ECOSYSTEMS AND RESOURCES OF THE MASSACHUSETTS COAST

INSTITUTE FOR MAN AND ENVIRONMENT / CZM Massachusetts Coastal Zone Management

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ECOSYSTEMS AND RESOURCES OF THE MASSACHUSETTS COAST

Written by: Carl Carlozzi
Kathryn King
William F. Newbold Jr.

Illustrations and Layout: William F. Newbold Jr.

Nauset barrier beach and Chatham Harbor looking South *Courtesy Army Corps of Engineers, NE Division*

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THE COMMONWEALTH OF MASSACHUSETTS

EXECUTIVE DEPARTMENT

STATE HOUSE • BOSTON 02133

MICHAEL S. DUKAKIS
GOVERNOR

Dear Citizen,

Massachusetts has long been a national leader in the protection and enhancement of its coastal resources and ecosystems. Local ordinances concerned with wetlands began in the early 1960's. Sensitive to local needs, the state Legislature passed a series of landmark laws which became a model for the rest of the nation: The Jones Act-The Coastal Wetlands Protection Act (1963), the Hatch Act-The Inland Wetlands Protection Act (1965), The Coastal Wetlands Restriction Act (1965), The Inland Coastal Wetlands Restrictions Act (1968), and the Wetlands Protection Law (1972) with amendments (1974), established Massachusetts once more as a forerunner in state environmental legislation.

The pioneering of a system of local Conservation Commissions, the establishment of ocean sanctuaries off our shores, and the creation of an Energy Facilities Siting Council further support a recognition of the importance of our coastal environments.

Massachusetts' foresight must continue in the future. This administration's development of a Coastal Zone Management program for its coastal areas along with the development of a local-based comprehensive growth policy for the entire state will help us to meet this goal. Through the development of long-term plans and management, we will be better able to balance the needs for future growth and development with enhancement and protection values.

However, building towards the future requires much more than state governmental insight and hard work. It demands an informed and involved citizenry. I urge you to join in our efforts. The Massachusetts coast abounds in natural resources which support varied commercial, recreation and aesthetic needs. Deciding on how these resources should be used in the future requires your participation.

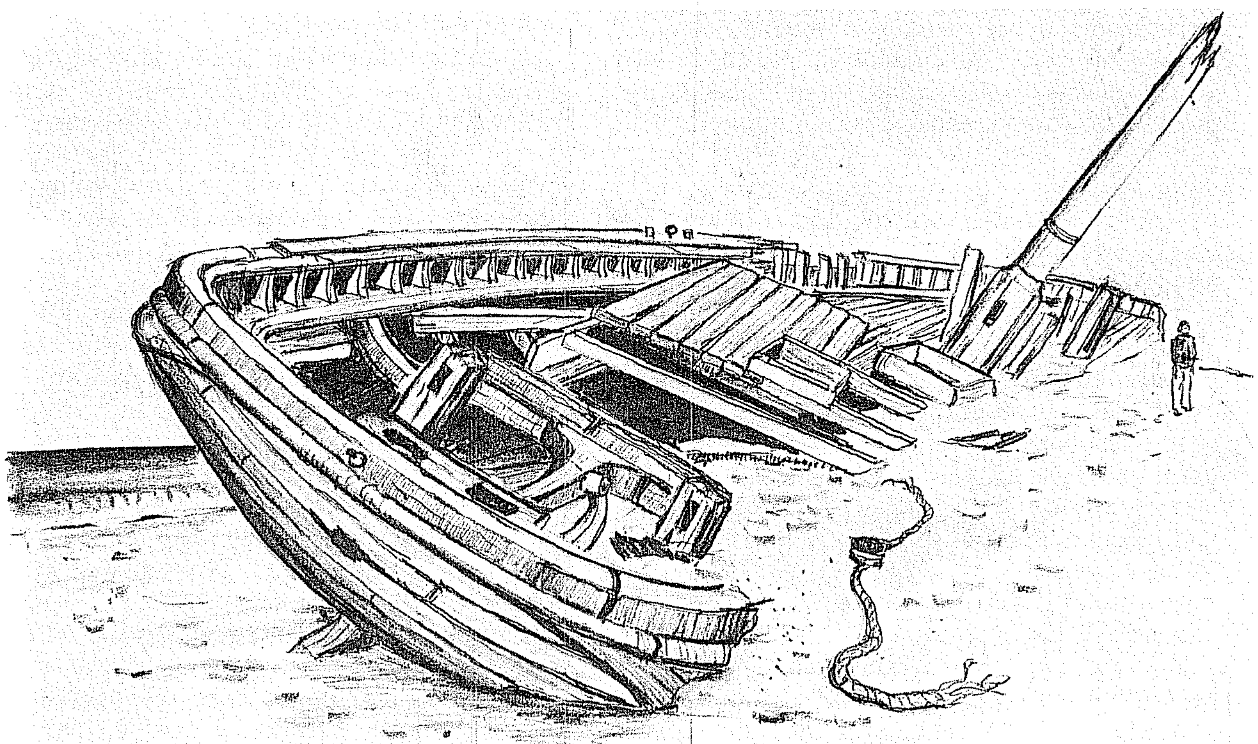
This publication discusses all the natural and many man-made systems making up the Massachusetts coastline, their importance as facets of the environment, and the ways in which they are used and altered by man. It has been prepared as a guide for all Massachusetts citizens to use in order to better enjoy and understand their unique heritage.

Sincerely,

Michael S. Dukakis

Michael S. Dukakis

INTRODUCTION



Roll on, thou deep and dark

blue ocean——roll!

Ten thousand fleets sweep

over thee in vain;

Man marks the earth with ruin——

his control

Stops with the shore. . .

Lord Byron

Childe Harold's Pilgrimage

canto IV, st. 179

The words of Lord Byron may have rung true nearly 160 years ago, but today they fall on more knowing ears. Man's domain stretches far out to sea and to the greatest depths of the oceans. Man's unknowing destruction has affected the seas and fragile shoreline.

The very wealth, beauty, and resources that convinced man to settle by the sea, work by the sea, and seek solace by the sea are threatened today. Congress recognized the extent of this danger to our coastal areas when it passed the Coastal Zone Management (CZM) Act of 1972.

The CZM Act of 1972 provides federal assistance to coastal states in a voluntary program of comprehensive land and water use management. Every coastal state in the nation eligible for federal CZM funds has established a CZM program. The Massachusetts Office of Coastal Zone Management is in the Executive Office of Environmental Affairs.

We have much to protect and develop in Massachusetts. The history and fate of the Commonwealth is intricately tied to the sea. From the arrival of the earliest European settlers, our natural harbors, productive fisheries, and maritime trading routes have provided man with food, housing, and a means of commercial support.

Ports developed and settlements grew along the shore. Today some 40 percent of the state's population lives in the 87 communities along the shore. Almost half of all the construction development in the state occurs in our coastal cities and towns.

Our coastal areas support commerce, industry, transportation, housing, recreation, commercial fishing, and tourism. The coastal areas are rich in history and tradition, and meet many of our vital aesthetic needs. However, these land and water uses often conflict, and we have come to realize in recent years that the myriad of uses that take advantage of the wealth of our coastal resources often wreak havoc on the most productive, sensitive, and complex environment on earth, the coastal ecosystem.

The commitment of the Massachusetts CZM Program to active public participation includes developing educational resources for the public. A better scientific understanding of the complexities of Massachusetts' coastal ecosystems will help in establishing the critical needs of the coastal zone, and in better understanding man's environmental impacts. This publication attempts to reach that "better understanding", by laying out clearly, concisely, graphically, and in lay language accurate information on Massachusetts' coastal ecology.

The forces of nature that create our coastal systems are dynamic. They reach beyond the boundaries of towns, regions, and states. Activities in one community can have repercussions many miles away. It is incumbent upon us, then, as participants in planning and management, to recognize the common interlocking relationships of natural systems, to think broadly in terms of resource management, and to consider the regional impacts of our decisions,

Man has not been wholly aware of the impacts of his past activities. We are still learning about the delicate ecology of the land and sea interaction.

In passing the CZM Act, Congress recognized the pressing need for resource management in the face of competing and ever increasing demands upon the land and water resources of coastal states. In this light, Congress realized the need for man's future activities to respect the fragile and vulnerable nature of coastal areas, and the need to halt unknowing destruction.

A better scientific understanding of the complexities of Massachusetts' coastal ecosystems will help in establishing the critical needs of the coastal zone, and in better understanding man's environmental impacts.
structively and with foresight to plan for the future economic, social, and environmental needs of the Commonwealth.

The remainder of this publication has been divided into four main sections. The first two parts present an overview of the natural forces and ecosystems respectively that form the productive basis for coastal resources. The next part describes man's use of coastal resources and the environmental consequences of man's activities. Finally, the report analyzes important broad coastal ecosystems and their resource wealth, complexity, and environmental health. This last section considers needs for future scientific research and information tied to the management of Massachusetts' wealth of coastal resources.

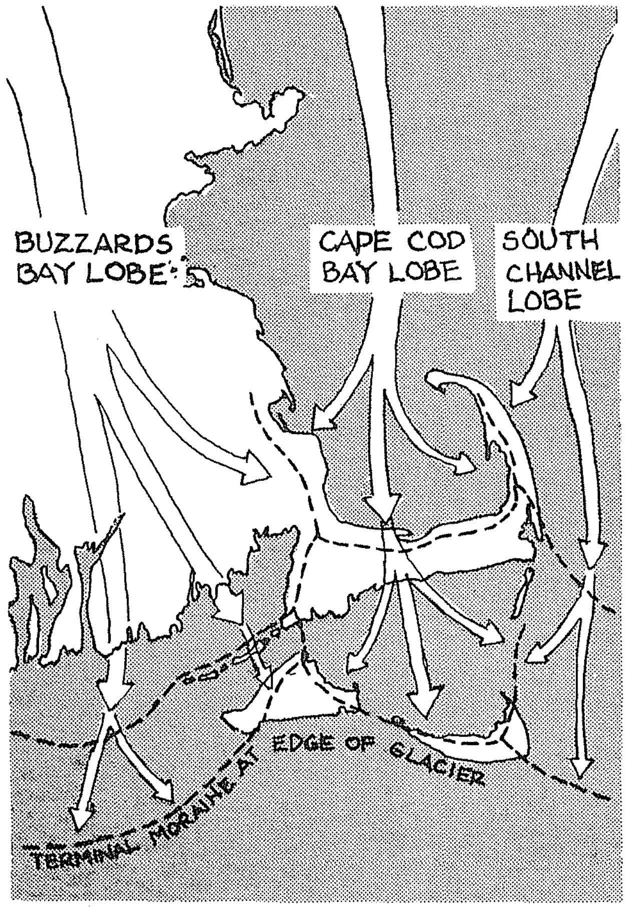
I. THE GEOLOGY OF THE MASSACHUSETTS COAST

To better understand the Massachusetts coast as it is seen today, it is necessary to look back into history at the major geologic events that formed our coastline. This part discusses geologic and meteorological actions that have built and sculpted the Massachusetts coast. There are two sections. The first describes significant historic occurrences and dynamics of the great continental glaciers and their contributions to coastal materials and landforms. The second section describes the present day-to-day and seasonal dynamics of water and weather as they alter the shape and chemical nature of the coast.

The Glacial Influence

The major features of today's coastline were formed 10,000 years ago during the stage of the last Ice Age known as the Wisconsin. The great glaciers made their final advance in the Northeast United States and in their retreat left the outlines of Cape Cod, Martha's Vineyard, Nantucket Island, the Elizabeth Islands and Long Island. Prior to the arrival of the glaciers, the Georges Bank and continental shelf, 200 miles east of Cape Cod, were an area of plains and low hills, many feet above sea level.

As the earth's climate cooled, the glacier grew in overall dimensions and began its journey to the southern shores of New England. As they grew, they absorbed more and more water and the sea level fell between 300 and 500 feet. The Wisconsin ice advance in Massachusetts consisted of three major ranges of massive, scalloped-edged, glacial movements, or ice lobes, known as the Buzzards Bay Ice Lobe, the Cape Cod Ice Lobe, and the South Channel Ice Lobe (See Figure).



During the Ice Age four successive glacial advances and retreats moved across New England. As the last glacier began to retreat about 10,000-12,000 years ago, tremendous amounts of glacial till [sand, silt, gravel, and boulders] were left behind. Runoff from the melting glaciers combined with the natural weathering forces of wind, rain, and waves have been constantly molding these deposits into the coastline we know today.

In its southward movement the glacier scrubbed rock material from northern lands and carried it as far as the southern limit of glacial advance. Gradually, as the climate warmed, meltwater from the glacier transported silt, clay, gravel, cobbles and boulders, and deposited them in terminal moraines at the edge of the glacial lobes. Water flowing form the glacier sorted finer and lighter material from the heavier gravels and boulders, depositing these sediments into bedded layers called stratified drift.

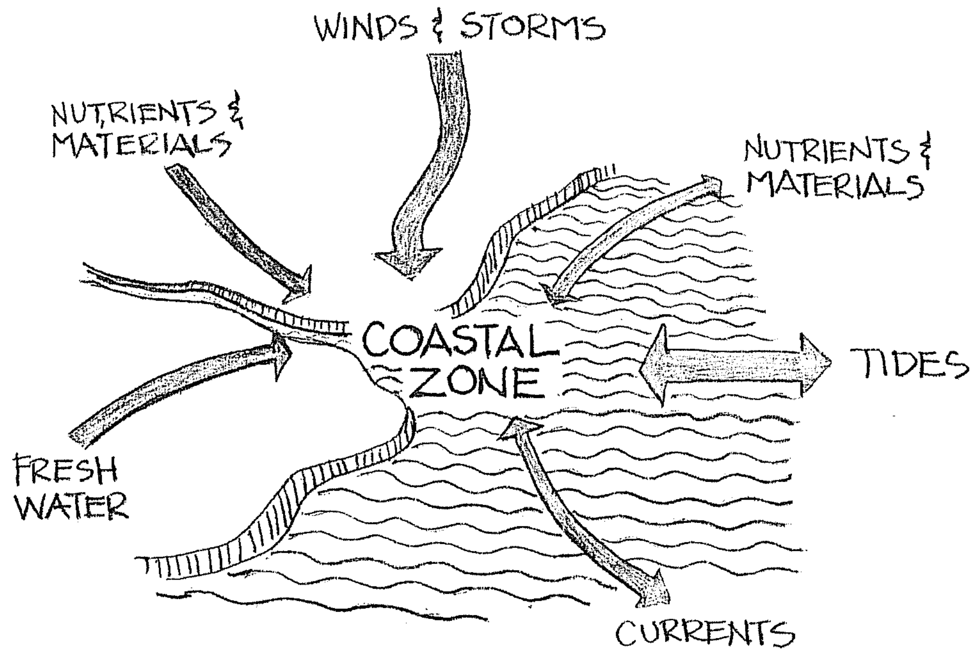
Looking at the entire Massachusetts coast today, the results of glacial action can be seen from the North Shore to Cape Cod and offshore islands. Glacial till and stratified drift deposits make up the principal landforms and subtidal forms. Along the North Shore the glacier left long, narrow, tapered mounds of till called drumlins. These have become the basis for such coastal landforms as the Plum Island barrier beach. Cape Ann's high rocky headlands and offshore rock reefs are overlain with large boulders and cobbles delivered there by glacial movement.

Drumlins, reworked by currents, waves and tides, provide the basis for the Boston harbor islands. These drumlins have been altered from their original shapes and finer materials have been redeposited to form a complex of sand spits and beaches in the harbor. Nantasket Beach was built in this way with sand deposits connecting several emergent and submerged drumlins. Further south, from Duxbury to the Cape and Islands, the glacier's historic presence is evident in the large terminal moraines that provide an elevated base for today's shoreline landforms. The high, dune-capped cliffs on the east shore of the outer

Cape are examples of these forms. The moraines also have provided materials for South Shore and Cape shoals, beaches, tidal flats and dunes. Features of these moraines are the small hills and deep depressions called knobs and kettles. Kettle ponds formed in deep holes created by large blocks of ice, left behind when the glaciers melted. Examples of kettle ponds can be found in Wellfleet and Truro. South and west of the Cape some terminal moraines were built high enough to avoid drowning in the rising ocean. Nantucket, Martha's Vineyard and the Elizabeth Islands are examples of moraines that achieved such heights.

As the Ice Age waned, the glaciers melted during the summer months, causing streams and rivers of meltwater to flow from the ice, carrying rock flour or clay silt in the form of finely ground rock, which settled on the ocean floor. Coarser and heavier materials were deposited at the southern edge of the glacial front. The accumulated debris formed what is called an outwash plain, the foundation of the present south shore of Cape Cod. As more melting occurred, the waters carved out glacial outwash channels in the outwash plain. The Bass River between Dennis and Yarmouth is an example of such an outwash channel. Similar outwash plains and channels created the shoreline and rivers of Buzzards Bay.

The effects of the Wisconsin glacier are still operating. The coast has a geologic history of subsiding shoreline and rising sea level. The land subsided under the weight of glaciers. As the glaciers melted and retreated, the land mass rebounded as its toploading pressure was relieved. Since this process happened faster than the rise in sea level, the land was not

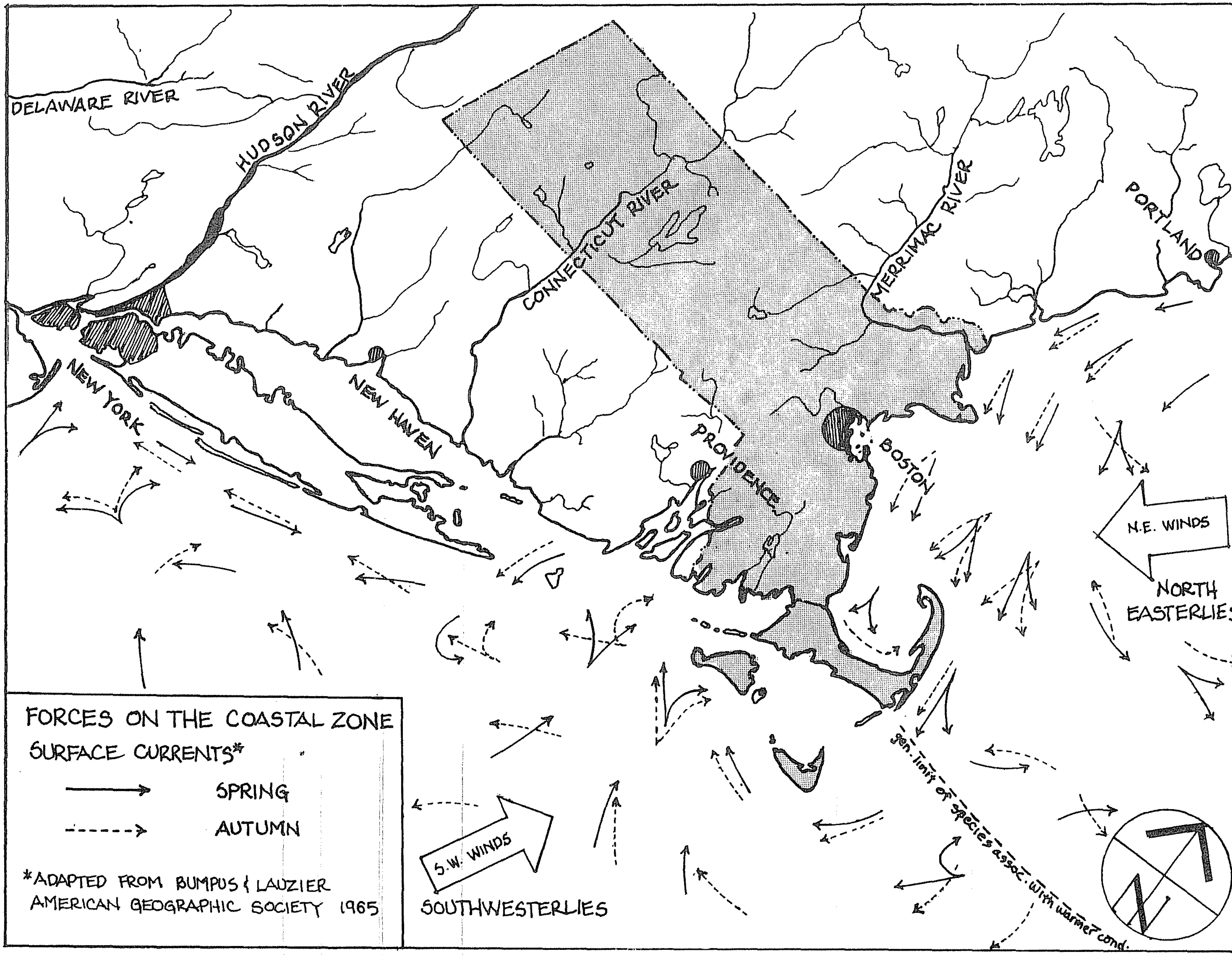


Because it marks the confluence of air, land, and ocean, the coastal zone is a highly complex and dynamic environment.

drowned. Later, the land once again subsided and as sea level rose, the shoreline was submerged at greater elevations. Today, the land continues to subside at the rate of about six inches every 100 years and the sea level is still rising as the polar ice cap glaciers melt.

The Dynamic Coastline

The coastline is never still. To the casual observer this seems obvious since the water conditions are ever changing. Tide and waves, storms and calm are the dynamics that cannot go unnoticed. But there are other actions revealed to a slightly more perceptive observer. The physical shape of the coast itself is constantly changing, in some places very rapidly. Certainly, this does not make the coast different in kind from all other places on the earth, but the rate of change is usually faster. Since the coastal zone is only a very narrow band at the junction of land and sea, it makes the relative importance of change a serious matter, not only to man, but to the survival of the intricate and productive systems of plants and animals that are found there. Like man, these organisms have continuously adapted to the coastal dynamics. The balances between


DELAWARE RIVER
HUDSON RIVER
CONNECTICUT RIVER
MERRIMAC RIVER
PORTLAND
NEW YORK
NEW HAVEN
PROVIDENCE
BOSTON
N.E. WINDS
NORTH EASTERLIES
S.W. WINDS
SOUTHWESTERLIES
gen. limit of species assoc. with warmer cond.
FORCES ON THE COASTAL ZONE
SURFACE CURRENTS*
SPRING
AUTUMN
*ADAPTED FROM BUMPUS & LAUZIER
AMERICAN GEOGRAPHIC SOCIETY 1965

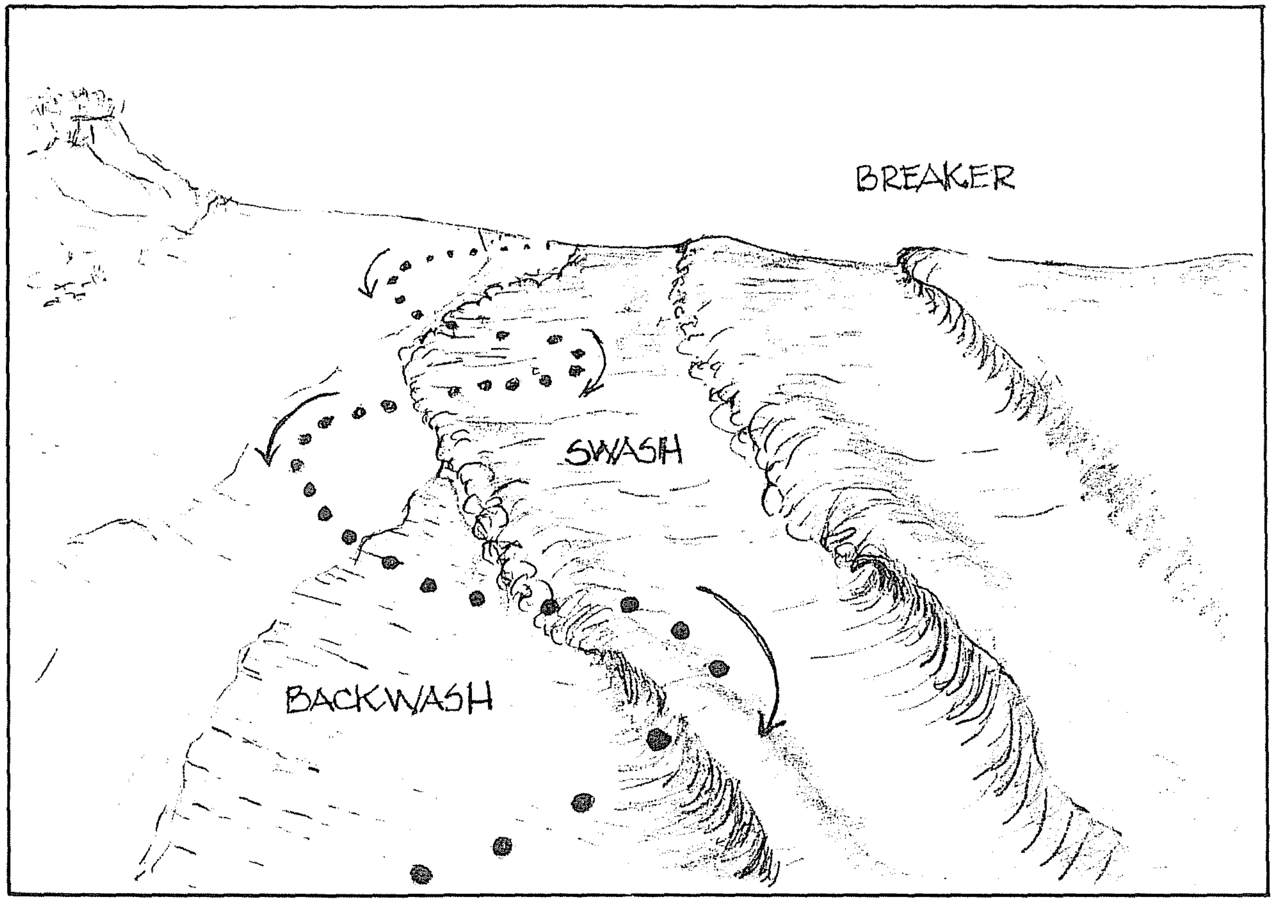
the organized biological arrangements and the changing face of the coast are often delicate when seen against the extremes of energy released through storms, sweeping ocean currents and large tides.

To better appreciate the conditions of coastal existence, it is helpful to think of the coast as the meeting and mixing place where fundamental forces and substances from both land and sea are joined.

Every day of every year materials are blown or washed from the land's surface and carried down to the sea. The constant renewal of the meteorological and hydrological systems powered by solar energy and gravitational forces guarantees that the transport of the earth's materials to the oceans will continue. Contained in the flows of water and wind are sands, silts, clays and organic particles along with dissolved chemical compounds from the land. These substances may accumulate in higher concentrations as they are transported to the sea, thus increasing the load for eventual deposition in the ocean.

This land-to-sea movement contributes basic materials for the building of coastal forms, and is the source of salts and chemical nutrients necessary to the health of coastal and oceanic ecosystems.

