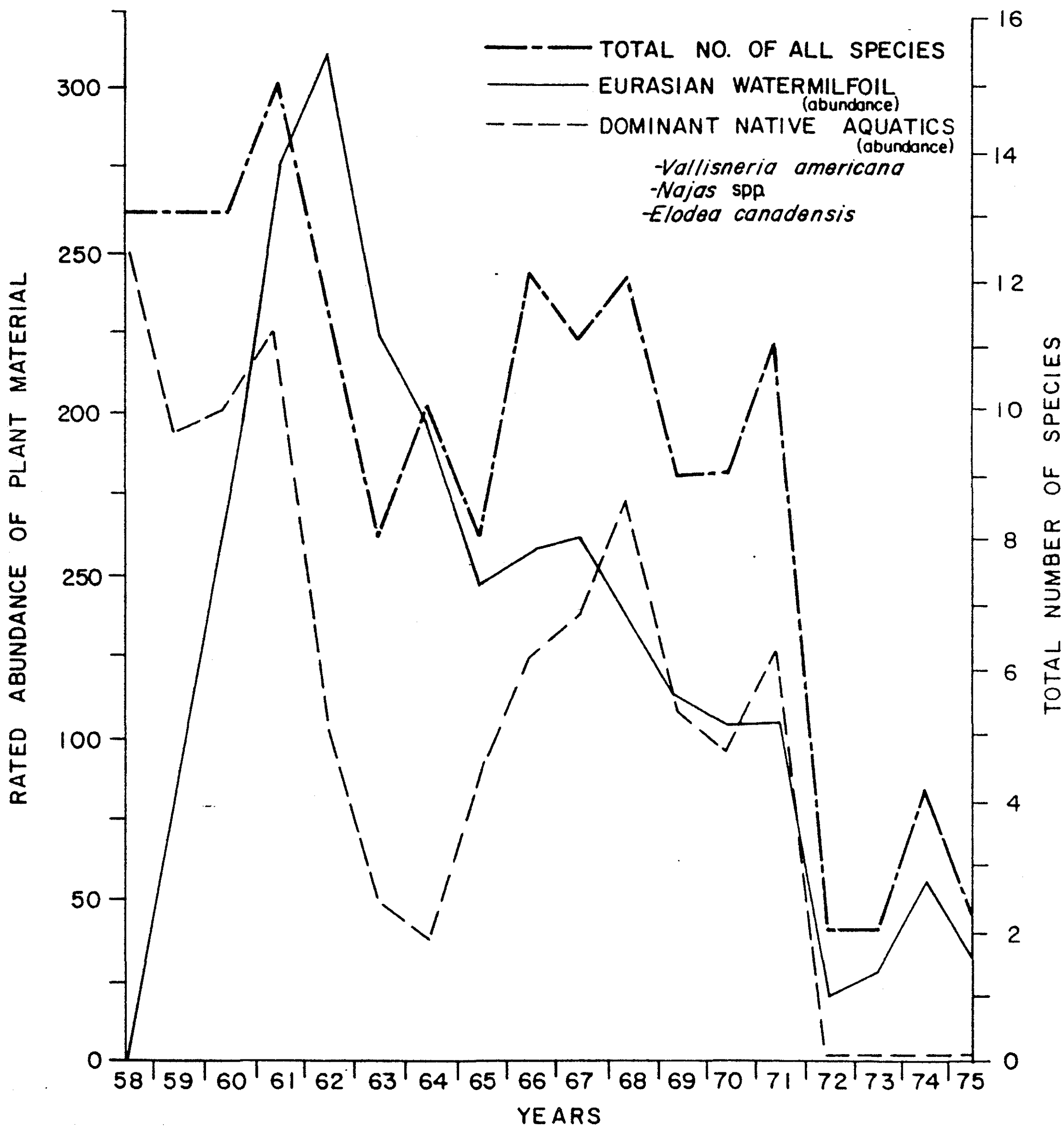


Figure 4. Population fluctuations of watermilfoil compared to the dominant native species and total number of species found on the Susquehanna Flats from 1958-1975 (figure adapted from Bayley et al. 1978).

most SAV areas, the changes that occurred in SAV distribution in each of the five-year intervals were sufficiently dramatic so as to appear quite distinct in the respective figures. Note, for example, the large changes in abundance of SAV in Susquehanna Flats area, Patuxent, and Potomac Rivers from 1965 to 1975. We are aware that the small scale is not suitable for small populations of SAV related to the size of the entire Bay, but the overall changes in SAV on a Bay-wide basis are more easily perceived on this size map. Though in some respects the following maps are qualitative, they represent the culmination of a large effort to incorporate whatever quantitative data were available with the most reliable qualitative data. These maps are the first effort to place into perspective the complex changes that have been observed in SAV populations over the last 20 years.

1965--

In 1965, SAV was quite abundant throughout the Bay and in all of the major tributaries (Figure 5) despite the compounding effects of the milfoil problem in the early 1960's (Bayley et al. 1978). One area, however, that had been reported to have abundant SAV (Cumming et al. 1916), but no longer contained any, was the freshwater tidal portion of the Potomac River (Carter and Haramis 1980, Carter et al. 1980). The SAV of this area apparently declined in the 1930s and had all but disappeared by 1939 (Martin and Uhler 1939). The lower reaches of the Potomac still contained abundant stands of vegetation in 1965 based on evidence from aerial photographs of the Coan, Yeocomico, and lower Machodoc Rivers and from personal accounts of local watermen. In addition, an intensive benthic survey for the soft shell clam, <u>Mya arenaria</u>, in the lower Potomac in 1961 revealed abundant stands of SAV. The lower reaches contained eelgrass, while numerous brackish water species abounded farther upstream (Pfitzenmeyer and Drobeck 1963).

1965-1970--

By 1970 there were still substantial stands of SAV throughout the Bay but evidence indicates some major losses had occurred in several areas (Figure 6). Vegetation in the entire Patuxent River had all but completely disappeared (R. Anderson, personal communication) by 1970, with declines being first noted in the mid-1960's. Anecdotal accounts indicate that populations of eelgrass adjacent to Chesapeake Biological Laboratory at the mouth of the Patuxent River were severely depressed in the late 1960's and gone by 1970. The vegetation in the lower Potomac River evidenced in aerial photographs of the 1960's was also almost completely absent. In addition, vegetation in many of the eastern shore upriver sections of the Choptank, Chester, Gunpowder, and Bush Rivers, as well as in the entire Nanticoke and Wicomico Rivers in the middle and upper Bay zones, was absent or in very reduced abundance (Boynton, personal communication).

SAV in some localized areas around the Bay, including Susquehanna Flats (Bayley et al. 1978) and the Chester River area (Anderson and Macomber 1980), had increased in coverage from 1965 to 1970, though not to previous levels. The increase in these years may have been the result of the reemergence of native SAV species in response to the decline of milfoil (Bayley et al. 1978).

One of the first significant surveys of the upper Bay during this period was that conducted by Stotts from 1967 to 1969 (Stotts 1970). Over

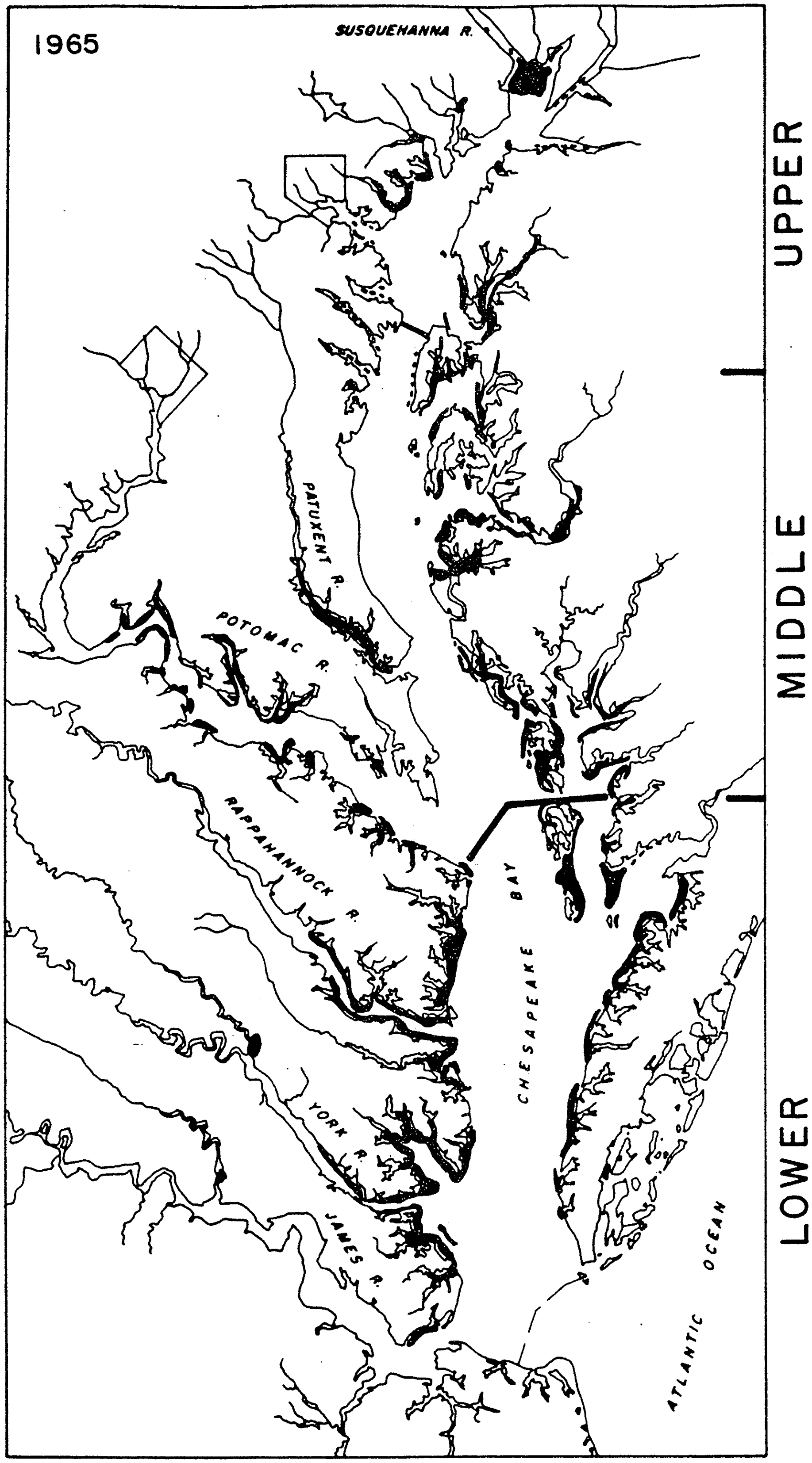


Figure 5 • Distribution of SAV in Chesapeake Bay - 1965.

