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I. Introduction

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". In completing the request, the "Coastal Wetlands of Virginia", Interim Report to the Governor and General Assembly was submitted in 1969.

The subjects of the study were the ecology of wetland areas, their value to the marine environment, their value to man, and man's relationships with wetlands. The distribution of Virginia's tidal wetlands was presented along with a description of the dynamics of the flora and fauna within them.

In addition the report presented recommendations for a wetlands definition and for the control of unnessary wetland destruction. The determination of ownership of wetlands and state aquisition of key areas was cited as necessary for proper management of the coastal zone wetlands. Further inventory and evaluation was recognized as being essential for proper management.

Specific scientific research needs were cited, namely studies of the interactions of wetlands and marine life, the influences of organic enrichment on marshes, and the stabilization of shorelines and barrier islands, as necessary to provide resource managers with facts on which to base management decisions.

The Institute has continued its interest in and concern for wetlands. Our identification and inventory activities and research programs have the common goal of answering crucial wetlands management questions.

Progress to date rests with the VIMS initiative and capabilities and with the harmonious cooperation of other individuals, institutions and agencies, both within and outside the Commonwealth. Further advances are almost assured, as evidenced by the increased interest in developing appropriate legislation, regulation and administrative apparatus and procedures for the wise management and preservation of wetland areas.

The identification phase of VIMS wetland-oriented activities is an interdepartmental and interdisciplinary effort to define various physical and biological parameters of tidal marshes. In addition efforts are being made to locate high priority wetlands; areas essential to the welfare of the marine environment, as a whole areas suffering considerable natural erosion and those areas suffering extensive disruption by man's activities.

The inventory phase, designed to quantify, evaluate and monitor wetland areas, providing essential knowledge to the Commonwealth, is also and will continue to be beneficial in programming the efforts of the third phase, the research aspect. The wetlands research program is a broad interdisciplinary, in-depth study of important physical, chemical and biological processes of tidal marshes. The various fields of research have been chosen on the basis of their timeliness and of the necessity to answer key management-oriented questions. The additional knowledge will result in less guesswork being incorporated at the management and engineering levels.

II. Identification

A. Definitions

When an entity enters the realm of interest to man it becomes necessary to identify it in a manner recognizable by all. The definition of the entity as recognized by various interests may assume many forms. Such may be the case for the entity wetlands. Though wetlands may be easily recognized, ecologists, civil engineers and laymen each have their own specific definition for them.

As requested by the Wetlands Study Commission, created by House Joint Resolution No. 60, VIMS prepared a definition of wetlands for the Wetlands Act, (1972 General Assembly). Prior to writing and submitting a definition, the wetlands definitions of other states were reviewed.

1. Tidal Wetland Definitions

New Jersey recently defined wetlands as any "bank, marsh, swamp, meadow, flat or other lowland subject to tidal action or coastal storm flowage, a definition very similar to one adopted in 1965 for Massachusetts coastal wetlands. Connecticut's wetlands definition included all land lying below an elevation of one foot above local extreme high water and upon which certain species of plants grew or could grow. Maryland's definition was less inclusive; only land lying below mean high water which supports aquatic growth was considered wetlands. Georgia defined tidal wetlands in a somewhat different manner. The term estuarine areas was substituted for wetland and was defined to mean all land lying below an elevation equal to five and six tenths (5.6') feet above the mean tide level.

None of these wetlands definitions however were considered adequate for Virginia's purposes and problems. Terms such as tidal action and coastal storm flowage as used in the New Jersey definition are rather imprecise and subject to considerable controversy. Definitions which include lands only to the mean high tide line would be seriously inadequate for Virginia. Most of the tidal wetlands in the Commonwealth lie slightly above the mean high water level. The Georgia definition is also not applicable to Virginia's wetlands. Wetlands by nature are dynamic and their structure is dependent to a great extent on the tidal range of the locality in which they are found. They are for the most part reasonably flat with the mean elevation probably near or slightly above the mean high water level. Since the mean high water level is a function of the tide range, and the variation in tide range in Virginia is nearly five feet, the mean geodetic elevation of the wetland surfaces is variable from locality to locality. A definition measuring a specified vertical distance above the mean tide level would not include all wetlands in those areas where a large tidal amplitude exists, but would include some upland areas in those locations where the tide range was small.

a) Physical Definitions verses Biological Definitions

Nearly all the coastal states, which have written into their codes a definition of wetlands, have incorporated lists of plants commonly found in low-lying areas as identification aids. One state has a purely physical definition based on the mean tide level. There are benefits and drawbacks to the use of either a physical definition or a wholy biological definition.

A definition based on lists of plants - a biological definition - would conceivably be all-inclusive of marshes. For example, if a given tract of land near a body of tidal water was vegetated with a specific combination of plants, it would be considered a wetland. A serious problem might develop, though, in locating the boundaries of wetlands and uplands. The question as to where the upland ends and the wetland begins would result in considerable controversy because of the gradual transition from one area to the other which occurs in some situations. The distinction between wetlands and uplands via vegetative characters would require the assistance of botanists, no two of whom might agree precisely on the location of a boundary. In essence a boundary would have to be arbitrarily selected rather than precisely located.

In addition wetlands are not restricted to those areas covered by vascular flora. The sand and mud flats which appear at ebb tide, are dominated by various forms of algae, diatoms, and invertebrates, some of which have a tremendous commercial and natural value. Yet vascular plants may not and often don't grow on those lands and consequently they-the lands, would not be considered as wetlands - by definition.

Equally important to the marine ecosystem are the steep banks and sand beaches of the Commonwealth. Though unvegetated in many situations, activities along them have significant impact on adjacent and remote marine environments. A botanical definition would not cover these areas.

b) Tidal Datum Planes

Before proposing a physical definition for wetlands it was necessary to evaluate specific features of tidal waters, namely mean low water, mean sea level, mean high water and the mean tide range. The paper by Boon and Lynch (1972) explains the details of tidal datum planes very well and may be consulted. A brief summary is necessary here, however.

Tides are dynamic, being dependent on gravity and the attraction of the moon and the sun. As the sun's and the moon's relative distance from the earth varies, so does the amplitude of the tides. Consequently the extremes of the tide, low water and high water vary daily, monthly and yearly. In order to average all variations in tide levels, a time period of 19 years is necessary.

The U. S. Coast and Geodetic Survey (Marmer, 1951) has therefore defined mean low water as the average of all low water levels over a 19 year period. The mean high water level has been similarily defined as the average of all high waters over a 19 year period. Mean sea level has been defined as the average height of the surface of the sea for all stages of the tide over a 19 year period, usually determined from hourly height readings (Boon and Lynch, 1972).