Unfortunately, not all materials transported from the land to the sea are benign and beneficial. The same forces that carry chemical nutrients such as nitrogen, phosphorous, calcium, iron, potassium, and others also move the waste products of human endeavor to the coast. These waste substances are often harmful either because they are over-concentrations of otherwise useful and needed



Waves striking a beach at an angle create a phenomenon known as littoral drift. In deep water a passing wave causes suspended particles to move in a circular path. But as the wave approaches the shore, this movement becomes horizontal in the direction of the wave. Suspended particles of silt or sand are then carried ashore and back out with the backwash. The dotted line indicates the general movement of sediments along the coast with the successive swash and backwash of the wave action.

materials or because they are directly toxic to living things.

When the land-derived materials enter the coastal areas, the currents, tides and waves of the ocean provide the major transport system for distribution and dilution. This action of transport from places of origin or concentration to places not richly endowed with nutrients and food sources spreads the chemical basis for biological productivity along the coastal zone and outward to the ocean.

River outfalls and estuaries are singularly important areas through which nutrients and food are moved. Many of the currents transporting materials from the outfalls carry them long distances. The good and undesirable influences of Massachusetts rivers such as the Merrimack, the Charles and the North, for example, will be felt in waters on the coast and in the open ocean.

Less dramatic but equally important are the local currents and daily tides. Along the entire coast occur lateral movements of water called longshore currents or littoral drift, produced by wave action. These flows are responsible for carrying loads of sediment from areas of erosion to areas of deposition, primarily in the coastal zone. As materials are eroded from beaches, sand cliffs and even rocky shores by strong waves and heavy rains during storms, they are picked up and transported by the littoral drift. Some of this material is redeposited on other beaches and some is moved outward to the depths of the open sea. In this way, the coast in some places is diminished by erosion, and in others nourished by deposition.

In many ways, it is the effects of the day-to-day stresses of winds, waves, tides, and currents rather than major storms that are the physical factors which determine the biologic systems occupying different locations along the coast and from the coast to the open sea.

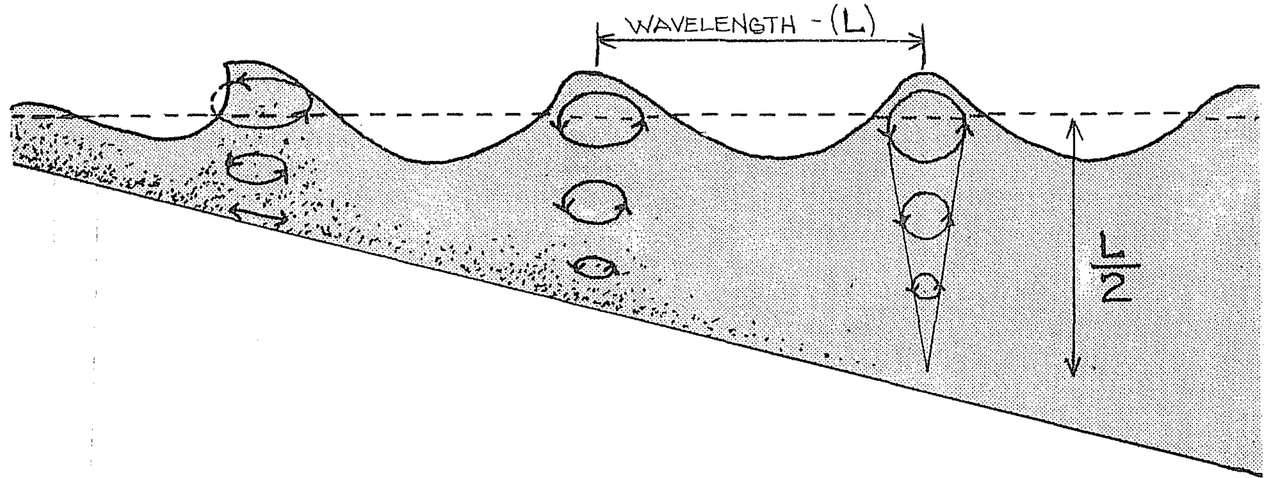


Diagram showing simplified wave mechanics. The arrows indicate the general motion of a suspended particle. The influence of a passing wave on bottom sediments is proportional to the wavelength measured crest to crest.

It is the average high and low levels of tide that determine the zonation of plant and animal species on all shores.

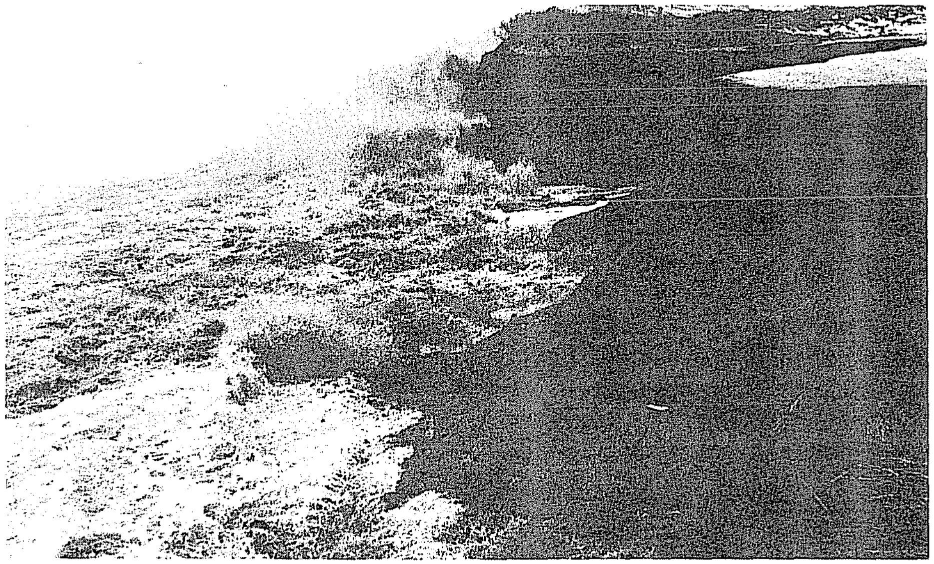
It is the depth of disturbance of waves coupled with turbidity that limits the growth of subtidal organisms on the floor of the sea.

It is the shape and composition of the ocean bottom, in combination with coastal currents and tides that influence species of fish in their choice of habitats.

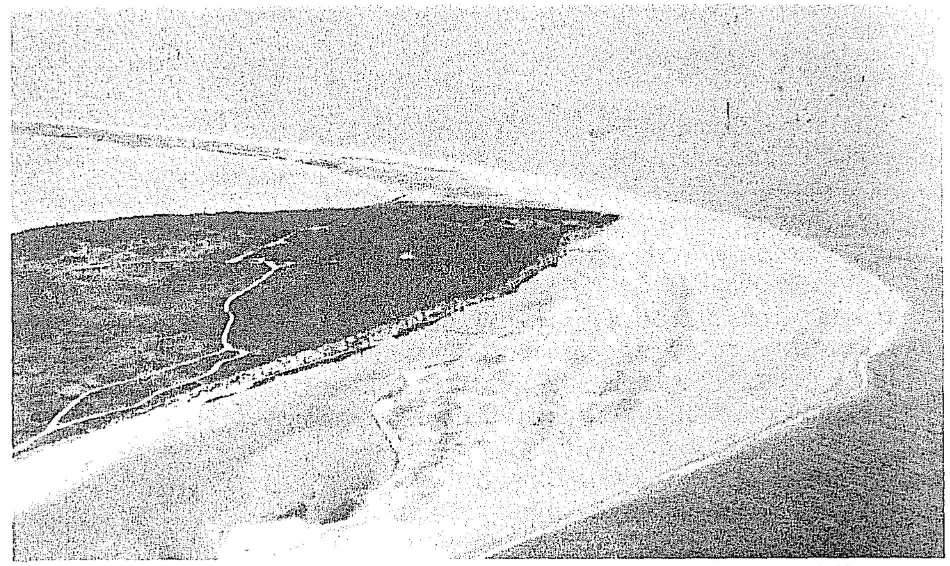
It is the patterns of flows, the circulation and mixing of fresh and saline waters in the estuaries, that fix the location of shellfish beds or the spawning areas of other mollusks (clams and scallops), crustaceans (crabs and lobsters) and fish.

And it is the transport and dilution of both beneficial and harmful chemicals and sediments by coastal and ocean currents that in large part determine the level of productivity of coastal ectosystems.

The dynamics of the coastal area are therefore essential to its ecological well-being in all cases. Flows of water, movement of materials, and fluxes in chemical composition provide the basis for a healthy environment for coastal organisms. Only in the extreme do the natural forces of the coastal environment seem to act against the survival of living things. But even in the event of more violent physical occurrences, there are mechanisms that protect against and minimize damage to the coastal ecosystems.



Storn waves eroding Coast Guard Beach Wellfleet
Courtesy Army Corps of Engineers, NE Division



Barrier beach Martha's Vineyard Courtesy CZM Office

Nature's Stabilizers

Despite the potential for constant erosion and shifting of the coastline, there is a stabilizing effect caused by the shape of the coast, the buildup of offshore barrier islands, and the growth of biological communities on shore and in the intertidal zones.

Rocky headlands may break the full force of storm-driven waves and tides, in this way creating quiet bays and coves where natural or man-made systems may exist without major disturbance. The arch of Cape Cod and the string of the Elizabeth Islands moderate the force of the ocean-born storms, thus giving Cape Cod Bay and Buzzards Bay ecological qualities not found in other parts of the Massachusetts coastal zone.

Barrier islands and shoals running parallel to the coast are formed by the deposition of materials eroded from the coast and carried by the littoral drift. These break the force of the waves and currents and protect the shore from the full erosive power of the sea. Because the islands and shoals are built of unconsolidated materials, they are subject to general erosion and to blowouts and washouts during storms. In the very long run, the general day-to-day balance between the movement of the littoral drift, tides and large ocean currents makes rebuilding of the barrier islands, shoals and beaches a periodic event.

The successful establishment of living communities of plants and animals is very important to the stabilization of both the shore and barrier islands. Beach grass and shrub communities protect against wind erosion of dunes. Salt marsh communities cushion some of the intertidal areas against the full forces of storm-driven water. In all instances, the presence of healthy vegetation is a natural mechanism providing a more stable base for the plants themselves, fostering a physically stronger biologic community, and allowing for the expansion of the community along its margins.

It Doesn't Happen Overnight

The dynamic mix of natural forces along the coast slows the development of large, highly productive and relatively permanent coastal ecosystems. Some Massachusetts salt marshes, for instance, have taken thousands of years to grow to their present size. All the while, they are subject to the physical stresses of changing weather, water movement and even dramatic changes in sea level.

Yet they survive and grow. Only monumental climatic alteration or geologic change would be sufficient to destroy or radically change the natural resiliance of the coastal ecosystems were it not for the presence of man.

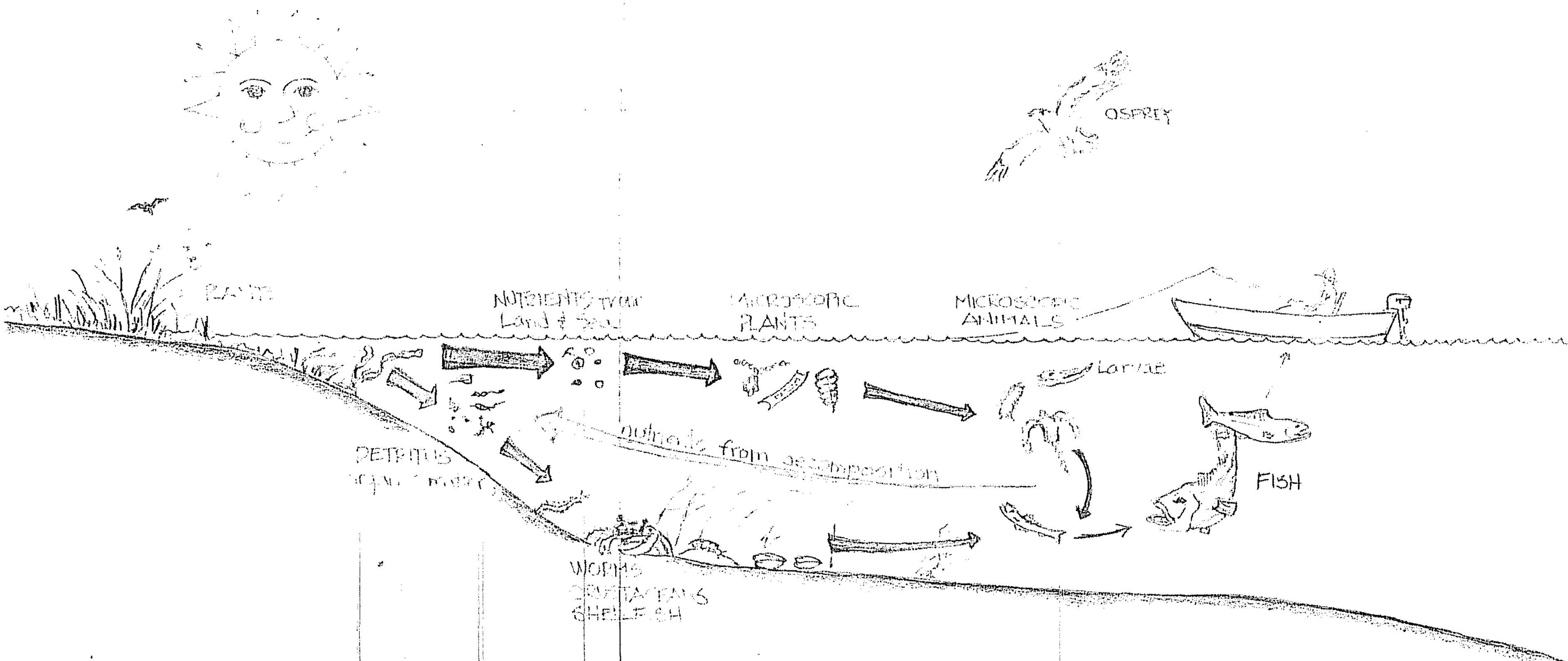
Pollution, dredging and filling of the intertidal and shallow water areas, and building and traffic on the dunes, all act, in the places where they occur, as equivalents to geologic or meteorological events occasionally occurring in nature. These man-induced stresses, however, are not simply occasional; they are widespread and becoming more frequent.

II. THE LIVING SYSTEMS OF THE COAST

The Ecosystem

The concept of ecosystems recognizes that all life is interconnected and interdependent. It rests on the understanding that there is an organization among plants and animals in response to their physical environment that promotes optimal efficiency in capturing, storing, and transferring the energy and chemical elements essential for life and growth within the group of organisms living in a given area. Since this process occurs both worldwide and locally, it is possible to think of something as large as one global ecosystem or as small as the groups of plants and animals living on one type of rock in the intertidal zone.

The fundamental physical and chemical conditions in the environment make it possible or impossible for particular organisms to survive in a particular place. It is for this reason that the living world exhibits such variety: species occupying any one place are only those that are adapted to functioning together in their local conditions of sunlight, physical forces, and chemicals.



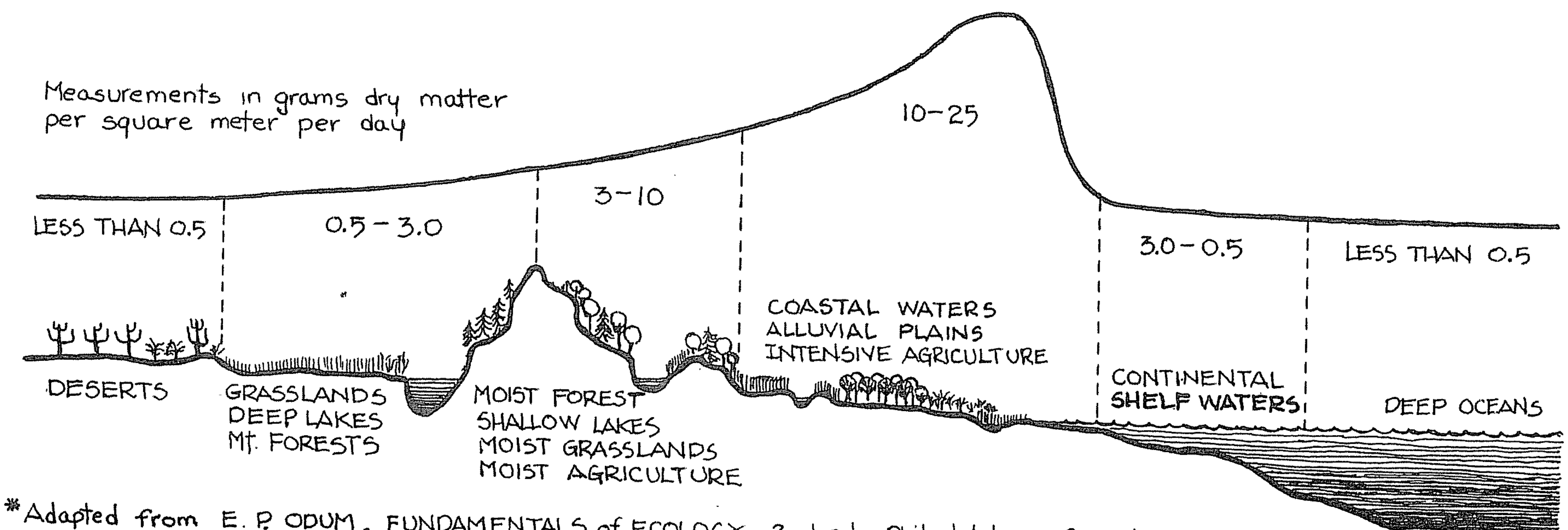
Nutrients born by the wind, currents and tides greatly enhance growth of plants living in the water and at the water's edge. The plants are then utilized in the system in two basic ways. The first is by direct grazing in which microscopic animals [zooplankton] consume microscopic plants [phytoplankton]. Larger plants are consumed by larger herbivores such as insects and waterfowl. The second way is less direct. Fragments of plant material known as detritus are attacked by a host of microscopic organisms [fungi, bacteria, protozoa] forming a "skin" over the fragments. An array of other animals know as detritivores [worms, shelllfish and crustaceans] feed on this protein rich "skin" and allow the remaining material to pass through their bodies to be utilized again. Carnivores then feed on these small herbivores and detritivores and they in turn become prey for still larger carnivores such as large fish, birds of prey, and man.

Modern environmental management increasingly depends on the growing knowledge of ecosystems as the basis for activities and programs. Such knowledge is also essential to all levels of private and public planning for land and resource use. Unlike earlier management techniques that tended to focus effort on the special resource features or species desired, today's efforts rely properly on managing whole ecosystems. Awareness that changes in any one part of the ecosystem, however small or remote, cause alterations in all other parts, sets the pattern for management.

The coastal zone of Massachusetts has many types of ecosystems. The following section summarizes each major type, describing essential physical conditions and dominant plants and animals making up the biotic communities found there. There is also a summary discussion of each system's sensitivity to human use and disturbance, such as pollution, filling, dredging, resource harvest, and the building of water-related structures. While the major elements of each ecosystem are known and the principles that govern the physical and biological interactions of each are understood, there is still a need for scientific research to better detail the true functioning of certain ecosystems in general or in particular places. Ultimately, it will be the degree to which improved knowledge of the coastal systems can be disseminated to, and consistently applied by, all coastal zone users and decision makers that will preserve coastal resources in the future.

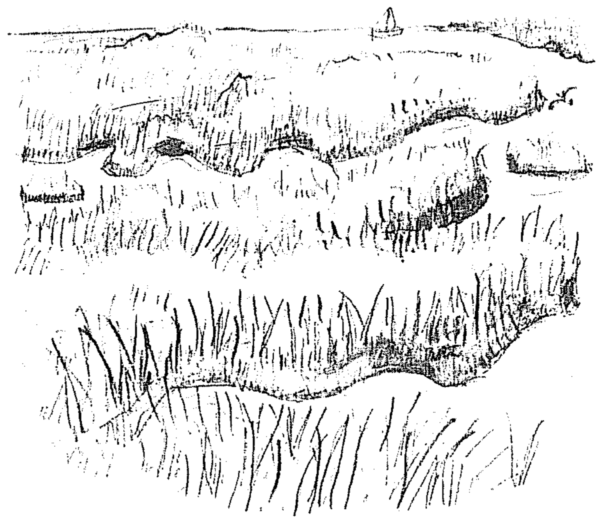
Ecosystems discussed in this section are: salt marshes, eel grass beds, sand dunes, sand beaches, tidal flats, rocky shores, salt ponds, barrier beaches—islands and estuaries.

DISTRIBUTION OF PRIMARY PLANT PRODUCTIVITY*



*Adapted from E. P. ODUM, FUNDAMENTALS of ECOLOGY, 2nd ed. Philadelphia: Saunders, 1959

SALT MARSH



The salt marsh is one of the most important ecosystems. These highly productive biological communities, varying in size from tiny pockets to thousands of acres, are found along the entire coast of Massachusetts. Salt marshes typically are located in intertidal areas behind barrier beaches, bordering pools of quiet water, or along the banks of tidal rivers.

Salt marshes add greatly to the aesthetic diversity of the coastal landscape, providing a source of recreational enjoyment through fishing, shellfishing, waterfowling, and general nature appreciation in all seasons of the year.

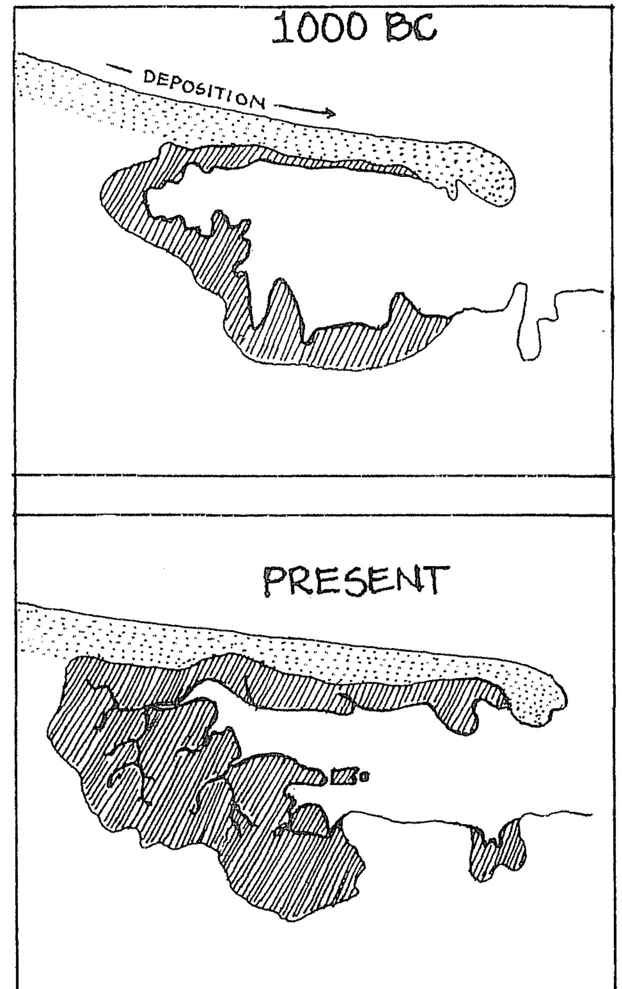
The salt marsh can be viewed as a "machine" transferring food and chemicals back and forth between the productive land systems and the open sea. As such, it fills a vital role in maintaining the physical-biological character of the near-shore area of the coast and in supporting the continued existence of fish, molluscs, lobsters, shrimp, and crabs in the deeper ocean waters.

The Massachusetts coast has several areas where extensive salt marsh systems occur. Large marshes are found in the estuaries of the Merrimack and Parker Rivers and on Plum Island. Salt marshes cover large areas of Massachusetts Bay in Saugus, Revere, and Quincy and smaller areas in Hingham and Cohasset. Marshfield derived its name from the broad marshes there. Further south, Duxbury also has large marshes. Extending to the tip of Cape Cod and along Buzzards Bay, salt marshes are tucked in bays and behind barrier beaches.

One of the most prominent Cape Cod marshes is Barnstable Marsh, four miles long and two miles wide, and located west of Barnstable Harbor. The history of Barnstable Marsh has been traced to its beginning approximately 11,000 years ago, some time after the glaciers retreated and when the sea was eighteen to twenty feet below its present level. (See figure)

This marsh is separated from Cape Cod Bay by a broad barrier beach built as sand was transported westward by the longshore current to form a spit across what is now Barnstable Harbor. Behind the beach in the calm waters, marsh grass seeds were able to germinate in the soft sediments that had been carried there by tides, rains, and rivers. Over many seasons, the decaying remains of marsh plants gradually accumulated. Under the living mat of vegetation, where high acidity and lack of oxygen greatly reduces the rate of decomposition, peat formed. The marsh grew along its landward and seaward edges.

The Barnstable marsh illustrates the process

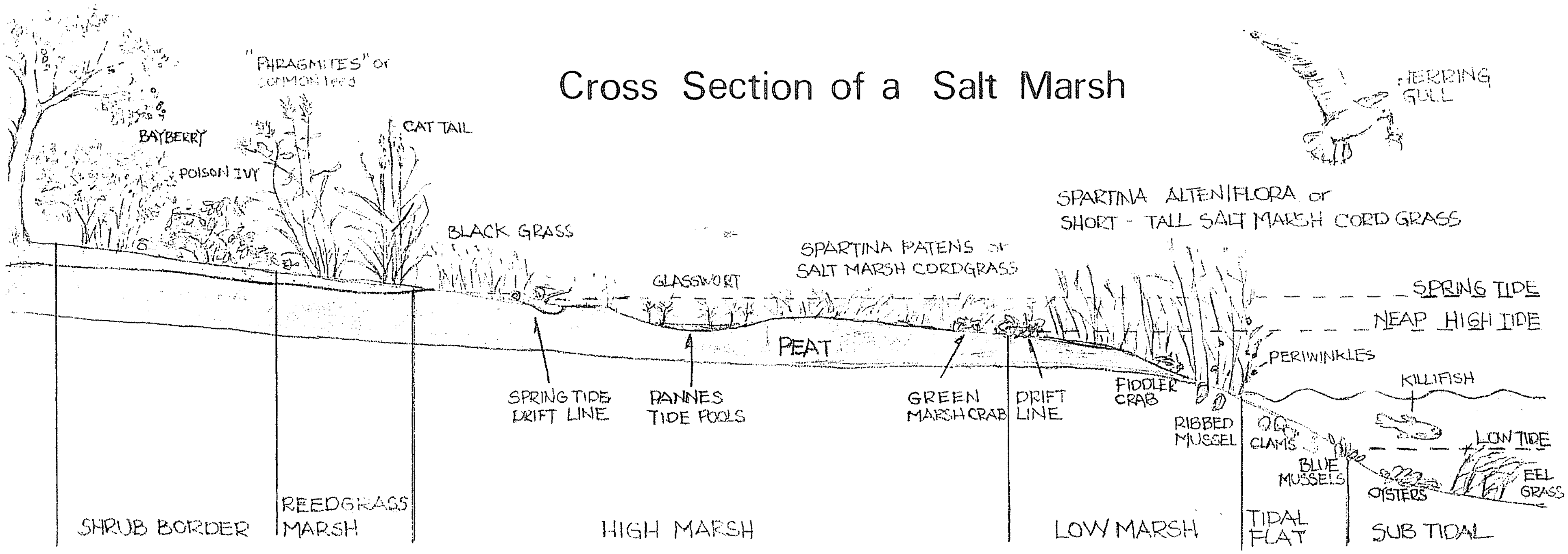


BARNSTABLE HARBOR*

Sand

Salt Marsh

*Adapted from A.C. Redfield in "Life and Death of a Salt Marsh" by J. Teal



One of the most productive ecosystems, salt marshes, are found in protected areas away from strong waves and currents. The spatial arrangement of plant and animal life is controlled by the tides, the plants of the salt marsh distributed or zoned according to differing exposures to salt water. Of particular significance is the border between the highly productive low marsh and the less productive high marsh or the upper limit of the areas inundated each and every day be the tides. Animals such as birds, fish, crustaceans, and mollusks likewise key their activities to the tidal ebb flow. In many Massachusetts salt marshes, a large portion of the plant productivity is carried off by tides and currents to be utilized by fishes nearby.

of salt marsh building as it occurs elsewhere along the coast where salt marshes have enlarged the coastal area and offered physical protection against storms and tides to more vulnerable shoreline features.

