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Wetlands Evaluation and Management in Virginia

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Preface

This study is the product of a larger project sponsored by the Wetlands Study Committee of the Virginia Bar Association. This scientific review of wetlands and their management was undertaken by students of Marine Affairs at the Virginia Institute of Marine Science, the School of Marine Science of the College of William and Mary. It is intended to provide an assessment of existing knowledge and the implementation of that knowledge in the management of Virginia's wetlands. A similar study, decidedly more legal in emphasis, was conducted by John Marshall Fellows at T. C. Williams School of Law at the University of Richmond.

Together the resulting documents should provide a framework for greater understanding of the nature and value of Virginia's wetlands and the effectiveness of the current Virginia Wetlands Act, as well as suggest possible improvements in Virginia's wetlands management regime.

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Editors

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INTRODUCTION

Complex biotic communities which have lately been recognized as being of vital importance to aquatic and upland ecosystems have evolved at Virginia's land-water interface. Most obvious are the beaches and vast intertidal stands of halophytic (salt-tolerant) plants on the periphery of the Atlantic Ocean, Chesapeake Bay and their subordinate estuaries. Less obvious, but no less important, are nonvegetated intertidal flats and coastal freshwater marshes. Inland swamps and freshwater marshes complete the inventory; though more limited in extent than their coastal analog.

Each of these areas might be called a wetland: land covered by enough water to promote the growth of hydrophytic (water-adapted) plants or constantly saturated soil conditions. A number of variables distinguish the individual ecosystems that are united by this common denominator. Figure 1 illustrates the classification scheme used in this paper to discuss Virginia's wetlands. The initial distinction separates vegetated from nonvegetated areas. The term nonvegetated refers to the absence of vascular flora but these areas may produce as much algal plant material as vegetated wetlands. Each of these major categories can be subdivided into tidal or non-tidal areas. Non-tidal wetlands are, by definition, not subject to tidal inundation. These generally inland areas are composed of freshwater marshes and swamps.[1]

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[1]Certain embayed bodies of water along the coast, like Back Bay, can be classified as a third type of non-tidal vegetated wetland. Silberhorn (1978) referred to these areas as "salt ponds" and noted that these frequently brackish water ecosystems were often once-tidal marshes or basins which have been isolated from tidal flux by deposits of sand.

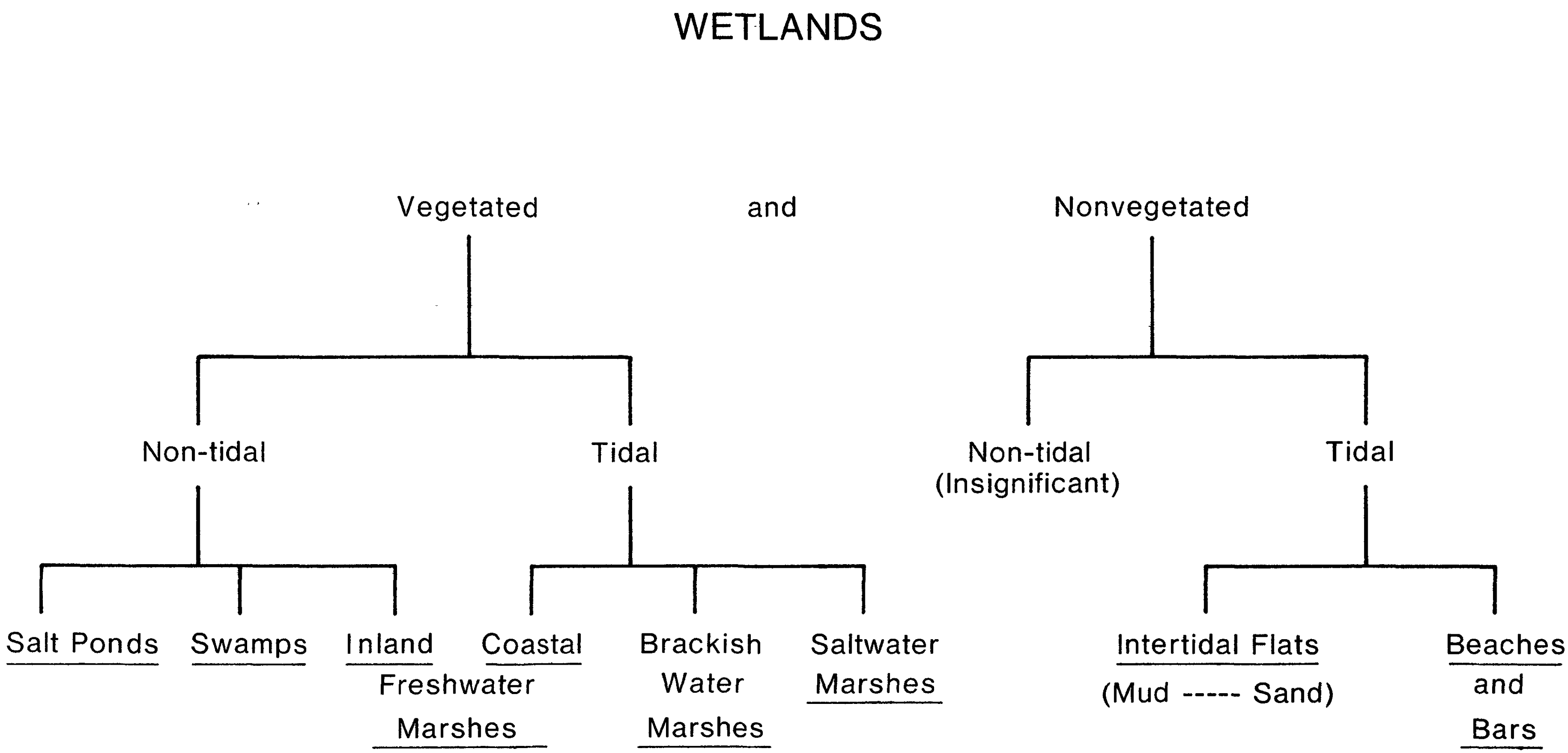
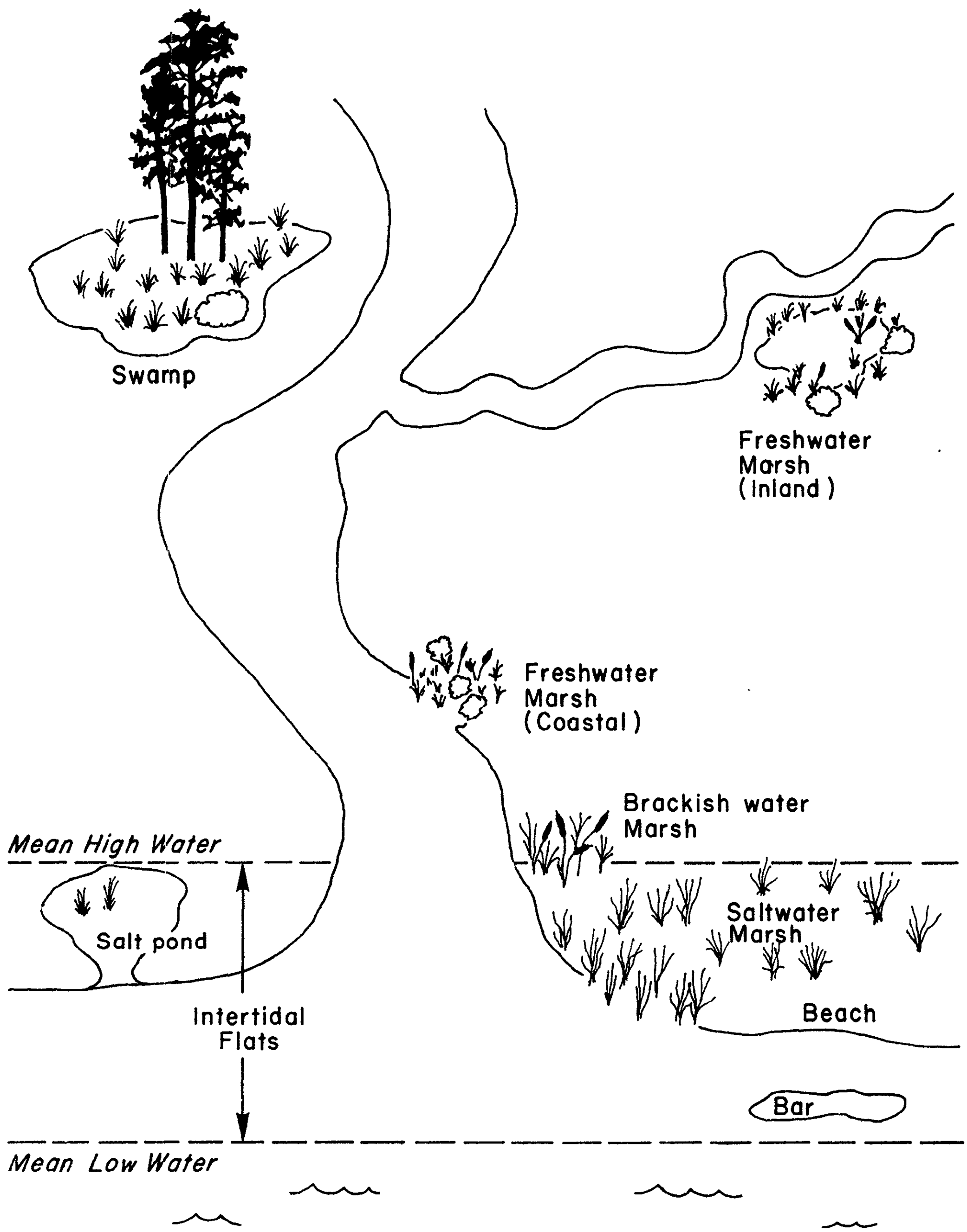


Figure 1

Categorical Breakdown of Wetlands

Coastal freshwater marshes, associated with the non-tidal portions of tidal rivers are considered tidal wetlands. Non-tidal nonvegetated wetlands are limited and considered insignificant in this discussion. Tidal nonvegetated areas include intertidal flats, which range in soil composition from sand to mud, as well as beaches and bars. Tidal vegetated wetlands have salinities which range from seawater to freshwater concentrations and include areas classified as coastal freshwater, brackish water and saltwater marshes. Vegetated flats, like eelgrass beds, which are constantly covered by water are considered subaqueous bottoms, rather than wetlands. As such they are already subject to a certain degree of state jurisdiction. The general geographic locations of these various wetlands types is presented in Figure 2. A more complete description of wetland types is incorporated in the body of this paper.

For thousands of years only natural changes altered these watery places. Wind, waves, ice, fire and erosion rearranged the geographic and topographic setting. Man's incursion was limited and of little import, until the advent of colonization. Early commercial structures presaged future anthropogenic changes such as filling, ditching, dredging, diking, grazing and polluting. Early policy in the Commonwealth of Virginia concerning wetlands reflected a desire for population and industrial growth. Alteration and reclamation of tidal marshes (used synonomously with vegetated wetlands) were considered actions of public benefit. Changes in this attitude did not occur until scientific research and growth of an awareness of the importance



Swamp
Freshwater
Marsh
(Inland)
Freshwater
Marsh
(Coastal)
Brackish water
Marsh
Mean High Water
Salt pond
Saltwater
Marsh
Intertidal
Flats
Beach
Bar
Mean Low Water

Figure 2

of maintaining essential ecological balances provided reasons for doing so. Substantive wetlands research of the 1960's and early 1970's addressed not only wetland processes and values, but methods of delineating the productive tidal marshes as well. Only after a standardized method of identification was formulated could a new ethic for wetlands use be prescribed. In Virginia's 1972 Wetlands Act, this management policy was limited to specific coastal wetland areas. Yet to be accomplished are accurate value comparisons between different wetland types, especially more inland freshwater marshes and swamps. The complexity and variability of wetland response to different environmental conditions has been well illustrated by recent studies.

In this report recent scientific literature has been reviewed to help clarify the nature and values of vegetated and nonvegetated wetlands. Boundary limits as well as various biological, chemical and physical parameters are reviewed to facilitate a better understanding of these environments. In addition, tangible and intangible values are discussed. With this background, the present Virginia Wetlands Act and Guidelines are reviewed from a scientific standpoint. Deficiencies in the 1972 legislation are highlighted and proposed revisions suggested.

BOUNDARIES

It is important for legal purposes to develop an exact definition or criteria for delineating wetland boundaries, since fluctuating water levels (in addition to other factors such as soil type and freshwater input) control the development of wetland communities. It follows that vegetated tidal wetlands boundaries are influenced by tidal variation.

Fortunately, tides have been monitored precisely for many years. Automated tide level monitors are available to record daily fluctuations. While most people are aware that the tide rises and falls twice a day and that some high tides are higher than others, few people are aware of the many variables responsible for these events. Table 1 presents a list of factors that influence tides. Because of the long term astronomical cycles involved, data collected over a period of at least 19 years are needed for accurate tidal datums to be calculated. The National Ocean Survey (NOS) has established a network of tidal benchmarks from which local surveys can be made. Boon and Lynch (1972) published a method to translate these tidal datums to virtually any location in Tidewater Virginia.

A. The Marcellus Study

There have been two major studies of tidal, vegetated wetlands boundary delineation in Virginia. The first, by Marcellus in 1972, is important because it was the basis for the elevational boundary definition incorporated in the Virginia Wetlands Act of 1972 (Code of

Table 1. Principal Tidal Variations - Cause and Effect
(From Boon and Lynch, 1972)

Cause	Effect
Earth's rotation	Movement of tidal bulges around the earth; produces two equal high waters and two equal low waters per lunar day (24 hrs. 50 min.). These are the basic semidiurnal (twice daily) tides.
Moon's declination with respect to earth's equator	Unequal high and low waters (diurnal) inequality) tending toward diurnal (daily) tides.
Moon's cycle between maximum (tropical) and minimum (equatorial) declination	Two tropical tides (maximum inequality) and two equatorial tides (minimum inequality) per tropical month (27 1/3 days)
Moon and sun in line with earth	Spring tides (maximum tidal range); high waters are higher, low waters are lower than usual.
Moon and sun at right angles to earth	Neap tides (minimum tidal range); high waters are lower, low waters are higher than usual.
Cycle of moon's orbit around earth with respect to the sun	Two spring tides and two neap tides per lunar month (29 1/2 days).
Moon closest to earth	Perigean tides (greater tidal range).
Moon farthest from earth	Apogean tides (lesser tidal range).
Elliptical shape of moon's orbit around earth	One perigean tide and one apogean tide per anomalistic month (27 1/2 days).
Long-term relationship between positions of earth, moon, and sun	Systematic variation in tidal range over 18-6 year cycle.
Land masses, bottom topography	Variations in mean tide level and mean range with location.
Wind and barometric pressure changes	Variations in local tide levels, often of considerable magnitude but usually having a short duration.
Worldwide increase in level of the sea in combination with slow sinking coast lands	Progressive rise in sea level of approximately 0.011 feet per year on the Atlantic coast.
Combinations of above	Observed tide.

Virginia, §62.1-13.2(f)). The study focused on defining the upper limit of tidal wetlands, which is called the ULM (upper limit of marsh). After reviewing the definitions established by other states, Marcellus decided that for legal purposes there were disadvantages to either a strictly biological or strictly physical definition. A biological (actually botanical) definition, i.e. defining wetlands in terms of vegetation, is the most accurate method, although it can be difficult to delineate because of the gradual transition, in some cases, from tidal marsh to inland areas. Each site would have to be examined by a qualified botanist. In addition, recent studies indicate wetlands should be not limited to areas with vascular flora. Justification for including nonvegetated tidal wetlands, i.e. intertidal flats, beaches and bars, will be presented later in this report. These areas are best defined physically because they lack easily identifiable vascular plants.

A physical definition, on the other hand, may be difficult to establish accurately. If such a definition can be established, however, there would be two distinct advantages. 1) It would eliminate the need for biological definition, thus including intertidal flats and sandy beaches; and 2) The ULM could be delineated by conventional surveying techniques. With these advantages in mind, Marcellus set out to establish a strictly physical definition.

Marcellus hypothesized that the boundary could best be defined in terms of the tidal range for any given locality; i.e. wetlands with large tidal ranges have an upper boundary at higher elevations with respect to mean low water (MLW) than areas with less extreme tidal ranges. To test this hypothesis, his group surveyed 24 locations throughout Tidewater Virginia. For the purposes of this study, Marcellus defined wetlands in terms of the lower limit of occurrence of two easily recognizable salt bushes, the marsh elder (*Iva frutscens*) and the groundsel tree (*Baccharis halimifolia*). This lower limit was called the saltbush line (SBL), and was considered by botanists to be very close to (slightly lower than, in fact) the true ULM.

