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COASTAL WETLANDS of VIRGINIA

INTERIM REPORT

VIRGINIA INSTITUTE OF MARINE SCIENCE
GLOUCESTER POINT, VIRGINIA

December, 1969

COASTAL WETLANDS OF VIRGINIA

Interim Report of the Governor

and General Assembly

by

Marvin L. Wass and Thomas D. Wright

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Dr. William J. Hargis, Jr.
Director

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Several students at the Institute have aided in the work: Maurice P. Lynch wrote the legal sections and G. Alex Marsh did the plant communities section; Victor G. Burrell provided information; Daniel Gibson, G. Alex Marsh and Robert Orth assisted in the field; Mr. Gibson also did literature survey work and Mr. Marsh identified most of the plants; Michael Fine reviewed most of the manuscript.

Dr. Davis of VIMS and Mr. Charles Gilchrist of the Commission of Game and Inland Fisheries, Tappahannock, Va., reviewed the section on faunal phenomena. Mr. Gilchrist and Mr. Fairfax Settle of the same office supplied much information on waterfowl, furbearers, and Back Bay. Mrs. Allene Barans began the identification of plants. Dr. Alton M. Harvill of Longwood College identified most of the grasses and sedges. Miss Anita Horsley and Mrs. Juanita Walker did most of the topographic map survey. Mrs. Prudence Huddleston has assisted in several ways, particularly in doing all the graphic arts. Finally, Mrs. Beverly Ripley has patiently typed and edited the manuscript through several drafts and the final version.

AUTHORS' FOREWORD

This is the second printing of the report. It is essentially the same as the first except that a number of typographical and other errors brought to our attention have been corrected. Comments and further corrections will be appreciated by the authors.

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ABSTRACT

Coastal wetlands represent only one per cent of the total area of the State, and marshes one-half of one per cent. Yet 95% of Virginia's annual harvest of fish (commercial and sport) from tidal waters is dependent to some degree on wetlands. Ducks, Rails, Snipe and many other kinds of birds could not survive without wetlands. Muskrat, Otter, Beaver, and Mink dwell in coastal wetlands. Tourists in burgeoning numbers come to loll on the beaches or to revel in the natural beauty of our wetlands. All users of these valuable natural resources, whether they seek pleasure or profit, pour dollars into the economic stream, provide jobs, and pay taxes.

Not amenable to quantification in economic terms at this time are the aesthetic qualities of these wetlands and their socio-psychological importance to various segments of society.

The valuable wetlands and other resources which enrich our lives and quicken the pace of our economic life are the heritage and property of all citizens of the Commonwealth, yet the wetlands which nurture them are not, for the most part, under public control. Can such a significant portion of the economic and sociological base of Tidewater continue to hang so tenuously on the mounting and uncontrolled pressures to capriciously dredge, fill, dike, and bulkhead wetlands and to convert them into housing developments, industrial sites, and, alas, garbage dumps?

Several rather distinct types of habitats are represented in Virginia's wetlands, e.g., the Eastern Shore seaside salt marshes and tidal flats, the shallow and nearly freshwater Back Bay with its rooted aquatic plants, the Giant Cordgrass marshes bordering the brackish nursery grounds, the freshwater marshes with their many species of plants, and the swamps which are at once picturesque and foreboding.

Wetland productivity ranges from very little on some small salt barrens to about 10 tons per acre per year dry weight in the best grass marshes. Productivity on the tidal flats, which apparently cover more area than does marsh on the Eastern Shore seaside, has not been determined but is probably at least one-fourth that in the marsh.

Most of the sport fish and other fish which together composed over 95% of the total Virginia catch in 1967-68 spend part of their lives in the brackish nursery grounds or in the Eastern Shore bays. The amount of dependency on these areas varies from total for the White Perch and Catfish to dependency only during the juvenile period for several species of sport and commercial finfish. Despite the brevity of the latter period, survival of the species hinges upon suitable conditions in the marsh-bordered spawning and nursery grounds.

While only a fraction of the total organic productivity from Virginia's permanent water may result from wetlands, it is obvious that waters bordered by wetlands provide essential food and habitats for most Bay sport fish during a critical part of their life history. Several of the most valuable species, including the Menhaden, several species of sciaenids (Croaker, Spot, and Sea Trout), four species of Shad and River Herring, the American Eel and the Sturgeon, spend their early lives in the nursery ground, in which a part of their food is derived from marshes.

The high productivity of the brackish and freshwater areas is seen in the greater abundance of fish caught there by VIMS trawl surveys than in higher salinity areas. While many of the fish found permanently in these areas are less desirable species (Hogchokers, Catfish, Carp and Gar), all are of potential value. Greater productivity is further shown in the newly introduced Marsh Clam, in ducks, geese and rails, in furbearers, and even in hordes of blackbirds.

Furthermore, it is these marshes that are the most aesthetically pleasing to those who appreciate freshwater fishing, the color of marsh flora, and relatively few biting insects. Floral displays are presented by pink Sea Mallow, white and crimson Marsh Mallow, brown Cattails, golden Beggar-ticks, bright red Cardinal Flowers, and spectacular 7-foot Turks-cap Lillies. Even most ducks found here--Wood Ducks, Hooded Mergansers, Mallards, Pintails, Shovelers, and Green-winged Teal--are more colorful than the blacks, browns, and whites of the ducks, geese and shorebirds of the seaside areas.

The salt marshes, seaside bays and beaches may not attract man primarily by color of the flora and fauna, but this is countered by the appeal of sun, surf, sand, wind, and aesthetically pleasing beachcomber objects. These benefits, as well as the great production of clams, crabs, oysters, sport fish, and the tremendous variety of bird life, enhance the aura of these wetlands.

Seaside marshes and flats are dependent on protection by the barrier islands. The latter are probably Virginia's most valuable non-urban real estate. The demand for public access to beaches, the need for erosion control and the value of these islands as natural areas will concern us in the immediate future, as exemplified by Assateague Island.

Erosion affects not only the barrier islands but also the shores of Chesapeake Bay and the banks of rivers unprotected by marshes. No survey of land lost by erosion has been made for the total coastal shoreline of Virginia but it could be as high as 40,000 acres since colonial times. Loss of "fast land" would be countered partially by the general filling of creeks at their heads by soil erosion, although this has degraded the creeks. Erosion studies have been made on the Potomac and Rappahannock rivers. Additional studies should be made in all the coastal counties, and efforts at bank and shore erosion control should be expanded to include these areas. Emphasis should be placed on control by vegetation whenever possible.

Moves to protect wetlands tend to be inversely proportional to their acreage in most states. Little effort is being made south of Virginia, except in North Carolina and Florida, while the states to the north, except Delaware, are all engaged in wetlands preservation efforts to a considerable extent. In many cases this vigorous effort has come only after much of their wetland heritage has been wasted or changed. In Virginia, ownership of the bottom by the State only to mean low water usually means that only that marshland and tidal flat which has been purchased is in State or Federal public ownership, except on the Eastern Shore. In the latter area, a careful survey is needed to determine actual ownership of much marshland.

Virginia has not adopted a legal definition of wetlands. Such a definition is needed before certain protective legislation can be enacted.

Wetlands, particularly near the coast, are habitats for many species of fish and birds which can survive only in such places. While no single species is known to be confined to Virginia waters and wetlands, this is the northern or southern limit for many plants and some fish and birds. Loss of even small amounts of wetland, especially the more productive areas, slowly erodes away the food and habitat base for hundreds of valuable and/or aesthetically interesting organisms.

Preliminary economic evaluation of wetland productivity indicates that an average acre of wetland generates primary tangible benefits of $78/year. These benefits largely accrue to the public rather than to the wetland owner; in fact, benefits to the owner are usually more restricted in type than are those to the general public. Although it is believed that some types of wetlands, such as regularly flooded marsh, are much more productive and valuable than others, no precise evaluation of any given type can be given at this time. This must soon be made possible, however.

Present wetland use and management is determined by the owner and often does not constitute the most beneficial use of the land to the public. Many uses are damaging public resources and hampering full public utilization of the productivity of the estuary. To insure continuing high yields from the estuary, to enhance its value to the economy, and to serve the best public interests, it will be necessary for the State to acquire or otherwise exercise some degree of control over the destructive uses of wetlands and their alteration.

There has been ample evidence in Virginia and elsewhere to demonstrate that reliance upon private management of public resources or of resources with a great public impact is rarely conducted in such a manner as to obtain the maximum public benefit from such resources. A number of methods are available to the State whereby these resources can be managed for the best public benefit. These include zoning, acquisition, regulation, and others. It is imperative that the most appropriate and effective methods be brought into action at once to prevent further degradation of coastal wetlands and a concurrent loss of productivity and value of this resource to all of the people of the Commonwealth.

Wetlands are vulnerable to alteration by natural and human forces, with the latter being the most important and the most easily controlled. As wetlands diminish, their value becomes greater both to those who would preserve them and to those who would alter or destroy them. Vulnerability is, therefore, related to value, but the values of wetlands to different interests are often not comparable. Wetlands, like flood plains, are not suitable for many human uses and attempts to make them suitable often represent losses, rather than gains, of human and natural resources. Decisions regarding the alteration and destruction of wetlands must take this into account and must consider all types of values, including the aesthetic as well as the purely economic. If this approach is not followed soon, there exists a strong possibility that a unique resource which would be held beyond price or any economic means of reckoning by future generations will be lost to the Commonwealth and its people.

HISTORY

The Virginia Institute of Marine Science (VIMS) was directed by House Joint Resolution No. 69, 1968, "to make a study and report on all marsh lands and wetlands in the State." The Resolution reads as follows:

> "Whereas, many of the marsh lands and wetlands in this State are absolutely essential to the life cycle of the marine animal species, salt marshes serve as nursery areas for many species of fishes, crabs and other marine animals, and marshes support shore and wetland birds and animals; and
>
> "Whereas, each year acres of marsh lands and wetlands are drained, dredged and filled; and
>
> "Whereas, the State must eventually undertake the preservation and protection of essential marsh lands and wetlands, and it is necessary for such purpose that those marsh lands and wetlands which are essential be accurately identified; now, therefore, be it
>
> "Resolved by the House of Delegates, the Senate concurring, That the Virginia Institute of Marine Science is directed to make a study and report on all marsh lands and wetlands in the State for the purpose of assessing their relative importance, respectively, to the marine resources of the State. The Commission of Game and Inland Fisheries and the Commission of Fisheries are directed to assist the Institute in its study. The Institute shall complete its study and make its report to the Governor and the General Assembly not later than December one, nineteen hundred sixty-nine."

Furthermore, the General Assembly of Virginia at its 1966 Regular Session had, by House Joint Resolution No. 59, created the Virginia Marine Resources Study Commission, which proposed the present study in its report to the General Assembly and the Governor of Virginia, October 23, 1967.

Chapter 9, Sec. 28.1-195 of the Code of Virginia directs the Virginia Institute of Marine Science to conduct hydrographic and biological studies of the Chesapeake Bay and the tributaries thereof and all the tidal waters of the Commonwealth and the contiguous waters of the Atlantic Ocean and to make such special studies and investigations concerning the foregoing as it may be requested to do by the Governor.

OBJECTIVES

Two points stand out in the above Resolution: 1) "it is necessary . . . that those marsh lands and wetlands which are essential be accurately identified . . ." and 2) ". . . a study . . . for the purpose of assessing their relative importance, respectively, to the marine resources of the State." It seems obvious from the wording that marine resources in all their diversity are considered essential to the welfare of the people of Virginia.

In attempting to comply with these broad directives, we have tried to do those things which would yield the most information in the shortest time. This first involved a survey of the literature on definitions and types of wetlands, followed by a survey of the areas of the various types of wetlands and their locations. Since productivity studies based on standing crops of marsh vegetation had not been published for any of Virginia's coastal area, it was decided to do as many of these as possible for this preliminary study. This entailed collecting in several types of marsh, which gave us an opportunity to photograph many features of wetlands and to collect many species of plants for a reference collection at VIMS.

The limited time available did not allow us to visit even all the coastal counties of Virginia and our efforts tended to be concentrated in a few areas. We felt particularly obligated to study marshes in the "nursery grounds" section of the Pamunkey River, which area had been the principal subject of a recent study by Van Engel and Joseph (1) on the aquatic system. We made three visits to the Eastern Shore to visit marshes and barrier islands, a complex area quite different from brackish and freshwater systems. At all times we sought insight into phenomena which might be particularly affecting the total ecology of an area. Messrs. Gilchrist and Settle of the Commission of Game and Inland Fisheries at Tappahannock, Va., kindly provided information on areas, species and situations with which we were unfamiliar. More comprehensive field studies are planned for the next phase of our work.

The literature on various studies from other Atlantic coast states was reviewed for findings pertinent to this State. Mr. Maurice P. Lynch, working with Dr. Hargis, searched for information on legal actions and authorities in Virginia and other states. His findings should aid in clarifying existing situations and in planning for future legislation involving the State's coastal wetlands. Further legal studies are necessary.

While statistics on the catch of estuarine animals are known to be inadequate, especially for certain fishes, we have used those data available for what we believe to be species particularly benefiting from wetlands in graphic comparisons of annual production during the last decade. Other pictorial material illustrates the complexity of the estuarine ecosystem.

Finally, we have attempted to evaluate wetlands in a very general and broad way and to make certain recommendations for the conservation and continuing study of these interesting areas.

DEFINITION OF WETLANDS

As might be expected, the definition of wetlands varies from one state to another. It also varies depending on the viewpoint of the definor. The Maryland definition (2) is concise but still broad enough to cover both inland and coastal wetlands. It includes "areas on which standing water, seasonal or permanent, has a depth of 6 feet or less and where the soil retains sufficient moisture to support aquatic or semi-aquatic plant life."

The Massachusetts definition (3) reads ". . . the term 'coastal wetlands' shall mean any bank, marsh, swamp, meadow, flat or other low land subject to tidal action or coastal storm flowage and such contiguous land as the commissioner reasonably deems necessary to affect by any such order in carrying out the purposes of this section."

A definition from the U. S. Department of the Interior (4) reflects emphasis on waterfowl utilization. It reads simply ". . . lowlands covered with shallow and sometimes temporary or intermittent waters."

Rhode Island (5) has a legal definition approved in 1965 and intended for use in marshland zoning. It reads: "A coastal wetland shall mean any salt marsh bordering on the tidal waters of this state, whether or not the tide waters reach the littoral areas through natural or artificial water courses, and such uplands contiguous thereto, but extending no more than fifty (50) yards inland therefrom, as the director shall deem reasonably necessary to protect such salt marshes for the purposes set forth (in the preceding section). Salt marshes shall include those areas upon which grow some, but not necessarily all of the following: (here 19 species of plants are named, some of which tolerate very little salinity--authors' note)."

Georgia (6), in a proposed "Coastal Wetlands Protection Act of 1969," patterned a definition after that of Rhode Island but altered it to include "any marshland or salt marsh within the estuarine area of the state." This bill was not passed by the legislature.

The State of Connecticut (7), in a new law concerning "Preservation of Wetlands and Tidal Marsh and Estuarine Systems," defines wetlands as "those areas which border on or lie beneath tidal waters, such as, but not limited to, banks, bogs, salt marsh, swamps, meadows, flats, or other lowlands subject to tidal actions, including those areas now or formerly connected to tidal waters and whose surface is at or below an elevation of one foot above local extreme high water and upon which may grow or be capable of growing specific species of plants (19 species are named)." This definition includes more area in terms of elevation than any other definition from an Atlantic coast state.

It would seem better to use the simple, all inclusive definition of "all the area between mean higher high water (MHHW) and mean lower low water (MLLW)." This definition would thus include not only areas vegetated with conspicuous plants but also the mudflats and beaches which are considerable in area and often of great value to the general public. The precise limits would require the services of a competent surveyor to determine, but in an area remaining in an undisturbed condition, the upper limit could be determined by the vegetation. The presence of plants of the genera *Iva*, *Baccharis* and *Borrichia* in saline areas, of *Typha*, *Scirpus*, *Spartina*, *Juncus*, *Sagittaria*, *Acorus*, *Peltandra* and *Pontederia* alone or in combination would denote the existence of a marsh. In a tidal swamp the upper limit of the tide can be detected by the usually sharply defined lower limit of overhanging branches. Wetlands often surround or lie adjacent to land above the usual high tide limit. These higher features range from waverows of sediment and flotsam thrown up near the water's edge to the long barrier islands on the Eastern Shore. Since marshes could not exist in the latter area without protection from the ocean, it would be well to append to the basic definition the statement "and those contiguous areas deemed necessary to the stability of the wetlands and the security of their biota." This would include the wooded "islands" surrounded by marsh, which serve as refuges during storm tides. The State already claims all land below mean low water (MLW) but even this line is probably frequently transgressed by waterfront property owners. Flood waters and hurricane tides would, of course, rise much higher than the limits of marsh vegetation and occasionally cover vast areas of the adjacent coastal plain. A complete and concise definition of a coastal wetland is, therefore, "all the area between MHHW and MLLW and those contiguous (highland as well as subaqueous) areas deemed necessary to the stability of the wetland communities."

Most of the coastal states claim ownership of aquatic lands to mean high water (MHW), Maine, New Hampshire, Massachusetts, Delaware, Pennsylvania, Virginia and Georgia being exceptions. In addition, most of them further define wetlands and marshlands on the basis of submergence and/or vegetation. Without title to wetlands, the State has little effective control over the uses that can be made of them. The present situation in Virginia tends to be artificial in that the management of a coherent biological unit (marshes and submerged wetlands) is usually divided between private and public ownership (the zone between mean high and mean low water is an ecological continuum). Such areas are most effectively managed as a unit and are so managed in most coastal states. These and other criteria are recommended as a basis for the enactment of enforceable standards for preservation of essential marshlands. The problems involved in this implementation will be discussed in another section.

DELINEATION OF TYPES OF WETLANDS

The areal survey of wetlands and associated contiguous features was done by use of topographic maps provided by the U. S. Geological Survey. The following physiographic features are denoted on the maps: marsh (swamp), wooded marsh, woods or brushwood, foreshore flat, sand area, perennial streams and water. In this report, wooded marsh will be referred to as swamp, woods as wetland woods, foreshore flat as tidal flats or mudflats, sand area as sand beach, and perennial streams as open creeks when known to be tidal.

1. Marshes are often considered synonymous with wetlands. However, we have chosen to include as marsh only those areas so designated on the topographic maps. This leaves out areas of permanent water with submerged aquatic plants attractive to waterfowl and fish. In the maintenance of estuarine food chains, marshes are more important than any other wetland above MLW. Marshes can be classified by a) salinity types, b) elevation, c) productivity, and d) types of vegetation present.

2. Swamps are wooded areas, although they begin as shrubby areas in brackish water. Nearly all swamps are located along the fresh tidal sections of the rivers entering lower Chesapeake Bay. The Blackwater and Nottoway rivers have only this type of wetland in Virginia.

3. Wetland woods include only wooded areas surrounded by marsh. These are usually small tracts resembling a Gulf Coast hammock from a distance but being on higher ground and usually dominated by loblolly pine on the larger and higher knolls. They occur almost entirely along lower Chesapeake Bay and the lower ends of the rivers.

4. Tidal flats may occasionally be vegetated with Eelgrass in higher salinity waters, Widgeon Grass in medium salinity reaches, and with Spatterdock, Pickerel Weed, Arrow Arum and submerged aquatics in freshwater. Since the seaside of the Eastern Shore has a much greater tide than other shores of the State, it has the most flats.

5. Open creeks include not only the water courses through marshes and swamps, as shown on the maps, but also considerable areas of the dendritic creeks bordering Chesapeake Bay and the lower parts of the rivers. If the mouth of the creek did not exceed about 800 feet in width, its entire area was censused. Thus, a fair amount of open water is included in this category but probably about one-half of it would be called marsh or swamp in most surveys.

6. Sand beach is largely confined to the ocean shore and lower Chesapeake Bay as denoted on the maps. On the Eastern Shore, it may be as much shell as sand, especially in washover areas, and may, as on the lower end of Parramore Island, include much peat outcrop on eroding beaches.

7. Ponds, in order to be included, were presumed to have been constructed on tidal water. This area would occasionally be greater than the original tidal acreage. Many ponds on tributaries of the Rappahannock and Potomac rivers disappeared in the recent flood but these were likely all above tide level. Borrow pits are a necessary adjunct to coastal development but these have only been censused where they obviously were dug from wetland, as on Wallops Island. Compared with the increase in area of farm ponds, the area of ponds built on tidal water remains small.

8. Temporary lakes are natural features, mainly developed landward on barrier islands. They are well developed only on Parramore Island where they only rarely go dry.

9. Dredged wetlands are not yet extensive in Virginia but will increase rapidly if several future development plans materialize. However, since our survey is largely based on maps over 15 years old, our figure for dredged area is surely too low. To establish more realistic figures, which are necessary to proper understanding and management, will require actual surveys, especially of active or vulnerable areas. Dredging, in itself, has little effect on wetlands if done in deeper water. Dumping of the dredged spoil, however, has affected hundreds of acres of wetland but we have not included this in our survey.

SURVEY OF WETLANDS

In conducting our census, we used a gridded overlay having 25 squares per inch, each square covering a map area equal to 3.67 acres. This system is tedious but reasonably accurate if done by a conscientious person. Many of the maps available to us did not indicate tidal flats. In addition, the older the map, the greater the likelihood of some change having occurred. However, the more culturally active areas have been mapped recently.

An earlier survey by the U. S. Fish and Wildlife Service (8) credited the State with 210,050 acres of coastal marshland, not including 24,050 acres of Coastal Open Fresh Water producing submerged aquatics. The first figure may be compared with that of only 177,073 acres obtained for marshland in our census. While Mr. Fairfax Settle of the Commission of Game and Inland Fisheries at Tappahannock believes that approximately 3,500 acres of wetland have been lost since then, this can account for only a small part of the discrepancy, particularly since most of the maps we used were made prior to 1954. Likely, the difference arises from our rigid adherence to a policy of putting all water areas shown in marshes into the "open creeks" category. Only 55% of our figure for this last item (60,918 acres) would be needed to balance the two surveys. It seems more logical to use the smaller figure because marsh plants obviously don't grow in permanent water, although submerged aquatics, micro- and macroalgae do.

The greatest discrepancy between the earlier survey and ours is in the category of permanent water, our figure of 1,428,200 acres being 233,300 acres greater. Inclusion of the 61,000 (60,918 rounded) acres of "open creeks" in our total undoubtedly accounts for some of the difference. Our figure, minus the creeks item, is only 13,000 acres less than that obtained earlier by Mr. Fred Biggs of VIMS, so we believe our data are reasonably accurate. A planimeter was used to compute the permanent water data. Much of this permanent water, other than that in the open creeks category, represents shallow areas which would be included in the Maryland definition of wetlands. This would be particularly true for the 100,771 acres assigned to seaside of the Eastern Shore and the 29,225 acres in the Back Bay and North Bay areas. Much of this area is heavily used by waterfowl in winter, by fish and shellfish all year.

We do not know the details of censusing involved in the U. S. Fish and Wildlife Service compilation (8), whether it was done using a grid system or with a planimeter. We know that aerial photographs were used, but since ". . . areas 30 to 40 acres in size . . . comprised minimum sized areas for delineation purposes," it would seem that many small wetland areas were ignored. The authors felt that ". . . the exclusion of small wetland areas below this size did not significantly affect the inventory of wetlands within a county." Because even small wetland areas may be important to the economy and productivity of a tidal tributary and we wanted to be as thorough as possible, we included all wetlands down to about 4 acres in size.

Tidewater Virginia was divided into eight geographic areas (Table 1) for census purposes: Potomac River, Rappahannock River, York River, James River, Chesapeake Bay, Eastern Shore Bayside, Eastern Shore Seaside, and Southeastern Virginia. Seaside of the Eastern Shore has almost three times as much wetland as any other area, and if Maryland criteria were used, it might have over one-half of the State total. The Virginia side of the Potomac River has only 8,800 acres of marsh due to the hilly topography. At the present rate of attrition, this small amount is declining rapidly.

The eight areas, which are reasonably distinct, except for that of Chesapeake Bay, are, however, not grossly disproportionate in their wetland area, although the types differ appreciably. Survey data are also given by U. S. Geological Survey quadrangles (Appendix). Areal data have also been compiled on 853 named entities, including 584 creeks, 161 islands, 56 marshes and 52 swamps. Creeks and other entities lacking names were not included in this finer breakdown of data.

Color infra-red photographs for much of the river shore and a small part of the Eastern Shore were made available to us by the National Aeronautics and Space Administration (NASA) installation at Wallops Island. This film, while mostly taken at an altitude of 20,000 feet, has nonetheless enable us to distinguish general types of vegetation. We plan eventually to obtain this type of film coverage from a lower altitude for all of our wetlands. Its use allows for rapid census of vegetation types and thus of ecological communities and can be very valuable and salutary in research and management.

Total wetlands encompassed by our definition would have an area of about 332,000 acres in Virginia. Of this total, 53% is marsh. The U. S. Fish and Wildlife Service survey (8) placed 63,800 acres in shallow fresh marsh, 15,400 acres in deep fresh marsh, 20,250 acres in salt meadows, 24,700 acres in irregularly flooded salt marsh, and 86,100 acres in regularly flooded salt marsh. The shallow fresh marsh is decreasing by changing to deep fresh marsh, as explained later. Otherwise, the proportions of these categories probably remain about the same.

North Carolina has 206,350 acres of marshland which is represented by 28% regularly flooded marsh, 49% irregularly flooded, and 23% coastal fresh. These proportions are in considerable contrast to those of the Virginia marshes which, according to the U. S. Fish and Wildlife Service survey (8), are 41% regularly flooded, only 21% irregularly flooded and 38% coastal fresh. These differences may account for North Carolina's having so much more Black Needlerush. This rather unproductive species seems to prefer irregularly flooded marsh. Regularly flooded salt marsh is generally conceded to be the most productive wetland. Apparently, only the marshes in the Wilmington area of North Carolina receive a range of tides near those occurring on Virginia's Eastern Shore seaside. It is difficult to conceive of Virginia's having twice as much fresh marsh as North Carolina has.

TABLE 1

Tidal Wetland Acreage by Geographic Areas*

	Temporary Lakes	Wooded Marsh	Marsh	Open Creeks	Woodland	Tidal Flats	Sand	Ponds	Dredged Areas	Totals
Potomac River	0	1,790	8,835	6,601	0	1,123	0	659	0	19,008
Rappahannock River	0	6,689	15,496	10,785	100	722	96	924	11	34,823
York River	0	3,083	23,482	5,939	1,134	3,131	169	1,418	0	38,356
James River	0	17,676	18,164	7,604	763	3,784	40	638	70	48,739
Chesapeake Bay	0	8,681	14,210	12,013	503	3,657	1,524	397	22	41,007
Eastern Shore, Bayside	0	139	17,706	12,681	0	440	9	151	0	31,126
Eastern Shore, Seaside	389	150	66,435	3,698	66	66,560	4,177	276	0	141,751
Southeastern Virginia	374	21,920	12,745	1,597	62	0	1,622	132	0	38,452
Total Acres	763	60,128	177,073	60,918	2,628	79,417	7,637	4,595	103	393,262

* Only wetlands presumed to be tidal are considered in this survey. Virginia has large tracts of coastal wetlands which are not tidal.

However, North Carolina has most of its estuarine water in sounds having only rather poor connections with the sea, while Virginia has its estuarine water in Chesapeake Bay and the tributary rivers. Virginia's only sound, Back Bay, has become an essentially freshwater lake, as have the two northernmost sounds of North Carolina.

In the U. S. Fish and Wildlife Service survey (8), Virginia was reported to have 270,000 acres of seasonally flooded land and wooded swamps. Our survey shows only 60,000 acres in tidal swamps, so the remaining 210,000 acres, while probably similar in their ecology, are on land above the range of tides. This category and all those other than marsh are difficult to compare with similar situations in adjoining states. Comments on ecology and values of wetlands will be given later.

All shoreline would be included in the usual wetland definition, although no undeveloped land may be visible at the waterline where ports and industries occupy the waterfront. In 1959, Mr. William Massmann, then of VIMS, calculated the amount of tidal shoreline in Virginia as 4,580 miles. We wished to obtain recent information on shoreline use, so a new calculation has been made using a K & E Map Measure. The larger total obtained (5,432 miles) probably results from using topographic maps rather than less detailed nautical charts. The shoreline was first divided into 24 geographic sections and four different categories (marsh, sand beach, dry and developed) (Table 2). Marsh shore (2,719 miles) accounts for one-half the total, most of it resulting from inclusion of the creeks which drain the marshes. Dry shore (2,045 miles) encompasses wooded and agricultural shore not shown as sand beach on the maps. Developed shore is mostly that having homes closely spaced, less than one-fourth mile apart, along the shoreline but also includes ports, industry and military waterfront. Obviously, developed shoreline, which, on the maps used (mostly 15 or more years old), measures only 472 miles (9% of the total), has increased and will continue to do so. Developed shore actually occupies 17% of the available high ground. Following completion of this tabulation, the shoreline was further subdivided (Tables 3 and 4) into harbors and ports, recreation, residential, industrial, conservation, military, and no present use, in accordance with a survey requested by a federal agency. To these seven categories was added one for NASA facilities since these did not fit in any of the others. This compilation reveals that the federal government owns about three times as much shoreline as the State does. The category "no present use" is somewhat of a misnomer since it includes all the productive marsh shore, much woodland shore and is otherwise mostly agricultural. Some of the latter is eroding rather badly.

TABLE 2

Miles of Tidal Shoreline in Virginia*

	Developed	Marsh	Sand	Dry
Potomac River	38	20		94
Potomac Creeks	34	130		327
Rappahannock River	23	66	3	153
Rappahannock Creeks	15	148		194
Piankatank River	8	8		32
Ware River	5	13		21
Severn River	6	16		28
Mattaponi River		72		51
Pamunkey River		85		52
York River	16	29		30
York Creeks	20	84		73
Chickahominy River		40		26
Chickahominy Creeks		54		26
James River	43	73	12	158
James Creeks	72	339		116
Ches. Bay E. Shore	1	78		28
Ches. Bay Mainland	20	26	36	18
Ches. Bay Creeks	123	71	1	227
Back Bay Creeks	8	200	21	17
E. Shore Bayside Creeks	28	273		220
E. Shore Seaside Creeks	12	800	43	88
Blackwater River		38		30
Nottoway River		46		36
Atlantic Ocean		10	80	
Totals	472	2,719	196	2,045

* The 24 areas listed above are reasonably distinct. All smaller creeks emptying directly into the Bay are included under Chesapeake Bay. Topographic maps produced by the U. S. Geological Survey or the Coast and Geodetic Survey were the bases for this survey. Since some of these maps were over 20 years old, it is likely that the amounts of shoreline in each category now differ from those given. "Developed shoreline" refers to shore which has homes or other structures spaced less than one-fourth mile apart. "Dry" shoreline is agricultural or wooded shore which would generally be fringed by marsh grass but is above tideline.

TABLE 3

Total (in miles) Shoreline Usage in Virginia

Ownership Code: a-Federal Government; b-State Government; c-Local Government; d-Universities, etc.; e-Private.

	Harbors & Ports	Recreation	Residential	Industrial	Conservation	Military	No Present Use	NASA
York River and Tributaries		7.8a	36.0e	1.0e		50.7a	417.2e	
James River and Tributaries	12.9e	17.8a 1.1c	115.5e	12.0e	5.6b	24.9a	768.9e	
Rappahannock River and Tributaries		0.5a	37.5e				562.5e	
Potomac River and Tributaries		1.6a 1.5b 1.6c	72.0e	2.7a 0.9e	8.4e	33.4a	520.9e	
Back Bay and Virginia Beach		3.0e	0.8e		40.4a	4.1a	197.2e	
Eastern Shore Bayside	0.8c		28.7e		17.7b		581.3e	
Eastern Shore Seaside			12.0e		57.5a 69.1b	0.8a	862.6e	29.7a
Chesapeake Bay	6.9a	0.9a 4.8b 2.7c 3.4e	139.0e	0.4a 2.1b 1.5e		3.6b 56.7a	299.0e	
Other Rivers			21.0e				267.0e	
Total Miles	6.9a 0.8c 12.9e	28.6a 6.3b 5.4c 6.4e	462.5e	3.1a 2.1b 15.4e	97.9a 92.4b 8.4e	170.6a 3.6b	4476.6e	29.7a
	21	47	463	21	199	174	4477	30

Grand Total = 5,432 miles

TABLE 4
Shoreline Usage (in miles) in Virginia

Ownership Code: a-Federal Government; b-State Government; c-Local Government; d-Universities, etc.; e-Private.

	Harbors & Ports	Recreation	Residential	Industrial	Conservation	Military	No Present Use	NASA
<u>York River and Tributaries</u>								
Clay Bank		5.4a	5.2e			17.9a	23.3e	
West Point			0.5e	1.0e			52.6e	
Williamsburg						16.5a	7.7e	
Yorktown		2.4a				16.3a	20.3e	
Other			30.3e				313.3e	
Total Miles		7.8a	36.0e	1.0e		50.7a	417.2e	
<u>James River and Tributaries</u>								
Drewry's Bluff				0.6e			20.8e	
Hog Island		8.3a			5.6b	1.1a	59.1e	
Hopewell			5.0e			2.7a	53.8e	
Mulberry Island			7.7e			10.9a	42.2e	
Newport News South	3.7e		8.1e	0.6e		0.8a	13.0e	
Norfolk South	9.2e	1.1c	27.1e	6.6e		9.4a	16.7e	
Richmond			7.5e	4.2e			4.6e	
Surry		9.5a	3.3e				10.6e	
Other			56.8e				548.1e	
Total Miles	12.9e	17.8a	115.5e	12.0e	5.6b	24.9a	768.9e	
		1.1c						
		18.9						
<u>Rappahannock River and Tributaries</u>								
Fredericksburg		0.5a	2.5e				14.7e	
Other			35.0e				547.8e	
Total Miles		0.5a	37.5e				562.5e	

TABLE 4 (Continued)

	Harbors & Ports	Recreation	Residential	Industrial	Conservation	Military	No Present Use	NASA
Potomac River and Tributaries								
Alexandria		1.6c	7.0e	2.7a 0.9e	1.4e	1.0a	5.9e	
Belvoir			4.6e		4.6e	12.8a	14.1e	
Dahlgren			1.8e			10.2a	66.3e	
Quantico			3.2e			7.2a	17.9e	
Stratford		1.3b	0.8e				18.1e	
Wakefield		0.2b 1.6a	5.2e				29.7e	
Widewater			2.4e			2.2a	21.5e	
Other			47.0e				345.3e	
Indian Head					2.4e		2.1e	
Total Miles		1.6a 1.5b 1.6c 4.7	72.0e	2.7a 0.9e 3.6	8.4e	33.4a	520.9e	
Back Bay and Virginia Beach								
Knotts Island			0.8e		3.8a		39.4e	
North Bay					36.6a		31.9e	
Virginia Beach		3.0e				4.1a	2.0e	
Other							123.9e	
Total Miles		3.0e	0.8e		40.4a	4.1a	197.2e	
Eastern Shore Bayside								
Parksley			0.9e		10.1b		55.1e	
Saxis			1.2e		7.6b		54.4e	
Wescott Point	0.8c		0.1e				19.0e	
Other			26.5e				452.8e	
Total Miles	0.8c		28.7e		17.7b		581.3e	

TABLE 4 (Continued)

	Harbors & Ports	Recreation	Residential	Industrial	Conservation	Military	No Present Use	NASA
Eastern Shore Seaside								
Boxiron					10.0a		14.2e	
Cheriton			1.2e		16.6b		71.6e	
Chincoteague East			3.0e		43.1a		24.3e	
Chincoteague West			3.6e		2.0a		84.3e	11.3a
Cobb Island					5.2b		89.5e	
					8.8b			
Ship Shoal Inlet					1.7a		79.6e	
Townsend			1.0e		38.5b	0.8a	56.7e	
Wallops Island							6.2e	18.4a
Whittington Point					0.7a			
Other			3.2e				436.2e	
Total Miles			12.0e		57.5a	0.8a	862.6e	29.7a
					69.1b			
					126.6			
Chesapeake Bay								
Cape Henry		2.8e	I3.3e			3.6b	19.2e	
		4.8b						
Hampton			10.3e			21.4a	18.2e	
Little Creek		1.9c	21.3e	2.1b		7.9a	11.7e	
Norfolk North	6.9a	0.6e	25.0e	0.4a		12.1a	3.3e	
		0.8c						
Poquoson East			0.2e			12.8a	9.8e	
Poquoson West		0.9a	15.6e	1.5e		2.5a	42.1e	
Other			53.3e				194.7e	
Total Miles	6.9a	0.9a	139.0e	0.4a		56.7a	279.0e	
		4.8b		2.1b		3.6b		
		2.7c		1.5e		60.3		
		3.4e		4.0				
		11.8						
Other Rivers			21.0e				267.0e	

THE MARSH AND THE ESTUARY

The roles of the marsh in the ecology of the estuary are many and varied. Biological, chemical, and physical systems interact in complex fashions (Fig. 1), many of which are very poorly understood. The vegetation of the marsh plays a key role in many of these processes. By converting inorganic compounds (nutrients) and sunlight into plant tissue, they are of prime importance as energy transfer mechanisms to consumer organisms in the marsh and estuary. At the same time that nutrients are being converted into vegetation, sediment and suspended materials are being mechanically and chemically removed from the water and deposited in the marsh. Were the nutrients not removed in the marsh, they might stimulate blooms of undesirable algae; were the sediment not removed, some of it would come to rest in navigation channels and on shellfish beds. The marsh vegetation slows flood waters and helps to stabilize channels, banks, and water levels.

In one way or another, the marshes are not only an integral and indispensable component of the estuarine community but also of the human community which surrounds the estuary. Small (and often subtle) changes in a given aspect of this complex web are often magnified exponentially as they are transmitted through the system. The resultant effect is often far removed in space and much greater in magnitude than was the initial displacement. All of these inter-related phenomena are the subject of the following discussion.

Primary Productivity and Nutrient Transformation

Primary productivity is that which results from the conversion of solar energy, carbon dioxide and water into carbon compounds by chlorophyll in plants. Nutrient transformation is the incorporation of inorganic materials into organic compounds. Of particular importance to the estuarine ecosystem is the transforming of complex molecules of cellulose by yeasts and bacteria into other carbon compounds digestible by animals and the changing of nitrogenous wastes of animals into compounds available to plants or lower animals. The marsh plants of Virginia receive ample sunlight for photosynthesis on virtually every day between the months of March and October. Our sampling has demonstrated that most of the marshes are quite productive. It has long been known that seeds of several brackish and freshwater marsh plants and the leaves and roots of some submerged aquatic plants are prime duck foods. The value of marsh vegetation, particularly salt marsh grass, to the estuary has been demonstrated only recently (9) and is still known to relatively few scientists.

The recent discovery of the mode of transfer of nutritive elements of grasses to aquatic animals used by man required more sophisticated research than was required in the analysis of duck foods. Members of

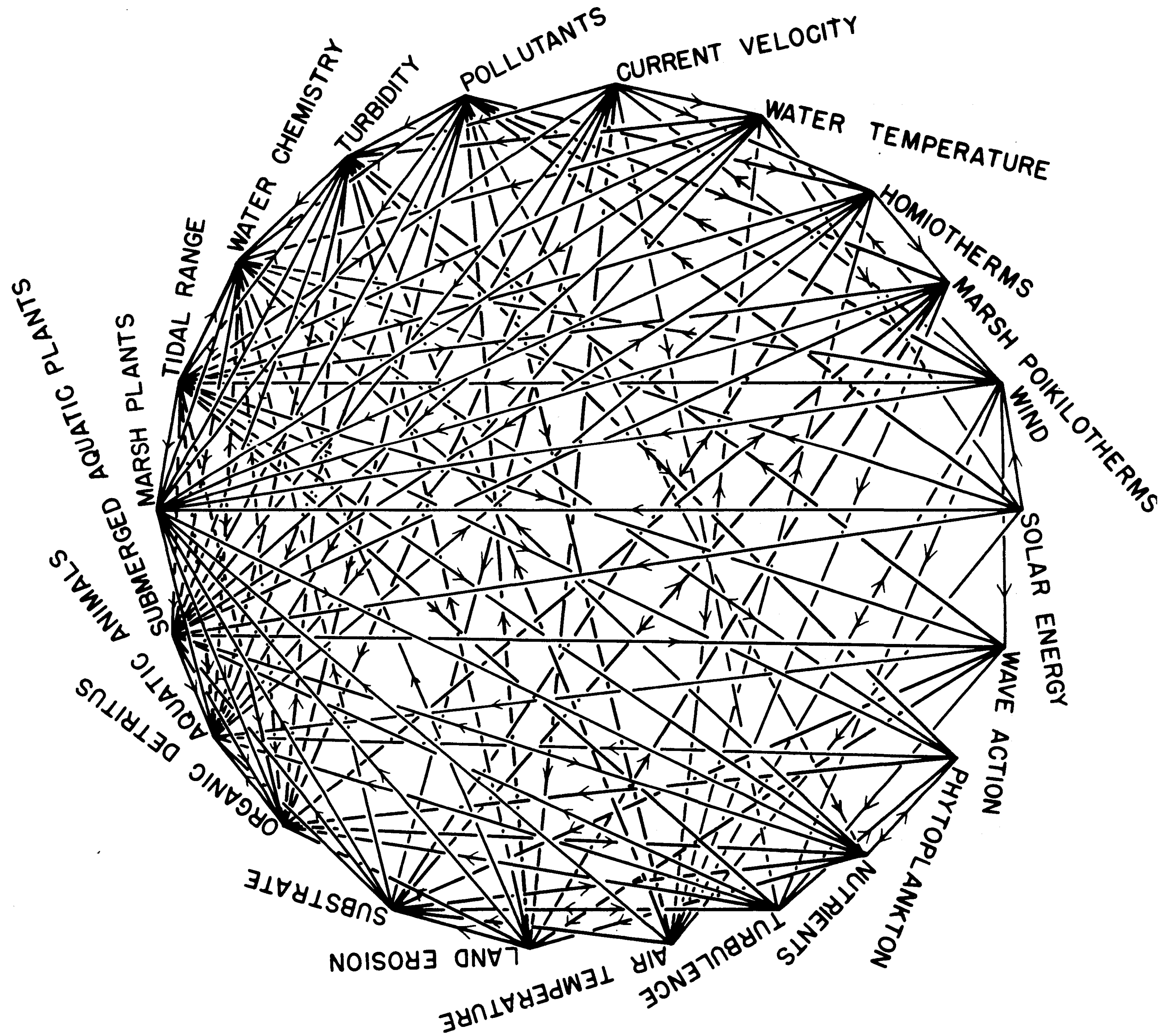

Fig. 1. Diagrammatic flow of biotic and physical effects, both unidirectional and reciprocal, in a marsh-bordered estuary. (See Appendix for explanation of interactions.)

the Ichthyology Department of VIMS (1) have determined the feeding habits of the juveniles of several fishes. These small fishes largely feed upon small crustaceans, and the link between the latter and marsh grass has been partly elucidated by ecologists in Georgia (9) and elsewhere but still needs further investigation to detail specific cases.