Research has confirmed the critically important role of salt marshes in the coastal zone. In West Falmouth, investigation of Great Sippewissett Marsh indicates that salt marshes export an abundance of food to coastal waters.

As in all biological systems, vegetation serves a variety of roles in the marsh. It is able to use solar radiation and nutrients to produce food; it reduces extreme temperatures, it transfers moisture from the soil to the air by means of transpiration; and it adds organic material to the marsh soil. While marsh plants use a large amount of the food they produce in order to survive in their rigorous environment, the remainder is available to be used as a source of nutrients by other plants and animals. This contribution can be substantial considering that each year, anywhere from five to ten tons of organic matter may be produced by each acre of salt marsh. Wheat fields, by comparison, yield one and one-half tons per acre per year; hay, four tons per acre per year, and deserts and oceans, one-third of a ton per year, making the salt marsh one of the most productive of all ecosystems.

Similar to most intertidal biotic communities, the salt marsh exhibits definite zones in the arrangement of its plant and animal species. (See figure) The limits of the marsh zones are determined by the plants' responses to varying salinity and the frequency of tidal flooding. This zonation is most easily seen in the occurrence of the marsh's two dominant plant species; the coarse, broad-leafed salt marsh cordgrass; and the smaller salt meadow cordgrass. The spatial occurrence of these two species marks, respectively, the extent of the low and high marsh zones. The high marsh zone is flooded only during extreme high tides and during storms.

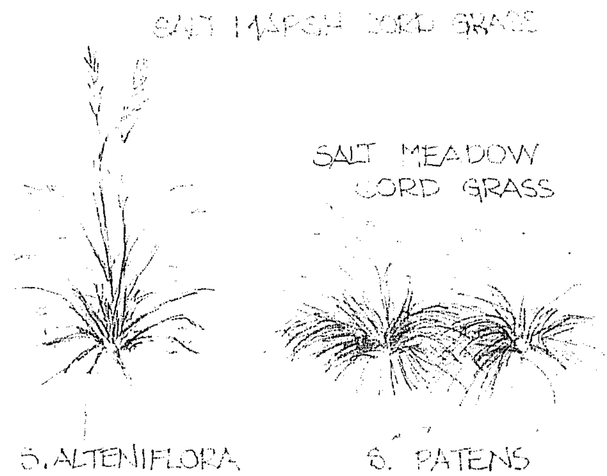
Bordering the upper zone between high marsh and land are found seaside goldenrod, blackrush and panic grass. Higher marsh ground that receives influxes of fresh water is often colonized by cattails and *Phragmites*—(reeds).

A most unusual plant species, glasswort, thrives in high concentrations of salt. It is often found within pannes, the shallow depressions in the high marsh filled by the flooding tide. Water is retained in the pannes, where salt concentrations rise due to evaporation, allowing glasswort to live without competition from plants that are less tolerant of salt.

Also contributing to the high productivity of the marsh, although not as obvious as the marsh grasses and border plants, are the microscopic algae that cover the muddy surface of the marsh. They appear as slicks of green and gold and are essential food sources for small invertebrate animals. These single-celled organisms are subjected to severe extremes in soil temperature and salinity, depending upon the season, the flow of the tides and the influx of fresh water. Since they are consumed by insects and crustaceans. Other deeper water organisms such as filter feeders utilize this food source as it is made available during tidal exchange.

Forming sizable mats, the blue-green algae appear throughout the year on the mud covering the tidal creek banks in the marsh and beneath the cordgrass stalks. These tiny plants are nitrogen-fixers, able to extract nitrogen from the air and convert it into a form that can be used by other marsh plants.

After the growing season, most of the plants die back and their leaves and stems become detritus. Decomposers, which are primarily aquatic bacteria, fungi, and protozoans, break down the detritus into minerals, gasses and water. Nutrient materials released by the decomposers are recycled and returned to the soil and water where they can be reabsorbed by plants. Broadleaf cordgrass decays more



THE SPARTINAS - THE MARSH MAKERS

quickly than salt meadow cordgrass because it is flooded daily and lacks any physical buffer to protect it from tidal destruction.

During the winter months, the algae continue to replicate their populations, supplying food to the marsh system. Marsh plants, bacteria, and animals consume only some of the available food energy produced in the marsh. The remainder is exported by the tides, rivers, and littoral drift to provide nourishment for life in the estuarine and coastal waters.

Many animals seek food, nesting sites, and shelter in the salt marsh. Clams, worms, and burrowing shrimps dwell in the tidal flats and marsh creek banks. At low tide, feeding crabs, shore birds, and insects explore these areas. Birds are attracted to the salt marsh in great numbers. Marsh hawks are year-round occupants. Marsh wrens, seaside sparrows, sharp-tailed sparrows, clapper rails, and others visit the marsh to nest and feed on snails, clams, crabs and minnows. Tidal creeks support the diet of great blue herons and snowy egrets. Insects and their larvae are plentiful and provide a suitable diet for birds and their young. Mussels, clams, and crabs are sought by larger birds and mammals. Marine animals follow the incoming tide to search for crabs, snails and worms. Bitterns and ospreys feed upon them. At low tide, marsh hawks and short-eared owls patrol the marsh in pursuit of mice and small birds.

In fall and winter, many migrating animals enter the marsh on their way to warmer climates. Herons, shorebirds, and other aquatic birds poke out worms, crabs, clams, and larvae living in the marsh mud.

Despite their importance to the general productivity of the coastal and oceanic environment, salt marshes have been disturbed in many ways by man. Thousands of acres of salt marsh have been destroyed by direct filling to provide sites for development along the shoreline. Other marshes have been used as convenient dumping grounds for dredged materials. Pollution, both in the water and in the air, can lower the primary productivity of marsh plants and interrupt essential nutrient cycles by destroying bacteria and animals species in the marsh.

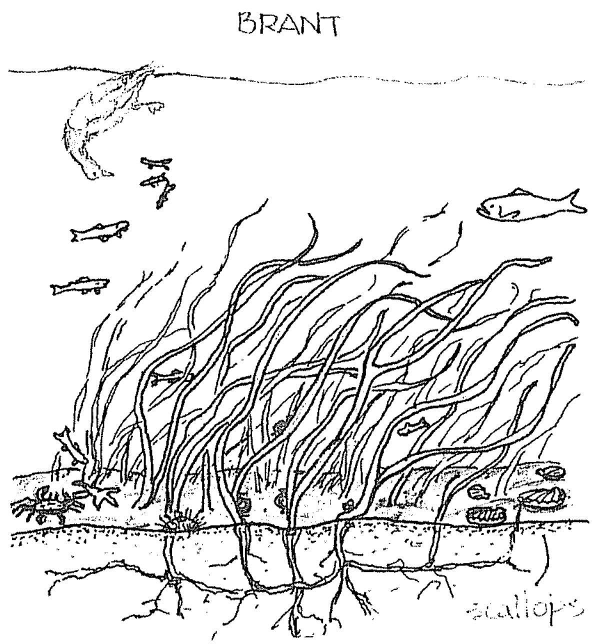
Stresses of all types are increasing. Management of salt marsh and related ecosystems is necessary if this most productive and important coastal resource is to continue its generous contribution to the ecological well-being and productivity of the coastal zone and ocean.

EEL GRASS BEDS

Beds of subtidal eelgrass are very important food production and nursery areas. This perennial plant is found in waters of varying salinity in depths ranging from just under low tide level to twenty feet below sea level in places where sunlight penetrates to the ocean floor, currents are not too swift, wave disturbance is low, and bottom sediments are favorable to plant growth. They flourish in salt ponds, bays, and at the mouths of estuaries and tidal creeks. Some of the more important eelgrass communities in Massachusetts are in Nantucket Harbor, Chatham Harbor, Buzzards Bay and off Cape Ann.

The character of the substrate is one of the factors determining the range of eelgrass. The plant prefers fine sediments ranging from sandy mud to fine sand. Where finer mud materials prevail, an overlay of protecting sand is essential to prevent moving water from stirring up and suspending particles of mud in the water, diminishing sunlight penetration, and thus reducing the productivity of eelgrass.

Eelgrass beds provide a variety of ecological services. They offer a substrate for other plant and animal life. They are consumed directly as food by grazing animals. They provide security to organisms requiring calm, protected waters and shelter from predators. They cycle nutrients in the subtidal coastal waters and provide a habitat for an array of marine animals such as winter flounder, pipe fish, scallops, brittle stars and jellyfish. They are a critical nursery area for bay scallops, which can only survive their first month of life by attaching themselves to eelgrass stems. Eelgrass nourishes the crabs, molluscs, worms, shrimps, and sea urchins which feed on detritus that the plants provide. Snails, crabs,



fish, and waterfowl feed directly on the leaves and stems and on the attached plants and animals. Brant geese depend on eelgrass as the singlemost important part of their diet.

Disaster struck the eelgrass beds of the North Atlantic coast in 1931. A "wasting disease" destroyed 99 percent of the standing stock. Brant and coastal populations of Canada goose and black duck declined rapidly when the grass beds were lost. Other marine populations—clams, crabs, and bay scallops—were reduced when their critical supply of eelgrass detritus and protected nursery grounds were eliminated.

In 1950, a small stand rejuvenated itself on the rocky shores of Cape Ann and the entire community of eelgrass organisms there once again stabilized. Eelgrass has also returned to other areas, such as Nantucket and Buzzards Bay, with the result that scallops and waterfowl have also returned in growing numbers.

Eelgrass primarily propagates by seeds and rhizomes as well as by the reestablishment of broken sections of plants. The growth rate and reproduction of eelgrass varies with the seasons because the plants are sensitive to water temperature. After a dormant or near-dormant period in winter, eelgrass growth accelerates in March or April, with flowering, seed development and seed germination occurring in May. While summer growth is rapid, warmer water temperatures discourage persistence of developed leaves and stems. During the summer months, these continuously break off and provide a supply of detritus for filter and deposit feeders. There is a brief resurgence of accumulated growth in the early fall just before colder conditions in November cause a general dieback of the stems and leaves, resulting in the release of the plant's largest contribution of detritus to other members of the eelgrass community. Because of the sensitivity of eelgrass to temperature, increasing use of coastal waters for power plant cooling, with its consequent thermal discharges, may alter the plant's life cycle. This would be especially influential during the reproductive period in May, when only slight variations from critical water temperatures could reduce flowering and seed development.

Other hardships for these plants to endure are the effects of dredging and the disappearance of the substrate in which they root. Increased silting and the flow of pollutants from industrial and urban wastes, sewage disposal, and oil spills further hamper the ability of eelgrass to survive.

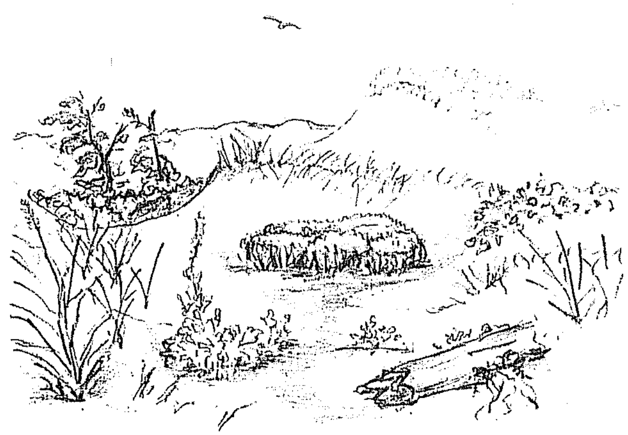
SAND DUNES

Sand dunes are most often seen in coastal areas where there is an abundance of glacial moraine material or where coastal currents have deposited sand carried from distant moraine sources. In Massachusetts, Cape Cod, Nantucket, Martha's Vineyard, and the Elizabeth Islands contain the greatest number and area of dunes. Dunes also are found on the North Shore along Plum Island, Boston Harbor and Plymouth.

Sand dunes offer a very unstable substrate for plants and animals because they are exposed to several natural stress factors, the most critical being the effects of freshwater availability, wind erosion, and wind-born salt spray.

The freshwater stress factor is caused by the porosity of the sand that allows rainwater to filter rapidly through it. Water held in the spaces between the sand particles is normally a reliable supply for the dune plants. During prolonged dry periods, however, only plants that have deeply penetrating roots or live on the dune's lower slope are able to absorb water from the deeper soil and groundwater zones in order to survive.

Wind erosion is both a creator and destroyer of dunes. Sand is blown from beaches to dunes and among dunes almost constantly, Where there is little or no protective vegetation on the dunes, sand moves in the general direction of the prevailing winds until it encounters an obstacle sufficient in size to trap it. Very often, sand shows a tendency to move away from the beach toward inland areas. The shifting mass of dune sand provides only a precarious surface for plants. Blown sand may even cover plants that have managed to establish themselves.



In cases where dunes front on the beach, storm-driven waves may wash over the beach berm and erode the dunes. (See figure.)

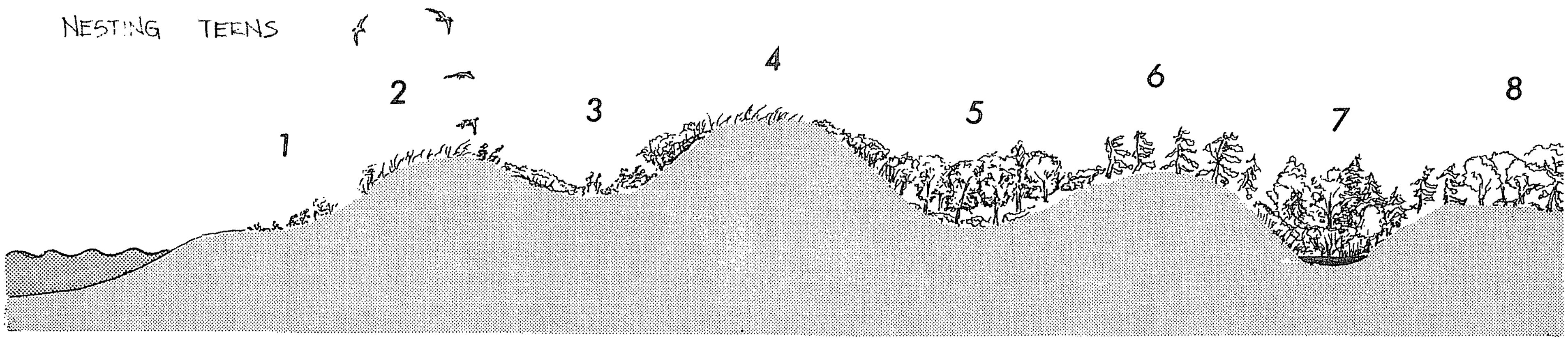
Winds carrying salt spray from the sea are a particular discouragement to plant growth on the dunes. Only plants that are adapted to the presence of salt by their growth form or physiology can survive.

In general, dunes lying inland from the beach are more protected and are, as a result, more fully stabilized by plant growth. There is a sequence of dune development from shore to inland that is analagous to the zonation of other coastal ecosystems. (See figure.) Similar to such other systems, the dune patterns or zones are disturbed by extreme storms and waves, and the physical abuse by people.

The dominant plant species of the sand dune is the American beach-grass whose scientific name, *Ammophilia*, means sand-lover. Its intricate network of roots and rhizomes anchors the sand, holding the dune surface in place. Waves transport sand to the shore, winds carry it inland, and the beachgrass stalks trap it. As sand accumulates, grasses grow up through it and the dune forms. Other species that can tolerate wind and salt are the beach pea, the seaside goldenrod, and the dusty miller. Behind the dune, a low depression called a slack or a swale occurs. This more sheltered environment is subject to less wind and salt damage. As successive dunes are created, those furthest from the reaches of the sea are more protected. The hardy species that flourish there, providing ground cover and dune stabilization, are bear oak, salt spray rose, beach plum, bayberry, poison ivy, beach heather, and bearberry. The inland dunes are known as secondary dunes as opposed to primary dunes, which are the first to be exposed to wave and wind action.

Further inland, woody shrubs are found on the back-slopes and in the low intervening hollows near the level of the groundwater table. The amount of soil moisture and the degree of exposure to salt spray are again limiting factors. The trees are staghorn and smooth sumac, gray birch, quaking aspens and young oaks. Among the lower shrubs, honeysuckle, blueberry and the wild rose form dense thickets. Scattered throughout the dune system are a variety of lichens, intimate associations of fungi and single-celled green algae. These grey-green, tangled masses grow on tree trunks and branches and on moist soil, helping to keep it in place. These dune communities are well protected and can be considered forerunners of maritime forest.

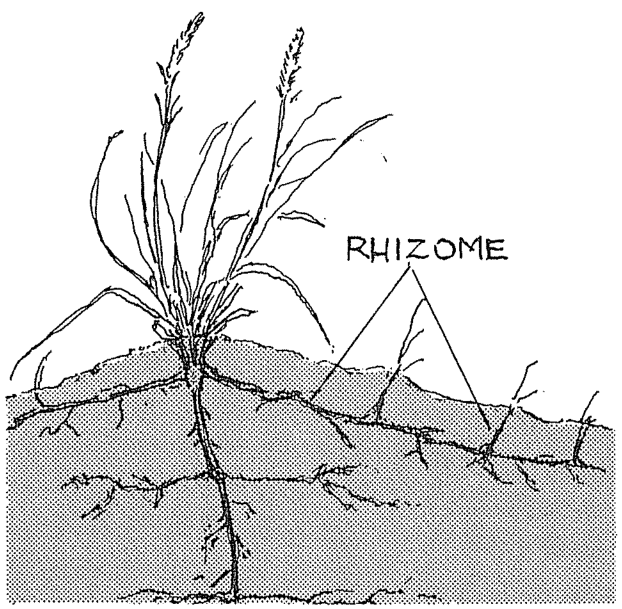
DUNES CREATE HIGHLY VARIABLE CONDITIONS FOR PLANT LIFE



1. The beach face is a very difficult environment for plants, being exposed to salt spray, intense sun and direct wave action. Sea rocket and seaside spurge, beach grass, and beach pea are adapted to the difficult environment.
2. The Fore Dune. High exposure to salt spray. Beach grass, beach pea, dusty miller, and seaside goldenrod.
3. Swale or interdune depression. Some protection from salt spray. Beach heather and poison ivy among others can be found here.
4. The high dune or primary aune. Exposure to salt spray. Dessication can be a problem over dry periods since the water table is deeper.
5. Under the protection of the high dune, the maritime forest begins to flourish, forming shrub thickets. Staghorn sumac, beach plum, honeysuckle, bayberry, wild rose and others predominate.
6. In many places on the Massachusetts Coast, most notably Cape Cod, nearly pure stands of pitch pine can be found on the more protected areas of the back dunes.
7. Swamp. Low interdune areas offer good protection from the ocean's influences. Red maple, tupelo, alders, shadbush, and willows grow in this moist environment. Occasionally, stands of white cedar are found in these fresh water swamps.
8. Mature maritime forest. Well protected from salt spray, but still subject to occasional exposure, are species associated with a mature maritime forest Black oak, black cherry, pitch pine, quaking aspen, red cedar, sassafras, and American beach grow well here.

Still further inland are swamps and bogs which originated in low interdune areas or perhaps at scenes of wind blowout. Primary species are red maple, black tupelo gum, alder, arrowwood, highbush blueberry and willows.

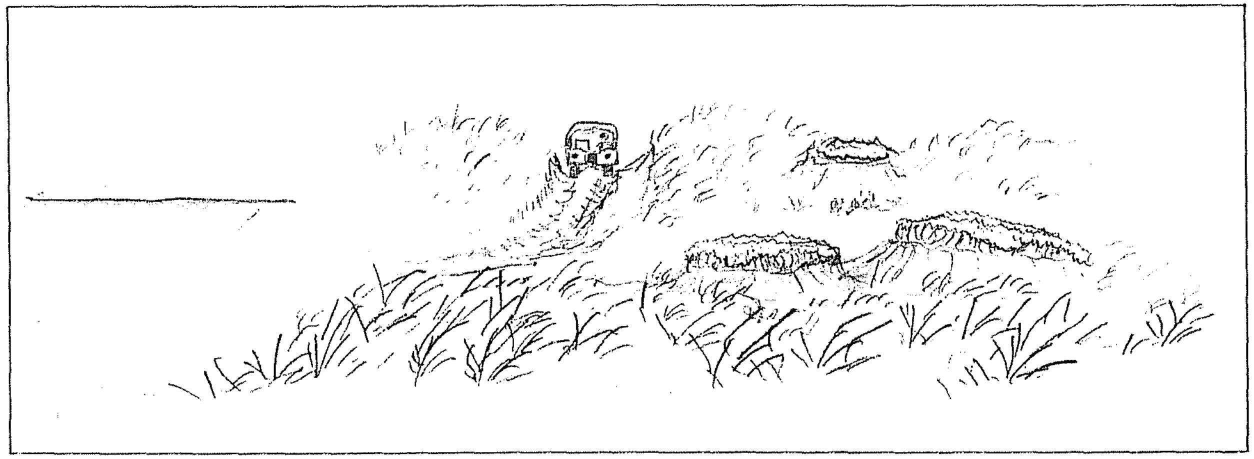
The most mature stage in the development of the sand dune community is the coastal maritime forest. The dominant species are black oak, red maple, American beech, black cherry, grey birch, quaking aspen, shadbush, red cedar, and sassafras. Stands of pitch pine and the exotic Japanese black pine are other features of coastal maritime forest. Pitch pines are not very resistant to salt damage. Their branches and tips are deformed by the pruning effects of salt spray. The Japanese black pine is salt-resistant, however; large numbers of seedlings of this species are being planted along the coast. Falling pine needles acidify a soil that is fertilized by minerals from salt spray. Acid-dependent plants such as blueberries, lady slipper orchids, partridge berries, and indian pipes are typical ground cover under the pines.



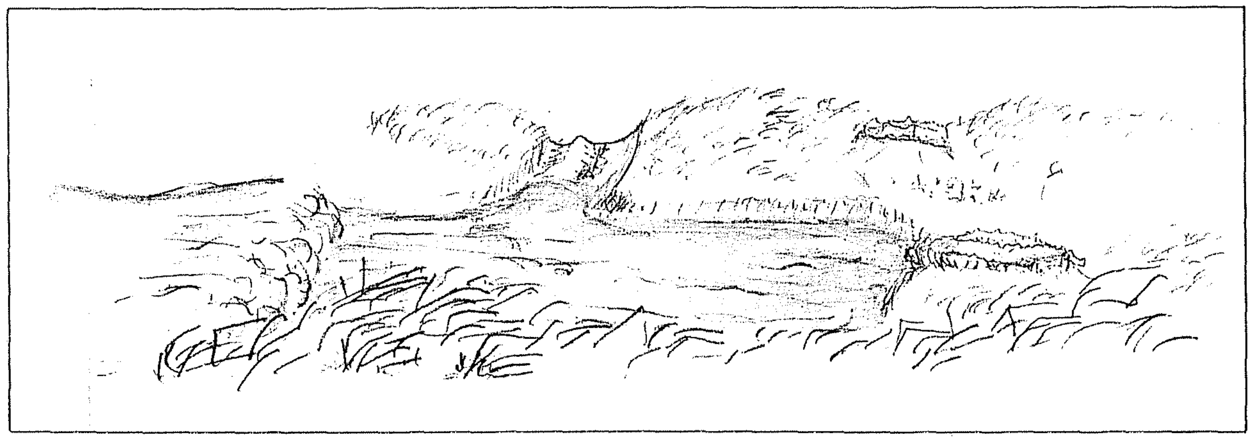
Dune ecosystems are very sensitive to the effects of human use. The abrasive action of foot and vehicular traffic is especially destructive. Repeated use of dune areas for impromptu paths and roads causes the destruction of beach grass communities and the subsequent reduction of dune stability.

Mining of dunes for builder's sand often changes their shapes and slopes, making wind and water erosion more severe. Increased movement of sand from one dune system to another can upset the fragile balance between wind force, gravity, water, and vegetation, causing loss of stability on the mined and neighboring dunes.

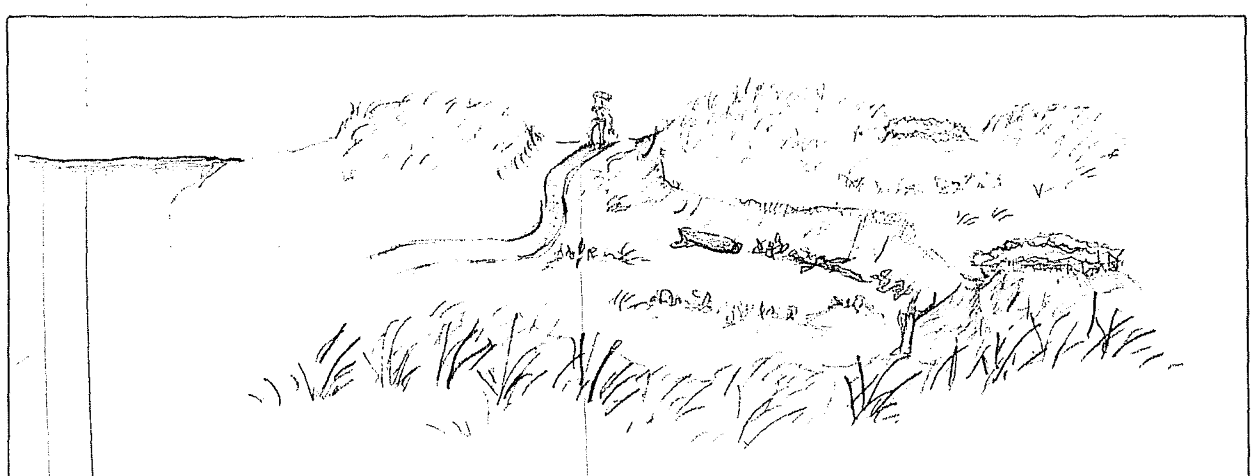
1. The dunes are very sensitive to man's influence. Both vehicular and pedestrian traffic crush the sensitive roots and stems of the otherwise hardy beach grass. With the anchoring ability of the grass gone, the wind blows away the loose sand, leaving a breach in the dune face.