The mean tide range has been simply defined as the difference in elevation of the mean high water levels and the mean low water levels determined over a 19 year period. To collect tidal data over a 19 year period to determine the various sea levels for specific locations is impractical for most purposes. However, there are methods for determining, with a high degree of precision, various tidal levels for most locations. The procedure requires establishing a tide gauge at the location in question and then calibrating it with a reference tide gauge for which 19 year records are available. Tidal data collected over a period of one month generally allows the acceptable establishment of the location of tidal datum planes. Boon and Lynch (1972) also discuss in detail the method of simultaneous comparisons for establishing tidal datum planes.

c) Legal Aspects of Mean Low Water

Up until the recent session of the General Assembly the term mean low water did not appear in the Code of Virginia. The term low water mark had previously been used to define the waterward limit of properties adjacent to the waters of the Commonwealth. The term low water mark was defined to mean "ordinary low water, not spring tide or neap tide, but normal, natural, usual, customary or ordinary low water, uninfluenced by special seasons, winds or other circumstances." Clarification of the term low water mark occurred in Scott V. Doughty, 124 Va. 358, 97 S.E. 802 (1919).

During the recent session (1972) of the General Assembly, the term low-water as had appeared in section 62.1-2 was amended to read mean-low-water. This amendment in recognition of the daily variations in the location of low water marks will simplify legal disputes over the position of the mean low water mark as there are precise methods for its determination.

2. The Establishment of a Physical Definition for Virginia Wetlands

a) Hypothesis

The distribution of vegetation in wetlands is dependent in part upon the elevation of the water table or in the case of tidal wetlands, the period of inundation. A recent discussion of the distribution of tidal wetland vegetation in Virginia can be found in Kerwin (In press). Because the water level in tidal marshes is ever-changing, it was hypothesized that the mean tidal range of any given locality in Virginia might be a controlling factor in the vertical distribution of wetland vegetation. If so, the elevation of specific vegetative species above a datum plane in a location with a small tidal amplitude, the difference being due to the tidal amplitude.

It was reasoned that, if the hypothesis were true, it would be possible to write a definition describing the vertical extent of wetlands as some function of the tidal range.

b) Surveying Results and Evaluation of the Hypothesis

The tidal amplitude in Virginia's coastal waters varies from barely measureable to nearly 5 feet. To test the hypothesis that the vertical elevation above a datum plane of specific wetland plant species was a function of the mean tide range, tidal bench marks representing specific mean tidal ranges throughout the Commonwealth were selected. (See Figure 1.) At each location two characteristic species of vegetation, *Iva frutescens* and *Baccharis halimifolia*, collectively known as saltbushes, were sought and their lowest elevation was determined. The ratio of the mean elevation of the saltbush line above mean low water to the mean tide range of the locality was then calculated. Table I. lists the elevations, tidal ranges and ratios of the saltbush line to the tide range for the vicinity of each tidal bench mark surveyed.

The average ratio for 111 measurements among 24 locations was 1.5, ranging from 1.1 to 2.2. The median distribution of the values fell between 1.3 and 1.4. An analysis of regression, an estimate of dependency of one variable upon another, indicated that the minimum elevation of the saltbush line was highly dependent on the tide range. (Probability of error less than .01). The equation for the regression line was:

$$Y = 0.65 + 1.12X$$

where Y is the minimum elevation in feet above mean low water of the saltbush line in a locality where the tide range is X feet. Confidence limits about the regression line (at the 95 percent level of confidence; see Figure 2) indicate the statistically accept ble variability in the elevation of the saltbush line for various tide ranges.

Convariance analysis of the relationship of the minimum elevation of the saltbush line and the tide range indicated that 90 percent of the variation in the saltbush line was related to variation in the tide range.

The hypothesis was proven to be true: It was found that the lower limit in vertical distribution of certain species of tidal wetland vegetation is dependent on the tide range. Therefore a physical definition based on a tidal datum plane and some function of the mean tide range was considered feasible.

c) A Definition

The saltbush line was used as a reference mark in estimating the relationship between wetland vegetation zonation and tide range because the species were widely distributed and were easily identified. The two species are found within wetlands, not at their upper limit. Consequently their lowest elevation does not represent the maximum upper limit of a wetland for a locality. The wetlands which contribute the most biomass to the detritus food web tend to be low lying and to be inundated by the tides. The lower limit of the saltbush line is generally within the limits of that zone flooded by spring tides.

