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MANAGING COASTAL BIOME INTERFACES

A Discussion Paper

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Introduction

Coastal resource management of the total biophysical system is a relatively new concept. Until the 1960's the main focus of resource management was on the management of resources as perceived by man with little concern for dependent elements of the system. In fact, recognition of environmental interactions and of their potential for mutual degradation has only recently become a public concern. In the United States the National Environmental Policy Act of 1969 and the Coastal Zone Management Act of 1971 marked turning points in the philosophy behind coastal zone management; management difficulties, however, did not decrease in the United States with the passage of these acts. On the contrary, management now focuses on the resource *system* rather than the dynamics of single elements of the system. Investigations of the interdependent phenomena within the coastal zone have become increasingly complex as our knowledge is refined and expanded. Consequently the only feasible solution is to translate appropriate physical and biological laws and theories into managerial principles of general applicability. A step in this direction was taken in 1972 when the Coastal Zone Workshop recommended:

> The creation of a national system of Coastal Area Preserves for the permanent protection of the basic genetic stocks of plants and animals and the essential components of their environments, which together constitute ecosystems.[1]

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[1] The Water's Edge: Critical Problems of the Coastal Zone. Ed. Bostwick H. Ketchum, MIT Press: Cambridge, 1972, p. 97.

The Man and Biosphere (MAB) Program (Project 8) can also develop scientifically based management principles compatible with the preservation of basic genetic stock. In the MAB program, the genetic stock and the essential environmental components are resources now widely recognized as finite and, in many cases, near exhaustion. A network of Biosphere Reserves is now being developed; as of 1975, 40 areas had already been designated. The inclusion of coastal areas not in the class of biomes is important because coasts (1) are the interfaces between oceanic and terrestrial biomes, (2) have unique flora and fauna, and (3) are among the most dynamic physical and biological environments. Management lessons learned in these environments will aid in the management of more stable biomes; however, the question of how these areas are to be managed to assure preservation of genetic stock and diversity must be answered first.

It is tempting to propose a *locked-gate* management strategy in which all human activities are precluded, thus permitting nature to take its course. However, because the Biosphere Reserves include areas not free of man's influence or devoid of potential commercial value, they fail to meet the criterion required for *island isolation*. Over the centuries, the genetic materials within the reserves have adjusted to man's presence and man has undoubtedly played a role in the speciation process as well as the extinction process.

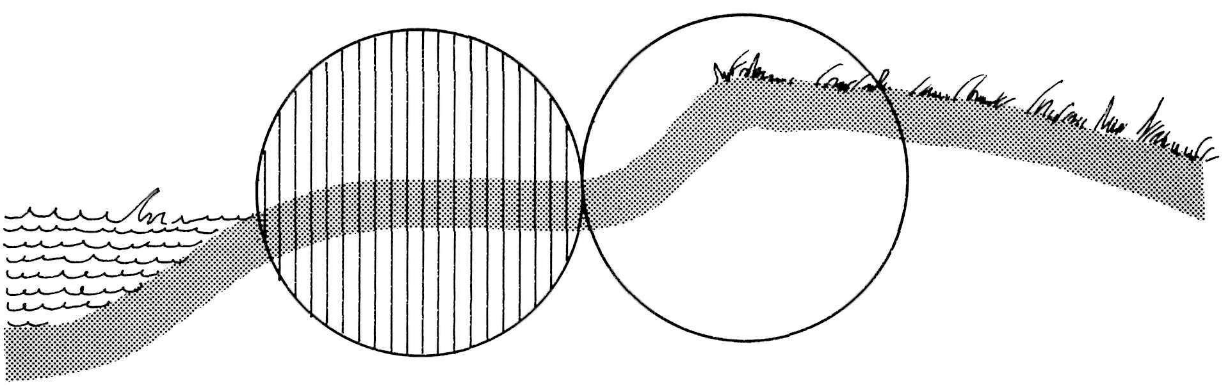
The question "What makes possible the resident genetic stock?" is central to any management focus. Although this would appear to be a call for experts in ecological or environmental genetics, the diversity of the required scientific knowledge and the number of Reserves involved preclude staffing of managerial positions with these experts. We must, therefore, turn to appropriate physical and biological laws and theories for managerial principles of general applicability.