2. Storm driven waves are now able to penetrate deep into the dunes, levelling mounds and filling depressions with sand.



3. The storm carries its own seeds for regeneration. Along with debris, the waves carry in seeds of beach grass and plants such as beach pea, sandwort, and sea rocket which germinate and begin to stablize the shifting sands and rebuild the gap in the dunes. Simple wood plank walks in place of roads or paths substantially reduce traffic damage to the plants and enables the regeneration process to continue.

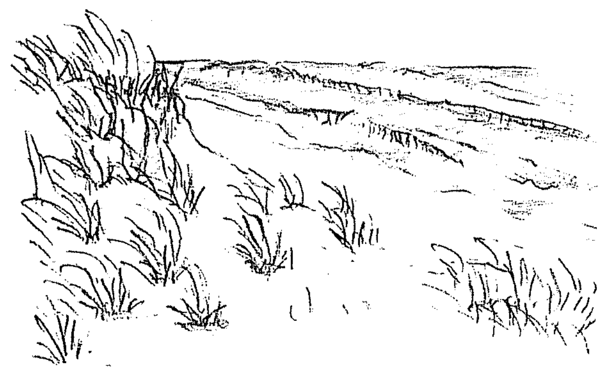


SAND BEACHES

Sandy shores are the most physically stressed, and consequently least productive, coastal ecosystems on the Massachusetts shore. Similar to rocky shores, the sand beaches are fully exposed to wave and tidal energy. Unlike rocky shores, the substrate is unconsolidated and unstable. Higher plants can find no anchorage, so that only unicellular algae are present to manufacture food within the beach ecosystem.

Sand beach environments are found from the North Shore to the Cape and islands. They are most prevalent where glacial materials are present to contribute sands, gravels, and cobbles for beach formation. Some sand material is also derived from inland erosion that is delivered by rivers to the coast. Only the Merrimack River is important in this regard in Massachusetts. The major stress factors influencing the lives of sandy beach plants and animals are high wave energy and summer drying and heat. The surface materials of sand beaches are subject to almost continuous movement. Wave and tidal forces shift sand up, down, and along the beach. From time to time this sand movement exposes or buries beach organisms. Washing by waves cleans the sand of water-holding organic and fine mineral particles, allowing rapid drainage. In the upper intertidal beachwater drainage may leave the beach community without moisture at low tide, and thus subject to high temperature stress.

Because there is so little opportunity for food-producing plants to exist on the beach, animal life is supported by imported detritus that originates, for example, in the highly productive salt marsh and eelgrass



ecosystems. Few animal organisms are adapted to the strenuous sandy beach environment, though their population may be high where coastal currents, tides, and waves are effective in importing a detrital food base. Most beach animals are filter or deposit feeders that must live below the surface of the sand, extending their siphons and tentacle plumes into the flooding tidewaters for feeding. Crabs and snails also emerge from their burrows on the incoming tide to search for food. Beach fleas, flies, crabs, and beetles flourish along the high tide line where they feed on the detritus left by the retreating water.

Terns and gulls find the high beach a suitable nesting site with nourishment for their chicks nearby. Gulls commonly carry scallop and clam shells to nearby roads and parking lots where they can be dropped and easily shattered, their meat quickly eaten.

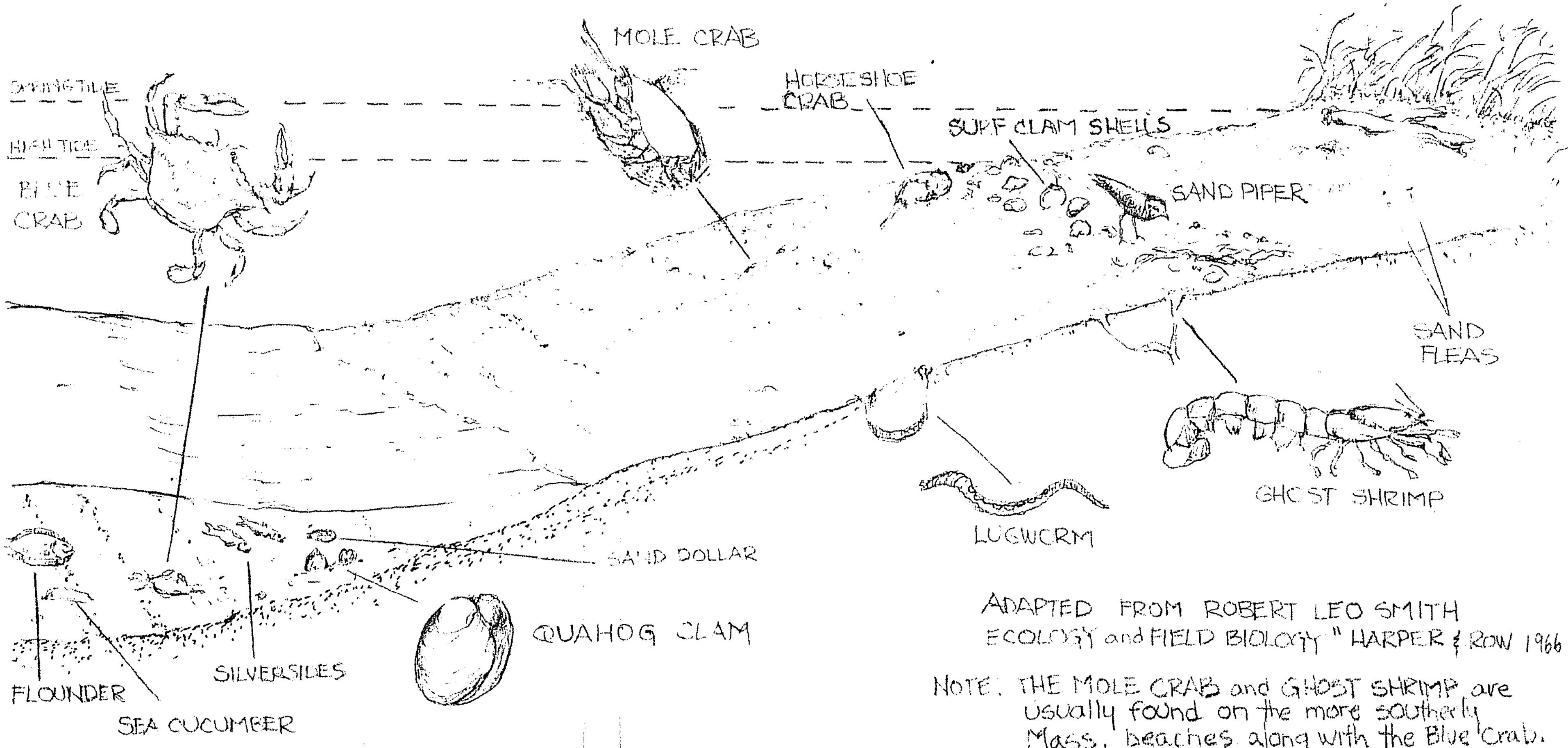
Seasonal stresses greatly influence sand beach organisms. Winter storms inflict severe damage by slashing away the sediments, carrying them downshore or to offshore bars, and flattening and narrowing the beach profile. As summer approaches, these deposits are shifted back and the beach rebuilt. As waves transport sediments to the shore from bars and shoals, the beach profile becomes wider and steeper. (See figure)

These changes in amounts and movements of beach material cause migrations of intertidal animals which seek less physically demanding environments and more reliable detrital food sources. Other major population changes in numbers or species relate to the success of annual reproduction--a high risk event in the difficult beach environment.

Beach organisms are especially sensitive to disturbance by vehicular traffic. Nesting birds are put under stress by traffic. Nests are sometimes destroyed, particularly those of terns, which prefer the more open lower beach where traffic is heaviest.

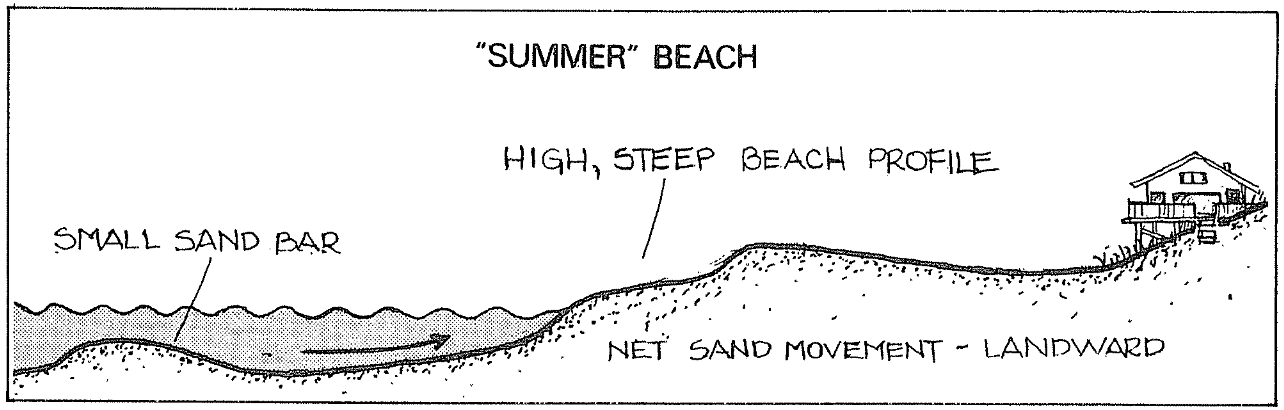
In some instances groins have been successful in retarding beach sand erosion in those areas where they have been built. But at the same time they prevent sand from moving naturally along the beach front, sand which would normally nourish beaches and spits further down the beach. This not only disturbs the equilibrium of the beach system but also interferes with the wishes of property owners who are trying to maintain their beaches downdrift from these structures.

A Section of Sandy Beach

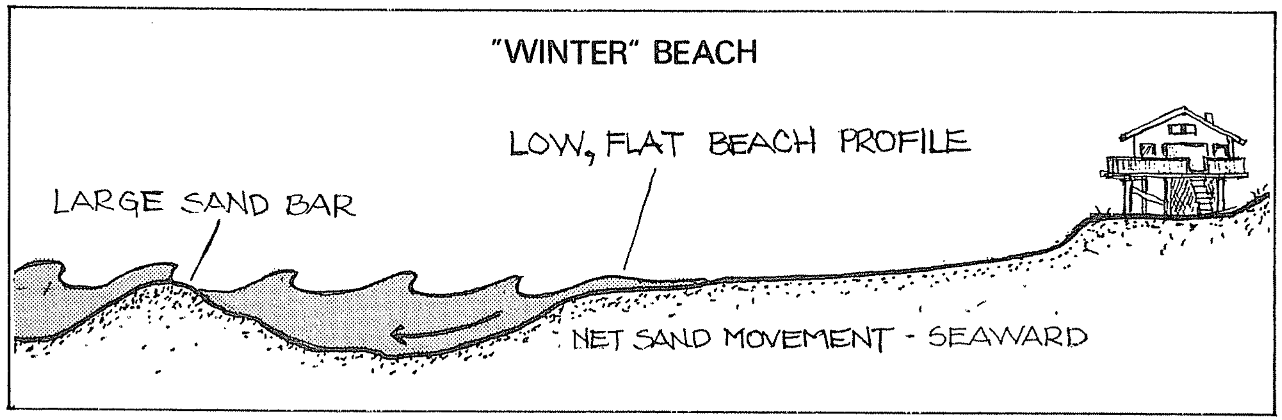


Only species adapted to the constant stress of pounding waves and shifting sands can inhabit sandy beaches. It is an ecosystem that produces very little of its own food and depends on the tides and waves to import organic matter. The animal species are generally small in size, have a low diversity, and are subject to wide fluctuations in populations.

Most sand beaches are very susceptible to weather changes over the seasons. During periods of calm weather, usually during the summer months, the gentle wave action causes a net sand movement onto the beach. This normally creates a high steep beach profile with a steep scarp at the water's edge and a small offshore sand bar.



In contrast to the calm conditions of summer, winter often brings numerous storms and powerful, erosive waves. The winter beach face is characterized by a low flat profile with the scarp much further back on the beach face and a large sand bar off shore. A caution to property buyers: before buying beach front property be sure to inspect the property after stormy conditions when the beach is likely to be reduced in size.

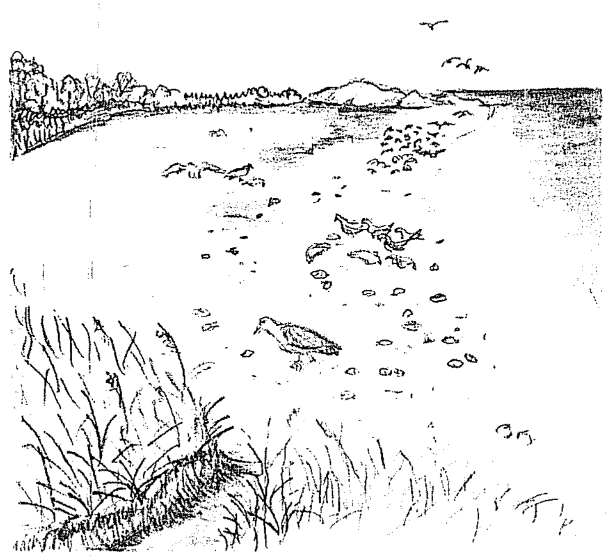


TIDAL FLAT

Tidal flats, also known as clam and worm flats, are common along most of the Massachusetts coast. They are found in estuaries, quiet bays, in back of barrier beaches, and in salt ponds. They also occur below the depth of wave disturbance along more open shores in very large embayments such as Buzzards Bay. These shallow, sloping flats exist in a range of salinity from sea water concentrations on the coast to less than one percent salt in the upper estuarine area. The substrate is composed of materials ranging from very fine silt and clay to coarse sands. In quiet waters, there is usually an accumulation of fine detritus mixed with mud. It is the combination of salinity, substrate quality, and the character of water movement over the flat that determines the species composition of the plant and animal community.

Major natural stress factors are those of salinity and temperature change. In estuaries especially, organisms may suffer from changes in salinity when fresh water flows are strong at low tide periods. Rainfall on exposed flats also produces low salinity stress. In summer exposed flats experience rapid rises in temperature and in winter the surface may freeze. There also may be stress from storms when increased currents, tides or waves may shift the otherwise stable sediments of the flats. Heavy accumulations of organic material in the mud flats can result in partial to complete removal of oxygen from the substrate.

Large plants do not take hold on the flats because of the arduous nature of the sand-mud environment. Instead, most of the plants are microscopic algae, and fungi that can tolerate surface exposure and do not need a physically stable surface on which to grow. The algae often migrate between the substrate surface at



low tide to the upper water layer at high tide. Most of the animals of the flats have adapted to daily environmental stress by burrowing beneath the exposed surface during low tide or by living there at all times. The algae of the flats are important food producers but they do not provide fully for the needs of the consumer animals.

The movement of tidal water as river currents carries the major supply of food, consisting of detritus and plankton, for these communities. This food source, the product of other coastal systems such as salt marshes and eelgrass beds, is capable of sustaining a high population of tidal flat animal life.

The population density of these animals is astounding. Measurements taken on intertidal flats at Barnstable Marsh indicate that the number of benthic animals range from 7,000 to 355,000 per square meter, with the gem and soft shell clams found in great numbers.

Mud flats rich in organic matter are usually found further up the estuary than sand flats and where sluggish currents permit detritus to settle on the bottom. When the flats are exposed at low tide, the animals retreat below the surface to escape dessication. Burrowing also is used for protection against summer heat and winter cold. Mud flats, which often are nearly even in grade level with low tide, drain and dry more slowly than sand flats.

The species of animal life in the tidal flats vary according to the proportions of sand and mud making up the area. This is typified by the distribution of clams on the Massachusetts coast. A familiar clam of the mud flat is the soft shell clam. When the substrate is made up of equal parts of sand and mud, the quahog or little neck is the most common species. In purely sandy habitats, razor clams can be found.

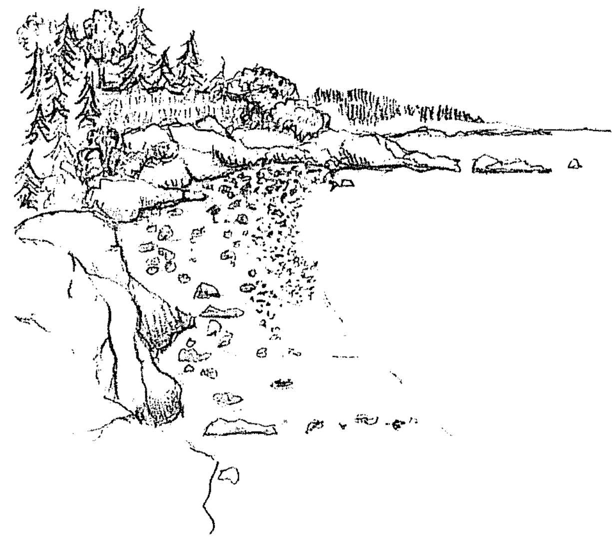
The distribution of animal species is also a response to salinity gradients. In areas where there are extreme fluctuations of salinity—the North River, for example—soft shell clams burrow deeply into the mud, which offers protection both from varying seasonal salinities and from predators. The quahog clam dominates some small bays and salt ponds of Cape Cod. Burrowing marine worms are adapted to the highly saline bays such as Rand's Harbor in Buzzards Bay. A particularly attractive species, the clam worm, a blend of blue-green and orange red, is a prized bait of fishermen. The fringed worm is only a partial burrower, extending its brightly colored tentacles above the sand surface to capture food and oxygen. The lugworm digs a U-shaped tunnel beneath the surface of the sand, using one end for feeding and the other for discharging wastes. Parchment, tube, and trumpet worms can also be seen on the flats, along with snails, whelks, and hermit crabs.

Feeding styles vary among the tidal flat animals in order to take advantage of algae and detritus that settle on the sediment surface or are suspended in overlying water. Many of the mud flat worms are deposit feeders, ingesting detrital remains and diatoms and other single-celled algae. Clams, on the other hand, are usually suspension feeders and their diet includes microscopic plants, detritus, bacteria, fungi, and yeasts which they extract from the water. The lugworm and sea cucumber ingest a large amount of sand and mud in feeding, retain nutrients and release undigested particles. Mud flat animals are directly important to the nutrition of larger fish. The winter flounder, for example, enters the flats on the incoming tide to feed on the exposed worms and molluscs. In that sense, the tidal flat animals act as a critical link between the primary production of the salt marsh, eelgrass, rocky shore and plankton communities and the desired sport or commercial fishes.

Tidal flat ecosystems are subject to several major stresses resulting from human use of the coastline and estuaries. Some forms of industrial and domestic pollution may cause direct losses of animals and plants through toxic action or the reduction of oxygen through the deposition of high amounts of organic wastes. Accidental spills of petroleum or petro-products also destroy tidal flat organisms. Sedimentation caused by upstream erosion may bury sand and mud flats, cutting off the burrowing and tube organisms from oxygen and food. This problem may be seen in the extreme where materials from dredging have been disposed on tidal flats. Finally, use of the tidal flat for vehicular traffic during low tide can compact the surface and crush many of the subsurface animals.

Clamming on tidal flat Salem

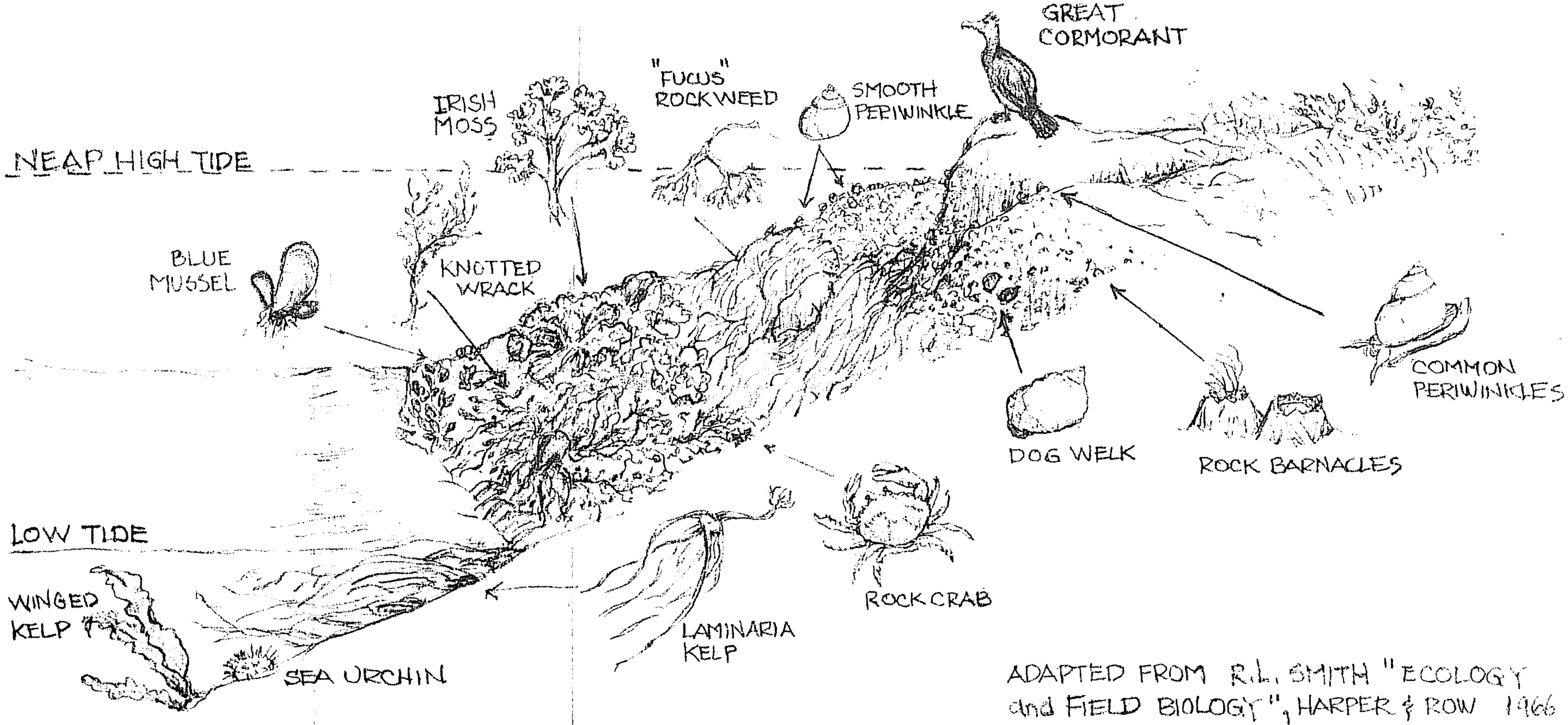
ROCKY SHORES



Rocky shore ecosystems are found all along the Massachusetts coast. They develop on the exposed faces of rocky headlands, such as those of Cape Ann and the North Shore, or on boulders and cobbles derived from moraine materials in places along the South Shore, Cape Cod, and the Elizabeth Islands. Rocky shore communities also occur on such man-made structures as rock jetties, groins, piers, and rip-rap.

Rocky shore ecosystems are typically exposed to great physical stress. Because the rock substrates on which the plants and animals live are usually steep, the effect of low tide exposure is intensified by rapid drainage. Without the ability to retreat below the surface at low tide, the animals and plants of the higher

A Section of Rocky Shore



The many plants and animals associated with the rocky shore have adapted to their difficult environment by developing means of firmly attaching themselves to rock. The tides determine their distribution or zonation by the amount of exposure to the elements that a particular species can endure.

zone of the shore endure periods of exposure to the drying action of wind, sun and summer heat. During rainstorms at low tide, the organisms are subject to the stress of low salinity. During winter, ice flows may scour the shoreline, and at all seasons of the year organisms of the rocky shores are buffeted by waves.

Cradled within and growing on the face of water-worn boulders and cobbles, plant and animal organisms adapt to zones that meet their respective sensitivity to tidal exposure. (See figure .)

Larger forms of algae play a dominant role in the productivity of the rocky shore ecosystem. They can be seen at a variety of elevations within and below the intertidal zone. These complex algae have no roots or rigid stems but fasten themselves to the rock-face with structures called holdfasts. Observation of the rocky shore community from the zone above the high spring tide level (the splash zone) reveals blue-green algae which leave a slippery scum on rocks and shells, and black lichens. Nestled in rock crevices, the rough periwinkle makes its home. Below this zone lies an area where barnacles abound. They provide a steady diet for the dog whelk, a carnivorous marine snail. Lower down are attached rockweed and knotted wrack, a brown algae that shelters mussels, smooth and common periwinkles, crabs, and limpets (snails with conical shells). Green algae here include the common sea lettuce. Red algae such as Irish Moss, sea laver, and dulse also appear. Grazing through this zone are crabs and sea urchins.

Large brown kelps make their home in subtidal waters that receive little light. Kelp plants attach themselves securely to the ocean floor by means of a holdfast. Sea urchins are very active predators on kelp beds, grazing heavily upon the holdfasts and the long stems, called stipes. Other grazers in the kelp community are snails, crabs, and shrimp. Many fish species, from larval to juvenile and adult stages, search kelp beds for food and shelter.

Tidal pools are a biologically interesting rocky shore subsystem and an important aesthetic, recreational, and educational resource found along parts of Cape Ann and the North Shore. Here are found coastal organisms that survive in depressions and catchments which usually occur at or above high tide level. They are exposed to little tidal action. Some are filled only by splashing waves and rainfall. Sea urchins are usually present in abundance; edible blue mussels are lodged in the sand, marine worms in their burrows, and sea anemones, dog whelks, and snails can be seen.

One of the most striking aspects of rocky shore plants and animals is that they live on a solid substrate. This means they must exist on a surface fully exposed to the stress of tides, waves, and currents. There is no opportunity to maneuver for living space above or below the surface as do organisms of sand and mud flat communities. Many of the plants and animals are long-lived and permanently anchored. Compared to other coastal systems, rocky shore animal populations exhinit less annual or seasonal change in numbers.

Also, unlike other coastal ecosystems, rocky shore communities use or retain very small quantities of the nutrients they produce. Because there is so much tidal and wave energy released against the rocky shore, much of the food material produced by the plants and animals is carried away as detritus and becomes part of the food chain for fish, crustaceans, and molluscs found in the open water or on nearby tidal flats and sand beaches.

The most significant man-induced stresses stem from the problems of pollution from domestic or industrial sources and the occasional oil spills common in most working harbors. Such stresses are most often noticed when the source of pollution is near the rocky shore community. The movement of water on and against the rocky shores tends to carry away pollution loads. Only constant exposure to high concentrations of pollution will bring about degradation of the rocky shores ecosystem. Spills of oil are an important problem because petroleum tends to adhere to the rocks and to the organisms themselves, resisting transport and dilution by waves and currents.