Our field observations and past experience with trawling in the "nursery ground area" of the Pamunkey River clearly show the transport of large amounts of dead vegetation to the adjoining water. This occurs mainly in winter and early spring when high tides and ice drift combine to carry the grass away. Plant stems pushed farther into the marsh rot in low piles until fine enough to be carried away the next year. The amount swept into the river is probably greater than that left in the marsh, allowing two years to carry away a season's growth. This material becomes water-logged and sinks and, although not yet fine enough to be ingested by suspension feeders, seems to form the main food of two species of amphipods, *Gammarus fasciatus* in freshwater and *Gammarus daiberi* in brackish water. The latter species is the most abundant amphipod in that reach of the estuary and the main food item for some juvenile fishes. Hence, many organisms are abundant in estuarine areas distant from the marshes because of the transport of detrital material from the marsh.

On the Eastern Shore seaside, one may observe in late spring the accumulation of drifted piles of *Spartina* stalks littering the outer beach of Parramore and other islands. Ragotzkie (10) commented on the sighting of rafts of these stalks 10 miles at sea off Georgia. Teal (11) calculated that about 45% of the total plant material was transported out of the marsh and into the estuary. It is apparent that where tidal range is extensive and inlets are frequent, large amounts of the tough stalks may be carried out to sea, ultimately to become particulate detritus and be eaten by small crustaceans upon which the Winter Flounder (*Pseudopleuronectes americanus*) in particular is known to feed. The most dense population that we have found of *Ampelisca abdita*, a small, filter-feeding amphipod, was in a channel near Wachapreague.

Only a small amount of grass (about 7%) is eaten by insects in the Georgia marsh (12); most of it is undoubtedly consumed by animals which feed on detritus, including some amphipods, isopods and decapods (shrimps and crabs) which can masticate partially decayed material. However, most detritus is consumed after it has been reduced to small particles, whence it is eaten by such creatures as very small amphipods, e.g., *Ampelisca abdita*, by the abundant Opossum Shrimp *Neomysis*, but probably mainly by bivalves as the particles move into channels and thence downriver. These molluscs include the Bent-nose Clam *Macoma balthica* in particular, *Macoma mitchelli* in quiet shallows, the Marsh Clam *Rangia* where it has been introduced, the Soft Clam *Mya arenaria*, the Hard Clam *Mercenaria mercenaria*, and the Virginia Oyster *Crassostrea virginica*. Some detritus comes secondhand from fecal pellets produced by amphipods, insects and other animals. However, decay by bacteria and fungi must be responsible for most of the fragmentation. It is in this latter process that the most important evidence has come to light in the last two decades. In Georgia, Odum and de la Cruz (9) found that recently dead stalks of Spartina had a protein content of only 6%, while the more decayed stalks were 24% protein. The respiration rate for particles under 64 μ (0.002 inch) was seven times greater than for an equal volume of particles larger than 239 μ (0.01 inch). This attests to the high biological activity of small particles and is attributed to the microbiota on them. Wood (13) reported that over 99% of the bacteria and small flagellates associated with sediment are adsorbed on these small particles. Later, Wood (14) reported that these small particles were richer in nitrogen and phosphorus than larger ones were. This is probably because small particles have a greater surface to volume ratio than do large ones and hence the larger surface area supports a greater biota.

It may well be that the value of detritus lies not in its chemical composition or caloric content but in the microinhabitants that it supports. Hence, a given particle may be ingested and stripped of the adherent microfauna several times before it is "exhausted" (15). Detrital particles, after colonization by bacteria, may have a protein content two or more times greater than did the original particle (11). Although many organisms cannot utilize the carbohydrates present in detrital particles (especially cellulose), they can utilize the micro-inhabitants of the detritus which are capable of converting the cellulose to proteinaceous material (16).

Plant material creates a biological oxygen demand (BOD) on the system when it enters the water since the heterotrophic organisms which degrade it and subsequently convert it to inorganic components require oxygen for respiration. It is thus fortunate that most of the vegetative debris enters the water in the colder months when oxygen content of the water is high. By June, new growth in the marsh and calmer weather largely halt the entry of further material. Oxygen values reach a low when the water is warmest and wind-mixing generally lowest, in August and September--a situation magnified by the effect of Hurricane Camille this year. The ensuing floods brought additional organic material high in BOD into the system and created an over-riding lens of freshwater which inhibited circulation.

The material contributed by higher plants is by no means all that is produced by wetlands. Teal (11) concluded that the amount produced by algae in a salt marsh was about one-fourth of that produced by Spartina. Pomeroy (17) found production by benthic algae at low tide at least five times as great in winter as in summer and production at high tide four times as great in August as in winter, the result being a nearly constant, daily production throughout the year. These data show that algae are most efficient at low light intensities. Most of the mud algae are diatoms which migrate vertically in the substrate. From a surface scum sample taken on June 10, 1969, on a mudflat in Bradford Bay near Wachapreague, Miss Victoria Roy, a student at VIMS, found seven genera of algae: Amphora (most abundant), Navicula, Rhizosolenia, Pleurosigma, Oscillatoria, Synedra, and Coscinodiscus. These unicellular algae may be quite important to the general productivity of the seaside bays on the Eastern Shore. Filamentous blue-green algae, which are often common on sheltered marsh shores and between Spartina clumps, fix nitrogen for use by higher plants and other algae.

Nutrients from sewage pollution may be beneficial to growth of marsh grass, although not necessarily so to the adjacent estuarine waters. Cordgrass has been seen to be taller and darker green where an odoriferous stream meandered through a marsh. In the open water, sewage and industrial nutrients also increase productivity, as in the upper tidal Potomac and in the James near and above Hopewell, but the increase is in the form of blue-green algae which have an objectionable smell and which, by their density and positive buoyancy, decrease light penetration. This raises the photosynthetic compensation point and thus could lower total productivity in the water column. Certain zooplankters may benefit from the increased production of diatoms stimulated by mild nutrient enrichment. Extreme excess of nutrients seems to have the opposite effect--algal scums must be degraded by oxygen-using bacteria before the nutrients are again available.

Marshes inundated daily are capable of absorbing considerable amounts of nutrients in warm months. This decrease in available nutrients could act to suppress "blooms" of undesirable algae since marsh plants generally tie up the nutrients until winter but algae quickly die and thus allow a continuous succession of blooms. A diminution in extent of low marsh would thus probably make more nutrients available to planktonic algae.

Algal production is probably higher in marshes than in the open estuary. A total of nine paired samples of phytoplankton taken in marsh thorofares and adjacent open river in the lower Pamunkey by Mr. Victor Burrell of VIMS in the months of September, October and November, 1966, showed 1.05 to 6.34 times as many diatoms in the narrow thorofare as in the open river for eight of the pairs. The ninth, taken in Eltham Marsh thorofare and the adjoining river in September, gave a difference of 2,808 times greater for the thorofare. Such extremely diverse data not only indicate the patchy distribution of plankton but also the need for further studies. Turbidity is probably usually less in a marsh, even at high tide, than it is in the adjoining body of water. Thus, phytoplankton productivity has generally been conceded to be low in the brackish and fresh portions of tidal rivers because of the silt load. However, it seems quite possible that the presence of marshes may increase total production of phytoplankton in these reaches of the rivers by reducing turbidity (18).

The productivity of phytoplankton and above-ground vegetation of plants is relatively easy to measure compared with determining the amount of plant food stored in roots. Underground plant parts range from the fibrous roots of the grasses to the thick rhizomes of several bulrushes (Scirpus species), all of which occur in Virginia marshes. The Yellow Pond Lily (Nuphar luteum) probably stores more food in its roots than any other aquatic plant does. The fate of these roots is unknown but it is generally agreed that in marshes as far south as those of Virginia the formation of peat is mainly by accumulation of roots, nearly all above-ground material being carried away by the tides or consumed by Fiddler Crabs, amphipods, isopods, and other marsh organisms.

Some Estimations of Productivity in Virginia Marshes

True productivity cannot be based on standing crop measurements alone. However, data from clipped plots give the best estimates for the amount of effort required. In our preliminary studies of productivity, we have obtained samples of vegetation dominated by 15 different plant species. In salt marshes it is usually possible to obtain square meter samples which contain only a single species. In a freshwater marsh this is almost impossible and one may find a dozen different species in one sample.

Samples were collected in plastic bags and dried in burlap sacks in two sterilizing ovens, in each of which a 100-watt bulb was placed. Temperatures obtained were near 100°F (38°C). Plants were dried until they were crisp, which required 1-4 days. Weighing was by a commercial spring scale to the nearest one-fourth ounce (7 g). The number of ounces obtained per square meter was divided by 7.9 to obtain a value for tons per acre.

Our 38 samples of 1 square meter each reflect the dominance of the Cordgrasses, 12 being of Smooth Cordgrass (*Spartina alterniflora*), 8 of Giant Cordgrass (*Spartina cynosuroides*), and 4 of Salt Meadow Grass (*Spartina patens*). Since *Spartina alterniflora* occurs as tall, intermediate, and short forms, depending on marsh elevation, samples can be separated by height. We divided ours into only tall and short since they were easily separable as such. The tall samples averaged 7.0 tons per acre (1,570 g/m^2), the short 3.0 tons per acre (695 g/m^2). One sample from nearly freshwater in the Poropotank River indicated a production of 10.75 tons per acre (2,410 g/m^2). Only two samples were obtained from the Eastern Shore, both from the Machipongo River. These gave values of 7.3 (1,725 g/m^2) for tall *Spartina* and 4.0 (920 g/m^2) for short. Both values are higher than an extrapolated mean of 5.1 tons per acre (1,140 g/m^2) based on 8 samples of tall *S. alterniflora* and 4 samples of short, the mean adjusted to correspond to probable nearly equal areas of the two types.

Smooth Cordgrass (*S. alterniflora*) characterizes or grows in more marsh than any other species in Virginia (8), as in other Atlantic coast states. It is difficult to compare yield data from other states because of differences in techniques and flora, but it seems almost a foregone conclusion that total productivity decreased northward because of shorter growing seasons. At the present time, only this species (*S. alterniflora*) has been sampled enough to make comparisons. The problem of determining annual production is that of adequate sampling. The statement has often been made in popular literature (19) that *S. alterniflora* produces about 2,000 g/m^2 or 10 tons per acre (dry weight) in Georgia marshes (actually, 2,000 g/m^2 equals 8.93 tons per acre). Odum (19) implied that this figure applied to the entire crop of this species in Georgia. However, Smalley (12) reported an annual production of 4.4 tons per acre (985 g/m^2) for this grass, also in Georgia. This compares with 2.9 (650 g/m^2) for North Carolina, 2.0 (450 g/m^2) for Delaware, and about 1.3 (290 g/m^2) for New Jersey (20). These studies were all based on extensive samples; that for North Carolina utilized 385 observations. Their range (in tons per acre) was 1.27 (285 g/m^2) (42 observations) to 28.0 (6,280 g/m^2) (one observation). The data from these four Atlantic coast states indicate that annual production in Virginia salt marshes is about 2.2 tons per acre (490 g/m^2).

Annual production is considered to be greater than standing crop although the two are considered to be nearly equal at the end of the growing season, because of the maturity of the plants (20). Our samples were mostly collected before the end of summer and, indeed, those taken in late summer were generally heavier. Since our samples indicate much greater standing crops, it might be surmised that our data are somehow biased. However, since our lowest value for S. alterniflora was 2.2 tons per acre (490 g/m^2), and this from a quite poor stand, we are not willing to agree with others who inferred that the productivity of the tidal marshes of Virginia lies midway between those of North Carolina and Delaware. This one species of grass probably covers only about one-third of our marshes and, while it is easily the most productive salt marsh species, the many species which comprise the brackish and fresh marshes show evidence of being as much or more productive.

While there is reason to believe that Georgia marshes do not average the 10 tons per acre (2,240 g/m^2) of annual production reported by Odum (19), it also seems likely that they average more than 4.4 (985 g/m^2). Smalley (12) gives 4,248 $kcal/m^2/yr$ (1,062 g) as the net production of S. alterniflora but Teal (11) cites Smalley (12) and gives the figure of 6,580 $kcal/m^2/yr$ (1,645 g), over half again as much. Williams and Murdoch (20) cite Teal (11) for the figure of 900 g/m^2 and in a footnote to the citation state that "Standing crop was estimated by assuming dry weight to be 40% of fresh weight," although neither Smalley nor Teal explained how their data were obtained. The highest figure given by Teal equals 14.5 tons per acre (3,250 g/m^2). This is for summer and is 44% higher than for autumn. These data for tall Spartina contrast with those for short Spartina, which are 22% higher for autumn than for summer. No explanation is given for this, but one can only assume that most of the lower leaves of the tall Spartina had died by autumn. Teal reported a yield equivalent to 4.0 tons per acre (895 g/m^2) for short Spartina marsh which covered 42% of his study area and 8.0 tons per acre (1,795 g/m^2) in autumn for the tall which covered 58% of the marsh. This gives an average annual production of 6.3 tons per acre (1,410 g/m^2). However, if one uses Teal's summer standing crop estimate, the resultant total is 10.3 (2,300 g/m^2). Odum (19) has stated that S. alterniflora produces two crops annually but we are unable to find the scientific basis for this statement.

On the matter of productivity based on standing crop estimates, it is our belief that each species of plant must be treated differently. For several, we separated the dead material from the live. In early summer, weights of the two were near each other, especially for S. cynosuroides. As the summer advances, most of the previous year's material rots away. Collections made in the fall have relatively little material left from the year before except with Juncus and some strong-stemmed species.

Black Needlerush (Juncus roemerianus) is generally considered the least valuable of the common marsh plants. Shaw and Fredine (4) declared that it "produces no food for wildlife." Our data represent only two samples, from which dead material was removed. These samples had a mean value of 2.9 tons per acre (650 g/m^2). This compares well with 3.3 (740 g/m^2) from Beaufort, N. C. (Williams and Murdoch, unpublished manuscript), but contrasts with data from Bodie Island, N. C. (21), where this rush yielded 5.0 tons per acre (1,120 g/m^2) one year and 7.1 (1,590 g/m^2) the next. Our data on S. patens grass show a mean yield of 3.6 tons per acre (805 g/m^2), which is unusually high because two of the four samples were from atypical enriched sites--one a roadbank, the other a beach drift line. Two Distichlis samples indicated a yield of 1.6 tons per acre (360 g/m^2). Waits' (21) extensive sampling at Bodie Island, N. C., gave a mean of 5.8 tons per acre (1,300 g/m^2) for S. patens and 5.9 (1,320 g/m^2) for mixed S. patens and Distichlis. On the basis of Waits' findings, one would expect Virginia salt meadows to yield not less than 3 tons per acre (670 g/m^2) annually.

Two less common salt marsh plants were sampled once. Fimbristylis, mixed with S. patens, weighed 2.7 tons per acre (605 g/m^2), and Sea Ox-eye (Borrichia) had a yield of 3.5 tons per acre (785 g/m^2). This leathery plant is characteristic of the more barren high marsh and often occurs near Saltwort (Salicornia) flats.

Among all the plant species sampled, the datum obtained for a clipping of Rice Cutgrass (Leersia oryzoides) was the most interesting in regard to yield. This grass grows to a length of many feet but always lies prostrate, more or less supported by other plants growing erect, until it flowers in September. It was found growing in a pure stand only in the Coan River Marsh above the Route 360 bridge. While admittedly difficult to sample because of its prostrate habit, the datum of 6.9 tons per acre (1,545 g/m^2) is indicative of the material produced by some of the fresh and low brackish marsh plants. However, our other data, based on two samples of Wild Rice (Zizania), two of Giant Cutgrass (Zizaniopsis), one of Olney Three-square (Scirpus olneyi) and one of Reed (Phragmites), average only 2.5 tons per acre (560 g/m^2). A sample of Spatterdock (Nuphar) indicated only 1.1 tons per acre (245 g/m^2). However, growth habits of certain plants make analysis difficult: Nuphar sends up new leaves all summer as older leaves are eaten by a species of small beetle. Arrow Arum (Peltandra virginica) produces new leaves in late summer after the first have died. Three-squares and Cattails produce extensive rhizomes. Some plants, e.g., Scirpus and Zizania, produce seeds of considerable value to waterfowl. Smartweeds produce an abundance of seed and vegetation in late summer. Thus, much of the fresh marsh produces two crops each year.

Most spectacular of all the Virginia marsh grasses is Giant Cordgrass (Spartina cynosuroides), which reaches a height of 12 feet and occurs in most brackish marshes having a salinity less than 15 o/oo, the optimum probably being about 5-10 o/oo. While we never found it growing without one or more smaller plant species, the samples we clipped were at least 95% Cordgrass biomass. Giant Cordgrass dominates the four lower marshes of the Pamunkey River and a similar reach in the Mattaponi River. Along many other rivers, as in some tributaries of the Nansemond, the stands, while small, are quite luxuriant.

Our eight samples ranged from 4.2 tons per acre (33 g/m^2) to 8.1 tons per acre (64 g/m^2), with a mean of 6.5 tons per acre (51.2 g/m^2), and indicate a greater productivity (Fig. 1a) than for any other plant except Rice Cutgrass, a comparatively scarce species.

The variety of plants growing in brackish and fresh tidal waters and marshes also makes possible a continuous input of organic material to the water. Arrow Arum (Peltandra) growing in shallow fresh marshes produces two crops of foliage each summer and these leaves quickly fragment. These and other fleshy-stemmed plants decay rapidly, while grasses, Smartweed and many plants producing showy flowers have stems which decay slowly. In low areas near watercourses, tall stems may be locked in ice and sheared off in winter. Otherwise, the old growth may require more than a year to decay enough to be carried away by high tides.

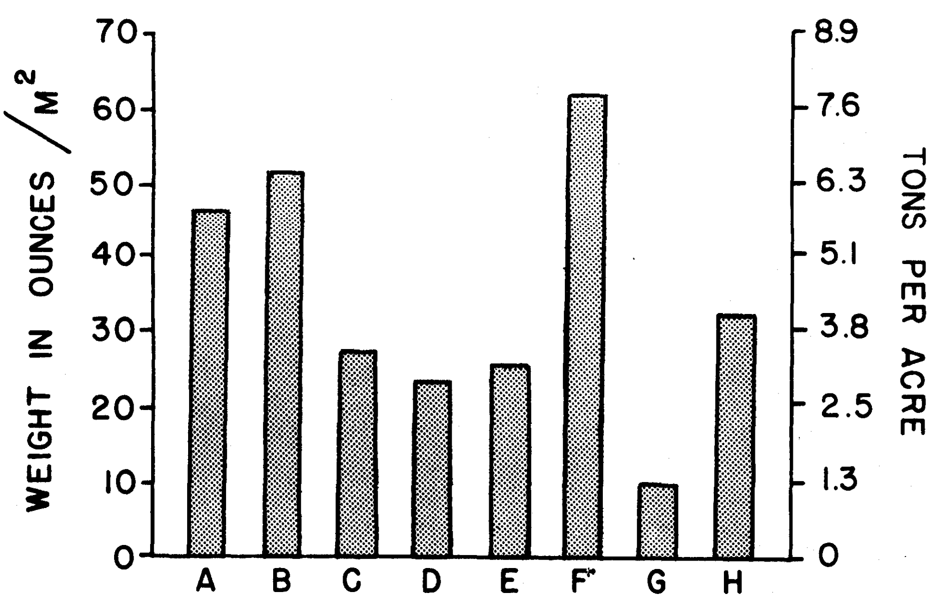

Fig. 1a. Marsh grass data (A - Spartina alterniflora; B - Spartina cynosuroides; C - Spartina patens, Distichlis spicata, Borrichia frutescens mixture; D - Juncus roemerianus; E - Scirpus olneyi, Zizania aquatica, Zizaniopsis, Phragmites; F - Leersia oryzoides; G - Nuphar advena; H - Typha angustifolia).

FAUNAL PHENOMENA

Use of the term "food web" instead of "food chain" merely recognizes the complexity of ecological systems where producers and lower organisms are usually fed upon by several organisms, although one may dominate at each level. The trophic structure of an estuarine community varies greatly from one season to another. In winter, reproduction ceases in the marsh and only a few aquatic invertebrates continue to breed. Many poikilotherms (cold-blooded animals), e.g., Blue Crabs and Hogchokers, cease feeding in winter. Spring brings a rapid rise in plant productivity and in numbers of zooplankton, meroplankton, and migrating crabs, fish and birds. Water temperatures lag behind air temperatures so that the onset of marsh activity may precede that in the water. Solar radiation and differences in types of autotrophs (primary producers, mostly plants) tend to initiate productivity in both marsh and water early in spring.

Were energy to flow along a single pathway from one trophic (energy) level to the next higher, relating primary productivity to production of commercial animals would be simplified and total production might be greater, but simple trophic chains are generally less stable than complex webs. No animals of food value to man, except possibly Muskrats and, in some areas, Geese, feed directly on Spartina grasses. Yet, these plants probably support more life in areas where they occupy large marshes than do the phytoplankters. The secret of this lies in the efficiency of the detritus-based food web as a major component of the estuarine ecosystem. The creatures involved in the grass ⟶ detritus ⟶ filter feeder ⟶ carnivore pathway are greater in numbers and vastly greater in biomass than are those in chains involving consumption of the living grass by herbivores.

A Simple Food Chain

The simplest community known to us in Virginia tidal waters is that in the James River from Richmond to below Hopewell. Extreme pollution has resulted in this over-simplified situation. Here great amounts of nutrients enter the water and are converted into plants; perhaps due to the toxic nature of certain pollutants or to their competing oxygen demands, very few animals are present to use this production. Marshes are nil in this reach but a considerable amount of tree leaves enters the water. Ordinarily, these are skeletonized by grazing benthic crustaceans and decayed by fungi and bacteria. But in the James, they are unmodified until swept farther down by floods to more ecologically normal areas. Only tubificid worms, universal indicators of poor conditions, remain in the bottom fauna of the upper tidal James, and even they are scarce in the main channel. Midge larvae may be found in small numbers, but aquatic insect larvae and freshwater molluscs are less abundant than one would expect. Thus, simple food chains result: sewage → algae → tubificids → catfish → man, or the tubificids may be eaten by Sandpipers. Dead Catfish may be consumed by Gulls and thus lengthen the chain. In such abnormal waters, a plankton-based chain also leads to production of young Shad and Herring under special seasonal conditions, but one must go downriver to find more normal food webs.

Nursery Ground Webs

The Chickahominy River, while having its productivity export capability partially blocked by establishment of a reservoir 24.3 miles from its mouth, nonetheless has extensive bordering marshes below the dam. These marshes are largely freshwater and similar to upriver reaches farther north along Chesapeake Bay. They contain a variety of plant species which produce seeds and vegetation desired by dabbling ducks such as Teal, Black Ducks, Mallards and Pintails. The same marshes provide plant roots and stems for Muskrats, which in turn provide furs and sometimes food for man, as well as food for Mink and Raccoons. These creatures are obvious and traditional members of the wetlands community, yet much more plant productivity is likely going into the recently introduced Marsh Clam *Rangia cuneata* and certain fish. These recipients could only obtain their share of marsh productivity via the detritus pathway. For the Clam, the detritus would have to be in the form of fine particles, and it might have gone through several other animals along the way. *Rangia* is in turn fed upon by many diving ducks, including Canvasbacks, Scaups, Ring-necked Ducks, and Buffleheads. Some juvenile fish prey on a detritus-feeding species of *Gammarus* amphipod.

The food web in an area containing extensive marshes is much more complex than in a river or impoundment lacking either submerged or emergent vegetation. In the latter situation, the primary productivity must come from plankton, whereas in the former, the sun's energy flows to the animals through a complex of plant life. This diverse pathway functions better in a tidal system which allows flushing of wetlands than it would in a pond where the biomass from fringing plants accumulates and slowly fills the pond.

Brackish areas are unique in many respects: high productivity of marsh plants, particularly of Giant Cordgrass; high tides which flush the marshes; highly turbid water; water temperatures colder in winter and warmer in summer than in the rest of the estuary; greater variations in salinity; fewer species of animals than in adjacent freshwater or saltwater; and high productivity of those organisms present. The murky waters are traversed annually by American Shad, Hickory Shad, Alewives, Blue-back Herring, Striped Bass, Lampreys and Sturgeon as they move inland to spawn, and by Eels as they go to sea. Juveniles of most of these fish and of many sport fish share the area with adults of the few resident species. The fresh and brackish marshes have a higher species diversity of plants than do the salt marshes. However, the aquatic system they support, the "nursery grounds," is quite simple compared to that of the Eastern Shore lagoons.

The nursery grounds are dominated by only four species of resident fish, the Hogchoker, Eel, White Catfish, and White Perch, of which only the last two are valued for sport fishing although Eels are fished commercially. However, these brackish, murky waters are vital to the juveniles of several sport and commercial fishes, including the Croaker (*Micropogon undulatus*), Spot (*Leiostomus xanthurus*), Weakfish (*Cynoscion regalis*), Silver Perch (*Bairdiella chrysura*), Black Drum (*Pogonias cromis*), Southern Kingfish (*Menticirrhus americanus*), and Striped Bass (*Morone saxatilis*). They are also used by juveniles of Menhaden (*Brevoortia tyrannus*), American and Hickory Shad and the Blue-back Herring and Alewife (*Alosa sapidissima*, *A. pseudoharengus*, *A. aestivalis*, and *A. mediocris*). Two ancient species migrating through this area include the Atlantic Sturgeon (*Acipenser oxyrhynchus*) and the scorned Sea Lamprey (*Petromyzon marinus*). Two species of Sturgeon occur in Virginia waters but the smaller species is very rare. The Atlantic Sturgeon was once abundant--466,270 pounds were taken from the four major Virginia rivers in 1880. In 1890, 814,400 pounds were taken and sold for 3 cents per pound. Thirty years later the catch was 22,183 pounds and the price was 23 cents per pound. In spite of the deterioration of rivers, the Sturgeon still holds on and the Virginia catch in the first five months of 1969 was 19,732 pounds, a dramatic increase from the 1,800 pounds reported for 1962. The reported commercial catch (Fig. 2) is from offshore but many fish caught in the Bay may go directly to restaurants. The Sturgeon feeds on mollusks and small fish (22), and thus possibly competed with Croakers when it was abundant. The Sturgeon spawns in freshwater, ascending "usually to about the reach of tide" where it liberates one to three million eggs (23).

The four species of *Alosa* commonly known as Shad and Herring spawn in tidal freshwater streams, including small tributaries meandering through marshes, in spring and early summer, after which they retreat to the sea. The Alewife run begins in March, a month earlier than the Blue-back run. Juveniles aggregate below the fall line in tidal freshwater (Fig. 3) until fall when they move toward the ocean where they remain for three to four years before returning to spawn. The Alewife and Blue-back Herring are commonly lumped as River Herring (or Alewives) in catch records. The two account for about 10% of the State's total commercial fish catch. Contrary to the catch of most fishes, that of the "Alewife" (Fig. 4, Table 5) has increased in recent years. In 1968, the number of permits issued for dipnetting Herring was almost 14,000, an increase of about 3,000 since 1960.

The juvenile fishes and those found as adults in the nursery grounds differ considerably in their diets (Figs. 5 and 6, Table 6). Mysids were eaten by nearly all species; 98% of the Weakfish held mysids but Croaker and Silver Perch stomachs contained greater volumes of these Opossum Shrimps. Weakfish derived most of their food from

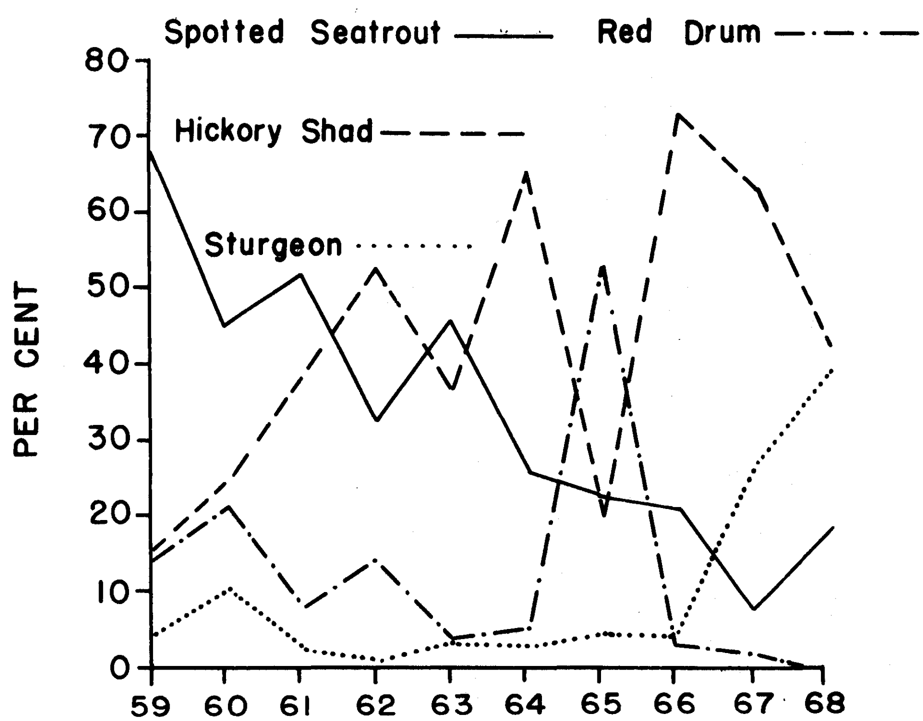

Fig. 2. Graph representing 0.03% of the commercial catch of wetlands-dependent fish for the 10-year period 1959-1968.

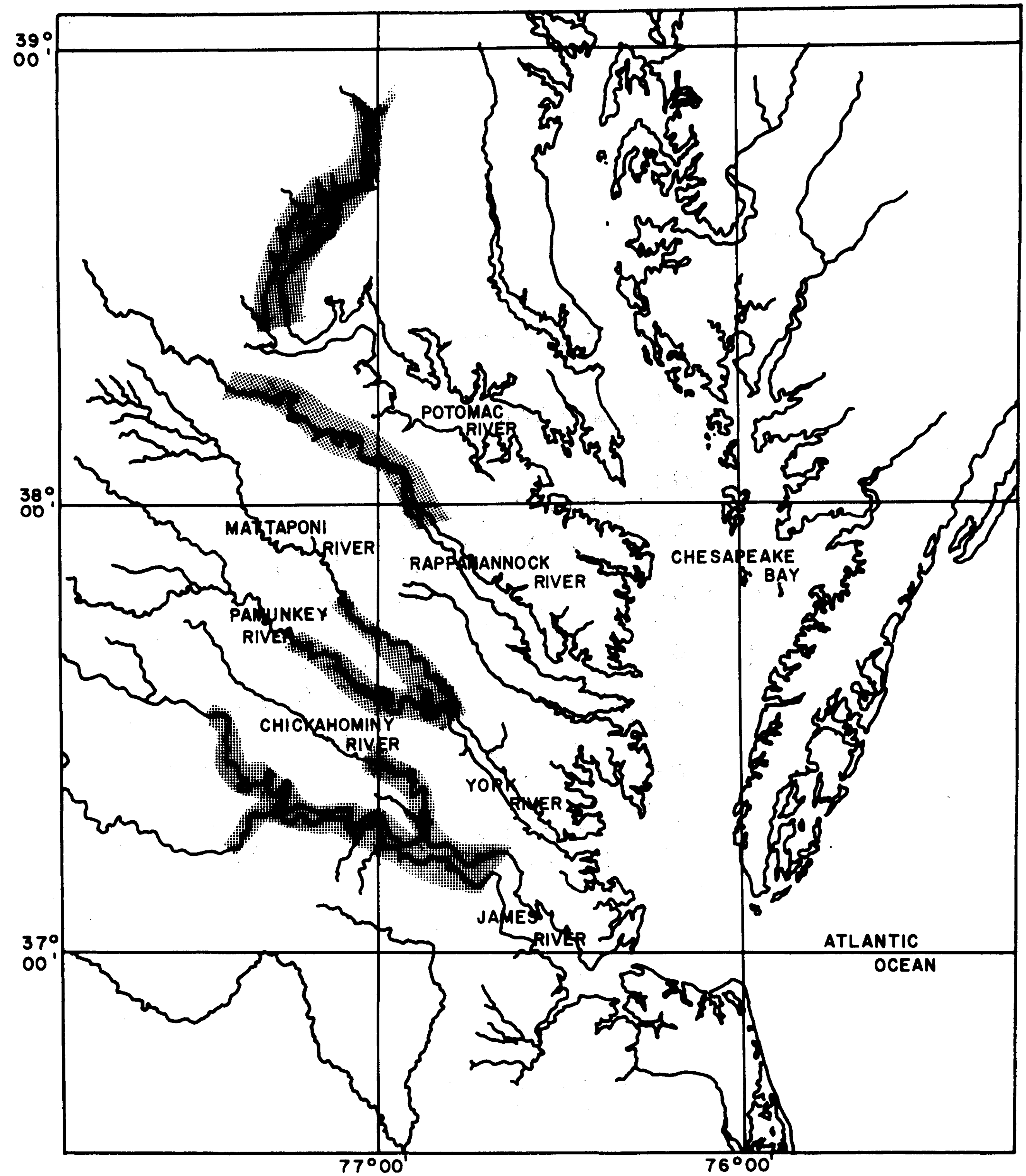

Fig. 3. Spawning grounds of Herring.

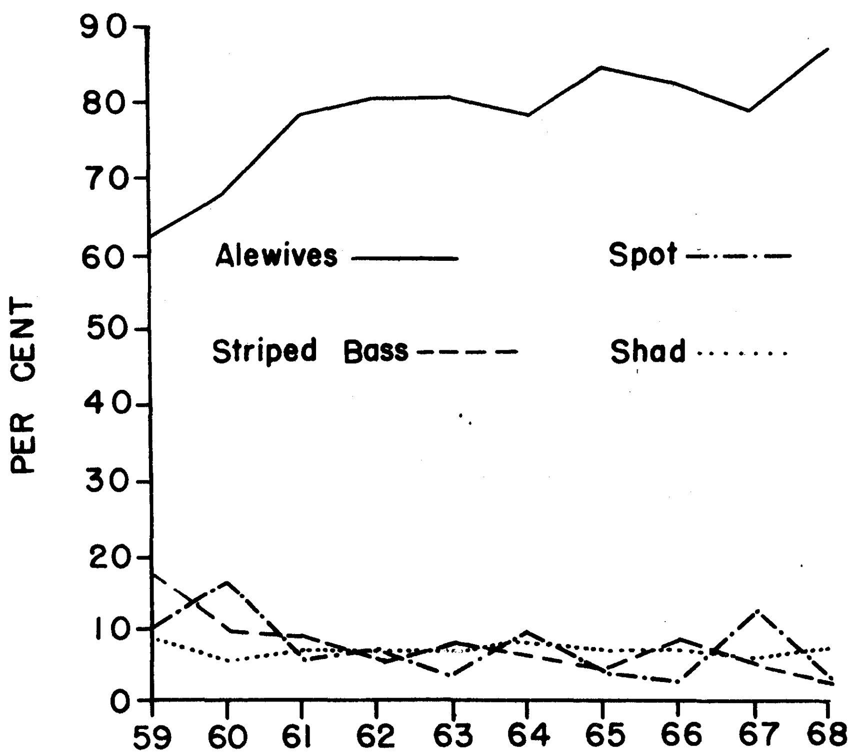

Fig. 4. Graph representing 11% of the commercial catch of wetlands-dependent fish for the 10-year period 1959-1968.

