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CHARLES H. HOCUTT[1]
JAY R. STAUFFER[2]
Ichthyological Associates
Drumore, Pennsylvania 17537

[1] Present address: Environmental Research & Technology, Inc., Concord, Massachusetts 01742.

[2] Present address: Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Abundance of Submerged Vascular Vegetation in the Rhode River from 1966 to 1973

ABSTRACT: Surveys on the distribution and abundance of submerged vascular plants in the Rhode River showed that there was an irregular decline in the amount of vegetation from 1966 to 1973, along with significant changes in species dominance. In 1966, redheadgrass (*Potamogeton perfoliatus*) and Eurasian watermilfoil (*Myriophyllum spicatum*) were both very abundant with lesser amounts of widgeongrass (*Ruppia maritima*), horned pondweed (*Zannichellia palustris*), sago pondweed (*Potamogeton pectinatus*), and elodea (*Elodea canadensis*). In 1967, all of these species declined substantially, and elodea disappeared entirely. In 1968, redheadgrass and horned pondweed returned in substantial abundance, but they again declined in 1969 and virtually all submerged aquatics disappeared in 1970. In 1972, horned pondweed and sago pondweed reached an eight-year peak, but other species remained at very low levels. In 1973, all species were low, and a prominent lack of vegetation similar to 1967, 1970, and 1971 occurred again. Elodea has not been seen in the Rhode River since 1966. We believe these changes represent a decline in environmental quality in the Rhode River that may have serious long-range implications.

Introduction

This report presents data on the abundance of five species of submerged vascular plants in the Rhode River (Fig. 1), a subestuary of Chesapeake Bay, seven miles south of Annapolis. Preliminary observations in the early 1960's indicated that the Rhode River had an abundant community of submerged macrophytes which was dominated in the mid-60's by Eurasian watermilfoil (*Myriophyllum spicatum*) and redheadgrass (*Potamogeton perfoliatus*). The former was part of an explosive growth of watermilfoil which occurred throughout the upper Bay in the early 1960's and displaced much of the native vegetation (Bayley, Rabin and Southwick 1968; Elser 1966).

We began accurate field surveys of submerged vegetation in Middle, Back and Rhode rivers in 1966. In this year, there was a prominent decline in the abundance and distribution of watermilfoil throughout the upper Bay, probably caused by the interaction of milfoil disease and increased turbidity (Bayley et al. 1968; Elser 1967). In 1967, virtually all submerged vegetation disappeared in the Rhode River, a phenomenon called the "Rhode River evanescence" by Elser (1967). We established an annual

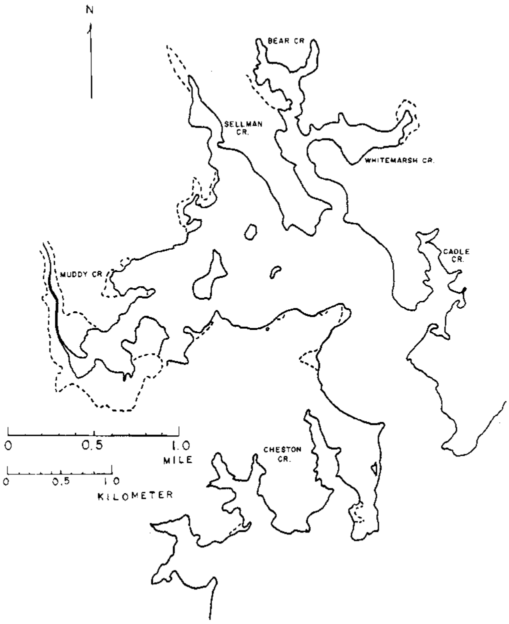

Fig. 1. Outline map of the Rhode River. Dashed lines represent marshlands with emergent vegetation such as *Spartina*, *Typha*, and *Scirpus*. Scale 1:24,000.

survey of the submerged vegetation in the Rhode River in order to quantify trends in the abundance of different species. In 1972 we extended this work with studies on standing crop biomass and net primary productivity. The present report provides data on the abundance of each species over the eight year period; a subsequent paper will deal with standing crops, and primary productivity.