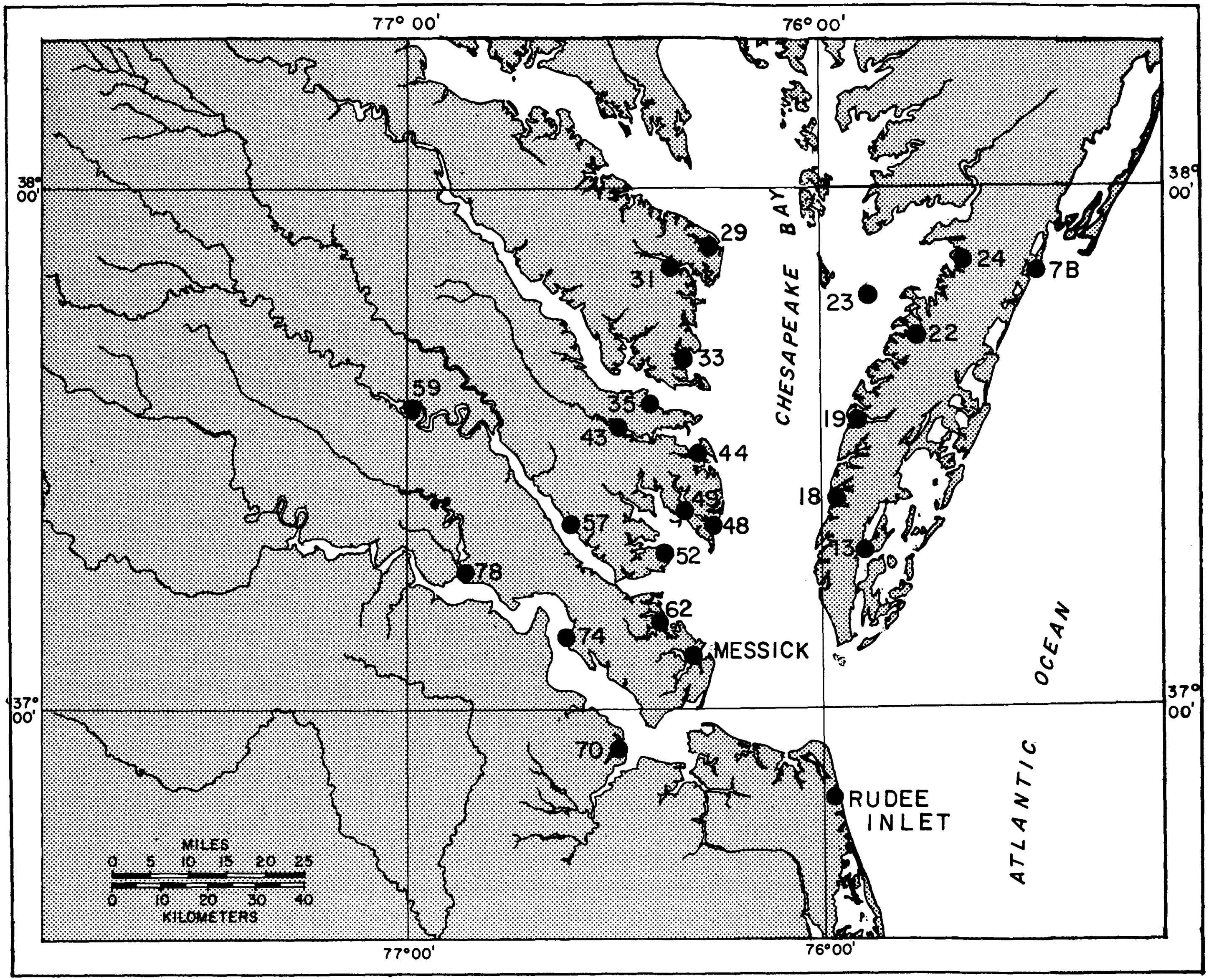

Fig. 1 Location of Survey Sites used for Determining the Elevation of the Saltbush Line

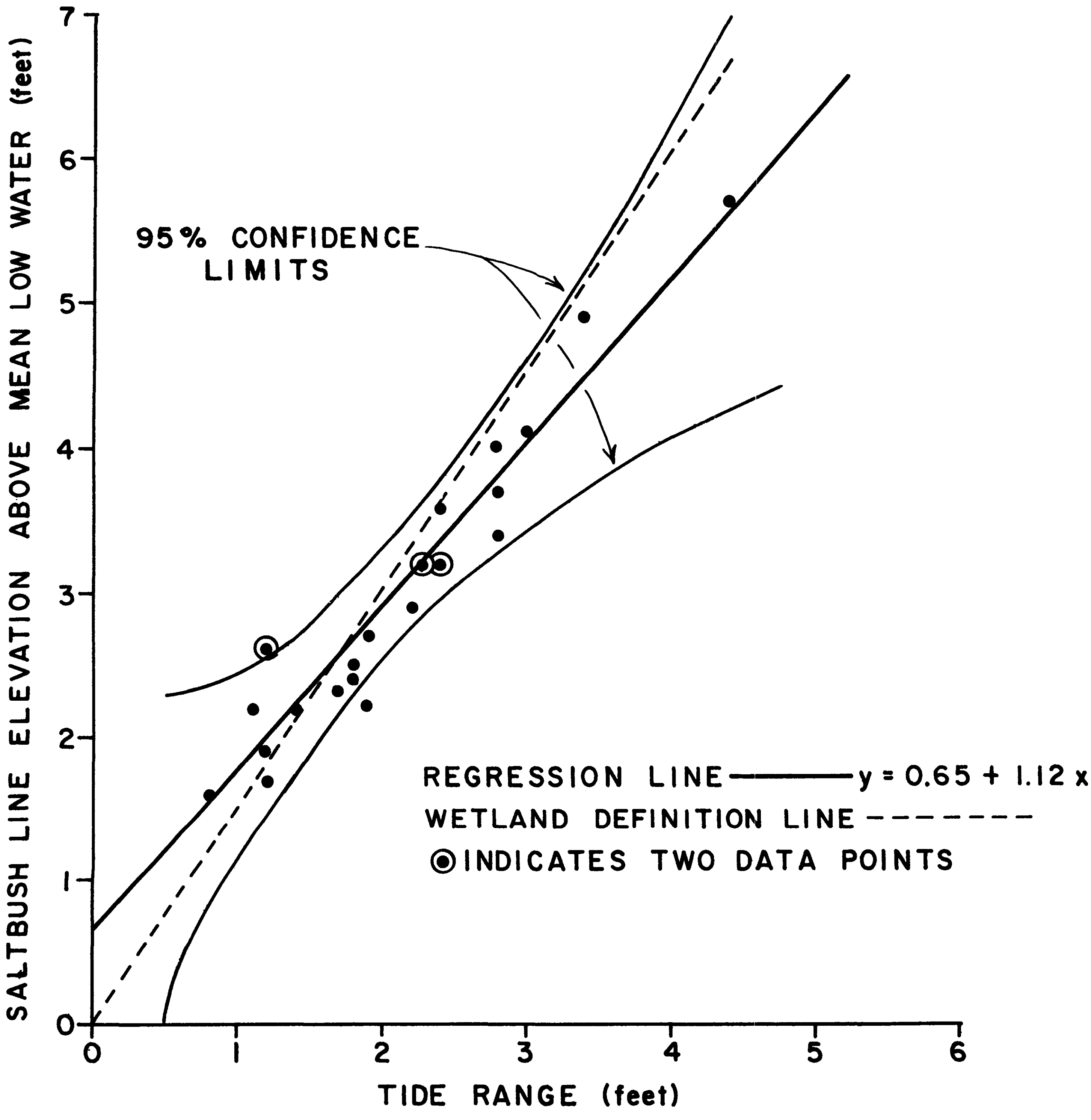

Fig. 2 Dependence of the Minimum Elevation of the Saltbush Line on Tide Range

TABLE 1. Measurement means, tide range, saltbush line: tide range ratio, and quality estimate for each site surveyed. /Salt Bush line (SBL)/