TABLE 5

Chesapeake Bay Fish Catches in Virginia (in hundreds of pounds)

	1959	1960	1961	1962	1963
Menhaden	3,435,054	2,029,913	1,965,846	2,627,651	2,266,019
Alewives	219,210	154,437	155,176	252,931	260,854
Striped Bass	64,218	22,642	18,484	19,265	27,434
Spot	36,134	37,523	11,315	22,513	13,940
Shad	32,467	13,438	13,241	22,163	23,091
Croaker	76,029	35,819	29,298	12,281	264
Catfish & Bullhead	36,875	15,235	24,691	24,322	17,541
Grey Seatrout	5,502	5,780	10,387	13,842	10,071
Fluke	4,617	3,123	2,345	2,182	1,845
White Perch	18,695	5,507	4,317	4,492	3,424
Eel	7,855	1,843	2,173	2,073	4,403
Carp	9,973	2,836	2,411	3,317	1,590
Bluefish	1,097	838	2,542	4,791	5,859
Black Drum	2,388	1,497	2,230	3,394	3,223
Blackback			800	300	
Gizzard Shad	3,299	2,264	974	736	202
Mullet	1,090	788	286	863	333
Spotted Seatrout	1,389	548	737	269	255
Hickory Shad	304	286	541	442	256
Red Drum	279	247	110	113	20
Sturgeon	85	125	36	800	18
Totals	3,956,560	2,334,689	2,247,940	3,018,740	2,640,642

TABLE 5 continued

Chesapeake Bay Fish Catches in Virginia (in hundreds of pounds)

	1964	1965	1966	1967	1968
Menhaden	2,848,125	3,132,709	2,374,623	2,202,269	2,697,172
Alewives	266,400	362,003	285,172	281,074	324,045
Striped Bass	18,855	22,102	27,491	16,768	16,135
Spot	30,949	17,017	10,513	42,533	11,161
Shad	26,374	29,332	23,310	21,378	25,915
Croaker	3,347	14,481	13,374	3,235	62
Catfish & Bullhead	14,602	9,397	11,229	9,300	10,684
Grey Seatrout	15,113	19,677	10,161	6,003	11,199
Fluke	3,392	4,781	2,862	19,003	21,634
White Perch	2,663	3,062	5,884	4,449	4,001
Eel	3,133	7,421	4,680	6,906	7,096
Carp	1,466	1,009	4,241	1,535	1,196
Bluefish	3,816	1,940	2,016	1,203	2,415
Black Drum	625	733	2,824	1,902	3,290
Blackback	250	945	1,829	7,981	8,240
Gizzard Shad	749	1,063	293	163	52
Mullet	395	173	32	9	80
Spotted Seatrout	234	404	116	37	58
Hickory Shad	576	349	409	284	138
Red Drum	46	925	18	11	1
Sturgeon	29	75	21	118	124
Totals	3,241,139	3,629,598	2,781,098	2,626,161	3,144,698

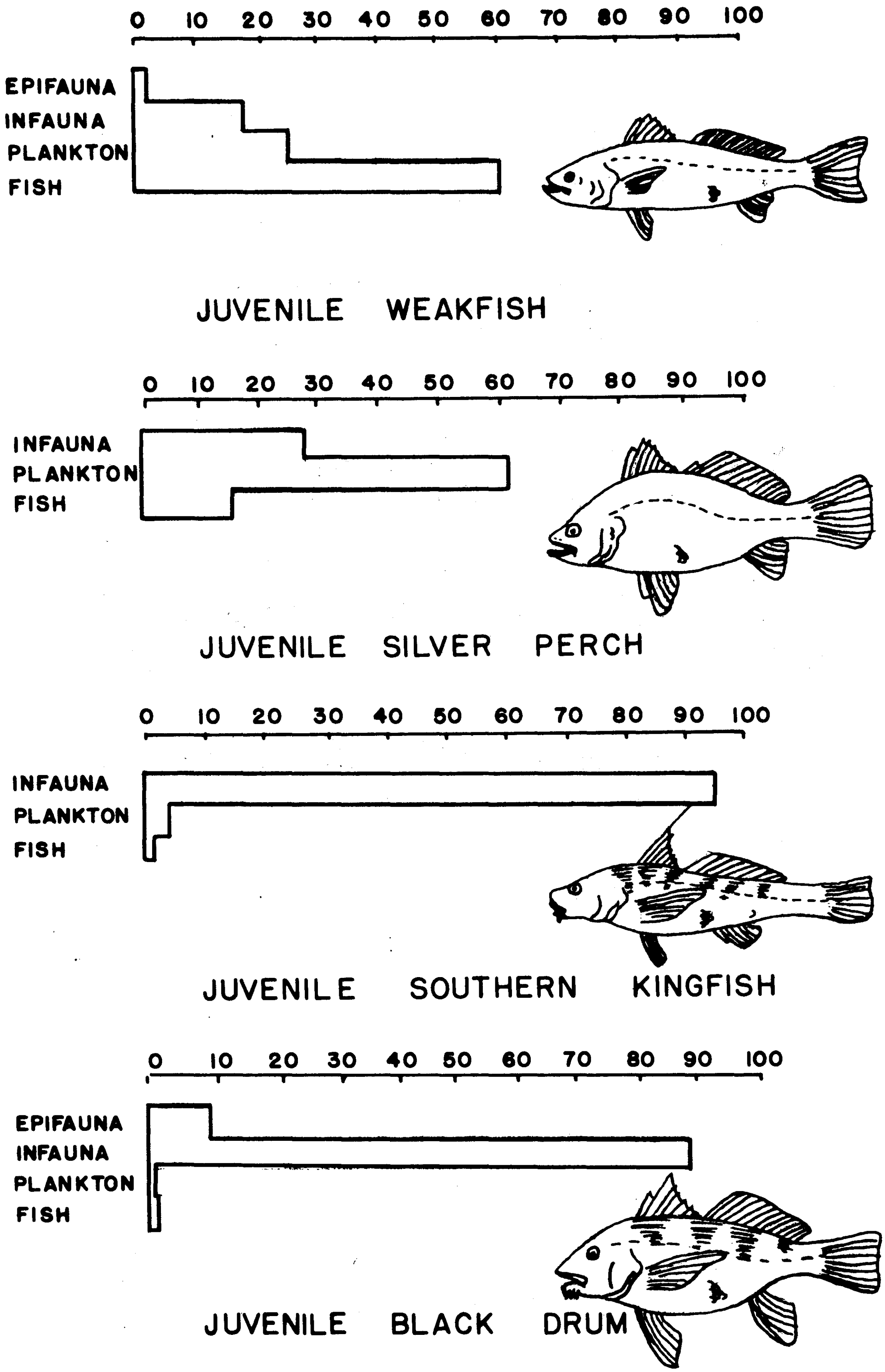

Fig. 5. Food of some fish in nursery areas by percentage of total volume. (1)

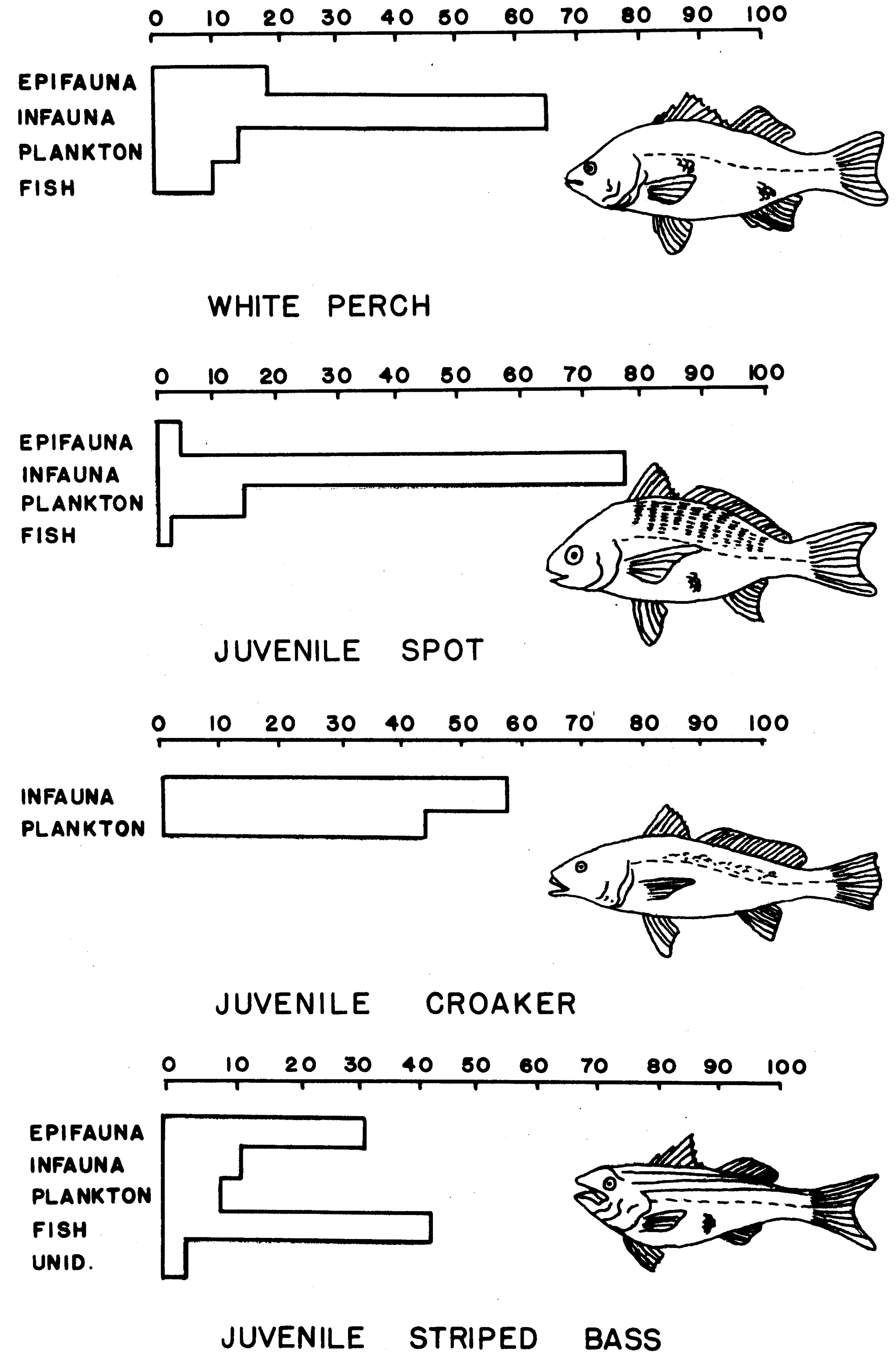

Fig. 6. Food of some fish in nursery areas by percentage of total volume. (1)

TABLE 6

Foods of Some Adult and Juvenile Fish by Percentage of Volume
(Data from Van Engel and Joseph, 1968)

Species	No. stomachs	Food: Epifauna	Food: Infauna	Food: Plankton	Food: Fish	Principal Food Items
White perch*	187	18.0	64.0	12.0	9.0	*Gammarus* (amphipod) and *Crangon* (sand shrimp) (54%)
Spot	162	2.8	76.5	13.0	1.0	Polychaete worms and amphipods (49%)
Croaker	102	0.0	56.0	42.0	0.0	Amphipods and mysids (83%)
Weakfish	268	1.5	18.0	25.0	60.0	Anchovies, gobies, and mysids
Silver perch	116	0.0	26.0	60.0	14.0	Mysids (60%)
Black drum	32	10.0	89.0	0.3	0.7	Small clams (73.5%)
Southern kingfish	35	0.0	94.0	4.0	1.0	*Crangon*, *Neomysis*, *Ogyrides*
White catfish*	86	21.0	51.0	27.0	0.0	Mysids, small clams, amphipods, and cumaceans
Hogchoker*						Polychaete worms
Striped bass**	297					Fish (50%), decapods, mysids, polychaete worms, insects, amphipods (mysids absent in James River bass)

* All sizes.
** Juveniles only; data from Markle and Grant (in press).

Bay Anchovies (Anchoa mitchelli) and Naked Gobies (Gobiosoma bosci). White Perch, White Catfish and Striped Bass were the most omnivorous. The diet of the latter species varied between rivers, but overall, about 50% of it consisted of Naked Gobies. White Catfish eat fish and invertebrates, including many Mulinia clams. It thus seems possible that this fish, along with the Black Drum and Diving Ducks, could benefit from the introduced Marsh Clam. The common Eel is taken commercially in fresh and brackish waters, up to 700,000 pounds being marketed annually. Small Eels feed mainly on amphipods and isopods; adults consume crustaceans, worms, fish, molluscs, and vegetation (22). Most of these fishes are probably demersal in their foraging. These fishes migrate varying distances, usually into the ocean. Thus, the nutrients first supplied by marshes are distributed far from sources. The Naked Goby, a very small fish, also migrates but only within a river system (24).

It is fortunate that evolution has allowed for this migration of the juveniles from their birthplace in the ocean or lower bay to waters perhaps too fresh for the adults to survive in, for in these turbid waters predation is lessened and food is abundant. Furthermore, the migrations of the different species are so timed that little overlap occurs in their occupation of the nursery areas. The breeding periods of some of the food organisms are not known, but two of the more common amphipods, Gammarus daiberi and Monoculodes edwardsi, reproduce throughout the year, thus insuring a food supply for juvenile fish. Adult demersal fish, e.g., the Hogchoker, may feed very little in winter but juvenile Croakers which arrive at the nursery grounds in mid-autumn need food to exist.

Adult fish must compete to some extent with juveniles for food but even here nature seems often to have made allowances, e.g., young Hogchokers are found farther upriver than old ones are. The crustacean species which apparently sustains more juvenile fish than does any other food item is the Opossum Shrimp (Neomysis americana). It is a planktonic species which migrates vertically, spending daylight hours hovering in the highly turbid waters just above the bottom. Here detritus moves with the tides and sustains this very important prey species.

Neomysis was evidently scarce in the James River in 1967; it was absent in stomachs of juvenile Striped Bass taken there, although it was one of the principal items in Bass from the York River and one-third as important in the Rappahannock as in the York (25). Various theories, such as pollution, have been advanced for its scarcity in the James, but it may be more than coincidental that a dense population of the Marsh Clam Rangia cuneata has existed in the James River low-salinity zone for a decade and in the Rappahannock River for five years. This Clam could conceivably feed on this rich detritus and deposit it as feces to the extent of leaving relatively little for mysid shrimps. This Clam now accounts for over 99% of the benthic biomass in a portion of the James River and may have altered the food web formerly present there, perhaps to the detriment of some crustaceans and, ultimately, to some juvenile fish.

Some amphipods migrate with changes in salinity (26) but most infaunal invertebrates probably maintain more stable populations than do the fish in the marsh-bordered nursery grounds. Most marine fish produce large numbers of young, survival of which is quite variable, as is reflected by commercial catches (Figs. 7-10). Small infaunal species produce few offspring at a time but tend to sustain stable populations available to fish and Blue Crabs.

The Blue Crab (Callinectes sapidus) has accounted for an increasingly larger proportion of the commercial seafood production in Virginia, partially because of the decline of other species, such as the Oyster (Fig. 11). This crustacean, like most sport fish, obviously gains some advantage by migrating considerable distances within Virginia's waters, the males particularly moving upriver to the head of salinity and often into freshwater. The gastric mill of crabs renders analysis of their food habits difficult, but when they occur in such abundance as occurred in late summer of this year, great quantities of infauna must be consumed. Crabs are known to grow well in some waters of relatively low salinity, e.g., in Back Bay (27). Summer drought allows crabs to go much farther upriver, thus increasing their feeding area. Predation and competition would likely be less for Blue Crabs in the nursery grounds.

The Menhaden (Brevoortia tyrannus) is, judging by the magnitude of its commercial catch, the most important user of these areas. This species has consistently accounted for 84-88% of the annual commercial tonnage of those fishes which seem to be somewhat associated with wetlands (Fig. 12). Menhaden, unlike Herring and Shad, are spawned at sea and the larvae then move into less saline water. As juveniles, they compete for planktonic microcrustacea with Bay Anchovies (Anchoa mitchilli).

Food webs in the brackish marsh community are simple relative to the communities of adjacent river channels where hosts of fishes feed on a variety of crustaceans. In the marshes, the diversity of consumers is low. Here are only the Red-jointed Fiddlers (Uca minax), a few insects and spiders and, in the narrow creeks, dense populations of Mummichogs (Fundulus heteroclitus). In these marshes, Muskrats are common and the presence of Raccoons is evidenced by scats composed of Uca exoskeletons. Since Raccoons are by far the chief predators of Muskrats (28) in tidal marshes, they compete with the much scarcer Mink. Raccoons can destroy only young Muskrats, while Mink feed mainly on adults. Raccoons are now largely without predators, except man, and thus probably are much more abundant than before large carnivores disappeared. Otters are probably more abundant in brackish areas than along fresh tidal creeks (29), and Deer often feed in marshland near woods.

Few birds nest in marshes lacking shrubs, but those which do will not nest elsewhere and they must inevitably diminish as this habitat is reduced. Long-billed Marsh Wrens are especially common in Giant Cordgrass marshes. Red-wings prefer shrubs or Cattails for nests but will nest on sedge tussocks found in freshwater marshes. Black

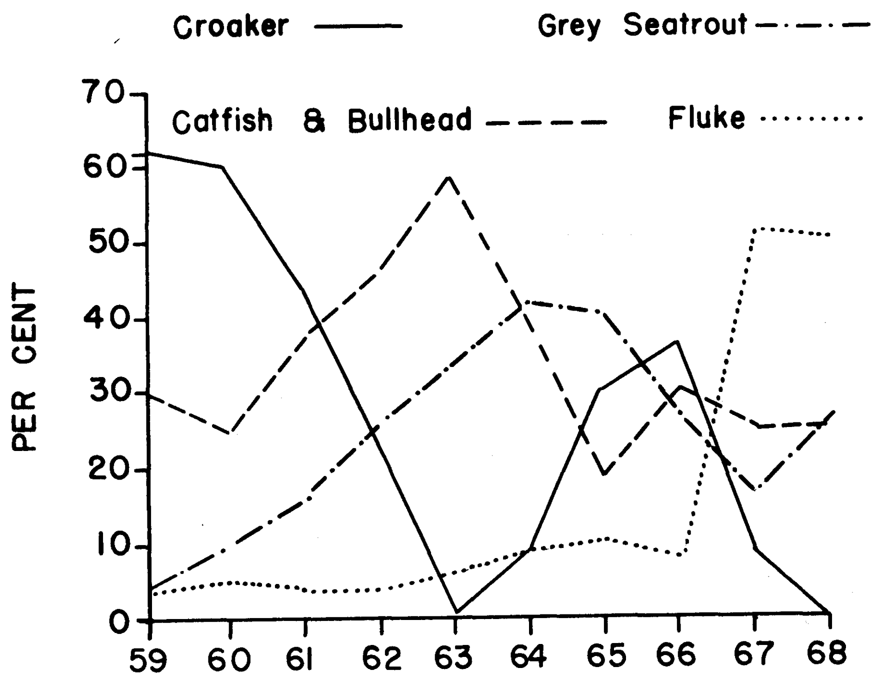

Fig. 7. Graph representing 2% of the commercial catch of wetlands-dependent fish for the 10-year period 1959-1968.

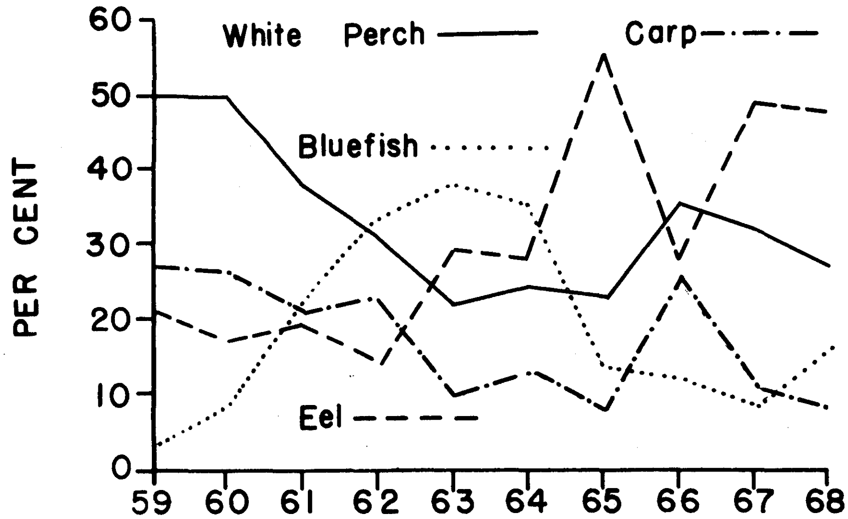

Fig. 8. Graph representing 0.5% of the commercial catch of wetlands-dependent fish for the 10-year period 1959-1968.

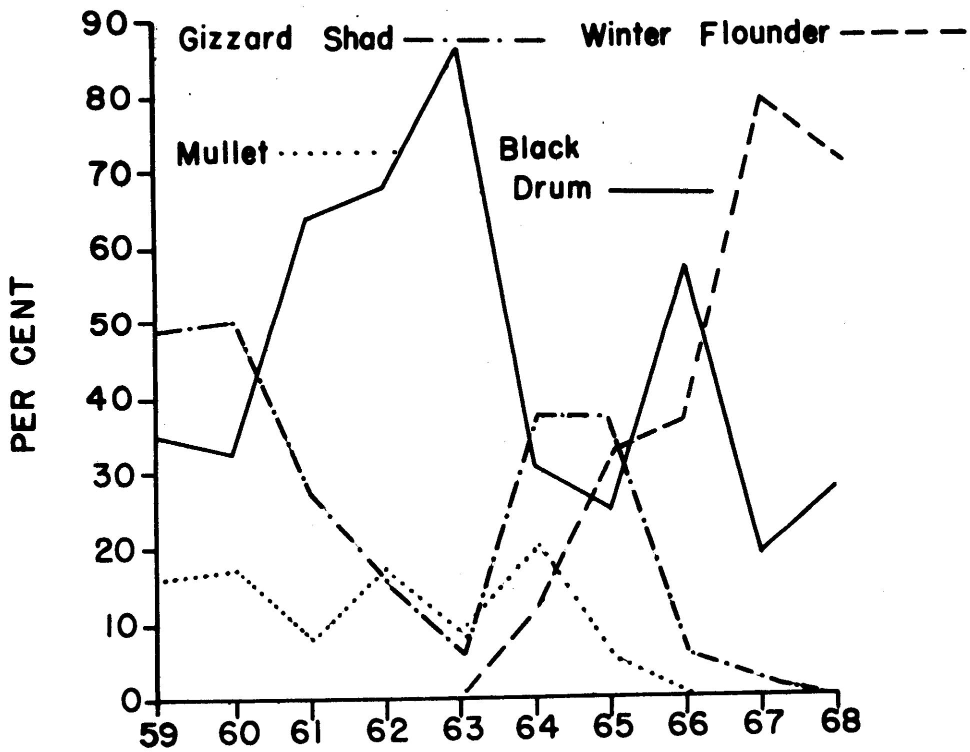

Fig. 9. Graph representing 0.2% of the commercial catch of wetlands-dependent fish for the 10-year period 1959-1968.

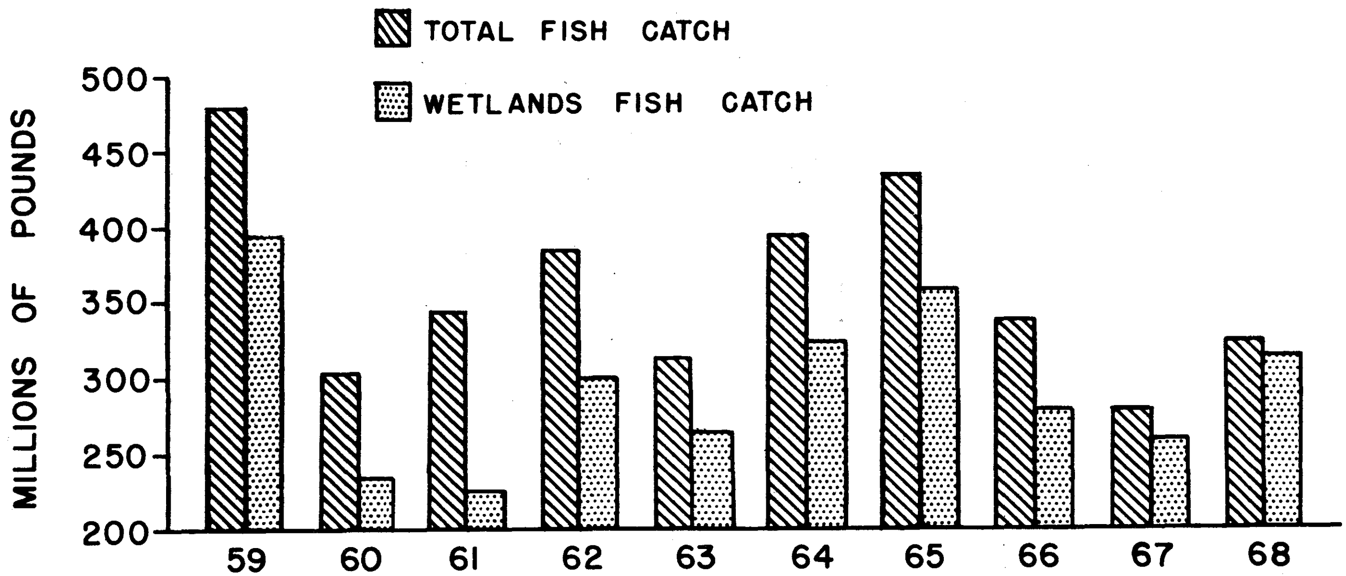

Fig. 10. Comparison of total fish catch with wetlands-dependent fish catch for the 10-year period 1959-1968.

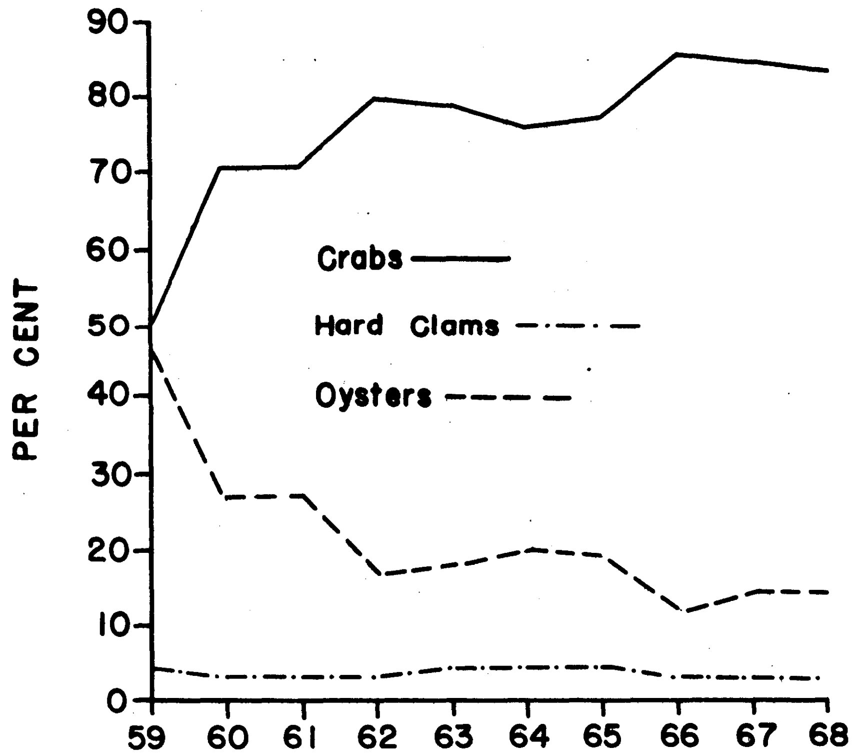

Fig. 11. Comparison of Crab, Clam, and Oyster catches for the 10-year period 1959-1968.

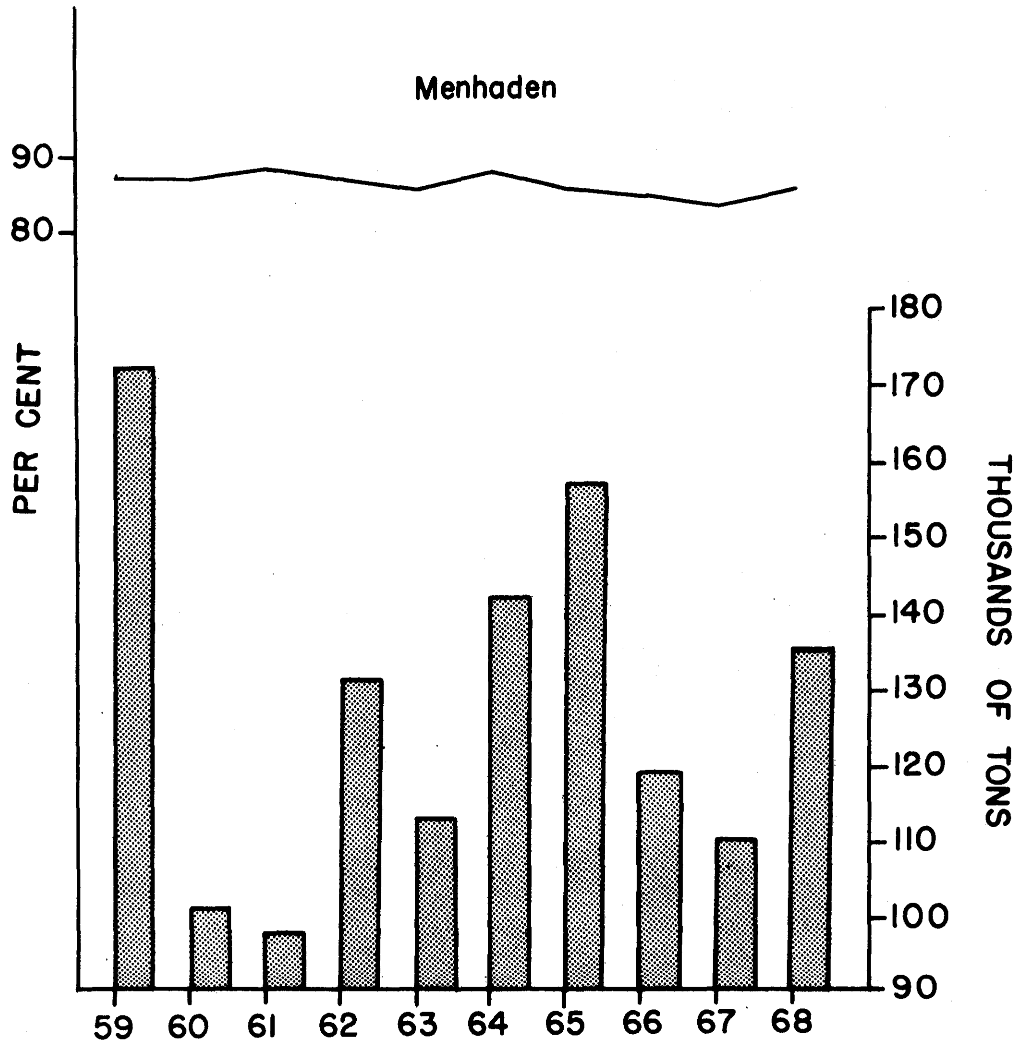

Fig. 12. Graph representing 86% of the commercial catch of wetlands-dependent fish for the 10-year period 1959-1968.

Ducks are probably increasing their breeding in these marshes. King and Clapper Rails nest and feed in these brackish marshes (29). Common Gallinules have recently nested in marshes of Middlesex and Fairfax counties (30, 31). Kingfishers, Mourning Doves, Crows and Grackles come to the marsh to feed occasionally. More often seen is the Great Blue Heron which must nest in trees in Virginia but flies many miles to feed. Common Egret and Louisiana Heron are less often seen.

It is during migration that these brackish marshes are particularly useful to birds. Spotted and Semipalmated Sandpipers, Greater Yellow-legs, and Rails appear in spring and fall. Snipe remain into the winter in reduced numbers. By August, Tree Swallows begin arriving and number in the tens of thousands in the Pamunkey and Mattaponi marshes in September. Blackbirds, mainly Red-wings, and Common Grackles also become abundant then. The latter undoubtedly consume much seed which might otherwise be available to ducks. The few Black Ducks present in summer have their numbers augmented by many more in autumn and are joined by Blue-winged and Green-winged Teal, Mallards, Gadwalls, Widgeons, Pintails and Shovelers in watery areas of the marshes. Ring-necked Ducks, Ruddy Ducks, Buffleheads, Redheads, Canvasbacks, Scaup and Mergansers appear in the river, but most conspicuous are the Canada Geese. The recently introduced *Rangia* Clams in the James and Rappahannock could provide food for Whistling Swans, since they feed heavily on molluscs. Waterfowl now have few predators in Virginia and thus exist largely at man's behest while they are here.

Freshwater Web

In the freshwater marsh, the diversity of plants rises sharply, but productivity of vegetation drops although food for ducks increases. The King Rail and Wood Duck use these areas year-round for feeding and King Rail nests in them. Freshwater marshes are also used heavily by the migrating Sora and King Rail during the fall of the year (29). The common fish-eating birds, the Kingfisher, Great Blue Heron and Green Heron, are attracted by minnows and small fish.

Productivity of fish remains high and this is part of the nursery ground of American Shad, Alewife, Blue-back and Hickory Shad. The introduced Carp (*Cyprinus carpio*) is possibly the principal species in terms of biomass. It also invades slightly brackish waters. Catfish and Eels are the chief commercial species but freshwater sport fish, including White Perch (*Roccus americanus*), Largemouth Bass (*Micropterus salmoides*), and Sunfishes (*Lepomis* species) are common. The perhaps overly-maligned Longnose Gar (*Lepisosteus osseus*) is present. This primitive fish feeds largely on Carp where the two occur together. Cyprinid minnows replace Killifish here, the Silvery Minnow (*Hybognathus nuchalis*) being one of the more abundant.

The abundance of fish promotes the population of Snapping Turtles. Painted, Red-bellied and Musk Turtles are common, every stranded log usually having its quota in summer. Snapping Turtles are inimical to the breeding of Black Ducks, largely preventing their reproduction in some areas (29). The common fish-eating birds, the Kingfisher, the Great Blue Heron and Green Heron, are attracted by minnows and small fish. Water snakes (Natrix) are present but seldom seen. Cottonmouth Moccasins occur only in Dismal Swamp and nearby parts of Southeastern Virginia. Many amphibians, from the Bull Frog to the Spring Peeper, occur in the freshwater marsh. In the Pamunkey River we found the Green Tree Frog climbing up the stalks of Wild Rice as the tide came in.

Several insects feed on the vegetation and even honey bees are common when certain marsh flowers bloom, but pestiferous insects (mosquitoes and tabanids) are scarce in comparison with the large numbers found in seaside marshes of the Eastern Shore. Since Carp are quite omnivorous, they may control tabanid larvae somewhat.

Studies conducted for five winters in a wooded swamp flooded only by abnormal tides indicate that the number of bird species resident in a swamp in winter is about twice that regularly found in winter in a mixed pine and hardwood forest. Those birds wintering in swamps include the Wood Duck, Woodcock, Winter Wren, Swamp Sparrow, Hairy Woodpecker and about 40 species also found in other habitats. Many, such as Robins and Bluebirds, are often more common in swamps. In summer, swamps are host to some of the scarcer Warblers: the Louisiana Waterthrush, and the Prothonotary, Black and White, and Parula Warblers. Complete ecological studies would likely reveal the presence of a variety of insects, spiders, amphibians, reptiles, birds and small mammals greater than that which would be found in any other woodland habitat in the State.

Cypress-Gum swamps are mainly found in Southeastern Virginia and most are not tidal. They are not found on the Pamunkey or Mattaponi but do appear along the Chickahominy and along Dragon Run. Little is known about the ecology of these swamps, but since the Cypress trees are usually mixed with hardwoods, the community is probably quite similar to that of pure hardwood swamps.

Marshes grade rather abruptly into swamps in the freshwater areas as shrubs and stunted trees give way to hardwoods and Cypress of commercial value. Many of these tidal or seasonally inundated areas still support forests of rather large trees. Den trees become increasingly scarce in a pulpwood economy and, while large trees are scarce in some swamps, those present have often fared poorly and have been operated on by the Pileated Woodpecker enough to produce nest cavities for Wood Ducks and Gray Squirrels. Raccoons may also use these or, more likely, a hole produced by rot. Swamps serve as refuges for many birds and animals during winter storms since snow usually melts more quickly in wet areas. Deer frequent swamps the year-round and probably nearly all other native mammals may occasionally be found there. A major factor in the ecology of many swamps in the last three decades has been the return of the Beaver. This industrious rodent has certainly benefited ducks, especially the Wood Duck, by creating numerous ponds, but it has also destroyed large numbers of valuable trees, such as the Red Ash.

Seaside Food Webs

The ecosystem on seaside of the Eastern Shore is likely more complex than that of the brackish nursery ground. If the world oceans constitute a single ecosystem, then one might call that of the Eastern Shore a lagoon-barrier island subecosystem, it being composed of several reasonably distinct, but nonetheless dependent, communities. Several plant communities exist, but it is the Smooth Cordgrass (Spartina alterniflora) marshes which particularly affect the whole system. The other plant communities are on the islands. The animal communities are those of the marsh, the lagoon waters, the lagoon bottoms, and the barrier islands.

The aquatic communities of seaside lagoons are strikingly different from the brackish nursery grounds and have even less similarity to the freshwater tidal community. Only the migratory fish which enter fresh water occur both there and in the lagoons. The lagoon environment differs from the brackish in having a relatively constant salinity, somewhat less extreme temperatures, a somewhat higher and more constant pH, a greater range of tides, and a greater effect of wind on the bottom because of longer fetch and shallower water. Biotically, it differs in having many more predators, probably poorer conditions for reproduction by fish because of a lack of aquatic higher plants for cover and lesser numbers of mysids and large amphipods, probably the most important foods of juvenile fish in the nursery grounds.

Probably four times as many species of fish have been found in the Eastern Shore bays as in the brackish zone of the rivers. Seaside lagoons are visited by many migratory fish which come from the ocean to feed on the abundance of lesser food fish, such as the Mummichog (Fundulus heteroclitus) and the Striped Killifish (Fundulus majalis). These small fishes eat a great variety of small benthic invertebrates and also ingest much detritus (22). Their abundance is indicated by the fact that a single sweep of a dipnet may procure more than a 10-quart pailful (32). In winter when ice covers some landside harbors, these small fish appear at small holes in the ice and are devoured by Herring Gulls.

Grant (33) found that in Indian River, Del., young Bluefish (Pomatomus saltitrix) over 90 mm (3½ inches) long had fed almost entirely on fish, Mummichogs composing 40% of the total food volume, with Silversides (23%), Menhaden (16%), and Bay Anchovies (8%) composing most of the remainder. Blue Crabs, polychaete worms and mysid shrimps were the most common invertebrates eaten. None of the eleven species of fishes consumed were sport fish, although the Eel is commonly taken by hook and line. Maximum length of the 262 Bluefish examined was 189 mm (ca. 8 inches). Six of the species of fishes eaten by Bluefish are largely demersal and commonly found in marsh creeks. Bay Anchovies and Silversides (two species) feed on copepods and other zooplankters. Menhaden switch from zooplankton to phytoplankton at an early age. The eleventh species, the White Mullet (Mugil curema) probably feeds mainly on particulate detritus. For some of these fishes, the algal productivity from the tidal flats, particularly of tychopelagic diatoms, may be more important than that from the marsh. Killifishes (22) probably depend most heavily on marsh productivity.

Some migratory fishes move in- and offshore, while others travel north or south along the coast. Several which hatch in the ocean and spend their juvenile invertebrate feeding period in the brackish nursery grounds move seaside to mature. One of these is the Black Drum (Pogonias cromis) valued as a sport fish, but not by oystermen and clammers because its principal food almost from hatching seems to be bivalves (1). Another consumer of clams and oysters is the Cow-nosed or Butterfly Ray (Rhinoptera quadriloba), a summer visitor throughout lower Chesapeake Bay.

Other migrants include: the Winter Flounder (Pseudopleuronectes americanus), the catch of which increased 33 times over the last five years; the Hickory Shad (Alosa mediocris) which has declined in numbers caught but still supports a small sport fishery on the Eastern Shore in the spring; the Red Drum (Sciaenops ocellatus) which has virtually disappeared from the commercial catch since 1966 due to a law which prohibits possession of more than two fish over 32 inches long; and the always scarce Tarpon (Megalops atlantica) which continues to be sought by sport fishermen on seaside Virginia. While the life histories of these four fish are not equally well known, the young of Hickory Shad and Tarpon are found in freshwater, while juvenile Red Drum and Winter Flounder have been taken in estuarine shallows. Migratory Bluefish (Pomatomis saltitrix), Whiting (3 species of Menticirrhus), Weakfish (Cynoscion regalis), and Spotted Seatrout (Cynoscion nebulosus) are quite certainly beneficiaries of the productivity of the Eastern Shore wetlands at some time. At times Winter Flounders feed exclusively on small infaunal amphipods, especially Ampelisca vadorum (34), a particulate detritus sweeper (35). One might expect the Summer Flounder to have similar habits, but Smith (36) found that its primary food in Delaware Bay was the Weakfish (Cynoscion regalis). Sharks which enter the bays in summer (37) likely eat some of the bony fish, further lengthening the food chain.

Analysis of a number of bottom samples for benthic infauna on both seaside and bayside of the Eastern Shore in shallow areas indicates a rather low diversity of invertebrates, similar to that found in creeks on the western side of Chesapeake Bay. A few species were abundant in a large proportion of the samples: the nereid worms Nereis succinea and Laonereis culveri; two capitellid worms which tolerate environmental stress, Capitella capitata and Heteromastus filiformis; and the isopod Cyathura. The latter and Nereis succinea typically thrive in shallow areas rich in organic debris.

Samples from deeper water in the Wachapreague channel have yielded the largest population of Ampelisca amphipods found in Virginia. Application of a pesticide for experimental oyster drill control (38) revealed the presence of a large population of the Mantis Shrimp (Squilla empusa). The food of this stomatopod is unknown but it has formidably spined pincers which appear well suited to catch small fish and glass shrimp. These predatory crustaceans, plus an abundance of Blue Crabs and bottom-feeding fishes, would tend to reduce populations of certain sedentary invertebrates. The Mantis Shrimp is a favored food of the Striped Bass.

The abundance of Hard Clams (Mercenaria) and Oysters (Crassostrea) on seaside is well known. For both species, conditions are obviously quite different from those in lower salinity areas. Hard Clams produce a much heavier set there than in Chesapeake Bay and the rivers, although it is difficult to see how predation could be less. Soft Clams are known only from the Chincoteague area where they are rare. Bay Scallops (Aequipecten irradians) seem to be coming back since their virtual disappearance along with the Eelgrass (Zostera marina) about 1931. The Scallops are still most common near Chincoteague where Eelgrass has persisted (32). Clams and Oysters feed on particulate matter originating with grass in the marsh or algae.

The Salt Marsh Cordgrass community (Fig. 13) is representative of that found in much of the marsh bordering lower Chesapeake Bay: Periwinkles (Littorina irrorata) which graze algae and detritus from Spartina stems, Ribbed Mussels (Modiolus demissus), and myriads of Marsh Fiddlers (Uca pugnax). The Square-backed Fiddler (Sesarma reticulatum) was not found but probably occurs. The Diamond-backed Terrapin, which in the early part of the century was shipped to Baltimore and New York in large numbers, is still reasonably common. However, a great many are apparently caught in crab pots where they soon drown. This terrapin feeds on salt marsh snails, probably the only creature which does so to any extent.

The most striking difference between the Eastern Shore seaside marshes and all the others is the diversity and amount of bird life. This is true at any time for the general area ,but for the marshes it is most noticeable at breeding time. Here are found the largest populations of the Clapper Rail and the only breeding sites in Virginia of the Forster's Tern, Willet and Laughing Gull. These four are the only species which nest in the Spartina marsh proper. The Clapper Rail nests in tall Spartina, laying 6-14 eggs, 9-12 being usual. Storms from the northeast frequently destroy nests, young and females (39). Laughing Gulls and Forster's Terns nest in small colonies often near each other. Both are dependent on Spartina alterniflora for their nests. The Terns, more so than Gulls, nest on the rafts of Spartina stems washed into the marsh by the highest tides of winter. Nesting success is low because a high tide usually destroys the first nest made. The young are not safe from drowning until they are feathered. Laughing Gulls gather considerable amounts of grass stems to build a nest high enough to be above the usual tide level. Willets construct nests in a greater variety of places, not only in the high

SEASIDE GRASS-BASED COMMUNITY

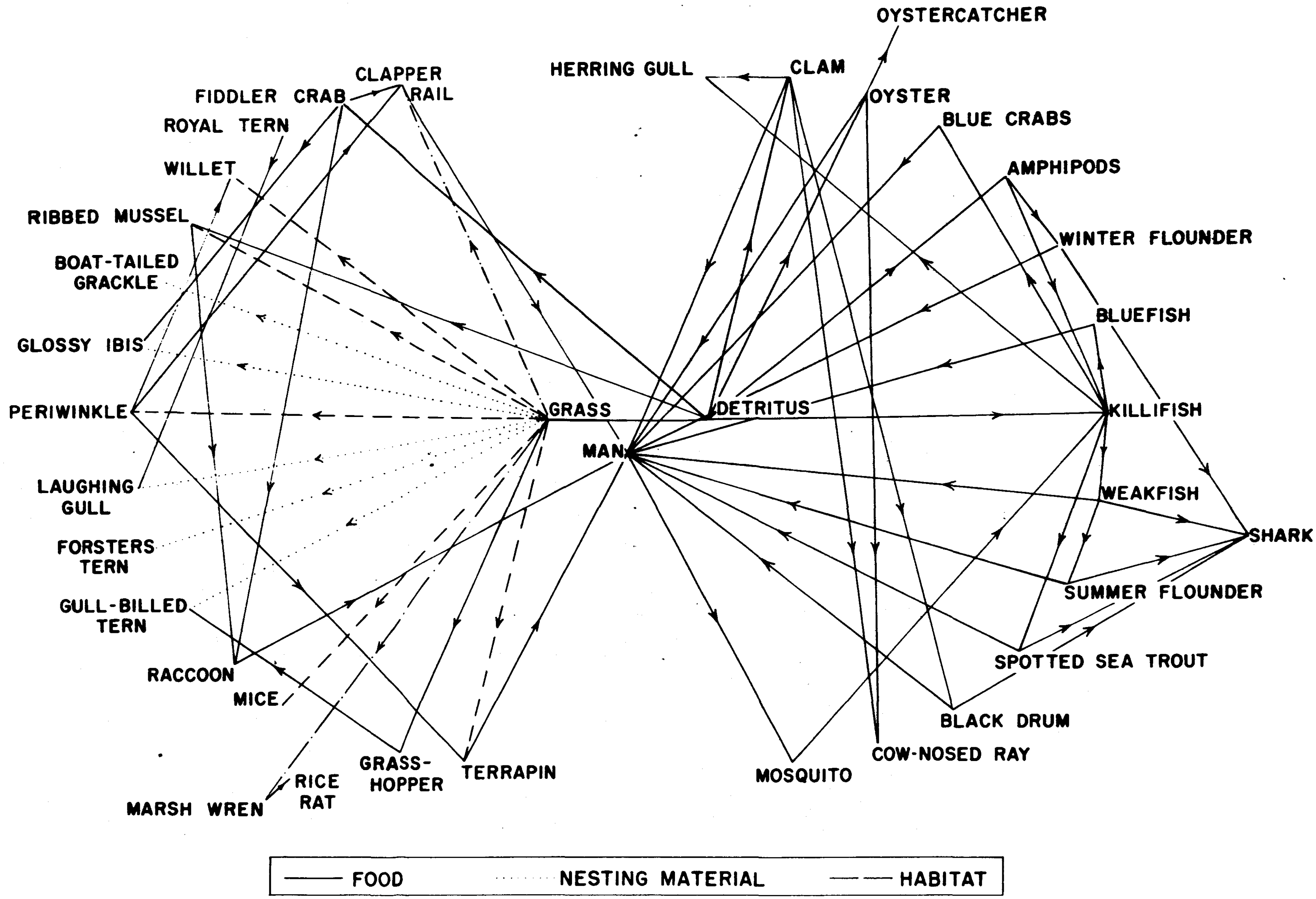

Fig. 13. Ultimate utilization of Smooth Cordgrass on the

Spartina marsh but also in the spoil bank heronries and in beach grass atop low dunes. They lay four eggs, whereas most other birds nesting on the Eastern Shore have a clutch of three or fewer. Willets are seen in marshes farther inland and may nest in some. As with all shorebirds, nests must be safe from predatory mammals. Raccoons, whose populations are now freed from pressures of larger predators, prevent the nesting of most shorebirds and seabirds on Parramore Island.