COMPOSITE ECOSYSTEMS

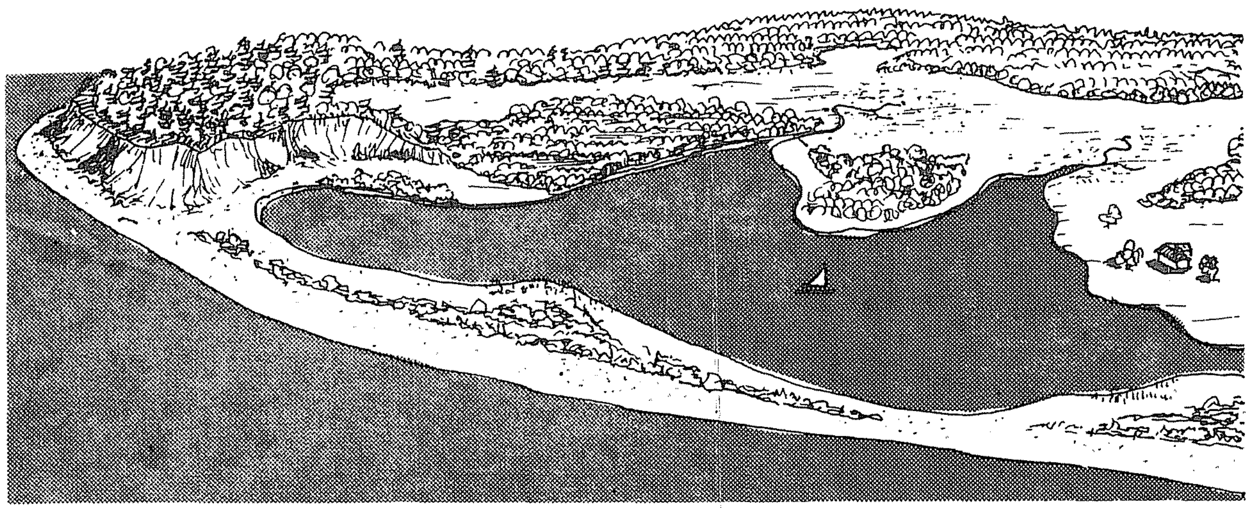
There are three major composite ecosystems found along the Massachusetts coast. Each of these contains two or more of the previously discussed ecosystems. The composite systems are characterized by high diversity and include in each case a high proportion of the most productive communities, such as eelgrass beds and salt marshes. The three composite communities are salt ponds, barrier beaches-islands, and estuaries.

SALT PONDS

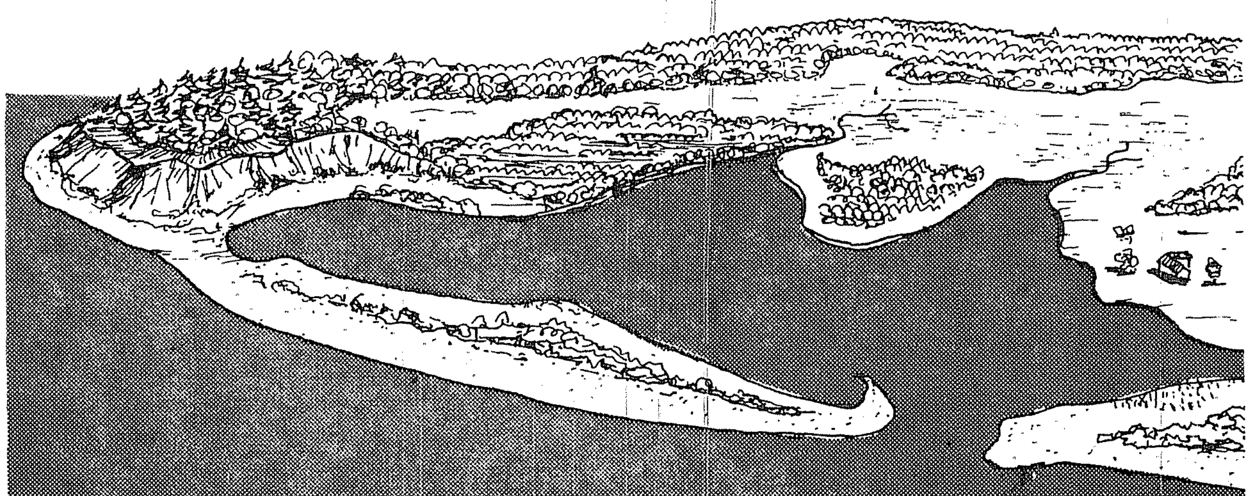
Salt ponds are shallow, tightly-enclosed bays formed as the result of glacial action or from sand spits closing off shallow bays. They typically developed from kettle-hole ponds that have narrow openings to the sea all or part of the time, and are therefore exposed to the influence of tidal exchanges of fresh water and salt water.

Since sunlight often penetrates to the floor of the ponds, they tend to constitute a photosynthetic zone from surface to bottom. On the basis of surface area and volume, they are therefore among the most productive systems on the coast.

Good examples of salt ponds in Massachusetts are found on Nantucket, Martha's Vineyard, the south shore of Cape Cod and along the shore of Buzzards Bay.



Occasionally a barrier spit or barrier beach will develop across a bay or inlet creating a salt pond that is isolated from the ocean. Once cut off from tidal flows salt ponds will gradually develop a brackish layer of water on the surface as fresh water accumulates in the embayment. This usually causes a drastic change in the environment of plants and animals accustomed to ocean level salinities.



Storm driven waves may breach the barrier, opening up the salt pond to tidal influences. Often the barrier is cleared by dredging when local residents wish boat access to the ocean or to reintroduce marine animals such as shellfish.

Ecosystems commonly associated with salt ponds are salt marshes, tidal flats, eelgrass beds, and to a lesser extent elements of rocky shores. This latter system often occurs where the construction of harbor and navigation works have created rock surfaces similar to natural outcrops and boulder faces. One of the most important ecologic aspects of the salt pond is its interdependence on various other productive ecosystems to permit the constant exchange of food and minerals between communities such as eelgrass and saltmarsh and colonies of crustaceans, shellfish, and worms found on tidal flats.

Eelgrass is a particularly important producer in the salt pond system, where conditions promoting its growth include the penetration of sunlight, a quiet substrate on the floor of the pond and a dampening of the effects of tides and waves.

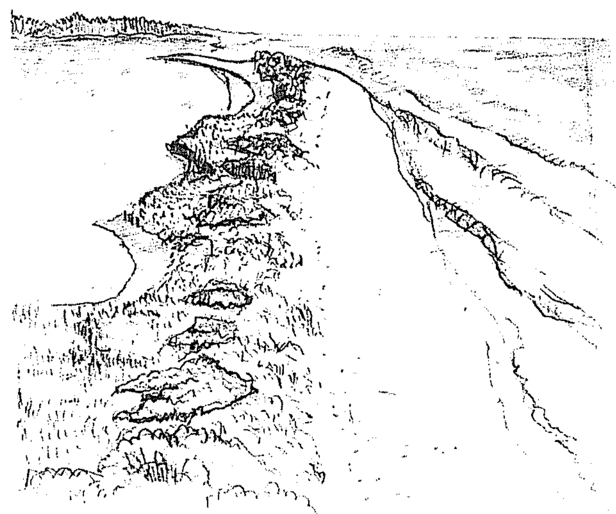
In some instances, sandbars created by the movement of adjacent dune or beach sands may close the salt ponds' shallow openings to the sea. When this occurs, there may be a natural stress on the salt pond system because of the influx of fresh water and the absence of tidal salt water exchange. Where the openings are closed for several months, the influx of fresh water may be sufficient to change the basic chemical environment to the point that all the shallows of the salt pond are transformed into a freshwater environment. While this phenomenon can and does cause mortality among the animal organisms of the shallows, such as oysters, clams, mussels, and marine worms, it usually does not last long enough to completely or irreversibly change the character of major plant communities.

Some of the important species of fish that occupy salt ponds are menhaden, scup, tomcod, winter flounder, white perch and tautog.

The ponds are also important as habitat for many kinds of water fowl, particularly black ducks, greater scaup, golden eye, Canada goose and mute swan. All the gulls and terns common to the Massachusetts coast also inhabit the salt pond community. Since they provide suitable growing conditions for eelgrass, salt ponds are a particularly important habitat for the bay scallop, now harvested on a commercial scale in salt pond areas.

In many instances, stresses on salt ponds are the result of human activity in adjacent areas. Almost all salt ponds in Massachusetts are near coastal communities and are used for recreational or commercial water traffic. The principal man-induced stress is the repetitive dredging of navigation channels and basins, necessary because the salt ponds are usually shallow and rapidly reshoal following dredging operations. Agricultural, domestic, and harbor wastes are especially damaging to the salt ponds because their circulation and low tidal exchange prevent nutrients and other pollutants from being flushed out of the salt pond system. There is a tendency for pollutants to build up in salt ponds to levels that adversely affect all forms of filter feeders and deposit feeders, rendering them unfit for human consumption or jeopardizing their survival. Such pollution is more apt to affect animal than plant life, which results in the failure of intermediate and low-level consumer groups such as clams, worms, and small fishes to transfer the products of eelgrass beds and salt marshes to the populations of larger fish.

BARRIER BEACHES—ISLANDS



Barrier beaches are built from sand and gravel transported by waves from a sediment source. They typically begin as sand spits that grow out from and parallel to the shore. Barrier beaches become islands when their connection to the shore has been breached by storm waves. Barrier islands and beaches are usually long and narrow and may have low elevations barely above high tide level or may contain high dunes.

Seen in cross section from the open sea to land, barrier beaches are composed of four major elements: a sand beach made up of an intertidal shoreface zone, a foreshore beach and a steep berm; dunes; a shallow sloping zone usually containing salt marsh; and a lagoon or salt pond separating the beach from the mainland. Ecosystem components that typically may be found are salt marsh, tidal flats, and sand dunes. On larger more developed barrier beaches stands of maritime forest can be found.

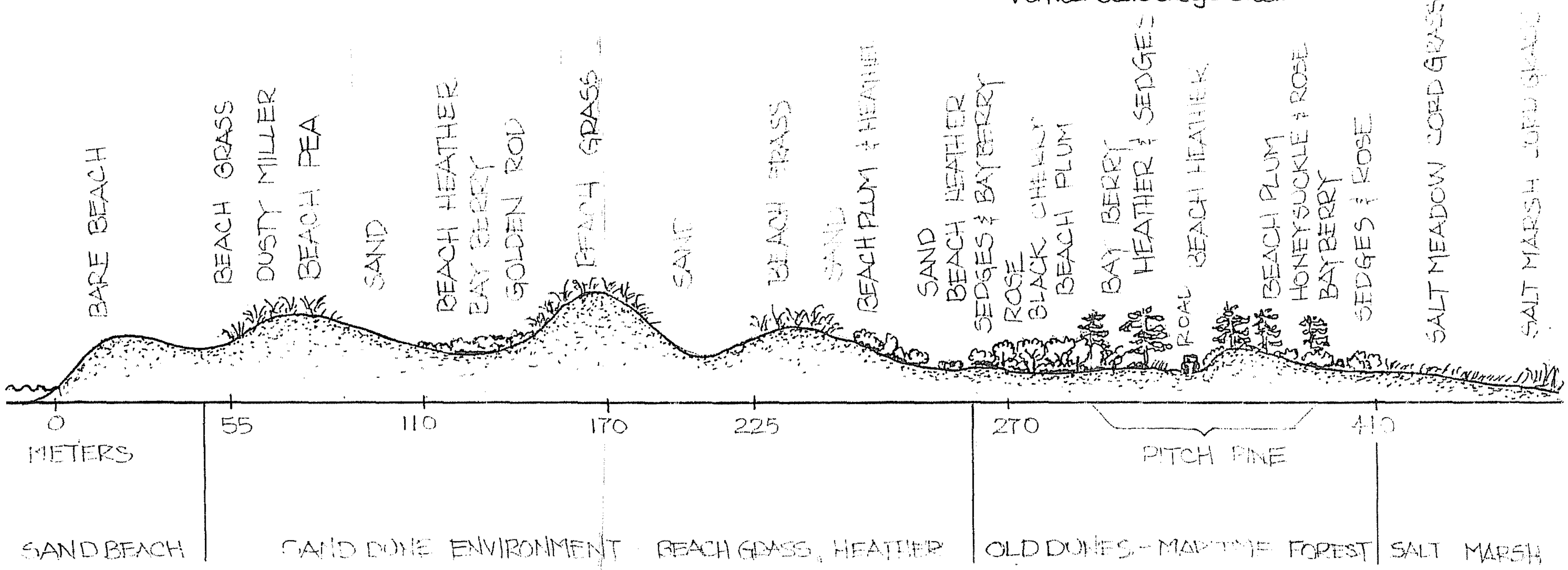
Major examples of barrier islands-beaches in Massachusetts include Plum Island, Duxbury Beach, Cranes Beach, Sandy Neck, Nauset Beach, Monomoy Island, Coatue Beach, enclosing the Nantucket Harbor salt pond, the south beach on Martha's Vineyard, and Horse Neck Beach.

Barrier beach systems, like sandy shores and dunes of the mainland are subjected to the erosional stresses of storm waves and winds. Because they are composed of materials that are easily eroded and transported by wave and littoral drift, their beach area and contours often change dramatically during and following stormy periods.

Washover is a very important event for the barrier island system. This occurs when heavy storms drive the sea across the island from foreshore to the marsh or lagoon. It is by this means that sand is carried up on and over the barrier above the high tide level. Washovers also carry sand from the barrier beach to the lagoon to create shoals and deltas. Where such washover deposits are placed on old salt marsh, dunes may form on them. Where deposits occur in the lagoon new salt marsh may form. While there is some loss of communities that are buried by the washover deposits, new communities arise to replace them and overall this process results in the slow migration of the barrier beach system toward the mainland.

CROSS SECTION of a BARRIER BEACH

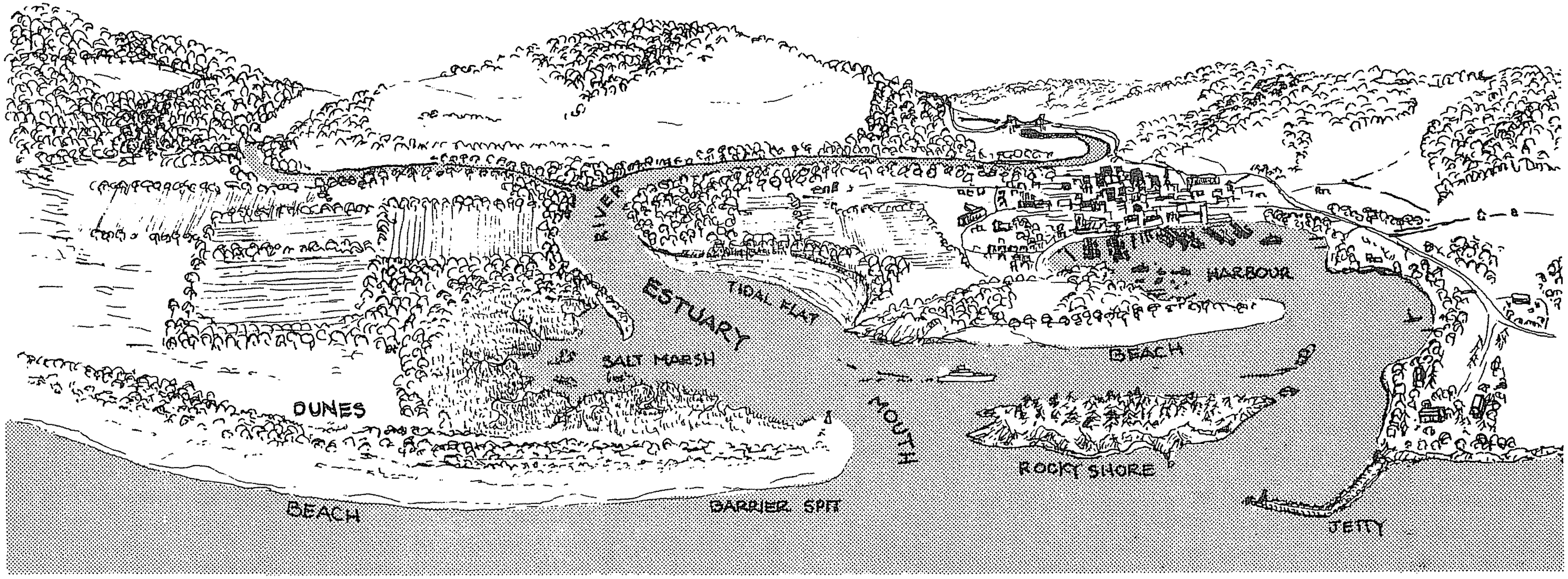
Adapted from Godfrey and Godfrey, Univ. of Mass.
"General transects across Plum Island"
Vertical scale exagerated.



Plum Island is an example of a well developed barrier beach system that has such features as salt marshes, sandy beaches, dunes and maritime vegetation. Some rocky shores created by the erosion of a glacial drumlin are found at the south end of the island.

The transect taken across the island demonstrates the changes in vegetation as one moves from the exposed beach to the more protected bay side. Research has shown that about 6,000 years ago the gradual rise of the sea level eroded glacial deposits off shore forming the barrier beach system. As the sea level continued to rise, the barrier beach system has been gradually pushed landward by the process of overwash and dune migration.

Major human stress factors on barrier beaches are much the same as those affecting beach and dune environments. Many of the State's important barrier beaches and islands have been publically acquired and now receive protection from most destructive forms of human use. Plum Island and Monomoy Island are National Wildlife Refuges. The National Park Service owns Coast Guard Beach and Jeremy Point. Horse Neck Beach is owned by the State, and several important beaches such as Sandy Neck, and Nauset are Town owned and protected. Public control of these and others has provided for reductions in such destructive uses as indiscriminate vehicle travel, disturbance of bird nesting areas and excessive concentrations of recreation activities.



The estuary marks the convergence of fresh water from streams and rivers with the ocean's salt water. The environment of an estuary is likely to change dramatically with the seasons and even daily with the tides. Often in the larger estuaries, a number of other coastal ecosystems are likely to be found along with man-made influences of harbors and ports, which further adds to the complexity of the environment.

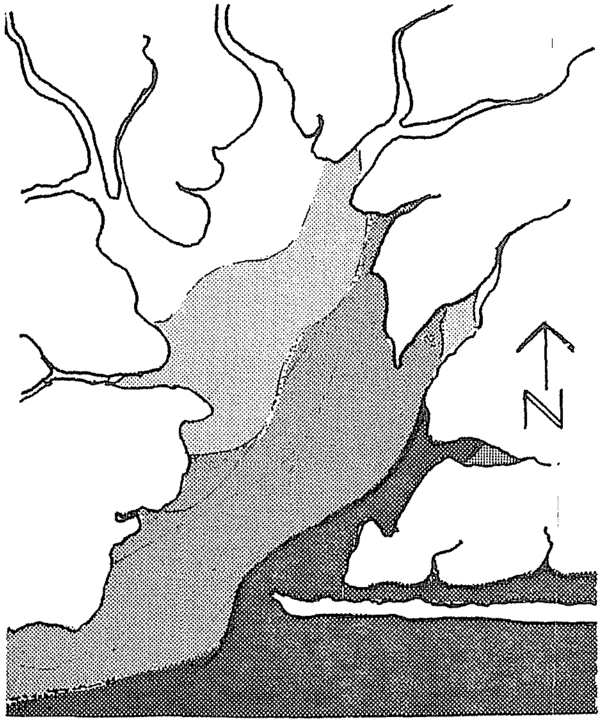
ESTUARIES

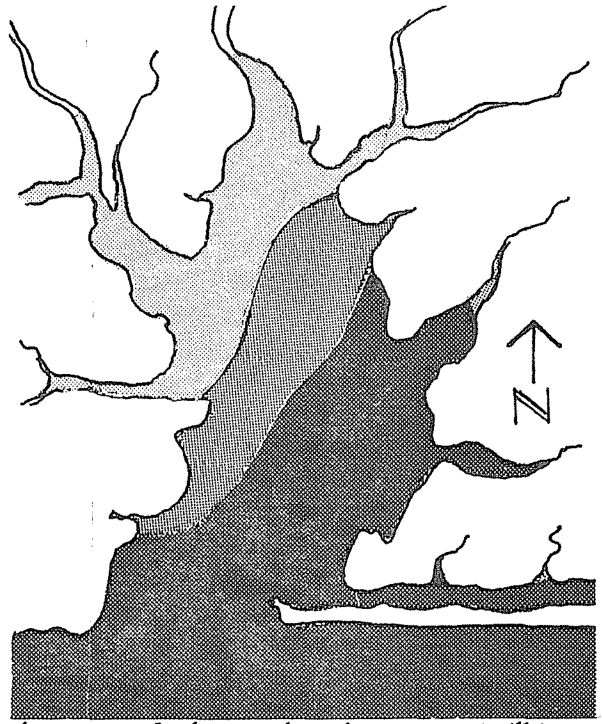
Estuaries are, among all the ecological components of the coast, the most significant in amount and variety of biological production. They may contain many of the ecosystems discussed previously in this publication. They are vital environments for most of the state's important biological resources. Because they provide physical conditions that allow effective development of navigation facilities, estuaries have been centers of much of the coastal social and economic growth. More than anywhere else on the coast, complex systems of natural life and human use have been created. These man-nature systems have rarely been compatible and as use rates expand and estuarine ecosystems are degraded, the costs in lost productivity have grown for both.

Estuaries are found all along the Massachusetts coast where fresh water flows meet and mix with salt water. River mouths are usually the place where estuaries form, though in some cases such as Nantucket Harbor, embayments with no strongly defined fresh-water source may produce estuarine-like conditions.

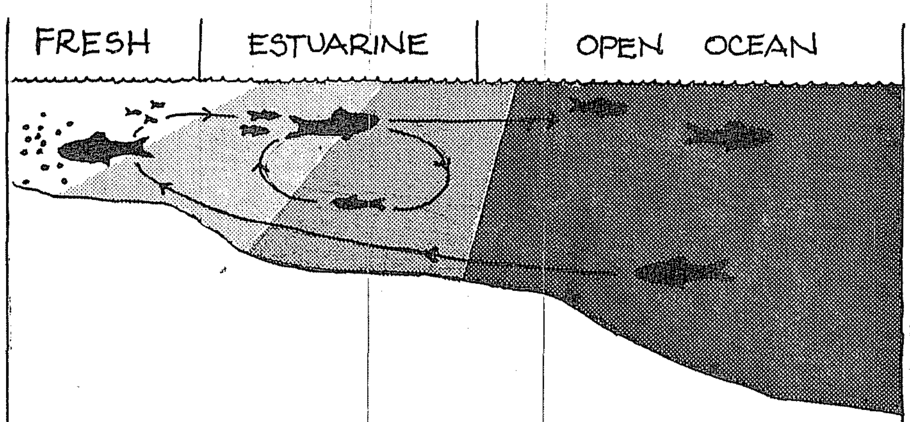
Three types of river estuaries exist, each of which is identified by the manner in which fresh water flowing downriver mixes with tide-driven salt water. A classic estuarine system is that known as the "salt water wedge", where strong river flows push lighter fresh water over the top of the heavier salt water to create a relatively sharp interface between the two kinds of water and opposing wedges of salt and fresh water.

Another type of estuary occurs where tidal currents are strong and force a turbulence at the interface of salt and fresh water to produce a partial mixing of waters. Where estuaries are broad and shallow, this process occurs more readily and is often accompanied by a circular motion of flow, induced by the effect of the earth's rotation on the moving water and known as the coriolis effect. This effect tends to cause fresh water moving downstream to concentrate on the right-hand side of the estuarine channel and salt water on the left. Since estuarine plants and animals are adapted to varying levels of salinity, their distribution through the river is influenced by the pattern of mixing and such features as the coriolis effect.





Salinity variations in an estuary. The concentration of salt varies considerably seasonally and even daily with the tidal ebb and flow. During rainy weather, fresh water runoff will push the salty seawater down the estuary. In dry weather, the seawater will intrude far up the estuary. The earth's rotation from west to east causes a phenomena known as the Coriolis Force, which slides the lighter fresh water to the right side of the estuary over the denser salt water.



Plants and animals are adapted to specific salinity ranges in the estuary. Certain fish [herring, shad, striped bass and others] known as anadramous fish are able to withstand the transition from sea water to fresh water and are required to spend stages of their life cycle in different parts of the estuary. The less dense fresh water tends to flow over the heavier salt water forming a salt water wedge along the estuary bottom.

A third type of estuary, where tidal mixing completely overcomes the seaward flow of fresh water and the waters of the entire estuary become totally mixed, is not usually found along the Massachusetts coast.

The most common system through New England and typical of the Massachusetts North Shore, where both the tidal influence and seaward movement of fresh water are strong, is the partially mixed estuary. In addition to the mixing of fresh and saline water, estuaries are also subject to a physical phenomenon where the push of water coming upstream is felt some distance from the mouth of the river. This push is known as tidal bore.

One of the most significant characteristics of estuaries is their capacity to concentrate a variety of both marine and fresh water productivity and resultant detritus. This occurs because a rough balance of forces between river flow and tides tends to slow the passage of materials and prevent total flushing through the river mouth and out to sea. A buildup of detritus is inevitable, as large amounts of suspended materials in the water are made up of living and dead organic particles and minerals.

Along the shallows and shores of the river, materials carried downstream and held in the estuarine zone begin to settle out, often creating large shoals that provide a base for the formation of salt marshes and tidal flat communities. The presence of large amounts of detritus and mineral nutrients provides a rich basis for the productivity of molluscs, crustaceans, worms, and small fish, and in this way an especially attractive food source for many commercial and sport fish.

Estuaries are critical environments for most commercial and many other freshwater and saltwater species of fish and shellfish. Some permanently occupy the estuary and others use it as habitat for part of their life cycles. Among the resident fish are forage species that are important in transferring food energy produced by the salt marshes, eelgrass beds, rocky shores and plankton to larger commercial and sport species. Some important resident forage fish are Atlantic silversides, sticklebacks, pipefish, cunners, mummichogs, and killfish. Larger fish which enter the estuary to feed upon the forage fish include the bluefish, striped bass, sea robin, Atlantic cod, Atlantic mackerel, pollock, and Atlantic herring.