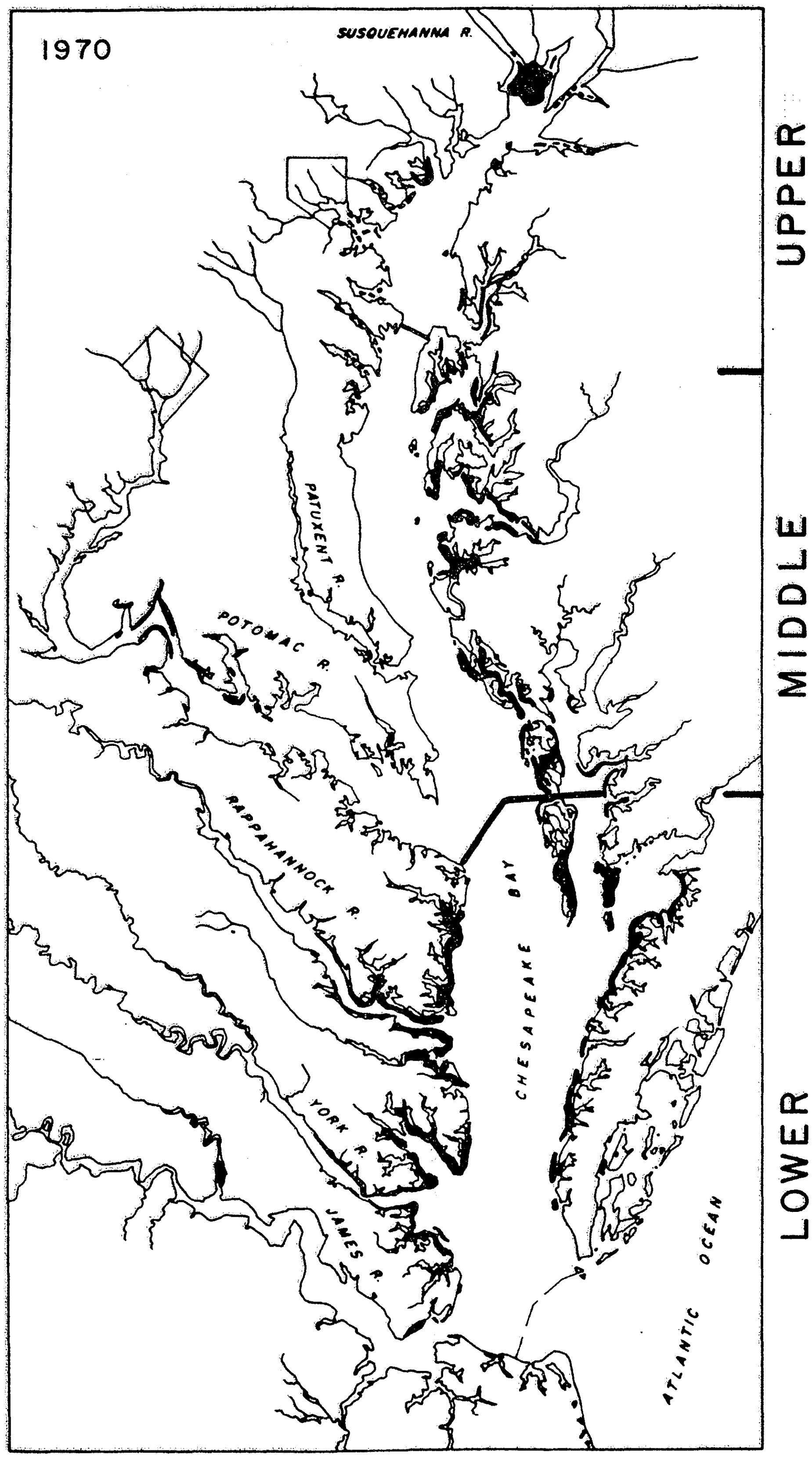


Figure 6. Distribution of SAV in the Chesapeake Bay - 1970.

1,000 transects were sampled from the Virginia - Maryland border to Susquehanna Flats. The survey findings indicate that many areas contained significant beds of vegetation, especially in the more southern locations, from the Choptank River to Smith Island. Stotts reported, however, that large declines of SAV occurred in July and August in several locations north of the Choptank and that SAV did not appear as robust as in the more southern areas, indicating that these systems were being stressed by environmental factors. Examination of aerial photographs taken in September, 1970, shows large beds of vegetation in the same areas where SAV was reported to be abundant by Stotts' survey, especially in the lower reaches of the Chester River, Eastern Bay, Little Choptank River, Honga River, and Bloodsworth Island.

In contrast to the declines evidenced during this period in the upstream, low salinity regions of the Bay and its tributaries, the higher salinity regions vegetated with eelgrass and widgeon grass showed as yet little evidence of any deterioration. Aerial photographs document that extremely dense beds characterized much of the shoreline of the lower Bay and its tributaries, and many areas showed a continued increase in coverage since the 1930's (Orth and Gordon 1975, Orth 1976, Orth et al. 1979).

1970-1975--

By 1975 the Bay-wide situation for SAV had changed dramatically along the entire length of the Bay proper (Figure 7). Indeed, the abundance of vegetation in 1975 represented what we feel was, until then, the lowest recorded abundance of vegetation in Chesapeake Bay and its tributaries as far back as records indicate. The decline of SAV that first began in the mid-1960s and continued to the early 1970's, was now observed in all sections of the Bay, with some areas affected more than others. This decline also appeared to accelerate after Tropical Storm Agnes influenced the Bay in June 1972.

Much of the information available for this period for the upper and middle Bay zones is from the 644 station survey of SAV conducted once a year in Maryland waters beginning in 1971 by the Maryland Department of Natural Resources and the U.S. Fish and Wildlife Service (Kerwin et al. 1977; unpublished files). Their data showed that SAV declined in the surveyed areas between 1971, when 28.5 percent of the stations were vegetated, and 1973, when 10.5 percent of the stations were vegetated (Table 5, Figure 8). SAV fluctuated at comparatively low levels from 1974 to 1975, decreasing to 8.7 percent in 1975. The number of major areas with no SAV increased from five in 1971 to 11 in 1975, an increase of 100 percent (Figure 1 and Table 5). This survey also shows that individual sections of the Bay had not exhibited a uniform trend, but that the head of the Bay and lower eastern shore have fared the worst, while the middle sections of the Maryland eastern and western shores fared the best.

Large reductions in vegetation were observed immediately after Agnes, in July and August, 1972, in many sections of the upper Bay zone (Figure 7), principally the Elk, Bohemia, Sassafras, Back, Middle, Magothy, and Chester Rivers, Howell and Swan Point, Susquehanna Flats, and the headwaters of the Bush and Gunpowder Rivers (Figure 7 and Table 5) (Kerwin et al. 1977). In addition, sections of the middle Bay zone, primarily those in the northern end, such as the Severn River, appeared to be rapidly denuded of grasses. The species that were most affected were the fresh and

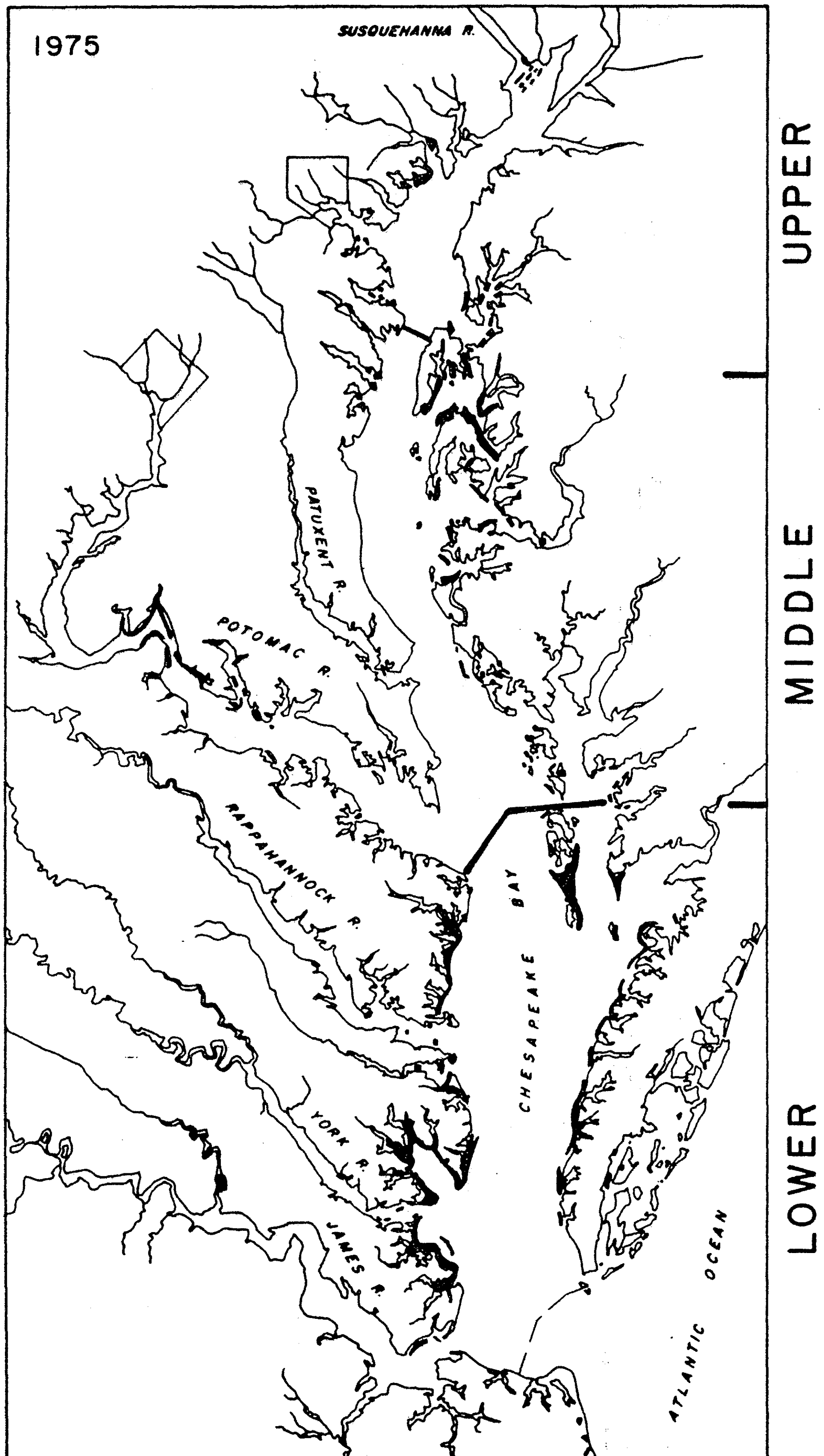


Figure 7. Distribution of SAV in the Chesapeake Bay - 1975.