Spoil from dredging could ultimately destroy many of the tidal marshes in the State, but on the Eastern Shore seaside old spoil banks provide optimum sites for heronries. The species utilizing these sites, in general descending order of abundance, are the Snowy Egret, Louisiana Heron, Little Blue Heron, Glossy Ibis, and Black-crowned Night Heron. In 1968, young of 2,992 of these five waders were banded on the Eastern Shore by Dr. Mitchell Byrd (31). None of these species were known to breed on the Eastern Shore before 1952 (40) except the Snowy Egret which had last been reported nesting in 1883. The Glossy Ibis, of which 264 were banded in 1968, was not definitely known from Virginia as late as 1952. The heronries contain young birds from late May to mid-August, with some succession of species evident. Boat-tailed Grackles nest in the *Iva* shrubs along with the Herons and Egrets. Willets compete with the ibises for space on the ground.

The Marsh Fiddler is a chief food of Clapper Rails, Willets and Ibises. Laughing Gulls are mostly fish-eaters, not having taken to scavenging garbage dumps as have their congeners, the Ring-billed and Herring Gulls, although they have been accused of eating Tern eggs (41). Birds living on Crabs find ample food nearby but Herons, Gulls and Terns fly many miles in search of small fish. *Fundulus* species are probably their chief food. Adult water birds have no enemies on the Eastern Shore but Crows and Gulls prey on eggs and young nestlings.

The barrier islands are all used by breeding birds to some extent. The islands of Chincoteague, Cobb, Hog, Wreck and Fisherman's have supported colonies of nesting Terns and Black Skimmers. Eight species of Terns nest on the Eastern Shore. A recently formed island on Dawson Shoals off Cedar Island had a large colony of Royal Terns in 1967. Predation by dogs and Laughing Gulls caused abandonment of the Royal Tern colony on Fisherman's Island in 1968 after the first nesting had been washed away by high tides (31). In 1967, a pair of Sandwich Terns nested on this island, the first confirmed nesting on the mid-Atlantic coast in 55 years.

Two uncommon species nesting in small colonies on the beach of Cedar Island in 1969 were the Gull-billed and Least Terns. Nests and eggs of both were found on June 10 of this year, and a large young of the former was seen on July 10. The Least Tern nested at Gloucester Point, along the Colonial Parkway above Yorktown, and at Jamestown until recently, but probably now nests in Virginia only on the Eastern Shore beaches. The Gull-billed Tern formerly nested in marshes but now nests only on outer beaches, where it collects stalks of *Spartina* to outline a nest on the sand. This is likely the only place it nests north of South Carolina. It feeds almost entirely on spiders and insects from the marshes (41).

Only three shorebirds nest on the barrier islands, the Wilson's and Piping Plovers and the Oystercatcher. Wilson's Plover reaches its northern limit in Virginia and the Piping Plover probably now has its southern breeding limit there, due to human disturbance farther south. Wilson's Plover nests on shelly washover areas where its eggs are difficult to see. Less common is the Piping Plover, which nests among low dunes. Both species feed along the beach. The Piping Plover is said to feed on fly larvae, beetles and marine worms (42); thus, if it were as abundant as formerly, it might be helpful in reducing the stable flies which breed in decaying seaweed on beaches. The food of Wilson's Plover is unknown but Palmer (42) believes "fiddler crabs probably are its mainstay." Since the species does not occur in marshes, the only "fiddler" it could eat would be the Sand Fiddler or Mole Crab (Emerita talpoida) which occurs only on surf-swept beaches. The Oystercatcher now reaches its northern limit in Virginia, where it occurs all year on the Eastern Shore. In spite of its food habits, this striking bird does not seem to be maligned by Eastern Shore oystermen. It also nests on sand but seems to prefer washovers near the marsh. On June 10, 1969, at the lower end of Parramore Island, we saw one large chick, one egg buried in the sand, a second which a parent had rolled from the sand, and a third destroyed by a predator, where the tide had washed over the island the previous night.

While the number of water birds breeding on the Eastern Shore is large (probably about 15,000 pairs), it is greatly exceeded by the number which stop during migration and by those which winter. Estimates based on Christmas counts indicate that about 50,000 may winter. Numerous non-breeding shorebirds and waterfowl remain through the summer, some Arctic-nesting shorebirds remain into June, and others, such as the large Whimbrels, return by early July. The Christmas bird counts on the Eastern Shore, done by some of the most competent observers on the Atlantic coast, in 1968 listed 139 species for Chincoteague and 157 for Cape Charles. Of the latter number, 73 are species normally associated with water, beach, or marsh habitat. The three most abundant species at Chincoteague were Brant, 4,911; Snow Goose, 3,839; and Black Duck, 2,050. While Cape Charles had 6,057 Brant and 1,833 Canada Geese, the presence of 73,197 common Grackles and 4,692 Starlings is indicative of the general deterioration of the environment in the country, with Blackbirds continuing to increase while their avian predators decrease.

The disappearance of Eelgrass from the Eastern Shore seaside was drastic for the Brant which fed on it and perhaps it affected many ducks as well (43). Brant slowly changed to a diet of algae, mainly Ulva, which imparts an undesirable flavor to the flesh, and probably many of those shot now are never eaten. Disappearance of Eelgrass might also have been somewhat detrimental to fish since samples of Zostera from near Chincoteague indicate an abundant associate fauna, particularly crustaceans, attractive to small fish. A study of fish commonly found in Zostera beds has apparently not been made on the Atlantic coast but would surely indicate extensive use of this habitat by fish. A brief study of Eelgrass fauna from Chincoteague Bay revealed an abundance of isopods and amphipods, favored foods of several fish.

Small wetland communities on the Eastern Shore include the ponds which are separated by all but the highest tides from the bays. One of the largest is at the north end of Cedar Island behind the old Coast Guard Station. While this area is colorful in summer, with a skirt of yellow-green algae encircling each grassy islet, the relationship of this productivity to the greater ecosystem is unknown. On the other hand, the long pond on either side of the road on Parramore Island has a lush growth of Widgeon Grass (Ruppia maritima), a food desired by several species of ducks. From a less beneficial aspect, this pond, which had a salinity of 8 o/oo on July 10, 1969, could be producing numbers of greenhead flies (Tabanus nigrovittatus). Another pond toward the lower end of Parramore had a salinity of 39 o/oo on July 10, 1969, and supported a dense population of a corixid, an aquatic insect.

Food webs have changed little at their bases since the coming of Europeans, but at the tertiary level, profound changes have occurred, many only recently. Audubon (44) spoke of the Minks, Raccoons, Wild Cats, and three species of Hawks which preyed on Clapper Rails. Hawks are now much reduced, the Peregrine Falcon being near extinction. The Raccoon is the only mammalian predator still common. Since the Clapper Rail feeds on a variety of common primary consumers, it ought to be as common as it was when Audubon collected 72 dozen eggs in one day in the New Jersey marshes.

Most of the waterbirds known from the Eastern Shore, including 36 shorebirds and at least 50 species of ducks, geese, terns, gulls and waders, have increased since their low points reached near the turn of the century, or in the 1930's for waterfowl. A few may continue to do so but factors other than natural predation, hunting and egging are now important to the welfare of most water-dependent species. These factors include human intrusion, pollution and pesticides. The lack of natural predation on adult birds may be a detriment since disease-carriers and genetically less fit individuals will be less likely to be removed from the population.

Raccoons have benefited from the absence of Bobcats and Wolves but a lesser mammal seems to have benefited most from the lack of predators on the Eastern Shore. This is a mouse, probably the Meadow Vole (Microtus pennsylvanicus). These little rodents are abundant on both Parramore and Cedar islands. In many places on the lower end of Cedar Island, large patches of dune grass appeared to have died but a closer look revealed that the new growth was being cut off by mice which had made numerous burrows. The effect of these rodents on the sand-holding ability of the decimated dune grass, and ultimately on the backside marsh, remains to be seen.

During the summer of 1969, Dr. Kenneth Esau spent two months at the VIMS Eastern Shore Laboratory at Wachapreague. He made trips to Parramore Island thrice weekly and saw only one hawk, a Buteo. Buteos are soaring hawks and feed on rodents more so than other hawks do, except Sparrow Hawks. On a visit to a tower on Smith Island, we found a few Vole skulls in owl pellets, probably left by the scarce Barn

Owl. The Cape Charles Christmas count of 1968 listed 20 owls, including a single Short-eared Owl, the only owl which typically feeds over marshes. More significant were the 112 hawks seen, including 42 Marsh Hawks which would likely reduce the rodents considerably during winter.

A microcommunity occurs on the inner parts of the islands where rafts of Spartina stalks are stranded by receding storm tides. The stalks usually form a layer several inches thick. If the live Spartina underneath is thick enough, it will force the dead layer a few inches off the ground. This usually seems to occur and underneath the mass is formed a haven for Orchestia amphipods, earwigs, isopods and a land snail. Carabid beetles may be the principal predators here, although mice make runways under the stalks and small terrapins find shelter from the blazing sun. Probably the only benefit afforded the aquatic community by this microhabitat is the receipt of the detritus remaining from the activities of the abundant amphipods.

Numerous lesser relationships, communities, and details remain to be investigated: What happens to the energy stored by the reputedly worthless Juncus roemerianus? What causes a marshy island, like Revel's Island, to become a Red Cedar copse? What has been the effect of overgrazing by sheep, deer, goats and cattle on some of the islands? What was lost and what, if anything, was gained when Zostera disappeared? But, for the Eastern Shore, a most important objective should be the study of the full importance of Cordgrass and tidal flats to the total system, from bacteria and blue-green algae to Oysters, Bluefish and man.

Of course, since the marshes and lagoons cannot survive without the barrier islands and they have been receding at a rapid rate since records have been kept, it is also important to study means of slowing beach erosion. This would involve an analysis of the significance of the beach grasses now found on the dunes. In addition, plantings should be made of the sedge (Carex kobimugi) found on Cedar Island, of Sea Oats (Uniola paniculata) now found on the Eastern Shore only at Kiptopeke, and of the Live Oak (Quercus virginiana), as well as other plants thriving on North Carolina dunes. The control of deleterious herbivores and small expenditures for fertilizer used to stimulate desirable flora could be more economical than control of blowing sand by artifacts.

Coastal Fresh Web

Back Bay and North Bay behind the narrow barrier beach adjoining North Carolina constitute a larger habitat remarkably different from that of the Eastern Shore lagoons. Here are over 29,000 acres of shallow permanent water lacking a noticeable tide and having a salinity normally less than 1 o/oo. The area has long been known as an outstanding waterfowl wintering ground (45) but has exhibited a great variation in aquatic plant production.

An extensive study of physical factors and vegetation was conducted over a 6-year period, 1958-64, on the Back Bay-Currituck Sound area (46) by biologists of the U. S. Fish and Wildlife Service and the states of North Carolina and Virginia. During this period, the "Ash Wednesday Storm" occurred (March 7, 1962). This storm forced ocean water into the bay and raised the salinity to about 4.5 o/oo, a most fortunate coincidence for the study.

The history of Back Bay portrays an excellent example of man's ability to deteriorate productive natural systems. Before the federal government put up sand fences to build a continuous dune along the coast, there was a luxuriant growth of aquatic vegetation (46). Sea water came through the washovers every year until the fences were built about 1934. Construction of locks at Great Bridge aided in lowering the salinity and extensive dredging increased turbidity. Where at one time fishermen made large catches of Flounder, Spot, Croakers, Trout and Rock and "32 fishing crews . . . at times . . . averaged about 1,000 lbs. per week per crew," the Carp had apparently become the most common fish by 1951.

The data of the report chronicle the last upsurge of productivity in the area and follow it to an all-time low. Production of vegetation fluctuated drastically during the seven years of the study (Fig. 14). In 1958, it was 5 million pounds on a dry weight basis, 11 million the following two years, 6.5 in 1961 and back up to 11 in 1962 following the spring storm. In 1963 and 1964, it was less than 300,000 pounds both years. The cause of this catastrophe is unknown but dredging in the northern part of the bay had made the water very turbid. The action of the salt in clearing the water was possibly as beneficial as any fertilizing effect. Not only was the crop of vegetation high in 1962, but the seed crop was much greater and _Rangia_ clams produced a set for the first time in several years (47).

Old records (46) indicate a great reduction in the number of waterfowl using Back Bay but the use in winter is still impressive. The 1968 Christmas count (48) for Back Bay listed 57,500 waterfowl, 72% of which were geese and swans. Almost one-half were Greater Snow Geese, a species wintering only along the mid-Atlantic coast. The 30 species of ducks seen numbered 16,800, 80% of which were Widgeon.

Plant productivity has again increased since the study was completed. However, dredging at the upper end of North Bay is scarcely countered by the small amount of seawater pumped in. The presence of a large population of Carp also contributes to turbidity. Shooting has declined in the area but large deposits of lead pellets still cause some poisoning of waterfowl (45).

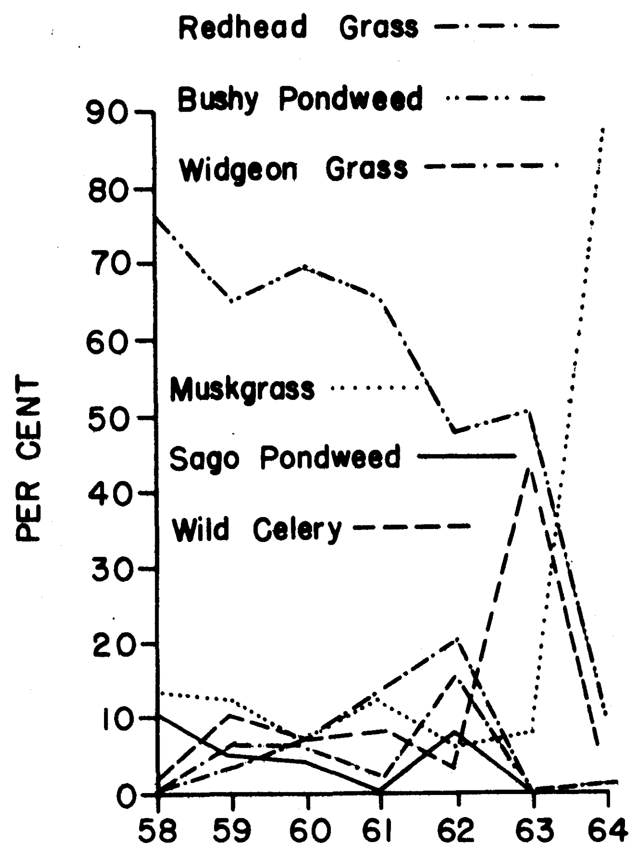

Fig. 14. Comparison of aquatic plant production in Back Bay during the 7-year period 1958-1964.

PLANT COMMUNITIES

by
G. Alex Marsh

Under a given set of environmental conditions, certain species of plants are better able to survive than others, i.e., they are physiologically and morphologically adapted to the characteristics of a particular habitat. Less well-adapted forms are unable to survive and are thereby excluded from this habitat. Competition between species is thus less pronounced under extreme or unusual environmental conditions, such as often occur in tidal marshes. Those species living within a given habitat compose the plant community, and wherever conditions of that habitat prevail, similar or closely related species may be expected to occur.

The nature of tidal marsh communities is determined by a complex of factors, foremost of which are salinity and elevation. Salinity, as a limiting factor, acts primarily on a geographical scale. From Virginia's Eastern Shore marshes up the coastal rivers to the fall line (approximately at Richmond on the James River), salinities range from full oceanic values to freshwater. Within a given marsh, elevation above mean low water apparently plays the major role in determining the composition of plant communities. From below the low-water mark to the shoreward extent of tidal excursion, plants show a pattern of zonation in accordance with elevation and consequent frequency of inundation. But just as there are gradual transitions with respect to salinity and elevation, plant communities also grade smoothly into each other, both geographically along the salinity gradient and vertically within a marsh.

For the following discussion of plant communities, I have arbitrarily divided Virginia's tidal marshes into four types: 1) high-salinity salt marshes, 2) brackish water marshes, 3) slightly brackish and freshwater marshes, and 4) swamps. Finally, a separate section is devoted to a resumé of the major floral characteristics of the Eastern Shore barrier islands. Although nearly 300 species of plants from these areas have been collected and identified over the past year, only the more important species will be mentioned here.

High-salinity Salt Marshes

Relatively few plants have evolved the necessary structural and physiological mechanisms to endure high salinities, anaerobic muds, and periodic tidal inundation. Consequently, salt marsh communities, such as those found extensively along the seaside of the Eastern Shore, are characterized by very low species diversity, and monospecific communities frequently occur over large local areas. The most abundant plant is the Smooth Cordgrass (Spartina alterniflora) which, at least between mean low water and mean high water, may be virtually the only vascular plant present. For reasons not completely clear, Spartina grows optimally in the muddy substratum near the low-tide mark and along the edge of the tidal creeks. The plants in these areas grow considerably taller than they do in slightly sandier substrates higher up in the marsh. This tall Spartina may be 4 to 5 feet high, while only a short distance away, short Spartina may not exceed a foot in height. Higher nutrient concentrations in the muddier areas may contribute to the production of the taller grass.

In their recent book entitled Life and Death of the Salt Marsh, John and Mildred Teal (49) have reviewed some of the adaptive mechanisms which enable Spartina to live in this rigorous habitat. I shall mention two of these mechanisms here to illustrate some of the problems involved with living in a salt marsh.

In order to be able to absorb vitally needed water from the conductile tissue, the plant cells accumulate unusually high intracellular salt concentrations (water will diffuse only from a region of low salt concentration to one of high concentration). The water in the sap and conductile tissues, on the other hand, is nearly salt-free. As water is absorbed via the roots, most of the salts are somehow excluded, and the few that do enter are actively secreted by special glands onto the blades. By establishment of these concentration differentials, Spartina is able to utilize water from a very saline environment, something few plants can do.

The roots, immersed in anaerobic muds, receive their necessary oxygen supplies via a system of hollow tubes extending down the leaves from small openings (stomata) on the blade surfaces. At high tide, these stomata are closed to prevent the tubes from filling with water. Excess oxygen in the roots diffuses into the mud and converts insoluble iron sulphide into soluble iron oxide which is then absorbed by the roots, satisfying the high requirement of Spartina for iron.

Above the level of mean high tide, other plants become intermingled with S. alterniflora, which becomes much less abundant at higher elevations (Fig. 15). Salt Meadow Grass (Spartina patens) and Marsh Spike Grass (Distichlis spicata) dominate those areas which are inundated only during high spring or storm tides. Also common may be one or two species of Saltwort (Salicornia sp.), a plant with inconspicuous scale-like leaves but with fleshy, cylindrical stems colored green by the presence of chlorophyll. The structural modifications of Salicornia are directly related to its highly saline environment and its consequent need for water conservation. Since leaves are the major sites of transpiration, their reduction and the development of succulent water-storage tissues are of definite survival value. The photosynthetic function is taken over by the stems. Consequently, a great many coastal plants have reduced and/or fleshy leaves, traits

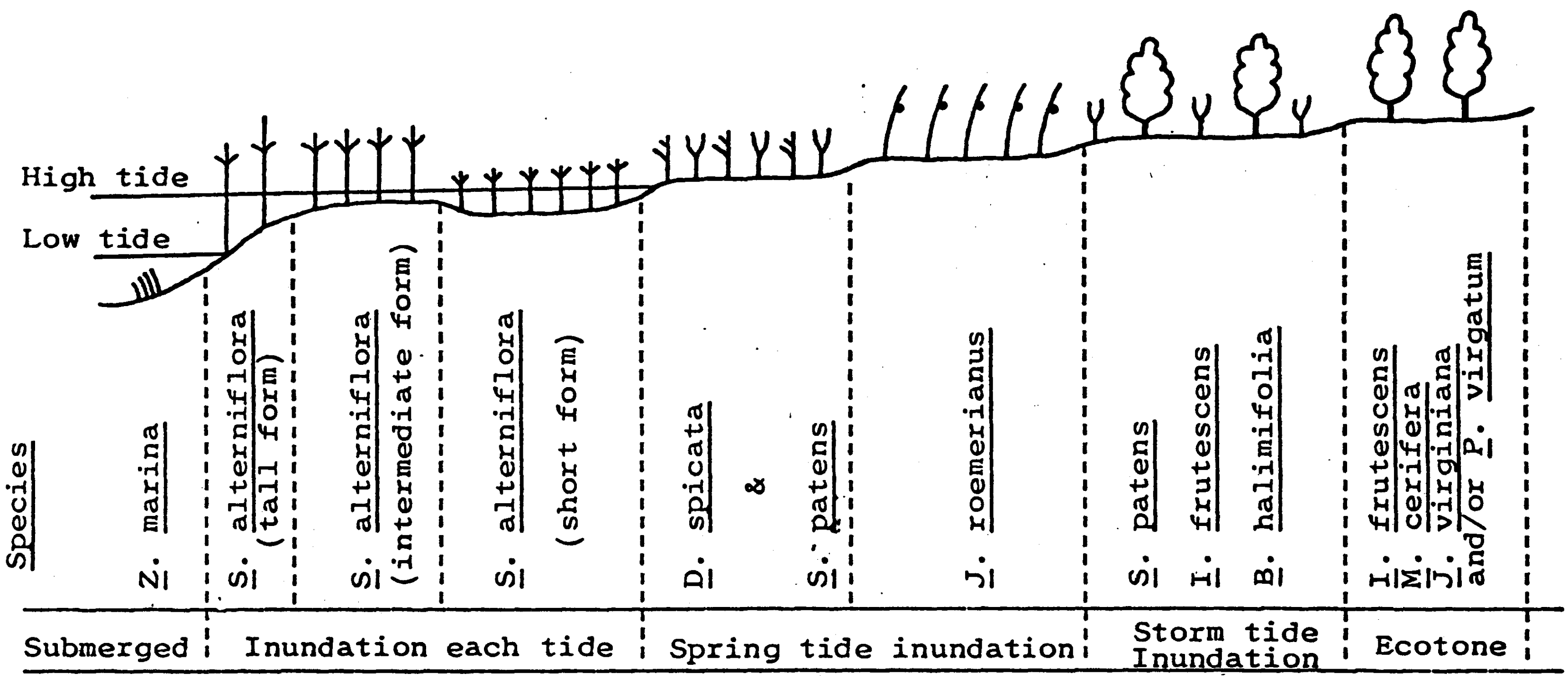

Fig. 15. Community zonation in the salt water marsh [from Kerwin (54)].

which, interestingly, are shared by most desert plants for the same reason. Black Needlerush (Juncus roemerianus) is another common plant which may occur in nearly pure stands above the mean high water level. At yet higher elevations are scattered low bushes of Marsh Elder (Iva frutescens) and Groundsel Tree (Baccharis halimifolia).

All of the plants mentioned so far have either been grasses, without flowers in the usual sense, or plants whose flowers are small and inconspicuous. More colorful species include the Sea Ox-eye (Borrichia frutescens), whose conspicuous yellow blooms are common in mid-summer, and the Sea-pink (Sabatia stellaris), whose delicate pink or white flowers may be seen among grasses of the high marsh. Sea Lavender (Limonium nashii) is also abundant in many areas.

Brackish Water Marshes

Brackish water marshes occur over a wide range of salinities and occupy a transitional zone between the true salt marshes and the freshwater habitats. These marshes are abundant along the western shore of Chesapeake Bay and extend for many miles up the coastal rivers.

Marshes in the lower portions of these estuaries contain many of the same plants found in the salt marsh. Spartina alterniflora dominates the intertidal region, while Spartina patens and Salicornia sp. are abundant in the high marsh with Distichlis, which often occurs in nearly pure stands over extensive areas. Large patches of Juncus roemerianus are also common and Iva frutescens and Baccharis halimifolia are abundant low shrubs in more elevated areas.

Many new species appear in the high levels of brackish marshes, including several kinds of bulrushes (Scirpus) and the grass Fimbristylis. Marsh Fleabane (Pluchea purpurascens) is conspicuous in late summer with its reddish flowers, and during fall the white blossoms of the Salt Marsh Aster (Aster tenuifolius) may occur among the Distichlis blades. Marsh Orach (Atriplex patula) is common in the high marsh but inconspicuous until fall when the stems, as well as the fleshy triangular leaves, turn a deep purplish-red. Farther back in the marsh, or on slightly elevated "islands," the Thoroughwort (Eupatorium serotinum) and the Partridge Pea (Cassia fasciculata) may be abundant, along with Bush Clover (Lespedeza capitata), whose dense heads of cream-colored flowers turn dark in the fall, resembling brownish pom-poms, above the shorter grasses and shrubs.

Extensive beds of permanently submerged vegetation grow frequently near the river mouths. During summer, Eelgrass (Zostera marina) forms dense meadows extending from the low-water mark into the river beds. The leafy portions of these plants break off in fall but grow back the following spring from the perennial underground rhizome systems. Widgeon Grass (Ruppia maritima) is also common subtidally in some areas.

Farther upriver in lower salinities, the vegetation becomes progressively more diverse. Giant Cordgrass (Spartina cynosuroides) replaces S. alterniflora. Distichlis spicata and S. patens soon drop out and various other grasses, rushes, and sedges become abundant. Wax Myrtle (Myrica cerifera) and Buttonwood (Cephalanthus occidentalis) commonly occur along the river banks, and the Beggar-tick (Bidens laevis) adorns the marshes in fall with its yellow sunflower-like blooms. The showy blossoms of the Rose Mallow (Hibiscus moscheutos) and the Seashore Mallow (Kosteletzkya virginica) are often conspicuous among the grasses in brackish marshes.

Slightly Brackish and Freshwater Marshes

In low salinities and in freshwater, plant diversity becomes still greater, and with the decreased tidal range, the extent of the marshes is more restricted. Both the Common Cattail (Typha latifolia) and the Narrow-leaved Cattail (Typha angustifolia) become abundant, and the Arrow Arum (Peltandra virginica) is conspicuous along the stream banks. Farther upstream, Peltandra is replaced by other aquatic species, including Pickerel Weed (Pontederia cordata), Golden Club (Orontium aquaticum), Spatterdock (Nuphar advena), and several species of Arrowhead (Sagittaria). Royal Fern (Osmunda regalis) is often common in the marsh interior and occasionally on the shore (Drake Marsh in the Rappahannock River), as are several species of Smartweed (Polygonum species) and the False Nettle (Boehmeria cylindrica). As the tidal streams narrow toward their source, their beds often become choked with Pondweed (Potamogeton species), Horned Pondweed (Zannichellia palustris), and other permanently submerged plants. The umbrella-like leaves of the Marsh Pennywort (Hydrocotyle umbellata) are frequent in moist areas away from the stream proper. Other common species in these swamps include the Water Hemlock (Cicuta maculata), Water Parsnip (Sium suave), Sweetflag (Acorus calamus), and several species of Dock (Rumex species).

Swamps

Beyond the fresh marshes lie the swamps. Perhaps less is known about these than about any other wetlands. The lower swamps, such as Cohoke in the Pamunkey, have probably never been logged. The trees, be they hardwood or cypress, grow slowly and most of the hardwoods become misshapen. Marshes are first invaded by Red Maple (Acer rubrum) and several shrubs. These are followed by Elms (Ulmus species), Red Ash (Fraxinus pensylvanica), Black Gum (Nyssa sylvatica) and, in some places, by Loblolly Pine (Pinus taeda) and Red Cedar (Juniperus virginiana). As the land becomes elevated with time, plant diversity increases. Spring Beauty (Claytonia virginica) and many species of sedges (Carex and Cyperus species), violets, marigolds and crucifers carpet the damp ground. Wild Plum (Prunus americana) blooms in April at the water's edge. Red Birch (Betula nigra), Tag Alder (Alnus serrulata), Black Willow (Salix nigra), Sweet Gum (Liquidambar styraciflua), Sycamore (Platanus occidentalis) and Persimmon (Diospyros virginiana) are but a few of the trees in the mature swamp. In summer, a few rare orchids may be found. Shrubs are often uncommon in the hardwood swamp and one can often walk more easily here than through upland hardwood.

Barrier Islands

The vegetation of Virginia's outer barrier islands (Fig.16) is quite variable, ranging from extensive Loblolly Pine and Oak-Maple forests on Assateague Island to the relatively barren stretches of dune grasses and shrubs predominating on some of the smaller islands to the south. Floral studies have previously been conducted on several of these islands, including Assateague (50), Parramore (51), and Smith (52). Additional studies have been carried out by VIMS personnel over the past year.

Assateague Island

This northernmost of the barrier islands straddles the Virginia-Maryland border and was not visited during this study. The following report is based on Harvill's (50) publication, which recorded a total of approximately 130 plant species. On the seaside of the island are extensive sand dunes, largely built by the Chincoteague Wildlife Refuge and maintained by plantings of Beach Grass (Ammophila breviligulata). The dominant plant on the stabilized dunes is Loblolly Pine (Pinus taeda). Associated with P. taeda are Wax Myrtle (Myrica cerifera), Bayberry (Myrica pensylvanica), Spanish Oak (Quercus falcata), Sassafras (Sassafras albidum), Black Cherry (Prunus serotina), Holly (Ilex opaca), Hercules Club (Aralia spinosa), Flowering Dogwood (Cornus florida), and a number of herbaceous species providing ground cover.

In swampy depressions between dunes, Red Maple (Acer rubrum), Black Oak (Quercus nigra), and Black Gum (Nyssa sylvatica) are dominants, while less common woody species include Red Bay (Persea borbonia), Sweet Gum (Liquidambar stryaciflua), and Red Chokeberry (Sorbus arbutifolia). Among the abundant herbaceous forms in these swamps are Royal Fern (Osmunda regalis), Cinnamon Fern (Osmunda cinnamomea), Netted Chain-fern (Woodwardia aereolata), and Black Willow (Salix nigra).

Much of the Virginia end of the island has been modified by refuge operations. Harvill recorded 88 species from this area, including Pluchea purpurascens, which formed the most striking community in the disturbed marshes.

Cedar Island

Cedar Island is located opposite the town of Wachapreague on Virginia's Eastern Shore. It is approximately 6.5 miles long, bordered on the east by sandy dunes and on the west by mudflats and Spartina marshes. The island is heavily wooded only on its north

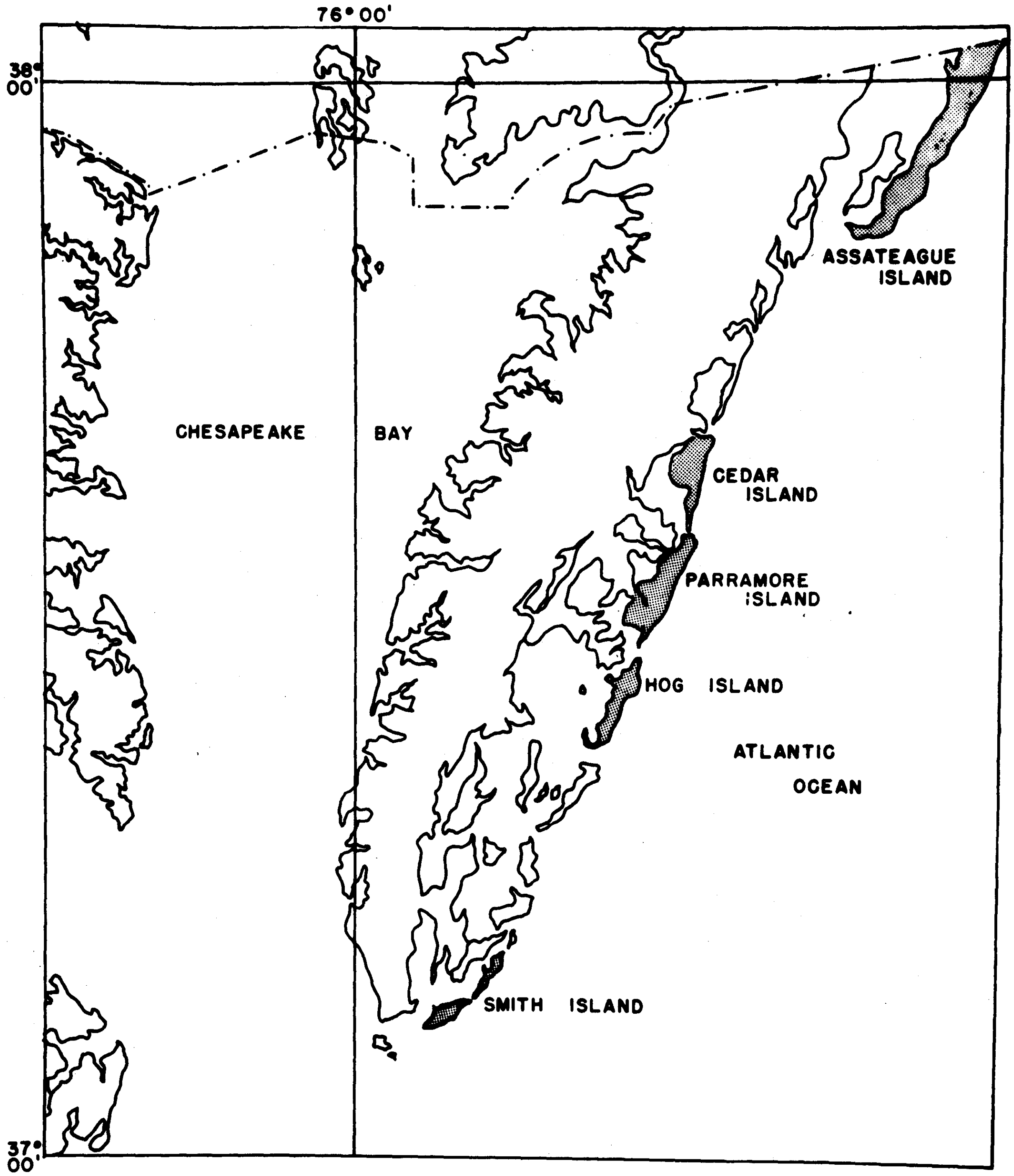

Fig. 16. Islands from which flora is reported on the Eastern Shore of Virginia.

end, with Loblolly Pine, Red Bay, Wax Myrtle and Red Cedar being the dominant woody species. Most of the island consists of low dunes and swales containing numerous herbaceous xerophytes.

Three collecting trips were made to Cedar Island during the summer of 1969; over 50 plant species were collected and identified, most of them from the southern portion of the island. Dune vegetation consists primarily of Beach Grass (Ammophila breviligulata), Russian Thistle (Salsola kali), Sea Rocket (Cakile edentulata), and Sandspur (Cenchrus tribuloides). Spurge (Euphorbia polygonifolia) also occurs here. In the swales behind the dunes, Seaside Goldenrod (Solidago sempervirens) is abundant, along with Teucrium canadense, Strophostyles helvola, Hog Peanut (Amphicarpa bracteata), Pennywort (Hydrocotyle verticellata), and Evening Primrose (Oenothera humifusa). Two species each of Sabatia (S. stellaris and S. brachiata) and Erigeron (E. bonariensis and E. pulchellus) are also common. Iva frutescens, Baccharis halimifolia, and Myrica cerifera are abundant along a low dune ridge on the back side of the island.

Parramore Island

Parramore Island is located south of Cedar Island and is second to Assateague as the most heavily wooded of the barrier islands. It is approximately 8 miles in length. Extensive marshes border the island to the west, while a series of dunes occurs along the seaside. Harvill (51) recorded 25 species of plants from Parramore occurring in six major communities. Thirty-five additional species have been collected and identified over the past year.

The dominant plants of the sand dunes are Ammophila breviligulata and Panicum amarum. Associated with these grasses are Salsola kali, Cenchrus tribuloides, Cakile edentulata, Atriplex arenaria and Euphorbia polygonifolia. In the swales behind the dunes are Scirpus americanus, Myrica cerifera, Iva frutescens, and numerous less common species. A low forest in the interior of the island consists primarily of Pinus taeda, Juniperus virginiana, Myrica cerifera, Ilex opaca, Persea borbonia, Prunus serotina, and Xanthoxylum clava-herculis. Common climbing species are Berchemia scandens and Mikania scandens.

Hog Island

Hog Island is located immediately south of Parramore Island. A single collection trip was made in August 1969. On each side of the road leading from the former Coast Guard Station across the island to the beach were low-lying areas and shallow-water ponds. The more common plants along the roadside and in these flats were collected. Myrica cerifera occurred at the northern end of an elevated wooded ridge which appeared to run the length of the island.

Spartina alterniflora and Spartina patens were common in the flats as well as Distichlis spicata and two species of Salicornia: S. europea predominated in the inundated areas, while S. virginica was confined to drier habitats. Along the roadside, Iva frutescens, Pluchea purpurascens, and Borrichia frutescens were common. Also present were Strophostylis umbellata, Daucus carota (Wild Carrot), Solanum carolinense (Nightshade), and Sabatia stellaris. On the dunes along the beach, Ammophila breviligulata and Salsola kali were dominant.

Smith Island

Smith Island is the southernmost of the barrier islands, located approximately 2 miles east of Cape Charles. A single collecting trip was made in August 1969. Falling tides permitted only a short stay on the island, but a number of plants were collected in the vicinity of the abandoned lighthouse and along the shore near the old landing. The southern end of the island consists primarily of low Spartina alterniflora marsh with interspersed islands of Persea borbonia, Juniperus virginiana, Myrica cerifera, and Phytolacca americana.

The ground in the vicinity of the lighthouse was carpeted with vines of Centrosema virginianum, Campsis radicans, and Strophostyles umbellata. Other common species were Iva frutescens, Achillea millifolium, Asparagus officinalis, Oenothera sp., Baccharis halimifolia, Prunus serotina, and Lepidium virginicum. Between the lighthouse and the landing, the most conspicuous flowering plants were Phlox drummondi and Monarda punctatum, with Chenopodium ambrosioides also common. Sea Lavender (Limonium nashii) and Salicornia europea were abundant in the upper intertidal zone. Phlox drummondi, Centrosema virginianum and Achillea millefolium are new additions to Clovis' (52) list of Smith Island flora.

FLORISTIC NOTES

While our botanical efforts were mainly concentrated on standing crop studies and basic community associations, we were also interested in adding to the herbarium collection of marsh plants at VIMS. The original collection had been made by Dr. Alton M. Harvill of Longwood College during a summer association with VIMS in the National Science Foundation RPCT program. It was our desire to obtain an herbarium specimen for each species, particularly the most common. Mrs. Allene Barans began the work of identification in May 1969 and was succeeded by Mr. G. Alex Marsh in July. At summer's end, the accumulated grasses and sedges and a few other plants were sent to Dr. Harvill for identification. He placed the 148 specimens in 75 species.

The general paucity of information on wetlands flora, particularly for those counties not bordering the ocean, was made evident by a check of the list produced by Massey (53). The knowledge of the flora seemed to diminish rather evenly up Chesapeake Bay, Northumberland County having only three plants listed from wet sites by Massey; these three included two ferns and a blueberry, scarcely typical wetland plants.

Upon comparison of the 272 species collected over the past summer with those listed by Massey, it was noted that 201 were new records for their respective counties. These new records are indicative of our spotty sampling and of a tendency to study areas nearest to VIMS and to its Eastern Shore laboratory. Gloucester County had 79 new records, Essex County 56, Mathews and Accomack 35 each, and New Kent 32, with the remaining records scattered among nine counties. Plants collected in Accomack County were from Cedar and Parramore islands and mostly not from marshes.

As the occurrence of new species appears to be somewhat proportionate to the extent of investigation, it seems clear that an accurate compilation of wetland flora in Virginia would require a considerable amount of further investigation. Our specimens will be made available to botanists working on a Flora of Virginia.

Rare or Unusual Plants

Some of the plants we found were not previously known from counties bordering Chesapeake Bay; others were known by only one to a few records for the State. Our most interesting find was identified by Dr. Harvill as *Carex kobimugi*, a sedge introduced from the Orient. While it turned out to be only the second record for Virginia, the first being from Princess Anne County, its interest to us was in the place where it occurred and in its growth habit. It was discovered growing on Cedar Island, Accomack County, where it covered an area about 40 feet in diameter. It appeared to have been there several years, slowly spreading out by means of stolons. The low blades were yellow-green and contrasted with the brown seed heads left from the year before. Most striking was the obvious way in which its tough blades had stopped the blowing sand so that the whole stand occupied a low hummock. No other large plants were noticed growing with it. This sedge was introduced from Japan and, while it must spread very slowly by seed, a single seed obviously reached Cedar Island. It would appear that this species would be of great value in holding shifting sand behind the foredunes on the barrier islands.