Methods

Surveys on the abundance and distribution of submerged aquatic plants were conducted throughout the summer months of 1966 to 1973. The field work was concentrated in June and July to coincide with the growth peaks of the five major species studied: Eurasian watermilfoil (*Myriophyllum spicatum*), and redheadgrass (*Potamogeton perfoliatus*), widgeongrass (*Ruppia maritima*) horned pondweed (*Zannichellia palustris*), and sago pondweed (*Potamogeton pectinatus*). Observations were also made on elodea (*Elodea canadensis*) in 1966, but it was not seen again in subsequent years.

The field surveys were conducted by completely traversing the shoreline with a shallow draft boat in water 2 to 4 feet deep at mean low tide ± 2 hours, and plotting the abundance and distribution of each species on a 1:24,000 outline map of the Rhode River and all its tributaries. Areal plots were made from frequent point samples; boundaries were determined by direct inspection and on-site mapping. If submerged vegetation was not visible from the surface, bottom rakings were taken every 50 to 100 feet.

Abundance was rated in four categories: Abundant = 70% or more coverage of the water surface or bottom if the plants did not reach the surface; Common = 20 to 70% coverage of the surface or bottom; Occasional = 5 to 20% coverage; and Sparse = only rare isolated plants obtained by a rake drag at least 50 feet in length. For purposes of numerical presentation in this paper, only the first three categories are used.

Maps were drawn for each species showing the total distribution and abundance at the height of the growing season. These maps were then translated into numerical data expressing the numbers of hectares covered by each species at each abundance level. This was done by placing a fine transparent acetate metric grid over the map and counting under a 10X magnifying lens the number of square millimeters subtended by each abundance category. When used in conjunction with the U.S.G.S. 1:24,000 outline map, one square millimeter of this grid equalled 0.0576 hectares of actual water surface. This provided an accurate estimate of the actual area covered by each species at each abundance level.

Since we wanted some mathematical expression of total abundance, which would combine both area covered and relative density, we computed an "Index of Abundance" for each species by using the following formula:

$$A_i = \sum 6(a) + 3(c) + 1(o),$$

where A_i equals the Index of Abundance; a is the number of hectares covered by abundant stands; c is the number of hectares covered by common stands; and o is the number of hectares covered by occasional stands. The multipliers of 6, 3 and 1, are proportional to the relative abundance in each of these stands; in other words, abundant beds have approximately 6 times as much vegetation as occasional stands, and twice as much as common stands, whereas common stands have approximately 3 times as much as occasional stands.

It would be desirable, of course, to have total biomass data, but we did not begin sampling standing crop biomass until 1972 and 1973, and more data are required before accurate biomass and total standing crop estimates can be made.

Results

All species of submerged vascular plants in the Rhode River showed considerable variations in abundance from year to year, with Eurasian watermilfoil and redheadgrass showing the most pronounced fluctuations (Table 1, Fig. 2). Eurasian watermilfoil declined sharply after 1966 and remained in low abundance for the next seven years. In 1966, beds of watermilfoil covered 58.7 hectares in the Rhode River, whereas in 1967 they declined to only 0.6 hectares. Redheadgrass also fell sharply, from 95.1 hectares in 1966 to 2.2 hectares in 1967, but it showed considerable regrowth in 1968 and 1969 to 41.9 hectares in the latter year. In 1970 and 1971 redheadgrass disappeared entirely and recovered only slightly in 1972 and 1973.

Widegeongrass, horned pondweed, and sago pondweed, though less abundant, were somewhat more stable. They still showed moderate fluctuations between years. Widgeongrass and sago pondweed both disappeared entirely in 1970; widgeongrass showed its best growth in 1971, whereas horned and sago pondweed showed their best growth in 1972.