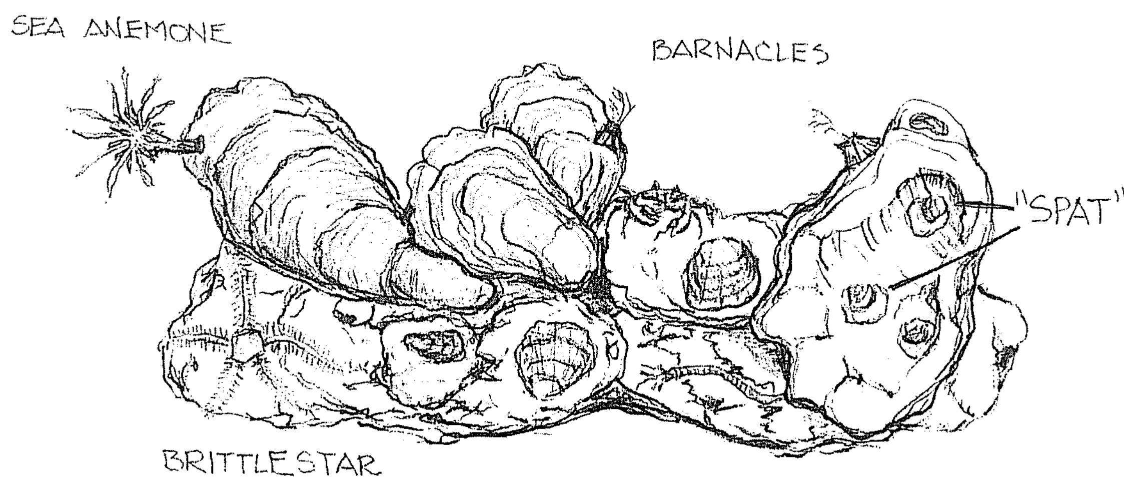
Most important are a number of fish species that require the estuary as a spawning or nursery habitat, including about two-thirds of the important commercial species, such as the menhaden, tautog, tomcod, scup, and winter flounder. In addition, other important species pass through the estuary in the process of moving upstream toward fresh-water spawning areas. These are the American shad, striped bass, alewife, blueblack herring, rainbow smelt, Atlantic sturgeon and the endangered short-nosed sturgeon. The young of these species depend upon the estuary as a source of food and a nursery as they drift downstream from the areas where they were spawned to where they will mature. (See figure) Estuarine tidal flats are particularly productive shellfish habitats. Estuaries are also one of the few coastal ecosystems that produce the salinity required by oysters.

Estuaries are particularly subject to a variety of man-induced stresses because they are the recipients of all manner of materials contributed to stream flow throughout their watershed. All types of pollutants are delivered to the estuary, where concentrations increase as the river becomes more sluggish and tidal action retards the flushing of materials out to sea.

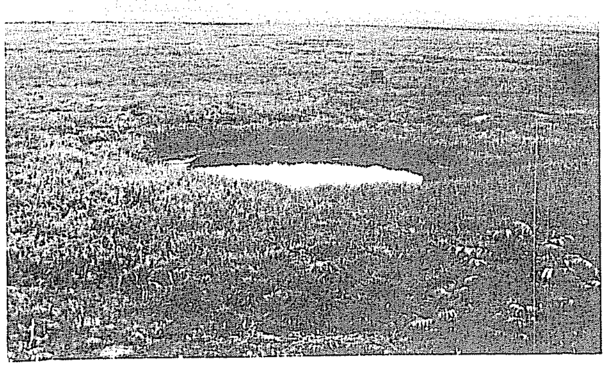
Activities designed to make these areas more suitable for water transport alter the normal shallow configuration of the estuary bottom through channel and harbor dredging. Dredging creates deep zones which support little biological productivity. Over the years, the shallows of many estuarine river channels have also been used for the deposition of dredged materials with a consequent burying of important tidal flats and salt marsh systems. In addition, dredging activities have released pollutants which were formerly trapped in bottom shoals and sediments and resuspended the sediment and polluting materials into the water.

Estuaries are influenced by certain kinds of engineering works upstream. Dams, while providing flood protection, also trap desirable detrital materials and prevent them from moving downstream into the estuarine zone. At the same time, they influence the strength of river currents in the estuary, which alters the relationship between such factors as upstream saltwater penetration and the effects of the tidal bore.

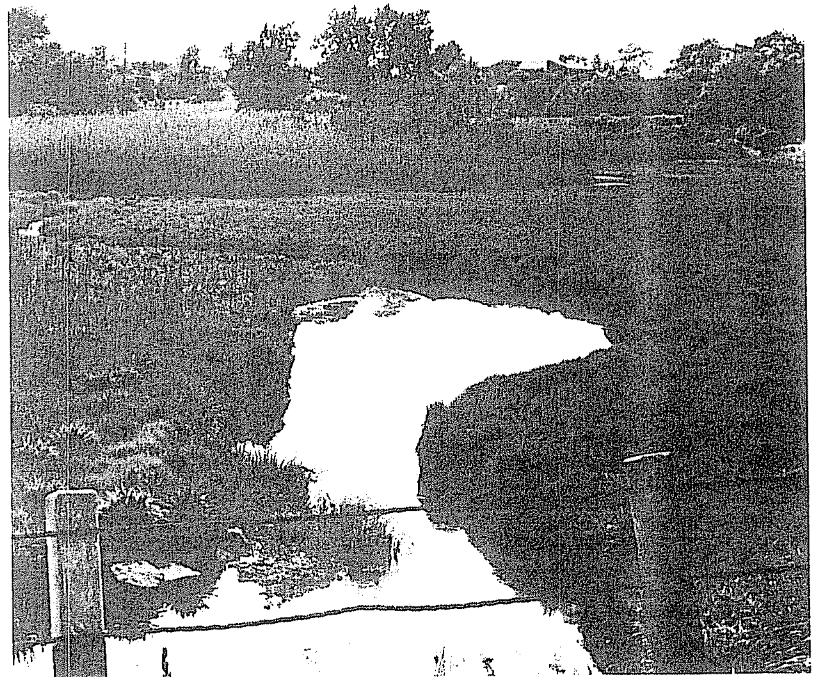
Construction of navigation structures and bridges in estuarine zones can change the circulation pattern of fresh and salt water, interfering with the process of mixing, and in some cases reducing the effective estuarine area available to species which are normal, temporary or permanent residents.



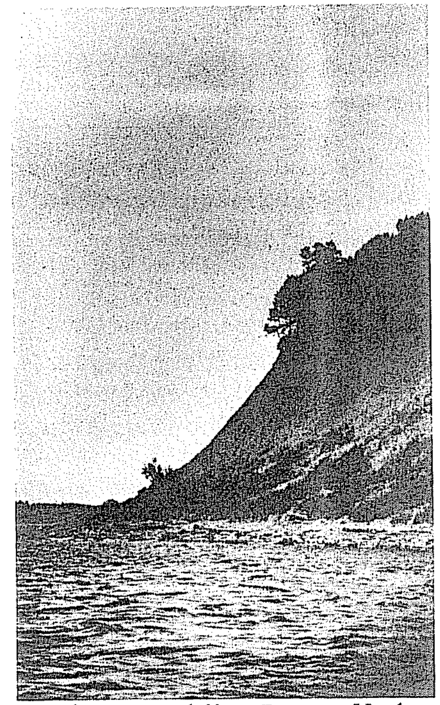
The oyster once found in great abundance along the Massachusetts coast is now harvested in only a few remote areas. The oyster needs brackish water and a firm bottom of rocks or shells on which the soft bellied young must fasten to nurture and mature.



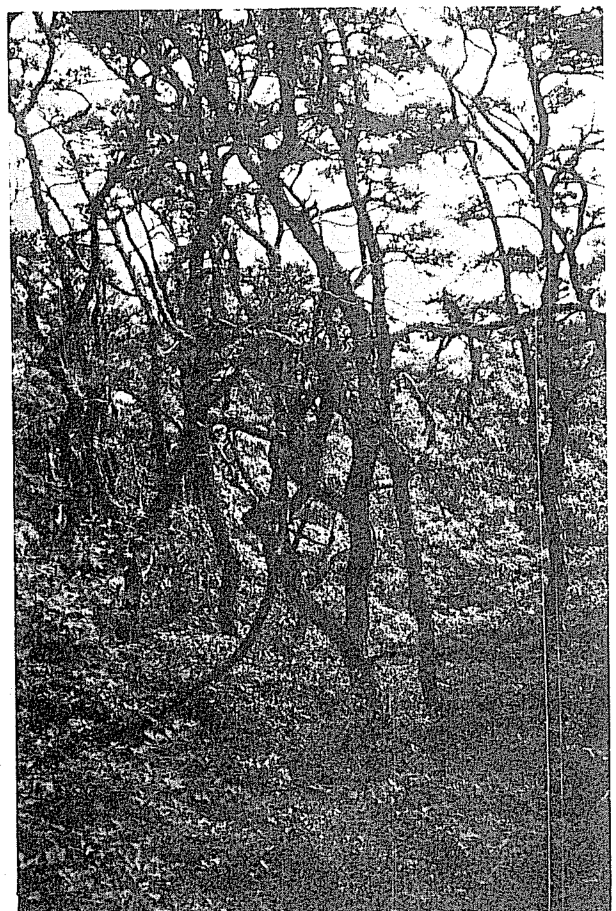
High marsh tide pool or panne. Salisbury



Upper edge of salt marsh Rowley



Eroding sea cliff Boston Harbor



Trees twisted by salt spray White Cedar Swamp Cape Cod National Sea Shore

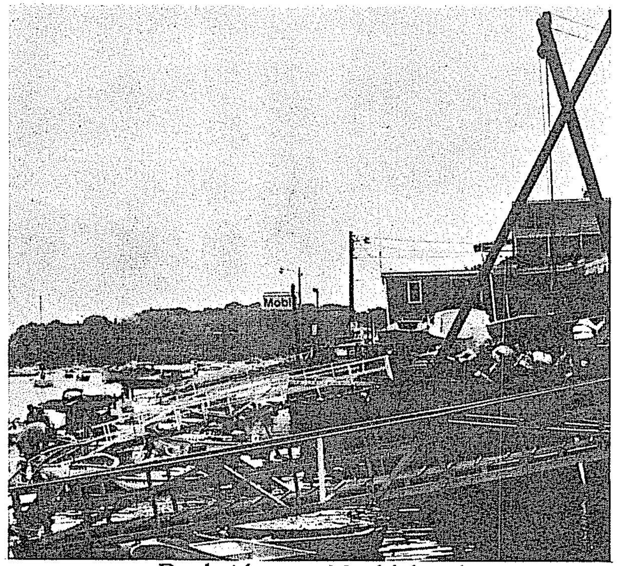
Sea gulls on tide flat Sandy Neck Barnstable

PLUM ISLAND—CAPE ANN—NORTH SHORE

There is great variety in coastal resources along Massachusetts' North Shore. The large salt marshes on the estuaries of the Merrimack and Parker Rivers are centers of coastal productivity, supporting important fisheries and waterfowl populations. The glacial boulder-strewn rocky outcrops of Cape Ann are a base for some of the State's most extensive rocky shores ecosystems.

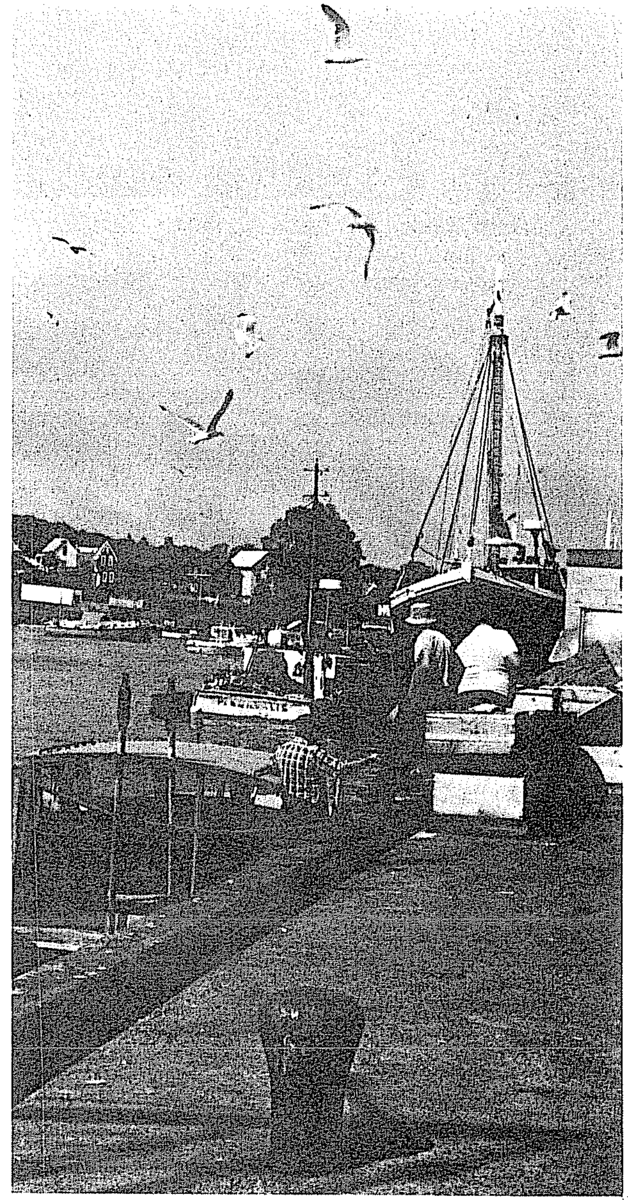
Visitors come by the thousands each year to enjoy the historic communities at Newburyport, Rockport, Gloucester, Salem, and Beverly. Fishing, swimming, nature study and sightseeing are opportunities available in many large and small bays and beaches. Barrier beaches at Plum Island and Cranes Beach are important recreational resources. The National Wildlife Refuge at Plum Island and the Parker River marshes offers continuing protections for all forms of plant and animal life, particularly waterfowl.

The concentration of resources of the North Shore has attracted many users. Over the years, the combination of users and growing demand for all forms of coastal resources has resulted in the loss or degradation of many resources and their supporting ecosystems. Many of the once important North Shore shellfish beds have been closed to harvest because of domestic and industrial pollution. Expansion of demand for marinas has overcrowded many harbors and will require future expansion of facilities. Pressure on urban beaches to the south has shifted much urban recreation demand to the North Shore areas. Many of these beaches, such as those at Cape Ann, Salem, Beverly, and Marblehead are not capable of serving additional users because of their small size and limited access.



Dockside Marblehead

Rocky shore Beverly



Fishing wharf Gloucester

LEGEND

ECOLOGICAL CLASSIFICATION

- Sandy Beach
- Rocky Shore
- Salt Marsh
- Tidal Flats
- Salt Ponds
- Dune Environments or Maritime Forest
- Barrier Beach
- Estuary

CULTURAL CLASSIFICATION

- Utilities
- Water Related Structures
- Institutional
- Commercial / Transport.
- Marinas
- Fishing Ports

PLUM ISLAND–CAPE ANN–NORTH SHORE

The following five maps of the Massachusetts coast are intended as simplified inventories of the major coastal ecosystems and some selected land uses, and are not to be used for management purposes. The "Cultural Classification" of land uses is defined as follows;

UTILITIES: Major power plants, sewage treatment plants.

WATER RELATED STRUCTURES: Major jetties, groin systems, seawalls and causeways.

INSTITUTIONAL: Coast Guard and military installations, research stations.

COMMERCIAL/TRANSPORTATIONAL: Large port facilities that serve industry, warehousing and storage or public boat transportation.

MARINAS: The larger complexes that serve recreational boating.

FISHING PORTS: A port that has a significant amount of dock space devoted to commercial fishing.

A more detailed explanation of these land uses is explained in Part III.

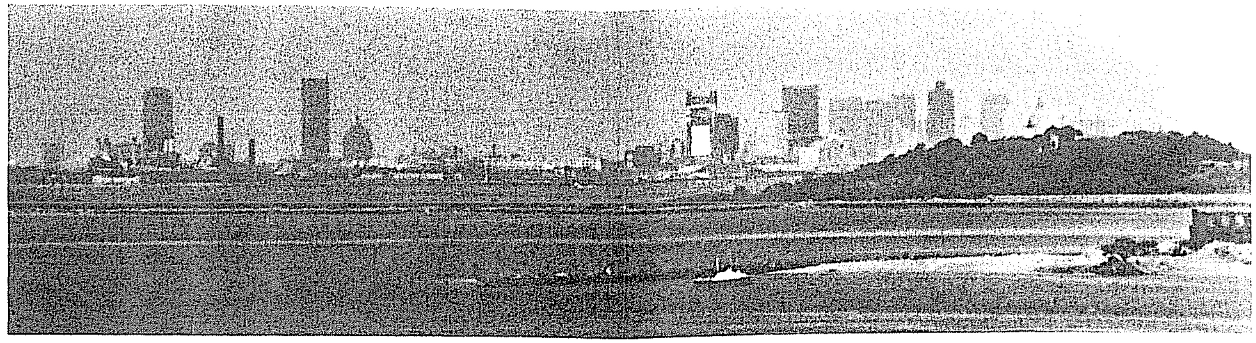
BOSTON HARBOR AND SOUTH SHORE

One of the largest ports on the Atlantic coast, islands of ecological, historic, and recreational interest, beaches, amusement parks, marinas, public institutions, factories, an international airport, power plants, and waste disposal facilities are all combined in this large bay that once produced a major fishery. Today from Lynn on the north to Quincy on the south the Metrpolitan Area of Boston exerts growing urban pressures on the remaining coastal ecosystems and resources.

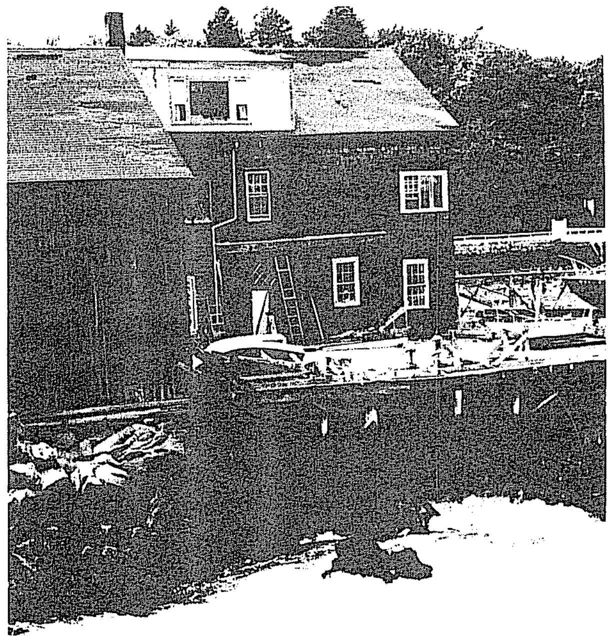
The large public beaches at Nahant, Revere, and Nantasket are overcrowded. Pollution has prevented the use of mollusk species that are often present in abundance. Much of the petroleum used in Massachusetts is delivered to terminals in Chelsea Creek, the Mystic River and Quincy. Future expansion of imports may require construction of additional deep water channels and storage areas, all posing increased risk of accidental spills and further destruction of estuarine ecosystems.

The Boston Harbor Islands are an important recreation resource with much potential for meeting future needs. Efforts by state agencies to improve access and facilities to some of the islands are being planned. The small outer islands are already recognized as valuable to coastal wildlife and are under protection to preserve them for wildlife habitat.

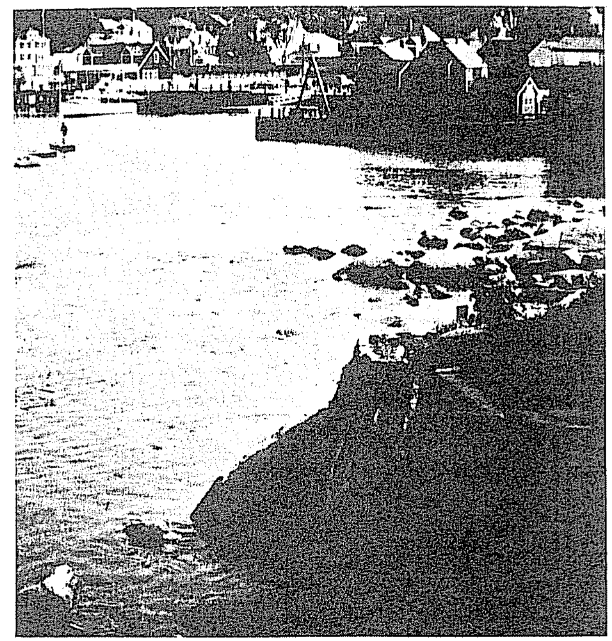
Few coastal ecosystems near the Boston Metropolitan Area remain in their natural state; the less disturbed Neponset and North Rivers estuaries and salt marshes are the rare exceptions.



Boston skyline from harbor islands

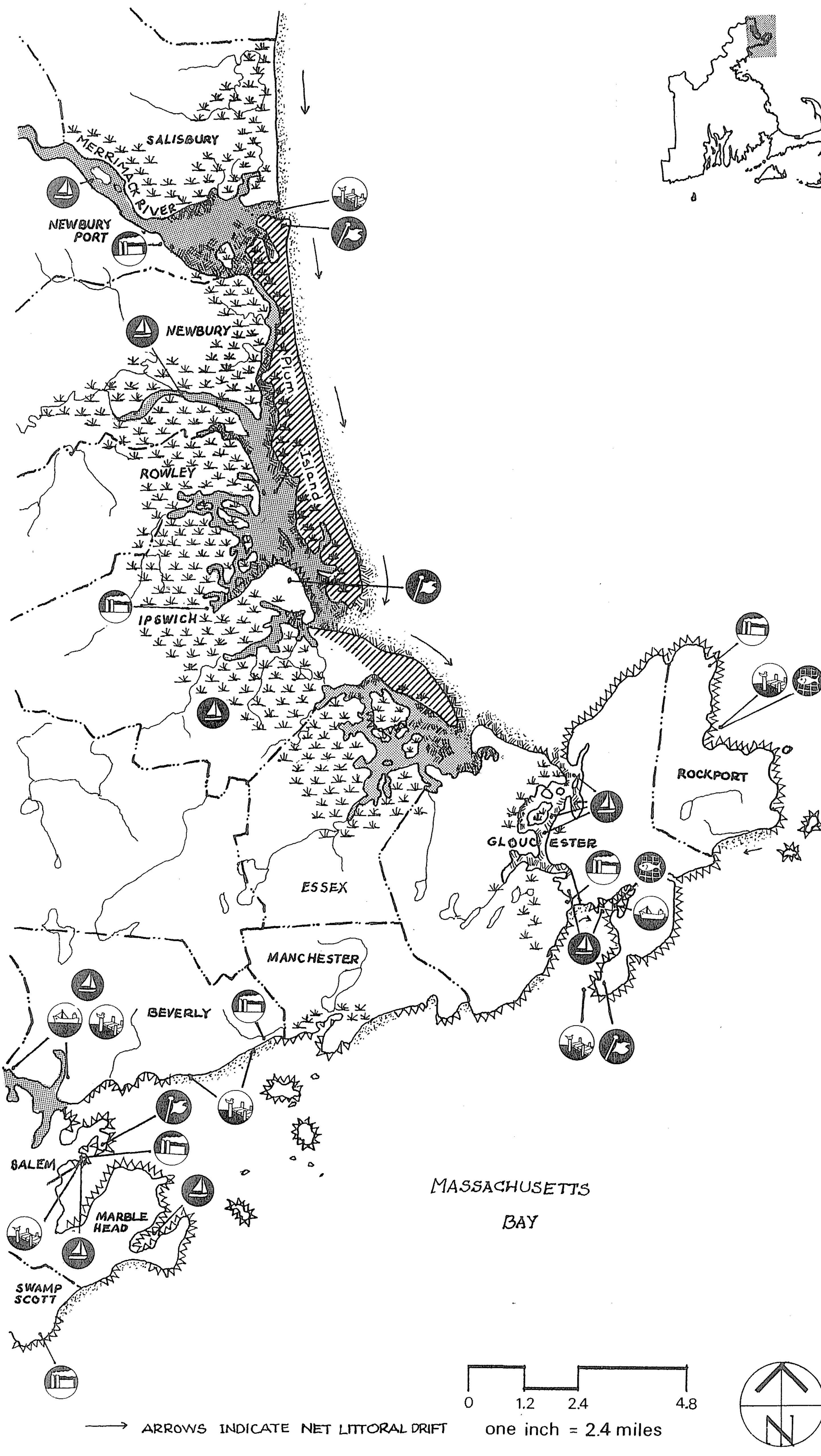


Rocky tidal pond



Cohasset

Nantasket Beach Hull



→ ARROWS INDICATE NET LITTORAL DRIFT

LEGEND

ECOLOGICAL CLASSIFICATION

Sandy Beach

Rocky Shore

Salt Marsh

Tidal Flats

Salt Ponds

Dune Environments or Maritime Forest

Barrier Beach

Estuary

CULTURAL CLASSIFICATION

Utilities

Water Related Structures

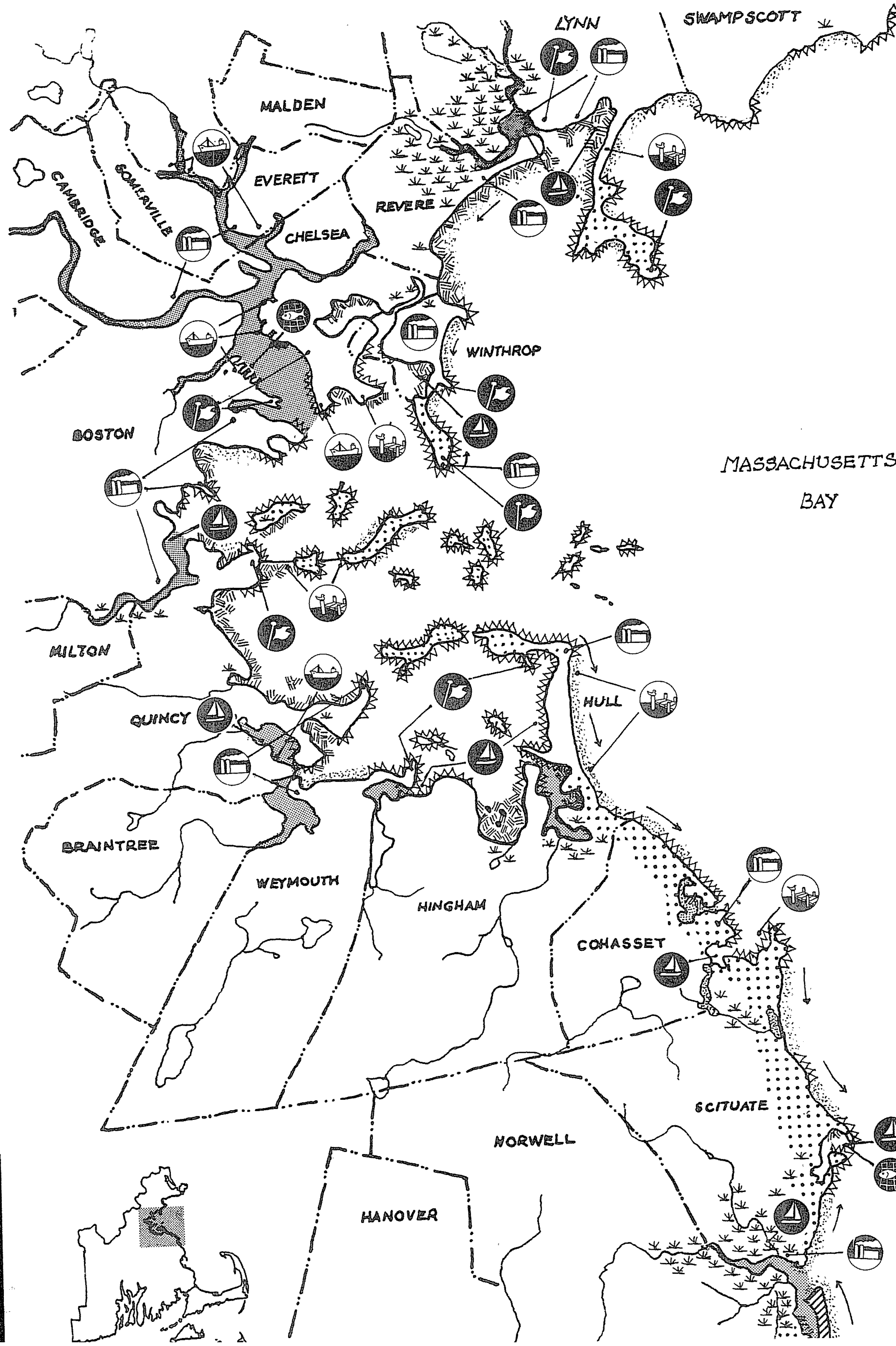
Institutional

Commercial / Transport.