Another interesting discovery was of two small stands of Live Oaks (Quercus virginiana) in Mathews County, one on the island at New Point and the other farther up the coast at the New Point Campground. This species has previously been reported from the Eastern Shore, but it was probably a single waif. Those oaks on the New Point island are, in general, quite healthy and capable of stopping much sand, but many have already been killed by the encroaching sea. The whole tiny island could disappear in 10-20 years since at least 100 yards of water now separate it from the lighthouse. An additional 36 species of plants were found on this island. Heretofore, Live Oaks were not known from north of Ocean View in Norfolk.

Most wetlands are dominated by grasses and sedges which may be striking in their luxuriance but not very colorful. Brackish and fresh marshes, however, often contain showy flowers. Most striking to us was the finding of several Turks-cap Lilies (Lilium superbum) in Hoskins Creek, one of which was 220 cm (86 inches) tall. Massey (53) listed this lily as found "in woods and wayside."

EROSION CONSIDERATIONS

Erosion in History

Although the Appalachian mountains were eroding eons before Europeans arrived at their foothills, had the valleys, hills and plains been losing soil throughout the geologic history of these mountains at the rate attained since John Smith's successful arrival, there might not even be a piedmont area today. Increased erosion of land following development of intensive agriculture is well documented (55). The Indians undoubtedly accelerated erosion slightly with their "fire-hunting" and primitive agriculture, but it was the intensive tillage required in growing tobacco, cotton and corn which did the most damage. The account of Gottschalk (56) particularly deals with the upper Chesapeake Bay but also contains much information from Virginia. This interesting report should be required reading for everyone concerned with the Chesapeake Bay. Gottschalk devotes three pages to sedimentation in the Potomac: In the 5-year period 1886 through 1891, the annual sediment load of the Potomac was calculated at 5,557,250 tons. The Potomac flood of April, 1937, carried 2,210,000 tons in five days. The importance of the natural catastrophe which may come but once in a lifetime is evidenced in the testimony from Congressman Lewis in 1804 when he spoke of the great ice jams which followed the hard winter of 1783-4. The ice, together with the flood torrents, considerably rearranged the Potomac channels. By 1941, $5,000,000 had been spent for dredging in and near the District of Columbia, over $2,000,000 of this being for maintenance. George Washington wrote in 1793 of the ". . . inexhaustible fund of rich mud (that) can be drawn as a manure" from the shallows and marshes along Mount Vernon. Dumfries, Va., county seat of Prince William County, and located on Quantico Creek, was once a flourishing tobacco port, as was Port Tobacco, Maryland, on the Port Tobacco River. Today, construction erosion is filling many of the upper tidal Potomac streams and embayments (57).

Gottschalk (56) comments that in 1905 the remnants of an attempted canal from Dumfries to deep water was still evident as a ditch 30 feet wide and 1 foot deep. There does not seem to be any indication of this canal at present. Between Dumfries and the Potomac, there is essentially no water deeper than 2 feet in a 3.5-mile section of stream; indeed, there is almost one mile of marsh and 0.5 mile of mudflats (U.S.G.S. topographic map, Quantico, Va.-Md., 1956). Neabsco Creek offers a similar situation in that the creek (U.S.G.S. topographic map, Quantico, Va.-Md., 1956) is less than 1 foot deep from its mouth to U. S. Route 1 (2 miles). Gottschalk (56) states that the creek was once navigable and ocean-going ships were built on its banks. The now silted creek valley was then 0.4 mile wide, the confines being clearly evident on the topographic map.

Perhaps the most interesting and different of the three erosion studies we have read is an unpublished report by two workers with the Soil Conservation Service, Frank D. Eastham, then at Warsaw, Va., and William A. Phillips at Franklin, Va. (58). This work gives some history of major erosion: Maryland lost 25,000 acres in 90 years; 125 feet of the Yorktown Surrender grounds have washed away; the isthmus connecting Jamestown Island to the mainland had disappeared before the Revolution and by 1900 the site of the original fort had vanished; Wakefield and Stratford plantations "are losing enormous quantities of timber and farmland"; many colonial cemeteries have washed away, that of Augustine Washington's family being "now but a dozen steps from the Potomac."

One does not have to look far to see evidence of the dynamic force of wind and water on Virginia's shorelines. Along the Poropotank River, one can see obvious erosion of deep peat banks at the mouth and evidence of sedimentation farther up where an old corduroy road is covered with 2 feet of silt at one point. At low tide submerged logs and pulp sticks obstruct passage from well below Miller's Landing. In colonial times lumber was brought up the Poropotank to build a mansion at a point above where a rather small bridge on Highway 14 now suffices to cross a creek no longer tidal and scarcely negotiable by a canoe (59).

On Timberneck Creek near Gloucester Point, the upper end continues to fill in (60), while a few miles below on the shore of the York River, a senior citizen told us that when he built his home there, the shore was covered with shrubs and grass. As soon as he and his neighbors cleared the shore, erosion began and 40 feet of shore was lost before seawalls were built. These were mostly flimsy, leaked soil in storms and did not present a pleasing view. Most structures built by owners have probably failed within a decade or two.

Erosion Today

Eastham and Phillips (58) defined the problem in saying: "Millions of dollars have been spent . . . to control erosion of these shores--often to no avail. Many structures are poorly conceived, improperly built, or constructed of poor material." They further said that properly designed structures may cost $100 per foot and that "Most landowners simply move back as the river moves in."

The enlightening part of their paper is the report of their research with grass as an alternative to expensive seawall and groin construction. They report the finding in 1955 by the supervisors of the Northern Neck Soil Conservation District of an erosion control method instituted by Mr. Fred Durham at his place on the Rappahannock River in Richmond County. "In 1945 Mr. Durham set out two rows of cordgrass (*Spartina patens*) about 800 feet long . . . (and) 2 feet apart . . . along the water edge at high tide." By 1960, this grass strip was "about 30 feet wide and two feet higher than the present beach." In addition, whereas the high tide had reached the base of the riverbank when the grass was planted, it now stopped 40 feet from the bank. This grass strip had weathered Hurricane Hazel without loss while other banks lost 8 to 20 feet in this storm.

Eastham and Phillips experimented with three salt-tolerant plants--Spartina patens, S. alterniflora and Needlerush (Juncus). S. alterniflora was planted up to mid-tide mark, S. patens to the 3-foot level, Bermuda Grass to 10 feet, and Kentucky 31 Fescue above that. While the authors declared that "The District supervisors are gratified over the results," this report or the authors are not mentioned in the "Virginia Tidal Riverbank Erosion Survey" (61), and the only reference to use of plants is the sentence "Bank sloping, along with various kinds of salt-tolerant vegetation, have also been tried." Nor is any reference to cost of structures made. Copies of this report were handed out in conjunction with a field trip in that area earlier this year, during which only one type of control was shown, that of bulkheading.

Erosion Prevention

Marshes represent the ecological climax obtainable on intertidal substrates. They are nature's way of stabilizing soil banks and protecting the high land. Marshes do for estuaries and coastal lagoons what dunes do for barrier islands. Marsh plants act as a baffle to slow tidal currents and flood waters (62) and as substrate collectors of clay particles. After Hurricane Camille, upriver marshes were covered with flood-borne fine sediment, yellowish-brown in the James River (63), gray-brown in the Pamunkey and upbay tributaries. The fine particles adhere until rain water washes them down to the marsh surface where they accrete or are flushed into creeks by rain and high tides. Upriver swamps catch much of the coarse material before it reaches the marshes.

Just as the coastal beaches build higher and toward the water in summer, so, too, do the marshes build upward and outward in summer. Coastal land masses subjected to longshore currents greater in one direction will be abraded in that vector and added to on the downcurrent side. Thus, the strong northeast winds of winter cause the sand-bar barrier islands of the mid-Atlantic states to move slowly southward. In tidal rivers the tendency is somewhat to erode the upper ends of marshes and aggrade the lower ends. But this obvious action is greatly modified by the ability of marsh vegetation to hold even the finest of sediment and ultimately to fill most of the tidal basin with marshes which alternate in their high land base to shore, producing meanders which greatly lengthen the channel. Currents strike the land at the river bend with erosive force, although in forested regions trees toppled into the water at these points catch larger flotsam and dampen the current.

Ebb tide currents are stronger than those of flood tides (10), an effect enhanced by added land runoff in late winter and spring. Shores of some marshes with a long fetch from a northerly direction, as those at the mouth of the Poropotank River, are obviously eroding. Flood waters may add enough drifting debris and sand to the stream side of a marsh to allow the growth of trees which, by their roots, help anchor the marsh. The activities of Beavers are slowly destroying the trees in some transition marshes.

Records indicate that much land along Virginia's shore has been lost in historical times and that this is continuing, perhaps even accelerating. Along the banks of the Rappahannock and its tributaries and along the south bank of the Potomac, annual loss along 951 miles of shoreline is estimated at 50 acres per year, although about 30 of these acres are eventually redeposited elsewhere. Even with redeposition, the value and utility of the land involved is almost always much less than the value in its original site (61).

Interestingly enough, the land that is lost annually in these areas from solid bank is equal to that from marshes and sandspits (0.05 acre/mile/year), although marshes and sandspits accrete more land than do solid banks (0.03 and 0.02 acre/mile/year, respectively). This is somewhat misleading in that the areas lost and gained by solid banks and marshes are not volumetrically equivalent. The loss of an acre of solid bank represents the loss of much more material than the loss of an acre of marsh; similarly, it would seem that accretion of an acre of solid bank would represent a greater volume of material than an acre of marsh, although it is not clear how such accretion could take place naturally. It is quite possible that the solid bank accretion mentioned in the report refers to material that is placed behind bulkheads and other structures, rather than true solid bank.

Loss of fast land is also very evident in places along Chesapeake Bay, as at New Point in Mathews County. In the Big Salt Marsh, Poquoson, Va., one can now see marsh grass growing where the old corn rows are quite visible, and just off this marsh at the mouth of Back River, the steel pier built during War II is now about 300 yards from shore (64). Some of this land has been marshland or, as on seaside, has affected the marsh by washing sand inland to cover it. Since sea level is rising at a rate of 10-15 inches per century along this coast (65), wetlands must either move inland or grow upward to maintain their existence.

Some river marshes, e.g., Hunter Marsh in the Rappahannock River, have accumulated a bed of silt and organic material over 30 feet thick above the Pleistocene blue clay. Each large river marsh is a former valley filled with peat, unconsolidated organic ooze and fine particles, the whole rimmed by coarser, more compacted sediment. The rate at which sediment accrues in a marsh depends on the type of vegetation, extent of the marsh and several other factors (66). Since sea level was once about 300 feet lower than it now is, it is obvious that tidal wetlands have moved inland and upward considerably. This process can be seen occurring along the lower end of Parramore Island where the old marsh bed of peat, with long dead stalks of Distichlis and Spartina evident, is slowly breaking up as it is first uncovered from beneath the receding dunes and then undercut by the waves.

In Virginia, erosion of the land, as evidenced in marshes (55), can best be seen in the longer tidal creeks, where homes built on navigable water in colonial times are now inaccessible by an outboard-powered skiff except on high water. More graphic is the protrusion of corduroy roads in many places. These pole or slab road beds may be covered to a depth of 3 feet by sediment. Although the age of these roads is unknown, they are probably less than 200 years old. Thus, as much as 5,000 cubic yards of soil per acre has been added to these marshes. One would have to date these logs to learn when the deposits were laid down. Agricultural erosion has likely lessened greatly in recent decades in the State due to abandonment of land, although one can still see dairies and piggeries contributing to erosion of river-banks. The amount provided by other sources--highway construction, breaking of pond dams during floods, bulldozer activity in mountain forests, and city storm sewer runoff--may be increasing. Sediment will settle out in the quietest water, which is likely to be at the creek heads. While a marsh would have to accumulate about 3 cubic yards/acre/year of sediment to keep pace with rise in sea level, the amount added to some creek marshes since the advent of Europeans is far in excess of the amount needed. Some of this high marsh, as along Taskinas Creek, is now quite barren of vegetation, while nearby Giant Cordgrass marsh flooded daily has a high yield.

Since sediment continues to enter the estuary from the headwaters and shores, the need to remove it continues. Material removed in shell and gravel dredging enlarges the tidal prism slightly but does nothing to deepen channels or alleviate sedimentation. The need for dredging is particularly crucial in Hampton Roads. Had it not been for the thousands of acres of marshes and shallow creeks in Virginia, the problem of siltation would likely have been much worse than it now is. This is illustrated by the action of the marshes on the James River between Richmond and the estuary. Here we find 25,390 acres of marsh and open creeks that operate as sediment traps. These trap an estimated 76,200 tons of sediment each year, or about 6% of the total sediment load of the river. The 17,676 acres of swamp in the area also trap some sediment, but the amount is unknown and is probably less per acre than that trapped by marshes. In rivers having smaller watersheds and greater marsh areas, such as the York and Rappahannock, the amount of sediment trapped in the marshes is even greater than 6% of the sediment load.

There is some evidence that the trend of wetlands toward an increase in high marsh may be reversing. However, this is resulting in the loss of the intermediate level marsh, mainly *Spartina cynosuroides*, rather than the highest marsh. The theory of Mr. Charles Gilchrist that this erosion results from the activity of Carp is based on years of experience and is borne out by our meager observations. It is well known that Carp destroy submerged aquatic vegetation in other areas. Carp do not ordinarily eat plants, but in their agitation of the mud for invertebrates and during spawning, they stir the less consolidated material and allow water currents to carry the sediment away. From the Route 360 bridge on the Coan River, we observed Carp stirring up yellow clouds of clay whenever they moved. Snow Geese and Muskrats may also accelerate this process. Mr. Ray Miller of Williamsburg has seen a marsh on the

Chickahominy River change in 20 years from dense Giant Cordgrass to a deep wet marsh of Pickerel Weed, Arrow Arum, and some Wild Rice. Lessening of erosion from the land could affect silt accretion by marshes but some force other than compaction would be required to account for lowering the level. If accretion does not balance sea level rise, the marsh will be lowered (relative to sea level).

Creeks are the main arteries of marshes. Nutrients are brought in and organic excess is carried away. Creeks are characteristically shallow at their mouths, deeper and with steep banks within the marsh. Where Uca minax (Red-jointed Fiddlers) or Sesarma reticulatum (Square-backed Marsh Fiddlers) are active, the banks may be bare and eroded. Burrows of the Crabs likely contribute to this and Raccoons aid it by digging out the Crabs. The fine cohesive sediments of marshes, when held by the fibrous roots of Spartina, allow a dynamic equilibrium which prevents lateral expansion by creek currents or encroachment of vegetation (67). Without the resistant material confining the channel, erosion would rapidly alter the channels. This can be seen on the Eastern Shore where the mudflat channels are broad and less meandered than are those of the marshes.

Spartina alterniflora is not confined to typical marshes. It also occurs as a fringe along hundreds of miles of Virginia shoreline where it has been effective in preventing erosion, particularly of sandy shores. The presence of Eelgrass (Zostera marina) in the shallows offshore from the Spartina aids in erosion prevention by slowing waves and piling nutrient-rich grass over the Cordgrass. This vegetative debris aids in building shallow peat and provides a wind and flotsam break of Marsh Elder (Iva frutescens) and Groundsel Tree (Baccharis halimifolia) shrubs. Longtime residents of rural Tidewater Virginia realize the value of a well-grassed beach. Newcomers prefer sand to coarse grass and sharp Mussel shells. Many are those who could happily afford to defoliate and slope the beach but sadly could not pay for a substantial seawall needed to protect the rapidly receding shoreline which resulted.

Nowhere is Saltmarsh Cordgrass more important and extensive than on seaside of the Eastern Shore. Here, normal tide range is as great as 4 feet and the range of storm tides may be 7 feet above MLW. The extensive mudflats in these bays, about 66,500 acres, were once stabilized by dense Eelgrass in the shallows. This grass disappeared about 1931 and is moving south from the Chincoteague area very slowly. This leaves the Cordgrass and Oyster rocks as the main stabilizing influences and there is a considerable shifting of channels in the larger bays. The Spartina seems able to hold the area it now occupies but unable to colonize the mudflats which may be higher than the creek banks where grass grows the tallest. Dense turbid plumes emanating from inlets are visible on high altitude aerial photographs (63) of the Eastern Shore seaside. Just how much soil is actually being lost is unknown. Part of the turbidity would certainly result from normal seaward movement of Cordgrass detritus. While erosion of the barrier islands and the recent building of a sizable island at Dawson Shoals are quite evident, it appears that the marsh-lagoon system behind them is quite stable. Danish marshes (68) are in equilibrium during quiet climatic periods but storms upset this regime until the system can readapt itself.

Marshes act as a buffer not only in prevention of erosion but also in stabilizing water flows. Peat is an excellent water absorbent and silt-clay particles also retain water if not too compacted. Tides are several inches higher in the upper parts of the tributary rivers than they are at the mouths, and were it not for extensive marsh development upriver, those sections would experience stronger tidal currents than they now do. The marshes absorb and release the water slowly. In periods of low flow, the marshes, being rich in impermeable clay-silt sediment, may aid in detering intrusion of salt water into aquifers. If drawdowns of the groundwater table occur, the presence of marshland with a deep peat or muck base possibly contributes most of the rain falling on it to groundwater rather than to the estuary.

EVALUATION OF WETLANDS

General Considerations

For a number of reasons, the placing of values (especially monetary) on wetlands is a difficult and controversial matter. Problems are encountered not only with evaluation of intangibles and aesthetics but even with tangibles.

One of the most important problem areas relates to the ultimate disposition of the goods, such as finfish and shellfish, that are either produced by the wetlands or which in some way are dependent upon the wetlands. Because of the complex inter-relationship of the wetlands and the estuary, most of the material produced by the wetlands is harvested far from the source of production.

The trophic relationships involved are often obscure. Bluefish are not commonly thought of as being closely tied to marshes; however, the Menhaden which constitute a large proportion of the food of Bluefish are somewhat dependent on the marshes (22). Since fish and other organisms, as well as detrital material originating in the marshes, are apt to be distributed throughout the estuary and even offshore, it is virtually impossible to state that a given group of organisms is entirely dependent on a specific marsh. It is quite easy, on the other hand, to generalize and state that without any marsh there would be but few Menhaden, Croaker, Diamond-back Terrapins, Spot, or other species. As a consequence, there is no lack of agreement that marshlands are of the utmost importance in the maintenance of estuarine fisheries and other facets of the economy of estuarine areas. There is serious disagreement as to how this importance can be measured and, more significantly, how the value of fisheries may be translated to the value of wetlands.

A second problem area concerns the techniques and method of approach in assigning values to marshland. The most basic approaches are those of August (69), Brown (70), and Critchen (71), who have taken the value of appropriate parameters, such as sport fishing, recreation, commercial fisheries, etc., and arrived at a summation which is presumed to represent the value of the resource. August (69) has further refined this sum by relating it to marshlands. He concluded that each acre of Maryland marshland produced biological values worth about \$200/year. Although details of computation are not given, one can infer his approach and apply it to the data of Brown (70) and Critchen (71) who studied North Carolina marshes:

Value ($)	Activity	Year
32,000,000	sport fishing	1966
65,800,000	consumer value of seafood[1]	1965
9,660,000	recreation[2]	1966
500,000	raw pelts[3]	1966
600,000	waterfowl hunting[4]	1965
Total $108,560,000		

Since North Carolina has 206,350 acres of marshes, a production of about $525/acre/year is indicated. Because not all of the activities listed are entirely dependent on marshes, a more conservative approach should be followed; moreover, as will be seen later, the expenditure attributed to sport fishing and waterfowl hunting may be quite high, as is true for the net consumer value of seafood, where a sevenfold increase was assumed. If only one-half of the yield is attributed to wetlands, about $250/acre/year are produced by North Carolina marshes. If the approach is valid, this estimate may be reasonable, since climatic and other factors are such that overall production in North Carolina should be somewhat higher than in Maryland. The estimate is quite comparable with that for Maryland.

The approach used for the estimation of wetlands value for Maryland and North Carolina may also be applied in Virginia:

Value ($)	Activity	Year
144,200,000	commercial landings[5]	1968
1,350,000	waterfowl hunting[6]	1967-68
200,000	furs[7]	1967-68
36,001,580	sport fishing[8]	1965
4,000,000	recreation[9]	1967-68
Total $185,751,580		

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1 This is the estimated net consumer value of the resource.

2 Recreation value is based on 1,932,000 visitors at Cape Hatteras National Seashore and Fort Macon State Park @ $5 each.

3 To be comparable with the net commercial fishery value, this figure should be about $3,500,000; as there is no information on turnover, it will be left at the raw fur value.

4 This is waterfowl hunting on Currituck Sound and several salt marsh impoundments only.

5 This figure has been modified from U.S.D.I. (C.F.S. publication 5000) estimated values of Virginia fish and shellfish landings in 1968 by assuming a sevenfold turnover (Brown, 1967).

6 From VIMS Factfolder, December 1968.

Footnotes Continued Next Page

This leads to the estimation that $1,050/acre/year are produced by Virginia marshes. If, again, a conservative approach is taken and only one-half of this is attributed directly to marshlands, it appears that about $525/acre/year are generated by Virginia marshes. This is twice the estimated production for Maryland and North Carolina, and may be due, in part, to inflation and the use of more current value estimates for Virginia than for the other states. For example, hunting licenses in Virginia increased from 200,000 in 1960 to 250,000 in 1967 and freshwater fishing licenses increased from 145,000 to 248,000 in the same period. Salt-water fishing has probably undergone a similar, if not greater, increase.

Analysis of the Conventional Approach

Many of the assumptions that have gone into the estimates of the actual economic value of the marshes may not be entirely defensible.

There are two basic approaches to estimating the benefits (values) derived from sport fishing and waterfowl hunting. The "user expenditure" method has been widely used by the Bureau of Sport Fisheries and Wildlife and by a number of state agencies (72). This method was used in the estimates previously given for Maryland, North Carolina and Virginia. It assumes that an individual will spend a given amount in the pursuit of these activities, this amount being divided among various items, such as food, lodging, transportation, equipment, etc.

An alternate approach has been used by various federal agencies in calculating the benefits that would accrue from these activities (73, 74). This has been termed the "user fee" method by White (72) and has been used by the Bureau of Commercial Fisheries and the Bureau of Sport Fishing and Wildlife (75) in evaluating sport fisheries. This method assigns a daily fee that would be paid by participants in an activity and does not consider any other expenditures. The fee is the net amount which could be realized by a concessionaire on the body of water in question. This is an interim procedure since many of the benefits are intangible and cannot be evaluated in the usual manner, that is, by observing a market value (73).

The use of one or the other method for Virginia results in quite different estimates. These may be compared as follows:

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[7] Base value of furs to trapper.

[8] From VIMS Factfolder, December 1968.

[9] There were almost 800,000 visitors at Westmoreland and Seashore State parks in the 1967-68 season (April-March). It is assumed that each of these spent $5 in the area.

Salt-water Sportfishing

User expenditure	$36,001,580/year[1]
User fee	6,356,000/year[2]

Waterfowl Hunting

User expenditure	1,350,000/year[3]
User fee	540,000/year[4]

The user fee approach seems more appropriately applied in evaluating expenditures in a reservoir, rather than in an estuary, and involves multiple use of gear and other items. If the user fee were based on rental of boat, motor, tackle, and other things normally supplied by the fisherman, it would certainly be much higher than $1.00 or so per day.

On the other hand, the user expenditure method generally does not recognize that much of the equipment is of multiple use (the same boat may be used for several types of fishing, as well as hunting) and that many of the expenditures are not solely attributable to the activity (the fisherman has to eat whether or not he is fishing). A basic fallacy in the user expenditure evaluation is the implication that if the activity were not available, the expenditure would not be made. It would still be made, but in a different sector of the economy.

The only actual user fees associated with estuarine fishing and hunting are those charged for "party boat" fishing, pier fishing, launching ramps, and fees charged for hunting privileges. Since, in general, access to the resource is not controlled, a general user fee would not be practical unless in the form of a license whose cost is predicated on the average cost/day that the user would be willing to pay.

Thus, waterfowl hunters fees would be applicable almost entirely to marshes, since without the marshes there would be few waterfowl and few hunters willing to pay for hunting. The sport fishery fee should be apportioned between the marsh and the aquatic portion of the system. If the resource were solely marsh or solely open water, user fees would be low, since the productivity of the system as a sport

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[1] VIMS Factfolder, 1968.

[2] 6,356,000 recreation days (1965 National Survey of Hunting and Fishing) at a user fee of $1.00/day (mean value for general recreation from Suppl. 1, Sen. Doc. 97, 1964).

[3] VIMS Factfolder, 1968.

[4] 135,000 recreation days (1965 National Survey of Hunting and Fishing) at a user fee of $4.00/day (mean value for specialized recreation from Suppl. 1, Sen. Doc. 97, 1964).

fishery would be low since both are essential components of the system. At the moment, there is no feasible method of apportionment other than assuming that the majority of the hypothetical sport fishery user fees are attributable to the productivity of the marshes because of the considerable dependency of estuaries on marshes.

A similar series of problems are encountered in the estimation of the value of commercial fisheries. As discussed in a previous section, almost all of the commercial fishery is dependent on species that, in turn, are dependent on marshes and other wetlands. In fact, of course, it is equally dependent on the aquatic portion of the system, but for purposes of discussion, it will be assumed that there would be no fishery without marshes and wetlands.

Fishery values would seem to be classifiable as tangible benefits within the definition given by Section D of Sen. Doc. 97 (73) as follows:

> "D.2. Tangible benefits: Those benefits that can be expressed in monetary terms based on or derived from actual or simulated market prices for the products or services or, in the absence of such measures of benefits, the cost of the alternative means that would most likely be utilized to provide equivalent products or services. This latter standard affords a measure of the minimum value of such benefits or services to the users...."

The tangible benefits that an area derives from the operation of a commercial fishery may be grouped into primary and secondary benefits, these being defined as (73):

> "D.4. Primary benefits: The value of goods or services directly resulting from the project....
>
> "D.5. Secondary benefits: The increase in goods and services which indirectly result from the project under conditions expected with the project as compared to those without the project...."

Project, as used in the document, refers to a hypothetical project whose benefit-cost ratio is being determined. The term "estuary, marsh, or fishery" may be substituted without altering the sense of the definition.

To be comparable with the evaluation of other benefits as defined by Sen. Doc. 97 (73), the commercial fishery should be considered in light of the primary benefits involved. Indeed, this is the case with regard to agriculture, whereby irrigation benefits are considered to be those benefits resulting from increased production due to irrigation. It seems clear that only primary benefits are intended.

Most estimations of the benefits of a fishery are not confined to the primary but also include the secondary. Herein lies the problem, for, although the primary benefits (dockside value of the catch) are generally available, secondary benefits must be estimated. This is generally done through the use of a "multiplier."

An example of this has been given (75) for the Atlantic coast commercial fisheries:

Value	Dollars (000)
Dockside	138,322
Processing	250,000
Wholesale	330,000
Retail	429,000

Thus, the multiplier for calculating the value increase in this fishery is 3.1. Brown (70) has applied a multiplier of 7 to the North Carolina commercial fishery; the same multiplier has been applied to the estimation of the value (primary and secondary benefits) of the Virginia commercial fishery as given previously.

In 1966, the value of the Virginia catch was $21,000,000; the value of manufactured fish products for that year was $28,600,000. Hence, a multiplier of 1.4 is indicated for Virginia. Rorholm et al. (76), in an intensive study of a marine economy in New England, found that the general multiplier for fisheries was 3.0. This is, however, based on the economic impact of fisheries over the entire economy. One may calculate, from their data, a multiplier based on inputs comparable to those given for Virginia and the Atlantic coast. This multiplier is found to be 1.5. As will be discussed later, the multiplier for a particular fishery in a given area is often unique in that it depends largely on all of the economic factors within that area.

An analysis of recreation (other than hunting and fishing) also suffers from the limitations discussed above. Outside of those activities like hunting which take place in or along the marshes themselves or are partially dependent upon the marshes, there is virtually no way at this time to assign recreation benefits which originate in the marshes. Most of the benefits derived from tourists, water-skiers, pleasure boating, and related activities are intangible. Intuitively, the logical approach is one based on the user fee concept rather than the user expenditure, as suggested by Sen. Doc. 97 (73). Although it is unlikely that more than a few would pay a fee to see or tramp through a marsh, they would be willing to pay to see birds and other wildlife produced in the marsh. The Everglades offers a good example of this, and the proposed Dismal Swamp flower gardens would be another. It would seem, within the definition of recreation used here, that the amount of primary and/or secondary benefits involving wetlands are essentially non-existent.

The trapping of furbearers provides tangible primary and secondary benefits. In Virginia, much of this activity is marsh-oriented.

This is especially true for Muskrats and Otter. Beavers, Raccoons, and other furbearers are commonly associated with marshes or other coastal wetlands. The value previously given can be regarded as a primary tangible benefit from marshlands and, as such, is directly comparable with dockside fishery prices and user fees for sportsmen.

Keeping in mind the inherent limitations of the input data, it is possible to revise the conventional estimate of the primary tangible benefits produced by marshlands.

Commercial landings	\$20,600,000
Sport fishing	6,356,000
Waterfowl hunting	540,000
Trapping	200,000
	\$27,696,000

With 177,073 acres of marsh, it may be seen that each acre of marsh produces primary tangible benefits of \$78 annually (assuming that one-half of the benefits are marsh-dependent). This may be generally compared with the benefits accruing from agricultural and other land uses. At 100 bushels/acre, corn will yield benefits of \$150, while peanuts may go \$300 or higher.

Input is needed for production in commercial fisheries and agriculture and the price received by the farmer and fisherman represents the cost of production and harvest, respectively, plus an increment of profit. This is also true for trapping. The benefits from sport fishing and hunting, since they are based on user fees, may be considered net. These benefits, rather than user expenditures, are comparable with commercial landings (49).

It is commonly stated that marshes are as productive as the best farmland (19) from an energy fixation viewpoint. It is then assumed that the products of the marsh (such as fish) represent net benefits because no labor, fertilizer, or other input is needed for the marsh to produce them. This is loosely true, but labor, machinery, and other energy or economic inputs are needed to harvest the benefits produced in the marsh.

The primary tangible benefits derived from marshland, if evaluated in a manner comparable to that applied to other sectors of the economy, would appear to be about one-half or less of that generated on an acre/year basis by agriculture. It may be that the inclusion of secondary benefits and intangibles, such as aesthetics, may increase the value of marshland at a greater rate than that of agricultural land. It is well to remember that beauty is in the eye of the beholder; for every individual who places a high value on the beauty of green acres of Cordgrass, there may be another who places an equally high value on the beauty of green acres of corn.

Modern architects and designers are becoming more "environmentally aware" and are striving to work with nature rather than against it. The marshlands along the rivers and estuary act as a buffer and preserve a sense of isolation even though there may be a busy highway or a housing development nearby. The replacement of marshes by houses, needless marinas, and other human artifacts would go far toward destroying the intrinsic aesthetic qualities possessed by marshes. Much of the aesthetic enjoyment of the tidal rivers and the estuary would seem dependent upon the preservation of the marshlands which often surround them.

A Realistic Appraisal of Wetlands

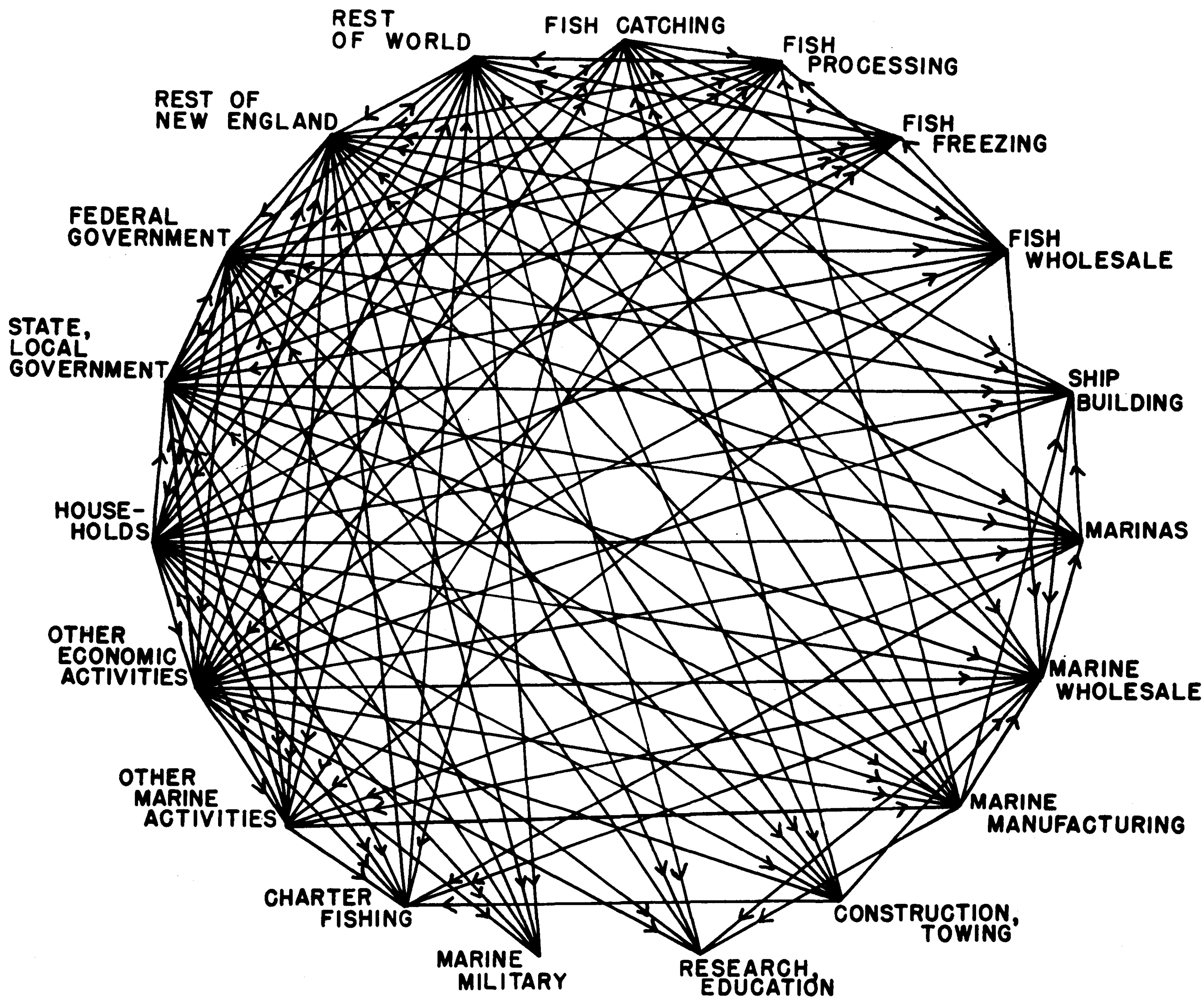
As noted above, most of the methods usually employed to evaluate the economic value of wetlands suffer from a variety of inherent disadvantages. An attempt to surmount some of these problems has been presented by Rorholm *et al.* (76) for a small area in New England. Their analysis does not primarily cover wetlands but is directed at the various inter-relationships in a marine-based economy.

The various sectors of the marine economy interact in a manner comparable to the various components of a food web. Rorholm *et al.* (76) have investigated these interactions and presented them in a quantitative fashion as the flow of goods between various sectors. Obviously, if there is a flow of goods in one direction, there will be a flow of money (payment) in the opposite direction. Often there will be found a movement of goods in both directions, but there can be a net flow in only one direction.

The tabular economic data of Rorholm *et al.* (76) have been converted to a graphic presentation which approximates the ecological equivalent of a food web (Fig. 17). It can be seen that the interactions are quite variable. Some sectors, such as frozen fish processing, are exporters for the web. Almost all of its output leaves the system with a concurrent flow of money to the processor. This money is then distributed within the web to pay for goods received by the processor. Other sectors, such as marinas, import goods. Hence, money paid into their sector from within the web is exported to pay for the goods.

Some sectors have a narrow economic base and purchase goods only from a few other sectors. This is characterized by fish wholesaling, which has a net flow of goods from only three other sectors. Hence, it is quite sensitive to the ability of these sectors to produce goods. On the other hand, the sector classified as "other marine" has a wide base, with goods originating in many sectors. In all of these considerations, of course, magnitude is as important as direction. The magnitude in these sectors is known but has been omitted since it is not generally applicable to Virginia. However, an idea of the magnitude of the interactions may be had from the example given by Rorholm *et al.* (76). Although the data are from New England, it is reasonable to assume that a similar pattern would prevail in Virginia. The interactions are depicted in Fig. 18.

The fish-catching sector's slice of the economic pie in the area is $25,484,000, which it receives from six other sectors in return for



GENERAL MARINE ECONOMY

Fig. 17. Inter-relationships between various sectors in a marine economy. Arrows indicate direction of net flow of goods from one sector to another. Figure constructed from data given by Rorholm et al. (76).

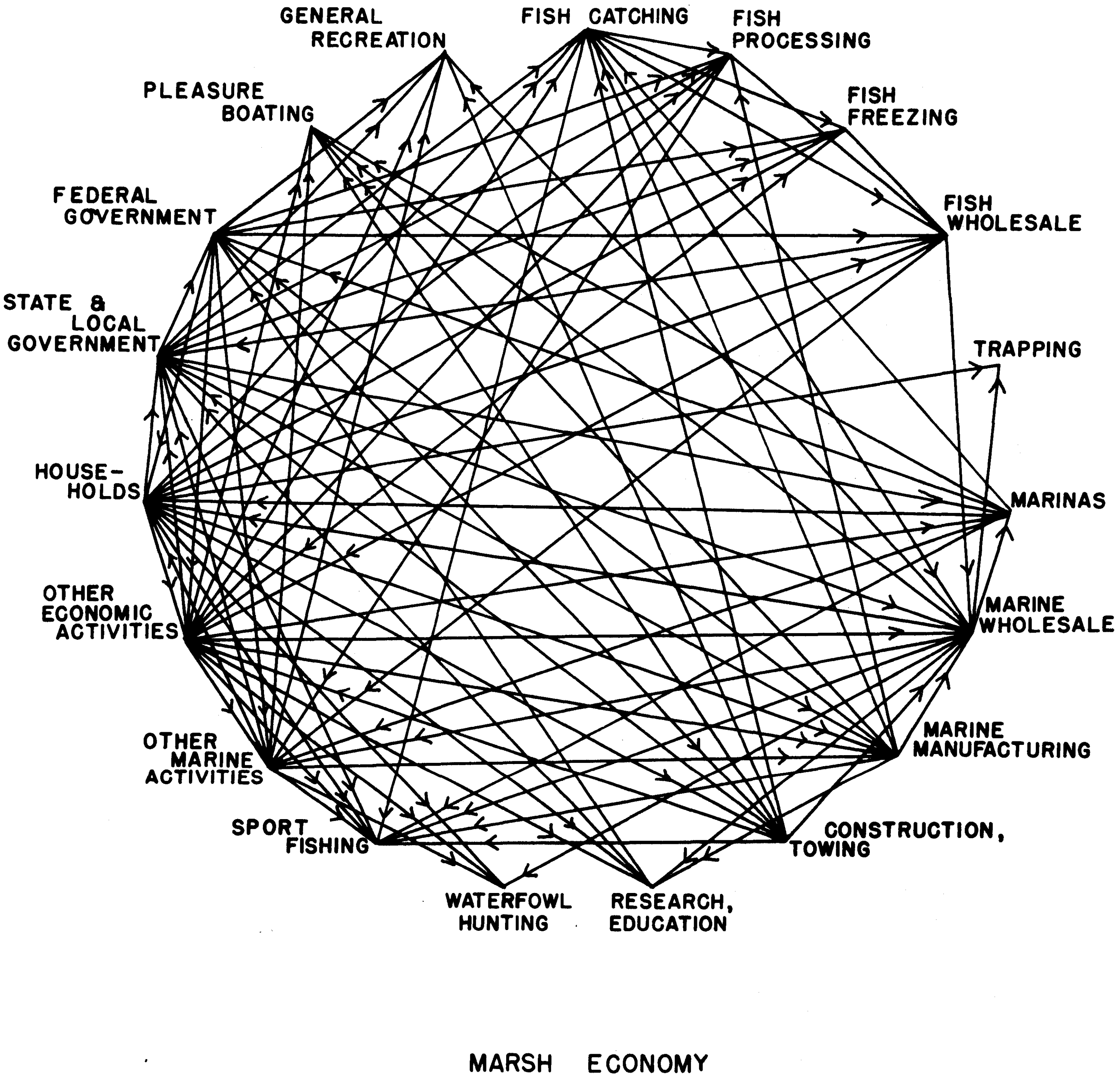


Fig. 18. Inter-relationships between various sectors in a marsh-centered economy. Arrows indicate presumed direction of net flow of goods. Compare with Fig. 17.

its goods (Fig. 19a). It, in turn, dispenses the same amount to seven other sectors (Fig. 19b). About $16,000 is cycled internally and represents that portion of the product consumed by the fishermen. All of the sectors involved (except fish-catching) have inputs and outputs to and from other sectors, this being the relationship given in Fig. 18. Any of the other components in Fig. 18 may be treated in a similar manner.

Several multipliers have been calculated by Rorholm et al. (76). As they point out, there are two ways of using a multiplier. Taking a multiplier of 3 of an economic sector as an example, a dollar produced in that sector will generate two additional dollars elsewhere. Alternately, an increased demand of one dollar for the sector's product will be reflected by an additional two dollars of demand within the system. The high and low multipliers for their system are as follows:

Multiplier	Sector	Value
General	frozen fish	3.74
General	research and education	1.95
Personal Income	marine military	1.22
Personal Income	research and education	0.62
Non-marine	other marine	0.50
Non-marine	ship and boat building	0.22

These multipliers are derived from interactions within a system having defined boundaries. If more sectors are added or the system boundary changes, the multipliers will also change.