The Coastal System

In broad generic terms coasts are the interface between land and sea. Environment gradients, both physical and ecological, are steep and highly variable in space and time. The coastal zone consists of a system of physical interfaces, interdependent and hierachically organized into primary and secondary interfaces.

Primary interfaces: The primary interface is that locus of the land/sea interface at which marine energies and forces are dissipated. In many areas of the world the primary interface is synonymous with the shoreline but there are exceptions, including barrier and fringing-coral-reef coasts. Within the coastal system, marine energies (waves, surges, and tides) are dissipated along the primary interface.

Figure 1

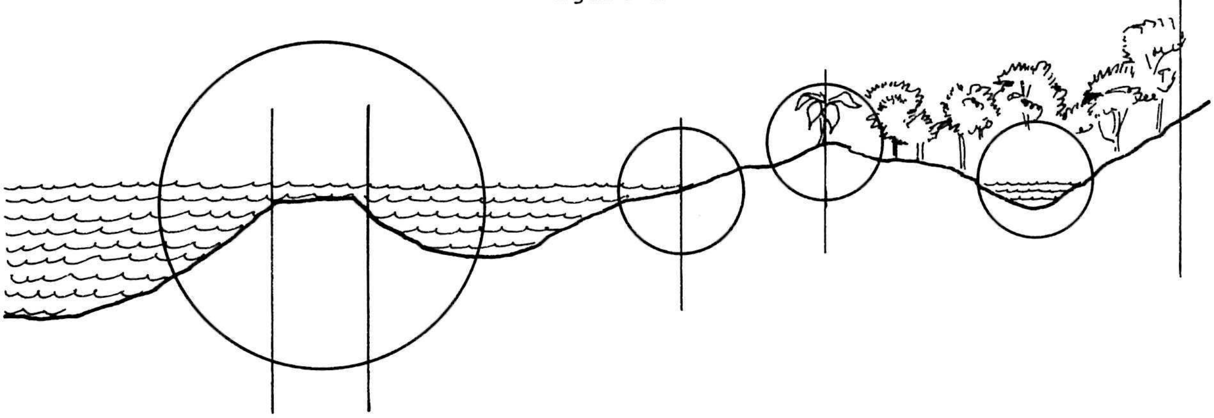


Primary interface (shaded circle) and secondary interface (open circle) on a sand coast.

During extreme storms, the position of the primary interface shifts, temporarily creating new, secondary interfaces both landward and seaward. Alteration of the morphology of the primary interface will have an impact on associated secondary interfaces normal to the coast and primary interfaces adjacent to and along the coast.

A classic example of the alteration of a primary interface is the construction of sand-fixing structures along sedimentary shorelines. Sediment trapped near the structures retards erosion and provides greater shoreline stability. The biological communities adjust to this increased stability: organisms intolerant of the extreme environmental conditions near the coast succeed those organisms tolerant of the instability. Similarly, when coral reefs fronting the shoreline are destroyed by mining or the pollution of inshore waters, waves normally dissipated as they cross the reef structures are no longer retarded; they reach the bay shorelines with greater energy. Geomorphologic and ecologic adjustments are inevitable; shoreline erosion leads to increased turbidity and eventually further reef destruction.

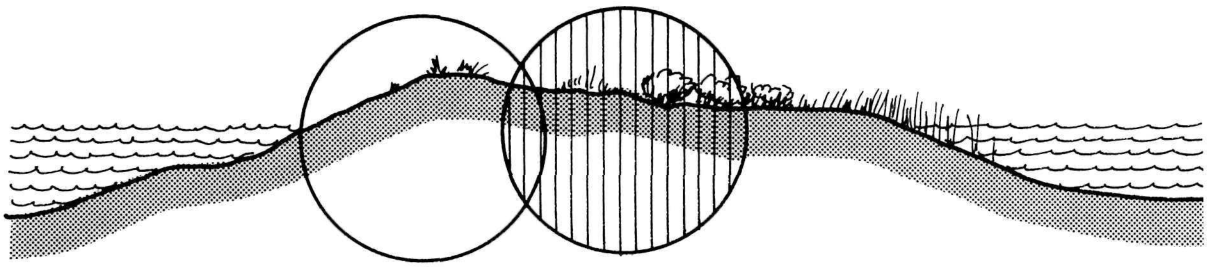
Figure 2



Primary interface (large circle) and a system of secondary interfaces (small circles) on a coral-reef coast.