Table 5. Percent of sampled stations containing submerged aquatic vegetation for various locations in the Maryland section of the Chesapeake Bay (compiled from U.S. Fish and Wildlife Service Migratory Bird and Habitat Research Laboratory (as reported in Stevenson and Confer, 1978) and unpublished files from Maryland's Department of Natural Resources) (**no stations sampled for this location).

River System	Avg. No. of Stations Sampled	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Elk & Bohemia Rivers	15-16	6.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sassafras River	10	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Howell & Swan Points	12	16.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eastern Bay	43-47	34.04	46.51	34.04	36.17	21.74	42.22	28.00	26.10	17.30	34.80
Choptank River	56-60	35.00	39.66	19.30	27.59	1.72	41.07	25.00	28.30	26.70	25.00
Little Choptank River	19	21.05	21.05	0.00	0.00	0.00	15.79	5.00	5.30	5.30	0.00
James Island & Honga River	34	44.12	35.29	2.94	5.88	5.88	8.82	3.00	0.00	0.00	0.00
Honga River	29-30	50.00	40.00	13.33	16.66	10.35	17.24	3.00	3.00	0.00	0.00
Bloodsworth Is.	40-46	37.50	22.73	10.87	11.63	6.98	2.22	4.00	0.00	0.00	2.20
Susquehanna Flats	27-37	44.44	2.70	0.00	13.51	11.11	8.57	11.00	2.70	8.10	0.00
Fishing Bay	24-25	8.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nanticoke & Wicomico Rivers	30-31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manokin River	14-15	40.00	46.67	13.33	20.00	7.14	6.67	20.00	0.00	0.00	0.00
Patapsco River	20-21	0.00	5.00	4.76	9.25	**	9.52	14.00	9.50	9.50	0.00
Big & Little Annemessex Rivers	18-20	70.00	60.00	30.00	57.89	33.33	30.00	30.00	15.00	0.00	5.00
Gunpowder & Bush River Headwaters	7-9	11.11	0.00	0.00	0.00	**	0.00	11.00	0.00	11.10	22.20
Pocomoke Sound (Maryland)	20-22	18.18	10.00	4.76	**	15.00	9.09	10.00	4.50	0.00	0.00
Magothy River	12	33.33	0.00	16.67	16.66	**	16.67	25.00	8.30	16.70	16.70
Severn River	13-15	40.00	20.00	26.67	26.67	0.00	46.15	20.00	26.70	20.00	13.30
Back, Middle & Gunpowder Rivers	22	13.64	4.55	4.55	4.55	9.09	4.55	9.00	4.50	4.50	9.10
Curtis & Cove Points	6-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.30	0.00
South, West & Rhode Rivers	8-10	0.00	0.00	0.00	0.00	0.00	12.50	0.00	0.00	0.00	0.00
Chester River	34-36	61.11	36.11	26.47	23.52	25.00	25.71	38.00	44.40	33.30	38.90
Love & Kent Points	8	0.00	0.00	0.00	12.50	0.00	0.00	0.00	0.00	0.00	0.00
Smith Island (Maryland)	11-17	64.71	45.46	25.00	35.29	22.22	35.29	24.00	5.80	17.60	47.10
Patuxent River	47-50	2.00	4.26	0.00	4.00	0.00	2.04	2.00	2.00	2.00	0.00
Percent of stations vegetated		28.5	21.0	10.5	14.9	8.7	15.0	12.3	9.6	7.9	9.8
Number of stations with no SAV recorded		5	9	12	9	11	8	8	12	13	16

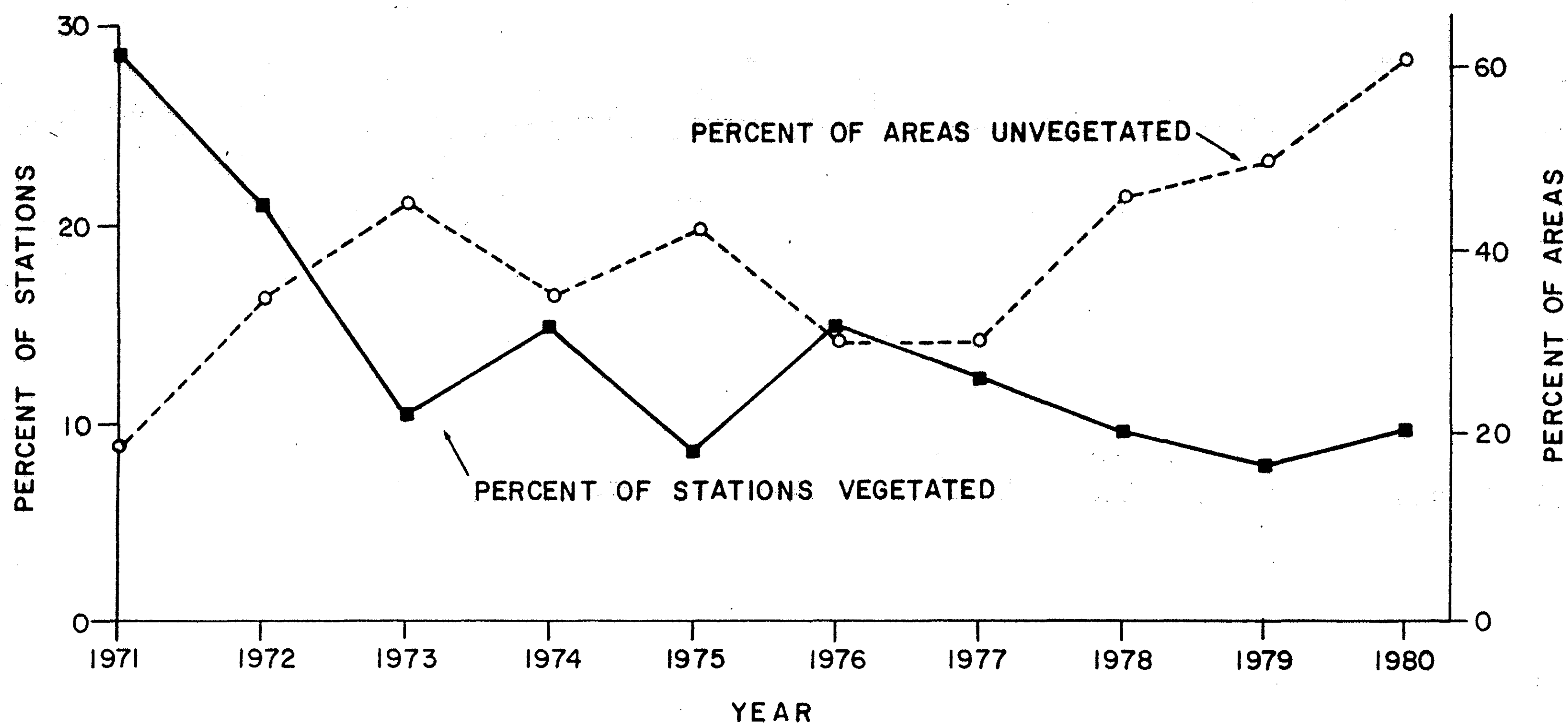


Figure 8. Trend in SAV occurrence in the Maryland portion of Chesapeake Bay. Values represent the percent of stations with SAV (n = 644 stations) and the percent of unvegetated areas (n = 26 areas) (from Kerwin et al. 1977; unpublished data from Kerwin et al. 1977; unpublished data from Maryland's Department of Natural Resources).

brackish water species: coontail (*C. demersum*), common elodea (*E. canadensis*), southern naiad (*N. guadalupensis*), wildcelery (*V. americana*), sago pondweed (*P. pectinatus*), and redhead grass (*P. perfoliatus*) (Table 1).

Vegetation in the middle and lower zones of the Bay started to decline in 1973. In the middle zone, regions affected were: the Choptank and Little Choptank Rivers, James Island, Manokin River, Big and Little Annemessex Rivers, and Bloodsworth and Smith Islands. Species affected in these areas included many of the same low salinity species that were rapidly lost from the upper Bay section in 1972 as well as the higher saline species, eelgrass and widgeon grass. The decline of SAV at some locations on the lower eastern shore where eelgrass and widgeon grass had predominated is shown in Figure 9.

In the lower zone, where data are available primarily from detailed aerial photographs (Orth and Gordon 1975, Orth et al. 1979), vegetation in the York, Rappahannock, and Piankatank Rivers, as well as in many small tributaries, was reduced substantially during this period (Figure 7). To highlight the changes that occurred with SAV communities in the lower Bay, six areas were mapped for historical changes in the distribution and abundance of SAV (Orth et al. 1979). These changes are shown in detail for one of the sites: Mumfort Island in the York River (Figure 10). SAV coverage in the lower Bay generally increased at all these sites from the 1930s to 1970; there was a marked decline beginning around 1970 (Figures 10 and 11). Our data, especially for the York River, indicated that the decline of SAV occurred in the summer of 1973, as evidenced by the presence of large beds of SAV in April 1973 that were absent in April 1974. Comparison of means indicated that there were significant differences between pre-1972 and post-1972 coverages at Parrott Island in the Rappahannock River ($p=0.001$), Mumfort Island in the York River ($p=0.002$), and East River in Mobjack Bay ($p=0.038$). At Jenkins Neck at the mouth of the York River, where the trend was more gradual, regression analysis indicates a significant decline ($p=0.02$). At Fleets Bay, just above the mouth of the Rappahannock River, regression analysis indicates the decline was significant ($p=0.019$). Only Vaucluse Shores on the eastern shore showed no significant decline ($p=0.14$).

Several distinct patterns in the decline of vegetation in the lower Bay are evidenced. First, it appears that losses of vegetation were greatest in all the areas where eelgrass formerly reached its upriver or upbay limits. For example, eelgrass beds disappeared from the Maryland portion of the eastern shore while remaining in the Virginia portion. Along the western shore of the lower Bay, SAV beds declined the most in the northern areas and least in the southern areas. Within the major tributaries, SAV disappeared, leaving only some beds at the mouths of the rivers. In nearly all the small creeks and tributaries where eelgrass beds continued to exist in 1975, the former distribution included areas further upstream. Second, in addition to the upstream-downstream movement, it appears that the vegetation declined in the deeper, offshore sections of the beds rather than in the shallower, nearshore areas (Figure 2).