The calculated multiplier for commercial fisheries in Virginia was 1.4. This seems low, but when it is considered that the only economic sectors involved were those directly concerned with fisheries, it may not be. If comparable sectors from New England are treated in the same fashion, the multiplier is found to be 1.5 for the fish-catching segment to the finished product; however, if all sectors are used, the general multiplier is 3.0. As the general multiplier for fisheries of the entire Atlantic coast was found to be 3.1, it seems reasonable to assume that the appropriate general multiplier for the value of the Virginia catch is slightly greater than 3.

A general economic web may be constructed for the Virginia marshland economy by modifying the input data. Ship-building, marine military, rest of New England, and the rest of the world have been eliminated, and trapping, waterfowl hunting, pleasure boating, and general recreation have been substituted in their place. It would be possible to add additional sectors, but these are so poorly understood that little would be gained. Some of these might be such items as nutrient trapping (eliminating the need for expenditure to construct treatment facilities), sediment retention (reducing dredging expenditures), and pest breeding (causing increased expenditure for pest control).

As expected, the web (Fig. 18) resembles the general marine economic web but several important differences are seen.

PAYMENTS TO CATCHING SECTOR

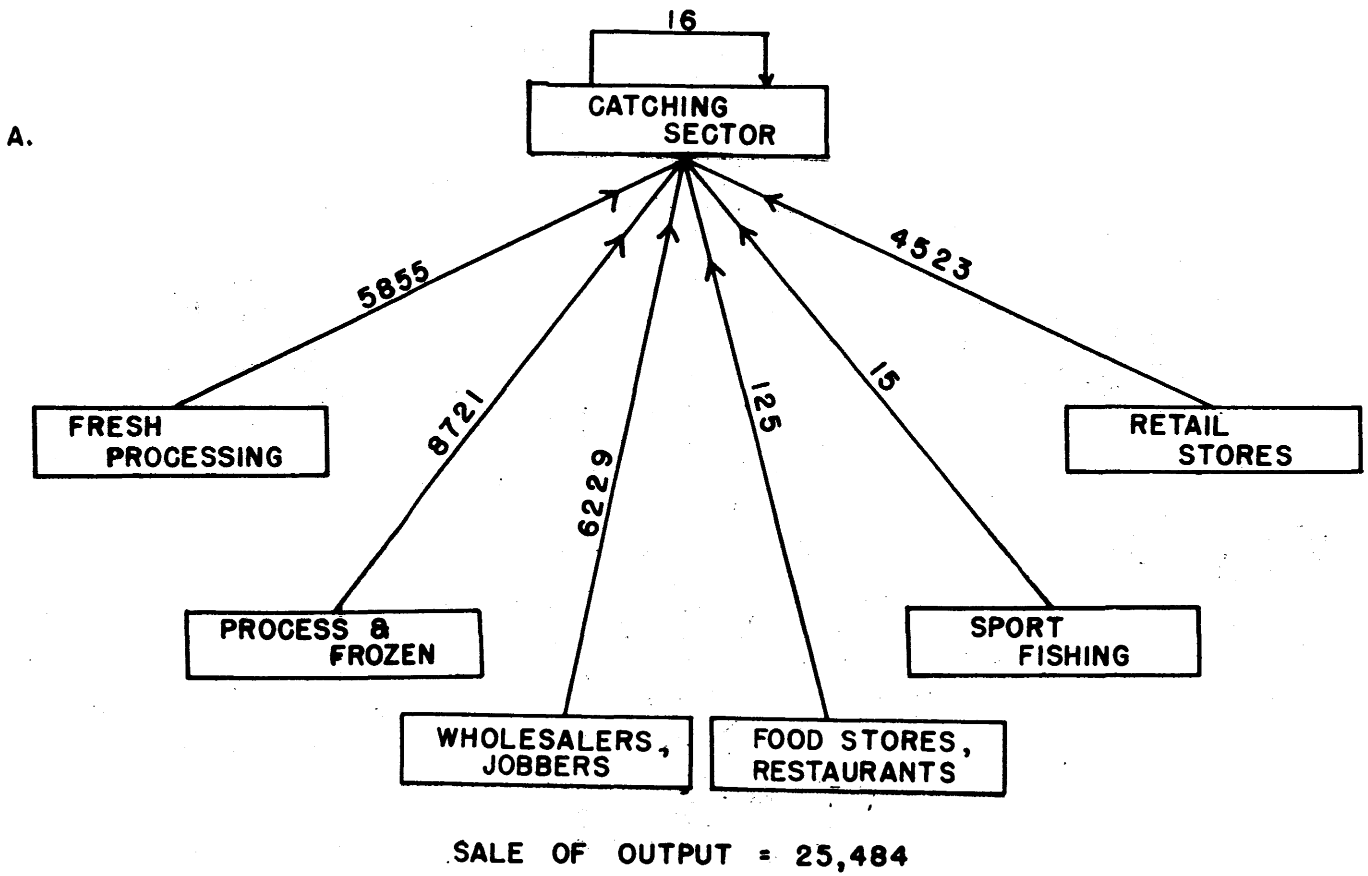
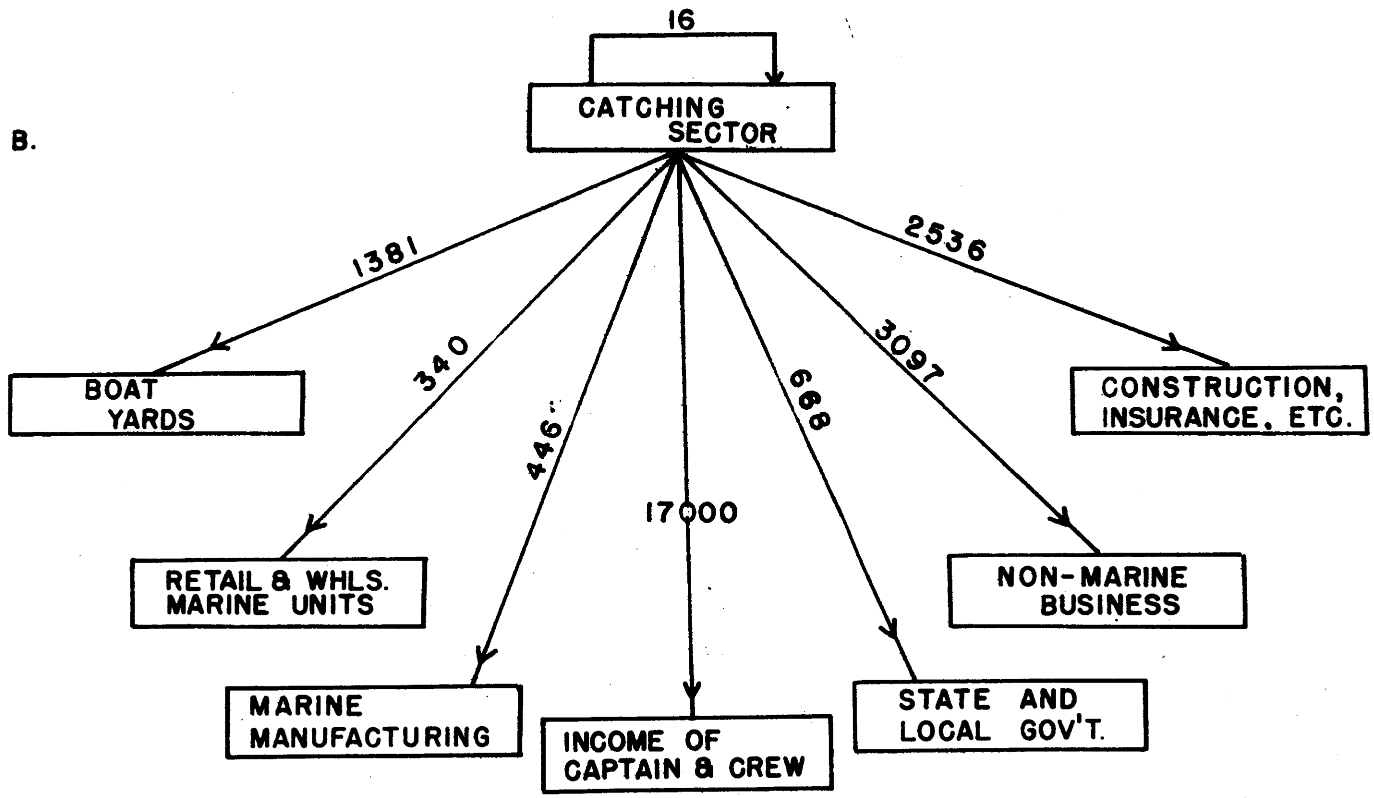


Fig. 19a. Flow of money in a marine economic sector (in $ X 1000). Diagram illustrates dollar inputs to the catching sector from other sectors. Data from a study of a New England marine economy (76).

PAYMENTS FROM CATCHING SECTOR

B.



PRODUCTION OF OUTPUT = 25,484

Fig. 19b. Flow of money in a marine economic sector (in $ X 1000). Diagram illustrates dollar inputs to other sectors from the catching sector. Data from a study of a New England marine economy (76).

The fishery sectors are almost entirely marsh-dependent. Any decrease in activity of these sectors would be reflected in those sectors with which they are associated. It is seen that they are associated with almost all of the other sectors. Trapping, waterfowl hunting, sport fishing, and, to a lesser degree, pleasure boating and general recreation are very closely associated with marshlands. The relationship of these sectors to the others is somewhat unique in that they are the recipients of goods rather than producers of goods. Hence, they provide the source of money to the producers but may be poorly associated with each other. A decrease in sport fishing, for example, would result in a decreased demand for the goods or services of nine other sectors of the economy.

Attempts at economic evaluation of trapping illustrate one of the problems involved in attempting to compartmentalize an economy. It interacts with only two sectors of the web, households (labor) and marine wholesale (supplies). It perhaps more properly belongs in a web involving fur buyers, processors, wholesalers, fur products manufacturers, additional wholesalers and jobbers, and, eventually, fur products retailers. These sectors will have little, if any, involvement with the other sectors. Thus, the raw value of pelts may be of little importance in the web, but of great importance in another.

The matter of exports and imports is of considerable significance to the marsh-based economic web. In general, exported products have a low multiplier value unless considerable processing is required before export, while imported products almost always have a high multiplier.

This may explain the low multiplier (1.4) that has been derived for the fish-catching sector in Virginia. Processing, freezing, and wholesaling are generally by-passed, with fishery products proceeding beyond the limits of the web (as to other states) with a minimum of intermediate steps. Thus, low value fish are exported and other economies benefit from the value added by processing. If all processing were done within the system boundary, the multiplier would be higher and it is possible that the dollar flow into the system would also be greater. A very similar situation exists in the agricultural economy. This has traditionally been a producer, rather than a processor, industry. Like all producers, the profit margin tends to be small. Hence, there has come about the formation of "co-ops" and "combines" that tend to place the processing and marketing sectors within the producer structure. Although the benefits of this are obvious, difficulties in practice have arisen because of the traditionally independent nature of the producer sector, or farmers. Such a phenomenon seems to be also prevalent in the producer sector of the fishery economy.

Unlike the New England web, it is not possible to put reliable dollar values on the interactions of the various sectors or to compute multipliers for a given sector because the requisite input information is largely unknown. However, Darnton and Meiburg (77) have applied a rationale similar to that presented previously in the analysis of the economic impact of Virginia ports. Their report indicated:

"1) That port-related activities create directly over 27,000 jobs for Virginians and generate almost $170 million in wage income.
2) That harbor-oriented activities employ almost 67,000 Virginians whose wages amount to over $460 million.
3) That this basic employment of 94,000 persons contributes to the support of an additional 131,000 persons, and therefore,
4) That one out of every eight employed persons in Virginia holds a job that is either directly or indirectly related to the activities associated with the states ports and harbor facilities."

They also computed a multiplier for port employment and found that it was 2.4. Were the data available, a similar approach could be used to evaluate the economic impact of marshes and marsh products on specified sectors of the economy.

Although the tangible benefit value of $78/acre/year assigned to marshlands is undoubtedly too low, it seems to be the most justifiable estimate at the moment. It does not, of course, consider intangibles (which have a value, even though it is not a readily recognized market value) or take into account the short-term vs. long-term benefits. These are often exclusive, whereby the short-term benefits, if realized, may preclude the possibility of long-term benefits accruing.

A major question which remains to be investigated concerns the validity of capitalizing the value of marshlands. This procedure is certainly acceptable for other sectors. There seems to be a diverse body of opinion regarding this procedure for marshlands. Regardless, if the estimated $78/acre/year is capitalized at 5%, one finds a capitalized value of about $1,550/acre. This implies that it would be necessary to invest $1,550 at 5% to obtain the net benefits produced by each marsh acre/year. It may then be argued that if an acre of marsh is placed in an alternate use category, such alternate use must generate $78/year for the system to "break even." Of course, this assumes that the long-term yield of marshland will not deviate from $78/acre/year.

In a conventional system, where the benefits accrue primarily to the owner of the benefit-producing apparatus, decisions involving alternate uses are reasonably straightforward. The owner of an acre of agricultural land which is capitalized at $1,000 will desire at least that amount for placing it in an alternate use where its production is lost to him (for example, if he sold it to a developer). If its use is lost for only a short period, he will usually settle for the net benefit or its equivalent.

In the case of marshlands, however, the majority of the net benefits rarely accrue to the owner. Hence, the capitalized value to the owner is usually small. This is recognized, in part, by low valuations (for tax purposes) on marshlands. However, the $78/acre/year of benefits does not disappear, nor does the capitalized value. Rather, they are found in other sectors of the economy. Therefore, if an acre of marsh is converted to another use, the capitalized value to the owner will quite probably be satisfied, but there is no guarantee that the actual capitalized value to the economy as a whole will be met. This raises a broad series of basic questions to be discussed in the next section.

Goals in Marsh Management

The obvious aim of a management objective is to do that which produces the most benefit, tangible and intangible, to the most people. This is at times modified by other considerations. In addition to the consideration of intangibles (such as aesthetics), Sen. Doc. 97 (73) provides:

> "II.C. Well-being of all the people shall be the overriding determinant in considering the best use of water and related land resources. Hardship and basic needs of particular groups within the general public shall be of concern, but care shall be taken to avoid resource use and development for the benefit of a few or the disadvantage of many...."

There are many types of marshes in Virginia, among which are regularly flooded, irregularly flooded, salt, brackish, and fresh. The flora and fauna of these various types are varied, as is their relative productivity. It is to be expected that the net benefits which accrue from each type will also be varied and distributed in different sectors of the economy. With little exception (such as waterfowl leases), almost all of these benefits accrue to sectors that are dependent on marsh productivity, but which have no control over the productivity.

Virginia House Joint Resolution No. 59 (1966) has recognized that the commercial seafood and fisheries, along with recreational activities, are an important facet of the Virginia economy, and recommend that they be encouraged and developed. As has been shown, these economic sectors are highly dependent on the marshlands.

Almost all of the marshlands are in private, rather than public, ownership and thus the control of the productivity of the marshes and the related estuaries is in large part determined by the private owners. The private owner will, of course, have his own idea of what constitutes the best use of his marshland. If it is possible for him to sell it or place it in an alternate use category whereby the benefits that he reaps are increased, he will generally do so. It is unlikely, and perhaps not even proper, that he will consider the loss of benefits in other economic sectors which may greatly exceed his gain. Even those sectors directly affected by such action, such as fisheries, may not consider the loss because such losses generally occur in small increments (whose aggregate may be highly significant) or because there is little effective action which can be taken by them. If it were proposed that one-half of the marsh acreage be filled or destroyed, there would no doubt be a more pronounced reaction from the sectors highly dependent on marshes.

It seems clear that the marshlands upon which several Virginia economic sectors are dependent cannot be directly maintained by these sectors, nor will they be managed by the owners to achieve a maximum net benefit to other than the owners. In the absence of public ownership, public benefits or rights are rarely given major importance in planning and management.

In the interest of maximizing the net benefits of all aspects of the economy, a number of precedents in regulation have been set in recent years. Among these is the crop acreage allotment system whereby the output of a producer is limited by an external agency. The system may be either voluntary or involuntary. At any rate, it would seem to violate the time-honored concept that the owner of land may do with it as he pleases. In practice, this freedom, however, extends only as far as the point where the freedom and rights of others are not infringed. Zoning or restriction of one sort or another is increasing. In the case of agricultural allotments, it is recognized that regulation may impose a hardship on some; this is minimized by offering a guaranteed support price for compliance or by payments to the owner for non-productive land.

Those payments represent a form of compensation called for under the due process clauses (Fifth and Fourteenth Amendments) of the U. S. Constitution. As has been discussed in the section of this report dealing with regulation and legal matters, zoning laws have often been struck down by the courts as they constituted a violation of due process. Under the due process clause:

1. The legislature may enact a law
   - (a) which does not affect private property so as to constitute taking without due process; and
   - (b) may condemn or appropriate private property for public use upon payment of just compensation for the property so taken.

2. Laws may not be enacted
   - (a) which take private property for a private use, even with compensation; or
   - (b) which take private property for public use unless payment is given for the property so taken.

Should the State undertake to regulate the productivity of marshlands, as it seems must happen if they are to remain productive, several criteria must be met.

In regulation, by zoning or otherwise, it must be demonstrated that the owner is not being so restricted in his use of the marsh as to constitute violation of due process. If due process is violated, however, this can be overcome by judicious use of eminent domain and appropriate compensation.

There ought not be any question as to whether private land is being taken for public use. It seems clear that general public benefit and interest is involved. As noted in the report Virginia's Scenic Rivers (78), "The farmer, for example, whose pasture fronts on a scenic stream might be quite willing to discuss ways of voluntarily preserving the beauty of the place, but vigorously oppose any plan for public access or ownership."

In some cases, it appears that the private owners of marshlands are content with the benefits that they are receiving, although many of these are intangible. Those who hold marshland for their own enjoyment or to prevent encroachment and preserve privacy do not seem likely to divert the marshes to alternate uses so long as the cost of owning them remains reasonable. In other cases, the owner may consider his marshland as an investment and derive little in the way of any kind of benefits from it. When the price is satisfactory, he will sell it and realize tangible benefits. If such a sale tends to bring about an end to the productivity of the marsh, the public interest becomes involved inasmuch as the marsh produces for the general public.

Assuming that the Commonwealth is of the opinion that the best use of marshes is their preservation as such, rather than conversion to other uses, some means must be devised to implement such preservation. Whether this will involve eventual state ownership of marshes or essential ownership (by controlling development), it cannot be accomplished without more information than is presently at hand on which to base such decisions.

It would seem that no matter which course of action is followed, money will have to be expended by the State. If outright ownership of the marshlands by the State is the answer, the State must be prepared to compensate the owner to the same extent as others who desire to purchase the land. Alternately, it might be possible through the payment of subsidies or other compensation to increase the benefits that the owner derives from marshland to such a level as to discourage sale. The implementation of such plans will be severely hindered by the lack of information regarding the value of marshlands to various sectors of the economy and to the public as a whole.

Prudence dictates that the destruction or conversion of marshland to non-productive uses ought to be discouraged until sufficient information is available regarding the economic and other effects of such uses. Some marshland may be expendable because of low productivity and other factors, and this marshland would perhaps be best diverted to other productive uses (such as housing or industry). It is not good business, however, to substitute a producing industry for producing marsh when it is possible to site the industry in such a manner as to reap the benefits from both industry and the marsh.

Decisions of this nature, if done intelligently, require more information than is presently available. It should be remembered that at any future time existing marshland can be converted to an alternate use, once converted, the conversion is usually irreversible and the option to decide best usage is lost. The exercise of this option in the future is contingent on the preservation of marshland at the present time.

VULNERABILITY OF WETLANDS

Relative Vulnerability

Just as they differ in productivity, value, and biotic composition, so do wetlands vary in vulnerability, that is, the degree to which they are susceptible to alteration and the probability that it will occur. Vulnerability cannot be discussed with reference to value, as these two parameters interact.

The wetlands most vulnerable to alteration by man-made disturbance are those currently proposed for such alteration and those which, because of their geographic location, seem likely to be altered in the near future.

Of the former, the Smith Island complex, Swanscut Creek, and Goodwin Island are illustrative examples. In these instances it is proposed to convert wetland into housing developments. In the course of this development, it is anticipated that the wetlands will be altered beyond recognition and recovery.

In the latter category are those wetlands which are in close proximity to population centers. Alteration of wetlands in these areas may be brought about by industry, housing, channelizing, public works, mosquito control, pollution, and road construction. Also included are wetlands somewhat removed from population centers. These are apt to be affected by sanitary landfills, agriculture, channel dredging and spoil disposal, construction, erosion, highways, waterfowl management, and other factors.

The least vulnerable wetlands seem to be those which are remote and/or inaccessible or which are in private ownership where it is not the intent of the owner to allow alteration in the foreseeable future. Of special interest are those lands held by state and federal agencies. These may or may not undergo some form of alteration, as for example, waterfowl management, roads, dredging and filling. Low vulnerability areas are difficult to identify because human needs and desires are not only increasing, but are changing. Near Cockpit Point on the Potomac, located about 30 miles from Washington, D. C., and in a sparsely populated area, it appears that a large sanitary landfill will be created to handle garbage from Washington.

Farther from home, there has suddenly developed a need to construct jetports (Everglades), "Disneylands" (Mineral King Mountain), and military communication facilities (northern one-third of Wisconsin) in areas which a short time ago were considered to have little, if any, possibility of such construction taking place. Thus, the status of low-vulnerability marshlands may change quickly and unexpectedly.

All wetlands are inherently subject to alteration by natural factors. The magnitude of such alteration varies tremendously depending on the nature, magnitude, and frequency of the responsible factors. This is particularly striking barrier islands of the Eastern Shore. One of these, Wreck Island, has moved westward about one mile since 1853. Many of the others are moving at the rate of 20 to 40 feet/year. As discussed earlier, all marshes must rise in absolute elevation to avoid destruction by rising sea level. Erosion has always been taking place, although its rate has been greatly affected by human activities (discussed earlier). These effects are not easily predictable since, for example, one hurricane may accomplish in a few days that which would take 20 years of normal storms and tides to do. However, the fact that marshes exist is in itself evidence that they have accommodated to catastrophic events as well as to ordinary natural phenomena.

Alteration, Vulnerability, and Value

The effect of alteration on wetlands is not, by definition, harmful. It may, in many cases, be beneficial. Whichever it is more often than not cannot be easily decided and depends largely on the viewpoint of the definor.

The waterfowler, fisherman, and nature lover often view alteration of wetlands as non-beneficial except where such alteration tends to increase the supply of waterfowl and fish or tends to preserve the original character of the wetland. If the alteration will produce employment and pay taxes, it is quite apt to be viewed as beneficial by those not more interested in other considerations.

On the surface, it would appear that wetlands which have a high value would be less vulnerable to alteration than those of low value. This depends, however, on those factors which enter into the value estimation of a particular marsh.

A few acres of marsh in a populated area may have a low productivity value, yet be considered quite valuable by residents in the area. It might represent an even greater value to the developer who desires to fill it. A conflict immediately arises and is not easily resolved.

Public awareness of the need for open space and parklands is constantly increasing (79), as is the public. As an area becomes more densely settled, the value of land itself increases. Undeveloped land and open space become increasingly vulnerable as the value they would have if they were altered increases. Of course, as this type of environment decreases, it becomes more valuable to those who wish it to remain unchanged.

The extremes are clear. At one end is found a minimum of alteration and disturbance; at the other is almost total alteration. Somewhere in between is the "happy compromise" between alteration and preservation. People must have homes, industry, roads, and all of the other amenities of a technological and affluent society. The well-being of such a society also demands open space and natural areas. Wetlands are a form of these.

It has not been long since the immense acres of White Pine were being cut in the lake states and the prairie grasslands were being converted to farms. That some of the pines or the prairie grassland should remain untouched was not considered. After all, the prairie and the pines seemed endless and were of little value in an unaltered condition to the society that then existed.

It is now an almost daily occurrence to hear of someone chaining himself to a condemned tree which stands in the path of a highway improvement or falling prostrate before a bulldozer that is scraping the grass off of a park that is destined to become a shopping center. Such efforts meet with little more success than they would have 100 years ago. Yet, the effort is being made now; it was not then.

The Decision to Destroy

It seems apparent that the current accelerating trend of altering wetlands with little or no consideration of the effects will ultimately lead to the loss of an irreplaceable resource. Such a loss is needless and can be averted through careful evaluation and planning.

Before wetlands are altered, all pertinent values must be examined and the decision based on the impact of alteration to the public as a whole. It is folly to destroy wetland which has a high value and significant public importance and put in its place housing or industry. The value of the marsh must not be computed solely in the cold monetary values of the economist but must also consider the right of the public to enjoy a marsh, the ecological importance of marshes, the benefits the economy derives from marshes and which could not otherwise be had, and that the swapping of a unique resource for the commonplace is hardly a good bargain. Unless it can be shown that there is no alternative site for the proposed alteration and that the overall benefits from alteration far outweigh the disadvantages, it should not be tolerated.

Many areas are not suitable for permanent human habitation. Attempts to do so almost always lead to disaster and gross economic loss, in spite of heroic efforts at prevention. Flood control is a case in point.

In equivalent dollars, flood losses in the United States were $212 million in 1936 and $356 million in 1957. The Corps of Engineers estimated that if there were no federal flood control measures, $965 million in annual losses would have taken place. During this period $4 billion were spent on flood control. The flood control program has, therefore, reduced annual losses by $609 million, yet losses are $144 million greater (annually) than at the beginning of the program (80).

Why? Primarily because the creation of "safe" flood plains entices human settlement on them with this settlement usually replacing agriculture.

The flood plains are not really safe, however, and the damage done to high value homes and industry by the occasional flood is much greater than that caused by habitual flooding of agricultural land. In addition to causing immense losses, the flood also generates strident demands for more flood control measures. Thus, the cycle continues. In short, flood plains are designed by nature for floods and cannot economically be made flood-proof.

McHarg (79) and others have pointed out that much the same situation exists with respect to barrier islands. Barrier islands are best utilized as just that. They are not best utilized for homes, industry, or even agriculture. Like flood plains, they must first be made "safe" before being diverted to alternate use and, similarly, cries for more protection become increasingly vociferous after each disaster. Already highly vulnerable to damage from natural causes, the islands are made even more vulnerable by human activity.

As seashore property, barrier islands are in great demand by those who wish to live by the sea. The premise that one may live where one desires is no longer entirely valid since we must all bear the consequences of the unwise decisions of a few. Not only is the destruction of a unique natural habitat involved, but also property, the marshes protected by the barrier island, and perhaps people as well. Out of public monies must come funds to protect against future damage and attempt to repair present damage, all of which is needless. We have not yet reached the point that there is no place to live except on barrier islands or wetlands. When we do, it will be an immense undertaking to make them habitable and any peripheral values that they may have will be destroyed in the process.

There are possibly some wetlands whose productivity is so low, whose aesthetic value is so poor, and whose overall character is such that their best use would be an alternate one. Even so, this may not at all justify such alternate use. Tidal wetlands are only about 1% of Virginia's land; marginal wetlands are even less. If the marginal wetlands are consumed, it must be justified over the use of marginal uplands that are present in far greater quantity.

There seems to be no mechanism at present to insure that this will be done. Decisions are rendered by the unrestricted competitive market as scarce resources are allocated in a sub-optimal manner (81). The only solution to the problem seems to be some form of public intervention which will result in a net gain from wetland alteration through a consideration of the uniqueness of the resource, its future possibilities, and alternate means of solution. Until such a mechanism is operative, wetland alteration must be viewed with trepidation and prevented when possible.

LEGAL ASPECTS OF WETLANDS[1]

by

Maurice P. Lynch

Wetlands Protective Devices

Until relatively recently, with the exception of conservationists and possibly some fisheries scientists and other ecologists, the emphasis on coastal wetlands has been on development rather than protection. Many coastal states had laws encouraging the exploitation and conversion of wetlands into what was then considered more useful areas.

A fairly comprehensive study of State, Federal, and local laws concerned with problems of the land-sea interface in the coastal zone was completed in September 1968 by a research team from New York University under a contract with the National Council on Marine Resources and Engineering Development (1).

The summary report of the study discusses such matters as wharfing and dredging and filling which are germaine to wetlands protection although most of these statutes involved were not designed specifically for wetlands protection.

The first legislation designed primarily to protect wetlands was passed by The Commonwealth of Massachusetts in 1963. This act (2) gave the State Director of Marine Fisheries the authority to impose conditions on soil removal, dredging, or filling operations on lands bordering coastal waters. This statute was challenged in the courts (3). The validity of the conditions imposed by the Commission of Natural Resources was upheld by the lower court and affirmed by the State Supreme Court, although the case was returned to determine if these regulations amounted to taking without due compensation. The original act had no provision for the exercise of eminent domain or compensation for taking. This was remedied in 1965 by a subsequent act of the legislature (4) which provided that the Department of Natural Resources had the right to restrict or prohibit dredging, filling, removing or otherwise altering or polluting coastal wetlands. If a landowner felt such restriction constituted a land-taking, he could petition the court and the state could assume ownership

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1 Citations for this section and the section "Wetlands Protection in Virginia" will be found at the end of the latter section.

of the wetlands under eminent domain proceedings. A similar act designed to preserve inland wetlands was passed in 1968 (5).

Since 1965, several other states have enacted protective legislation. In 1965, Rhode Island (6) passed a program for coastal wetlands which provides that the Director of the Department of Agriculture may, after public hearings, by written order recorded in the registry of deeds in each city or town where land is located, designate coastal wetlands or parts thereof, the ecology of which shall not be disturbed and the use of which shall be restricted to uses compatible with preserving the purity and integrity of the coastal wetlands. A provision is incorporated whereby owners may file for damages in the state Superior Court within two years of the date of recording of the restrictive order. In 1967, Maine (7) and New Hampshire (8) passed legislation requiring a permit from the Wetlands Control Board (Maine) or the Water Resources Board (New Hampshire) before any dredging or filling in coastal wetlands could be undertaken. The respective boards were given authority to deny or modify the applications for dredging or filling. Unfortunately, neither of these states provided for the taking of the land if the courts vacated the directives of the control agencies as being so restrictive as to be a taking without compensation. Connecticut enacted wetland protective legislation in 1969 which included provisions for taking land by eminent domain (9).

The latest state to pass similar legislation is North Carolina (10). This act is somewhat similar to that of New Hampshire and Maine in that no provision is made for the taking of land by eminent domain. This act becomes effective January 1, 1970.

Prior to the Massachusetts legislation in 1963, attempts at wetland protection were usually made at the local level. One approach tried was that of zoning. Sometimes this approach was not successful; for example, a 1964 decision by a Connecticut court invalidated a zoning ordinance that limited the use of a section of marshland to parks, playgrounds, landings, docks, wildlife sanctuaries, farming and vehicle parking, especially where some of the land was under contract for residential development and some had been assessed for a sewer line (11). In some of the Northeastern coastal states, local authorities (towns, cities or counties) have control of many of their natural resources. Local Conservation Commissions have been established in some of these states. One of the earliest states to use this approach was Massachusetts which passed an act in 1957 which enabled the cities and towns of the Commonwealth to establish Municipal Conservation Commissions (12). New York (13) and New Jersey (14) also have local conservation commissions. The powers of these commissions vary greatly. In New York, the commissions are advisory in nature, while in New Jersey the commissions are authorized to acquire property by purchase, gift, devise, bequest or lease. Many of these local commissions have done much for wetland protection. In Barnstable, Mass., for example, the activities of the local council have resulted in the setting aside of 3,300 acres of tidal marsh as a conservation area and the appropriation in 1962 for an additional $15,000 in town funds for the acquisition of additional open areas (15).

Local control of wetlands, however, does not always result in protection of these areas. In Maryland, for example, Worcester County has control over establishment of bulkhead and fill lines and regulations governing dredging along the shores of the county (16). This local control has resulted in the loss of much wetland to developers (17).

One of the most successful conservation groups organized below the state level is California's San Francisco Bay Conservation and Development Commission (18). Originated as a study commission to investigate environmental, economic, and other factors in the bay area, it had interim powers to regulate filling and dredging. After a long and bitter legislative struggle, and largely as a result of popular pressure and opinion, the Commission became a permanent organization on August 7, 1969 (19). This Commission has almost complete authority over the filling of areas, extracting of materials or any proposed substantial changes in use of any water, land, or structure within the area of its jurisdiction. The Commission also has broad powers in determining future use of Bay shoreline.

An approach that has been taken by several states is that of acquisition. Connecticut (20), Pennsylvania (21), New Jersey (22), Maryland (23), and Washington (24) all have programs of land acquisition that are either specifically designed for, or can be used for, wetland acquisition. New Jersey and Pennsylvania are funding their programs under bond issues; New Jersey's program, The Green Acres Land Acquisition Act of 1961, provided $60,000,000 under a "Green Acres" Bond Issue, $40,000,000 of this for state acquisition and $20,000,000 to finance local acquisitions. Most of these acquisition programs allow the program directors to accept gifts and bequests of land. Some allow the purchasing of conservation easements in property in addition to fee simple purchases. Washington funds its acquisition with that portion of the state gasoline tax paid by boaters. North Carolina provides that 1/8 of 1% of the net proceeds of the taxes on motor fuels be turned over to the North Carolina Wildlife Resources Commission for purchase of wetlands (25).

The U. S. Land and Water Conservation Fund Act of 1965 (26) provides for matching funds (up to 50%) that can be used to purchase coastal wetlands and other types of unimproved land.

I have not discussed all of the wetlands protective devices available to all of the states. Many of the statutes that can be used to protect wetlands were not specifically designed for this purpose and, therefore, are not covered here. Appendix I contains a brief summary of the wetlands protective devices of all the coastal states with the exceptions of Alaska and Hawaii. A discussion of those state statutes relative to wharf and pier construction and some of the statutes pertaining to dredging are discussed in the report to the National Council on Marine Resources and Engineering Development (1).

Wetlands Protection in Virginia

Virginia has no specific statutes in the Code relative to coastal wetland protection. There are some statutes and a constitutional article that do provide some measure of protection to some of the coastal wetlands. Two statutes and the constitutional provision listed below pertaining to ownership of lands are particularly pertinent.

1. Article 175 of the Constitution of Virginia states that

> "The natural oyster beds, rocks and shoals, in the waters of this State shall not be leased, rented or sold, but shall be held in trust for the benefit of the people of this State, subject to such regulations and restrictions as the General Assembly may prescribe, but the General Assembly may, from time to time, define and determine such natural beds, rocks or shoals by surveys or otherwise."

Some wetlands and shallows are included within the area thus protected.

2. Title 62, Section 62-1, states in part that

> "All of the beds of the bays, rivers, creeks and the shores of the sea within the jurisdiction of this Commonwealth, and not conveyed by special grant or compact according to law, shall continue and remain the property of the Commonwealth of Virginia, and may be used as a common by all the people of the State for the purpose of fishing and fowling, and of taking and catching oysters and other shellfish . . ."

and,

3. Title 41, Section 41-81, which states that

> "All unappropriated marsh or meadow lands lying on the Eastern Shore of Virginia, which have remained ungranted, and which have been used as a common by the people of this State, shall continue as such common, and remain ungranted, and no land warrant shall be located upon the same . . ."

Unfortunately, with increasing importance being placed on tidal wetlands, only one of the three types of land mentioned in the above items, the natural oyster beds, rocks and shoals, can be accurately located. The location of much of the "commons land" bounding the shores of the sea has long been lost to record. Historians and jurists have attempted to locate these lands without success (27). Embrey (28) suggests that the only way to locate these lands might be a diligent search of the Land Office records in the State Capital or by the recovery of maps reportedly sent to the Spanish King Phillip by Zuniga, his Minister to the Court of England.

The commons land on the Eastern Shore of Virginia may be located by the tax maps of Accomack and Northampton counties presently being prepared by the Division of Taxation. Unfortunately, personal contact with individuals preparing these maps indicates it will be several years before these maps are completed.

The ownership of wetlands in Virginia is a complex subject. A thorough discussion of this subject will be found in Miller v. Commonwealth (27). Very few of the grants issued either by the London Company, the British Crown, or the Commonwealth passed title to that land between ordinary (mean) high tide and ordinary (mean) low tide. In 1819, however, the Virginia General Assembly passed an act entitled "An act to explain and secure the rights of the owners of shores on the Atlantic Ocean, the Chesapeake Bay, and the rivers and creeks thereof within this Commonwealth." This act stated (29):

> "Whereas doubts exist how far the rights of owners of shores on the Atlantic Ocean, the Chesapeake Bay and the rivers and creeks thereof, within this Commonwealth, extend; for explanation whereof, and in order effectually to secure said rights;
>
> 1. Be it enacted by the General Assembly, that hereafter the limits or bounds of the several tracts of land lying on the Atlantic Ocean, the Chesapeake Bay, and the rivers and creeks thereof within this Commonwealth, shall extend to ordinary low water mark; and the owners of said lands shall have, possess and enjoy exclusive rights and privileges to, and

> along the shores thereof, down to ordinary low water mark: Provided, That nothing in this act contained shall be construed to affect any creek or river, or such part thereof, as may be comprised within the limits of any survey; And, provided, also, that nothing in this section contained shall be construed to prohibit any person or persons from the right of fishing, fowling and hunting on those shores of the Atlantic Ocean, Chesapeake Bay, and the rivers and creeks thereof, within this Commonwealth, which are now used as a common to all the good people thereof; nor to repeal the sixth section of an act, entitled, An act for reducing into one the several acts concerning the land office; ascertaining the terms and manner of granting waste and unappropriated lands; for settling the titles and bounds of lands, directing the mode of processioning, and prescribing the duty of surveyors, passed the seventeenth day of December, one thousand seven hundred and ninety-two."

The immediate effect of this act was to essentially grant to every person owning land bounded by tidal water another moiety of land. In some cases, where extensive salt marshes abutted on the highland, this could have involved a substantial amount of land.

There is a strong possibility that the amounts of land claimed by persons on the Eastern Shore (and other areas) under this act of the General Assembly may be excessive. Close inspection of the areas may reveal guts or drains, which do not ebb dry at ordinary low water, cutting through the property. If this were the case, then ownership would end at the low water mark on the side of the gut (30).

In 1854, French v. Bankhead (31) declared that under the act of 1819 conveyances subsequent to the act also passed title to low water even though the boundaries were stated as running by the high water mark. This decision was further strengthened by Waverly Water Front and Improvement Co. v. White (32) which held that a deed seeming to grant land only to the high water mark was too ambiguous to overcome the presumption of an intent to convey all of the land to the low water mark.

Despite these two decisions indicating that land deeded or granted by the high water mark actually passed to the low water mark, some of the grants on the Eastern Shore islands were described by high water boundaries (33), while others granted in the same period were described by low water boundaries (34). One possible explanation for this apparent discrepancy is that some of the areas described by the high water mark abutted on commons ground, and therefore the land between high and low water was incapable of being granted.

The highest priority should be assigned to locating precisely state-owned marshland, particularly on the Eastern Shore of Virginia, and reclaiming any marshlands that have been claimed by individuals in error.

Those sections of the Code dealing with water pollution, particularly Art. 62.1-14 which states in part

> ". . .It is the policy of the Commonwealth of Virginia and the purpose of the law to: (1) maintain all State waters in or restore them to such condition of quality that any such waters will permit all reasonable public uses and will support the propagation and growth of all aquatic life, including game which might reasonably be expected to inhabit them, (2) safeguard the clean waters of the State from pollution, (3) prevent any increase in pollution and (4) reduce existing pollution."

and Art. 62.1-17 which says

> "It is hereby declared to be against public policy and a violation of this chapter punishable under Art. 62.1-44 for any owner who does not have a certificate issued by The Board to (1) discharge into State waters sewage, industrial wastes, other wastes or any notions or deleterious substances or otherwise alter the physical, chemical or biological properties of such State waters and make them detrimental to the public health or to animal or aquatic life or to uses of such waters for domestic or industrial consumption or for recreation or for other uses."

might serve as a basis for action to protect wetlands from development if it could be shown that in the process of development, substances deleterious to aquatic life or water quality would be added to the system. In this context, the increased sediment load derived from dredging and filling may be a pollutant in the water column.

Title 62.1, Section 62.1-3, at first glance, seems to offer protection to coastal wetlands. Closer reading, however, shows that to a large extent the Marine Resources Commission does not have discretionary power relative to filling, if a bulkhead line has been established, and certain types of shoreline construction. As this section now stands, the Marine Resources Commission has no discretionary authority over construction of private docks and landings for non-commercial use, erection of any structures associated with marinas and boatyards for commercial use unless existing oyster leases, previous easements or Baylor Survey ground is involved (providing State Department of Health requirements are met), seawalls and jetties incident to controlling erosion and certain other types of construction. The Marine Resources Commission does have more authority regarding dredging. Article 62.1-3 does not require the Commission to approve dredging associated with items mentioned above. There does not appear to be any provision, however, for regulation of channel dredging by a riparian owner as authorized under Section 28.1-118.

This section should be amended to give the Marine Resources Commission more discretion in the issuing of permits. The Commission should have the authority to deny permits, including marine permits, when, in its opinion, the proposed development would be substantially detrimental to the marine environment. Disruptions of sport and commercial fisheries, ecological systems and impairment of water quality should be among the aspects considered in the deliberations. Riparian owners should be required to obtain permits for all modifications to coastal wetlands, including piers and bulkheads, and such permits should be subject to review and approval, modification or disapproval by the Commission.

The Virginia Institute of Marine Science should be required to advise the Marine Resources Commission of the biological, physical, geological and chemical consequences and to recommend modifications that might lessen the ecological impact of the proposed alterations.

Those wetlands owned by the State in the Back Bay area are specifically singled out for protection (35) in that the Commission of Game and Inland Fisheries is directed to regulate or prohibit drilling, dredging and other operations which would harm the area for fish and wildlife.