Secondary interfaces: Secondary interfaces are caused by periodic or episodic increases in sea level above levels associated with the lunar tidal cycle. A temporary relocation of the primary interface, usually landward, creates new soil and salinity conditions. Secondary interfaces can result from spring or neap tides, storm surge, wind-transported sands, and salt particles. Average positions of secondary interfaces change during persistent trends, such as a progressive sea-level rise.

Figure 3



Primary interfaces during extreme storm conditions are the secondary interfaces during fair weather.

When man constructs large dikes or barrier dunes to control extreme short-term departures from the previous sea level, the by-product is usually a dramatic change of the secondary interfaces. Secondary interfaces landward of these structures were originally responses to the periodic inundation of salt water and salt spray. When such areas are protected from saltwater flooding, the system undergoes major ecological adjustments.

Coastal zone managers must recognize both primary and secondary interfaces as landscape indications of zones of change, with the frequency of change increasing as one approaches the primary interface. Alteration of either of these interfaces can have significant impact, both physical and biological, on other parts of the system.

Ecotones: Over the last few centuries vast areas of the midlatitudes have been changed, largely by agricultural practices, into complex land-use patterns. Ecological studies of these landscapes have led to the formulation of the edge-effect or ecotone concept: an increase in variety and in density of species at junctions of communities. The edge-effect concept has subsequently become a cornerstone of modern wildlife management (Fig. 4).