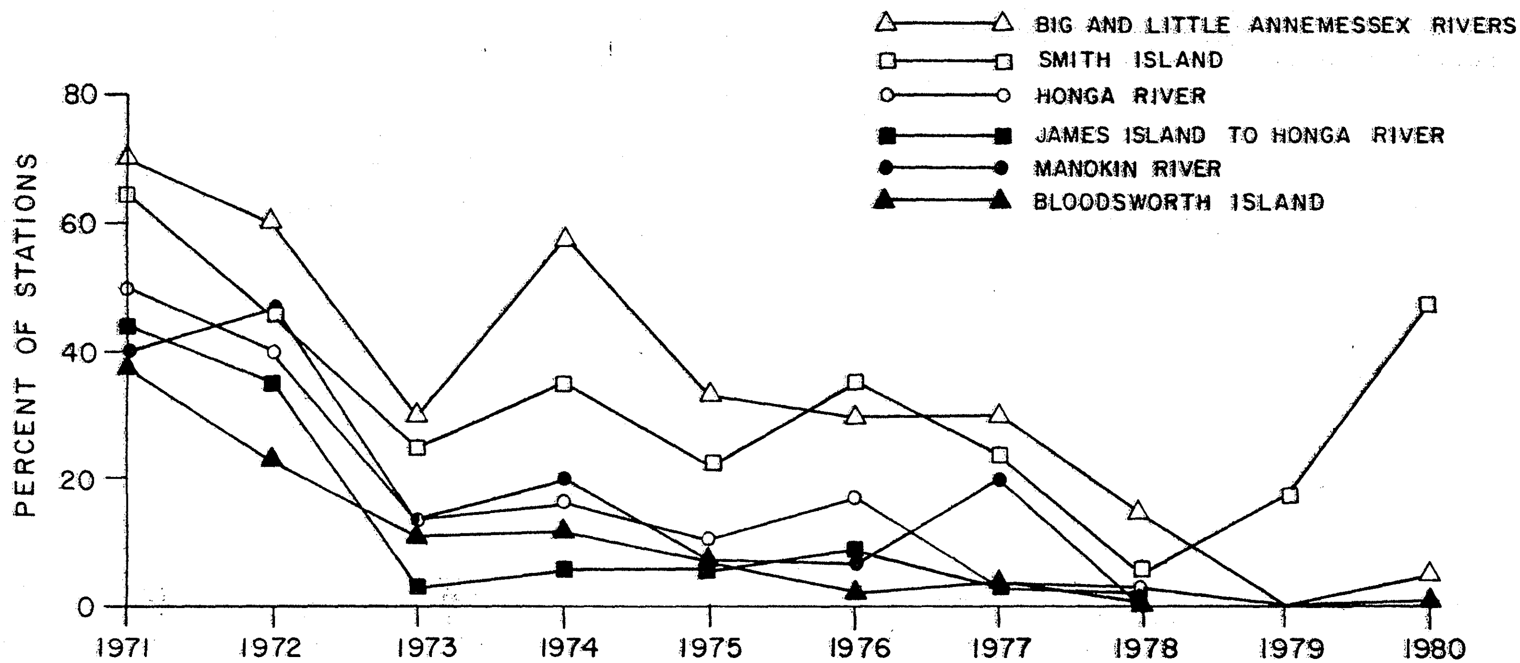


Figure 9. Trends in SAV occurrence in six areas in the middle Bay zone where SAV had markedly declined (data from Kerwin et al. 1977; unpublished data from Maryland's Department of Natural Resources).

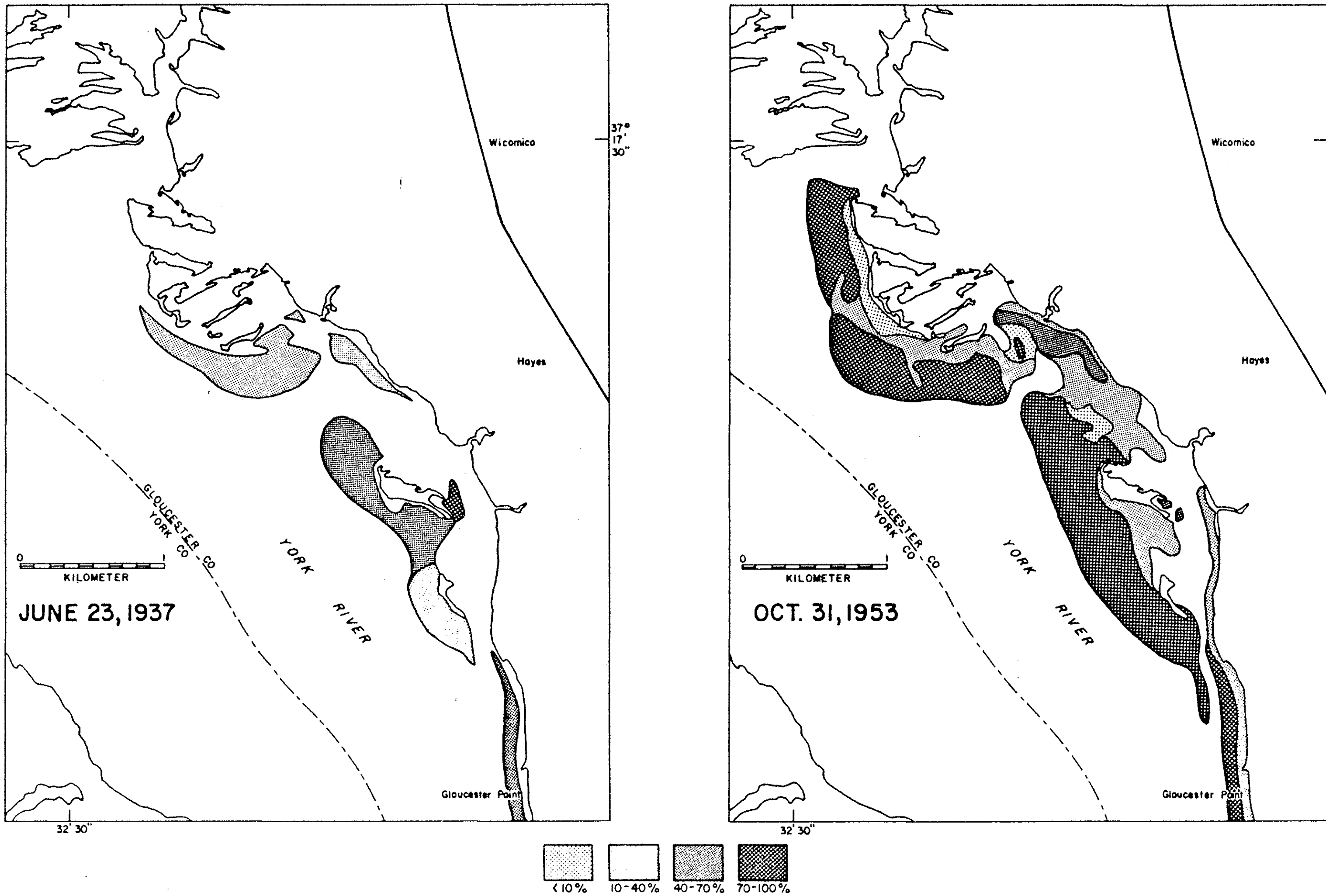


Figure 10. Changes in the distribution and abundance of SAV at the Mumfort Island area in the York River, 1937-1978. Density of SAV shown as very sparce (10% coverage), sparce (5-40%), moderate (40-70%), or dense (70-100%)(data from Orth et al. 1979).

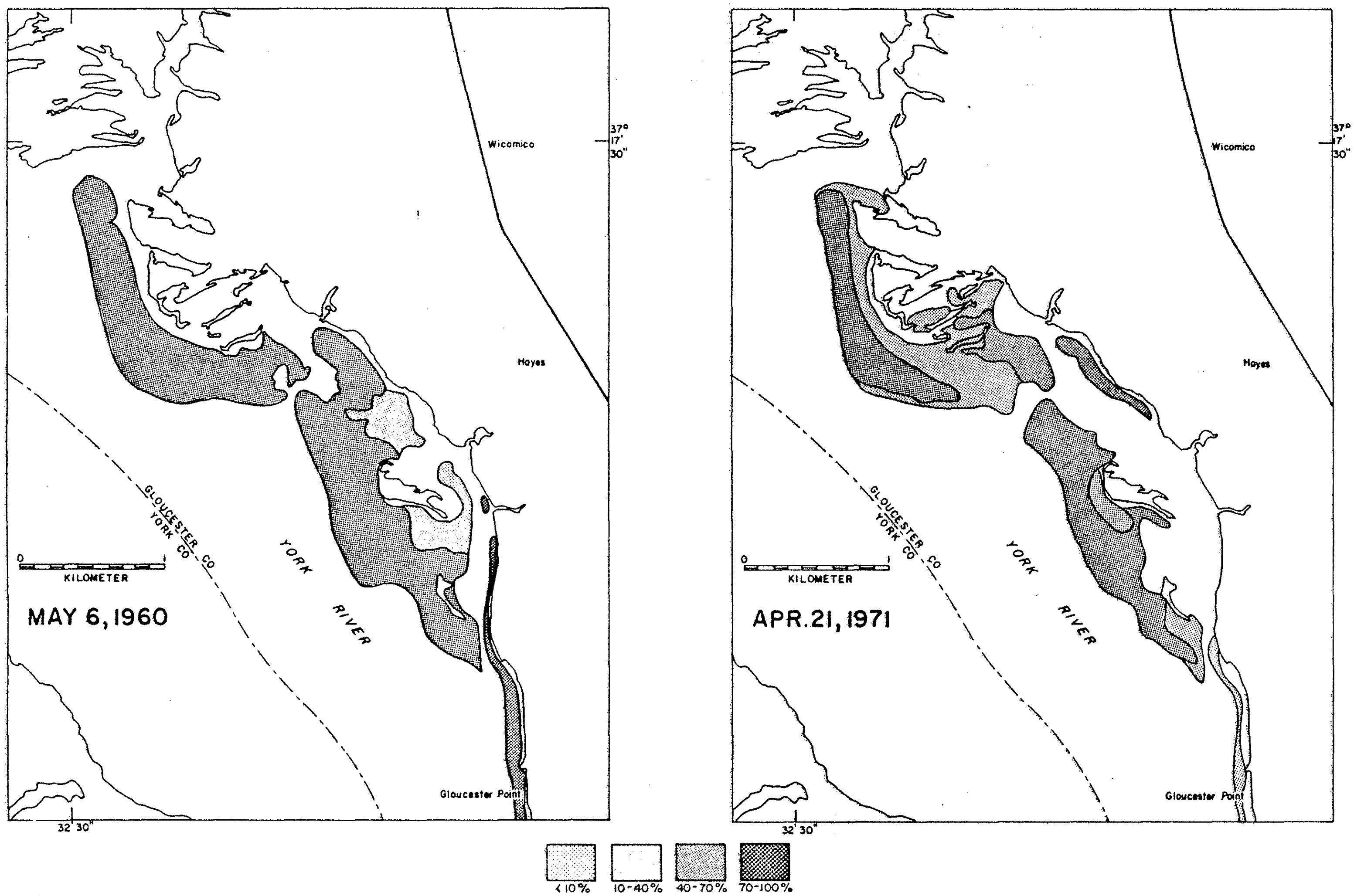


Figure 10. (continued)