Other sections of the Code pertinent to this topic are Sections 62.1-190 through 62.1-193 and 33-69, which cover the dredging of sand and gravel from the beds and shores of the waters of the State. Unfortunately, only Section 33-69, which covers the dredging of sand and gravel by the State Department of Highways, subjects the dredging to approval by the Marine Resources Commission.

As long as much of Virginia's coastal wetlands is in private ownership, problems will arise regarding regulation of these lands. The ultimate solution to this problem is for the Commonwealth to acquire those coastal wetlands which require preservation. The next best techniques are those which give the State some level of control over the fate of the wetlands, such as zoning and easements.

Funds should be made available to allow the State to acquire either title to coastal wetlands or conservation easements in these lands. In addition, provisions should be made to acquire lands from individuals by means of gifts or bequests.

Sources of funds for purchase of lands might be:

1. Increased user fees from commercial exploiters

2. Recreational user fees (salt water fishing licenses)

3. Un-refunded portions of the State Gasoline Tax paid by boat owners

The State agency which is given control over a wetlands acquisition program should be given powers of eminent domain regarding wetlands.

References for Wetlands Protective Devices and Wetlands Protection in Virginia

1. Garretson, A. The Land-Sea Interface of the Coastal Zone of the United States. Legal Problems Arising Out of Multiple Use and Conflicts of Private and Public Rights and Interests. Report to National Council in Marine Resources and Engineering Development. September 1968 152 p.
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2. M.G.L.A. c. 130, section 27A.

3. Commission of Natural Resources et al. v. S. Volpe & Co., Inc., 349 Mass. 104, 206 N. E. (2d) 666, 1965.

4. M.G.L.A. c. 130, section 105.

5. M.G.L.A. c. 131, section 40A.

6. R.I.G.L.A. Section 2-1-13 through 2-1-17.

7. Title 12 M.R.S.A. Sections 4701-4709.

8. New Hampshire R.S.A. 483A:1 through 4.

9. Connecticut Public Act 695, January 1969.

10. N.C. 1969 Advance Legislative Service No. 7, Section 113-229.

11. Dooley v. Town Zoning Commission, 151 Conn. 304, 197 A(2d) 770, 1964.

12. M.G.L.A. c. 223.

13. New York Town Law Section 64-b.

14. N.J.S.A. 40:56A-1 through 40:56A-5.

15. Address of Robert F. Hutton to Wetland Symposium, 1966 Northeast Fish and Wildlife Conference, Boston, Mass., on Legal Wetlands Protective Devices, 19 January 1966.

16. Code of Public Laws Worcester County 1968, Section 15A.

17. WASHINGTON POST 11 June 1969 p. C1.

18. West's Ann. Gov. Code (Calif.) 66601 through 66661.

19. See the Conservation Foundation Newsletter, June 9, 1969, for the background of the San Francisco Bay struggle.

20. C.G.S.A. section 26-17a.

21. 32 P.S. Section 5001 through 5012.

22. N.J.S.A. 13:8A-1 through 13:8A-18.

23. Maryland Code Act 78A, Section 19A.

24. R.C.W.A. 43.99.010 through 43.99.910.

25. N.C.G.S. 105. 446:2 (1969).

26. Public Law 88-578 (78 Stat. 897).

27. Miller v. Commonwealth, 1966 S.E. 557, 159 Va 924, 1932; Embrey, Waters of the State 221-229.

28. Embrey, Waters of the State 227.

29. Acts 1818-1819 Ch 28, p. 40, Rev. Code 1819 Ch 87 presently Code of Va. Title 62.1, Section 62.1-2.

30. Whealton and Wisherd v. Doughty. 72 S.E. 112; 112 Va. 649, 1911 Whealton and Wisherd et al. v. Doughty 82 S.E. 94; 116 Va. 566, 1914 Scott v. Doughty 97 S.E. 802, 1919.

31. French v. Bankhead 11 Gratt (52 Va) 136, 1854.

32. Waverly Water Front and Improvement Co. v. White, 33 S.E. 534; 97 Va 176, 1899.

33. Grants 122, 1902-1910 Grant to W.W. Dixon 40 acres on Racoon Island 24 June 1903.
Grants 123, 1908-1921 Grant to H.W. Cobb 210 acres on Prouts Island 9 and 10 December 1913.

34. Grants 121, 1890-1902 Grant to E. T. Powell 1,422 1/2 acres on Hog Island 2 February 1901.

35. Code of Virginia Title 62.1, Section 62.1-5.

APPENDIX

Legal Wetland Protection Devices
(Citations for this section are included with the text)

Maine: Title 12 Me. Rev. Stat. Ann. Sec. 4701-4709

A Wetlands Control Board passes on all removal, fill, dredging or sanitary sewage disposal proposals involving coastal wetlands. Public hearings must be held on the proposal. Appeals may be taken to the Superior Court. No provision is made for compensation if the Court decides the restrictions imposed by the Board constitute the equivalent of a taking without compensation.

The Wetlands Control Board consists of the Commissioners of Sea and Shore Fisheries and of Inland Fisheries and Game, the Chairman of the Water and Air Environmental Improvement Commission, the Chairman of the State Highway Commission and the Forest Commissioner or their delegated representatives.

1967, amended 1969.

Maine also has a wetland acquisition program funded at $20,000 annually.

New Hampshire: N.H. Rev. Stat. Ann. 483-A:1 through 483-A:4

A Water Resources Board passes on all excavation, removal, filling or dredging proposals. A public hearing must be held. A rehearing provision is included. No provision is made for taking by eminent domain. The Water Resources Board is supplemented for purposes of these decisions by the following officials or their respective designees: Director of Fish and Game, Marine Biologist, Biologist for Fisheries, Commissioner of Safety, Executive Director of Water Supply and Pollution Control Commission, Chief Aquatic Biologist of the Water Supply and Pollution Control Commission, Commissioner of Highways, Commissioner of Resources and Economic Development, Director of the Division of Parks, Director of Planning and Research in the Division of Economic Development.

1967, amended 1969.

A small acquisition program is being pursued.

Massachusetts: 1) Mass. Gen. Laws Ann. ch. 130 Sec 27A

The Director of Marine Fisheries may impose such conditions as he deems necessary on dredging or filling operations to protect shellfish or marine fisheries. A public hearing will be held by the local selectmen.

1963, minor modifications 1965, 1969.

2) M.G.L.A. ch. 130, Sec 105

The Department of Natural Resources may restrict or prohibit dredging, filling, removing or otherwise altering or polluting coastal wetlands. There is provision for taking land by eminent domain.

1965.

3) M.G.L.A. ch. 130, Sec 40A

The Department of Natural Resources has the same authority essentially over inland wetlands as coastal wetlands.

1968.

4) M.G.L.A. ch. 223

This act authorizes localities to establish Municipal Conservation Commissions. The Commissions could, among other opportunities, acquire land for conservation purposes.

1957.

Rhode Island: R.I. Gen. Laws Ann. 2-1-13 through 2-1-17

These acts establish a public policy of preserving the coastal wetlands of the state. The Department of Natural Resources may, after public hearing, designate coastal wetlands or parts thereof, the ecology of which shall not be disturbed. This designation will be recorded in the registry of deeds in each city or town where the land is located. The right of appeal is allowed for 2 years after recordation. Provision is made for award of damages.

1965.

Rhode Island has a limited acquisition program.

Connecticut: 1) Conn. Gen. Stat. Ann. 26-17a

This act provides that the State Board of Fisheries and Game may by purchase, exchange, condemnation, gift, devise, lease or otherwise acquire tidal wetlands or easements, interests or rights therein. A further provision states that when municipal property tax on tidal wetland is unpaid for six years, the State Board of Fisheries and Game must be notified. If the Board desires, it may direct the municipality to foreclose and then, by paying the lien and expenses of the municipality, obtain the property.

1967.

2) C.G.S.A. 25-10 through 25-17

These statutes provide for the dredging of sand and gravel from lands under tidal and coastal waters. This is regulated by the Water Resources Commission, supplemented by a member designated by the Shellfish Commission. Public hearings must be held. Shore erosion, navigation and living resources must be considered.

1957 amendments through 1963.

3) Local zoning for marshland protection has been attempted unsuccessfully in Connecticut. Dooley v. Town Zoning Commission, 157 Conn 304, 197A 2d 770, 1964.

4) Public Act No. 695 Jan. 1969.

This act provides that the Commissioner of Agriculture and Natural Resources will inventory all wetlands. Once inventoried all draining, dredging, excavation, dumping and filling and erection of structures on lands designated as wetlands shall be regulated by the Commissioner.

Provision is made for court review of the Commissioner's decision, and provision is made for compensation for regulations felt to be takings.

New York: N.Y. Town Law 64-B

The town board of each town is authorized to appoint a Town Conservation Advisory Council which may conduct research into land areas of the town, coordinate activities of unofficial bodies and engage in educational activities. The councils will also keep an index of all open areas within the town and an index of all open marshlands, swamps and all other wetlands.

1967.

New Jersey: 1) N.J. Stat. Ann. 12:5-3 through 12:5-8

The Board of Commerce and Navigation must pass on all plans for development of waterfront which involves the construction or alteration of a dock, wharf, pier, bulkhead, bridge, pipeline, or any other similar or dissimilar waterfront development. Public hearings may be held. No provision is made for eminent domain.

No references are made to protection of natural resources.

1914.

2) N.J.S.A. 13:8A-1 through 13:8A-18

This is New Jersey's Green Acres Land Acquisition Act of 1961. The act provides for purchase of lands for public recreation and conservation of natural resources. A sum of $60,000,000 was made available by a Green Acres Bond referendum. The acquisition program is under the direction of the Commissioner of Conservation and Economic Development. Of the total amount available, $20,000,000 was for the purpose of supporting local acquisition. In addition to fee simple acquisitions, acquisition of conservation easements is permitted.

1961.

3) N.J.S.A. 40:56A-1 through 40:56A-5

This legislation enables municipalities to appoint Conservation Commissions. The commissions have the authority, subject to the approval of the governing body, to acquire land or conservation easements on land. The commissions are required to keep an index of private and public open areas including marshlands, swamps and other wetlands and may engage in research and educational activities.

1962.

Delaware: No Delaware statutes relative to wetland protection were found. A limited acquisition program is in effect.

Pennsylvania: 32 Penn. Stat. 5007 through 5013

These statutes provide for the acquisition and preservation of open spaces to meet needs for recreation, amenity and conservation of natural resources. Public hearings are required. Condemnation is authorized. Land acquired shall be offered for resale subject to conservation easements or restrictive covenants limiting land to designated open space use. The Department of Forests and Waters and the Department of Agriculture are authorized to obtain land under these statutes. This acquisition is to be financed by public bonds.

1968.

Maryland: 1) Ann. Code of Md. Art 78A section 19A

This section established a Land Acquisition Division under the Department of Public Improvements to acquire land for state projects funded under the "Outdoor Recreation Land Loan of 1969" or "Program Open Space."

1969.

2) Counties in Maryland may have Codes of Public Local Laws which may pertain to coastal wetlands; for example, the Code of Public Law Worcester County Section 15A establishes a fill and bulkhead line and a borrow area limit line. Section 15B of the Code creates a Shoreline Commission whose duties include regulating and determining bulkhead lines, shorelines and fill lines.

1965.

Virginia: See main text.

North Carolina: 1969 Adv. Legislative Service No. 7, Section 113-229.

The North Carolina Department of Conservation and Development shall pass on all excavation and filling proposals. If any state agency raises an objection to action of the Department of Conservation and Development, a meeting of a Review Board composed of Directors (or designees) of the Department of Administration, the Department of Conservation and Development, the Department of Water and Air Resources, the Wildlife Resources Commission, the Board of Health and any other agency designated by the Governor, may be held. The Review Board may affirm, modify or overrule the action of the Department of Conservation. Provisions for appeal to the courts are provided. No provision is made for taking by eminent domain.

1969, effective 1 January 1970.

An acquisition program is in effect funded by part of the state motor vehicle tax fund (N.C.G.S. 105. 446.2 1967 amended 1969.

South Carolina: No wetlands protective legislation other than usual fish and game laws and water pollution laws were found. No active acquisition program is being pursued.

Georgia: An attempt to establish a Coastal Wetland Protective Board failed to pass the 1969 Georgia General Assembly. Otherwise only usual fish and game laws and water pollution control laws are germaine to wetland protection.

Florida: Florida Stat. Ann. Section 253.12 through 253.124

These sections provide for sale of state submerged land by the Trustees of the Internal Development Trust Fund, the establishment of bulkhead lines, and regulation of filling by local authorities, subject to review by the Trustees. Prior to the sale of land or establishment of bulkhead lines or approval of fill applications, a biological and ecological study, and sometimes a hydrographic study, must be conducted. Ecological or biological impairment is sufficient to prevent sale or limit bulkheading and filling.

1963, amended through 1967.

Alabama: 1) Alabama Code Title 8, Sections 232-252

The Director of Conservation is vested with authority to develop state-owned swamplands. These laws are designed to encourage exploitation.

2) Alabama Code Title 38, Sections 119 through 122

These statutes set forth the right of riparian owners. These authorize and encourage riparian owners to develop lands abutting on tidelands owned by the state by filling and improving these tidelands.

1915, 1932.

The Department of Conservation is authorized to acquire lands in connection with fish and game programs.

Mississippi: Mississippi Code Sections 7549.7-01 and 7605-09

These sections give Port Commissioners or County Port Authorities, respectively, full jurisdiction and control over lands below mean high tide, including filling and dredging operations. The title to oil and gas remains in the state. These statutes are designed to encourage development of the submerged lands.

Mississippi has no acquisition program.

Louisiana: In addition to general water pollution control legislation, legislation relative to mineral leasing (oil wells) is the only pertinent legislation in Louisiana.

Texas: Rev. Civ. Stat. Texas, Articles 4051 through 4056a

These statutes give the Texas Parks and Wildlife Commission management control over marl, sand, gravel and shell deposits in the navigable streams, bays, bayous, and the Gulf of Mexico within jurisdiction of the state. Prior to issuing dredging permits, the Commission must consider possible damage to oysters, oyster beds and fish.

California: 1) Wests Ann. Fish and Game Code Section 5653

The Department of Fish and Game may regulate the use of any vacuum or suction dredge equipment used in any river, stream or lake of the state.

1961.

2) Wests Ann. Gov. Code 66601 through 66661

The San Francisco Bay Conservation and Development Commission is established permanently with the powers to issue or deny permits after public hearings for any projects involving the placing of fill, extracting of materials or making any substantial change in use of any water, land or structure within the area of its jurisdiction. The Commission should make a continuing review on the nature, extent, estimated cost and method of financing of proposed acquisition of private property for public use. No provision for taking by eminent domain is provided.

1965, amended 1969.

Oregon: 1) Revised Statutes 1967-1968, Section 273.425

The State Land Board must consider conservation of natural resources when leasing or disposing of state land.

2) R.S. 1967-68, Sections 274-355 through 274-375

The Fish and Game Commission shall be notified of all dredging. If this dredging involves possible damage to fish spawning areas, the Fish and Game Commission will develop a program to minimize the damage.

Washington: 1) Rev. Code Wash. Ann. 43.51.650 through 43.51.705

A Sea Shore Conservation Area is established covering the sea coast of Washington. This area is for recreational use only. The State Parks and Recreation Committee administers the land.

2) R.C.W.A. 43.99.010 through 43.99.910

The State Parks and Recreation Committee is authorized to acquire lands for marine recreation. This acquisition will be financed by that portion of the state motor vehicle fuel tax paid by boat owners.

RECOMMENDATIONS

Management Recommendations

1. A definition of wetlands should be adopted by the State for use by those governmental units, particularly counties, which wish to zone their wetlands as conservation lands.

2. Since zoning powers derive from the State, it should prepare a series of guidelines for zoning of wetlands, shorelines and shallows. Where local or regional zoning authorities fail to act in an adequate manner, the State should be prepared to assume zoning responsibilities directly.

3. Steps should be taken at once to halt, by any means possible, uncontrolled or unnecessary alteration of wetlands. This policy should be followed until such time as a mechanism is established to protect public values from damage by these alterations.

4. The Marine Resources Commission, as the present legal lead agency for management of coastal resources, should be given the statutory authority to approve, modify, or disapprove plans for all proposed modifications or alterations to coastal wetlands, whether governmentally or privately owned. Such modifications and alterations should include dredging, ditching, diking, filling, bulkheading, constructing of piers and wharfs, and any other activities which affect the ecology of coastal wetlands or the estuarine flora and fauna associated with coastal wetlands.

    Those portions of the Code of Virginia which specifically prevent the Marine Resources Commission from effectively regulating activities such as dredging and disposal of sand and gravel or channel dredging by riparian owners, and marina and boatyard construction should be changed so as to permit effective protection of these public values.

    The Virginia Institute of Marine Science should be required to advise the Marine Resources Commission of probable consequences of modifications and what, if any, changes can be made to proposed modifications or alterations to mitigate or eliminate environmental and ecological damages.

    A review board, composed of the heads of the Commission of Game and Inland Fisheries, State Water Control Board, Virginia Department of Health, Department of Conservation and Economic Development, Department of Agriculture, Department of Highways, Commission of Outdoor Recreation, Virginia State Ports Authority, Division of State Planning and Community Affairs, and the Virginia Institute of Marine Science, should be constituted as an avenue of appeal from decisions of the Marine Resources Commission pertaining to other public agencies or subdivisions where coastal wetland issues are involved. Appeals from decisions involving private individuals and businesses should be made through the civil courts, rather than through the review board. We are of the opinion that Federally-sponsored projects (excluding those for defense) should be subject to joint State-Federal review.

5. The ownership and boundaries of wetlands in many areas are unclear or of doubtful validity. It is suspected that a considerable area of wetlands may be in State ownership without State cognizance of such ownership. Immediate action should be undertaken to locate precisely those coastal wetlands owned by the State. Action by the General Assembly should be taken to place the burden of proof of ownership of disputed lands on private claimants rather than on the State.

6. Tax-delinquent coastal wetlands should revert to the Commonwealth upon the satisfaction of tax liens by the Commonwealth to the municipalities. These lands should not be offered by tax sale until each of the State agencies listed above shall approve of the sale. In addition, an immediate moratorium should be placed upon disposition of all wetlands currently in the hands of the State government or the courts.

7. New land created by nature which does not accrete to riparian land, such as the sizeable island at Dawson Shoals in Accomack County, should be retained in the possession of the State. Especially to be prohibited are accretions which have resulted from unauthorized obstructions of normal channels.

8. Acquisition of wetlands by the State should proceed as rapidly as possible. This effort should concentrate at the present on those wetlands which are of particular ecological value.

   Provisions should be made in the statutes to prevent speculation on those wetlands designated as high priority for purchase. To adequately protect the rights of owners, the anti-speculation provisions should have a definite time limit when applied to specific tracts.

   Since many coastal wetlands are bordered by sub-aqueous lands leasable for various purposes by the Commonwealth, the Marine Resources Commission should be requested to be extremely cautious in leasing bottoms near areas designated as high priority for acquisition by State or other governmental agencies. The Commission should also be requested to notify those State agencies which may be concerned with wetland acquisition, preservation, or development, whenever applications for leasing in high priority areas are pending.

9. Certain shallow areas immediately adjacent to coastal wetlands are as highly productive as the adjacent wetlands. These areas should not be leased by the Commonwealth for any purpose that

would reduce their productivity. The Virginia Institute of Marine Science should be directed to inform the Marine Resources Commission of the location of such productive shallow, sub-aqueous areas.

10. A fund for purchase of coastal wetlands should be instituted. This fund could be financed by:

    1) General Fund appropriations
    2) Bonds
    3) Increased commercial user fees
    4) Recreational user fees (salt water angling licenses, boat registration fees, etc.)
    5) Unrefunded taxes on fuel used in motor boats
    6) Gifts
    7) Specific appropriations
    8) Joint State and Federal programs for land acquisition and management

    Monies should be appropriated at once from the General Fund and should continue until other sources are available. Continuing Special Fund or General Fund appropriations may be necessary to provide matching monies. This fund could also be used to compensate those individuals for lands deemed by the courts to be taken as a result of regulations imposed on prospective alterations by the Marine Resources Commission. Title to lands acquired under this program should initially be vested in an appropriate State agency.

11. Sound management of Virginia's wetland resources requires a continuing knowledge of their status through surveillance of these resources, particularly in those areas where rapid changes are occurring. Once original survey data are acquired, the information should be handled by an automatic data processing system. Information should be in such format as to allow rapid sorting and retrieval for comparative purposes, i.e., comparison of current survey data with the original base line data. In accordance with the intent of the Resolution authorizing this investigation of wetlands, it is important that the Virginia Institute of Marine Science develop and maintain an inventory of all coastal wetlands (now being done under provisions of H. R. No. 69) in as much detail as possible. Funds for this work must be augmented and continued. The inventory should be kept current and should include such items as the specific conditions of wetland areas, their contribution to estuarine productivity, their vulnerability to alteration and their current economic status.

Research Recommendations

1. It is clear that estuaries and littoral waters are closely dependent upon adjacent wetlands and that a proper balance must be preserved as the coastal zone is developed by man in order to maintain vital features of both. Not clear are certain details

of dependence and of the vital values and features. Interactions between estuarine and coastal waters and wetlands must be more carefully delineated and established.

The role of wetlands in the productivity of the estuary must be more clearly documented, especially with regard to species of economic and social importance. Documentation will indicate the most fruitful avenues of approach in wetland management, and will permit more accurate evaluation of the importance of different types and tracts.

2. Several species of small crustaceans occupy a critical position in the food webs of wetland-dependent fishes. The ecology of these crustaceans is poorly understood although it appears that they subsist largely on plant material of wetland origin. An understanding of this aspect of wetland ecology could indicate means of maintaining or increasing desirable species. Also important is an understanding of the susceptibility of these crustaceans to pesticides.

3. Problems associated with artificial organic enrichment are becoming increasingly severe and it appears that in the near future large sums of money must be spent on sewage treatment facilities designed to remove nutrient materials. Information regarding the ability of wetlands to assimilate nutrients and means of augmenting such assimilation may, by reducing the treatment facilities needed, reduce the amount of funds required for facilities. This information may also indicate means of increasing the productivity of the estuary through intelligent disposal of organic wastes.

4. Research is needed to ascertain methods of stabilizing shorelines and barrier island dunes through the use of vegetation. There is evidence that this may be much less costly and much more effective than physical structures currently employed.

5. Deliberate burning of wetlands is commonly practiced in Virginia. Employed judiciously, it may reduce fire hazards. Although fire is a useful tool in fire prevention or wetland management in some areas, its ecological effect in Virginia is largely unknown. This should be investigated to determine if regulation is needed.

6. Several introduced species have appeared in Virginia within the last century (Carp) or within the last two decades (Marsh Clam, Nutria, Cattle Egret, Glossy Ibis). These animals, while all of commercial value or aesthetic interest, could be interacting unfavorably with species that have long existed in the State. The ecology of these species should be better known.

7. A Japanese sedge has become locally established in Virginia. It should be carefully studied to evaluate its effect on native species. This sedge may prove superior to some native species for dune stabilization. A hybrid cordgrass is rampant and regarded as

a pest in England; however, this species may prove useful in areas that do not support native cordgrass. In light of the experience with other introduced plant species, introductions cannot be advocated without exhaustive research, no matter how promising the initial evidence may appear. In addition, native species, such as Live Oak and Sea Oats, not now found on seaside of the Eastern Shore should be investigated.

8. Large areas devoid of vegetation often occur in marshes. The cause of these is unknown, but it has been observed that erosion proceeds rapidly in their vicinity. It is not clear whether these areas are a recent development. This phenomenon should be investigated. If only one group of plants is involved, the underlying cause may be a specific disease.

9. Old corduroy roads are being uncovered in some marshes. In addition to being of scientific interest as indicators of rates of sediment deposition, they are of historic value. Steps should be taken to obtain the information that these artifacts offer before they are destroyed.

10. Mosquitoes and Green-head Flies are abundant in some places, especially where salinity is high. The use of biocides as control measures has had severe effects on non-target species, such as birds, fishes and crabs. A better understanding of the life cycle and ecology of noxious species could indicate control measures which do not involve such hazards.

11. Swamps are the least understood component of the coastal wetlands. Their role as sediment traps, sanctuaries for rare and unusual species, and primary producers should be investigated so that appropriate management procedures may be formulated for them.

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APPENDIX

GLOSSARY

Amphipoda--large order of laterally compressed crustaceans with the first thoracic segment fused with the head and lacking a true carapace.

Anaerobic mud--sediment devoid of oxygen and rich in hydrogen sulfide.

Aquifer--permeable material through which ground water moves.

Autotrophy--a type of nutrition in which complicated organic molecules are synthesized from carbon dioxide and water.

Benthos--organisms associated with the bottom of a body of water.

Biogenic--resulting from the activity of living organisms.

Biological oxygen demand (BOD)--the oxygen required by aerobic organisms, as those in sewage, for metabolism.

Bloom--mass outbreak of phytoplankters in nutrient-rich waters.

Borrow pits--excavations from which fill material was removed.

Brackish--pertaining to the waters of bays and estuaries, salty but of lower salinity than sea water.

Compensation point--the light intensity at which the release of photosynthetic oxygen equals the utilization of respiratory oxygen.

Consumers--those organisms in an ecosystem which feed upon other organisms; often divided into primary consumers (plant eaters), secondary consumers (carnivores which eat primary consumers), etc.

Demersal--occurring on or near the bottom.

Detritus--fine particulate debris of organic or inorganic origin.

Ebb tide--the outgoing water (tide).

Ecology--the study of the relations of organisms to their environment.

Ecosystem--all organisms in a community plus the associated environmental factors.

Ecotone--transition area between two adjacent communities.

Epifauna--sessile or sedentary benthic organisms living on the bottom.

Estuary--tidal body of water linked to the sea at one end and measurably diluted by freshwater at the other.

Fastland--the land behind a marsh.

Fetch--the uninterrupted distance travelled by wind over water.

Filter feeder--an animal that obtains its food by filtering small particles from water.

Flagellates--microscopic protozoans and algae which use flagella (long whip-like structures) for locomotion.

Flood tide--the incoming water (tide).

Flotsam--materials found floating on the water.

Hammock--a woodland surrounded by marsh.

Heterotrophy--type of nutrition characteristic of animals and some bacteria and true fungi which depend on organic matter from other plants and animals for food.

Hydrography--the science of the measurement, description and mapping of the surface waters of the earth.

Infauna--benthic organisms which burrow into the bottom.

Intertidal--area on a beach between mean high water and mean low water.

Isopoda--large order of dorso-ventrally compressed crustaceans with the thoracic segment fused with the head, abdomen short, and some or all segments fused.

Littoral--intertidal.

Longshore currents--the flow of water parallel to a beach caused by waves approaching the beach at an angle.

Meroplankton--organisms in the plankton for only part of their life cycle.

Microbiota--microscopic plants and animals of a habitat or region.

Microfauna--microscopic animals of a habitat or region.

Mean higher high water (MHHW)--average height of the higher high waters at a place over a 19-year period.

Mean lower low water (MLLW)--average height of the lower low waters at a place over a 19-year period.

Monospecific community--a community dominated by one organism.

Nutrient transformation--the biotic cycling of nutrients from inorganic to organic compounds.

pH--a measure of the hydrogen ion concentration or the relative acidity or alkalinity of a solution; a pH of 7 is neutral, greater than 7 alkaline and less than 7 acid.

Photosynthesis--the process in green plants of utilizing radiant energy from the sun to synthesize carbohydrates from carbon dioxide and water.

Phytoplankton--microscopic algae and fungi suspended in the water column.

Poikilotherm--cold-blooded animal.

Productivity--the rate of energy storage of an ecosystem.

Primary productivity--total quantity of carbon fixed by photosynthesis per unit time. It is usually approximated by measuring dissolved oxygen evolved, amount of a radioactive C^{14} label taken up, or the standing crop of chlorophyll in a sample of phytoplankton.

Respiration--sum total of all chemical and physical processes by which organisms (plants and animals) utilize organic materials as sources of energy and heat; usually oxygen is used and carbon dioxide and water are the chief end products.

Rhizome--a root-like subterranean stem, commonly horizontal in position, which usually produces roots below and sends up shoots progressively from the upper surface.

Salinity gradient--a decrease in salinity with distance away from the sea.

Sediment--mineral or organic matter deposited by water, air, or ice.

Standing crop--the total weight of organisms present at any one time, usually expressed as dry weight.

Suspension feeder--filter feeder.

Swale--a low wet place.

Tidal prism--the volume of water between high and low tide.

Topography--the features, relations, or configurations of a structural entity.

Transpiration--the escape of water vapor from plants.

Trophic level--one of the several successive levels of nourishment in a food chain; plant producers constitute the first (lowest) trophic level and dominant carnivores constitute the last (highest) trophic level.

Turbid plumes--discharging water ladened with sediment.

Tychopelagic--a benthic organism which enters the water column.

Vascular plant--higher plant provided with conducting vessels.

Xerophyte--plant adapted to dry conditions.

Zonation--the occurrence of typical animals and algae on specific regions of a beach, piling, or any object in the water.

Zooplankton--floating or weakly swimming animals.

MARSH-ESTUARY INTERACTIONS

The diagram illustrating the interactions between physical and biotic interactions (Fig. 1) is drawn with the factors most involved on the left-hand side. The following commentary will begin with major interactors and proceed clockwise around the diagram.

1. Marsh Plants. Affected by:

   a) Tidal range causes a greater luxuriance where daily inundation occurs.

   b) Water chemistry determines the species of plants present and their productivity to a great extent.

   c) Turbid water during a high tide coats photosynthesizing surfaces and affects production of organic compounds.

   d) Pollutants--Organic pollution often enhances plant growth; thermal pollution increases growth in some plants, decreases it in others.

   e) Water temperature, especially where tides cover the soil, affects growth and seed germination.

   f) Homiotherms affect marsh plants in several ways--Building of nests by birds has little effect, grubbing for roots by Muskrats and Snow Geese has long-lasting results; grazing by Nutria may deprive aquatic animals of food but increases phytoplankton production since feces would be swept into the water; Blackbirds and waterfowl may eat most of the seed produced by some marsh plants but ducks are known to carry seeds to new areas; Marsh Wrens and Yellow-throats eat grasshoppers and other insects which feed on marsh plants; finally, man benefits physically and aesthetically from marsh plants in many ways and has eminent domain over their survival.

   g) Marsh poikilotherms are here intended to include Fiddlers, Crayfish, insects, frogs, snakes, turtles and those fish which live in close proximity to the marsh. Square-backed Fiddlers eat considerable quantities of <u>Spartina</u> grass, grasshoppers may eat 5% of the total grass production and leaf hoppers suck the juices of plants, Carp erode away the soil from plant roots.

   h) Wind is needed to pollinate plants but strong winds may cause some plants to lodge.

i) Without solar energy, green plants could not grow.

j) Plants also require nutrients and may grow better next to channels because certain minerals are more available there; plants also release stored nutrients as microbes degrade dead tissue.

k) Some perennial marsh plants grow a little during the winter but warm air temperatures are needed for fast growth.

l) Land erosion affects plants by depositing more silt in marshes--usually this accumulates more in creeks and results in destruction of productive marsh; type of soil substrate, if clay or sand, seems minor in affecting type of plant growth, but a tough peat base is much more erosion resistant.

m) Plants provide abundant detritus to the estuary if tidal range or floods are effective.

n) Smaller aquatic animals feed on detritus supplied by plants.

2. Tidal range is highly important to an estuary. Its greater height in the brackish to fresh zones and on seaside makes those areas more productive. Higher tides have many effects:

a) They provide for greater exchange of nutrients and waste products.

b) Turbidity is increased.

c) Current velocity is heightened on the ebb tide and dampened (in rivers) on the flood.

d) Water temperatures are moderated over the wetlands by being cooled in summer and warmed in winter.

e) Homiotherms are able to feed in marshes and flats when the tide is out, except for ducks which usually find food more available at high tide. Birds and mammals which breed in the marsh must elevate their nest structures above the highest tide levels.

f) Likewise, Fiddler Crabs must enter their burrows and snails must climb up the grasses to escape predation by fish as the tide comes in. On the Eastern Shore, some species of fish lays its eggs in the shell cavity of a dead Ribbed Mussel at high tide, and live Mussels and marsh Oysters can feed only when the tide is in. Insects may stay above the tide, but the Greenhead Fly and Salt-marsh Mosquito (*Aedes solicitans*) evidently deposit their eggs when the tide is out. The Striped Killifish "adheres to the very shore's edge" (22) on a flood tide and other small fish probably do the same, ranging into the marsh on the highest tides.

g) High winds greatly amplify tides, piling water into the Bay with sustained northeast wind and blowing it out with prolonged northwest winds in winter. In the latter situation, gulls have an opportunity to carry off shellfish on very low tides. Killifish burrow in the mud to escape death, but some invertebrates may die when frozen during low tide.

h) Wave action obviously affects more area during high tides.

i) Phytoplankton composition would be quite different in marsh pools and guts if tides did not provide an exchange of water. Since plankton productivity is higher in marsh pools than in the river, tides carry this living material to the estuary.

j) Nutrient exchange requires tidal transport.

k) Turbulence is more dependent on wind than on tides, but tides alone have an effect.

l) Organic detritus would not be supplied to the water in significant amounts without good tidal exchange.

m) Aquatic animals benefit from wetlands through the agency of tides.

n) Submerged plants may benefit from nutrients released from marshes but they also are prevented from growing on mudflats bared at low tide.

3. Water Chemistry. Oxygen, salinity, phosphorus, nitrogen and, in freshwater, alkalinity are particularly involved. Water chemistry is affected by many factors and, in turn, affects many others.

a) Turbid waters become clearer in the estuary due to the flocculating effect of saline water.

b) Pollutants affect water by their biological oxygen demand (BOD). Marshes help aerate the water during high tide and they release the least organic matter in summer when oxygen is naturally low. Pollution, either organic, toxic, or thermal, exerts the greatest influence in the summer. Saline water coagulates fine particles and causes them to sediment out, resulting in a diminution of organic pollution to safer levels.

c) Water temperature strongly affects chemical reactions, which tend to double with each 10°C rise.

d) Wind affects water chemistry mainly by oxygenating the water but also by producing high tides which flush detritus and nutrients from the marsh.

e) Solar energy causes photo-oxidation of some chemicals and otherwise affects chemistry by providing energy for storms.

f) Phytoplankton requires nutrients and also produces oxygen by day and uses it by night.

g) Nutrients produced elsewhere become part of the total water chemistry.

h) Land erosion brings clay, organic material and toxic wastes which affect normal water chemistry.

i) Substrates have a lesser effect on the overall chemistry, but the myriad stems of marsh plants are instrumental in accumulating clay particles at least temporarily.

j) Water chemistry and organic detritus interact--saline water precipitating fine organics while organics supply nutrients.

k) Aquatic animals require ample oxygen, especially the more active organisms, but they produce carbon dioxide which affects pH and reduces the rate of oxidation of organic debris.

l) Submerged aquatic plants release large amounts of oxygen, some of which they need for respiration at night. Nutrients and salt concentrations which cause one plant species to luxuriate may be deleterious to another.

4. Turbidity, the condition of having varying amounts of suspended materials in water, is particularly evident in tidal freshwater.

a) Pollutants increase turbidity.

b) Strong currents increase turbidity, as evidenced by the Hurricane Camille floods.

c) Water temperature is affected by turbidity--dark water absorbs more heat.

d) Wave action also increases turbidity.

e) Turbidity affects phytoplankton by decreasing the compensation point depth but phytoplankton by their abundance may affect turbidity.

f) Air temperature secondarily affects turbidity simply by heating the upper layers of water, thereby promoting stratification.

g) Land erosion is the source of most clay particles which produce turbidity.

h) Organic detritus increases turbidity, thus affecting phytoplankton production but at the same time nurturing a great amount of animal biomass.

i) Aquatic animals may be benefited or harmed by turbidity, depending on the nature and amount of the suspended materials.

j) Submerged aquatic plants are adversely affected by turbidity. Silt-laden rivers support little aquatic vegetation.

5. Pollutants have both direct and indirect effects which may often be complex and occur far from the source of pollution.

a) Warm-blooded animals are particularly affected by toxic pollutants such as chlorinated hydrocarbons. The Bald Eagle has become rare in Virginia in less than a decade because of DDT.

b) Cold-blooded animals of the marsh, such as Fiddler Crabs and Mosquitoes, are directly affected by pesticide pollutants.

c) Some pollutants--dust, aerial sprays and smoke--are carried by wind.

d) Sunlight is effective in decomposing many pollutants.

e) Warm air aids dispersal of dust and smoke.

f) Land erosion has historically affected the upper tidal reaches of rivers and creeks more than any other pollutant.

g) Organic detritus from sewage and manure often causes noxious pollution.

h) Aquatic animals, such as bivalve molluscs, may be adversely affected by silt and clay pollution. Pesticides particularly magnify in organisms as they enter a food chain via the detritus pathway and end up in tertiary carnivores such as the Osprey and humans.

i) Aquatic plants are adversely affected by excessive sewage wastes and severe siltation.

6. Current velocity varies with rain, tides, wind, and cross-section of a river.

a) It affects water temperature by making it more uniform.

b) Strong currents make feeding more difficult for ducks and grebes, as well as for swimming mammals.

c) Currents and turbulence are directly proportional to each other.

d) Land erosion products are carried distances proportional to the current velocity.

e) The same condition as in (d) applies to organic detritus.

f) Aquatic animals, especially smaller ones, are particularly affected by strong currents.

g) Submerged aquatic plants are seemingly less affected by currents.

7. Water temperatures may vary up to 60°F. The activities of the biota are much influenced by temperature.

a) Wind usually moderates water temperatures, but it also promotes mixing and thus general warming.

b) Temperature of the water ultimately depends on the sun's warmth.

c) Temperature of water and air together modify climates of wetlands.

d) Aquatic animals being cold-blooded have their activities dependent on water temperature; some cease feeding in winter.

e) Submerged aquatic plants typically regress in winter.

8. Homiotherms (warm-blooded animals) are less important to man than their aquatic relatives but scarcely less interesting.

a) Raccoons seem to feed in marshes mainly on Fiddler Crabs and Crayfish most of the year, although we did find one scat composed of only _Macoma balthica_ shells. Wrens feed on insects and Rails on a variety of small animals.

b) While less affected by temperature than poikilotherms are, homiotherms must still adapt to the rigors of summer's heat and winter's chill.

c) Muskrats prefer marsh peat substrates for their houses and ramifying burrows. Otters like slick creek banks to slide on. The Belted Kingfisher requires vertical clay banks for nest sites. Ground-nesting birds need dry sites, except for Rails, Coots, Gallinules and Willets which may use rather damp nest sites. These animals have adapted to marsh living but many others only come to marshes and swamps for food.

d) Many homiotherms, especially birds, feed on aquatic animals such as frogs and small fish.

e) Some ducks, such as the now scarce Canvasback and Redhead, eat rooted aquatic plants as most of their diet.

9. Marsh poikilotherms are mainly Fiddler Crabs, Killifishes, turtles, insects and a surprising number of spiders.

a) All of these creatures are able to retreat to shady or watery places when air temperatures become severe.

b) They are affected mildly by land erosion if silt fills their burrows, clouds the water and coats the vegetation.

c) Fiddlers feed on detritus somewhat and create more, as do most of the animals.

10. Wind is most effective in conjunction with high tides and its influence is particularly felt in seaside and bayside areas.

a) Solar energy is largely responsible for wind.

b) Wind, in turn, produces waves.

c) Wind, through waves, is largely responsible for turbulence in shallow waters.

d) Wind and air temperatures have a reciprocal relationship.

11. Solar energy may be blocked by cloud cover and its effect altered by the sun's angle to the earth, but it is otherwise independent of earthly phenomena.

a) Air temperature is most affected by the sun's heat.

b) Submerged aquatic plants depend as much on the sun, and thus also on clean water, as do the marsh plants.

12. Wave action depends highly on direction fetch and tide level, thus its effect on wetlands varies greatly.

a) Waves are directly responsible for most turbulence.

b) Bank erosion results in exposed areas if the land is unprotected by grass, gentle slope, or artifices.

c) Beach and marsh substrates are altered if waves carry away finer materials and deposit them in quieter waters.

d) Aquatic animals must be able to cope with strong waves or retreat from them.

e) Aquatic plants, such as Eelgrass, are torn loose and deposited on beaches by waves.

13. Phytoplankton consists of one-celled plants, particularly diatoms and dinoflagellates.

a) Phytoplankton change inorganic nutrients into organic compounds capable of being digested by certain crustaceans and fishes.

b) Turbulence may supply nutrients to phytoplankters but may also make the water turbid and thus reduce the light supply.

c) Organic detritus is partially produced by phytoplankton, especially in summer.

d) Many aquatic animals feed directly on plankton.

14. Nutrients include inorganic and organic compounds.

a) Erosion of the land produces certain nutrients but may also tie up others on clay particles.

b) As with phytoplankton, rooted aquatics utilize simple compounds to produce complex food substances.

15. Turbulence refers particularly to the vertical mixing of water.

a) Substrates may be eroded by turbulent water.

b) Organic detritus is kept in suspension by turbulence.

c) Aquatic animals, particularly filter feeders, require some turbulence.

d) Submerged rooted plants probably thrive better where turbulence is only moderate.

16. Air temperature varies daily and seasonally and affects the activities of all organisms in shallow water, flats and marshes.

17. Land erosion produces only minor amounts of beneficial organic detritus. Erosion of high ground is largely detrimental.

18. Substrate type often determines the kinds of benthic animals present.

19. Organic detritus is essential to many aquatic animals. Submerged aquatic plants may contribute considerable detritus in some water.