		No. of Measurements	Elevations, Tide Range in Feet: Mean	Elevations, Tide Range in Feet: Range	Tide Range (TR)	SBL TR	Area Quality Rating
Eastern Shore (Seaside)							
7B	Gargathy Neck	4	4.2	4.1-4.3	3.0	1.4	High
13	Oyster		5.7		4.4	1.3	Low
	Rudee Inlet	3	4.8	4.7-4.9	3.4	1.4	Low
Eastern Shore (Bayside)							
23	Watts Island	5	2.7	2.7-2.8	1.6	1.7	High
18	Wilsonia Neck	4	2.7	2.4-2.8	1.9	1.4	High
19	Occahannock		2.3		1.7	1.3	Low
22	Onancock		2.5		1.8	1.4	Low
24	Muddy Creek	5	2.9	2.5-3.2	2.2	1.3	High
Western Shore Chesapeake Bay							
29	Little Wicomico	5	1.6	1.5-1.8	0.8	2.0	Low
31	Glebe Point	7	2.7	2.3-3.1	1.2	2.2	Low
33	Fleets Bay	7	2.2	2.0-2.6	1.1	2.0	Low
35	Mill Creek	5	2.5	2.4-3.0	1.2	2.2	Low
43	Freeport (Piankatank R.)	8	2.2	1.9-2.5	1.4	1.5	Low
44	Milford Haven	4	1.7	1.5-2.0	1.2	1.4	High
48	New Point	3	2.4	2.4-2.5	1.8	1.3	Low
49	Mobjack Bay	6	3.2	2.9-3.5	2.4	1.3	High
52	Browns Bay	6	3.2	3.0-3.3	2.4	1.3	High
62	Fish Neck Poquoson	9	3.2	2.9-3.5	2.3	1.4	High
	Messick	7	3.2	3.0-3.5	2.3	1.4	Low
James River							
70	Chuckatuck Creek	6	4.0	3.6-4.3	2.8	1.4	High
74	Fort Eustis	2	3.6	3.6	2.4	1.5	Low
78	Chickahominy River Bridge	8	2.2	2.0-2.5	1.9	1.1	Low
York River							
57	Claybank	6	3.4	3.2-3.6	2.8	1.2	High
59	Lester Manor	3	3.7	3.7-3.8	2.8	1.3	Low

Of the 24 sites surveyed, 10 were broad expanses of marsh and were considered to be significantly valuable to the marine ecosystem. The remaining 14 were generally narrow fringing marshes. For the purposes of developing a wetlands definition they were considered to be of lesser value. The mean ratio of the 10 most valuable areas was 1.4. Because marshland extends above the lower limit of the saltbush line, the ratio 1.4 was raised to 1.5, which was to be multiplied times the tide range of a locality in order to define the limits of wetlands. Further, it was decided that mean low water should be the datum on which to define wetlands for two reasons. One, in Virginia ordinary low water or mean low water is the datum separating public from private lands. Second, a much more clear wording of a wetlands definition could be had by using mean low water as the datum rather than mean sea level or mean high water.

The definition of tidal wetlands for the Wetlands Act was then written as follows:

Wetlands means all that land lying between and contiguous to mean low water and an elevation above mean low water equal to the factor 1.5 times the mean tide range at the site ---.

d) Utility and Adequacy of the Definition

The utilization of the definition requires the determination of the mean low water level and the mean tide range for the site or region in question. The upper limit of wetlands by definition is then located at the elevation equal to 1.5 times the mean tide range measured above the mean low water level. The principles of the definition are illustrated in Figure 3.

After preliminary surveying had been completed, the data evaluated, and the factor 1.5 suggested as a tentative factor to multiply times the tide range, close attention was given during succeeding survey trips to determine whether the elevation 1.5 times the tide range above mean low water reached agricultural land, hardsurfaced roadways, lawns, pastures, or recreation areas.

Careful observations did not reveal that any such lands would be included within the limits of the proposed definition even in low-lying areas as Mathews County, Poquoson, Hampton, Watts Island, and Chincoteague.

The physical definition was therefore considered to be physically sound, adequate with respect to the most valuable wetlands, and most respectful of private landowner interests and rights.

B) High Priority Areas

Those sections of the coastal zone which are under immediate pressure of being developed for utilization for purposes other than what they offer naturally are of prime concern to local, state and national citizens, groups and agencies. The loss of a natural area can have far-reaching implications e.g. the loss of habitat for wildlife in general,

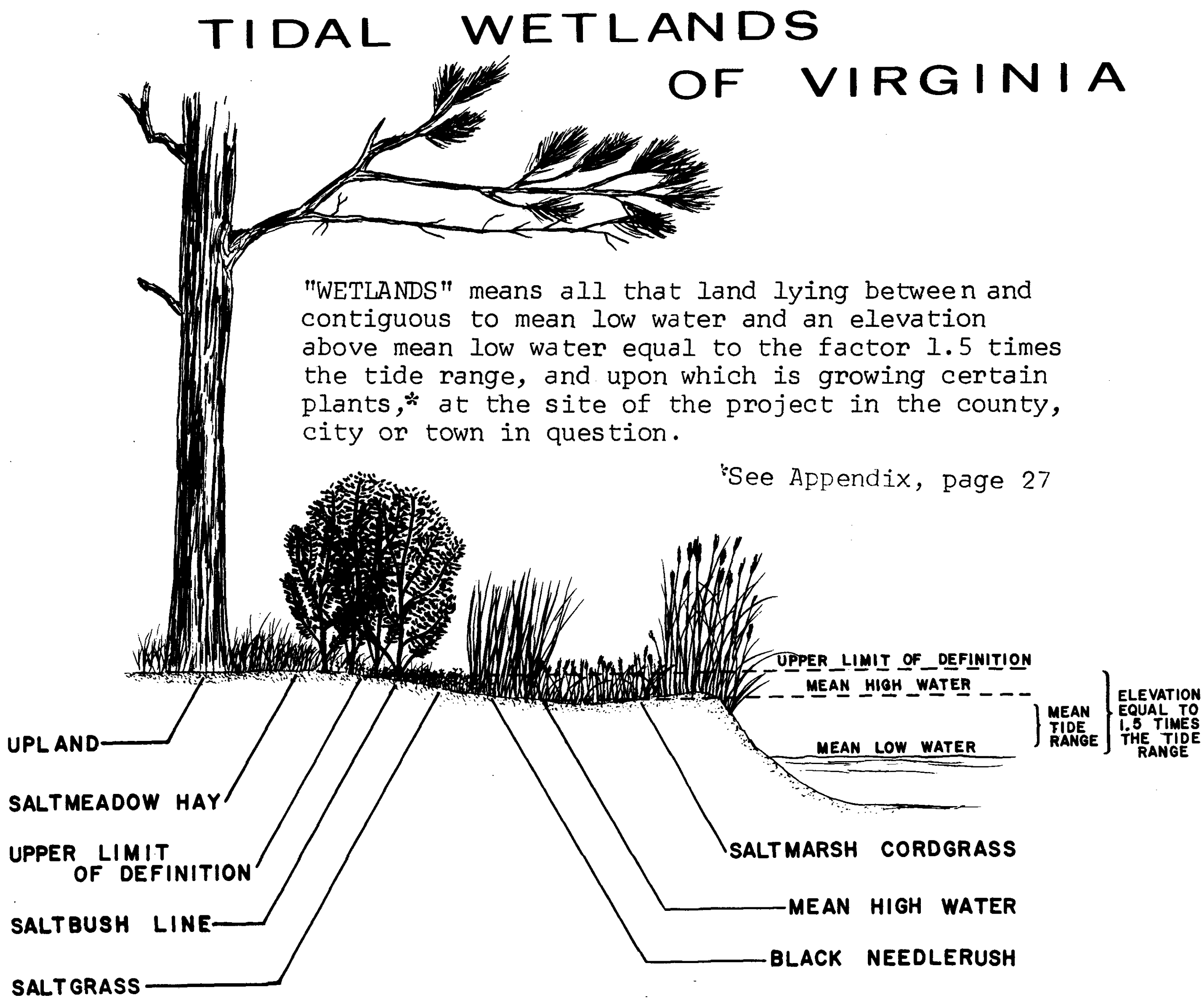

Fig. 3 Tidal Wetlands of Virginia - A Pictorial Description of the Definition of Wetlands