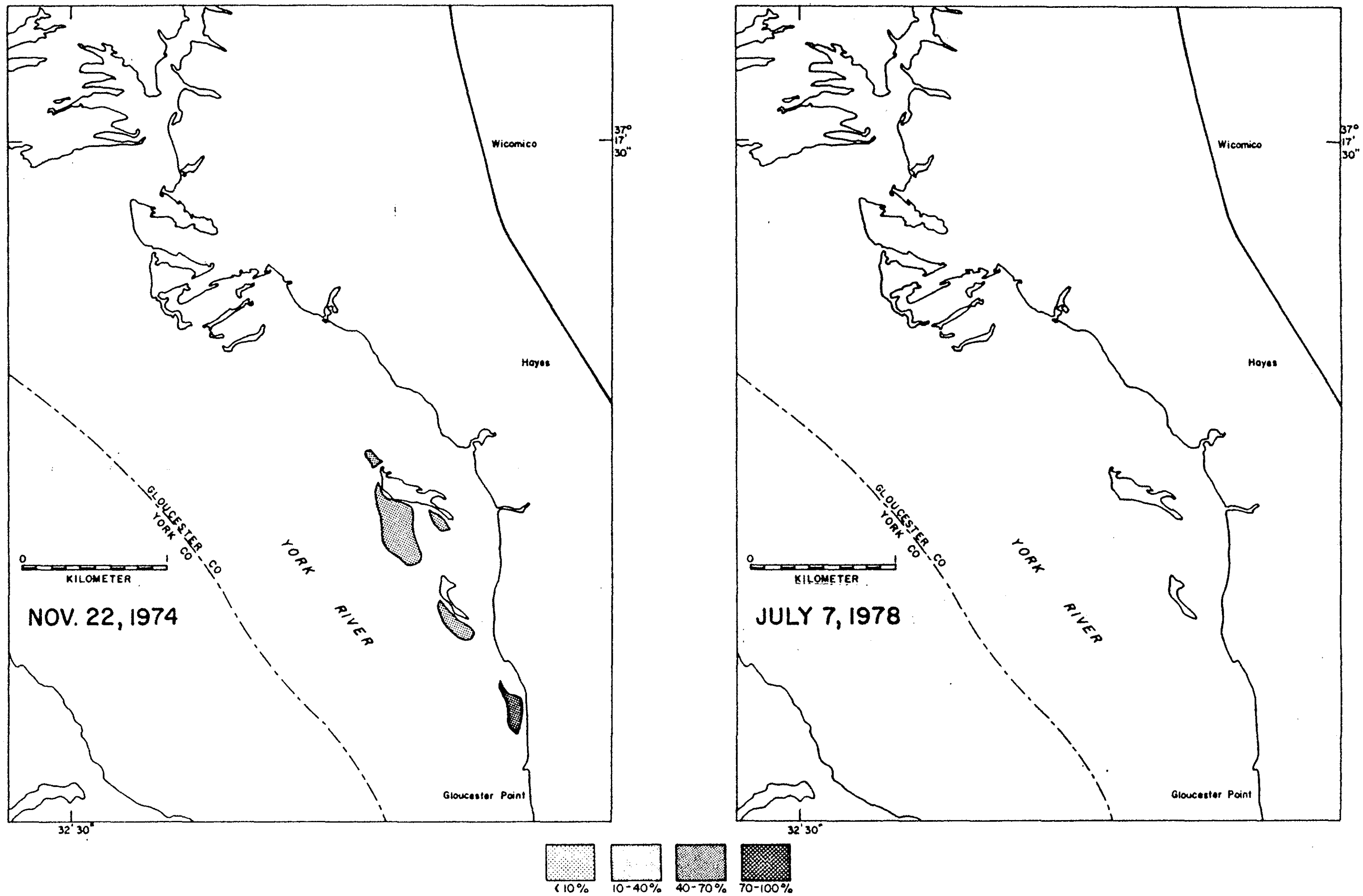


Figure 10. (continued)

1975-1980--

Between 1975 and 1980, the Bay-wide status of SAV appeared to be one of continuing decline in almost all areas of the Bay (Figure 11). The upper Bay survey by the Maryland Department of Natural Resources continued to show a small percentage of stations vegetated with SAV with a trend toward decreasing levels to 1979 (unpublished data). A small increase was observed in 1980, but this was due to a large increase in vegetated stations at the Smith Island site (Table 5 and Figure 9). All sites, where a decline in abundance in the early 1970's from the lower eastern shore was observed, except for Smith Island, continued to decline to much lower levels (Figure 9). Another significant point was the continual increase in the number of areas that contained no SAV. By 1980, 16 areas, or 62 percent of the total areas identified for this survey now contained no SAV, compared with five areas or 19 percent in 1971 (Table 5 and Figure 8).

In the lower Bay zone, the total for the mapped areas of the western shore from the Rappahannock River to the James River between 1974 and 1978 remained similar (Table 3). Although there were observed declines, losses were offset by increases in the sizes of some grassbeds, especially those in Mobjack Bay. Losses were observed in many of the smaller beds that remained in some localities after the 1973-1974 period, but had totally disappeared by 1978, particularly in Fleets Bay, where 76 percent of the vegetation mapped in 1974 declined by 1978. Between 1978 and 1980, almost all sections of the lower Bay declined. Now, in some sections (Rappahannock River and Reedville), almost no SAV remains (Table 3, and Figures 11 and 12).

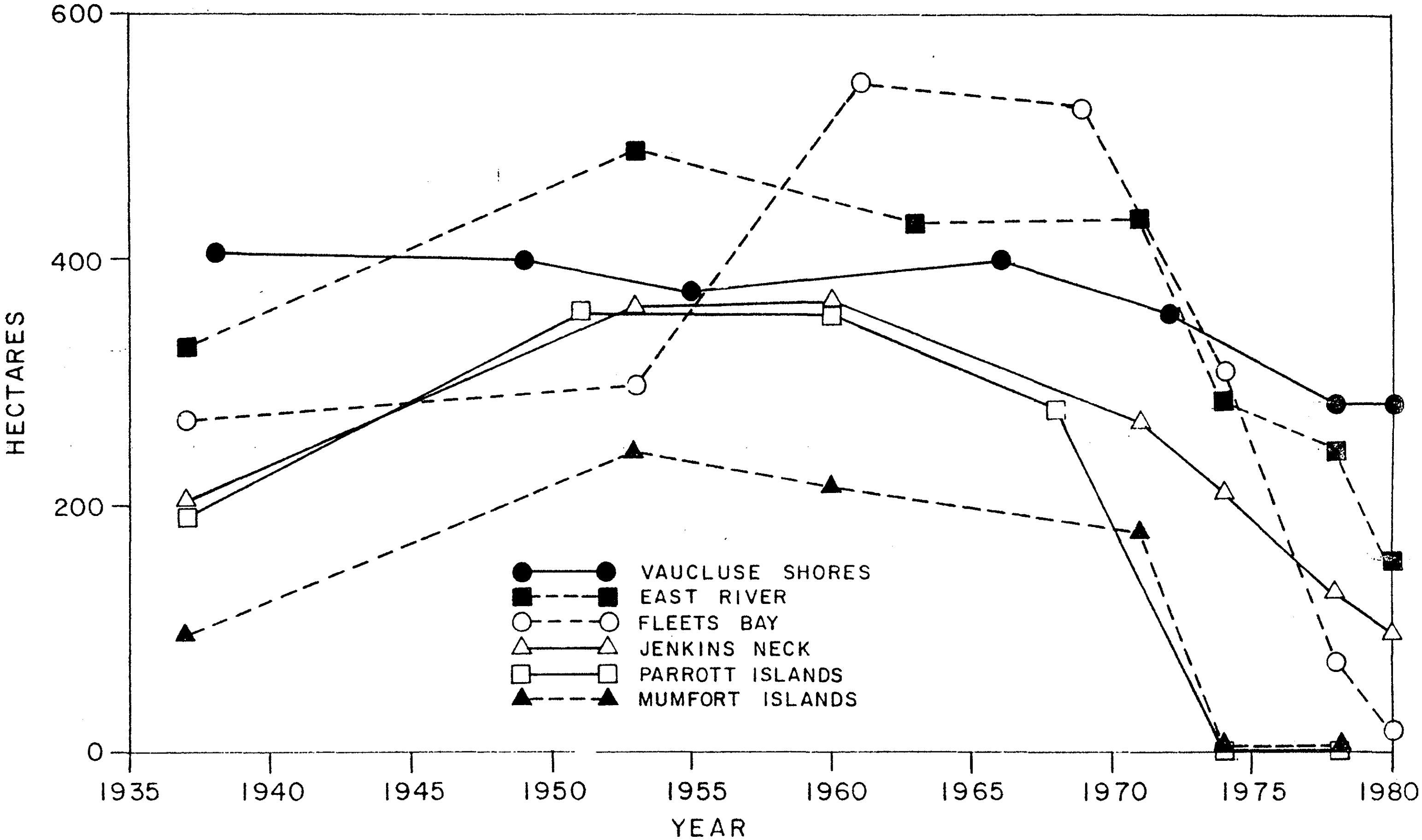


Figure 11. Trends in SAV coverage at six sites in the lower zone of Chesapeake Bay (data from Orth et al. 1979).