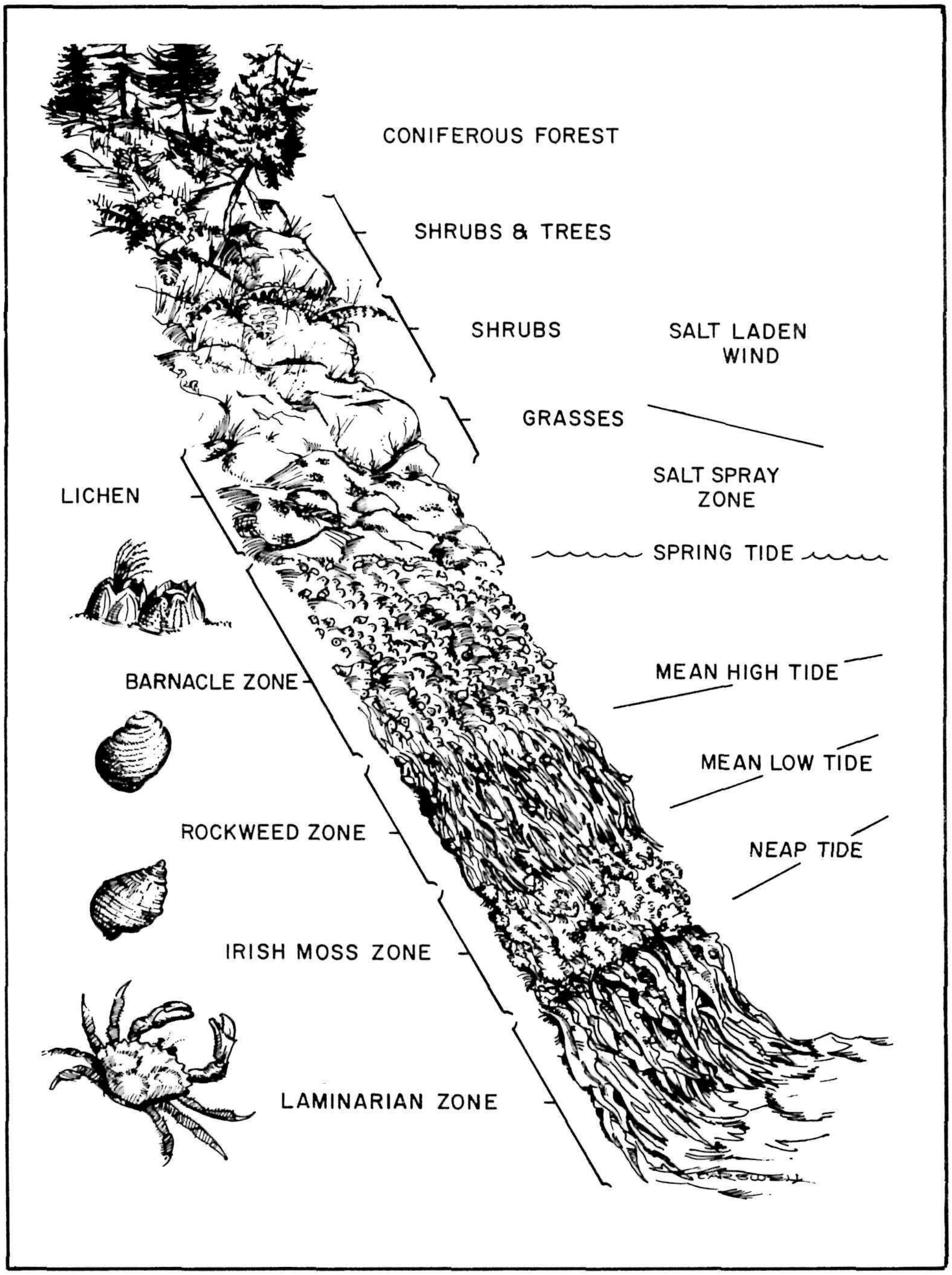
In wildlife management of terrestrial systems, the resource (variety and density) can be expanded by artificial construction of edge communities (ecotones): a common practice in the United States. In many coastal areas, man has simplified the ecotonal system until its biological productivity and diversity have been substantially reduced. When dikes and barrier dunes are constructed to stabilize coastlines, shrubs and trees rapidly replace grasslands. In the grasslands ecotones previously sustained by periodic saltwater inundations disappear, flora and fauna unique to the ecotone are destroyed, and the reproductive cycle of numerous organisms dependent on the coastal ecotones is halted. Thus alteration of physical interfaces and associated ecotones can lead directly to the extinction of species.

Coastal Biome Interfaces as Biosphere Reserves

From a global perspective the coastal environment is the interface (ecotone) between oceanic and terrestrial biomes (Fig. 5). Because most of the world's coasts are north-south oriented on the eastern and western continental margins, there is a great diversity of coastal-biome-interface classes. A large-scale edge effect is clearly present; the various coastal biome interfaces contain both terrestrial and oceanic species. Abundant forage materials and nutrients attract many species and many species depend upon the coastal habitats for part of their life cycle. Without adequate coastal environments, numerous species now residing in the terrestrial and oceanic biomes of the world would face extinction. Coastal environments should be of primary importance in the Biosphere Reserve Program.