Data collected by the group is presented in Figure 3(a). Line B, elevation of the saltbush line above mean low water, is plotted against the tidal range (the horizontal axis). Because of the close correlation of this line with line A, an elevation above mean low water equal to a factor of 1.5 times the mean tide range, it appeared that the working hypothesis was true; the boundary was in fact dependent on tidal range. Marcellus suggested that this elevational defintion be used to delineate the legal boundary in the Wetlands Act. This physical definition was accepted but an additional biological definition was also incorporated. To fit the final definition, wetlands must fall within the specific elevation *and* be covered by at least one of 35 wetlands vascular plant species listed in the biological definition. With this specific vegetation requirement, intertidal flats and sandy beaches were intentionally excluded from protection under the 1972 legislation.

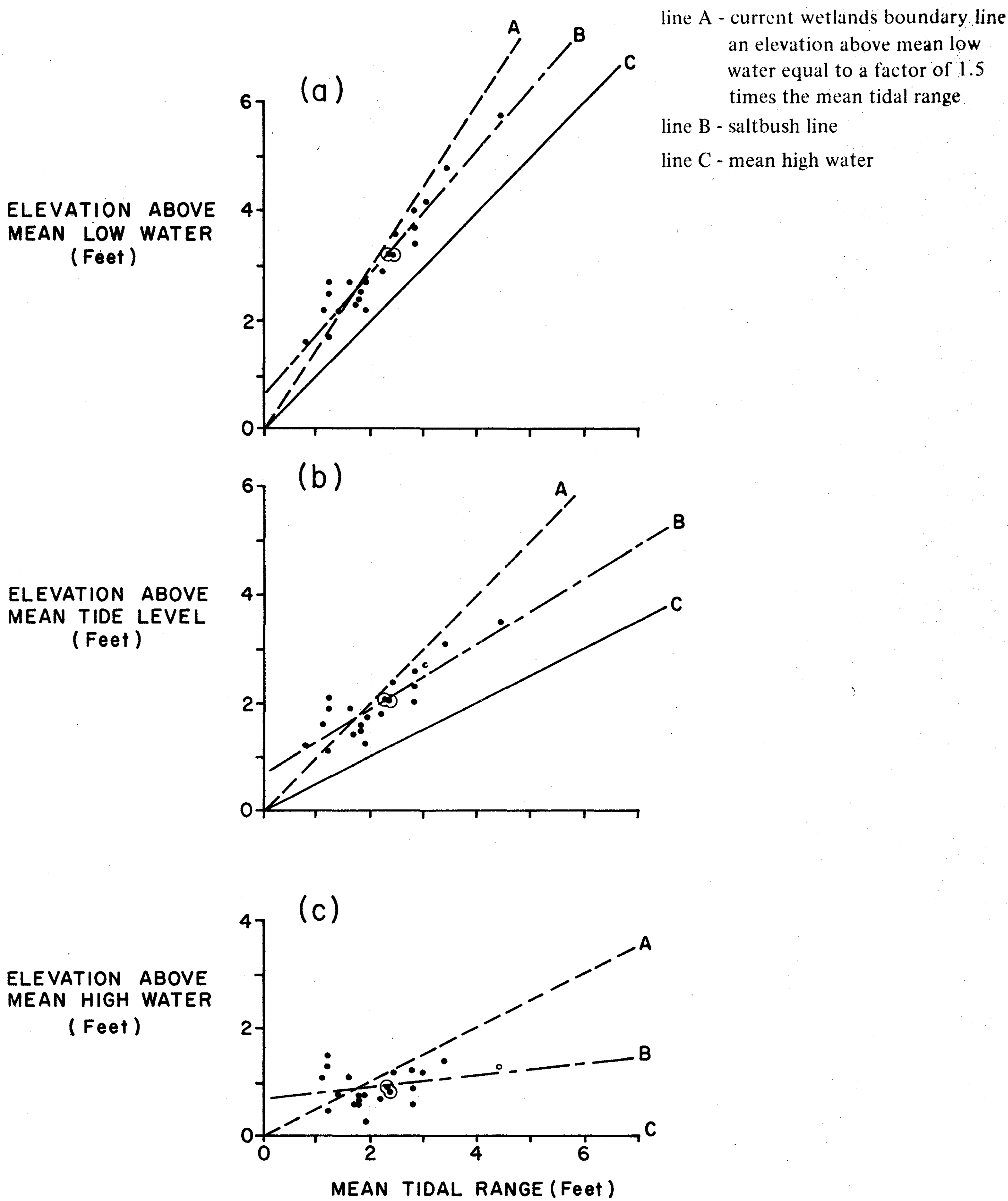


Figure 3 - Note that the relationship between line A and B changes but the nearly parallel relationship between line B and C remains constant. (Data from Marcellus, 1972, replotted by Boon, et al, 1977)

B. <u>The Boon Study</u>

Five years later, Marcellus' work was reviewed by Boon, et. al. (1977). By reporting Marcellus' data, they noted an interesting trend which can be seen in Figures 3(a), (b), and (c). In each graph, line A is the elevation of 1.5 times tidal range above mean low water (the current legal boundary), line B is the elevation of the salt bush line and line C is the elevation of mean high water (line C corresponds to the horizontal axis in 3c). Each graph represents the same data; the vertical axis represents elevation with respect to three different tidal datums: MLW, mean low water (graph 3a), MTL, mean tide level (graph 3b) and MHW, mean high water (graph 3c). The horizontal axis represents the mean tidal range for each graph. As the reference tidal datum changes from MLW to MHW (from graph a to c), the similarity between lines A and B decreases. The nearly parallel relation between lines B and C, however, remains. This implies that the elevation of the saltbush line can be better approximated as a constant elevation above mean high water (slightly less than 1 foot).

Other evidence led the group to further question the legal definition. Since fluctuating water levels are important factors controlling development of marshlands, the percentage of time that any given elevation is flooded should be closely related to the extent of marsh development at that elevation. When Boon's group examined tidal data collected at five stations scattered throughout Tidewater Virginia, they found no consistency among values for frequency of immersion of the elevation of the current legal wetlands boundary line. There was, however, a consistent frequency of immersion of an elevation approximately 10 inches above MHW. This corresponds roughly to the elevation of the saltbush line above MHW as seen in graph 3(c), and is additional evidence of a direct relationship between the upper limit of marsh and MHW.

An important exception to this general pattern was noticed. Marshes surrounding broad, shallow bays that have small tidal ranges but remain exposed to storm tides (e.g. Chincoteague Bay), have upper marsh limits at higher elevations than might be predicted. These marshes would extend beyond both the current legal boundary, and a boundary defined as an elevation of approximately 10 inches above MHW. We will refer to these areas again later.

To test the hypothesized relationship between the upper limit of marsh and MHW, Boon's group surveyed the elevation of the ULM with respect to MHW at 13 sites for which precise tidal datums were available. For the purposes of this study, the ULM was defined as that point where upland vegetation becomes more abundant than wetlands vegetation. Marcellus had predicted that this definition would be difficult to apply in areas of gradually merging wetland-upland vegetation because it would be subject to the judgement of qualified botanists, who might disagree on the placement of this boundary. As a preliminary test to determine if, in fact, this disagreement would be significant, the ULM was determined at two sites by two different botanists, each having no prior knowledge to the other's choice. In this study at least, close agreement was obtained. Further research is needed to test the consistency of this definition.

Each marsh surveyed by the Boon group was classified as either fresh or salt (criteria for this grouping was not mentioned). Analysis of the data revealed a consistent elevational difference above MHW for each type marsh. The upper limit of salt marshes was found at about a foot above MHW (average 0.95 ft., range 0.8 - 1.2 ft.); for coastal fresh water marshes it was about 7 inches above MHW (average 0.59 ft., range 0.5 - 0.8 ft.).

Assuming that the 1) ULM determination and 2) salt-fresh marsh grouping are reproducible, this may be a more accurate definition for the elevation of ULM. The problem of areas such as Chincoteague, which are subject to extreme storm tides, however, remains unsolved. An elevational definition including these areas will require further research; they might have to be treated individually. There is a precedence in the current legislation for separately incorporating specific, unique areas as wetlands under the Act. The 1975 amendments included a special definition for wetlands bordering Back Bay and North Landing River in Virginia Beach and Chesapeake which have little or no tidal range. Specifically, these areas are designated as:

> ". . . all marshes subject to regular or occasional flooding by tides, including wind tides, provided this shall not include hurricane or tropical storm tides and upon which one or more of the following vegetation species are growing or grows thereon subsequent to the passage of this amendment..."

followed by a list of 24 wetlands plant species (Code of Virginia, §62.1-13.2).

Thus, despite the fact that these areas have no significant tidal fluctuation, they were included as wetlands. In this case, a biological definition was used to by-pass inconsistencies with the Act's tidal requirements. Perhaps a similar "special definition" could be used to incorporate other unique areas, like Chincoteague.

A biological definition would probably be the best way for Virginia to delineate its non-tidal wetlands in order to incorporate them under comprehensive wetlands legislation. The boundaries of these inland freshwater marshes and swamps could be defined at the point where upland vegetation becomes more abundant ($\geq$ 51% of the plants) than the wetlands species. As exemplified by Back Bay and North Landing River, these boundary limits may be irregular and will necessitate site-specific examination by botanists for delineation. This type of procedure is already utilized by local wetlands boards to define the limits of tidal vegetated areas and appears to be accurate and efficient.

C. Adequacy of the Current Definition

According to a review of the first two years of implementation of the Wetlands Act (Jones, 1976), boundary disputes have not been a serious problem. In the Guidelines for local management of wetlands (Marcellus *et. al.*, 1973), local authorities are advised to regulate any project that involves the shoreline, or digging or filling low wet areas near the water. They are further advised that a high degree of accuracy of boundary delineation may not be necessary. Since there have been no cases to date involving wetland boundary disputes, this prediction appears to be accurate.

Many states, including Virginia, have found it necessary to map their wetlands. A technique frequently used is color infra-red aerial photography. Except in cases where tree canopies interfere, a skilled photo-interpreter can approximate the upper wetlands boundary almost as accurately as can be done in field surveys. Virginia's current inventory is based on extensive field observation with the aid of topographic maps and aerial photographs. Sketches of marshes as small as 1/4 acre (and sometimes smaller) are superimposed on U.S.G.S. topographic maps. Tracings of the resulting maps are made which are suitable for inexpensive reproduction by offset lithography (as opposed to the expensive photo-maps produced directly from aerial photographs, used by some other states).

These inventory maps are used by wetlands board members who evaluate the importance of protecting wetlands against development. Since an inventory of plant species is included with the maps, planners can to some extent classify wetlands in terms of productivity and importance to the local ecology. It is important to note that wetlands, like any other land-sea boundary, are subject to change over time. Therefore, it is imperative that these maps be periodically updated to keep them accurate. Funding should be provided for this purpose.

VEGETATED WETLANDS

I. INTRODUCTION

Many functional roles have been attributed to wetlands in fresh, estuarine and coastal systems. They provide valuable (and often essential) habitats for many species of animals. They possess the ability to assimilate pollutant loads from adjacent waters, converting biological wastes into reusable products, thereby stabilizing and maintaining water quality. In many cases they serve as erosion buffers protecting upland areas. By far the most widely recognized value is their ability to produce organic carbon in the form of plant material which eventually becomes available to higher forms of life as food.

The benefits of a marsh may be far reaching, as in the case of Virginia's Eastern Shore for example, where fish migrating along the middle Atlantic coast are known to utilize vast saltmarshes as spawning, nursery, and feeding grounds (Wass and Wright, 1969). On the other hand, a small marsh fringing an inland lake or pond may contribute to the ecosystem of a limited geographical area. This should not imply, however, that the saltmarsh is more valuable than the freshwater marsh. In this particular example, the aquatic animal species of the inland lake may be solely dependent upon its fringing marshes as a source of food or nursery ground, whereas the species comprising middle Atlantic fisheries are not solely supported by Virginia's Eastern Shore habitat.

Relative contributions to the overall ecological systems vary from one wetland to the next. It is necessary, therefore, to distinguish between different wetland types for the purpose of assessing their relative values. The simplest distinction separates vegetated from nonvegetated areas. Vegetated wetlands, those areas whose surfaces are inhabited by vascular plants, are the subject of this chapter. The number of distinctly different values attributed to vegetated wetlands and the diversity of ecosystems require further delineation of more specific subsets within the category of vegetated wetlands. No single, indisputable classification, however, is universally accepted by scientists and resource managers. (Cowardin, et al., 1977). This is reflected in the discrepancies among the definitions of 'wetlands' incorporated in individual state legislation designed to protect them.

Although the Virginia wetlands legislation was enacted in 1972, scientific study and improved understanding of these areas has been ongoing. Through a review of current scientific knowlege, this chapter will attempt to describe the distinguishing characteristics and ecological values of all types of vegetated wetlands, as well as the factors which determine their relative value. More specifically, to accomplish this latter goal, the present classification of wetlands accepted by the General Assembly and incorporated in the Virginia Wetlands Act will be examined.

II. THE NATURE OF WETLANDS

The term 'wetlands' refers to lowland at least periodically covered by shallow water. They have been variously referred to as marshes, swamps, bogs, wet meadows, potholes, and sloughs. Recently beaches, bars, and intertidal flats have been included in the definition. The permanent bottoms of streams, reservoirs, lakes, and rivers are not, nor are watery areas that are so temporary as to have little or no effect on the development of moist soil vegetation (Shaw and Fredine, 1956). Generally it can be inferred that wetlands are areas in which the influence of shallow water, either permanent or temporary, is the primary factor determining the inhabitance of the land surface by certain species of plants and animals. The definition of wetlands under current Virginia legislation includes, with the exception of two special cases, only those vegetated areas which are influenced by tidal waters (Code of Va. Ann., 9: 62.1-13.1).

Tidal wetlands occupy the transition zone between land and sea. In low lying areas with gentle relief, these wetlands can be extensive. If protected from the erosive powers of the ocean surf, these areas will be invaded by algae, saltmarsh cordgrass and an abundance of invertebrate animals. In addition to recognizing tidal areas, a more comprehensive definition of vegetated wetlands would include the non-tidal marshes and swamps of upland areas as well.

Biologists often speak of the successional stages of development of a community. For example, if a plowed field in Tidewater Virginia, is abandoned, only a short time will pass before it will be invaded by weeds, low shrubs and tree seedlings. It is not hard to imagine how this land will gradually become a pine forest and finally a hardwood forest, assuming that no outside force intervenes. Should the community stabilize at this point, it is called a climax community. The entire process is called ecological succession.

Abandoned field systems such as this have been studied in detail by ecologists. Long term observation and measurements, such as clearing small squares of land and weighing the vegetation, have yielded productivity data illustrated by Figure 4 and Table 2.[2] Of greatest interest is net production P_N, the difference between gross production P_G and consumption, or respiration, R. Greatest net productivity occurs at 30 years, when a forest is still young.

The natural sequence of events of succession in an abandoned field can obviously be disturbed by a natural disaster such as a fire or flood. If, for example, fires occurred frequently, the forest system would remain young. A similar situation exists in areas subject to regular flooding, such as marshes in the intertidal zone. Because flooding maintains the ecosystem at an early stage in the

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[2]Productivity can be measured in terms of mass (weight) or energy (calories). To determine the energy content of a vegetation sample, the cuttings would be dried and burned in a bomb calorimeter.

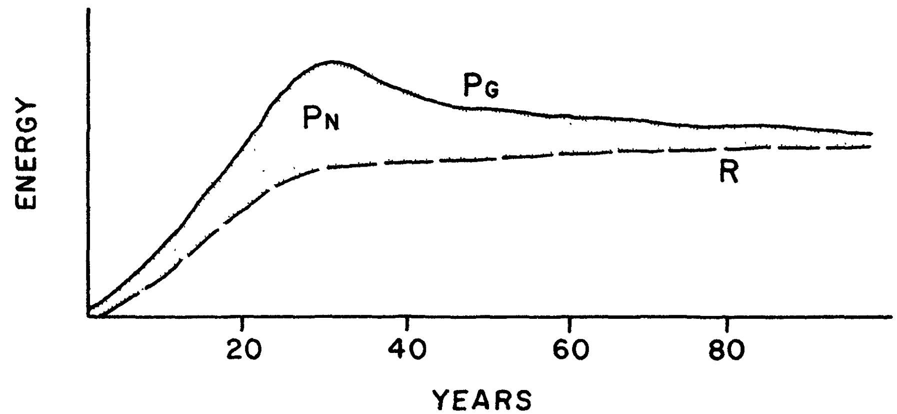

Figure 4. Energy produced by vegetation in a Forest ecosystem. P_G is Gross Productivity, R is Respiration. Net productivity (P_N) is the area between P_G and R. Note that it reaches a maximum value when the system is approximately 30 years old, well before the climax stage. Redrawn from Odum (1972), data from Kira and Schidei (1967).