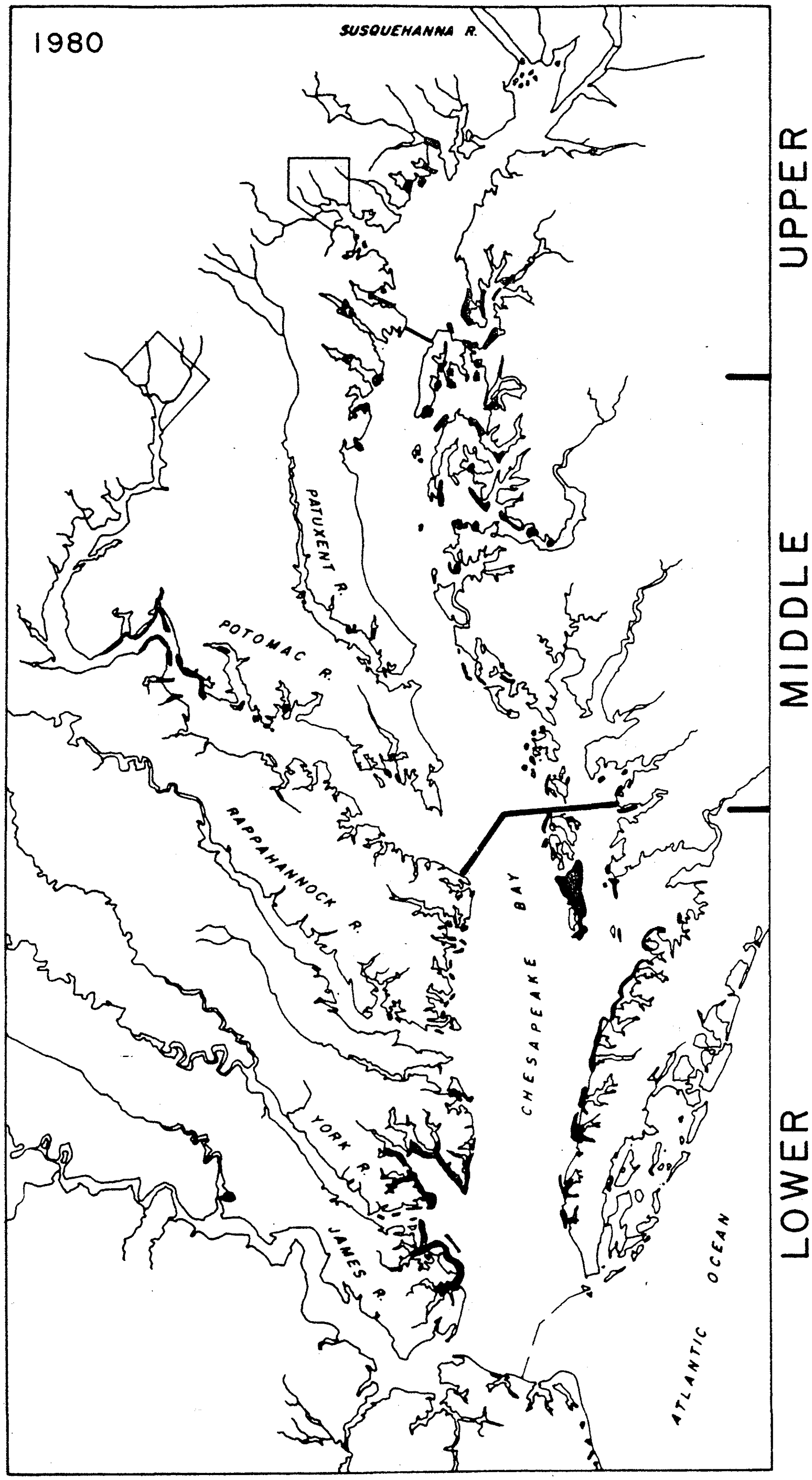


Figure 12. Distribution of SAV in Chesapeake Bay - 1980.

SECTION 5

THE ATLANTIC COAST

There is little evidence to suggest that there have been recent significant changes in SAV distribution along the east coast of the U.S. comparable to those documented for Chesapeake Bay. The uniqueness of the Chesapeake Bay estuary, with its extensive littoral areas and marked salinity gradient makes comparisons difficult. In addition, only recent interest, by the scientific community and management agencies in SAV communities, has resulted in any significant work on the historic distribution of SAV in other areas.

Eelgrass is a species distributed widely along the coastline of the eastern United States and Canada, from North Carolina to Nova Scotia. As mentioned in the previous section, eelgrass populations underwent a dramatic reduction along the east coast of the U.S. in the 1930's. This decline had dramatic effects on waterfowl populations, fisheries, and shoreline erosion. Declines in other years were noted by Cottam (1934, 1935), but recovery always followed these declines in most of the reported areas. At present, North Carolina, which has extensive beds of eelgrass located within its bays and sounds, with a few beds found along the tidal rivers, is attempting to determine the present distribution of SAV in the region. Researchers in the area report no apparent widespread changes in eelgrass distribution in the last 10 years (M. Fonseca, G. Thayer, personal communication). There have been localized changes in eelgrass beds, but these have been due to physical perturbations by man or to other localized distrubances. Davis and Brinson (1976) report on the distribution of SAV in the Pamlico River, but again report no significant, recent changes in their abundance. In South Carolina and Georgia there are, at present, no significant stands of SAV, primarily because of the very turbid conditions that exist in the estuaries found there.

North of Chesapeake Bay there appears to be no SAV in the Delaware Bay at present, and data on whether it ever occurred there are not available. In New Jersey, SAV beds dominated by eelgrass and widgeon grass are found in the sounds located to the west of the barrier islands (Good et al. 1978, Macomber and Allen 1979). There is a lack of historic data on SAV in the region but, again, there is no direct evidence of any large scale changes in the existing beds.

New York researchers indicate no reports of significant losses in eelgrass beds; on the contrary, eelgrass appears to be increasing in abundance (Churchill, personal communication).

Rhode Island SAV beds persist in many of the small tidal lagoons adjacent to Long Island Sound. These systems still contain abundant vegetation and apparently have not undergone recent significant alterations.

In Massachusetts, Maine, Canada, and Rhode Island, there have been no reports of changes in SAV communities. Accurate data are lacking, however, because there are no scientists presently involved in any extensive SAV research programs.

In summary, it appears that the declines in eelgrass or other SAV species in the Bay are not part of a widespread and synchronous loss of vegetation along the east coast of the U.S., although these conclusions are hampered by the lack of comprehensive data on the current and historical distribution of SAV in other areas. It is most likely that the water quality problems affecting the distribution of grasses in the Bay are regional in nature, involving the Bay, its tributaries, and their drainage basins.

SECTION 6

WORLDWIDE PATTERNS

As in Chesapeake Bay, many coastal and estuarine regions of the world contain varying amounts of shallow water areas that support SAV beds ranging from large, very dense areas in the Caribbean to small, sparse areas in some European countries. The grass beds around the world occur under a wide range of physical, chemical, and biological parameters. Yet despite these differences, they share a common ground in their functional roles in their respective ecosystem: a habitat and nursery area, a food source for waterfowl, a sediment stabilizer, a nutrient buffer, and a source of detritus. Recent interest in SAV systems worldwide has paralleled the increasing interest in the role and value of Bay SAV systems and an interest in their proximity to industrialized areas, causing them to become increasingly stressed by man-made perturbations. Recent examples from the Netherlands (Nienhuis and DeBree 1977, Verhoeven 1980), England, (especially some very pertinent examples from freshwater areas) (Wyer et al. 1977, Eminson 1978, Phillips et al. 1978), Wales (Wade and Edwards 1980), Scotland (Jupp and Spence 1977), Denmark (Sand-Jensen 1977, Kiorboe 1980), France (Peres and Picard 1975, Maggi 1973, Verhoeven 1980), Israel (Litav and Agami 1976), Australia (Cambridge 1975, Larkum 1976), Japan (Kikuchi 1974a, 1974b) and the Virgin Islands (Van Epoel 1971), suggest that losses in SAV communities are highly correlated with changing water quality conditions. In many of the above examples, where SAV has been described as greatly reduced or declining, this reduction has always been associated with decreasing water clarity as a result of increased eutrophication, with subsequent increases in epiphytes and phytoplankton due to sewage or agricultural inputs, or as a result of higher loads of suspended sediments due to dredging or runoff from deforested areas.

On the other hand, increases in water clarity have been shown to result in expansion of SAV. The diking of the Gravelingen estuary in the Netherlands resulted in a salt water lake with reduced currents and no tidal effects. This resulted in a reduced total suspended solid load, and, thus greater light penetration. Subsequently, eelgrass increased almost 400 percent in 10 years and was found in water depths of up to five meters, far deeper than before the diking (Nienhuis 1980).

Large reductions of SAV communities have also been associated with natural causes of diseases. The eelgrass wasting disease of the 1930s, which resulted in massive declines of eelgrass along the east coast of the U.S. and west coast of Europe was originally attributed to a disease organism, Labyrinthula, but later attributed to climatalogical changes in temperature (Rasmussen 1973, 1977). In Australia, decline of SAV was attributed to migrating sand waves that smothered the grasses (Kirkman 1978). However, the more recent declines cited in the literature have been associated with man-induced alterations rather than with natural ones.

There are still vast areas of SAV in many parts of the world, particularly in the Gulf of Mexico, the Caribbean, and Australia that are not presently affected by industrial or urban development [one area in southern Florida was estimated to have 500,000 ha (1,235,000 acres) of turtlegrass (Thalassia testudinum) (J. Zieman, personal communications)].

In those areas where development has occurred, SAV communities declined, especially in deeper beds, because of the reduction in quantity of light -- a pattern that parallels the situation in Bay SAV communities.

SECTION 7

CONCLUSIONS

The period of 1965 to 1980 represents what we feel was an unprecedented decline of SAV in Chesapeake Bay. Loss of SAV communities was first observed in the late 1960's in the upper Bay areas, and in particular, the Patuxent, lower Potomac River (SAV beds in the freshwater tidal portions had been absent since the 1930's), and the upper reaches of some of the smaller tributaries (for example, the Chester and Choptank Rivers). By 1970, almost all the vegetation in the Patuxent River and lower Potomac River was gone. The decline of SAV in the Bay accelerated in the early 1970s and continued through 1980, with the most rapid decline occurring from 1972 to 1974. Several sections in the Bay that once contained abundant SAV virtually had none by 1980 (for example, the Patuxent, Piankatank, and Rappahannock Rivers); other sections had only small stands remaining (for example, the Potomac and York Rivers, and Susquehanna Flats). In addition to this trend of SAV populations declining from "up-estuary" to "down-estuary", it appears that within individual beds the declines occurred first in the areas of greatest depth.

The present abundance of all SAV species in the Bay [16,000 ha (39,520 acres)] is probably the lowest level recorded in the Bay's history. Figure 13 shows this cumulative pattern of decline over the last 20 years, with the arrows representing the former to present limits of distribution. Figure 14 outlines these sections of the Bay where SAV has been most severely affected.

SAV in the Bay has experienced other large scale changes in the recent past, although none involving so great a spectrum of species types. In the 1930's, a decline of SAV primarily involved eelgrass except for the tidal freshwater portion of the Potomac River where all SAV species disappeared. Eelgrass gradually returned to all areas of the Bay, but there has been little regrowth of SAV in the upper Potomac. In the late 1950's and early 1960's, the sudden rapid expansion of Eurasian watermilfoil created problems by choking many waterways in sections of the Potomac River, Susquehanna Flats, and western tributaries of the upper Bay.