Marinas

Fishing Ports

BOSTON HARBOR – SOUTH SHORE

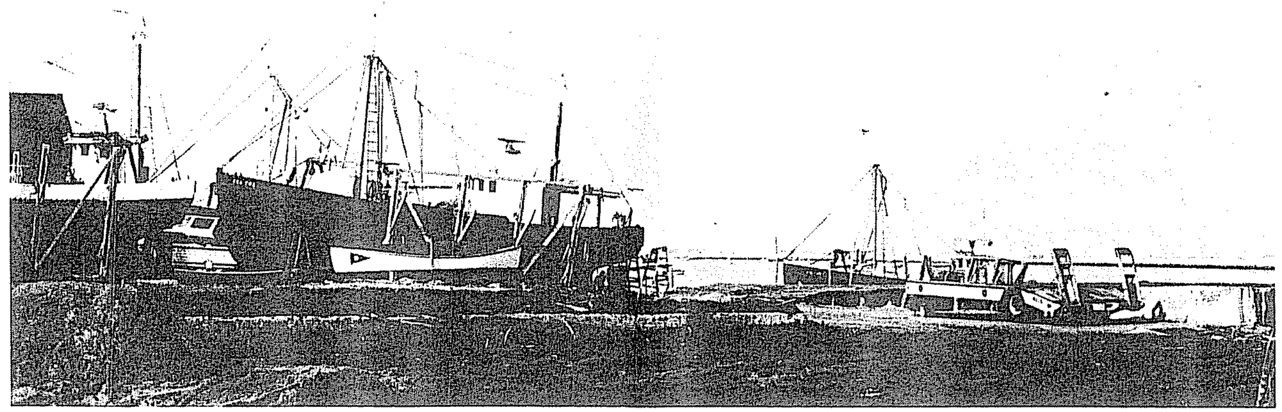

LYNN
SWAMPSCOTT
MALDEN
EVERETT
CAMBRIDGE
SOMERVILLE
REVERE
CHELSEA
WINTHROP
BOSTON
MASSACHUSETTS
BAY
MILTON
HULL
QUINCY
BRAINTREE
WEYMOUTH
HINGHAM
COHASSET
SCITUATE
NORWELL
HANOVER

CAPE COD BAY

The coast from Marshfield south, around the inshore of the Cape to Provincetown and down the outer cape to Chatham is an extensive coastal area still rich in natural and productive ecosystems. Major barrier beaches at Duxbury, Barnstable, Wellfleet, Eastham, and Orleans protect valuable tidal flats, marshes and salt ponds. Glacial material is abundant and has given rise to many beaches and their resultant dune systems. Maritime forest covers large portions of the coastal landscape. Commercial and sport fishing remain active and the tidal flats offer clams. Fishing ports are at Plymouth and Provincetown.

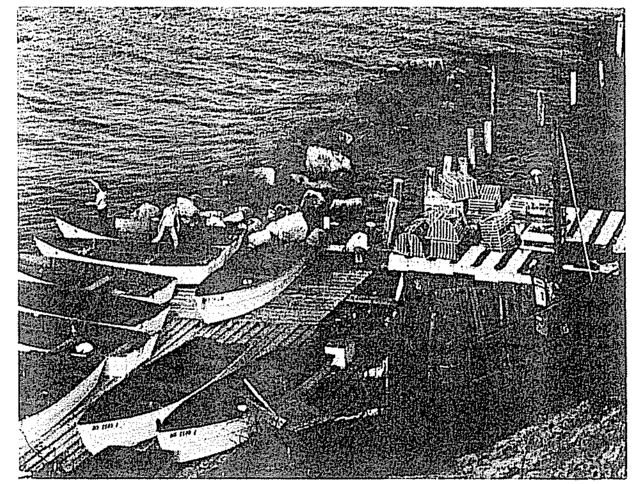
The last two decades have brought increasing pressure on this valuable coastline. Major improvements in highway access coupled with the rapid expansion of recreation demands have generated growth of permanent and vacation populations. Resorts, marinas, shorefront homes and all their required services have grown and proliferated. Construction of coastal works to facilitate the activities of the growing population has occurred in once undisturbed estuaries, tidal creeks, bays and ponds. The natural dynamics of shore erosion and deposition have been impeded and sometimes accelerated as property owners increasingly seek to avoid the loss of beachfront property from normal erosion. Groundwater withdrawal to meet new needs may reduce the water flow in the Cape's streams, adversely affecting the freshwater and saltwater patterns in estuaries and salt ponds and threatening their productivity.

Reaction to new and enlarging demands for land and resource use has produced some positive actions to preserve areas of scenic beauty and historic or natural value. Nature preserves have been established and historic districts declared. A major action by the federal government has created the Cape Cod National Seashore in Wellfleet, Truro, Provincetown and Orleans.

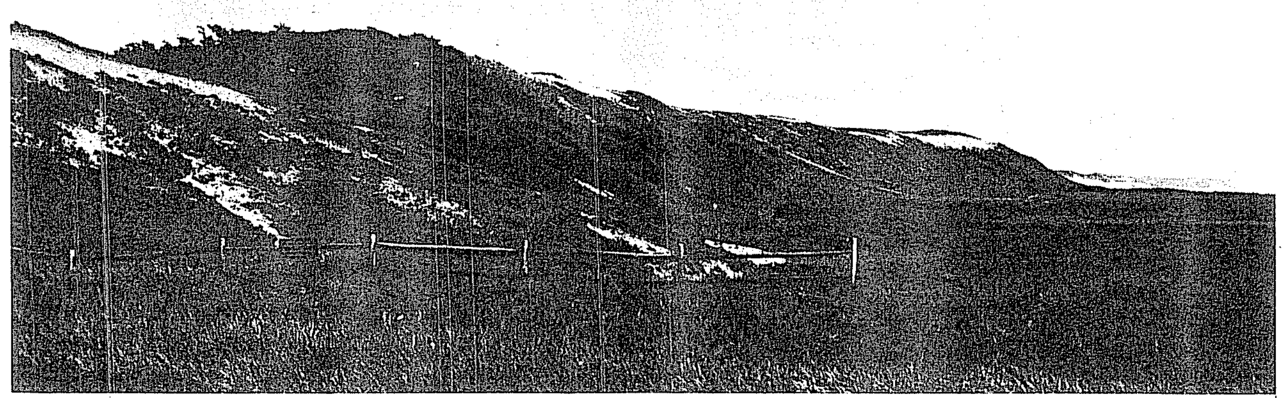


Fishing boat in dry dock *Provincetown Harbor*

Boardwalks *Nauset Beach*



Lobster wharf *White Horse Beach*



Dunes *Wellfleet*

CAPE COD BAY

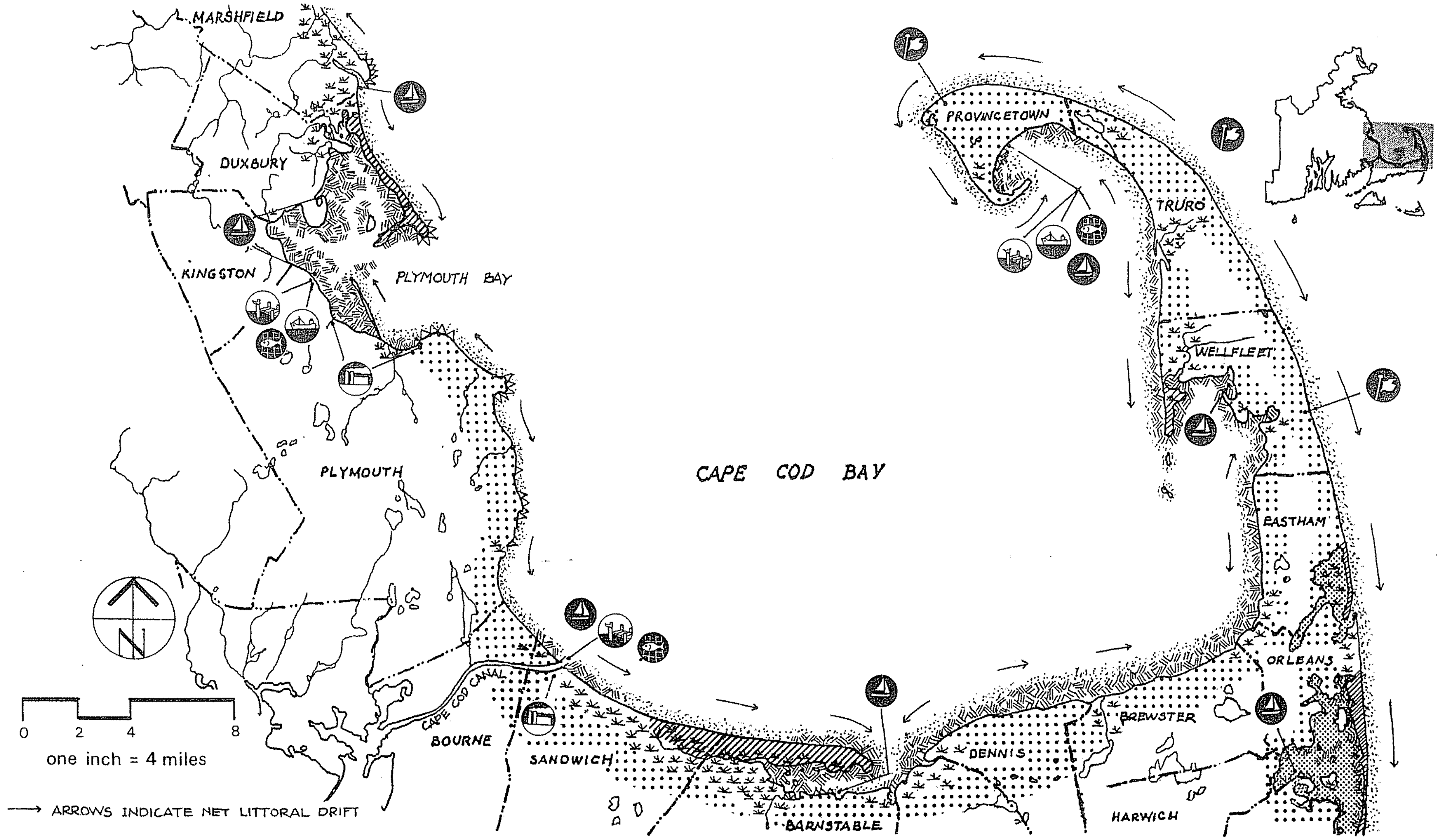
LEGEND

ECOLOGICAL CLASSIFICATION

- Sandy Beach
- Rocky Shore
- Salt Marsh
- Tidal Flats
- Salt Ponds
- Dune Environments or Maritime Forest
- Barrier Beach
- Estuary

CULTURAL CLASSIFICATION

- Utilities
- Water Related Structures
- Institutional
- Commercial / Transport.
- Marinas
- Fishing Ports



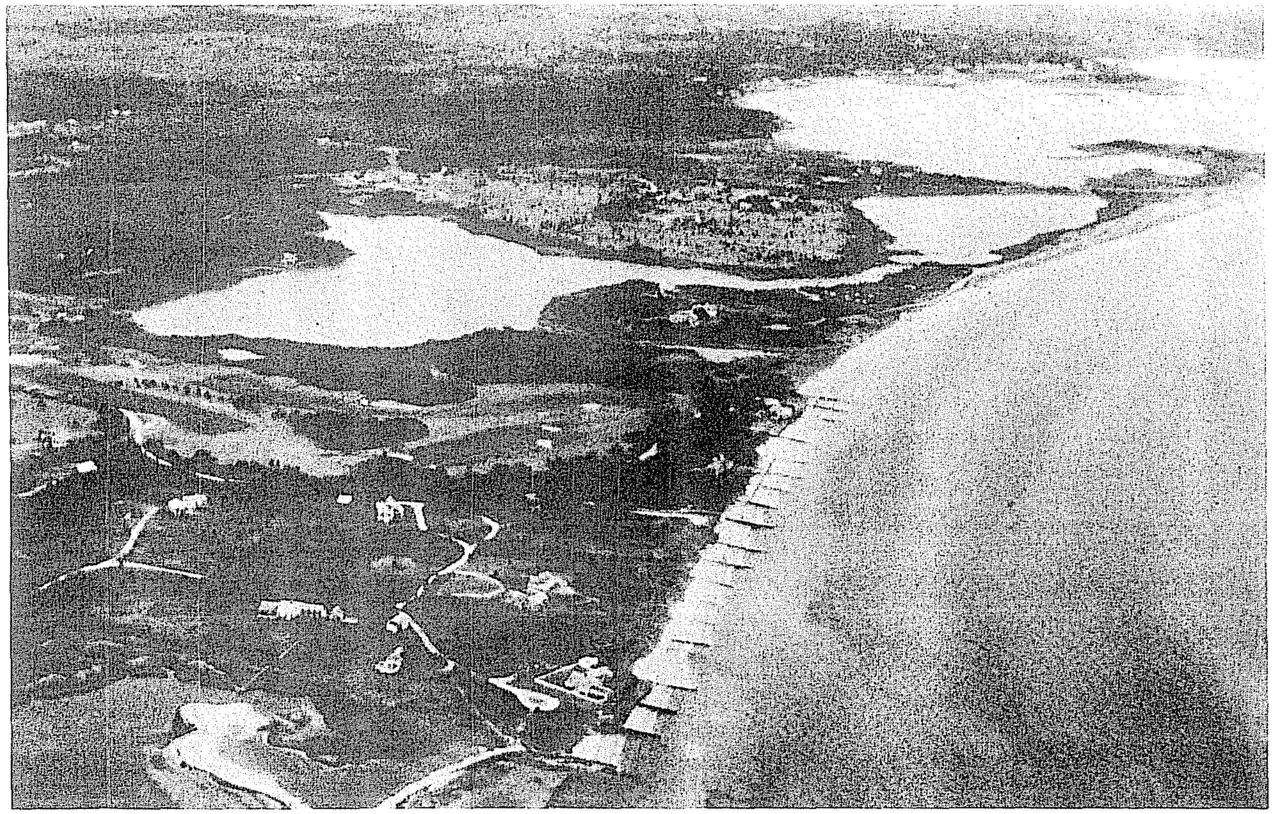
MARSHFIELD
DUXBURY
KINGSTON
PLYMOUTH BAY
PLYMOUTH
CAPE COD BAY
PROVINCETOWN
TRURO
WELLFLEET
EASTHAM
ORLEANS
BREWSTER
HARWICH
DENNIS
BARNSTABLE
SANDWICH
BOURNE
CAPE COD CANAL
0 2 4 8
one inch = 4 miles
ARROWS INDICATE NET LITTORAL DRIFT

SOUTH SHORE OF CAPE AND THE ISLANDS

The south shore of Cape Cod, Nantucket, and Martha's Vineyard is a region of glacial outwash rivers and salt ponds. Erosion of sands along the open coasts is often rapid but the resistant boulders offer a substrate for rocky shores biota. Glacial sands are plentiful and in protected areas behind the larger barrier islands such as Monomoy, beaches and tidal flats have developed. Nantucket, the site of the early American whaling industry highlights the many historical resources of the region. One of the world's most renowned marine science complexes is at Woodshole in Falmouth. Fishing is an important activity in the sound with striped bass and bluefish being sought after by sport fishermen in boats and in the surf off Monomoy, Nantucket and the "Vineyard." Nantucket shoals to the east of the island are a valuable spawning area for many fish of commercial and recreational importance. On Muskeget Island, the rare and threatened beach meadow vole has its only home.

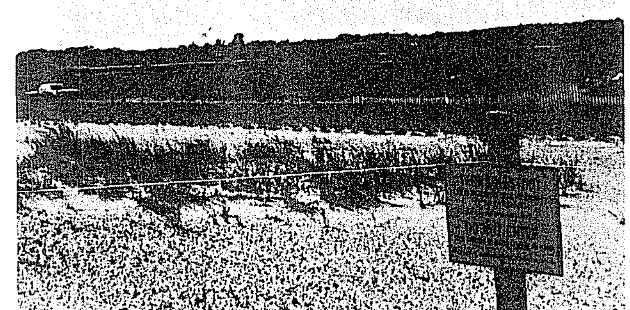
Growth pressure like that along the inner shore of the Cape is disturbing the coastal resource bordering Nantucket Sound. Rapid conversions of land and shoreline to vacation, residential, and resort uses has diminished the extent and productivity of coastal ecosystems. Dredging, filling, and construction in the south shore salt pond harbors has intensified use and pollution in these low tidal circulation environments. The marshes and tidal flats are the ultimate recipients of the effects of human use here as elsewhere on the Massachusetts coast. The impacts from human use are likely to continue to grow. Upgrading the Route 25 connector from the metropolitan area or instituting rail passenger service to the Cape may accelerate development pressure causing further stress on ecosystems and recreational resources.

Actions to forestall environmental losses have been encouraged by towns and regional groups. New planning efforts are being tried in Martha's Vineyard and Monomoy Island has been declared a National Wildlife Refuge.



Beach stabilization project Martha's Vineyard Courtesy CZM Office

Giant sea turtle carried ashore by hurricane Nantucket Island



Terns nesting on beach Dennis

SOUTH SHORE of CAPE COD and THE ISLANDS

LEGEND

ECOLOGICAL CLASSIFICATION

- Sandy Beach
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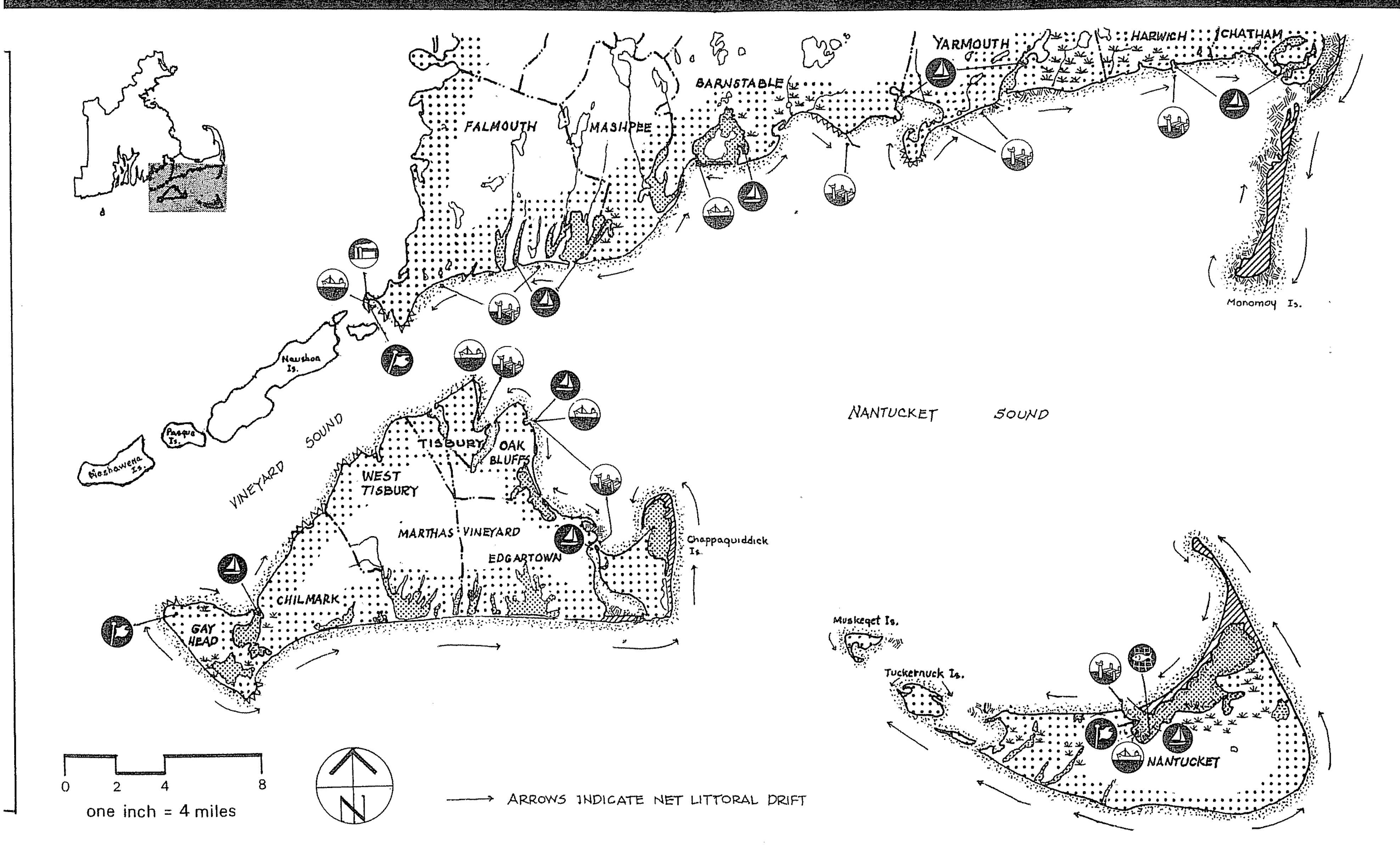


YARMOUTH
HARWICH
CHATHAM
BARNSTABLE
FALMOUTH
MASHPEE
Monomoy Is.
Naushon Is.
Pasque Is.
Nashawena Is.
VINEYARD SOUND
NANTUCKET SOUND
TISBURY
OAK BLUFFS
WEST TISBURY
MARTHAS VINEYARD
EDGARTOWN
Chappaquiddick Is.
CHILMARK
GAY HEAD
Muskeget Is.
Tuckernuck Is.
NANTUCKET
0 2 4 8
one inch = 4 miles
N
ARROWS INDICATE NET LITTORAL DRIFT

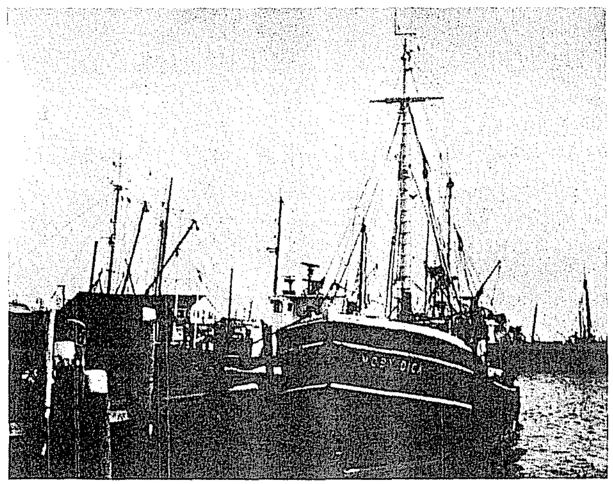
BUZZARDS BAY AND FALL RIVER

Protected by the enclosing Elizabeth Islands and strung with rocky shores and headlands, Buzzards Bay is a special coastal region in the Commonwealth. Its eclosed nature modifies the effects of storms and tides and creates an almost estuarine or salt pond condition. Its protected waters historically have been attractive for harbors. New Bedford services much of the fishing industry. Fall River is an important transfer point for petroleum products. Like the southshore of the Cape, glacial out-wash valleys and kettleholes have created the estuaries and salt ponds of the region. These are attractive locations for marinas and, in the eastern part of the Bay, support most of the important tidal flat ecosystems. The relatively inaccessible Elizabeth Islands are a particularly important coastal area. There human uses have remained low compared to the rest of the Massachusetts coast. Many parts of these islands exhibit almost undisturbed and pristine-like natural beach, dune and forest systems.

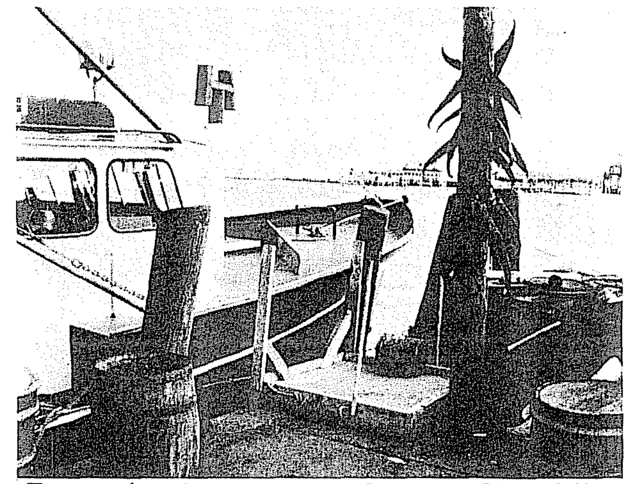
Because of the prevalence of heavier glacial materials, sand beaches are found mostly in small pockets; though there are extensive barrier beach systems in Westport where Horse Neck Beach State Park is located.

Although New Bedford and Fall River are major metropolitan centers, therefore creating some environmental stress, much of the Buzzards Bay region is comparatively undeveloped. Remaining open areas along this coast offer opportunities for enhancing economic growth through tourism and recreation as well as conservation.