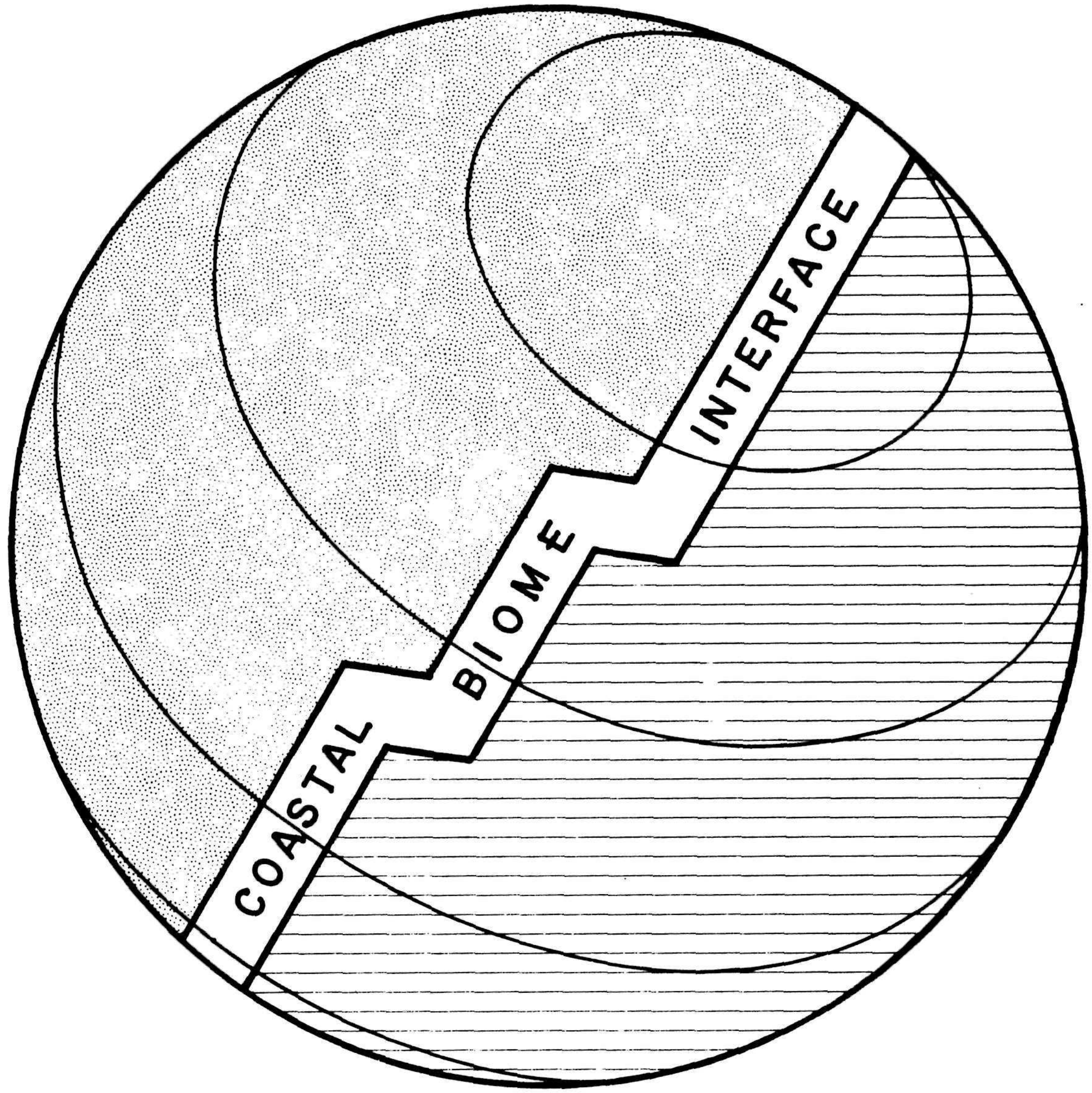
Species diversity in coastal environments differs markedly from those of terrestrial and oceanic systems. Biomes are highly diverse at low latitudes and have low diversity at high latitudes (Table I); in contrast,

Figure 4



In rock-bound, midlatitude coasts, the ecotones of the primary and secondary interfaces are highly condensed in space.

Figure 5



The coastal interface separates provinces of the world's major oceanic and terrestrial biomes.

Table I

Species and Genetic Diversity

<u>Definitions:</u>

Species Diversity: The number of species per unit area.

Genetic Diversity: The number of gene alleles within a population.

<u>Generalizations</u>:

1. Both species and genetic diversity are high in geologically diverse areas.
2. With increasing latitude species diversity decreases and genetic diversity increases.
3. In spatially heterogeneous environments there is more opportunity for disruptive selection and thus speciation; both species and genetic diversity are high.
4. Both species and genetic diversity increase with increasing proximity to ecotones and physical interfaces.
5. Continental species tend to have higher genetic diversity than island species.
6. Geological Time Theory: The older an area is geologically the greater its species diversity.
7. Ecological Time Theory: Species diversity increases with time elapsed since an environmental disturbance.
8. Species diversity first increases with each successional stage and then decreases as the climax stage is approached.

biological diversity within the intertidal zone is high in the mid- and high-latitude rock-bound coasts and lower at low latitudes. In the coastal environment, diversity is highest when the substrate is consolidated, lowest where mobile sediments dominate.