20. Relatively few aquatic animals feed directly on rooted aquatic plants.

TABLE 1a.*

Tidal Wetlands of the Potomac River

Quadrangle	Wooded Marsh	Marsh	Open Creeks	Tidal Flats	Ponds	Total
Alexandria '65	51	161	128	66	48	454
Belvoir '65	239	290	290	360	7	1,186
Blakiston Island '46	7	290	521	0	62	880
Dahlgren '55	92	1,215	514	44	99	1,964
Heathsville '46	360	1,376	4	0	88	1,828
Indian Head '56	0	136	18	4	7	165
King George '55	0	18	99	0	0	117
Lottsburg '44	0	125	400	0	26	551
Machodoc '43	0	1,178	602	0	55	1,835
Mathias Point '54	0	117	0	0	0	117
Morgantown '53	0	33	26	0	4	63
Mount Vernon '56	51	92	33	62	0	238
Passapatanzy '66	114	657	180	0	0	951
Piney Point '46	0	95	22	0	7	124
Quantico '56	609	514	169	587	7	1,886
St. George Island '42	0	128	172	0	4	304
Stafford '46	136	172	191	0	0	499
Stratford '46	0	385	143	0	18	546
Sunnybank '46	0	525	1,354	0	110	1,989
Wakefield '46	51	576	543	0	40	1,210
Widewater '66	18	400	51	0	4	473
Yeocomico River '43	62	352	1,141	0	73	1,628
Total acres	1,790	8,835	6,601	1,123	659	19,008

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* See also Appendix Figures 1 and 2.

TABLE 1b.

Tidal Wetlands of the Rappahannock River

Quadrangle	Wooded Marsh	Marsh	Open Creeks	Woodland	Tidal Flats	Sand	Ponds	Dredged Areas	Total
Champlain '43	37	1,549	301	0	0	0	33	0	1,920
Deltaville '64	0	158	1,009	33	429	59	55	11	1,754
Dunnsville '44	4	257	110	0	0	0	0	0	371
Fredericksburg '66	415	15	0	0	0	0	0	0	430
Guinea '66	1,215	0	0	0	0	0	246	0	1,461
Haynesville '47	0	881	697	0	0	0	0	0	1,578
Irvington '49	0	338	1,523	0	0	0	110	0	1,971
Lancaster '49	0	407	455	0	0	0	0	0	862
Litwalton '48	0	829	760	0	0	0	40	0	1,629
Montross '43	870	103	161	0	0	0	0	0	1,134
Morattico '44	37	1,090	341	0	0	0	26	0	1,494
Mount Landing '44	562	1,674	217	0	0	0	77	0	2,530
Occupacia '49	128	631	59	0	0	0	128	0	946
Passapatanzy	64	147	0	0	0	0	0	0	211
Port Royal '47	606	628	169	0	0	0	0	0	1,403
Rappahannock Academy '47	539	195	48	0	0	0	0	0	782
Rollins Fork '49	1,284	363	110	0	0	0	0	0	1,757
Saluda '65	723	690	305	4	51	0	11	0	1,784
Samos '49	0	569	172	0	0	0	4	0	745
Tappahannock	95	3,721	1,200	26	0	0	125	0	5,167
Urbanna '46	0	943	1,952	0	0	37	18	0	2,950
Wilton '64	110	308	1,196	37	242	0	51	0	1,944
Total acres	6,689	15,496	10,785	100	722	96	924	11	34,823

TABLE 1c.

Tidal Wetlands of the York, Pamunkey and Mattaponi Rivers

Quadrangle	Wooded Marsh	Marsh	Open Creeks	Woodland	Tidal Flats	Sand	Ponds	Total
Achilles '65	0	1,901	2,096	484	639	84	29	5,233
Aylett '49	0	642	294	0	0	11	110	1,057
Beulahville '51	213	0	51	0	0	0	7	271
Clay Bank '65	0	1,251	1,218	290	558	0	275	3,592
Gressitt '65	0	2,521	525	345	837	0	55	4,283
King & Queen '49	0	2,202	33	0	224	0	0	2,459
King William '49	0	1,248	305	0	7	15	7	1,582
New Kent '65	2,606	2,378	389	0	349	0	132	5,854
Old Church '50	0	2,617	525	0	0	0	77	3,219
Shackelfords '65	70	18	11	0	0	0	0	99
Toano '65	0	1,119	95	0	121	0	66	1,401
Truhart '49	0	668	7	0	0	0	0	675
West Point '65	110	5,189	125	0	0	26	132	5,582
Williamsburg '65	84	1,640	261	15	374	0	528	2,902
Yorktown '65	0	88	4	0	22	33	0	147
Total acres	3,083	23,482	5,939	1,134	3,131	169	1,418	38,356

TABLE 1d.

Tidal Wetlands of the James River

Quadrangle	Wooded Marsh	Marsh	Open Creeks	Woodland	Tidal Flats	Sand	Ponds	Dredged Areas	Total
Bacon's Castle '57	209	217	51	0	33	0	22	0	532
Benn's Church '65	0	1,699	1,064	0	217	0	22	0	3,002
Bowers Hill '65	4,202	206	459	0	0	0	0	0	4,867
Brandon '65	154	1,751	323	0	59	0	0	0	2,287
Charles City '65	1,138	1,020	378	62	415	0	0	0	3,013
Chester '52	407	33	176	0	0	0	0	0	616
Chuckatuck '65	2,261	2,132	70	0	345	0	33	0	4,841
Claremont '66	473	81	0	0	29	0	169	0	752
Drewry's Bluff '52	106	0	0	0	0	0	0	0	106
Dutch Gap '52	316	261	0	0	0	0	15	0	592
Hog Island '65	114	973	206	0	172	22	11	0	1,498
Hopewell '54	1,354	327	242	0	0	0	0	0	1,923
Mulberry Island '65	0	1,325	84	0	562	0	0	0	1,971
Newport News N '65	217	345	33	0	154	0	0	0	749
Newport News S '64	0	620	198	66	444	0	0	0	1,328
Norfolk S '65	26	59	661	0	92	0	0	0	838
Norge '65	48	3,024	884	635	77	0	40	0	4,708
Providence Forge '66	1,318	0	0	0	0	0	88	0	1,406
Richmond '68	451	29	0	0	0	0	15	0	495
Roxbury '65	1,707	26	0	0	0	0	40	0	1,773
Savedge '66	195	484	334	0	22	0	22	0	1,057
Suffolk '54	0	305	70	0	0	0	0	0	375
Surry '65	341	785	294	0	29	0	0	0	1,449
Tunstall '66	951	334	0	0	191	0	40	0	1,516
Walkers '65	947	554	1,182	0	0	0	4	0	2,687
Westover '65	741	319	455	0	796	0	0	0	2,311
Yorktown '57	0	1,255	440	0	147	18	117	70	2,047
Total acres	17,676	18,164	7,604	763	3,784	40	638	70	48,739

TABLE le.

Tidal Wetlands of the Eastern Shore Seaside

Quadrangle	Wooded Marsh	Temporary Lakes	Marsh	Open Creeks	Woodland	Tidal Flats	Sand	Ponds	Total
Accomac '57	128	0	1,440	165	0	960	0	0	2,693
Boxiron '64	0	0	139	26	0	0	0	37	202
Cape Charles '48	0	0	160	0	0	2,080	0	0	2,240
Cheriton '55	0	0	3,040	73	0	3,520	0	0	6,633
Chincoteague E '65	22	213	1,600	88	0	320	1,960	44	4,247
Chincoteague W '65	0	0	6,080	855	0	640	965	70	8,610
Cobb Island '42	0	0	848	95	0	16,480	0	0	17,423
Exmore '43	0	0	1,760	382	0	0	0	0	2,142
Girdletree '46	0	0	168	0	0	0	0	0	168
Great Machipongo '42	0	0	320	7	0	800	0	0	1,127
Little Machipongo '42	0	0	6,400	176	0	10,240	0	0	16,816
Mappsville '42	0	0	5,440	264	0	0	0	0	5,704
Metomkin Inlet '57	0	0	5,440	257	0	960	415	48	7,120
Nassawadox '42	0	0	7,840	183	33	15,200	0	0	23,256
Ship Shoal Inlet '48	0	0	3,840	239	0	4,160	37	26	8,302
Townsend '55	0	0	6,560	103	33	1,760	0	0	8,456
Wachapreague '57	0	176	12,800	587	0	9,440	345	51	23,399
Wallops Island '65	0	0	2,560	198	0	0	400	0	3,158
Whittington Point '64	0	0	0	0	0	0	55	0	55
Total acres	150	389	66,435	3,698	66	66,560	4,177	276	141,751

TABLE 1f.

Tidal Wetlands of the Eastern Shore Bayside

Quadrangle	Wooded Marsh	Marsh	Open Creeks	Tidal Flats	Sand	Ponds	Total
Cheriton '55	0	0	319	66	0	0	385
Chesconessex '42	0	2,081	969	0	0	0	3,050
Crisfield '46	0	95	0	0	0	0	95
Elliot's Creek		Included in other maps					
Ewell		Included in other maps					
Exmore '43	0	0	708	0	0	0	708
Franktown '43	0	275	2,734	0	0	0	3,009
Great Fox Island '42	0	224	0	0	0	15	239
Hallwood '47	0	683	158	0	0	0	841
Jamesville '43	0	675	3,197	0	0	66	3,938
Nandua Creek '42	0	286	169	0	0	11	466
Parksley '42	0	5,461	855	0	0	15	6,331
Pungoteague '43	0	1,218	2,797	0	0	0	4,015
Saxis '42	139	6,015	294	0	0	44	6,492
Tangier Island '42	0	631	92	0	0	0	723
Townsend '55	0	11	327	0	0	0	338
Wescott Point '55	0	51	62	374	9	0	496
Total acres	139	17,706	12,681	440	9	151	31,126

TABLE 1g.

Tidal Wetlands of the Western Chesapeake Bay Shore and

Smaller Tributaries

Quadrangle	Wooded Marsh	Marsh	Open Creeks	Woodland	Tidal Flats	Sand	Ponds	Dredged Areas	Total
Cape Henry '64	1,204	48	206	0	301	217	0	0	1,976
Deep Creek '54	6,419	488	88	59	0	0	0	0	7,054
Fentress '54	0	4,048	0	0	0	0	0	0	4,048
Fleets Bay '49	0	738	2,169	0	0	66	37	0	3,010
Gloucester '65	0	176	70	15	0	0	0	0	261
Hampton '65	37	2,063	584	51	158	195	37	0	3,125
Kempsville '52	514	198	15	0	0	0	0	0	727
Little Creek '64	0	51	407	0	26	62	0	0	546
Mathews '65	0	1,868	3,259	176	1,072	349	132	0	6,856
New Point Comfort '64	0	877	859	121	888	169	29	22	2,965
Norfolk N '65	0	139	286	0	110	349	0	0	884
Poquoson E '64	44	2,187	99	62	0	117	26	0	2,535
Poquoson W '65	103	220	991	0	213	0	26	0	1,553
Princess Anne '65	360	48	0	0	228	0	0	0	636
Reedville '44	0	558	2,231	4	0	0	110	0	2,903
Ware Neck '65	0	503	749	15	661	0	0	0	1,928
Total acres	8,681	14,210	12,013	503	3,657	1,524	397	22	41,007

TABLE 1h.

Tidal Wetlands

Quadrangle	Temporary Lakes	Wooded Marsh	Marsh	Open Creeks	Woodland	Sand	Ponds	Total
Creeds '54	0	2,584	2,224	334	0	0	0	5,142
Knotts Island '54	0	11	2,980	136	0	866	29	4,022
Moyock '54	0	3,321	477	242	0	0	0	4,040
North Bay '53	0	117	5,982	110	62	613	103	6,987
Pleasant Ridge '54	0	8,966	862	437	0	0	0	10,265
Virginia Beach '65	374	81	220	338	0	143	0	1,156
Total acres	374	15,080	12,745	1,597	62	1,622	132	31,612
Boykins* '42		1,867						
Holland* '43		2,415						
Raynor '44		631						
Sebrell '57		150						
Sedley '44		683						
Vicksville '57		132						
Zuni '44		962						
Total acres		6,840						

*See introductory material.

Boykins and Holland quadrangle are 1:62,500 scale; each covers an area equal to four smaller quadrangles.

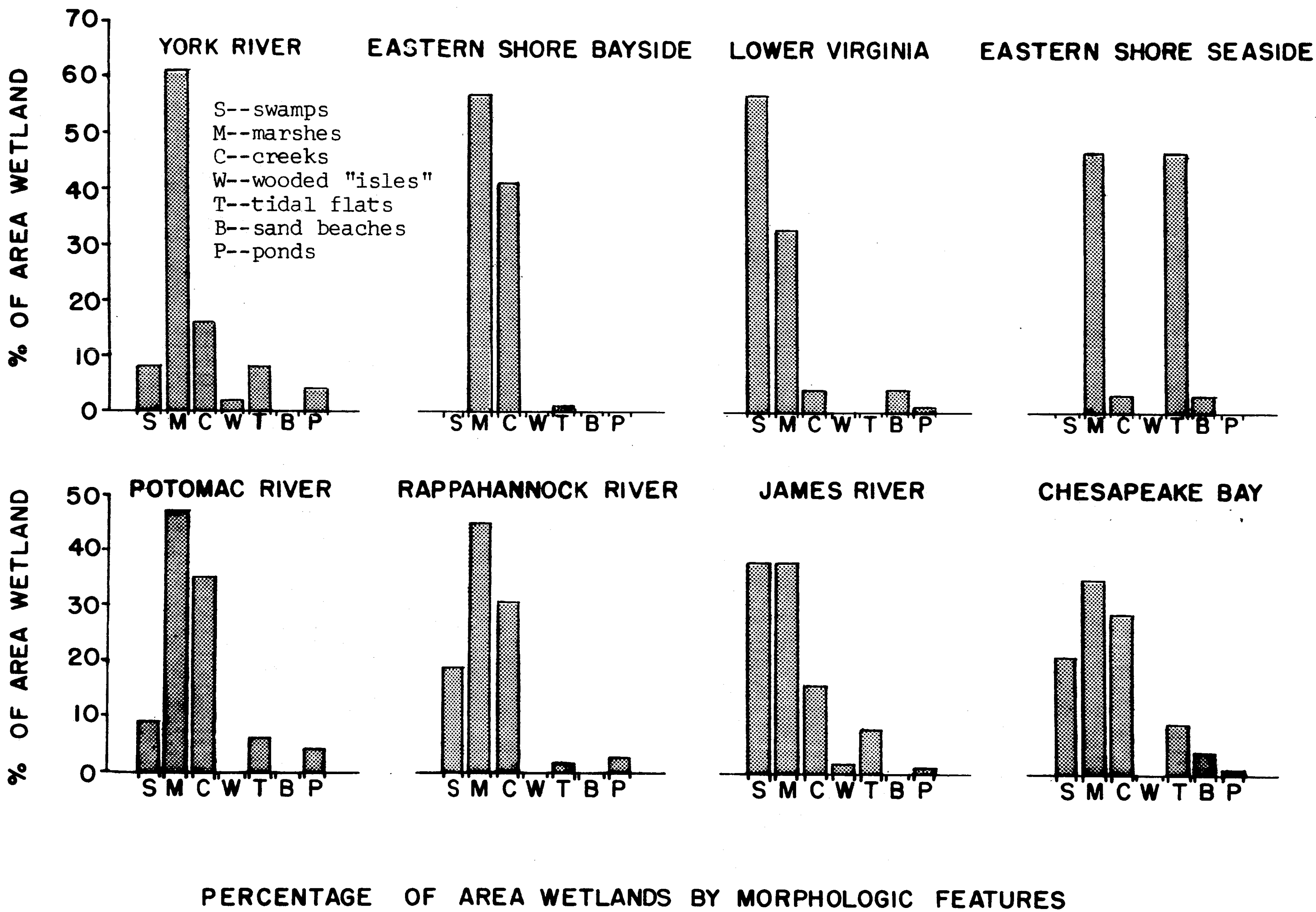
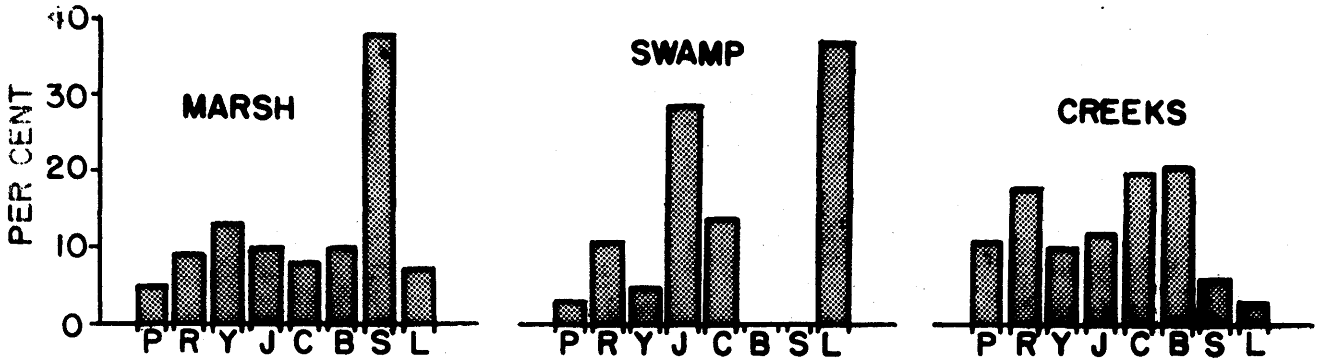
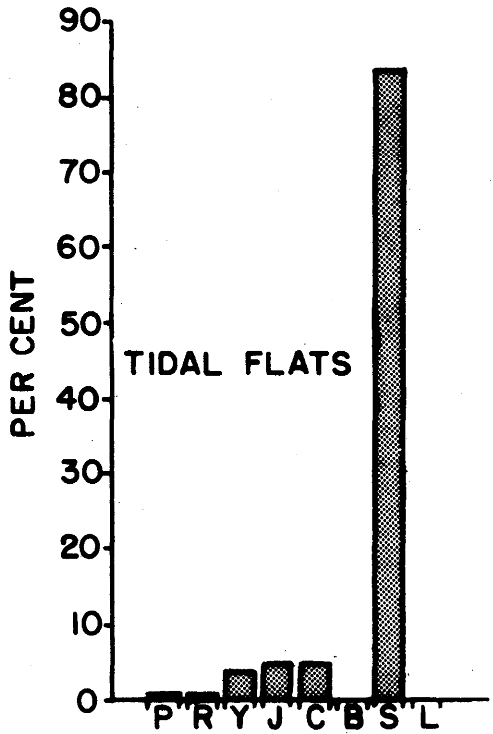
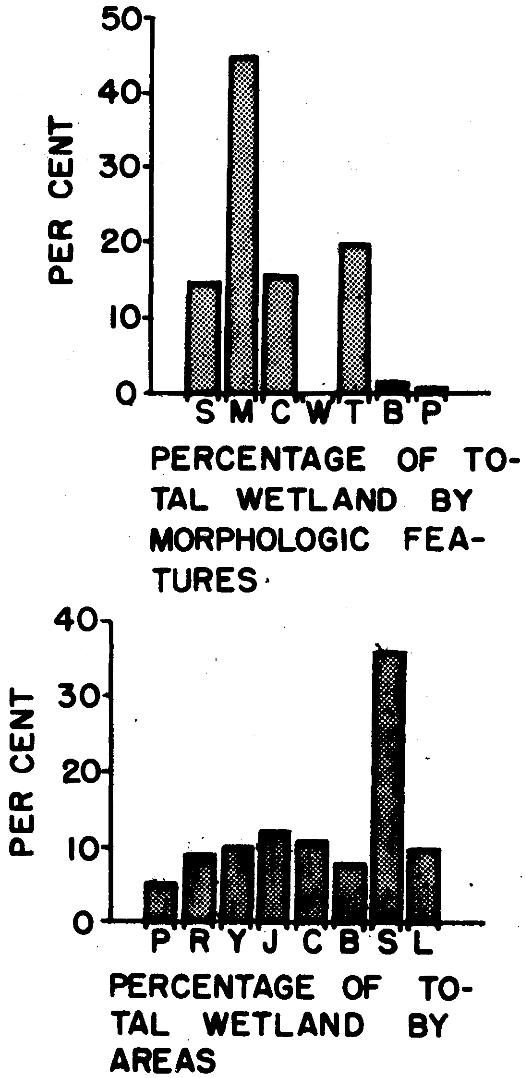

% OF AREA WETLAND
70
60
50
40
30
20
10
0
YORK RIVER
EASTERN SHORE BAYSIDE
LOWER VIRGINIA
EASTERN SHORE SEASIDE
S--swamps
M--marshes
C--creeks
W--wooded "isles"
T--tidal flats
B--sand beaches
P--ponds
S M C W T B P
POTOMAC RIVER
RAPPAHANNOCK RIVER
JAMES RIVER
CHESAPEAKE BAY
PERCENTAGE OF AREA WETLANDS BY MORPHOLOGIC FEATURES

Figure 1.

PERCENTAGE OF INDICATED WETLANDS BY AREAS







P - Potomac
R - Rappahannock
Y - York
J - James
C - Chesapeake
B - Eastern Shore Bayside
S - Eastern Shore Seaside
L - Lower (Southeastern) Virginia

Figure 2. Wetland locations by area and by type.

KEY TO APPENDIX FIGURES 3a-e

Wetland Areas (other than military, research and industrial) Owned by the State and Federal Governments

Potomac River

1. Mason Neck (future State Park)
2. Wakefield National Park
3. Westmoreland State Park

Rappahannock River

4. Nanzatico Wildlife Refuge

York River

5. Mattaponi Indian Reservation
6. Pamunkey Indian Reservation
7. York River (future State Park)
8. Colonial National Historical Park

James River

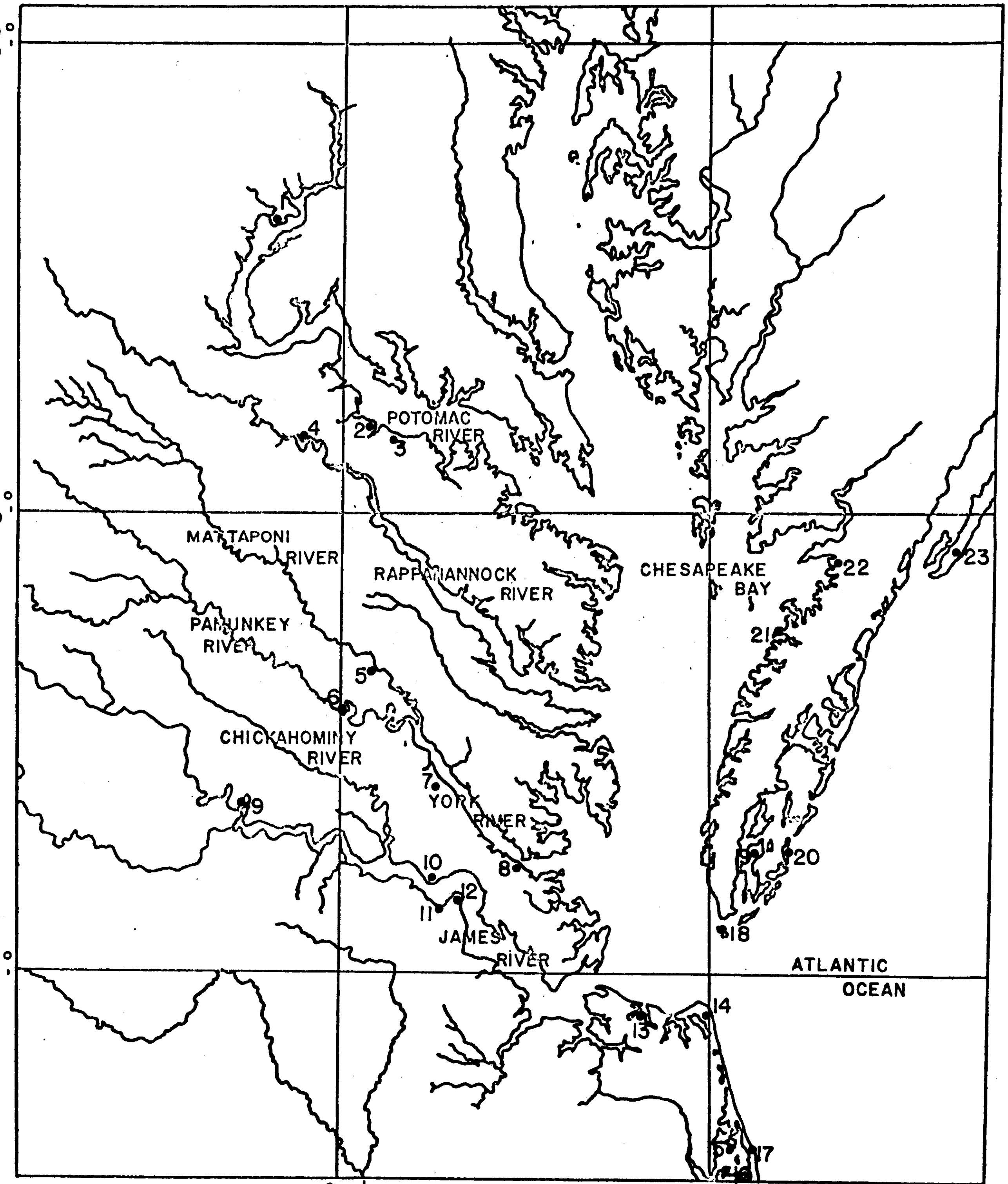
9. Presque Isle National Wildlife Refuge
10. Colonial National Historical Park
11. Chippokes Plantation (future State Park)
12. Hog Island State Waterfowl Refuge

Chesapeake Bay

13. Norfolk Municipal Azalea Gardens
14. Seashore State Park
15. Back Bay National Wildlife Refuge
16. Trojan-Pocahontas Wildlife Refuge
17. False Cape (future State Park)

Eastern Shore

18. Fisherman's Island National Wildlife Refuge
19. Mockhorn Island Wildlife Refuge
20. Wreck Island Natural Area
21. Parkers Marsh Natural Area
22. Saxis Island Wildlife Refuge
23. Chincoteague National Wildlife Refuge


39°
00'
38°
00'
37°
00'
77°00'
76°00'
POTOMAC
RIVER
MATTAPONI
RIVER
RAPPAHANNOCK
RIVER
PAMUNKEY
RIVER
CHICKAHOMINY
RIVER
YORK
RIVER
JAMES
RIVER
CHESAPEAKE
BAY
ATLANTIC
OCEAN
2
3
4
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23

Figure 3a.

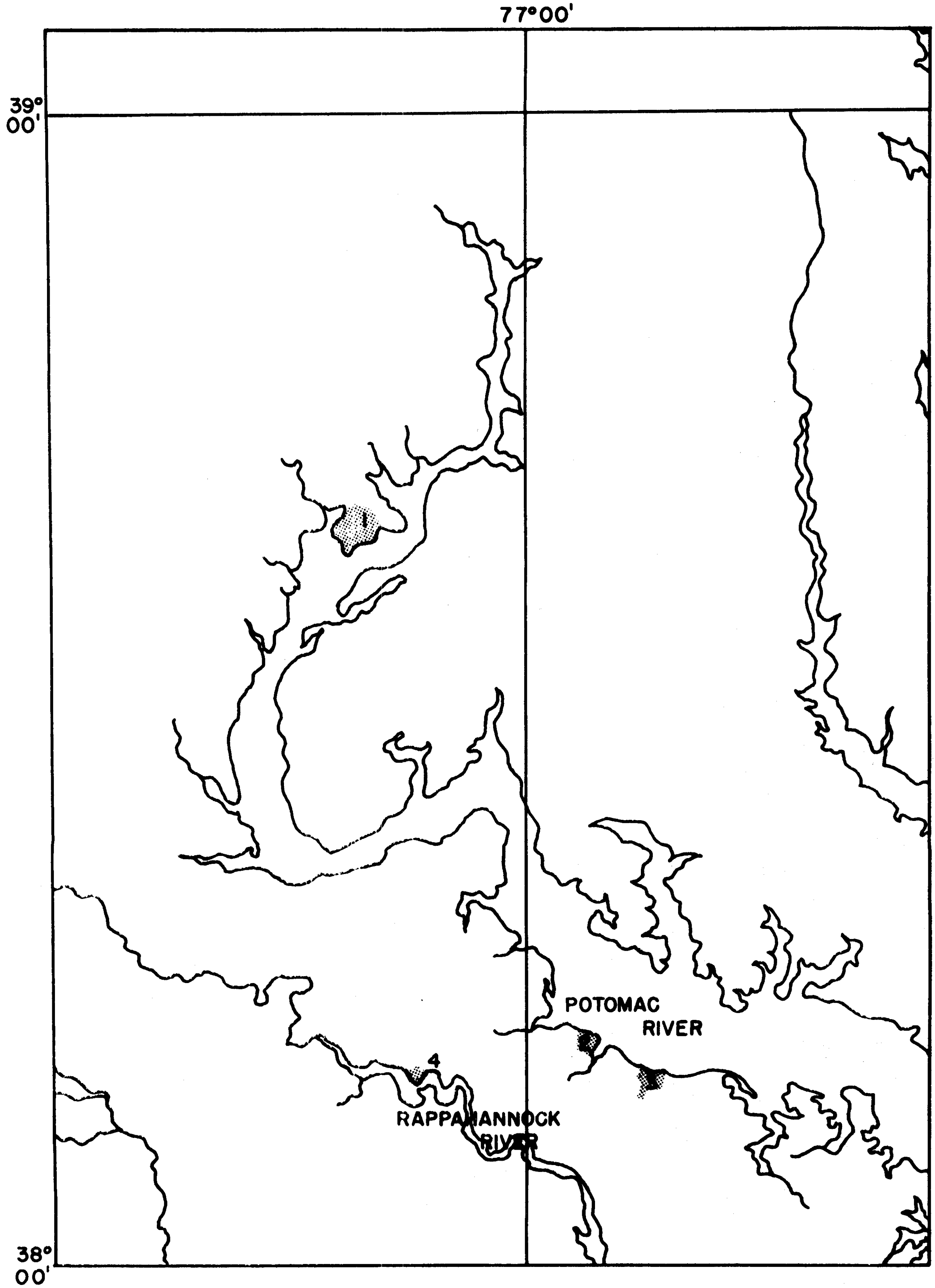

Figure 3b.

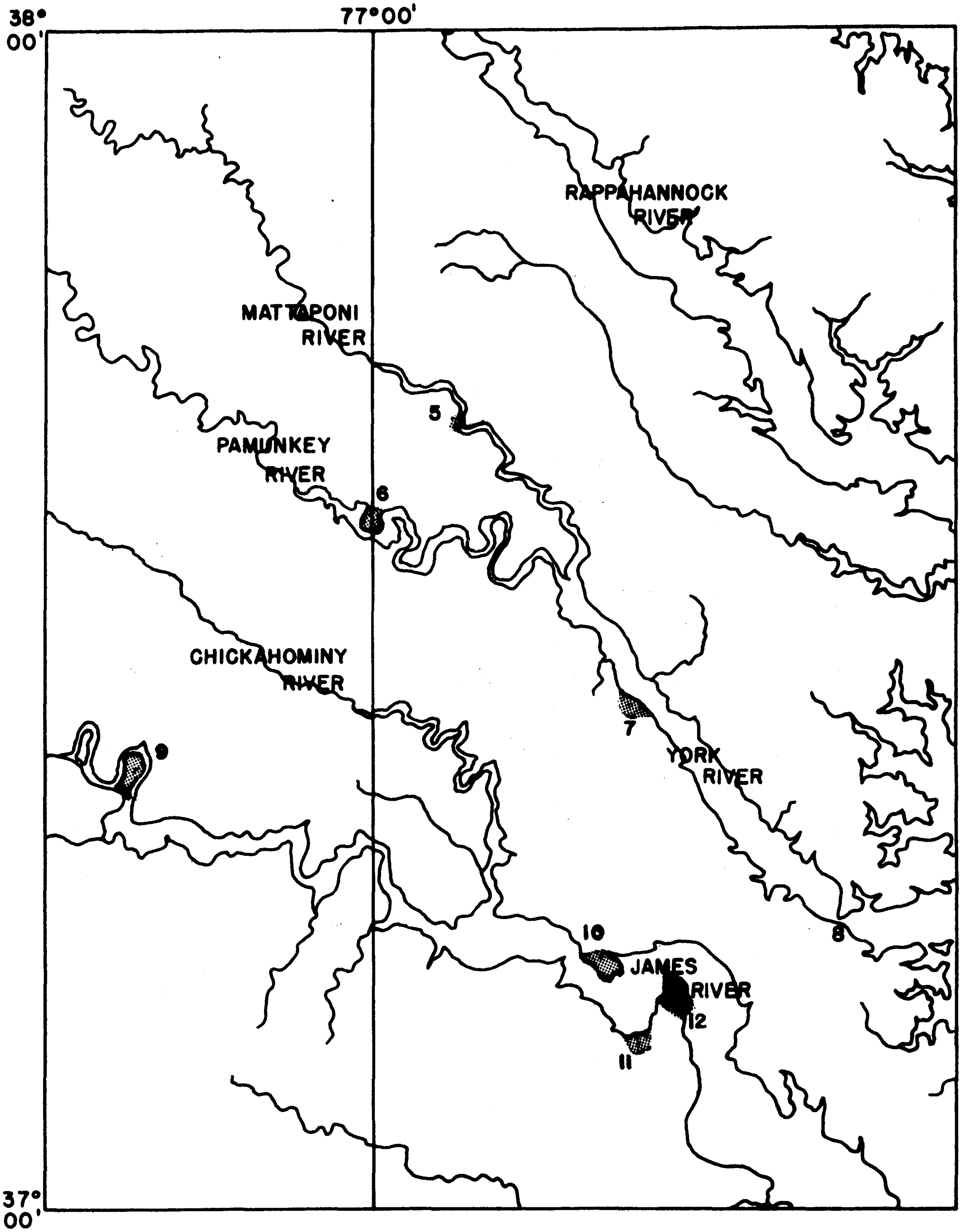
38°
00'
77°00'
RAPPAHANNOCK
RIVER
MATTAPONI
RIVER
5
PAMUNKEY
RIVER
6
CHICKAHOMINY
RIVER
7
YORK
RIVER
9
8
10
JAMES
RIVER
12
11
37°
00'

Figure 3c.

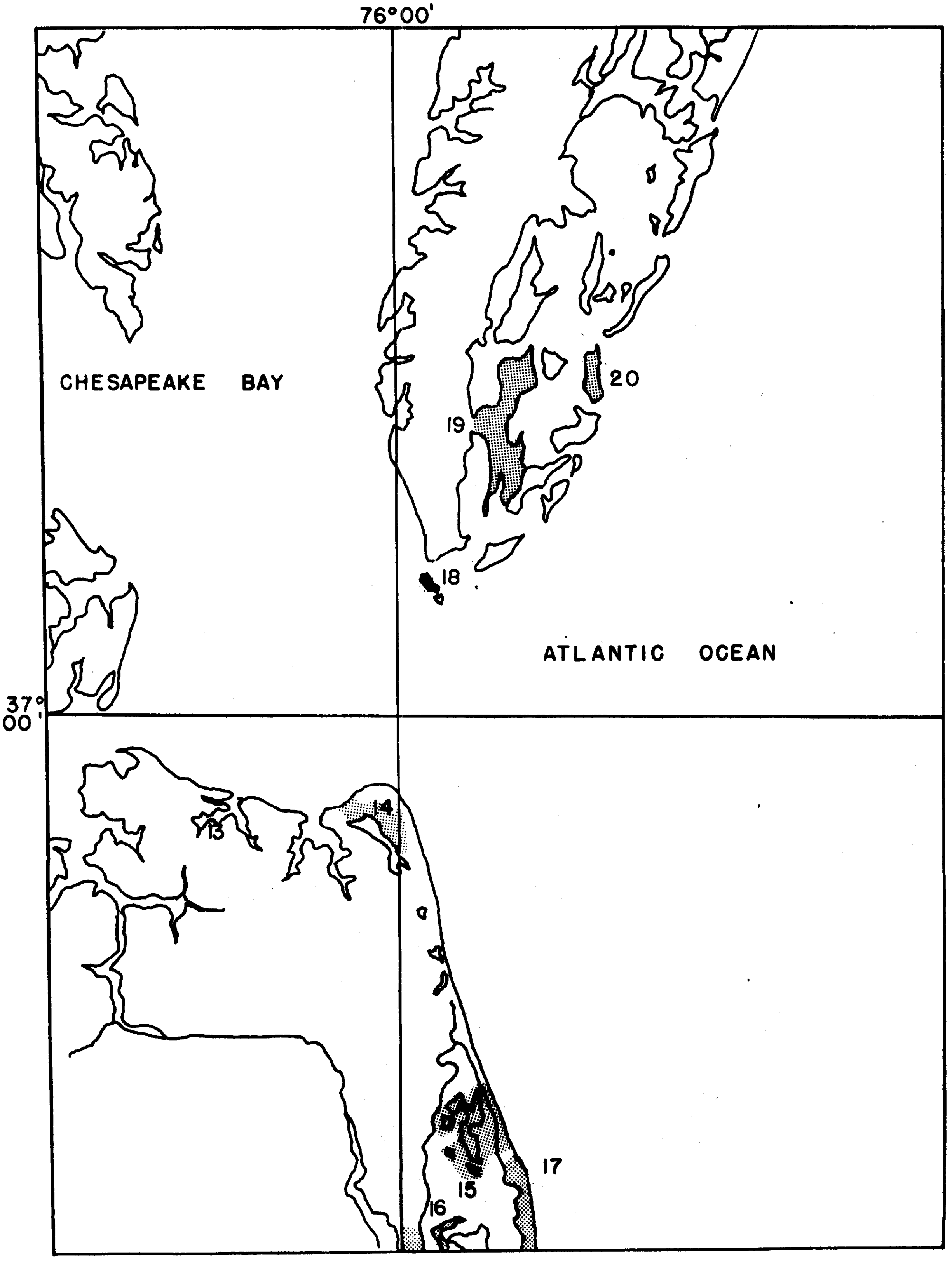
76°00'
CHESAPEAKE BAY
ATLANTIC OCEAN
37°
00'
13
14
15
16
17
18
19
20

Figure 3d.

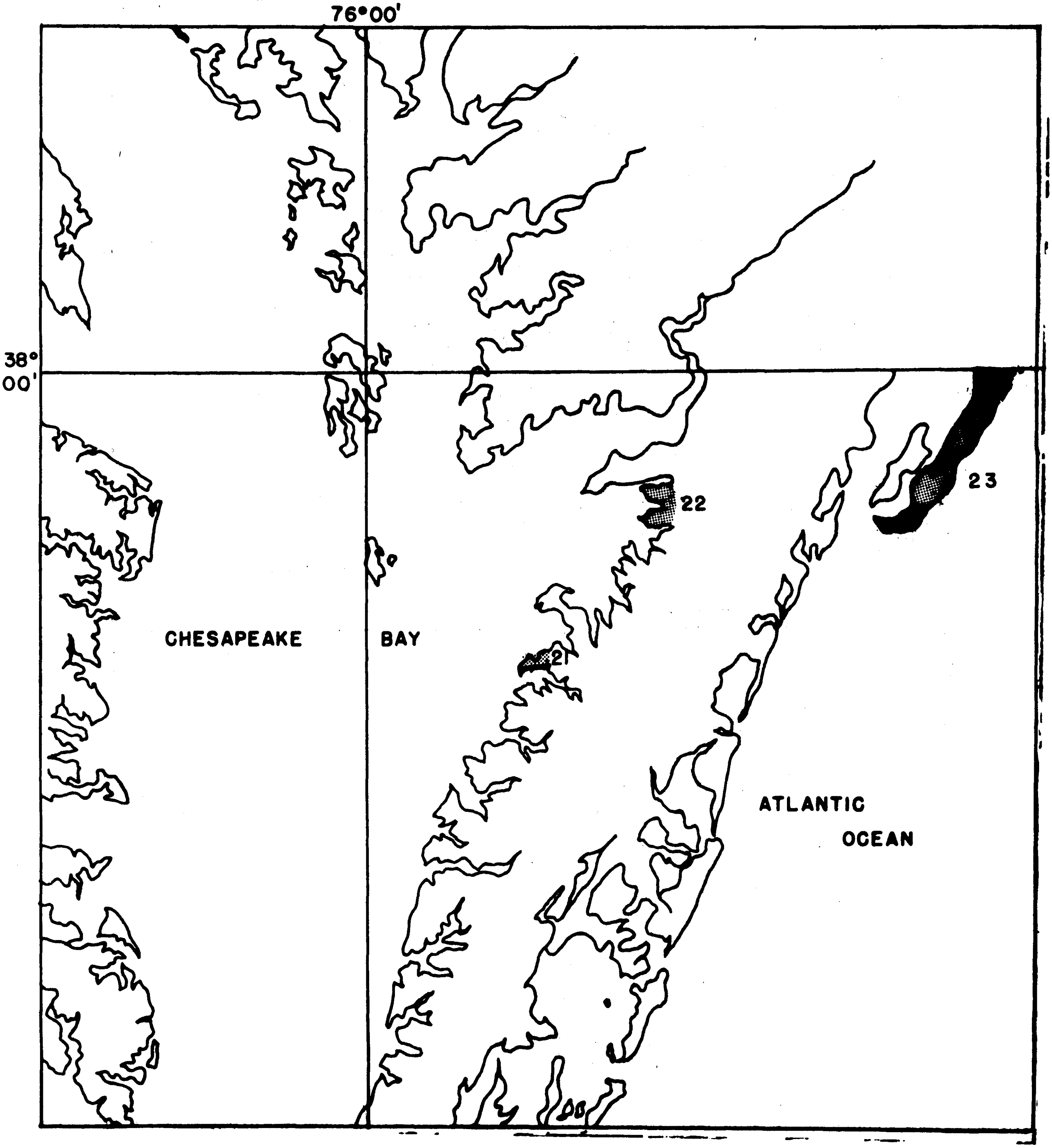

Figure 3e.