the loss of fish spawning and nursery grounds, the loss, both direct and indirect, of food resources of marine organisms and coupled with pollution, generalized reduction in the quality of the environment. These areas under pressure to be developed may be classified as high priority areas. As the principle marine science agency of the Commonwealth, VIMS has a prime interest as well as a responsibility to the people of Virginia to identify and evaluate these high priority areas and to make known the consequences of their intended uses. Within the coastal zone two areas of major concern are the wetlands and the shallows.

1. Wetlands

Many factors must be considered in the evaluation of wetland projects. Aside from the actual ecological value of the marsh, three key factors are (1) the effects on marine life in the vicinity of the project as well as elsewhere, (2), the effects of the project on water quality and (3) the effects, direct and indirect, on other values and attributes belonging to the people of the Commonwealth.

In the past land-use planners may not have fully evaluated these factors or even considered them at all in some of their "development" projects. In addition, knowledge of the impact of various activities on fisheries, wildlife and general environmental qualities was quite possibly unknown or if so, unheeded. Consequently wetland areas were altered or destroyed. As a result a great amount of wetland area has already been lost, and other wetlands are being lost daily through needless disturbances.

Because the wetlands of Virginia are essential to marine biological commerce as well as other public values, and because there are a finite amount of wetland areas, it was clearly essential that a wetland management program be established and put into operation in order to conserve the remaining areas. The Wetlands Act (1972 General Assembly) became the first such program implemented in Virginia to regulate the uses to which wetlands are put.

2. Shallows

Until recently there has been relatively little said about the tidal flats and adjacent shallows. Though they have been slighted verbally, they are little less important ecologically than the marshes.

Mud flats and shallows often have dense algal and diatom populations. Heterotrophic and holotrophic bacteria are also plentiful and contribute markedly to the productivity and fertility of these areas. Materials produced on the flats are often carried into deeper waters by currents to become part of the complex biological food webs. Upon inundation of the flats, fishes and crabs move across them from adjacent shallows in search of food.

Two very important vegetative species of shallow subtidal bottoms of estuaries are eelgrass, *Zostera marina*, and widgeon grass, *Ruppia maritima*. The expansive beds formed by those two species might be likened as submerged marshland consisting of the plants, themselves, and the millions of smaller animals and plants using plant surfaces for attachment and support. The vegetation is not only important as a detritus producer, but also as a habitat and feeding area for fish, shellfish, numerous benthic organisms and many species of waterfowl.

In freshwater tidal shallows the above two vegetative species are replaced by a tremendous variety of rooted aquatics which serve the same function in those areas.

Though less obvious to the casual observer the macroalgae found living on the bottom and also attached to the rooted vegetation is of tremendous ecological significance as an energy producer.

Dredging operations can silt over or actually remove grasses and algae from large expanses of bottom. Filling activities may not only cover and obliterate these productive beds, but also cause losses by siltation on adjacent areas. The impact of the loss due to this activity is not known in detail, but could obviously be considerable. Consideration is given to the productivity of shallows that may be destroyed by various activities and the consequences of such destruction on the economics of the marine ecosystem when high priority areas are evaluated.

III. Inventory

Ecologically sound management of natural systems is dependent on a detailed knowledge of the composition and the dynamics of those systems. Without a baseline knowledge of the components of systems, the effects of perturbations cannot be anticipated or evaluated. An inventory and monitoring program, properly designed and implemented contributes vital data to systems managers, making their decision-making more precise, objective, and easy. The Institute of Marine Science is making valuable contributions to coastal zone managers and researchers via special reports and publications and through personal communication on specific topics and projects. All agencies with management and planning responsibilities are provided consulting services, reports and advice. In addition the institute has established a Marine Environment and Resources Research and Management System. MERRMS is essentially a data retrieval system whereby all pertinent information on file for various considerations of a given problem can be rapidly accessed and reviewed for management and research oriented discussions.

A. Floral and Faunal Checklist

The floral and faunal composition of the Virginia coastal zone, though fairly well known, has never been compiled into one all-inclusive annotated checklist. Hence, an exhaustive literature search coupled with detailed field surveys has provided the data for a comprehensive checklist of the Biota of Chesapeake Bay and its tributaries. Included in the list are authors notes and comments on macro and microalgae and higher plants, fishes, water and wetland-oriented birds, and all invertebrates except insects. The list will be of value to anyone pursuing information on groups or specific organisms found within the coastal zone of Virginia.

B. Wetlands

1. Aspects of Significance

Wetlands are vital to the bioeconomy of coastal marine waters. However, not all wetlands have equal value to specific organisms in the marine environment and conversely not all organisms utilize equally the contributions of a specific wetland.

Specific factors which are considered to be highly significant in the evaluation of a wetland include the species of vegetation present along with their abundance and distribution; the elevation of the marsh surface relative to local tidal features, and the dynamics of internal water flow. Though each of the factors may be recognized as a separate feature, they are all interrelated to a certain degree, with the local tidal features being a dominant factor.

Simply because low marsh areas are flooded more frequently by high tides, and are thereby flushed most, they are considered more important than high marsh areas. In the saltwater regime, the low marsh area is generally dominated by saltmarsh cordgrass, *Spartina alterniflora*, which usually produces, annually, a greater biomass of vegetation than any other wetland species in Virginia. In the freshwater tidal zone no one species of vegetation can be cited as dominant over all, though arrow arum, Peltandra virginica, is one species that is often extremely abundant. Edaphic features as well as intraspecies competition may be significant in determining what species of vegetation dominates a specific location. In addition, edaphic factors, competition and morphological features may regulate stand density and growth vigor, an aspect which also is useful in determining the productivity of a given wetland.

High marsh areas, because they are irregularly flooded, are of lesser significance to marine organisms. The biomass per unit area on high salt marsh areas is generally less than that of low marsh areas. Where the vegetation on low marsh may be broken off and washed away by winter storms, such probably occurs infrequently in high marsh areas; thus contributions from the latter are usually delayed. High marsh vegetation decomposition may take place primarily at the location of growth. Periodic extreme high tides may then sweep away the smallest particles long after the low marsh vegetation has been removed.