Considering the entire submerged macrophyte community, the years of greatest abundance were 1966, 1968

TABLE 1. Annual abundance of submerged vascular plants in the Rhode River: hectares covered and indices of abundance.

	Eurasian milfoil *Myriophyllum spicatum*		Redheadgrass *Potamogeton perfoliatus*		Widgeongrass *Ruppia maritima*		Horned Pondweed *Zannichellia palustris*		Sago Pondweed *Potamogeton pectinatus*	
Year	H*	I**	H	I	H	I	H	I	H	I
1966	58.7	180.6	95.1	296.1	7.5	25.6	3.3	10.4	2.9	9.0
1967	0.6	1.4	2.2	6.7	2.0	4.5	2.3	7.2	1.3	4.6
1968	3.8	4.6	34.7	163.5	3.4	11.3	14.5	49.0	2.1	7.4
1969	4.5	13.0	41.9	141.6	2.4	5.7	12.1	37.7	0.4	1.0
1970	0.3	0.3	0	0	0	0	0.8	2.0	0	0
1971	0.7	2.1	0	0	6.1	28.2	2.8	7.0	1.2	6.9
1972	3.9	6.6	3.6	3.6	3.2	6.8	20.7	68.0	9.3	19.8
1973	1.5	2.5	2.1	6.8	1.7	1.8	5.5	15.1	1.8	2.8

* H = hectares covered with occasional, common and abundant categories; see text for descriptions
** I = Index of Abundance; see text for definition

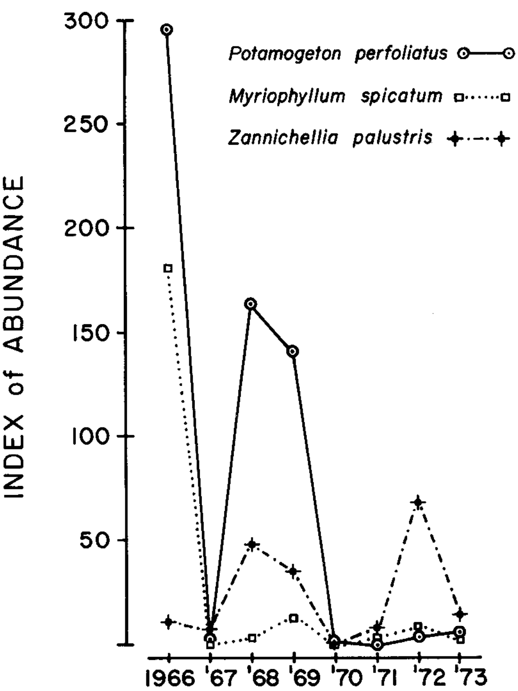

Fig. 2. Relative abundance of dominant species of submerged vascular plants in the Rhode River, 1966–73.

and 1969; the years of least abundance were 1967, 1970 and 1973.

The Index of Abundance for the three dominant species, redheadgrass, Eurasian watermilfoil, and horned pondweed, over the 8-year period, showed the general decline in total submerged vegetation, the extreme fluctuation between years, and also the shift in species composition (Fig. 2). In 1966, the dominant species were milfoil and redheadgrass. In 1967 all species declined sharply and there was an absolute scarcity of submerged macrophytes in the Rhode River. In 1968 and 1969, redheadgrass and horned pondweed returned in moderate abundance, but in 1970 all species declined again to produce an even greater lack of submerged vegetation than in 1967. In 1972 horned pondweed returned in moderate abundance to become the dominant species (Fig. 2). The general trend in submerged vegetation throughout the eight-year period, however, has been erratically downward.

Discussion

The dynamic nature of submerged aquatic plant communities in esturarine environments has been noted by Elser (1967) and Steenis, Stotts and Rawls (1971). Elser observed the remarkable disappearance of vegetation in the Rhode River in 1967, and Steenis et al. have also documented major declines and disappearances of submerged macrophytes in other subestuaries of Chesapeak Bay. For example, they reported that elodea (*Elodea canadensis*) was abundant in Neale Sound off Cobb Island in 1968, but totally absent the next year. Similarly, coontail (*Ceratophyllum dermersum*) formed solid beds in Reed Creek off the Chester River in 1970, but then disappeared in 1971. Steenis et al. refer to comparable situations where horned pondweed (*Zannichellia palustris*), curly pondweed (*Potamogeton crispus*), and redheadgrass (*P. perfoliatus*) all showed abundance in certain locations one year and virtual disappearances the next.