The latitudinal symmetry of atmospheric and marine environments and the global variety of geology provide a wide range of coastal environments (Fig. 6). Because the genetic diversity of these environments is functionally related to the physical dynamics of the interfaces, the natural order of physical processes is vital to the preservation of the genetic stock. Knowledge of the interdependencies of various life forms and physical processes must be used to achieve the realistic management of coastal biome interfaces.

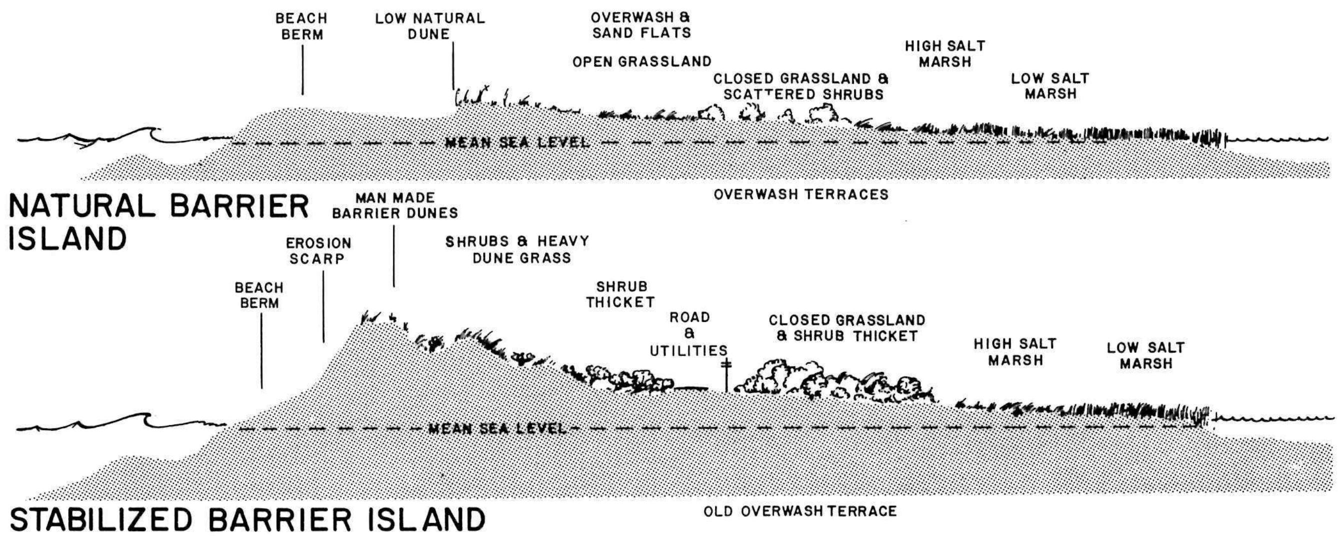
For instance, barrier islands are common on sandy coasts in the mid- and high-latitudes throughout the world. Along the United States Atlantic and Gulf of Mexico coasts, several barrier islands have been set aside by the United States National Park Service as national seashores. Over the past 20 years considerable management experience has been gained, and the areas have been studied by many scientists. During the early 1900's residents of these low coastal areas prudently restricted themselves to the landward side of the islands. They recognized the instability of the seaward side caused by storm-generated waves and surge. During the 1930's barrier dunes were constructed fronting the sea to stabilize the system. Within 10 years, sand fences erected on the back side of the beaches (the secondary interfaces) trapped enough wind-blown sand to create a linear chain of high dunes. To further stabilize the systems, grasses were planted on the new dunes.

Although this three-decade effort succeeded in stabilizing the barrier islands, the unfortunate consequences have now been recognized. High

Figure 6

Because coasts are geologically diverse and complex, genetic and species diversity are high.