The extent of the marsh-water interface may be highly significant in determining the ecological value of a wetland. It is believed that, within limits, the greater the length of shoreline in relation to the marsh surface area the greater the chances for frequent transport of detrital materials off the marsh and into the water for incorporation into marine food webs. In addition extensive and complex drainage patterns within wetland areas, associated with large shoreline length-marsh surface area ratios, result in more diversified habitats, a factor which can increase the utilization of an area by fish and wildlife.

2. Evaluation

Many other factors in addition to the abundance, and distribution of grasses, shoreline lengths and marshland elevation must be considered prior to evaluating the ecological significance of a wetland area to man. What species of fish or shellfish are found in the area and what is their relationship to the detritus from the marsh? Additionally, what are the numbers and the life stages of the organisms of direct or indirect value? What is the degree of dependence of the organisms of importance on the wetland? What contributions to waterfowl populations and mammal populations does the area offer? What resources of the area are currently being used by man? These are but a few of the many queries that can be made concerning the value of a particular wetland area. As each area is probably unique, all-inclusive statements concerning wetlands in general are difficult to make. Each area should be investigated and analyzed separately before ranking it among all other areas.

3. Wetland Information Acquisition

An efficient management system will be dependent on rapid acquisition, integration and evaluation of pertinent information. When information is not available, costly delays are eminent. Such has been the plight of many aspects of coastal zone management.

Data acquisition on plant distribution, stand density, standing crops, productivity, etc. from wetland areas can be an exceedingly laborious and time-consuming task. Wetlands, by their nature are low and more often than not, very damp. Traversing some marsh areas is virtually impossible because of soft sediment deposits. The collection of quantitative information from such areas is extremely difficult because of man's relative immobility there.

In addition to the difficulties in working within marshes, management questions generally concern only small portions of large areas. Though information may be available for the general site location, the needed detail for a specific location is often lacking.

Consequently, personnel usually must visit each site in order to gather information for the specific management questions. Unfortunately, with decisions for many different areas often pending at one time, considerable delays on some projects can occur simply because of the inability of personnel to reach all sites shortly after questions arise.

While visiting specific sites, floristic notes, photographs and records of other parameters are made. In addition, specific field trips into unstudied areas are made to expand the inventory date file. Along with research activities, notes are made on wetland features in each site being investigated. Aerial surveillance and photography have also been utilized to obtain wetland information, broaden perspectives and decrease the time required for reconnaissance.

Imagery from the National Aeronautical and Space Administration are being acquired and utilized. High altitude (60,000 feet) photographs have been examined for perspective overviews of wetlands covering a broad area. Lower altitude (10,000-20,000 feet) imagery acquired from the U. S. Department of Agriculture, NASA and the Virginia Department of Highways has been examined for greater detail about specific sites.

At present a contract exists between the Virginia Institute of Marine Science and NASA-Wallops for securing and evaluating low altitude (1000-5000 feet) imagery. Overflights of the Eastern Shore barrier islands and marshes and of York River-Pamunkey River wetlands have been made. The low altitude, high resolution imagery has been helpful in evaluating shoreline processes over time and for mapping wetland vegetation and waterway distributions.

Upon receipt of imagery for specific areas, corrections for tilt and yaw are made with a Kelsh Plotter. Subsequent to corrections linear and areal measurements are made using planimeters and digitizing systems. The digitizing systems, usage time generously donated by the NASA-Langley Research Center, have greatly facilitated wetland and shoreline studies. The digitizing system automatically records on data cards specific coordinates along the boundaries of various features of interest. The data are then processed by the computer facilities at the Institute. Special programs allow the information to be retrieved in a number of tabulated forms. In addition the data can be conveniently stored and at future dates recovered and analyzed in conjunction with data obtained then.

C. Shorelines

Those areas fronting the ocean or exposed to expansive bodies of water are highly dynamic. The passage of an atmospheric storm may result in profound movements of the land-water interface. Though an understanding of the mechanics involved in shoreline erosion and accretion is only obtained through detailed research and which is essential for management decisions, informative and useful information can be obtained through analysis of periodically published maps.

One of the Institute's current investigations has been to evaluate the changes in the tidal shorelines of the state as they have changed during the past 110 years. Maps from the U. S. Geological Survey, from as early as 1859 and as recently as 1970 have been used for the analysis. A report on the study will be published at a later date.

D. Inventory Needs for Better Wetlands Management

1. Commonsland

Perhaps the most important consideration in the wetlands inventory is ownership. At present there is confusion over ownership, acreages and boundary line locations. A compounding matter has arisen through island migration as has occurred on the Eastern Shore. This is a legal concern of paramount importance to the state, and to localities, with respect to taxation and acquisition investigations.

2. Wetlands and Marine Biological Products of Commerce

Wetland areas of significant importance to the marine bioeconomy must be delineated in light of future needs of current legislative proceedings. More specific measurements of the interrelationships with wetlands of oysters, clams, bluecrabs, and the many species of commercially and recreationally important fishes must be investigated. Though such investigations fall within the mid and long-term research activities of the Institute the output will have a direct input into the classification mechanisms of the inventory program.

3. Shoreline Processes

A program whereby shorelines in key locations are monitored should be initiated. The degradation of shoreline vegetation, natural or otherwise, or the deterioration of existing stabilization structures can result in severe economic and biologic losses of wetlands, and uplands, due to erosion during storms, and to the covering of valuable shellfish grounds and fish spawning and nursery areas by the sedimentation of shoreline materials. A monitoring program would allow corrective measures to be taken prior to significant damage occurring. Photographic remote sensing techniques have the greatest potential for immediate use in this inventory need.

4. A Prototype Inventory Study

As requested by the Gloucester County Planning Commission an evaluation of the county's shoreline and wetland areas was made in mid-winter, 1971. Personnel examined specific wetland tracts, estimated their ecological value, and provided recommendations for their future usage. In addition, shoreline features such as erosion sites, areas of potential for public beaches, and sites for boat launching facilities were located. Suggestions were provided which would help county officials determine how to evaluate the impact of new industries on the environment as well as evaluate other coastal zone uses.

The study, just being completed, was extremely beneficial in assessing the pertinance of information, data presentation methods, and time requirements necessary for high quality, useful surveys.

IV. Research

VIMS wetlands research activities have been coordinated interdepartmentally to study the total realm of the wetland-estuarine ecosystem. This approach allows an integrated appraisal of relationships between physical and biological parameters and will greatly aid in the economic evaluation of wetlands.