ECOSYSTEM	ANNUAL PRODUCTIVITY Kcal/m^2
MARINE	
Open ocean	1,000
Coastal zones	2,000
Upwelling zones	6,000
Estuaries and reefs	20,000
TERRESTRIAL	
Deserts and tundras	200
Grasslands and pastures	2,500
Dry forests	2,500
Boreal coniferous forests	3,000
Cultivated lands with little or no mechanization	3,000
Moist temperate forests	8,000
Mechanized agriculture	12,000
Tropical and subtropical rain forests	20,000

TABLE 2. Estimated gross primary production (annual basis) of the biosphere and its distribution among major ecosystems (from Odum, 1971).

ecological succession process, it is referred to as a pulse stabilized ecosystem (as is the forest system mentioned above).

Despite recurrent flooding, some hardy organisms survive and flourish. Sessile organisms find the intertidal zone a particularly favorable habitat. Tides, winds and currents allow these organisms to benefit from accelerated nutrient cycling and waste removal. Energy which would normally be spent for food gathering and excretion can be conserved. For these reasons, intertidal areas are very fertile habitats. They contribute to the productivity of estuaries, which are unsurpassed by any other ecosystem. As can be seen in Table 2, estuaries are almost twice as productive as mechanized agriculture, and of course require no plowing, irrigation, fertilizer, or pesticides. Virginia is well endowed with estuaries, most importantly, the Chesapeake Bay and its tributaries which comprise the largest estuarine system in North America.[3]

Although not part of the current management regime in Virginia, inland freshwater marshes and swamps are important components of the Commonwealth's wetlands. These non-tidal areas are inundated by freshwater on a regular or occasional basis and can be distinguished from non-wetland areas by the presence of plant species that are dependent upon flooding to survive. Metzgar (1973) classified

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[3]Although Virginia's estuaries are naturally fertile, they are sensitive to natural and man-made disturbances like hurricanes and pollution. The net result of these stresses is a reduction in the number of species in the estuarine system (Copeland, 1969).

interior (i.e. inland) wetlands in Maryland as follows:

(a) seasonally flooded basins and swamps

(b) inland fresh meadows

(c) inland shallow freshmarsh

(d) inland open freshwater

(e) shrub swamp

(f) wooded swamp

(g) bogs

Some shrub and wooded swamps were also classified as coastal (i.e. tidal) by Metzgar, indicating that it is often difficult to accurately determine whether an area is subject to tidal influence. In Virginia, for example, upper reaches of certain tributaries of the southern branch of the Elizabeth River (a tidal estuary) border the Dismal Swamp (considered a non-tidal wetland) and the boundary between the tidal and non-tidal areas is indistinct.

A review of the effects of the draining (i.e., destroying the wetland-nature) of these inland marshes and swamps will provide a general understanding of the values these natural areas offer. Rulison, et al. (1972) performed a cost analysis evaluation of wooded swamp drainage projects in North Carolina. The wooded swamps altered by these projects are typical of others in the southeastern coastal plains of the United States (including Virginia). These projects sponsored by the Soil Conservation Services (U.S. Department of Agriculture) and the U. S. Army Corps of Engineers usually amounted to dredging a channel through the center of the swamp. This technique is referred to as stream channelization and has been highly controversial. Proponents note that these efforts have been effective in reducing local flooding, by lowering the water table, and thereby, stabilizing the local farm economy. Mosquito populations decrease also.

Such drastic alteration of these natural areas, however, has adverse effects as well. While hunters find drained areas more accessible, the populations of wetland animals they may seek are reduced. Specifically the numbers of wood ducks (*Aix sponsa*), mallards (*Anas platychynchos*), black ducks (*Anas rubripes*), mink, wild turkey and fish such as the yellow perch (*Perca flavescens*) and largemouth bass (*Micropterus salmoides*), are all reduced. For the most part, this wildlife becomes scarce because the wetland vegetation which provides their habitat is not supported by the drier environment. In addition to these naturally important plants, there is also an extreme reduction in commercially valuable stands of timber, including bald cypress (*Taxodium distichum*), tupelo gum (*Nyssa aquatica*) and black gum (*Nyssa sylvatice*) associated with drainage projects.

Dried wetlands have a much reduced capacity to absorb rain and run-off water increases in volume, turbidity and pollutant load. Prior to channelization, run-off from adjacent farm lands drained slowly through the swamps, allowing time for sediment, organic matter, nutrients and chemicals to settle out and be assimilated into the wetland ecosystem, instead of entering local rivers in large volumes. In some cases, a lowered water table may also have deleterious effects on the processes of recharging natural aquifers.

It is expected that future scientific research, similar to the North Carolina effort, will support and clarify these and other values of non-tidal vegetated wetlands. Thus, the importance of Virginia's inland marshes and swamps in terms of wildlife, waterfowl and water quality should support inclusion of these non-tidal wetlands under a comprehensive management scheme.

III. A CLASSIFICATION OF WETLANDS

A comprehensive classification of all types of aquatic environments was prepared by Cowardin, *et al.* (1977) for the U. S. Fish and Wildlife Service, and was intended to apply nationwide. The level of discrimination, however, does not differentiate between the individual components of broad wetland categories. Subsequent researchers have found that the classification of vegetated wetlands according to the assemblages of certain species of plants is a reasonable approximation of the most definitive unit of classification (McCormick, 1978). Few wetland animals, however, have ranges that coincide precisely with the distribution of a particular type of vegetation. Most animals range through several types of vegetated and non-vegetated areas. In addition, distinguishing one area of marsh from another for the purpose of managing the associated animal species may conflict with a classification useful for controlling shoreline erosion or other wetland functions. In spite of these contradictions, however, there appears to be a consensus that classification according to vegetation is the most practical, (*i.e.* easily inventoried and mapped), method available (McCormick, 1978, Cowardin, *et al.*, 1977 and VMRC, 1974). The Guidelines for implementing Virginia's 1972 legislation use such an approach to classify tidal vegetated wetlands in the Commonwealth (VMRC, 1974).

To provide an understanding of the effects of environmental conditions on the inhabitance of saturated soils by plants, a classification of wetlands in the Northeastern U. S. recently compiled by Silberhorn (1978) is presented here. Wetland areas in this classification are distinguished by having either permanent or temporary overlying waters (swamps v. marshes) and characterized by the effects of salinity on vegetation. The inclusion of these definitions here does not imply that they constitute the most viable classification scheme for the purpose of managing wetland resources. They do, however, provide an example of the complexity of classifying the diverse environments that compose vegetated wetlands.

AFTER SILBERHORN (1978)

A. Saltmarshes

Saltmarshes are coastal wetlands influenced by regular or irregular saltwater inundation. They typically have a definite vegetational structure. Zones generally occur in bands parallel to the shoreline and are characteristically dominated (50% surface cover) by a single species of plant. This feature of single-species dominance is directly contrasted by the mixed-species communities of fresh-water environments.

These marshes, by definition, occur only in saltwater environments. They are typically found at the seaward edges of the coast, including the landward shores of barrier islands, the lagoon type marshes of the Eastern Shore, and along the mouth of the Chesapeake Bay.

B. Brackish Marshes

Brackish marshes are coastal wetlands influenced by both fresh and saltwater regimes; hence the vegetation may include both freshwater and saltwater species. At nearly saline conditions (35 o/oo salinity)[4] the plant community is similar to that of the saltmarsh. Similarly as one approaches the freshwater regime (less than 5 o/oo) the freshwater marsh community is present. These marshes, then, are transitional between strictly salt and freshwater regimes. They are found fringing the shores of Chesapeake Bay and its tributaries, and therefore constitute the most widespread wetland type occurring within Virginia's coastal zone.

Lagoons are basins enclosed by land and cut off from the influence of the tide. They are often brackish, however, because of their close proximity to the sea. Back Bay, located in the southeastern corner of Virginia's coastal zone, is a good example of a lagoon. Yet, Back Bay has also been described as being more like a freshwater lake (Wass, 1969). Although Virginia's 1972 Act directs that only tidal wetlands are to be protected, Back Bay, a freshwater non-tidal coastal lagoon, has been included as an exception to the rule (Va. Code Ann., 9:62.1-13.2j).

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[4]Salinity is traditionally measured in parts per thousand (o/oo) or grams of salt/kilogram of seawater.

C. Freshwater Marshes

These are interior, coastal wetlands that are dominated by herbaceous[5] plants and may be irregularly or regularly flooded by freshwater (< .5 o/oo salinity). The amount of freshwater they receive depends to a great extent upon rainfall and, hence, can vary from season to season. In the uppermost reaches of the tributaries of the Chesapeake, these marshes are bathed with freshwater by daily tides.

Freshwater marshes are further categorized as inland or coastal and shallow or deep. They are all characterized, however, by a greater diversity of plant species than saltmarshes. Although certain plants will occasionally occur in pure stands, these communities generally exist as mixtures, without the single-species dominance that characterizes saltwater marshes. This is an important feature since the diverse plant types provide a greater selection of habitats for wildfowl and terrestrial animals. The tender roots and tubers of the herbaceous vegetation provide a more direct food source for these creatures than the salt-tolerant species of the saltmarsh.

D. Swamps

Dr. Silberhorn defines swamps as being wetlands dominated by

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[5]The term "herbaceous" is usually applied to plants whose stems remain soft and succulent (in contrast to "woody") (Keeton, 1967).

trees which are seasonally flooded with up to 30 cm of water. He also implies that these are strictly freshwater environments. They occur along meandering streams, shallow lakes, on flood plains of major rivers, or low areas behind coastal marshes. In fact they often occur in close proximity to marshes. The soil is usually mucky - i.e. covered by water, or at least saturated. Swamps are inhabited by a diverse community of coniferous and deciduous trees, sedges, shrubs, and ferns.

E. Shallow-Littoral Water

These areas are the land/water interfaces of ponds, lakes, and rivers vegetated by rooted and floating aquatic plants. The plant forms include submergents, floating-leaved plants, and emergents. This littoral zone can be considered as the transition between open water and the marshes or uplands. Some of the emergent vegetation are the same species as those which populate marshes. The floating plants and submergents, however, are distinct life forms which are not found in other wetland areas. These plants are directly accessible to certain open-water aquatic animals. This wetland type occurs below the mean low water level and is outside of the protection provided by the 1972 Act.

F. Salt Ponds-Grass Beds

This category includes embayed bodies of water, isolated from the tidal action of the ocean. They are often formed when once-tidal marshes or basins are enclosed by deposits of air and waterborne sands (*e.g.* spits and barrier islands). They are characteristically in close proximity to the ocean, but can be brackish as a result of freshwater drainage. The definition for saltponds specifies that two submergent plants eel grass (*Zostera marina*) and widgeon grass (*Ruppia maritima*) are the dominent species. Although Back Bay also fits this description, this area is a freshwater wetland and therefore has many more species of plants than the two mentioned above. The classification outlined above was intended to apply to the New England states, and does not necessarily correspond to the vegetated wetlands native to Virginia.

The most extensive studies of wetlands in Virginia are being done by the Virginia Institute of Marine Science (VIMS) at Gloucester Point. Under Section 62.1-13.4 of the Act, the Institute is obligated to inventory the tidal wetlands of the Commonwealth, and with this input, the VMRC is directed to from time to time promulgate guidelines "which scientifically evaluate wetlands by type and which set forth the consequences of the use of these wetlands types." (Va. Code Ann., 9:62.1-13.4). This mandate has produced a series of inventories, one for each municipality in Tidewater. Each inventory includes extensive descriptions and maps of the wetlands occurring within the corporate limits of the county, city or town. In addition, the Virginia Marine Resources Commission issued the *Wetlands Guidelines*, prepared with the scientific advice and assistance of VIMS (VMRC, 1974). The Guidelines identify Virginia's coastal wetlands by type, and describe the consequences of the use of these types.

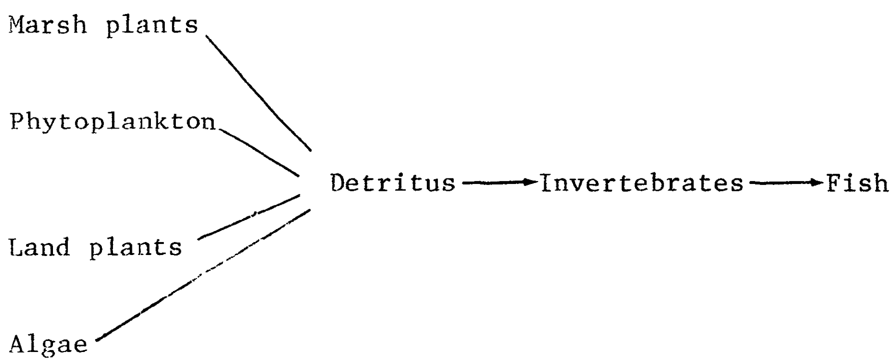
A very accurate classification of Virginia's wetlands has resulted from this work. The Guidelines refine the broad classification outlined above by further identifying plant community types within each of the salt, brackish and freshwater wetland categories. The wetlands of each municipality have been visited, mapped, and described as to their characteristics and values by a technical advisor from VIMS. The need for a review of each wetland on a site by site basis is well recognized, evidenced by the present inventory of wetlands Virginia brought about by the Act. An inherent problem with a definition of wetlands types that is overly general is 'exceptions to the rule'. They create conflicts which make definitive management difficult.

The present management scheme for the protection of Virginia's wetlands will be examined in a later section of this paper. The definitions and policies of the Act are discussed along with the guidelines intended to implement these policies. In the following section we describe the values of vegetated wetlands to provide the reader with an understanding of natural wetland functions such as productivity, nutrient cycling, and floodwater storage. We will discuss how current understanding of these valuable wetland functions provides a basis for management, but, we will also discuss how our current lack of understanding limits the efficiency of any wetlands management scheme.

IV. THE VALUES OF VEGETATED WETLANDS

A. Productivity

The creation of plant material is most important to the aquatic ecosystem because animal species utilize this material as a food source. Few organisms can feed directly on plant stems, seeds, and roots, however. Most aquatic species are indirectly fed by marsh plant production. When the marsh plants die, they are mascerated by physical processes and attacked by bacteria and other micro-organisms to form detritus. Detritus, laden with the bacteria feeding on it, has greater nutritional value to higher animals than undecayed plant material (Dept. of Interior, USFWS, 1977). Small invertebrates, such as worms and crab, feed on this detritus. These animals are in turn grazed upon by fish and shellfish. Hence, a simple food chain is established in which detritus is a common link.



Many studies have been conducted to estimate how much plant material is produced in a given area of marsh over a given period of time (usually an annual period). Generally the plants of a given area are clipped and weighed. Although useful for comparing the productivity of one species of plant to the next, such techniques generally under-estimate total marsh production (Dept. of Interior, USFWS, 1977). This deficiency arises because the production of (plant) material from sources other than the vascular plants, i.e. phytoplankton and mircoalgae, as well as below ground root systems, are not assessed with the clipping technique. Stowe, et al. (1971) demonstrated in a Louisiana marsh system that these other sources account for nearly 40% of the total marsh production (Mendelssohn, 1973).

The results of productivity studies imply that the mixed plant communities of freshwater wetlands produce a greater amount of plant material than an equal area of saltmarsh dominated by a single species of plant (Wegham, et al., 1978). In mixed communities the species composing the community rarely reach their peak standing crops simultaneously. Consequently, the peak standing crop of a mixed community may not exceed a monospecific community but the production through an entire growing season is greater (Wegham, et al., 1978). The generalization that freshwater marshes are more productive than salt marshes is not always accurate, however, because the productivity of individual species can vary from one area of a given marsh to the next. For example, saltmarsh cordgrass (Spartina alterniflora) which dominates the saltmarshes in low areas, has been measured to produce anywhere from 500 - 3,000 grams of plant material per square meter (g/m^2) annually (Dept. of Interior, USFWS, 1977). Another saltmarsh species, the black needlerush (Juncus roemerianus) produces slightly less material annually (500 - 2,000 g/m^2), but is again highly variable. One factor which accounts for intra- and inter-specific variability of production is the amount of nutrients available for growth.

Studies of this complex system are ongoing. Scientists recognize that the diversity of hydrographic conditions affecting wetlands would require an investigation of each particular case to accurately determine the value of productivity. Yet, such a study would require at least a year to complete for each wetland site under consideration. In light of the need to make value assessments rapidly, the wetlands manager must rely on technical information that can be accumulated within the time constraints of his duties. For this reason, identification of plant community types, which can be used to indicate general differences in community productivity, are used for making management decisions.