On a much broader latitudinal scale, the entire east coast of the United States and the west coast of Europe, eelgrass populations also declined during the 1930's. This decline was subsequently followed by a gradual return in most areas. Near Chesapeake Bay, in the shallow lagoons behind the barrier islands of the Delmarva Peninsula, the eelgrass has never recovered. This has drastically affected the scallop industry that was associated with this species of SAV. Regarding the decline of SAV in the 1960's and 1970's in Chesapeake Bay, there is little evidence yet to suggest that a simultaneous decline occurred with SAV communities in other areas along the east coast of the United States. Reports indicate that on a worldwide basis, despite their abundance in certain areas, SAV communities are becoming increasingly affected by man-induced perturbations, declining in areas where there is extensive industrial and/or urban development.

Given the current situation, a very important question can be raised as to the ability of these systems to return to their previous levels of

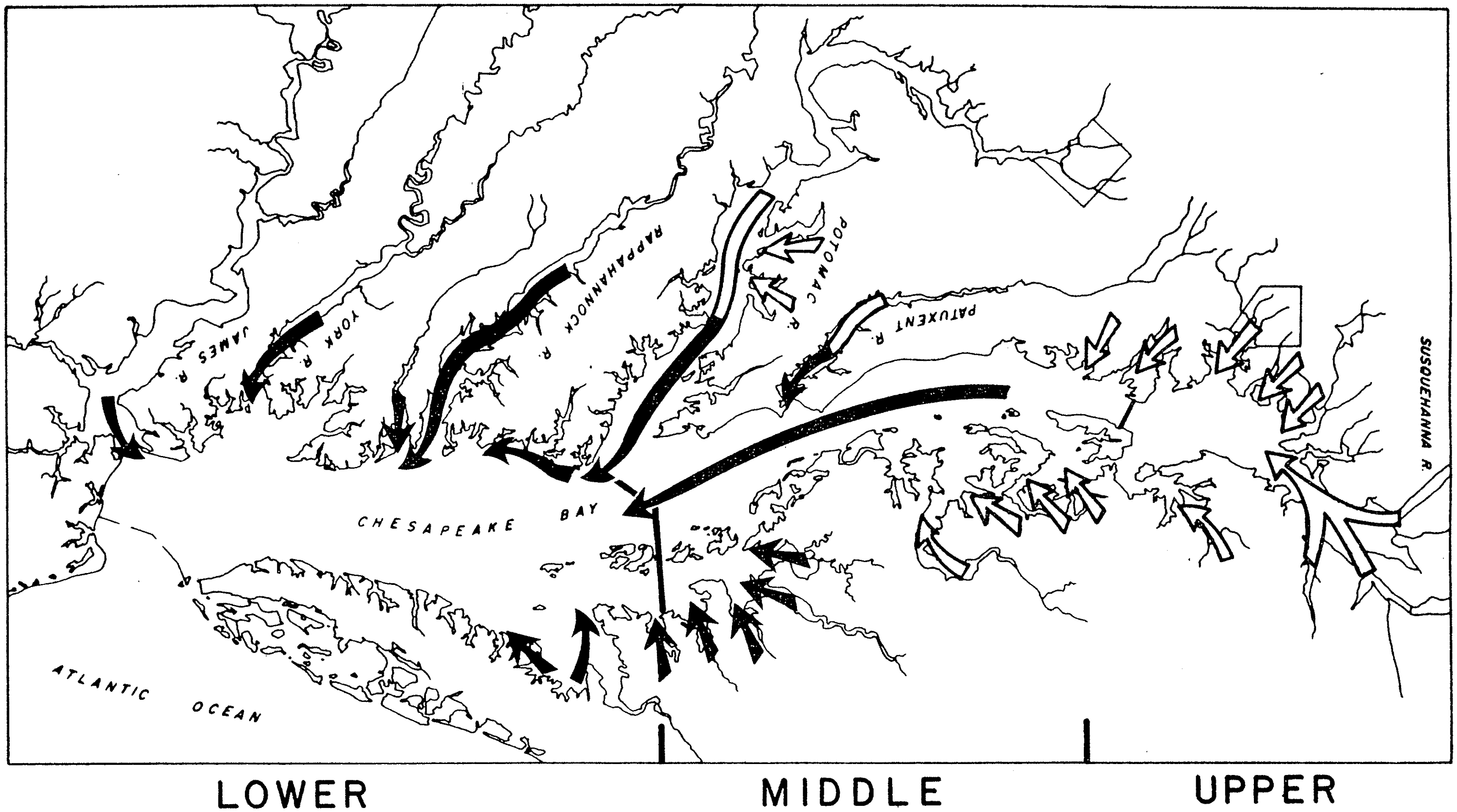


Figure 13. Pattern of recent changes in the distribution of SAV in Chesapeake Bay. Arrows indicate former to present limits. Solid arrows indicate areas where eelgrass (<u>Zostera marina</u>) dominated. Open arrows indicate other SAV species. (Orth et al. 1982)

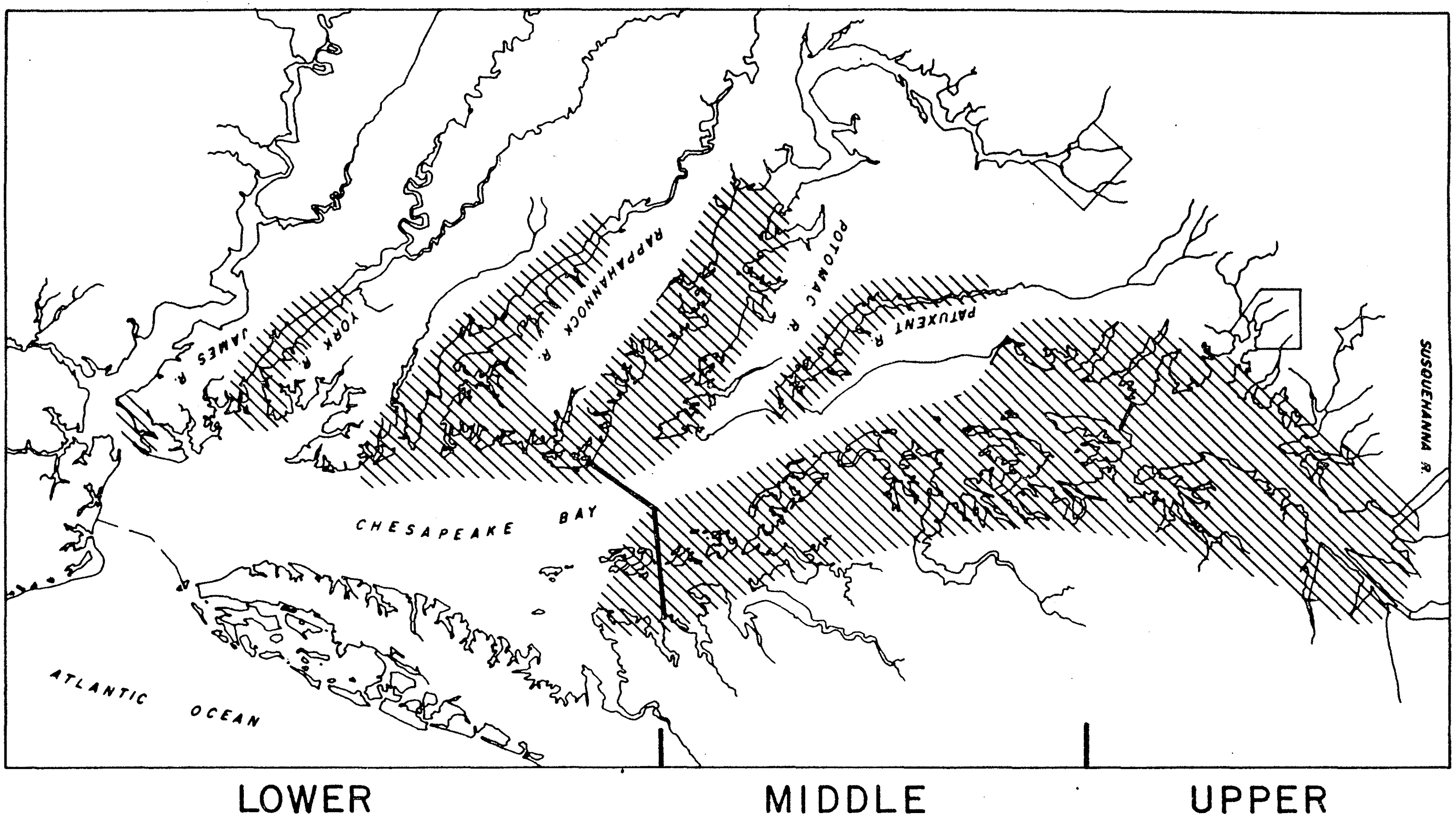


Figure 14. Location of sections of the Bay where SAV has experienced the greatest decline.

abundance in the Bay. Indeed, recovery may not occur because the current levels of SAV are so low or non-existent that natural recruitment via vegetative propagation or seed dispersal may be limited. Recent success with SAV transplantation experiments, moving whole plants into denuded areas in the Potomac River and lower Bay, indicates that these regions may now be capable of supporting SAV (Orth et al. 1981; V. Carter, personal communication). Thus, transplanting SAV may be a viable method, and in some areas the only way, for the reintroduction of these plant communities.

The future of SAV in Chesapeake Bay is one of uncertainty. We know that historically there have been several periods of SAV decline in the Bay. The vegetation has returned to some areas; others have remained barren. The pattern of continued decline of SAV in the Bay over the last 20 years suggests a chronic deterioration of water quality. Unless the complex interaction of factors leading to this deterioration can be understood and reversed, SAV communities in many areas may remain a part of the Bay's past.

LITERATURE CITED

Anderson, R. R. 1972. Submerged Vascular Plants of the Chesapeake Bay and Tributaries. Chesapeake Sci. 13:587-589.

Anderson, R. R., and R. T. Macomber. 1980. Distribution of Submerged Vascular Plants, Chesapeake Bay, Maryland. Final Report, U.S. EPA Chesapeake Bay Program. Grant No. R805970. 126 pp.

Bayley, S., V. D. Stotts, P. F. Springer, and J. Steenis. 1978. Changes in Submerged Aquatic Macrophyte Populations at the Head of the Chesapeake Bay, 1958-1974. Estuaries. 1:171-182.

Brush, G. S., F. W. Davis, and C. A. Stenger. 1981. Sediment Accumulation and the History of Submerged Aquatic Vegetation in the Patuxent and Ware Rivers: A Stratigraphic Study. U.S. EPA Final Report, Grant No. R80668001.

Brush, G. S., F. W. Davis, and S. Rumer. 1980. Biostratigraphy of Chesapeake Bay and its Tributaries: A Feasibility Study. U.S. EPA Final Report, Grant No. R205962. 98 pp.