Sometimes these disappearances are followed by a resurgence of growth in subsequent years, but in other cases, the disappearances were followed by long lag phases of many years with little or no growth. Redheadgrass, wild celery (*Vallisineria americana*), sago pondweed (*Potamogeton pectinatus*), and horned pondweed all seem to be aggressive plants in re-colonizing barren areas. Only horned pondweed is an annual plant, growing from seed, whereas most submerged macrophytes are perennials, growing from rhizomes, tubers or roots. Regrowth from either seeds or vegetative parts obviously requires persistance of living propagules, plus appropriate conditions for germination and growth.

Many kinds of ecologic factors can kill propagules or prevent germination and growth. Steenis et al. (1971) felt the most prominent factor preventing subsequent growth of submerged macrophytes was turbidity, either physical or biological. Physical turbidity results from resuspension of sediment within the water as a result of such factors as wave action, carp spawning, and physical agitation from boats, or from siltation and land run-off. Many disappearances of vegetation have been associated with prolonged muddy water, usually after a series of storms when excessive shore erosion and land run-off roiled up the water for an extended period.

Some disappearances have also been associated with continued plankton blooms, a form of biological turbidity which can have the effect of shading and killing submerged vegetation. Both blooms of green algae, such as *Chlorella*, and the brown and red tides of dinoflagellates (*Gymnodinium* sp.) which occur in eutrophic portions of the Bay can eliminate submerged macrophytes. Two examples of this are Back River near Baltimore, and the Potomac River, south of Washington. Both rivers have highly eutrophic conditions below sewage outfalls, Back River receiving most of the sewage from Baltimore city, and the Potomac from Washington, D.C. Both rivers have frequent and prolonged plankton blooms, along with other forms of pollution, and both are devoid of submerged vascular vegetation throughout extensive areas downstream from sewage outfalls. In the early 1930's Uhler reported seeing ducks feeding on redheadgrass and wild celery from the old 14th street bridge in Washington, D.C. This valuable habitat has now been destroyed for 40 miles below Washington, an area of over 250,000 acres (Steenis et al. 1971).

Submerged vascular vegetation is also absent from the Patapsco River subestuary, where the turbid and polluted conditions of Baltimore harbor have eliminated suitable habitat.

Many species of submerged aquatics have a compensation point of approximately 2% in terms of light; that is, they require approximately 2% of the ambient surface light for germination and growth (Meyer et al. 1943). In unpolluted waters of the bay, 2% of the surface light reaches depths of 4 and 5 feet, providing adequate light conditions throughout the shallow-water zones of submerged vegetative growth. In polluted and turbid waters, however, less than 2% of the ambient surface light reaches the depths of 2 or 3 feet, and light becomes a limiting factor. In the Rhode River, light penetration studies were begun in 1968, and sampling at the mouths of Muddy and Sellman Creeks showed that the summers of 1968 and 1969 had greater light penetration to 5 feet than the summers of 1970, 1972 and 1973 (Table 2). Although these studies are not conclusive, they suggest that high turbidity and poor light penetration in the latter three years, especially in 1973, may have been a major factor in the reduced growth of submerged plants in these years.