B. Nutrient Cycling (Maintenance of Water Quality)

Estuaries are important contributors to the growth and health of urbanized regions because of the amount of waste which these active ecosystems can assimilate without a significant reduction in water quality (Gosselink, *et al.*, 1973). This free service of nature has often been taken for granted or assumed to be unlimited in capacity. It is becoming apparent that the mid-Atlantic estuaries are now so overloaded that oxygen and other aspects of water quality are reduced to undesirable levels for fishing and recreation (Gosselink, *et al.*, 1973).

Tidal and estuarine wetlands play an important role in the natural ability of contiguous open water to purify and assimilate pollutants, thus maintaining the quality of aquatic environments. Chemical and biological processes work cumulatively with physical processes like sediment collection, shoreline buffer effects and other hydrologic conditions to accomplish the water quality maintenance function of estuaries.

As a result of the high rates of primary production and organic soil deposition in the presence of air-water-soil interfaces, wetlands are the site of intensive biogeochemical cycling of important elements, including nitrogen and phosphorous (Axelrad, 1974). Phosphorous and nitrogen are essential to vascular plant growth as well as phytoplankton growth, and low concentrations of these elements in water often limit the photosynthetic productivity of estuaries (Fournier, 1966 and Thayer, 1974). On the other hand, high concentrations of nitrogen and phosphorous introduced with municipal wastewaters, without adequate dilution by water circulation, can cause overproduction of certain algae resulting in scums and odors which make water undesirable for use in supply systems, recreation, and industry (Bentley, 1969). Thus any alteration in concentrations of these nutrients in the waters circulating through the wetlands can have significant effects on the health of adjacent waterways.

Many studies have been conducted to ascertain whether marshes are contributing or removing nutrients from overlying waters. In a North Carolina saltmarsh dominated by black needlerush (Juncus roemerianus) Byron (1968) estimated that 41% of the nitrogen entering the system during several fall tidal cycles was not returned to the estuary, suggesting that the marsh served as a sink for nitrogen. Grant and Patrick (1970) reached a similar conclusion when they measured an average daily reduction of phosphate (an oxygen-containing or oxidized form of phosphorous) and nitrate (an oxygen-containing form of nitrogen) in water flooding a marsh (6.4 pounds and 13.1 pounds per acre per day respectively). Valiela, Teal, and Sass (1973) observed uptake of nitrogen and phosphorous by saltmarsh plots treated with sludge from a secondary sewage treatment plant. The treated plots exhibited an ability to utilize much of the additional nutrients available in the sludge.

Results such as those presented above led many authors to conclude that marshes might serve as natural tertiary treatment systems, hence protecting open waters from nutrient overloading (Gooselink, et al., 1973). Recently, however, studies of nitrogen and phosphorous cycling in saltmarshes have pointed out that this speculation may be premature (Bender and Correll, 1974). Data derived from three wetland study sites in the Chesapeake Bay show that the oxidized forms of nitrogen and phosphorous (nitrate and phosphate) are indeed assimilated by the marsh. Transformation of these elements by photosynthesis into plant material, with subsequent export to the detrital pool of the adjacent waterways, however, causes little, if any, net annual loss of nitrogen or phosphorous to the marsh (Axelrad, et al., 1976). The authors add, however, that the high, irregularly flooded salt meadow (Spartina patens) marshes appear to have some capacity for phosphorous removal. Researchers working in freshwater wetlands, while indicating that our knowledge is still inadequate, have similarly concluded that these wetlands do not serve as significant nutrients sinks (Prentki, et al., 1978 and Klopatek, 1973).

A somewhat different effect of saltmarshes on the adjacent water chemistry was hypothesized by Pomeroy, et al., (1972). In a Georgia marsh study, he found the flux of phosphate between the marsh and water column was so rapid that the level of dissolved phosphate in adjacent waters varied little throughout the year, despite variations in input to the whole system. The marsh sediments apparently act as both source and sink, effectively buffering the effects of large intermittent additions of phosphate to the estuarine system. Studies in Louisiana have also demonstrated this phenomenon (Ho, et al., 1970). These findings do not, however, demonstrate the ability of wetlands to deal effectively with continual inputs of excess nutrients, like those associated with human waste (Axelrad, et al., 1976).

This should not imply, however, that wetlands are not valuable in maintaining a healthy, productive ecosystem. The results of all of the above studies (and others like them) illustrate the dynamic nature of the natural cycling of the chemical elements essential to life. It is this cycling of nutrient elements into organisms, and back into the inorganic nutrient pool which perpetuates future generations of plants and animals.

Due to the lack of information and clear understanding of nutrient cycling in each wetland type, it is difficult to compare the relative values of different wetland areas. One can visualize, however, that areas with the greatest marsh water-open water exchange and circulation (e.g. a tidal saltmarsh) will have the greatest impact on the health of adjacent ecosystems. The amount, sources, and chemical nature of the circulating water compose what scientists term an area's "hydrology". The local hydrology of a particular wetland has a significant effect on the nutrient cycling, sediment filtering, erosion buffer capacity, as well as the productivity value of the specific area of concern (de la Cruz, 1978). In fact, a number of scientists propose that hydrogeologic factors would be a logical basis for wetlands classification (Sloey, et al., 1978, Cowardin, et al., 1977, and de la Cruz, 1978). Accordingly, the effects of hydrology on ecosystem structure was extensively described by Gosselink et al. (1978) and is summarized as Appendix I.

The Gosselink description of the hydrologic effects on marshes illustrates the complexity and interdependance of various wetland components. Specifically, it illustrates the need to consider hydrologic factors when comparing the life-support value of various wetland types. Quantifying mineral cycles to accurately assess the balance of nutrient cycling and productivity would require extensive monitoring of evapotranspiration,[6] gas exchange, surface runoff, and subsurface flows. Such a scientific study could not be practically applied to all wetland areas in a state-wide management effort. Yet, the classification presented earlier (after Silberhorn) is roughly based on hydrologic regimes (swamps _v._ marshes). Gosselink expands this concept to assess the usefulness of comparing the ecological function of different wetland types based on rough estimates of hydrology:

1. _Productivity_ is strongly influenced by so many factors that generalizations based on hydrology may be impossible to make. Comparison of productivity is complicated by various temperature regimes and growing seasons. Productivity does appear to increase with the increase of water circulation (_i.e._ marsh _v._ swamp).

2. _Flux of organic materials_ - it is expected that as flooding increases, the proportion of production exported also increases.

3. _Nutrient cycling_ - On a continuum from low energy standing water swamps to high energy marshes, the internal cycling of nutrients is reduced. Dependence on external sources of nutrients increases, however. In other words, the nutrient cycling in swamps is self-contained, whereas tidal marshes are relatively open systems, and thus affect the nutrient budget of a much larger geographical area.

In summary, one can say that the greater the amount of water circulation over a wetland surface, the greater the impact that wetlands will have on adjacent environments. Yet Gosselink's generalizations do not take into account the influence of wetlands

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[6]The term "evapotranspiration" refers to the continuous loss of water from a plant by evaporation through small openings (stomata) in the leaves (Keeton, 1967).

relative to the influence of other sources of life-support factors. For example, what percentage of detritus is contributed to a lake system by its fringing marsh compared to that input through a rainwater runoff from adjacent terrestrial plant communities? The relative contribution of wetlands vis-a-vis other systems on the adjacent aquatic environment must be determined to accurately assess the value of wetlands as a potential energy source.

Difficulties also arise when one attempts to manage various wetlands types according to the role they play in maintaining water quality. Accurate assessment of this valuable function would require an in-depth field study of each particular wetland site because current understanding indicates that nutrient cycling in wetlands is highly variable from one area to the next and from season to season. Reliance on such studies would not be practical since the resource manager must use the technical information that can be made available to him within a limited period of time.

C. Sediment Control

Stabilized, vegetated wetlands function as settling and filtering basins, collecting sediment and other suspended material in the complicated root and stems systems on their surfaces (Metzgar, 1973). The physical structure of marsh surfaces serves to retard the velocity of river and tidal currents, thereby reducing erosion. In addition, floodwaters are induced to release their suspended sediment. Once sediments and other materials are deposited, the plant stems, leaves, and roots serve to retain them in that location. This process is a key factor in building and maintaining the wetland substrate.

The function of wetlands as a sediment sink is important to the maintenance of aquatic life and water quality. The presence of sediment particles in the water column inhibits light penetration into the water, reducing the amount of light energy available to the phytoplankton for photosynthesis. Silt removal by marshes also reduces the deposition of sediment on other valuable areas, such as oyster beds or navigational channels and harbors.

D. Flood Prevention and Erosion Control

Coastal and inland wetlands along the shores of larger lakes and rivers benefit those areas by altering their hydraulic environments. These effects include the storage of surface run-off and tidal surges; alteration of river flows, waves, and tidal currents and the buffering or stabilization of coastal lands from erosion.

Flood Water Storage - When high tides coincide with other factors, like high winds and rain, they can magnify the total effect of coastal high water situations. As a large mass of wind-driven water enters an estuary with great momentum, it can go nowhere but inland. All low-lying areas immediately adjacent to the estuary or river are potential flooding sites. Vast marshes (and swamps) adjacent to the water body provide an absorbent area for this water to occupy (i.e. a flood conveyance area). If former wetlands are filled or otherwise destroyed by development, the natural flood plain provided by the wetland will no longer be available to protect inland areas from severe damage.

Though widely recognized, the floodwater storage ability of wetlands has not been well documented. A 1975 study of the Charles River, Massachusetts by the Army Corps of Engineers determined that if 40% of the river's wetlands were lost, flood stages in the middle and upper reaches of the river would increase two to four feet, increasing annual monetary losses by an estimated $800,000 (U. S. Army Corps of Engineers, 1975).[7] Similar studies in Connecticut indicate that wetlands reduced peak river elevations (Dewey and Klopper, 1964). When recent severe flooding struck eastern Pennsylvania, two bridges like those destroyed elsewhere were left standing below Cranberry Bog, a natural flood conveyance area (Niering, 1968). The lack of more specific information on the function of wetlands in conveying flood waters makes it difficult to accurately assess the relative value of different wetland types in terms of this important function. Some generalizations, however, can be inferred from a broad understanding of the nature of flood water storage. The amount of water stored in a given wetland is a function of the area: the larger the wetland, the greater the storage capacity. One author estimates that a wetland covered by one foot of water holds 330,000 gallons of water per acre (Johnson, 1969).

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[7]In this case, the Corps reversed a recommendation for construction of a dam, suggesting the protection of 17 wetland parcels, constituting 8,500 acres.

Wetlands adjacent to open water would have a more immediate effect in reducing high water levels than areas remote from open water systems (e.g. swamps). Swamps may, however, reduce the input of surface water into open water basins if they are located within the natural drainage pattern. It is important to illustrate the real need for open water flood storage. In a small tidal tributary of the York River, subject to high water levels during storms, the capacity of a fringing acre of wetland to store 330,000 gallons of water would absorb a large portion of the flood water entering the creek during storm conditions. These wetlands, then, are of great value to the flood-prone shores of the tributary they flank. On the other hand, an acre of marsh bordering the Chesapeake Bay would hold only an insignficant fraction of the total volume of flood water. The loss of an acre of marsh along the Chesapeake Bay would not produce the significant increase in high water effects that would develop if that acre were lost in a smaller tributary.

Although wetlands are valuable as flood conveyance areas, the management of this function involves the preservation of very large areas of wetland (8,500 acres in the Massachusetts example). Therefore, it would seem that the site-specific nature of the Virginia Wetlands Act makes it a less than effective tool for preserving the large-scale natural flood conveyance functions of wetlands. Also, since the Act regulates activities only in tidal areas, important inland flood control areas, like freshwater marshes and swamps, are not protected.

Erosion Protection - The physical and biological characteristics of wetlands can influence wave action, river flows, and tidal currents. Physcially, the low, gently sloping elevation of wetland surfaces dissipate wave energy which would otherwise have a destructive impact on dry embankments. The sponge-like qualities of the vegetation offers absorption for a limited amount of wave shock (Metzgar, 1973). The complicated root and stem systems of the vegtative cover serve to bind the soil, slowing its erosion (Metzgar, 1973 and Byrne and Anderson, 1977).

Wind generated waves are the principle erosion agent. Hence the shores of the Chesapeake Bay, the Eastern Shore barrier islands, and the shorelines of wider rivers, are the areas in Virginia which suffer the most severe erosion. An estimated 21,000 acres of land in Virginia has been lost during the 100 year period from 1850-1950 (Byrne and Anderson, 1977).

Sea level has been rising at an estimated rate of 10-15 inches per century (Wass and Wright, 1969). The vegetative cover of marshes facilitates soil accumulation by slowing river and tidal currents, thereby depositing sediment that would otherwise remain suspended. The accretion of this material allows the marsh to grow upwards, keeping pace with sea level, thereby maintaining itself in a dynamic system. Wass and Wright (1969) describe marshes as nature's way of maintaining a buffer protecting the uplands from the erosive forces of the advancing waters.

For an estuarine marsh to keep pace with sea-level rise, it would require about 3 cubic yards of sediment per acre per year (Wass and Wright, 1969). In Virginia, an estimated 5,000 cubic yards per acre or more has accumulated in the marshes over the past two centuries. One coastal study estimated that Virginia's 25,000 acres of marshes retain 76,000 tons of sediment each year (Wass and Wright, 1969).

Fringing wetlands also serve to reduce or divert current flows of rivers and tides. Here the erosive force is reduced by the vegetation which acts as a baffle to reduce water velocity (Wass and Wright, 1969). This decreased velocity causes the waters to deposit their sediment load. The configuration of meandering marsh creeks and broad tidal flats can cause diversion and retention of peak tidal current flows. This phenomenon was demonstrated by Boon (1975) in an Eastern Shore saltmarsh. He observed two current flow peaks during ebb tide which were of less magnitude than the single rush of water expected during this phase of the tidal cycle.

In general, marsh grasses along shorelines reduce erosion by binding the soil and decreasing the velocity of water currents. The value of a marsh in protecting shoreline areas from erosion, then, should be considered when making management decisions. In fact, the recent Virginia shoreline erosion study completed in 1977 recommended that, whenever possible, natural stands of grass should be left untouched (Byrne and Anderson, 1977). The following is a simple list of factors which should be considered when determining the protective value of a particular wetland site:

1. The amount of wind-generated wave energy which is incidental to the specific site.

2. The slope, maximum elevation and area of the particular site.

3. The type of vegetation covering the wetland, since the root systems of different plants have different capacity for soil stabilization.

The VMRC Guidelines developed pursuant to the Virginia Wetlands Act, reflect extensive consideration of types of vegetative cover and their stabilizing characteristics. Most valuable are wetland grasses, which have intricate rhizome[8] systems that effectively trap sediments. Upland sedges and bushes are less efficient because of their less complicated root structure. Freshwater broad-leafed plants are less valuable still, because they have relatively shallow roots which die in the winter. They also occupy softer muds more susceptible to erosion than sands.

The technical reports which accompany the VMRC Guidelines point out some specific research needs which could improve the management of wetlands for preventing erosion (Silberhorn, Dawes, and Barnard, 1974):

1. What is the minimum <u>width</u> of marsh necessary to provide an effective buffer?

2. Can erosion buffer characteristics be improved by replacing broad-leaved freshwater plants with more erosion resistant grasses, sedges and bushes?

3. How does natural or artificial vegetative cover compare to man-made structures (bulkheads, rip-rap cover) in terms of efficiency in protecting shorelines, and cost <u>v</u>. benefit considerations.

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[8]The complex bud and nodule structure characteristic of rhizomes, thickened branches of a plant's root system which serve as storage deposits of food material, create effective sediment traps.

The answers to questions such as these will provide a more accurate management scheme for utilizing the natural erosion buffer capacity of wetlands. Considering the limits of our present understanding, however, the existing Virginia Guidelines provide a practical tool for making decisions based on the ability of vegetative types to stabilize tidal shoreline soils. Because authority under the Act is limited to the Tidewater area, the fringing marshes of larger upland lakes are, however, left unprotected.

E. Fisheries

Virginia's coastal wetlands make up only one percent of the total area of the state. Yet, this small area provides a wide variety of habitats for various species of plants and animals. A habitat for any given species is an area with the proper physical, chemical, and biological conditions for the species to carry out its life processes. More simply defined, it is the region where a plant or animal naturally lives. Wetland habitat types in Virginia include the Eastern Shore's seaside saltmarshes and tidal flats, the shallow and nearly freshwater Back Bay area with rooted aquatic plants, the giant cordgrass marshes bordering brackish nursery grounds and the non-tidal freshwater marshes well inland from Virginia's coast (Wass and Wright, 1969).