The research areas selected were chosen on the basis of their importance to answering immediate wetland management questions. The work has been designed to evaluate the natural loss and accretion of wetlands, the seasonal rates of production and total amount of vegetation produced on marshes in different salinity regimes, the seasonal pattern of detritus movement and nutrient flux in salt marshes, and the biological composition and function of the shallows. In addition, seasonal fish distributions are being evaluated with respect to the productivity of the water throughout tidal-water rivers. The following sections discuss the various research projects currently in progress.

A. Shorelines

1. Tidal Creek Flow and Suspended Sediment Load

As is well known many wetlands are interlaced with a complex series of creeks and channels. Of lesser knowledge though is the flow rate and suspended sediment load of those creeks on flooding and ebbing tides. A unique sampling device to evaluate sediment transport processes in salt marsh drainage systems has been designed and is being used to help answer such basic questions as: What amounts of material, both organic and inorganic are transported into and out of the marsh? What are the sources of the materials? Where are they deposited? What are the long-term trends of the transport processes in terms of creek evolution? This research problem has reached the state of field data collection and results will soon be ready for preliminary analyses.

2. Beach Migration Studies

Considerable emphasis is being placed on the dynamics of shoreline erosion along the Eastern Shore barrier islands. Records of movement rates are being made and concepts of stabilization are being considered. Photographic remote sensing techniques are being utilized to help evaluate specific changes, especially the dynamics of the coastal inlets and Wachapreague Inlet in particular. Studies of shoreline movements in other areas will be initiated in the coming year.

B. Wetlands

1. Wetland Vegetation Production and Salinity

That high-salinity tidal marshes rank among the most productive areas of the world has been well documented. Yet, the relative productivity of a given wetland plant species throughout the salinity range in which it is found is not well known, nor is the relative productivity of low salinity marshes in general.

The requirements of wetland evaluation surveys prompted the development of the wetland production study currently being conducted. Via the harvest method, the vegetation production on three marshes located in different salinity regimes is being studied. Along with vegetation data, soil samples are being collected and analyzed for their phosphorus, nitrogen, potassium, calcium and magnesium content.

Cursory analysis of the productivity of the three marshes suggested that low salinity marshes are more productive than high salinity marshes, with marshes in mid salinity regimes being intermediate in productivity. Table 2 lists the salinity regime and productivity of three Virginia marshes during 1971.

TABLE 2. Productivity of Macrophytic Vegetation and Salinity Regime in three Virginia Marshes from July 1 to November 18, 1971.

Marsh	Productivity Gms/m^2/study period	Salinity 0/00 Mean	Salinity 0/00 Range
Wachapreague	356	31	29-33
Carter Creek	467	11	3-19
Ware Creek	546	4	1-11

A more detailed analysis of the data especially with respect to individual species and their responses to soil nutrient concentration will be made at the termination of the project. The results of this research problem will have immediate application in VIMS Wetlands classification and ranking program.

2. Detritus Flux in Tidal Marshes

The "life" of marsh vegetation does not stop at the end of the growing season, although its form and appearance undergoes dramatic changes. Mechanical, biological and chemical mechanisms, through time, break the vegetation into smaller and smaller particles that eventually reach colloidal size and finally their molecular constituents.

Throughout the process of decomposition the particles serve as energy sources for microscopic and macroscopic organisms. The mechanism of energy transfer from high salinity marshes into the marine environment has been extensively studied in more southern coastal marshes. However, the meso- and oligohaline regions of the estuaries have not been studied in great detail, especially in Virginia. Yet, a major portion of the annual fish and shellfish harvest comes from these medium to low salinity areas. As part of the estuarine research program, a study of the seasonal detritus flux in a mesosaline and an oligosaline marsh is being conducted.

The objective of this research project is to determine the import and export of detritus during complete tidal cycles at various times of the year. Samples taken at intervals of one hour will be analyzed for the concentration of the dissolved and the particulate organic carbon fraction and the inorganic carbon fraction. Preliminary results indicate that the concentration of carbon in the water is highest at low slack tide and lowest at high slack, suggesting a net export of the material. By correlating carbon concentrations with tidal flows, the wetlands contributions of energy to the estuaries will be better understood.

3. Nutrient Flux in Tidal Marshes

The productivity of a water body is, among other factors, dependent on the load of nutrients it carries. Nitrogen and phosphorus, the two nutrients considered to be limiting in the potential primary productivity capable of being obtained, are largely present in their inorganic oxidized forms; nitrate and phosphate. As estuarine waters flood tidal marshes, the grasses, the phytoplankton and the algae assimilate the nutrients and incorporate them as new growth. Subsequently the plant materials may be eaten by other higher organisms or may die and be washed out of the marsh. The eventual release of their nutrients to the water via the processes of decomposition starts the cycle anew.

Preliminary results of the research indicate that river water tends to supply inorganic nitrogen to the marshes, but the marshes supply phosphates, organic nitrogen compounds and ammonia nitrogen to the river. In addition there appears to be a tendency for slightly more primary production to occur in marsh waters on flooding tides than on ebbing tides.

The objectives of the research are to determine, quantitatively, the forms of dissolved nitrogen and phosphorus entering and leaving marshes, the rations of similar forms and the rates of conversion of nutrient forms unavailable for primary productivity to those forms which are available. Answers to these questions may prove highly significant in evaluating wetland areas in terms of their influence on the rates of eutrophication of estuaries.

C. Shallows

The eelgrass beds of the shallows as mentioned earlier should be given much greater emphasis. A recently completed study of the infauna of eelgrass beds substantiates their value in the marine environment.

The objectives of the study were to examine the distribution, relative abundance and community structure of infauna in various eelgrass beds in the Chesapeake-York River and in an eastern shore embayment.

The results of the study indicated that within eelgrass beds animal density was very high in comparison to unvegetated areas and that there was a general decrease in species abundance with decreasing salinities.

Eelgrass is recognized as having considerable utility in stabilizing sediments as well as providing habitat and detrital food to marine organisms (Orth, 1971).

D. Fish Investigations

1. Lower York River Fish Study

As part of the analysis of lower York River fish populations, the species composition and utilization of eelgrass beds is being investigated. The shallow water seining conducted periodically in conjunction with deep water trawling has indicated that many species of fish, especially juveniles of direct or indirect economic importance, are often abundant in the patches of eelgrass. Evidence such as this suggests a necessity for an inventory of the distribution and extent of eelgrass in the Chesapeake Bay and tributaries. Development projects having potential detrimental effects on this vital vegetation should be reexamined for less damaging alternatives.

2. Fish Nursery Ground Research

Other investigations, also conducted by the Ichthyology department, are centered about estuarine fish nurseries. Emphasis rests upon the ecology of each species within its respective nursery and the monitoring of adult populations within Virginia's rivers.