Another factor of importance may be an interaction of light and plant disease. The pronounced decline of Eurasian watermilfoil after 1966 was associated with two pathological states in the plant, one known as Northeast Disease and the other as Lake Venice disease, both place names taken from the localities in Maryland where these conditions were first described (Elser 1967). Northeast disease, characterized by stiff broken stems and leaflets, flattened petioles fused into the basal leaflets, and black lesions on the leaves and stems, was thought to be of viral etiology (Bayley et al. 1968). Lake Venice disease,

TABLE 2. Light Penetration in the Rhode River: Percentages of ambient surface light reaching various depths. (April-May-June averages, 2 stations, 10 samples/month/station. Samples for 1973 taken during July and August).*

Depth in feet	1968	1969	1970	1972	1973
1	48.5	56.4	44.3	36.6	42.8
2	28.9	36.6	16.1	13.6	9.6
3	14.9	21.0	7.1	4.8	4.55
4	9.6	13.3	3.8	3.2	1.8
5	7.0	7.9	2.0	2.0	0.5

* Stations located in the broad mouths of Muddy creek and Sellman creek, 200 feet offshore. Light readings taken at mid-day with GM Submarine Photometer, Model 15M04, using Weston Photocell Model 856, Type I.

characterized by flaccid leaves and stems and an excessive accretion of epiphytic ooze, has been studied by Bean and Klarman (1972) who isolated a number of gram-negative bacteria from the diseased tissues. Bacteria alone would not produce the disease in the laboratory, but a combination of bacterial inoculation plus reduced light intensity evoked the full symptoms of Lake Venice disease. Hence, this research showed the interaction of a pathologic agent and environmental factor in producing plant disease.

Salinity is another ecological factor which influences the growth and distribution of submerged macrophytes in estuarine environments. The salinity of the Rhode River normally varies from less than 2 ppt in the upper reaches of its tributaries to 10–12 ppt in the mouth off Cheston Point. It also varies seasonally, with lowest salinities usually occurring in the spring, and highest in late fall.

In this study salinities were routinely measured at the surface and bottom near the junctions of Muddy and Sellman creeks with the Rhode River proper. At these stations, salinities varied from a low of 1.4 ppt to a high of 10.7 ppt, and usually averaged around 7 to 8 ppt during the summer periods. No consistent correlations appeared between changes in salinity and changes in submerged plant populations. The summer of 1972 was notable for very low salinities following tropical storm Agnes in late June of that year. These low salinities were accompanied by high turbidities and high nutrient levels which persisted for most of the summer.

All of the plant species in this study grow well in fresh water and also thrive in brackish conditions up to 10 or 15 ppt (Martin and Uhler 1939). Hence, it is not likely that the salinity changes seen in this study could be responsible for the drastic population fluctuations seen. Widgeongrass, while capable of growth in fresh water, does best in moderate salinity, and can tolerate salt concentrations as high as 28 ppt. It is the only species which might have been deleteriously affected by the very low salinities following tropical storm Agnes in 1972.

The lack of vegetation in the Rhode River and other subestuaries of the Bay may have serious consequences if it persists for several years. Submerged vegetation is important in providing food for migrating and wintering waterfowl, cover for young fish, and habitat for many epibiotic and commensal organisms. It is undoubtedly important in both grazing and detritus food chains. Loss of submerged vegetation will have ramifications throughout the estuarine ecosystem to the highest trophic levels. For example, there has been a dramatic increase in the terrestrial feeding of swans (primarily in corn and green grain fields) in the Chesapeake Bay region in recent years, which may have been partially caused by a lack of normal aquatic vegetation.

No quantitative estimate is currently available of the normal role of submerged vegetation in total estuarine productivity, but we think the assumption is safe that it should be an important component of primary productivity in a healthy estuary. Although pronounced annual fluctuations are common, the dramatic fluctuations of recent years, including total disappearances over several years, suggest serious problems of ecosystem instability and deterioration. Prolonged disappearance over a period of years drastically delays recovery of plant beds, even when conditions become favorable. All species, except horned pondweed, are perennials, and depend upon viable root systems for annual growth. If these root systems are destroyed, recovery will be very slow.

Acknowledgments

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Charles H. Southwick and Frank W. Pine

Department of Pathobiology
The Johns Hopkins University
School of Hygiene and Public Health
Baltimore, Maryland 21205