Wetland areas provide vital spawning and nursery grounds where juvenile fish can feed, protected from predators and unfavorable water conditions; adhesive eggs can find substratum; and free floating eggs and delicate larval forms can find refuge from strong currents and intensive sunlight (Metzgar, et al., 1973). Coastal wetlands also serve as an important source of nutrients for valuable commercial fish and shellfish. The National Estuary Study (U. S. Fish and Wildlife Service, 1970) indicated that the value of estuarine-connected commercial fish landed was about 300 million dollars. The full retail market value of these fish was estimated to be $1.1 billion (Sports Fishing Institute, 1976). McHugh (1966) stated that nearly two-thirds of the total catch of fish and shellfish from waters off the East Coast of the United States and well over half of the entire U. S. commercial catch is made up of estuarine-dependent species. In 1967-1968, 95% of Virginia's annual harvest of commercial and sport fish from tidal waters was found to be dependent to some degree on wetlands. Most of these fish spent at least part of their lives in brackish nursery grounds or in the Eastern Shore bays (Wass and Wright, 1969). Several species, like the white perch and catfish, are totally dependent on these areas throughout their lives, while other species of sport and commercial finfish rely on these habitats only during their juvenile stages. Despite the brevity of this latter period, survival of these species hinges upon suitable conditions in the marsh-bordered spawning and nursery grounds (Wass and Wright, 1969).

Among the most valuable species which spend their early lives and critical periods of development in wetland nursery grounds are menhaden, croaker, spot, sea trout, four species of shad and river herring, the american eel, sturgeon, and blue crab. Of these fish, menhaden consistently accounted for 84-88% of the annual commercial tonnage in Virginia (Wass and Wright, 1969). The dominance of menhaden as the most important commercial fishery is delineated in Virginia's landing statistics for 1974. The National Marine Fisheries Service statistics on Virginia's fisheries showed that 380 million pounds of menhaden were caught, having an ex-vessel (gross dollar returns to fishermen) value of $112 million. The value of the menhaden catch exceeded the second most important commercial fishery in the State (surf clam) by $4.4 million (U.S. Dept. of Commerce, 1977).

Reintjes and Pacheco (1966) have stated that physical, chemical and biological factors of the estuarine environment affect, and determine to a certain degree, the population of menhaden. Menhaden spawn in the ocean during the winter months and as larval fish are transported into the Chesapeake Bay by bottom saline currents. During the early spring, they are feeding in the sluices and muskrat runs of tidal marshes (Metzgar, et al., 1973). These young menhaden represent not only the largest commercial catch on the Atlantic Coast, but also a rich protein food source for other fish like juvenile striped bass (Metzgar, et al., 1973).

Many commercial shellfish also rely on wetlands for their food source. They are highly dependent upon the unicellular algal forms that derive their principal nutrients from material produced in marine (coastal) wetlands (Metzgar, et al., 1973). Further depdendence of shellfish on coastal wetlands is well summarized in Metzgar's 1973 publication, Wetlands in Maryland:

> Coastal wetlands bordering large expanses of shoreline are highly important to the establishment and maintenance of many natural and seeded oyster bars, particularly those that are in tributaries and small bays. Natural grounds are critical for perpetuation of the osyter, soft clam and hard clam fisheries. Wide natural dispersal and protection facilitated by numerous adjacent wetlands ensure that some oyster grounds are protected from damaging natural acts and promote reproduction and harvesting. Maintenance of these shellfish populations provides the brood stocks whose free floating microscopic larvae repopulate harvested or naturally devastated areas.
>
> Nearness of oyster and other shellfish grounds to wetlands may provide protection from the summer encroachment of oxygen poor bottom layers of water that limit the life of sedentary animals in deeper waters. Wetlands also provide some measure of protection to shellfish and other bottom life against burial from sedimentation, if shoreline areas were otherwise devoid of vegetative cover.

The value of wetlands for the oyster and clam industry can easily be expressed in terms of dollars. Ranking second to menhaden as the most commercially important species, the 1974 clam harvest in Virginia was worth over eight million dollars. Virginia's oyster industry's catch for the same year was valued at 4.8 million dollars. The combined value of the shellfish landings represent a thirteen million dollar fishing industry (U. S. Department of Commerce, 1977).

While many other species of shellfish such as mussels, barnacles, and limpets are not themselves commercially important, they do convert planktonic algae into proteinaceous material which serves as a food source for various birds and fish (Metzgar, et al., 1973).

Striped bass constitute an important sports fishery, dependent on wetlands for valuable nursery grounds. After spawning in brackish tidal waters, the newly hatched fry are carried by tidal currents to shoal areas and wetlands which provide both food and shelter. The wetlands synthesize the nutrients which produce algae and other plant materials required by the microscopic animals fed upon by striped bass fry. In their early developmental stages, the striped bass move into estuarine nursery grounds to feed on various species of invertebrates and smaller fishes. As adults, they utilize many types of fish (menhaden, anchovies, spot, white perch), small blue crabs, and numerous invertebrates as their sources of food (Metzgar, *et al.*, 1973).

Sports fishing is important to millions of Americans not only as a form of relaxing recreation, but also as a rapidly growing industry. In 1970, 29 million freshwater fishermen spent 3.7 billion dollars on fish equipment, bait, guides, food, lodging, transportation, licenses, and other fees. In the same year, 5 million Atlantic Coast salt water fishermen spent 636 million dollars (U. S. Bureau of Sport Fish. & Wildlife, 1970). This represents 53% of the total number of saltwater fishermen in the U. S., who spent 1.2 billion dollars in 1970. From these figures alone it is easy to understand why recreation ranks fourth as America's largest and fastest growing industry (Ducsik, 1974).

F. Waterfowl, Wildlife, and Recreation

In addition to fishing, hunting ranks high as one of America's favorite forms of recreation. Americans engaged in hunting number in the millions; in 1970 2.9 million waterfowl hunters spent 244 million dollars in pursuit of the sport. Waterfowl in the Atlantic Flyway[9] were hunted by 586,000 people who spent more ($85 million in 1970) than any of the other waterfowl hunters of the Mississippi, Central or Pacific Flyways (U. S. Bureau of Fish. and Wildlife, 1970).

Wetlands along the Chesapeake Bay provide protective wintering and resting sites for several species of migrating waterfowl in the Atlantic Flyway. The Bay's wintering population of waterfowl has been estimated to be more than one million in recent years (Metzgar, et al., 1973). More than half the North American swan population winters in shoal coastal waters of Chesapeake Bay, Back Bay, Currituck Sound, and portions of Albermarle and Pamlico Sounds (Lynch, 1968). Birds like the canvasback duck, which winters in the coastal and inland waters of the Chesapeake Bay, and greater snow goose, which winters entirely in the marshes of the South Atlantic Coast, are dependent on wetland habitats for species welfare (Lynch, 1968 and Metzgar, et al., 1973). While swans are only present in the marsh for shelter during stormy weather, they do depend on the marsh for food (Lynch, 1968).

Aquatic vegetation makes up almost half the diet of the majority of migratory waterfowl (Metzgar, et al., 1973 and U. S. Department of

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[9]Atlantic Flyway is one of four regional divisions of the United States and is used to describe the migration pathways of waterfowl as they fly up and down the Atlantic Coast during different migration periods of the year.

Agriculture, 1939). Ducks, geese and swans commonly feed on the seeds, tubers, root stocks and foliage of water plants (Metzgar, et al., 1973). Other common wetland food sources include snails, bivalves, crustaceans, insects and fish (Metzgar, et al., 1973 and U.S. Department of Agriculture, 1939).

Commmonly found in both fresh and brackish marshes, pondweed is the most frequently eaten species of plant followed by wildcelery (freshwater) and widgeongrass (U.S. Dept. of Agriculture, 1939). Other plant species found in both communities include threesquare sedges and cattails. In Tidewater the sedges probably support more muskrats than any other plant community, and cattails provide nesting sites for long billed marsh wrens, redwings and yellow-necked blackbirds, and forage for the rootstock consuming goose and muskrat (Silberhorn and Warriner, 1976 and Wass, and Wright, 1969).

As noted earlier freshwater marshes are characterized by a high diversity of plants as well as a relative abundance of available food for waterfowl (Wass and Wright, 1969). Plant species commonly found in freshwater tidal marshes provide food for muskrats, blackbirds, ducks and other wildlife. Examples include pickerelweed, arrow arum, arrowhead, yellow pond lily, water duck, smartweed and rushes, while wild rice, sweet flag and rice cutgrass are found in both tidal and nontidal freshwater marshes as well as in swamps.

These freshwater marsh plants also provide material for wildlife lodge construction, in addition to providing vital nesting and breeding areas. In 1942, Beecher showed that the number of bird nests in marshes was positively correlated with the number of plant communities present. Beecher's studies also indicated that the presence of several plant zones rather than homogenous stands resulted in greater benefits to wildlife. A 1974 study by Patterson indicated that wetland heterogeneity was important to waterfowl productivity and that it is the structure rather than the taxonomic composition of emergent marsh plants that is of greatest importance to nesting birds (Weller, 1978).

Freshwater swamps also constitute a unique and valuable natural resource for a variety of game animals, birds, waterfowl and fish. Wildlife commonly found in swamps include bears, squirrels, raccoons, deer, mink, wild turkey, wood, black and mallard ducks, chain and redfin pickerel, yellow perch and bass. Swamps not only serve as wintering sites for migratory waterfowl, but also as valuable breeding areas for wood ducks during the spring and summer seasons (According to Burdick (1971) wood ducks constitute up to 30 percent of all ducks bagged in eastern North Carolina).

Disruption of natural habitats threatens the well-being of many species common to the swamp ecosystem. Man-made changes in the stream channels of swamps have been correlated with marked reductions in the number of game-size fish and species diversity (or measure of the number of different species present), making swamps much less attractive for fishermen (Tarpleg, et al., 1971). In addition, the new channel systems rarely have the naturally low, sloping banks that serve as breeding areas for shad, herring and related commercial species that move into the swamps from estuaries or the ocean to breed (Rulison, et al., 1972).

The Great Dismal Swamp in Virginia covers approximately half a million acres of wilderness and serves to illustrate the value of swamps to Virginia's wildlife. The Dismal Swamp has a rich bird population, supporting 80 species of breeding birds. The winter blackbird roost is the largest in the country and is estimated at 30 million birds, made up of red-wing blackbirds, common grackles, brown-headed cowbirds, rusty blackbirds, and starlings (Meanley, 1972). In addition to its assortment of birds, many species of mammals, reptiles and amphibians are also common to the Dismal Swamp. of these, the black bear, bobcat, white-tailed deer, river otter and wildturkey help make the Swamp a unique and valuable wilderness area.

Vegetated wetlands provide a colorful and natural setting in which the 4.5 million bird and wildlife photographers of America can capture the true beauty of the animals which depend on these areas (U.S. Bureau of Sport Fish. & Wildlife, 1970). Freshwater marshes appear to be the most aesthetically pleasing areas, providing freshwater sports fishing, colorful floral displays and relatively few biting insects (Wass and Wright, 1969).

Whether tidal or nontidal, vegetated wetlands have significant protective, commercial, recreational, and esthetic values.

NONVEGETATED INTERTIDAL AREAS

I. INTRODUCTION

Nonvegetated intertidal areas contain a wealth of both tangible and intangible products desired by society today. One of their most obvious values, for man's developmental activities, is exemplified by the number of shoreline permits granted by the Army Corp of Engineers each year.[10] Other equally important values include the roles these habitats have in maintaining ecosystem food chains, prevention of shoreline erosion, harboring shellfish resources and providing public recreation. A better understanding of the resources available in Virginia's nonvegetated wetlands and their importance is the aim of this section.

Wetlands, as defined by the Virginia Wetlands Act of 1972, encompass only that portion of the vegetated intertidal zone which meets specific vegetative and elevational criteria. A scientific definition, however, is much broader:

> "land where the water table is at, near or above the land surface long enough to promote the formation of hydric soils or to support the growth of hydrophytes. In certain types of wetlands, vegetation is lacking and soils are poorly developed or absent as a result of frequent or drastic fluctuations of surface

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[10]From January 1973 to April 1976 permits were granted for 35,364 ft. of piers, 58,468 ft. of bulkheading, 7,928,875 cubic yards of dredge or material, 1,019,858 cubic yards of deposit or fill, 25,050 ft. of jetty construction and 1,978,607 cubic yards of spoil disposal in intertidal areas.

> water levels, wave action, water flow, turbidity or high concentrations of salts or other substances in the water or substrate. Such wetlands can be recognized by the presence of surface water or saturated substrate at sometime during each year and their locations within, or adjacent to, vegetated wetlands or deep water habitats." (Cowardin, 1977).

Under this definition, nonvegetated intertidal areas are included as wetlands. Therefore, sand and mud flats, and bars and beaches, as well as the more traditional vegetated wetlands, are included in this definition.

II. NONVEGETATED WETLANDS TYPES

A. Intertidal Flats

Sand and mud flats are generally defined as areas of unconsolidated sediments that are flat, irregularly shaped and usually continuous with the shoreline. These intertidal areas are divided into the categories listed below according to sedimentary composition (Cowardin, 1977):

1. Cobble-Gravel: predominantly cobble and gravel with shell fragments and finer sediments intermixed.
2. Sand: predominant component is sand; other particles may be mixed in.
3. Mud: predominantly silts and clays, usually high in organic content, tend to be anaerobic below the surface.
4. Organic: exposed soils of formerly vegetated wetlands.

These intertidal flats are created and controlled by the combined effects of currents, tides, wave action and available sediment type (Postma, 1967, Groen, 1967, Bartburger, 1976, Reineck, 1967, and Anderson, 1972). The sediment sources in these areas are extremely important in the maintenance of the intertidal flat. The most obvious sources of sediment are shoreline erosion and the watersheds which empty into the estuarine system. These reservoirs, known to contribute significant amounts of sediment to the estuarine system, are not the sole sources however. Two other processes, eolian transport and overwash,[11] have been shown to be important sediment

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[11]Eolian transport refers to the movement of sand by wind and the term "overwash" is applied to sand carried over beach dunes by waves or storm surges.

sources in several systems. According to Bartburger (1976), sand fencing for dune stabilization (which might reduce eolian transport and overwash) can be detrimental to the total ecology of a barrier island system. Through investigations of available sediment sources and historical erosion and run-off data, he found approximately one half of the sand present in the system was unaccounted for if one considered only river-borne sediments and shoreline erosion. Further investigation demonstrated that eolian transport and overwash were contributing the missing portion of the sediment load to the island interior, marsh, and tidal flat systems.[12]

In all estuarine systems, the hydrographic and meteorological forces mentioned above cannot independently maintain a tidal flat area if sedimentation rates are low. Biologically important forces, such as dense populations of molluscs, filter the finer sediments and

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[12]An example of disrupting these processes to the detriment of an area can be found at Cape Hatteras, North Carolina. According to Dolan (1972, 1973) and Godfrey and Godfrey (1973) massive dune ridges were constructed which concentrated the wave energy on the beach face and artificially created dune line creating severe beach and dune erosion. In addition, sediment nourishment to the interior of the island, lagoonal shores and marshes was small or totally lacking. Instead of the sands being overwashed onto the island to keep the land abreast of sea level rise, the sands are now being eroded and carried out to deep water. According to Dolan (1972, 1973) the cost of maintenance of these barrier island systems may exceed the economic and psychological value attached to their existence. Barrier islands in their natural states are not being destroyed by nature but are responding to the natural sea level rise by retreating landward. Dolan (1972, 1973) believes states should carefully consider their plans for future development (or lack of development) in the new shoreline areas now in their possession.

return them to the surface as pseudofeces and fecal pellets[13] which are more difficult to suspend (Postma, 1967 and Waneless, 1975).[14] In addition, resuspension of these sediments may be further decreased by the presence of mucilaginous films[15] from diatom communities and algal mats (Waneless, 1975).

B. Beach and Bar Systems

There are several definitions for beach and bar systems. According to Bascom (1951), "a beach is a deposit of material which is in transit either along shore or on and off shore." It is characterized by the following three elements:

1. Quantity of rock material
2. Shoreline area in which material moves
3. Energy supply which moves it

Cowardin (1977) defines a beach as "an unconsolidated sloping land form composed of sand, gravel, or cobbles which is generated by wave and current action." The beach is continuous with the shore and extends landward to a distinct break in land form or substrate type

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[13]Fecal pellets are bodily wastes excreted after ingested material has been subjected to digestive processes while pseudofeces are ingested materials that pass through an organism's body without being altered by the digestive system.

[14]Postma (1967), summarizing Verwey (1952), stated that within a few days to a few weeks a filter feeding assemblage of organisms could filter the complete water mass located over a tidal flat.

[15]Mucilaginous films are adhesive, slimy masses of a gelatinous substances, similar to plant gums and usually containing proteins and sugars, which are secreted by diatoms and other plant-like organisms.

(i.e. foredunes, cliff bank, or zones of vegetation). Bars are described as elongate ridges, banks, or mounds, bordered on at least two sides by water. Both of these areas may be irregularly flooded or exposed to cyclic tidal inundation.