Cambridge, M. D. 1975. Seagrasses of Southwestern Australia with Special Reference to the Ecology of Posidonia australis in a Polluted Environment. Aquat. Bot. 1:149-161.

Carter, V., and G. M. Haramis. 1980. Distribution and Abundance of Submersed Aquatic Vegetation in the Tidal Potomac River--Implications for Waterfowl. In: Bird Populations--A Litmus Test of the Environment. J. F. Lynch, ed. Proc. Mid-Atlantic Nat. Hist. Symp. Audubon Nat. Soc., Washington, D.C. pp. 14-19.

Carter, V., J. E. Paschal, and G. M. Haramis. 1980. Submersed Aquatic Vegetation in the Tidal Potomac. In: Proc. Conf. Coastal Zone 1980. ASCE/Hollywood, Florida. pp. 17-20.

Cottam, C. 1934. Past Periods of Eelgrass Scarcity. Rhodora. 36:261-264.

Cottam, C. 1935. Further Notes on Past Periods of Eelgrass Scarcity. Rhodora. 37:269-271.

Cottam, C., and D. A. Munro. 1954. Eelgrass Status and Environmental Relations. J. Wildl. Mgt. 18:449-460.

Cumming, H. S., W. C. Purdy, and H. P. Ritter. 1916. Investigations of the Pollution and Sanitary Conditions of the Potomac Watershed. Treasury Dept., U.S. Public Health Service Hygenic Lab. Bull. No. 104. 231 pp.

Davis, G. J., and M. M. Brinson. 1976. The Submersed Macrophytes of the Pamlico River Estuary, North Carolina. Water Resources Res. Inst. Univ. North Carolina, Rep. No. 112. 202 pp.

Eminson, D. F. 1978. A Comparison of Diatom Epiphytes, Their Diversity and Density, Attached to Myriophyllum spicatum in Norfolk Dykes and Broads. Brit. Phycol. 13:57-64.

Good, R. E., J. Limb, E. Lyszczek, M. Miernik, C. Ogrosky, N. Psuty, J. Ryan, and F. Sickels. 1978. Analysis and Delineation of the Submerged Vegetation of Coastal New Jersey: A Case Study of Little Egg Harbor. Rutgers University, New Brunswick, N.J. 58 pp.

Gutsell, J. S. 1930. Natural History of the Bay Scallop. U.S. Bur. Fish Bull. 46:569-632.

Hartog, C. den. 1970. The Seagrasses of the World. Verhandel, Afd. Naturk. Koninklyke Ned. Akad. Van Werenscl. Tweede Reeks, Dul 39, No. 1. 275 pp.

Hitchcock, A. S., and P. C. Standley. 1919. Flora of the District of Columbia and Vicinity. Contrib. from the U.S. National Herbarium Vol. 21, Smithsonian Inst., 329 pp. & 42 pl.

Heinle, D. R., C. F. D'Elia, J. L. Taft, J. S. Wilson, M. Cole-Jones, A. B. Caplins, and L. E. Cronin. 1980. Historical Review of Water Quality and Climatic Data from Chesapeake Bay with Emphasis on Effects of Enrichment. U.S. EPA Final Rep. Grant R806189. 128 pp.

Jupp, B. P., and D. H. Spence. 1977. Limitations of Macrophytes in a Eutrophic Lake, Loch Leven. II Wave Action, Sediments and Waterfowl Grazing. J. Ecol. 65:431-466.

Kerwin, J. A., R. E. Munro, and W. W. A. Peterson. 1977. Distribution and Abundance of Aquatic Vegetation in the Upper Chesapeake Bay, 1971-1974. In: The Effects of Tropical Storm Agnes on the Chesapeake Bay Estuarine System. J. Davis, ed. Chesapeake Research Consortium, Inc. Publication No. 54. The Johns Hopkins Univ. Press, Baltimore. pp. 393-400.

Kikuchi, T. 1974a. Japanese Contributions on Consumer Ecology in Eelgrass (Zostera marina) Beds, with Special Reference to Trophic Relationships and Resources in Inshore Fisheries. Aquacul. 4:145-160.

Kikuchi, T. 1974b. Marine Submerged Vegetation in Seto. Naikai. 1971. Census by Nasei Regional Fisheries Research Laboratory, Hiroshima. 39 pp. with English translation.

Kiorboe, T. 1980. Production of Ruppia cirrhosa Grande in Mixed Beds in Ringkobing Fjord (Denmark). Aquat. Bot. 9:135-143.

Kirkman, H. 1978. Decline of Seagrass in Northern Areas of Moreton Bay, Queensland. Aquat. Bot. 5:63-76.

Larkum, A. W. 1976. Ecology of Botany Bay I. Growth of Posidonia australis in Botany Bay and Other Bays of the Sydney Basin. Australian J. Mar. Frwtr. Res. 27:117-127.

Litav, M., and M. Agami. 1976. Relationship between Water Pollution and the Flora of Two Coastal Rivers of Israel. Aquat. Bot. 2:23-41.

Macomber, R. T., and D. Allen. 1979. The New Jersey Submerged Aquatic Vegetation Distribution Atlas. Final Rep. N.J. Rept. Env. Protection, Div. Coast. Res. 28 pp.

Maggi, P. 1973. Le Probleme de la Disparition des Herbiers a Posidnies dans le Golfe de Giens. Science et Peche. Information I.S.T.P.M. No. 221:7-20.

Martin, A. C., and F. A. Uhler. 1939. Food of Game Ducks in the United States and Canada. U.S. Dept. of Agr. Tech. Bull. 634, Washington, D.C. 308 pp.

Nienhuis, P.H. 1980. The Eelgrass (Zostera marina) Subsystem in Brackish Lake Grevelingen--Production and Decomposition of Organic Matter. Ophelia, Supp. 1:113-116.

Nienhuis, P. H., and B. H. DeBree. 1977. Production and Ecology of Eelgrass (Zostera marina) in the Grevelingen Estuary, Netherlands, Before and After the Closure. Hydrobiol. 52:55-66.

Orth, R. J. 1976. The Demise and Recovery of Eelgrass, Zostera marina, in the Chesapeake Bay, Virginia. Aq. Bot. 2:141-159.

Orth, R. J., and H. Gordon. 1975. Remote Sensing of Submerged Aquatic Vegetation in the Lower Chesapeake Bay, Virginia. Final Report, NASA. NASA-10720. 62 pp.

Orth, R.J., and K.A. Moore. (In Press). Seed Germination and Seedling Growth of Zostera marina L. in the Lower Chesapeake Bay. Aquat. Bot.

Orth, R. J., K. A. Moore, and H. H. Gordon. 1979. Distribution and Abundance of Submerged Aquatic Vegetation in the Lower Chesapeake Bay, Virginia. U.S. EPA Final Report. 600/8-79-029/SAV1. 199 pp.

Orth, R. J., K. A. Moore, M. H. Roberts, and G. M. Silberhorn. 1981. The Biology and Propagation of Eelgrass, Zostera marina, in the Chesapeake Bay, Virginia. Final Report. U.S. EPA Grant No. R805953.

Peres, J. M., and J. Picard. 1975. Causes de la Rarefaction et la Disparition des Herbiers de Posidonia oceanica sur les Cotes Francaises de la Mediterranee. Aquat. Bot. 1:133-139.

Perry, M. C., R. E. Munro, and G. M. Haramis. 1981. Twenty-Five Year Trends in Chesapeake Bay Diving Duck Populations Proc. 46th North American Wildlife and Natural Resources Conf. Wash., D.C. pp. 299-310.

Phillips, G. L., D. Eminson, and B. Moss. 1978. A Mechanism to Account for Macrophyte Decline in Progressively Eutrophicated Freshwaters. Aquat. Bot. 4:103-126.

Pfitzenmeyer, H.T., and K.G. Drobeck. 1963. Benthic Survey of Soft-Shelled Clams, Mya arenaria, in the Lower Potomac River, Maryland. Chesapeake Sci. 3:67-74.

Rasmussen, E. 1973. Systematics and Ecology of the Isefjord Marine Fauna (Denmark). Ophelia 11:1-495.

Rasmussen, E. 1977. The Wasting Disease of Eelgrass (Zostera marina) and Its Effects on Environmental Factors and Fauna. In: Seagrass Ecosystems: A Scientific Perspective. C. P. McRoy and G. Helfferich eds. Marcel Dikkor, Inc., New York. pp. 1-51.

Rawls, C. K. 1978. Myriophyllum spicatum. In: Summary of Available Information on Chesapeake Bay Submerged Vegetation. J. C. Stevenson and N. Confer eds. U.S. Fish and Wildlife Service, Office of Biological Services. FWS/OBS-78/66. pp. 14-31.

Sand-Jensen, K. 1977. Effect of Epiphytes on Eelgrass Photosynthesis. Aquat. Bot. 3:55-63.

Seaman, W. H. 1875. Remarks on the Flora of the Potomac: Field and Forest. Bull. Potomac side. Naturalists' Club 1:21-25.

Stennis, J. H. 1970. Status of Eurasian Watermilfoil and Associated Submerged Species in the Chesapeake Bay area - 1969. Add. Rept. to R. Andrews, U.S. Fish and Wildlife Service. Patuxent Wildl. Research Sta. 27 pp.

Stevenson, J. C., and N. M. Confer, Eds. 1978. Summary of Available Information on Chesapeake Bay Submerged Vegetation. U.S. Fish and Wildlife Service, Office of Biological Services. FWS/OBS-78/66. 335 pp.

Stewart, R. E. 1962. Waterfowl Populations in the Upper Chesapeake Region. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Wildl. No. 65. 208 pp.

Stotts, V. D. 1970. Survey of Estuarine Submerged Vegetation. Maryland Fish and Wildlife Admin. Maryland Pittman-Robertson W-45. 7 pp.

U.S. Fisheries Digest.

van Eepoel, R. P. 1971. Water Quality and Sediments of Lindbergh Bay, St. Thomas. Caribbean Res. Inst. Water Pollution Report No. 11. 33 pp.

Verhoeven, J. T. 1980. The Ecology of Ruppia-Dominated Communities in Western Europe. III Aspects of Production, Consumption and Decomposition. Aquat. Bot. 5:77-86.

Wade, P. M., and R. W. Edwards. 1980. The Effect of Channel Maintenance on the Aquatic Macrophytes of the Drainage Channels of the Monmouthshire Levels, South Wales, 1840-1976. Aquat. Bot. 8:307-322.

Wetzel, R., R. van Tine, and P. Penhale. 1981. Light and Submerged Macrophyte Communities in the Chesapeake Bay: A Scientific Summary. This Volume.

Wyer, D. W., L. A. Boorman, and R. Waters. 1977. Studies on the Distribution of Zostera in the Outer Thames Estuary. Aquacult. 12:215-227.