Figure 7



Natural and stabilized barrier-island coasts: Physical stabilization of the landscape alters the ecological organization of the island.

barrier dunes prevent periodic storm-surge overwash of the barrier islands. With a stable substate and the reduction of a salt-spray penetration, shrubs have replaced grasses that originally dominated many parts of the island. The encroachment of shrubs and trees was so rapid that controlled burning was instituted as a remedial management measure. Seaward of the dunes, storm waves now confined to the most active part of the beach zone periodically breached and eroded the dunes; this led to a continuous maintenance program. By the 1960's the active beach was so narrow that even modest storm waves eroded the dunes. Since maintenance and replacement of the dunes became increasingly difficult, in some locations even impossible, management action shifted to the eroding beaches. Groins, sandbags, sea walls, and beach nourishment are now used to stem the trend of erosion. By 1975 more than $20 million have been used to keep the Cape Hatteras system stable; and, although this effort resulted in expanded use of the resource, the gain has been shortlived and the cost has been the degradation of the environment.

Although failure of this man-over-nature stabilization strategy might be attributed to the periodic occurrence of extreme storm events, many more complex causes must be considered. In addition to the episodic storms, there has been a persistent rise in sea level which under natural conditions would result in a landward migration of the islands. Storms have also been increasingly severe over the last three decades.

We have learned from these barrier-island experiences that a natural environment cannot be perpetuated by precluding the operation of the natural processess. The physical landscape cannot be changed without also changing the entire ecological environment. The coastal environment is the interface of physical processes; any interference with these processes changes the entire system. These are changes in the position and dynamics of the physical and the ecological interfaces. From our assessment of the management history of Cape Hatteras National Seashore (North Carolina), and Assateague National Seashore (Maryland), we believe that the natural range and scale of physical processes must be understood and this knowledge employed as the basis of all elements of any environmental management plan.

The following facts must be considered as management guidelines are established and modified.

1. Management decisions affecting one interface also affect adjacent interfaces; management costs of interface modification extend well beyond the area to be modified.
2. Management decisions physically affecting primary interfaces are at best short-term or temporary while those affecting more mature communities have long-life expectancy.

3. A management strategy based on stabilizing physical interfaces usually leads to ecological degradation.
4. The more dynamic interfaces and ecotones within the coastal zone should be incorporated into the MAB network as early as possible.
5. Restoration projects should rely on native materials, and the forms enhanced should be consistent with natural forms.
6. Facilities located within the area of the physical interfaces and ecotones must be short-lived, temporary developments that adjust or respond to the changing interfaces.

Although these facts and guidelines were originally developed for sedimentary coasts, their applicability is general. Since many of the MAB coastal reserve areas have not been studied in detail, their first-phase management strategy will have to be developed from 1) experience in other coastal areas, 2) an information system constructed from information already existing, and 3) newly acquired resource inventories.

Recommendations

We recommend that the directors of MAB Project 8 assume and maintain the initiative in developing a management strategy for MAB coastal areas, and that this strategy be based upon the principle that *the natural range and scale of physical processes must remain unchecked within the biosphere reserves.* This is especially true for trend and episodic climatic events. Without the impact of these, the environment is without the needed stresses. In ecological terms, communities will evolve toward climax types instead of the natural, interrupted succession or disclimax common to the coastal environment. Consequently, the genetic and ecological diversity, which is the object of preservation, will be altered. It is the very complexity of natural boundaries which makes possible the high diversity. This complexity is dependent on change.

In order to meet the urgency of early planning, we recommend:

1. That guidelines (*Handbook for Management*) be prepared and specific recommendations made for management of MAB Coastal Biosphere Reserves with the biological and physical dynamics of the coastal system as their base. A comprehensive state-of-the-art review of coastal zone management should be included.
2. That methods be recommended, including specific designs for baseline studies and data-acquisition systems, and that priorities be set.
3. That the *Handbook for Management* be written as a useful field guide, not an academic document; that the *Handbook* include a series of case studies or field examples of very practical problems dealing with science (design) and landscape management.
4. That the *Handbook* have three sections:
    a. Background: Physics and biology of the coastal system (how it works).
    b. Investigation: Design of a monitoring program, including data sources, priorities, and recommended analysis (research).
    c. Application: Examples and solutions of the most commonly occurring coastal management problems; i.e., pollution, erosion, misuse.