In general, the slope of the beaches, the wave character and the average particle size are related, i.e. the greater the slope, the larger the particle size (Hedgpeth, 1957 and Bascom, 1951). The majority of beach material movement consists of an exchange between offshore (underwater) bars (ridges) and the berm.[16] These offshore bars may be considered products of erosion appearing when violent wave action cuts back the berm and deposits the beach material in ridges offshore (Bascom, 1951). These bars modify waves approaching the shore. The outer slope of the bar is relatively steep causing the larger waves to break and reduce their wave energy (Bascom, 1972). This decreased wave energy has less erosive ability as it approaches the beach face. Both areas, bar and beach, have high surface permeability, variable surface moisture and relatively low organic content (Cowardin, 1977).

The major constraint on the sand conservation and maintenance of these systems is not the seasonal offshore movement, but the longshore movement of sand. Waves which stike the shore at an angle transport millions of tons of sand. If the prevailing waves arrive in this

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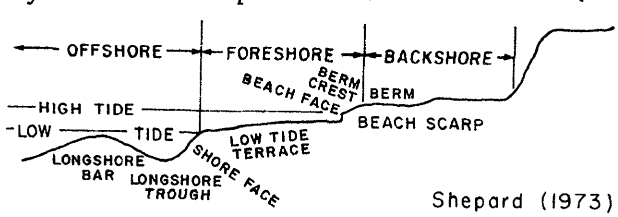
[16]As shown in this classic diagram of beach subdivisions, the berm is the nearly horizontal portion of the beach (commonly used for sunbathing).



Shepard (1973)

manner, littoral currents often flow constantly (Hedgpeth, 1957 Bascom, 1951). Although these currents are not sufficient to move the sand on their own, turbulence in the surf zone suspends the particles enabling a relatively weak current to move a large amount of sand (Bascom, 1951).

III. BIOLOGY OF NONVEGETATED WETLANDS

Biological systems in all nonvegetated intertidal areas are subjected to rigorous biological, chemical and physical stresses. These stresses involve principally: 1) duration of exposure or inundation, 2) magnitude of wave or tidal action, 3) nature of substratum, 4) topography of shore, 5) physico-chemical parameters, e.g. dissolved oxygen, temperature and salinity, and 6) inter or intra-specific competition (Grey, 1974 and Orth, 1978). The location and number of individual species varies from habitat to habitat with 80% of the species present being found in the top 15 cm of the sediment.

A. Macrofauna[17]

Since it is the interdependence of flora and fauna that maintain the energetic economy of an area, an understanding of the feeding types prevalent in an area is necessary to understand the ecology of a given intertidal zone. Intertidal habitats are utilized by fauna of five main feeding types (Grey, 1974):

1. Deposit feeders — feed on sediment deposits and associated fauna and flora, e.g. - polycheate worms

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[17]Macrofauna are organisms like worms and molluscs, that are usually large enough to be seen with the naked eye. Microfauna in contrast, are animals too small to be seen without magnification. This term is usually applied to soil dwelling organisms. The term meoifauna commonly refers to minute animals adapted for living in the spaces between sand grains (Barnes, 1974).

2.	Suspension feeders	feed on particles filtered from the water column, e.g. - barnacles, oysters
3.	Scavengers	feed on carrion present in habitat, e.g. - blue crab
4.	Carnivores	feed on living fauna - predator, e.g. - oyster drill
5.	Omnivores	feed on living flora, fauna - predator, e.g. - periwinkles,

Although intertidal areas are under severe physiological and biological stresses, the inhabitants have adapted to these conditions. Characteristically, there are a large number of small organisms present which are more important to the overall economy of the intertidal areas than the larger, more commercially important species. One gram of substrate may contain as many as 500,000 bacteria, thousands of diatoms, algae, nematodes, copepods, ostracods, amphipods, etc. The predominant macrofauna in the intertidal zone are the polycheates, molluscs and crustaceans. Many of these organisms can retreat into the lower levels of the sediment where the environment is more protected. They therefore experience a less rigorous physical environment. The water content in this region is higher and the temperature is more stable. Mud flats tend to drain more slowly than those composed of sand and are therefore exposed to environmental extremes for a shorter period of time during a tidal cycle (Grey, 1974).

The organisms present in depositional, low energy environments are predominantly deposit feeders which constantly rework the sediments. Reworking of bottom sediments is a product of the intense activities of deposit feeders. These organisms cause extensive changes in their environment through the creation of a pelletized surface and a decrease in surface sediment compaction (with a resultant increase in sediment water content). The production of extremely unstable bottoms is limited mainly to the deep subtidal areas. Intertidal and shallow subtidal areas tend to be stabilized by populations of benthic diatoms, grasses, and algal mats (Rhoads and Young, 1970). Bioturbation and reworking of sediments is a normal estuarine process. It aids in reducing anaerobic[18] conditions, facilitates the entry of aerobic bacteria and oxygen into the sediments, accelerates decomposition and returns nutrients like phosphates, carbon dioxide, and ammonia to the sediment water interface to be utilized again (Grey, 1974). Where these organisms are abundant, they may rework the sediments and thereby cycle nutrients several times before the nutrients are isolated from further biological activity by long term sedimentation[19] (Gordon, 1966).

The dominance of specific organisms found in intertidal areas varies with the environment they inhabit. In tidal flats,

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[18]Sedimentary organisms may function in an aerobic (oxygen containing) or anaerobic (oxygen deficient) environment. Dependence on either of these environmental conditions may be partial (facultative) or complete (obligate). Hence an obligate anaerobe can only exist in the absence of oxygen.

[19]Sedimentation in an estuarine system is a continuous process of building up the intertidal area thereby keeping pace with sea level rise. Detrital material (potential nutrients) is slowly buried unless retrieved and returned to the surface through bioturbation and sediment reworking.

polycheates, crustaceans, and molluscs usually predominate. Various studies indicate that particle size was the determining factor in the development of the faunal distribution zones (Orth, 1978 and Howard and Dorjës, 1972).

In contrast, the more exposed beach and bar habitats are composed of strikingly less diverse fauna predominated by rapidly burrowing filter feeding molluscs and crustaceans, scavenging crustaceans, and a few large burrowing polycheates. Individual species are highly specialized for the rigorous environment and populations are often very dense. Zones of distribution are nearly as pronounced as in the more stable tidal flats. It is also a transition habitat where evolutionary migrations of species from water to land have occurred. One of the better known examples of landward migrations is Ocypode, or the ghost crab, commonly found along our Virginia beaches (Hedgpeth, 1957).

The influence macrofauna have on the intertidal systems depends on the energy requirements and amount of organic matter utilized by the macrofauna, which varies with each individual species. George (1964) and Hibbert (1977) found that only a small portion of the nutrients available were actually used for biomass products like flesh and gamete production. Most of the nutrients were returned to the system as fecal pellets or pseudofeces to continue cycling in the food chain.

B. Meiofauna, Bacteria and Fungi

Intertidal habitats support a varied population of meiofauna. In the past these organisms have been considered only a minor link in the food chain. More recent investigations, however, demonstrate their true importance as primary consumers and potential high energy food sources (Platt, 1977 and Sikora et al., 1977). Nematodes are usually the dominant organisms in a meiofauna community. They may represent from 67% to 97% of a community's inhabitants (Sikora, et al., 1977). As a major component of the meiofaunal community, nematodes may be an important high energy food source for higher trophic levels.[20]

Bacteria and fungi, some of the smallest components of the intertidal community, exert influence over both the sediments and overlying waters. The large numbers, rapid reproduction, and intense biochemical activity of these organisms affect the physical, chemical, and biological properties of the area they inhabit. Intertidal habitats usually exhibit both anaerobic and aerobic conditions with the extent of each zone determined by oxygen penetration into the sediments. Tidal flats in particular, are regions of relatively stable sediments causing strong reducing (low oxygen) layers to form

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[20]Ecologists use the phrase "trophic levels" to refer to the successive levels of nourishment in a food chain. A simple food chain, which designates the sequence of energy movement through organisms, would proceed from producers (plants) to primary consumers (herbivores, like rabbits) to succeeding levels of consumers (including carnivores, like foxes) and always ending with decomposers (usually bacteria and fungi) (Keeton, 1967).

below the surface. In these anaerobic areas facultative anaerobes (bacteria and fungi) decompose materials at a lower energy level and slower rate than aerobic bacteria. Anaerobic decomposition, though slow, is essential to recycling vital nutrients, such as carbon, nitrogen and phosphorus, in tidal flats. Microbial communities are responsible for the conversion of nutritive materials into forms which may be utilized by many species in higher trophic levels (Orth, 1978).

These biochemical effects created by bacteria and fungi may affect the distribution of other organisms. The dissolved oxygen content of overlying waters may be depleted by the respiration of large bacterial populations in areas of high organic content. By establishing aerobic conditions, and restricting oxygen availability to the uppermost layers of the sediment, bacteria and fungi may indirectly influence the distribution of infauna (Orth, 1978). In addition, the hydrogen ion concentration, may be slightly higher (therefore the pH lower) in areas with high bacterial activity.[21]

C. Flora

Although classified as nonvegetated, intertidal areas contain various nonvascular plants capable of significant productivity. The various types of plants found in intertidal areas are phytoplankton,

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[21]Many organisms are extremely sensitive to changes in the acidity or alkalinity (pH) of the surrounding environment. Changes, however slight, in the pH of overlying waters can be detrimental to organisms whose vital metabolic processes can only occur within a narrow range of hydrogen ion concentration.

benthic macroalgae and benthic microalgae. With the exception of the macro-algal plants, major components of these populations are pennate diatoms and dinoflagellates (Grey, 1974 and Orth, 1978). Most living benthic algae are found in the top few centimeters of sediment although only those algae in the top several millimeters are photosynthetically active (Orth, 1978).

The wider range of physical environments makes the productivity of intertidal areas more variable than marshes. In some areas gross primary productivity of a tidal flat adjacent to a saltmarsh cordgrass (Spartina alterniflora) marsh was equal to that of the marsh algal community (Orth, 1978). In 1977 Cadée and Hageman, in a study of organic carbon sources in a tidal flat, found that primary productivity was related to tidal levels. Intertidal areas submerged for the longest period of time were less productive than the upper elevations of the flat.

The benthic flora present in the intertidal regions are of substantial importance to the primary productivity of the area. Rapid algal turnover provides rapid recycling of nutrients. Primary consumers benefit from its availability when other food is scarce. Benthic algae also contribute to the detrital pool consumed by blue crabs, oysters, copepods, fiddler crabs, mussels, mollusc larvae, snails, mysid shrimp, and fish (Orth, 1978).

Tidal resuspension of benthic microflora, in areas of expansive tidal flats, is important to the total primary productivity in the water column. During periods of low phytoplankton biomass (late spring and summer), productivity in the zone of resuspended sediment contributes a major percentage of primary productivity in the water column. Seasonal changes in food resources available to zooplankton may be the result of tidal resuspension (Roman, and Tenore 1977). Buried flora represents a standing stock of primary producers, activated when an area is disturbed by storms. Thus in areas with extensive intertidal zones, the benthic microflora can be as important as the phytoplankton in primary productivity (Cadée and Hageman 1974).

In addition to contributing to the primary production of nutritive elements, benthic diatom communities are important in the stabilization of some marine sediments. In a study of seven diatom species, Holland, et al., (1974) found that four, which secreted mucilaginous films, significantly retarded resuspension of fine sediments. By so doing these diatoms appear to retard the laminar flow of sand. This effect can be enhanced by the vertical migration of benthic flora in the upper sediment layer in response to environmental stress. Sediment stabilization augments sunlight penetration, creating a selective advantage for autotrophic plants.[22]

Species of macroalgae, the more visible forms of the benthic algae, occur in some intertidal regions. Woodin (1977) reported two polycheates which attached a species of drifting macroalgae to their

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[22]Organisms can be divided into two groups on the basis of their methods of nutrition. Fully autotrophic ones (the majority of which are photosynthetic plants) manufacture the organic nutrients they need from simple, inorganic elements. Heterotrophs (most animals and plants that lack chlorophyll) on the other hand, must obtain prefabricated organic nutrients from the environment (Keeton, 1967).

tubes, utilizing it as food. This association, was found to reduce dessication, salinity and temperature (2°C cooler) on the polycheate and enabled the macroalgae to expand its habitat and colonize new areas during non reproductive periods. Other species of macroalgae may be found attached to other available firm substrates, like oyster shells or pilings, as well.

IV. VALUES OF INTERTIDAL AREAS

Delineating the nature and relative importance of resource values for specific properties of a habitat is extremely difficult. Natural biological systems are not easily described by universal or rigid value guidelines. Therefore, value assessments must be flexible enough to apply to even the most complex habitats.

The following section will discuss several important values associated with the nonvegetated wetlands described previously.

A. Primary Productivity

As mentioned above, benthic algae in intertidal flats are important to the primary productivity of the surrounding ecosystem. Their importance and value vary form one intertidal area to another and are affected by the following variables:

Variable	Effect
The proximity of the intertidal area to a highly productive marsh (*e.g.* *Spartina alterniflora*)	Lessens the relative importance of primary productivity of the intertidal zone
The total expanse of the non-vegetated intertidal habitat within a particular area	The more nonvegetated habitat per unit area, the more important its primary productivity
The time of the year	Benthic algae productivity is more important during periods of low phytoplankton activity

The physical characteristics of the area	The more dynamic the physical regime, the less benthic algae present, and therefore lower primary productivity

To determine the relative productivity for any given intertidal area, these variables should be evaluated individually. Two examples of this concept are cited below:

1. An intertidal beach is not as valuable a site of primary productivity as a tidal flat located in a fairly quiescent environment due to the more dynamic nature of the beach environment which would preclude the colonization of any substantial numbers of benthic algae.

2. Tidal flats of similar sediment composition, size, and physical regimes may vary in relative value in relation to their surrounding ecosystem. If tidal flat #1 is located adjacent to a large and highly productive marsh while tidal flat #2 is adjacent to a marsh low in productivity, tidal falt #2 will be of a higher value to its particular area in terms of primary productivity.

B. Nutrient Cycling

Nutrient cycling is a continuous transfer process between water, sediment and biota of the environment. Essential elements like sulfur, phosphorus, nitrogen, and carbon are released by decomposing organisms during the breakdown of complex organic substances from plants and animals. The importance of decomposers cannot be emphasized enough, for without them, nutrient cycling would be seriously disrupted. A state of dynamic equilibrium exists between nutrient concentrations present in the water and concentrations present in the sediment. Each element is represented by a complete spectrum of compounds from fully oxidized, in upper, oxygen-rich sediment layers, to fully reduced in lower oxygen-deficient sediments.

In many tidal flats decompositional demands for oxygen exceed the supply, creating anaerobic environments or reducing zones. The sediment depth at which these zones are found varies with the porosity of the sediments and vertical mixing of the water. The boundary of this environment occurs where oxidizing processes are replaced by reducing conditions. The properties of this boundary, called the redox-potential discontinuity or RPD layer, is known to enhance the cycling of nutrients (Wood, 1965). A vertical sediment section therefore, would show a visually observable RPD layer separating upper aerobic layers from lower anaerobic layers.

A continual interchange between chemical states occurs at the RPD layer, as oxidized compounds and elements fuel reducing reactions and vice versa. Thus organisms in both aerobic and anerobic sediment layers are supplied with the specific nutrient forms they require. Few of the nutrients important to growth and reproduction are lost; rather many are recycled. Loss of nutrients to the system has been prevented by the evolution of microorganisms capable of utilizing nutrients while reintroducing them back into the system for use by larger forms.

For some elements like phosphorus, the sediment acts as both source and sink (Orth, 1978). The reservoir-like nature of these intertidal areas maintains high levels of productivity even when nutrient availability from external sources appears to be critically low.

In the same publication, Orth described several factors which determine the effectiveness of all these biogeochemical processes:

1. Exchange capacity of the sediments
2. Exchange rate of sediment-water interface
3. Amount of local biological activity
4. Relative tidal cycle
5. Flushing rate of the body of water

In summary, nutrient cycling in nonvegetated intertidal areas is important in maintaining a dynamic balance in food chain. In addition, tidal flats, in conjunction with marshes, may be able to assimilate high nutrient loads through absorption in the sediments and biological activity. This ability to treat high nutrient loads could be of monetary importance to man as a less expensive alternative for treating his waste materials (Gosselink, et al., 1973).

C. Fisheries

Fish and Crustaceans - Intertidal areas are recognized as important feeding grounds for many commercially important fish and crustaceans (Grey, 1974). Zijlstra (1972) illustrated the importance of the rich intertidal area of the Wadden Sea in Netherlands as a nursery and feeding ground for demersal fish.[23] Striped bass and other small fish utilize intertidal flats as a nursery, feeding on polycheates, molluscs, and crustaceans (Grey, 1974 and Orth, 1978).