Measurements of nutrient levels, primary productivity, species compsoition and abundance of plankton, and food habits of juvenile fishes are being made to help assess fish production in specific rivers. Several species of herring including the American Shad, are of major interest in this study because of their importance to the commercial fishing industry.

Tidal marshlands are significantly important to fishes in an indirect sense, e.g. nutrients released through the decomposition of plant materials are utilized by phytoplankton which may be consumed by other planktonic organisms and those in turn by fishes. In addition plant detritus serves as attachment sites and/or nutritional sources for variety of biological forms, both plant and animal. Fishes may consume the detritus and utilize the various bilogical forms as food.

In addition the marshland creeks and pools serve as reproductive and nursery areas for many of the fishes preyed upon by the numerous species which enter the estuary during part of the year.

The present research is being conducted in the James, the Rappahannock and York Rivers, each of which is influenced by a different pollution load. Comparisons of fish statistics for each of the three river systems will allow a more detailed understanding of the influences of pollution and of wetlands in fish production.

E. Wetland Foraminifera: Ecology and Distribution

The most important factor in the evaluation of an effect of some environmental alteration after it has occurred is the knowledge of what the conditions were beforehand.

Only recently have there been attempts at monitoring and recording existing conditions in wetlands so that data would be available for the determination of the effect of various influences. One possible way of evaluating previous conditions is to look at the paleomarsh sediments. The ecology and distribution of Foraminiferida in an estuarine marsh system are being examined with this in mind. Significant differences in species and population densities between high and low marsh areas and between different marshes within the James River estuary have been noted.

Attempts to correlate marsh foraminiferal populations with measured environmental parameters for the purpose of establishing base lines from which changes due to pollution or sea level changes may be measured will be made.

V. Additional Research Needs for Better Estuarine Zone Management

A. Wetland Classification and project evaluation criteria

Possibly the most important aspect of any management program is the criteria upon which operational decisions are made. The lack of criteria results not only in hap-hazard business operations but also in deviations from the general policy upon which the management program was established.

The management of tidal wetlands of Virginia, the provisions for which were established by the 1972 General Assembly, will require the classification and ranking of wetlands by type. VIMS is currently developing criteria by which this task may be accomplished. One prerequisite to the development and use of a wetlands classification and ranking system is a detailed knowledge of all major inhabitants, their life requirements, their relationship to the physical, chemical and biological dynamics of the environment, and their values to man.

Existing literature and knowledge are being drawn upon to formulate these wetland classifications and ranking criteria. As the criteria are used and tested it is certain they will help identify areas of insufficient knowledge where research efforts should be concentrated. In addition information acquired from research may demand alterations in the criteria to strengthen weak point.

An additional set of criteria for evaluating wetland projects must also be developed for the management system. Though idealistic evaluation criteria may be proposed a prerequisite to their practical use is a conceptual understanding of the values a management system, respectful of all rights involved, can accept under a given set of circumstances. These criteria may possibly be more challenging to establish and implement than the wetland classification and ranking criteria because of the more complex social-economic development problems that must be answered.

The criteria by necessity must not be influenced by political boundaries but must consider the resource values on a regional basis. The criteria must allow for accurate evaluation of the importance of specific wetlands to marine resources and to wildlife in general. They must also allow for the evaluation of the potential public benefit to be derived from a proposed wetlands project versus its potential detriment to resources of public importance. The resources being dealt with, though often in private ownership, do have direct and indirect values in many ways to many more people than just the owners of the wetland properties.

The Wetland project evaluation criteria will be continously evaluated for their accuracy, objectivity, efficiency and practicality. It is almost certain that alterations and modifications of the initial criteria will be made as new information from research and social studies become available.

Though the establishment of criteria for classification and evaluation of wetlands and wetlands projects is not research in the sense quite often envisioned by most individuals, it is definitely research from a management point of view. It is the application of the knowledge from basic research and problem oriented applied research to a management problem of broad perspective.

B. Marsh Grasses

Research on the effect of marsh grasses and shrubs in preventing shore erosion is needed. Methods of growing, transplanting and establishing such plants on beaches need to be devised. Eel grass beds obviously retard erosion by slowing wave action and forming seasonal berms on the beach. The extent of this value needs to be demonstrated and publicized.

C. Bulkheads

Attention needs to be focused on the establishment of bulkhead lines and the need for controlling such activity. Legislation relating to such lines needs to be reviewed, perhaps in consultation with the directors of agencies concerned with bulkheading. The matter of pier construction also should be reviewed.

D. Island Migration and Effects on Wetland Productivity

Further research needs to be done on the effect of island migration on the productive shallows and marshes of the Eastern Shore seaside bays. The costs and benefits of measures to control erosion should be carefully evaluated and compared with the long-term effects of no action being taken.

E. Oil Spills and Wetlands

The potential deleterious effects of oil spills on wetlands is another area of extreme importance. VIMS has made preliminary investigations of the effects of oil on wetland vegetation and is planning to continue and expand its research in that field.

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APPENDIX

The wetlands definition as printed below was extracted from the Wetlands Act,

Code of Virginia, 62.1-13.3 (f)

"Wetlands" means all that land lying between and contiguous to mean low water and an elevation above mean low water equal to the factor 1.5 times the mean tide range at the site of the proposed project in the county, city or town in question; and upon which is growing on July one, nineteen hundred seventy-two or grows thereon subsequent thereto, any one or more of the following: saltmarsh cordgrass (Spartina alterniflora), saltmeadow hay (Spartina patens), saltgrass (Distichlis spicata), black needlerush (Juncus roemerianus), saltwort (Salicornia spp.), sea lavender (Limonium spp.), marsh elder (Iva frutescens), groundsel bush (Baccharis halimifolia), wax myrtle (Myrica sp.), sea oxeye (Borrichia frutescens), arrow arum (Peltandra virginica), pickerelweed (Pontederia cordata), big cordgrass (Spartina cynosuroides), rice cutgrass (Leersia oryzoides), wildrice (Zizania aquatica), bulrush (Scirpus validus), spikerush (Eleocharis sp.), sea rocket (Cakile ecentula), southern wildrice (Zizaniopsis miliacea), cattails (Typha spp.), threesquares (Scirpus spp.), buttonbush (Cephalanthus occidentalis), bald cypress (Taxodium distichum), black gum (Nyssa sylvatica), tupelo (Nyssa aquatica), dock (Rumex spp.), yellow pond lily (Nuphar spp.), marsh fleabane (Pluchea purpurascens), royal fern (Osmunda regalis), marsh hibiscus (Hibiscus moscheutos), beggar's ticks (Bidens sp.), smartweeds (Polygonum sp.), arrow-head (Sagittaria spp.), sweet flag (Acorus calamus), and switch grass (Panicum virgatum).

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