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[23]He found 64% of the sole and 80% of the plaice first year stock to occur in the Wadden Sea which is 50% tidal flats. Beukema (1976) supported the idea of the Wadden Sea tidal flats as feeding grounds. His study showed that the predation by the fish was centered mainly on the zoobenthos.

Commercially important species which utilize the intertidal flat at some point during their life history include striped bass, croaker, spot, sea trout, and flounder. The juvenile blue crab (*Callinectis sapidus*), another commercially important species, utilizes the tidal flat when young because of food availability and protection from predators. Penaid shrimp, which spawn offshore, also migrate to the flats for food and protection during early growth stages (Odum, 1971).

The intertidal beach zone is also an important habitat for fish of several species. Lipton and Travelstead (unpublished) listed the following species known to utilize the James River intertidal area as a nursery ground:

alewife (*Alosa pseudoharengus*)
blueback herring (*A. aestivalis*)
shad (*A. sapidissima*)
striped bass (*Morone saxatilis*)
croaker (*Micropogon undulatus*)
menhaden (*Brevoortia tyrannus*)
hog choker (*Trinectes maculatus*)

Peak abundances were found in August and September, when juveniles of several species utilized the nearshore area for feeding.

Large scale destruction of intertidal flats and beach areas would of course have an immediate effect upon the benthic populations present. Secondarily, there could be large-scale impacts upon the estuarine dependent fisheries which utilize these areas for nursery and feeding grounds.

Mollusc - The oyster (*Crassostrea virginica*) and the hard clam (*Mercenaria mercenaria*) are two commercially important species which inhabit the intertidal zone in Virginia. In most low saline environments, the oysters may be found in tidal and subtidal habitats. It is important to note that in high saline environments Crassostrea virginica is found only in intertidal areas due to high predation and disease pressures. Mercenaria sp. is characterized by an extensive geographic range and inhabits the high salinity bays, inlets and sounds. This species is important to the recreational clammer as well as supporting the largest commercial clam industry in the U.S. It has accounted for approximately 17% of the volume and 53% of the total ex-vessel value in the past (Ritchie, 1977). Unfortunately, productive bottoms for both these species are being irreversibly damaged through dredging and fill operations and pollution in the coastal states. It has been projected by Chestnut (1974) that continued industrial and population growth will damage additional coastal areas.

D. Recreation and Aesthetics

Recreation in the nonvegetated intertidal zone is an industry of increasing economic importance for coastal states. Ducsik (1974) stated that the Bureau of Outdoor Recreation projected an annual increase of 10% to 12% in public use of coastal recreational areas. In 1968, it was estimated that some 112 million people spent $14 billion pursuing recreational activities in the coastal zone (Ketchum, 1972).[24]

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[24]The greatest demands for facilities are placed on these areas by the daily and weekend user. The populations exerting the greatest pressures on coastal recreation are those from large metropolitan areas located within a 125 mile radius (Ducsik, 1974).

The projected increase of coastal zone use presents problems which will increase in magnitude in the years to come. One serious problem is that most recreational facilities are fixed and already filled to capacity. Coastal areas not only attract large numbers of recreational visitors but must increasingly accomodate large residential populations (Ducsik, 1974).

The suitability of coastal areas for recreational activities depends on several factors, summarized below from Ketchum (1972) and Ducsik (1974):

Climate - warm temperate regions attract large populations

Proximity - plays an important role in the over burdening of coastal areas near large metropolitan areas

Competition - accommodating multiple uses, e.g. industry, recreation, and private ownership

Shoreline Erosion - 25% of total shoreline (U.S.) exposed to wave and current action has significant erosion problems greatly exacerbated by man

Pollution - poor water quality from sewage, oil spills, pesticides, and industrial effluents - affects every major coastal city

Living Resources - sports such as hunting, fishing, and wildlife observation depend on natural fauna and flora

Within nonvegetated wetlands, beaches support the widest variety of recreational uses. As a result, beaches are subject to the most use by the largest number of people at the lowest cost. Tidal flats, on the other hand, were considered to be in less overall demand recreationally than the beaches (Ducsik, 1974). Any member of the

Audubon Society, however, would vouch for the importance of tidal flats as birdwatching havens.[25]

Recreational use by the beachgoer ranks low on the scale of serious impacts to the environment. This should not imply that there are no problems involved with recreational usage. Dune vegetation adjacent to beaches may be destroyed and adverse effects may develop with the secondary invasion of irresponsible development, pollution, dredging or filling of areas for residential and commercial use (Ducsik, 1974).

Although difficult to quantify, recreational and aesthetic values of "natural" areas are of increasing importance to our society. Pressures for public retreats, like coastal beaches, are growing with little increase in the amount of land available. Careful planning and management of intertidal areas should be a part of Virginia's conservation (i.e. reasonable use) efforts.

E. Shoreline Protection and Stabilization

Intertidal flats, bars and beaches are all valuable to some

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[25]The availability of these shoreline areas for public use is already restricted for the teaming throngs of recreationalists. Within the 28 contiguous coastal states there are 60,000 miles of shoreline. Of this 60,000 miles, only 21,900 miles is suitable for recreation with 4,350 as beach and 6,214 miles as other wetlands. Within the Atlantic Coast alone, only 3% of the recreational shoreline is public. In the more densely settled North Atlantic and Middle Atlantic regions there are 5,912 miles of recreational shoreline of which 5,654 miles are under private control (Ducsik, 1974). Obviously, there is a lack of recreational facilities for use by the public.

degree in shoreline protection and stabilization. Both sand and mud flats cause waves to spread out, decreasing their velocity and lowering their energy (erosive potential) before striking the shoreline. These areas further stabilize the sediment from resuspension by supporting mucilaginous producing algae which bind the sediments.

The primary value of a sand bar is its ability to shoal and break offshore waves (thereby decreasing their wave energy as they approach the shore) during periods of stormy weather. Occasionally these bars are removed during periods of severe storms, but will reform during periods of calmer weather. Intertidal beaches are also dynamic shoreline defense structures. Beaches are created as a product of energy dissipation from oncoming waves. Some natural erosion does occur through processes like long-shore transport, with the concomitant accretion of this material on other shores. Once man begins tampering with these dynamic systems (through groins and jetties or beach stabilization programs to prevent overwash) shoreline erosion can become a problem of enormous consequences with domino-like effects that are often difficult to terminate or reverse.

F. Feeding Grounds for Birds

Several studies have shown the intertidal zone to be of paramount importance as feeding grounds for certain bird species (Goss-Custard, *et al*., 1977I, Goss-Custard *et. al*., 1977II Goss-Custard, 1977, Bengston & Bo Svensoon, 1968 and Reading and McGrorty, 1978). This dependence on the intertidal zone varies from a facultative to obligate response. Exposed mud flats support a diverse population of feeding birds because of their large macrobenthic populations. The large collective biomass and near-surface location of these animals, enable the birds to forage with little expenditure of time and energy.

Two major species of obligate shorebirds are the oyster catcher (Haematopus ostralagus) and the ringed plover (Charadrius hiaticula) (Eltringham, 1971). Oyster catchers feed mainly upon small cockles and a few types of polycheate worms. When its preferred prey is not present, the oyster catcher will shift to other organisms. Their food preference makes oyster catchers characteristic of depositional environments which normally harbor large numbers of shellfish (Heppleston, 1971 and Reading and McCrorty, 1978).

Many species utilize the areas as habitats on a more seasonal basis. The knot, (Calidris sp.), breeds in the tundra region and overwinters in areas such as Morecombe Bay, Lancashire, England. The black bellied plover (Pluvialis squatarota), relies heavily on intertidal mud flats for their main food source during its two seasonal migrations (Orth, 1978). A local study at the Windmill Point dredge spoil island in the James River indicated that the sand beach perimeter and extensive tidal flats and basin of the island attracted a large number of avian migrants. These open areas were more popular than the surrounding woodland community and the island's mud flats supported the largest number of shoreline species, including the killdeer (Choradrius rociferus), western sandpiper (Calidris mavri) and semipalmated sandpipers (Calidris pasillus) (Wass and Wilkins, 1978). For a complete list of shorebirds and waterfowl which may utilize the intertidal region for feeding grounds, refer to Wass, *et al.* (1978).

Whether facultative or obligate, each type of waterfowl depends in varying degrees on the intertidal area. Large scale destruction or alteration of these areas may have severe ecological effects on the birds which utilize them.

G. Effects of Intertidal Areas on Water Quality

Microbial processes which occur in the sediments of intertidal areas determine the reducing conditions which may affect water quality. Specifically, free sulfide concentrations formed in the anaerobic layers may create some water quality problems[26] (Bella, *et al.*, 1972). Free sulfides in the water are considered a major contributor to the chemical oxygen demand (COD), a measure of water quality. If released to the overlying waters in sufficient quantities, sulfides are toxic to fish, crustaceans and a variety of microinvertebrates. The water quality in high energy intertidal areas with sandier sediments, good drainage, and low organic content, are less likely to have water quality problems associated with free sulfides than mud flats (Bella, *et al.*, 1972).

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[26]Hydrogen sulfide is normally present in intertidal areas as part of the pH dependent systems. (H_2S $H^+ + HS^-$ $2H^+ + S^=$). Under aerobic conditions biological and chemical reactions utilize oxygen as an hydrogen ion acceptor. Under anaerobic conditions, when oxygen is unavailable, sulfides take on that role for some elements.

CURRENT WETLANDS MANAGEMENT
IN VIRGINIA

Coastal wetlands and the associated shoreline are dynamic complexes of physical, chemical, biological, and human factors. No two segments of shoreline are exactly alike. Consequently, no two acres or fractions of an acre of wetland have the same characteristics or values. Considering the human factor, every proposal to alter the wetlands has a public and private concern different from every other proposal. Because of the diverse number of possible wetland situations, the task of weighing values lost aginst values gained can only be made on a case by case basis.

Virginia's Wetlands Act cites standards for use and development to prevent the unreasonable alteration of wetlands of 'primary ecological significance' and specifies that development, when necessary, should occur in wetlands of lesser value (Va. Code Ann., 9:62.1-13.3). The wetlands manager in Virginia is faced with the task of reviewing proposed wetland projects and granting or denying permission to alter wetlands in accordance with the policy of the Act. To do this he must have the ability to differentiate between wetlands of primary significance and those of lesser value, as well as the ability to determine the reasonableness and necessity of a proposed project.

The Wetlands Guidelines, developed with advice from the Virginia Institute of Marine Science and promulgated by the Virginia Marine Resources Commission, are intended to provide the information needed to make these decisions in a timely manner. (The applicant must be notified within 90 days. Va. Code Ann., 9:62.1-13.5). The Guidelines identify different wetland types, according to vegetation, occurring in the area protected by the Act. Each type is then ranked in order of its estimated overall ecological value. This classification and ranking system is designed to give the reviewer the ability to rapidly characterize wetlands of greater to lesser signficance. The Guidelines further set forth criteria that can be used to judge the reasonableness and necessity of some of the more common activities involving wetlands.

Determining Ecological Signficance, Reasonableness and Necessity

With the exception of some clearly defined special cases, only the vegetated wetlands of Virginia's tidal rivers, bays and estuaries are subject to the permitting requirements outlined by the current Virginia legislation. There is good reason for protecting these coastal marshes. Because of their close proximity to Virginia's wide expanse of coastal and estuarine waters, the impact of these wetlands can be far reaching, affecting the commerce and recreation of a very large segment of the population of the Commonwealth. In contrast, inland wetlands, such as freshwater swamps and lake marshes, have an impact on a much more limited geographical area, and are thus a resource of lesser apparent concern to the general public. Yet, an ecologist could well argue that these non-tidal wetlands are indeed of "primary ecological significance" to the smaller inland ecosystem. Careful consideration of the ecological functions and values of non-tidal as well as non-vegetated wetlands, as discussed in this paper, supports the extension of Virginia's wetland management authority and responsibility to cover these areas. Such an extension would require recognition and acknowledgement, in the Wetlands Act, that non-tidal and nonvegetated wetlands are also valuable natural resources which, in their natural states, are essential to the ecological systems of which they are a part. It is important to note that such changes in the legislative definition of wetlands should also clarify the status of coastal freshwater marshes associated with the non-tidal portions of Virignia's tidal rivers, bays and estuaries. Some of these coastal wetlands fall within Virginia's current wetlands definition (1.5x the tidal range plus the presence of specified vegetation), but any legislative amendment should clearly include coverage of such areas as with non-tidal vegetated wetlands.

Standards, Policies and Guidelines

In addition to the jurisdictional limitation, there are other deficiencies in the current Virginia Wetlands Act and implementing Guidelines. One of the most significant is the ambiguity surrounding the designation of wetlands as being of "primary" or "lesser ecological significance." According to §62.1-13.3, Standards for Use and Development of Wetlands, wetlands of "Primary ecological signficance shall not be altered so that the ecological systems in the wetlands are unreasonably disturbed." There is no definition either in the Act itself or in the Guidelines, however, of where the demarcation between areas of 'primary ecological significance' and those of 'lesser significance' should be established The Wetlands Guidelines (VMRC, 1974) identify twelve distinct wetland types based on plant community types and then rank them in descending order of overall ecological value. Several of the types have been calculated to have nearly equal values, so the twelve types are arranged into five groups, with Group I wetlands more valuable than Group II, Group II more valuable than Group III, and so on. The Guidelines do designate Group I wetlands as being of greater ecological value than the other four groups but the distinction of decreasing values between those groups is not definitive enough for a clear determination of where primary ecological significance ends. This ambiguity means that the Act as written could, by implication, only protect Group I wetlands. Some clarification is obviously necessary if the policy of restricting development to wetlands of lesser signficance is to be retained. Perhaps a more logical policy would be to allow development, after all alternatives have been considered, in wetland areas that would yield the least adverse impact on natural ecosystems. The Guidelines give the wetland manager the ability to make this kind of a distinction to the degree that vegetation indicates ecological values. The accuracy of a wetlands manager's assessment of ecological significance is limited because he has neither the time nor the technical ability to make field measurements of productivity and nutrient cycling, survey waterfowl or keep a tidal record of each particular site. Several authors do, however, support the use of plant community types in a classification scheme because it provides the most practical and reasonable approximation of vegetated wetland values currently available (McCormick, 1977, and Cowardin, et al., 1977).

There is a similar problem of interpretation in §62.1-13.3 associated with the phrases 'unreasonably disturbed' and 'irreversibly disturbed' (referring to the ecological systems of wetlands). There is no elaboration elsewhere in the Act or in the Guidelines to specify the characteristics of an unreasonably disturbed ecological system or an irreversibly disturbed wetland. Inherent in a clarification of 'unreasonably' or 'irreversibly disturbed' wetlands, should be some consideration of the cumulative impacts of a number of individual projects in a given area. Under the present management scheme, a local wetlands board treats each application, and thus each parcel of wetlands acreage, individually, as if it were an isolated entity. There is no recognition of the potential impact an activity may have on adjacent wetland sites or the overall impact of several individual activities in a given wetland system. Consideration of cumulative impacts should be included in an identification of specific criteria whereby a local wetlands board may judge the potential ecological disturbance of a wetland activity.

To facilitate a judgement of the 'reasonableness' of a proposed activity, some scientists have proposed the development of an economic formula or model which would translate field measurements into a common currency that could be used to compare the natural values of wetlands with the market value of a piece of property. Thus, theoretically, the reasonableness of a proposed wetland activity could be tested through the normal economic and legal procedure of weighing equivalent values lost against values gained.

Gosselink, et al. (1973) attempted to equate the value of an acre of a Spartina marsh in terms of dollars, based on productivity, nutrient cycling, and fishery survey data. They deduced an annual return of $4,150 based on the various beneficial marsh functions. An income-capitalization technique which translates the income potential of a piece of property into a market price value yielded a sale value of $83,000 per acre of marsh. These figures have been used in federal proceedings concerning wetlands, including the 1974 U.S. Council on Environmental Quality's report which read:

> "A study last year...estimating that natural functions of tidal marshes...is worth $85,000/acre/year compared to $1,000-$3,000 per acre if filled for urban use" (CEQ, 1974).

First, there is an error in the above passage as Gosselink's results have been misquoted. The market sale value was calculated as $83,000, but this is not an 'annual return'.

More serious, however, is the fact that the model has since been challenged by both scientists and economists (Shabman, 1977, and Bender, 1975). The scientists specifically argue that Gosselink overestimated the ability of the marsh to act as a tertiary waste treatment facility, while the economists attack his cost accounting and income-capitalization techniques. In general, there is a strong feeling in the scientific community that we are currently too ignorant to assign monetary values to the functions of a natural system (Hershner, 1978). Additionally, an economic baseline is not, and probably should not be the only criteria for making management decisions for the conservation of natural resources. Recognition that the natural functions of wetlands are essential to the ecological systems of which they are a part and that the maintenance of such systems is necessary for the common good (human health and well-being) lays a much broader framework for wetlands management than a questionable economic model.

The final section of the Guidelines (Ch. IV) provides the criteria to be used for evaluating proposals based on the purpose of the various wetland projects. The criteria generally recognize the rights of the riparian owner to improve access from his property to navigable water, and to protect his property from erosion. Piers, bulkheads, and dredged channels are listed as acceptable uses provided that significant marine fisheries, wetlands and wildlife resources are not unreasonably affected to their detriment. Activities which could just as well be conducted on existing fastlands are considered unnecessary. Also excluded are large scale alterations which create new waterfront property in areas which are not naturally contiguous to navigable water.

The Guidelines further describe the best engineering practices currently available for some of the more common wetland projects. For example, the location and design of structures for preventing shoreline erosion is a highly technical subject. A study of one county's shoreline showed nearly 50% of the existing shoreline defense systems to be ineffective or poor in design (VMRC, 1974). Ineffective structures can certainly be considered 'unnecessary'. The Guidelines help the wetland manager to evaluate proposed projects and, in fact, the decision-making process under Virginia's Wetlands Act provides technical assistance to builders rather than prohibiting their activities. A greater percentage of permits have been approved with modifications than denied (Jones, 1976).

When a wetlands project is denied, justification for that denial through the process of weighing values lost against values gained is required. The Guidelines, however, contain only a general statement that necessary uses are permitted, with large scale alterations restricted. For more effective management of our wetland resources, some elaboration on 'necessary' 'reasonable', and 'unreasonable' wetland uses as well as clear criteria for determining the necessity of a proposed activity would be warranted amendments to the provisions of Virginia's Wetlands Act.

SUMMARY

A. Values and Research Needs

Virginia's wetlands possess a number of ecological, economic and social values that suggest a need for special management. The major contribution tidal, vegetated wetlands make to the primary productivity of coastal and estuarine sytems is well-documented. The scientific community also recognizes the significant contribution of intertidal areas without vascular plants to the primary productivity of the surrounding ecosystem. Some recent studies suggest that intertidal flats may be even more important to the productivity of an area than the tidal, vegetated wetlands currently covered by Virginia's 1972 Wetlands Act (Boesch, 1978).

The roles of tidal and non-tidal, vegetated and nonvegetated areas in nutrient cycling and associated water quality control can be significant. A thorough understanding of the complexities of these roles and the potential use of these areas as natural tertiary waste treatment sites is still being developed.

Intertidal flats, beaches and bars compose a natural, dynamic system of shoreline protection and stabilization. Biologically-secreted mucilaginous films bind and stabilize the sediments of sand and mud flats. Tidal vegetated wetlands also contribute significantly to erosion and sediment control by reducing the velocity of currents and floodwaters and trapping sediments in complicated root and stem structures. These sediment traps enhance the productivity of overlying waters (by augmenting sunlight penetration) and reduce sedimentation in valuable navigation channels and on oyster beds.

Intertidal areas and coastal vegetated wetlands are valuable feeding, spawning and nursery grounds for a number of commercially and recreationally important fish. These areas provide a rich source of nutrients and protection from predators. The intertidal zone is inhabited by the oyster (*Crassostrea virginica*) and the hard clam (*Mercenaria mercenaria*), which constitute two extremely important commercial fisheries.

Many species of waterfowl utilize the intertidal zone as feeding grounds. Large macrobenthic populations provide food for a number of bird species, some of which are wholly indigenous and others which are migratory. Vegetated wetlands not only provide food, but also protection and nesting sites for waterfowl and migratory birds. There is some indication that the diverse plant species of non-tidal (freshwater) marshes make them even more valuable to birds than their tidal counterparts. Tidal and non-tidal vegetated wetlands provide an abundance of plant material for animal forage, construction and breeding habitat.

Although difficult to quantify, a number of recreational and aesthetic values are associated with Virginia's wetlands. The pristine nature of many wetlands and the abundance of wildlife attract naturalists, birdwatchers, hunters, fishermen and others. The sandy shoreline provides enjoyment for the swimmer, sunbather, fisherman and boater, as well as inspiration for the poet and artist. One need only visit Virginia Beach on a summer weekend to appreciate the historic yet growing interest in coastal recreation.

It should be emphasized, however, that there are still deficiencies in our understanding of all wetland types in Virginia. The values discussed in this paper suggest that all these areas should be preserved or carefully managed - at least until the scientific state-of-the-art provides the means to accurately assess those values. Such a policy would require the extension of Virginia's wetlands management authority to include non-tidal vegetated areas, (inland swamps and inland freshwater marshes), beaches, bars, and nonvegetated intertidal flats. Concomitantly, the Commonwealth should support wetlands research providing answers for wise and effective management. The findings of this study suggest several of these research needs:

1. Although a classification of vegetated wetlands based on vegetative cover is considered the most practical and definitive method currently avialable (McCormick, 1978), value assessments using a single parameter are by no means comprehensive. The intensive field and laboratory investigations currently necessary to assess a wetland's response to multiple hydrologic and biologic factors on a site-specific basis are prohibitive. Research efforts should focus on the possiblity of refining value assessment techniques. Surely the improved accuracy in assessment would be well worth a reasonable

increase in costs to the Commonwealth.[27] It should be re-emphasized that, although limited, the current Virginia Guidelines, based on values associated with different vegetative regimes are reasonably accurate.

2. Similarly, methodologies for assessing the values of non-tidal wetlands (i.e. inland swamps and freshwater marshes) as well as nonvegetated wetlands should be developed, or at least their feasibility should be investigated. Measurements of values like productivity, nutrient cycling and support of fisheries in non-tidal vegetated wetlands would be similar to the same studies in their tidal counterparts. Analyses of sediment samples from intertidal flats could yield information on productivity, and nutrient cycling, as well as the nature of the biological communities present and the fisheries, birds and wildlife they would support.

3. Attempts should be made to develop a practical method of delineating and classifying intertidal areas similar to the techniques used by local boards to identify tidal, vegetated wetlands. Analysis of sediment sample parameters like sediment type (i.e. on a continuum from mud to sand), depth of the RPD layer and the nature of the biological communities present could provide a relatively simple means of characterizing non-vegetated wetland types.

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[27]A two-year study to explore the possiblity of developing an ecological rating system for coastal wetlands was recently completed in the state of Rhode Island (Oviatt, et al., 1977).

4. For future management reference, a shoreline inventory of intertidal areas should be conducted (perhaps through aerial photography).

5. Although to date, boundary disputes under the current Virginia Wetlands Act have not surfaced, some changes in the definition will be necessary if Virginia's management authority is extended as proposed. The possiblity of a new, more accurate elevational definition, like that suggested by Boon, et al. (1977) should be assessed. In addition, specific recommendations for the elimination or alteration of the current biological definition to include non-tidal and nonvegetated areas must be investigated. Areas with unique boundary problems should be treated separately (e.g. Chincoteague Bay).

6. Appropriate studies should be undertaken to develop a comprehensive understanding of the problems associated with specific uses of Virginia's wetlands (e.g. the specific effects of dredge and fill operations on intertidal flats).

7. Virginia should investigate potential, directed applications for its wetlands. For example, studies could assess the possiblity of using wetlands as shoreline stabilization to protect development, as natural waste treatment or aquaculture sites. To facilitate these studies, Virginia could preserve (in their natural condition) specifically designated wetlands as research sites.

B. Some Management Implications

Review of the existing Virginia wetlands legislation and VMRC Guidelines reveals some deficiencies and ambiguities from a scientific viewpoint. Most important is the prveiously-discussed exclusion of nonvegetated tidal wetlands (i.e. intertidal flats, beaches and bars), as well as nontidal vegetated wetlands (i.e. inland freshwater marshes and swamps). Comprehensive wetlands management in Virginia should include these areas in order to conserve the valuable attributes discussed in this paper.

When considering amendments to the Wetlands Act to cover additional wetlands, some review of the current boundary definition should be undertaken. As discussed earlier, an improved physical definition, like the one proposed by Boon, et al. (1977), would facilitate elimination of the current biological requirements and thus include non-vegetated areas under a single tidal wetland definition. Unique areas, like Chincoteague as well as the Back Bay and North Landing River systems, should continue to be defined separately. In these cases, upper boundaries could be established where non-wetland species of vegetation begin to dominate the area ($\geq$ 51% of the plants present). Similarly a biological definition based on specific vegetation dominance could be used to delineate the boundaries of nontidal vegetated wetlands.

Although no evaluation scheme utilizing only a single parameter, like vegetation, would be considered scientifically comprehensive, the classification system employed in the current VMRC Wetlands Guidelines is well-developed and valid as a simple, practical means of classifying tidal, vegetated wetlands. Should Virginia's management authority not be extended, these Guidelines would remain an effective management tool. The only potential limitations to the effectiveness involve some ambiguities in the Act itself. Under the Standards for Use and Development Section of the 1972 legislation (Va. Code Ann., 9:62.1-13.3), several critical phrases are introduced without definition or clarification. The Act directs that

(1) Wetlands of <u>primary ecological significance</u> shall not be altered so that the ecological systems in the wetlands are <u>unreasonably disturbed</u>; and

(2) Development in Tidewater Virginia, to the maximum extent possible, shall be concentrated in wetlands of <u>lesser ecological significance</u>, in wetlands which have been <u>irreversibly disturbed</u> before July one, nineteen hundred and seventy-two, and in areas of Tidewater Virginia apart from the wetlands.

There is no explanation in the Act or the Guidelines of what distinguishes areas of "primary ecological significance" from those of "lesser ecological significance". When combined with the evaluation scheme used in the Guidelines (<u>i.e.</u> Group I - V wetlands) the Act's mandate could be interpreted to constrain only those development activities within Group I wetlands. It can be easily inferred that the subsidiary groups, II - V, are wetlands of "lesser ecological significance" and therefore sites for development. Such an assumption would be inconsistent with the intent of the Act, current scientific knowledge and the Guidelines themselves which indicate that the distinction of total environmental value between groups is not always large or clear-cut. If this terminology is retained in the Act, there must be some clarification of how a determination of "ecological significance" relates to the management Guidelines developed by the VMRC.

The other ambiguity in this section of the Act involves the definition of wetland ecological systems which are "unreasonably disturbed" or "irreversibly disturbed". There should be some specification of how an "unreasonable" disturbance is measured. For example, if the dependent fisheries are used as a criteria, activities that would preclude feeding and spawning or decrease the optimum sustainable yield below a certain point could constitute an "unreasonable" disturbance. In addition, activities that would remove more than 50% of the wetland vegetation might be considered "unreasonable". Specific criteria which are developed and utilized must be clearly identified and explained either in the Act itself or in the mangement Guidelines.

Similarly, the legislation or Guidelines should clarify the definition of "irreversibly disturbed" wetlands. Whatever criteria are used to identify these areas should be clearly delineated. Such a concept is suggested by Cowardin, <u>et al</u>. (1977):

> "Areas with drained hydric soils that are <u>no longer capable of supporting hydrophytes</u> are not considered wetlands."

Whether the current legislation is retained or new, broader wetlands management authority is extended, it would be appropriate for the VMRC to review the current Guidelines under their mandate to "from time to time promulgate guidelines..." (Va. Code Ann., 9:62.1-13.4).

There are other sections of the current Virginia legislation or its implementation, which could create potential problems, but an in-depth review of these more legal or political issues is not appropriate in this report. For purposes of identifying potential problems, the following concerns are set forth below:

1. §62.1-13.5 (Model Wetlands Zoning Ordinance §3(b)).

   Shellfish cultivation is a permitted wetlands use. Large scale aquaculture would be permitted but could have significant adverse impacts.

2. §62.1-13.5 (Model Wetlands Zoning Ordinance §7).

   Failure of a local wetlands board to act within a specific time on a permit application results in automatic granting of the permit. The VMRC may review and reverse any local board decision. If no local decision occurs the VMRC may be precluded from reviewing and possibly reversing the grant of a permit under such circumstances thereby thwarting the general management scheme of the Wetlands Act.

3. §62.1-13.5 (Model Wetlands Zoning Ordinance §9(2)(b)).

   No specific criteria and time frames are used to decide whether the public and private benefits of an activity outweigh the public and private costs when issuing permits, and

4. §62.1-13.4

   The status of the Wetlands Guidelines is unclear: Are they recommendatory or regulatory in nature? Since they are an essential element of wetlands management, they should clearly have the force of law

Hopefully, these and any other concerns about the legislation in its present form will serve as a catalyst for discussion among qualified individuals in other disciplines.

CONCLUSION

Virginia has a wise policy of careful management of wetlands as valuable, finite, natural resources. The current legal definition of wetlands, should, however, be expanded to include non-tidal vegetated areas (like inland swamps and freshwater marshes), intertidal flats, and beachs and bars. Whether the extension of management authority to these areas should be achieved through direct amendments to the 1972 Virginia Wetlands Act or as part of a more comprehensive coastal resources management program is a subject for political and legal debate. The significant fact is that all wetlands, vegetated and nonvegetated, tidal and non-tidal, have ecological, economic and social values that justify their conservation. Current deficiencies in scientific understanding should only serve to make Virginia even more cautious of potentially detrimental wetlands use and management decisions.

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APPENDIX I

Response of Ecosystems to their Hydrologic Regime

(From Gosselink and Turner, 1978)

The following attributes of the hydrologic regime are of greatest importance to the biological activity.

The SOURCE determines chemical constituents, such as oxygen, salinity, and nutrient concentration. The VELOCITY affects turbulence, and the ability of the water to carry suspended materials. The RENEWAL RATE describes the frequency of replacement of the water. It is a function of water depth, frequency of flooding, and velocity, and is one of the most difficult parameters to measure and predict as it varies from day to day, season to season, and year to year. The TIMING, that is the frequency of inundation and its regularity, influences the potential for system succession and evolution.

Four chemical and physical properties of the substrate (wetland soils) are strongly influenced by the hydrological regime.

Water - Under most conditions of plant growth, water is a limiting factor. However, wetland plants must cope with periods of coverage by standing water, and for this reason the major effect of water is secondary and its influence is not directly limited except through secondary responses, such as limiting oxygen availability in the root zone.

Nutrients - The necessity for, role of, and limitation placed on plant growth by the inorganic nutrients of phosphorous and nitrogen are well documented and will not be further amplified here.

Toxins - Toxins have a controlling role in ecosystems by affecting growth and development. They can be natural, such as salt or hydrogen sulfide or man-made, such as pesticides.

Oxygen Availability - The flooded condition of wetlands soils results in an anaerobic environment, and this in turn leads to a large number of chemical variations from oxidized soils. Generally, growth is reduced in anaerobic soils.

A. Ecosystem Response to Hydrology

Spatial Heterogeneity - The diversity of hydrologic conditions create several niches which species may inhabit. Habitat availability is considered the major determinant of community diversity in ecosystems.

A major factor influencing species richness is spatial heterogeneity, the greater the number of niches, the more opportunity for successful invasion by a species. First, flooding waters provide a vehicle for movement of life-giving elements. This may have the effect of minimizing spatial heterogeneity because of uniform mixing of these elements, resulting in monospecific stands of wetland vegetation. On the other hand, the hydrologic regime can cause elevational and substrate differences, which are a chief source of species diversity in wetlands. Whether this diversity changes through time is dependent upon whether the developing biota have the reciprocal effect of modifying the hydrologic regime.

Productivity - The availability of growth-limiting nutrients is a function of concentration (i.e. source) of the nutrients and of renewal. In addition to being the source of nutrients, water is also the source of toxins. Most prominant of these are salts associated with seawater. Under saturated conditions, with low renewal rates (swamp conditions, for example) the depletion of O_2 in soils leads to a number of chemical changes, which together have an effect on productivity.

B. Flux of Organic Materials

Wetlands are generally net producers, where production of plant materials in the wetland exceeds consumption by wetland feeders. The fate of this excess material is strongly influenced by the hydrologic regime. At one extreme are depression swamps which accumulate most of their productivity as peat. At the other extreme Teal (1962) estimated that highly flushed saltmarshes export about 45% of their net primary production of organic matter. Certainly, hydrology is of great influence on the use of wetland plant material as a food source by adjacent aquatic consumers.

Nutrient Cycling - Gosselink does not elaborate on nutrient flux other than to note that the nutrient load in flooding waters is dependent on the volume of water and its source (concentration).

Thus, standing water wetlands may be nutrient-poor if the only input is rainwater. Tidal marshes, on the other hand are replenished daily with nutrient-rich waters.