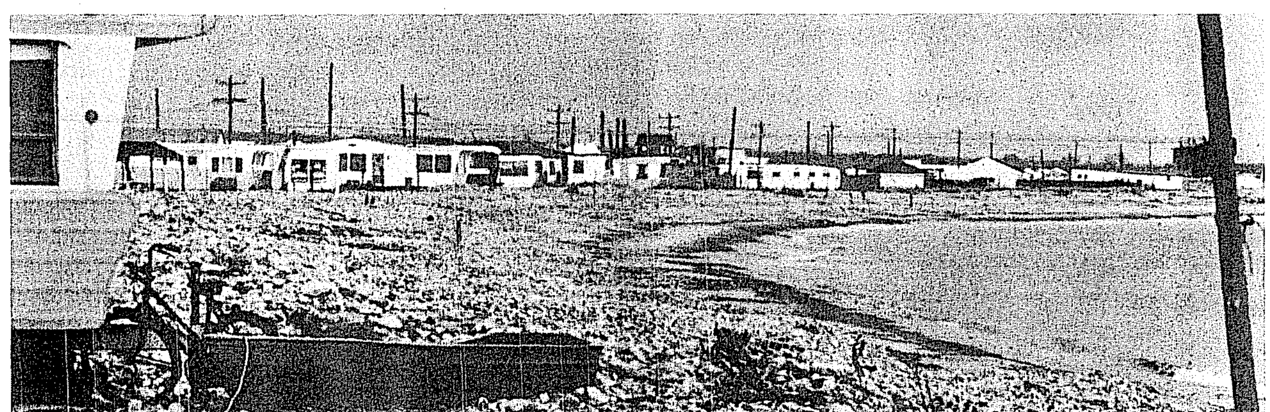
Elizabeth Islands   Courtesy Allen Look



Fishing trawlers   New Bedford



Tuna tails   Westport   Courtesy CZM Office



E. Horseneck Beach   Westport   Courtesy CZM Office

BUZZARDS BAY and FALL RIVER

LEGEND

ECOLOGICAL CLASSIFICATION

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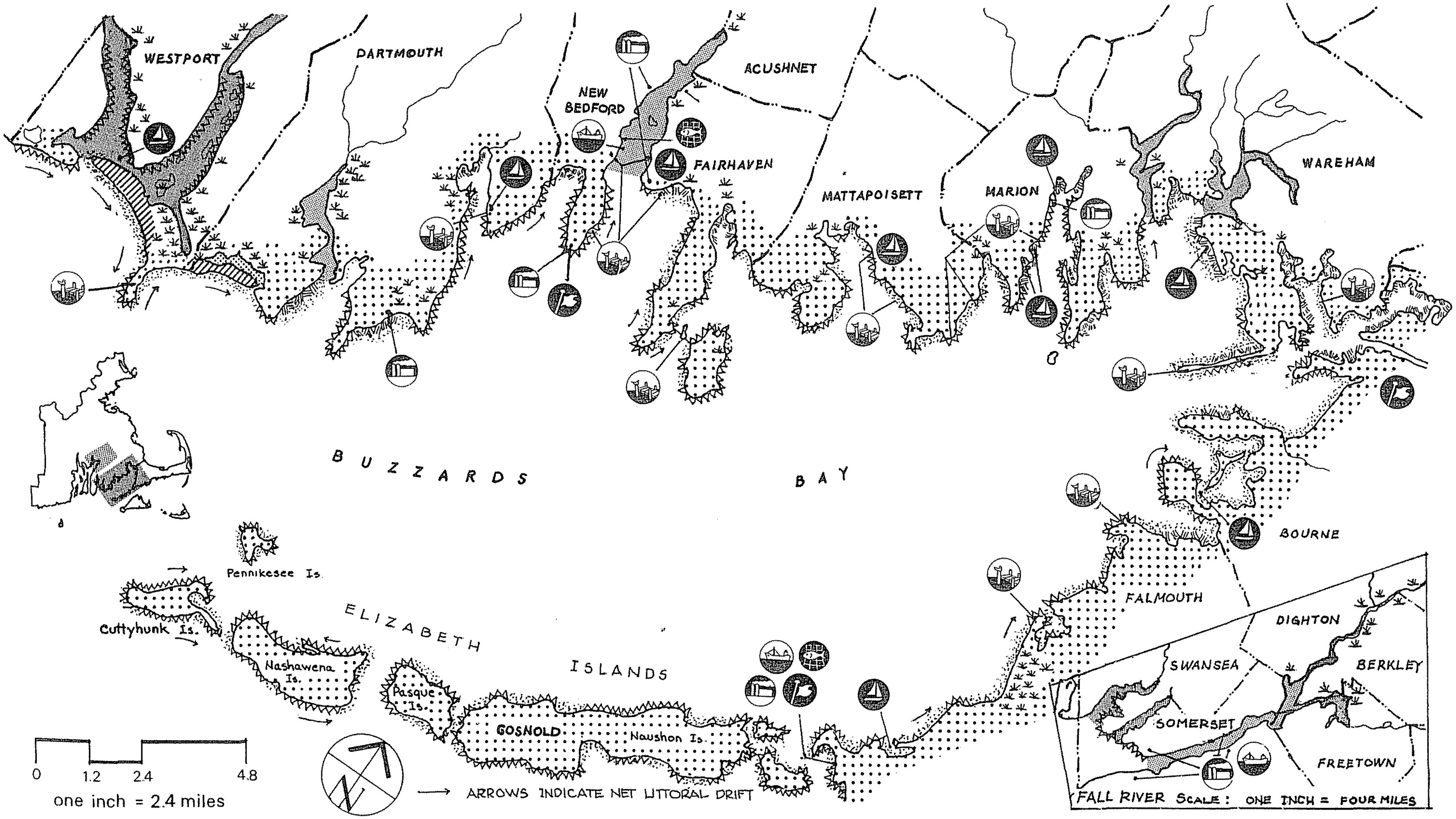
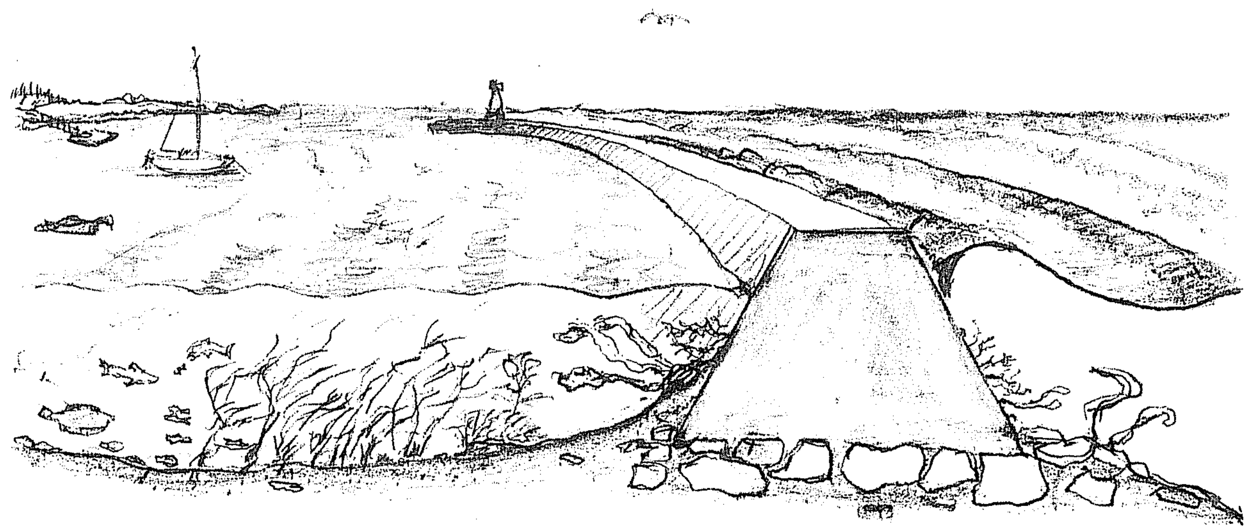


WESTPORT
DARTMOUTH
NEW BEDFORD
ACUSHNET
FAIRHAVEN
MATTAPOISETT
MARION
WAREHAM
BUZZARDS BAY
BOURNE
FALMOUTH
Pennikesee Is.
Cuttyhunk Is.
ELIZABETH ISLANDS
Nashawena Is.
Pasque Is.
GOSNOLD
Naushon Is.
0
1.2
2.4
4.8
one inch = 2.4 miles
ARROWS INDICATE NET LITTORAL DRIFT
DIGHTON
SWANSEA
BERKLEY
SOMERSET
FREETOWN
FALL RIVER
SCALE: ONE INCH = FOUR MILES

III. COASTAL RESOURCES AND THEIR CULTURAL USES

The shorline comprises both biological resources and physical features. Man harvests biological resources by such means as trawling, line fishing, agriculture, shellfish digging, and hunting. Man utilizes coastal physical resources either in their natural state or by enhancing them to serve shipping, commercial, residential, and recreational needs. This second first discusses physical resources of thè Massachusetts coast and the way man's manipulation of those resources can alter ecological process. The second part discusses important living resources and describes some of their major ecological requirements and sensitivity to human activities.



Man made structures built to stablize the shoreline often modify the environment in various ways. The pounding waves of the exposed side of the jetty above, simulate the stressful environment of the rocky shore, while the protected side may allow the estblishment of plants and animals associated with low energy ecosystems [eelgrass, tidal flats, salt marshes].

The Physical Resources

Protected and relatively quiet bays and river mouths have, throughout the history of human use of the coast, been especially valued. Such places provide safe harbor for boats and ships, and a stable base for the construction of the engineered works and buildings that serve water transportation and commerce. In taking advantage of the naturally occurring protected areas, man has learned to manipulate available resources to increase the total area of protected shoreline. Through the building of coastal works such as protective breakwaters, jetties, bulkheads, and navigation channels, centers for coastal and ocean transportation have grown in number and extent. These facilities imitate geologic forms, especially that of the rocky shore ecosystem, and in many ways successfully alter the way basic energy and forces of nature are expended along the coast.

Efforts to increase the extent of sheltered coastline have also included the expansion of building sites suitable for water transportation structures, housing and recreation. The filling of intertidal flats and salt marshes has been a common occurence not only in Massachusetts but along the entire Atlantic coast. Very often, material for filling came from dredging operations necessary to create or maintain shipping and boating channels. In other instances, fill material was pumped to the shore from the ocean bottom.

Erosion of many parts of the coastline, a normal occurrence, continuously threatens the places where people live, work and recreate. All along the Massachusetts coast there are frequent examples of efforts to retard the process of erosion. Groins and rip-rap are devices often built for this purpose. Our efforts to eliminate erosion in one place have often accelerated it in others. Structural changes at the mouths, or in natural channels, of estuaries have altered the pattern of river flows and ocean currents, to encourage the accumulation of pollutants in these areas.

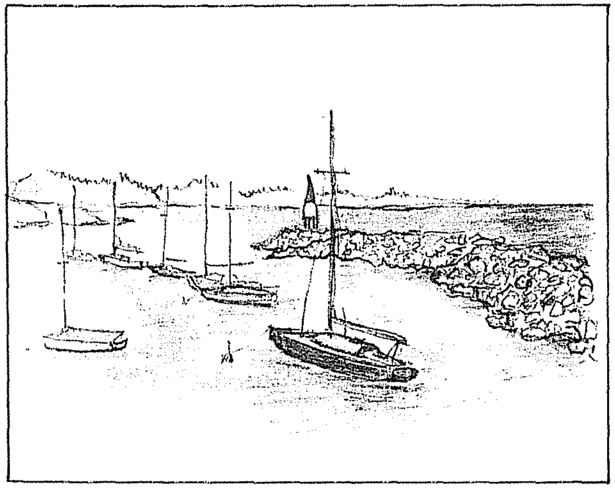
Access to the shoreline is itself a problem. The geologic form of the coast deters people from making easy use of many resources. Steep rocky cliffs, shifting dunes, the many outfalls of large and small rivers, and the daily inundations of tidal flats all act as barriers to the shore or to travel along it. Construction of roads, causeways, and bridges has been the principal means for overcoming the difficulties of access.

The increase in private ownership of the shore has reduced public access to coastal resources. Private development has also brought about many small but significant physical changes in the coastline, the effects of which are similar to those of the major commercial and public works in our large ports and harbors.

These physical alterations of the coast have rendered the search for particular resources more successful. In many instances also, the value of coastal resources accrues to more people than those who live by the sea. The large ports of Boston, Gloucester, and New Bedford have a social and economic impact both on Massachusetts and the nation. Lesser examples such as Newburyport, Rockport, Plymouth, Provincetown, and Nantucket serve as local, state, and regional centers for commercial fishing and recreation. Major port facilities have played an historical role in diversifying the culture and economy of the state.

Today, however, people are becoming more sharply aware that the historical and continuing uses of the coast have been levying a toll on its natural resources. As each change has taken place, we have lost or diminished the productive capacity of important coastal ecosystems.

JETTIES

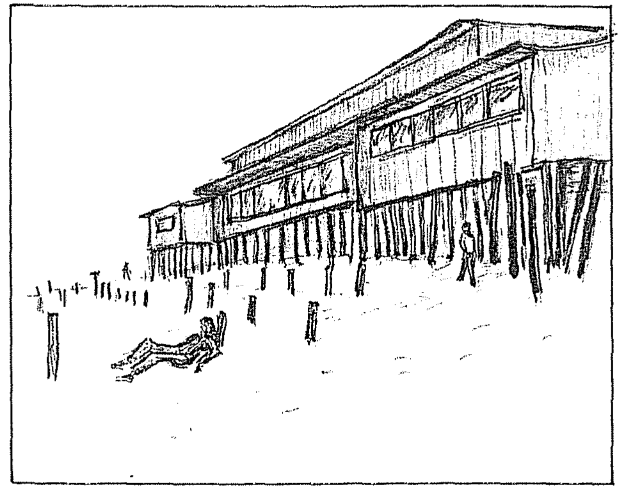


Jetties are linear barriers built of large rock or concrete. They are positioned to reduce the effects of storm wave surge or the force of strong currents. Jetties may be built parallel to offshore bays and river mouths to protect boat harbors or perpendicular to the shore to protect navigation channels of harbors and marinas.

Impacts

- Exposed face of jetties mimic rocky shore environments and induce the development of rocky shore ecosystems.
- Behind the jetty, lagoon, or quiet bays, ecosystems may develop encouraging eelgrass beds or subtidal worm and clam communities to form.
- Some jetties act like groins to trap sand in one location and intensify erosion effects elsewhere.

PILINGS



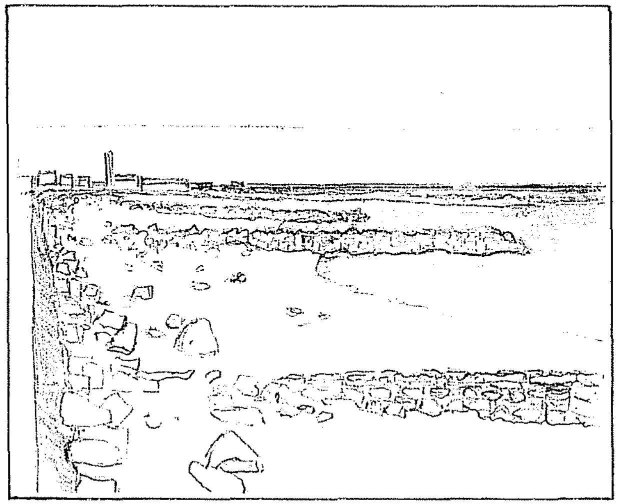
Pilings are made from treated wood poles, concrete or steel. Piles are driven or placed in holes in the substrate.

They are used to provide support for buildings, pier platforms, docks, or general protection for shoreline structures. Pilings are effective in extending usable space above high tide for coastal works.

Impacts

- Pilings change the substrate available to coastal organisms and create quasi-rocky shore ecosystems.
- Encroachment of structures over sand beach or tidal flat communities.
- May alter the pattern of river and tidal flows

GROINS

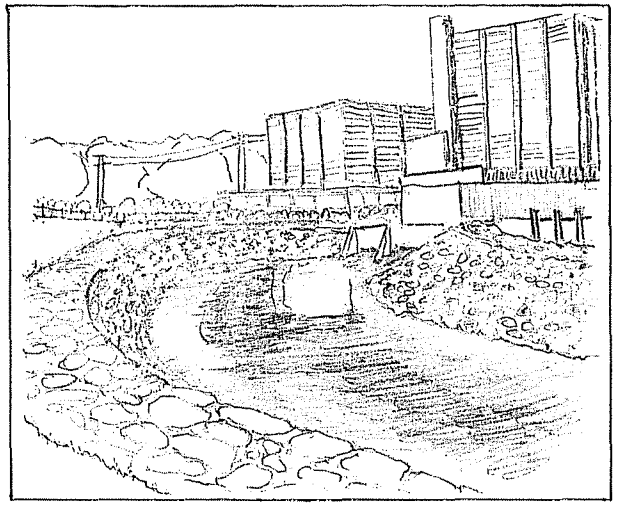


Groins are linear structures built perpendicular to the shore. Their purpose is to interrupt the normal pattern of littoral drift and wave refraction to prevent local shoreline erosion or encourage sand deposition. They are built of large rocks or concrete and their length and height vary with the strength of littoral flow, tide levels and storm strength.

Impacts

By lessening erosion and trapping sands and silts at one place along the shore, groins prevent the transport of shore building materials to downdrift shore areas. Therefore they tend to intensify the effects of erosion in those areas.

OUTFALLS

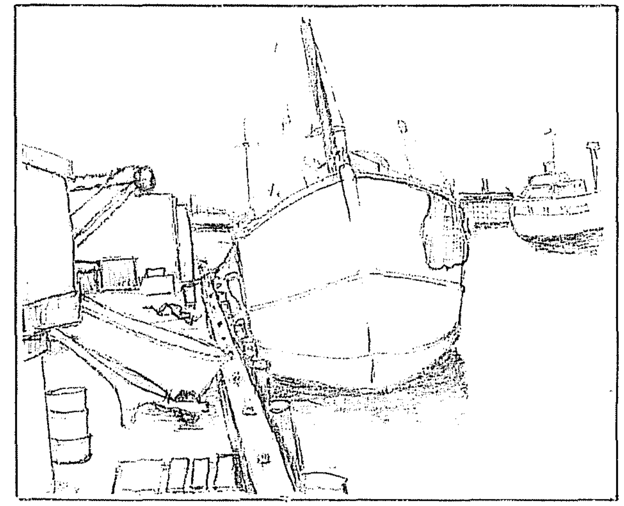


Power plants are built on the coast to take advantage of plentiful water for cooling purposes.

Impacts

The principal environmental effect from power plants is the discharge of heated water into the immediate area of the coast. Warm water raises average temperatures in the local marine enviroment. This may discourage these organisms that have particular temperature ranges for carrying out their life cycle (eelgrass for instance) or in summer months causing reductions in the concentration of oxygen in the affected waters. In some cases, the higher environmental temperatures may favor the growth of some organisms (such as oysters) by extending their growing season in early spring or fall months. Often fish normally associated with warmer waters will establish themselves in the area of the thermal discharge, a precarious situation during the colder months if the power plant shuts down.

COMMERCIAL FISHING PORTS

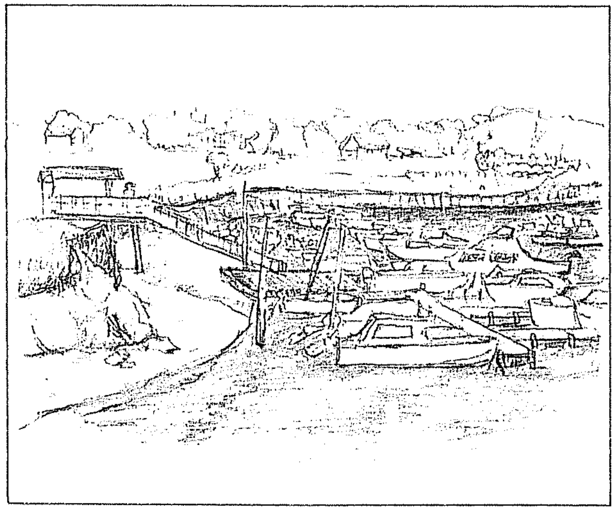


Larger port facilities serving commercial fishing and ocean-going vessels occur in major embayments and estuaries along the coast. In most instances, port facilities require major alterations in the sea and river bottom for the development of deep water channels and harbor and turning basins. Port facilities commonly include piers, docks, dry docks, warehouses, storage tanks, fuel depots and processing or manufacturing industries. They are served by major access roads, railroads and trans-shipment staging areas.

Impacts

Because of their size and complex services, commercial ports use extensive shoreline acerage, much of which is built on fills covering coastal systems such as salt marsh and tidal flats. Since all forms of coastal construction are associated with commercial ports, impacts are typically the same as those noted for most of the structures or uses mentioned previously in this part of the publication.

MARINAS



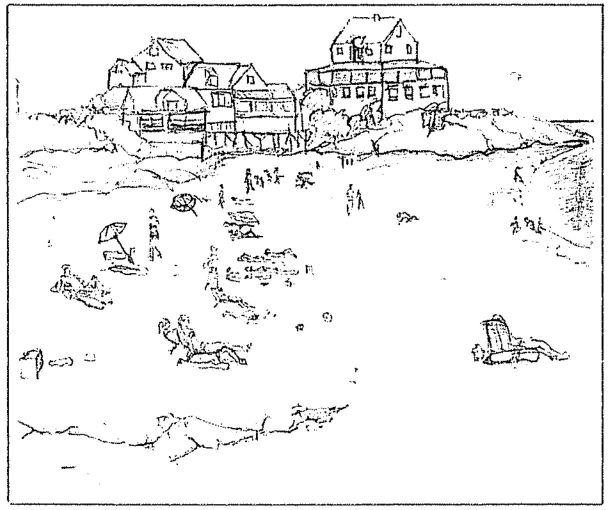
Marinas serve recreational boating. They include mooring space, docks, piers, and small craft maintenance facilities. Marinas are located all along the coast in bays, estuaries and the mouths of tidal creeks. Like larger deep water commercial harbors, channels and basins may be dredged to assure adequate depth for safe navigation.

Impacts

Because of the location for marinas they often cause the degradation of eelgrass beds and salt marshes. In addition, they may cause effects such as:

- Petroleum pollution from boat engine discharges.
- Maintenance, dredging disturbances
- Shoreline fills, bulkheading, piling and buildings may replace natural systems.

BEACH COMMUNITIES



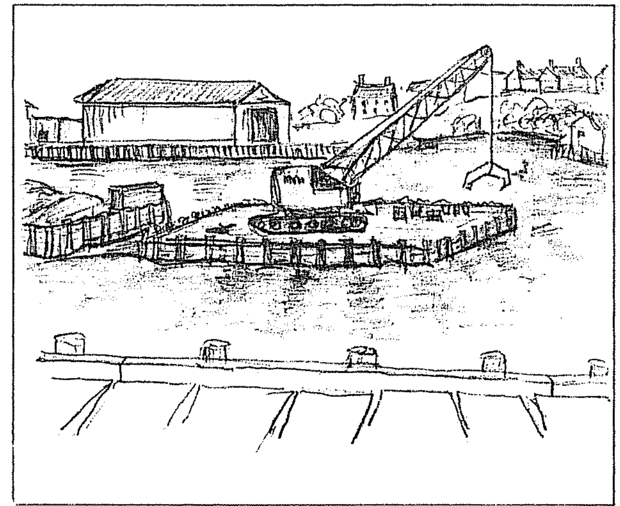
Beach communities usually have roads, recreation buildings, hotels and vacation houses constructed near or on the upper beach or primary dunes.

Impacts

Concentrations of human activities and buildings in beach and dune environments often cause the following impacts.

- Replacement of shoreline ecosystems by buildings, roads, and parking areas.
- Increase of dune erosion through the destruction of beachgrass.
- Disturbance of nesting birds.

DREDGING/FILLING



Dredging is used to create and maintain deep channels and basins for navigation in bays and estuaries. Dredging is also used to obtain sands and gravels from the floor of the sea or from riverbeds for construction purposes.

Impacts

Dredging causes the following changes in coastal environments.

- Destruction of bottom habitats and organisms from removal of sediment.
- Increase in suspended sediments in dredging area.
- Reintroduction of organic and inorganic pollutants from bottom sediments into water.
- Disposal of dredged materials may bury aquatic or terrestrial ecosystems.

The Biological Resources

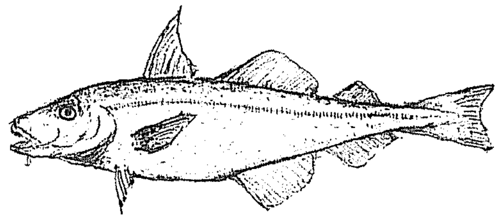
Many kinds of animals and plants of the coast have been historically important to human survival and pleasure. These living resources are the products of the ecosystems. They have been defined as resources by cultural habit and custom as have the ways in which they are used and appreciated.

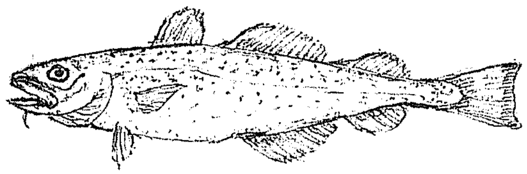
Commercial harvest of molluscs, crustaceans, and fish occurs today in much the same way it occurred in the past. The value of the "catch" is significant to the state's economy and food supply. Recreation uses of these same resources increase yearly as more gain leisure time and the affluence to enjoy the coastal environment of Massachusetts.

While there is a higher and more widespread value placed on coastal areas, there is, simultaneously, a serious threat to the future of the coast's living resources. Direct actions such as the over-harvest of desired species and the replacement of habitat by coastal construction pose an obvious and serious threat to the resources. Indirect and less apparent impacts on the biological resources raise equal if not more significant levels of potential resource degradation. Pollution in ecosystems such as salt marshes, eelgrass beds, and tidal flats may reduce or eliminate bacteria, fungi, filter and deposit feeders and other detritus feeders, breaking the link between the primary food-producing plants and the important fish resources. Thermal discharges from power facilities can alter the species combination of fish and mollusc populations in eastuaries and near shore habitats. Sedimentation of productive waters can increase turbidity and thereby reduce the amount of sunlight penetrating to aquatic vegetation and lower the level of primary food production on which the mollusc, crustacean, and fish resources depend.

The following pages illustrate some of the more important living resources of the Massachusetts coast.

Haddock





Cod

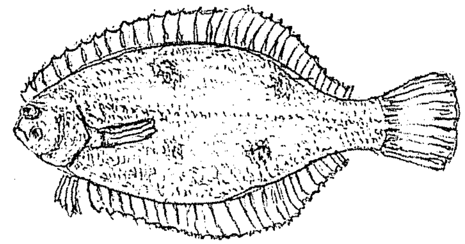
These fish are two of the most important commercial species found along the Massachusetts coast. They are not the products of the near shore ecosystems but are influenced, especially during their immature stage, by the amount and kind of small crustacean productivity generated by coastal systems.

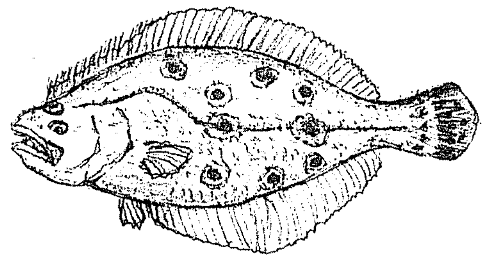
Cod are spawned at roughly the 20 fathom contour off the North Shore above Cape Ann, the South Shore, and in the area of the Nantucket Shoals. During their first year many are found in the near shore areas in very shallow water. Adult cod eat mollusks, larger crustaceans, urchins, sea cucumbers and worms.

Haddock are close relatives of the cod. They are generally reliant on the Georges Bank for spawning, but do not move as close to shore as cod during their immature or mature stages. Like the cod they are voracious predators and tend to move constantly in search of food. They have a wide range of prey including all the types eaten by cod and, in addition, some fish.

Principal impacts on cod and haddock include overfishing and disturbance of spawning grounds by repeated trawler runs. Since they are dependent to some degree on coastal ecosystems for their food, reductions in the productivity of those systems may reduce the survival of young fish. Also, pollution of near shore waters can reduce the success of the larvae that spend several critical months in shallow coastal areas.

Winter Flounder





Summer Flounder

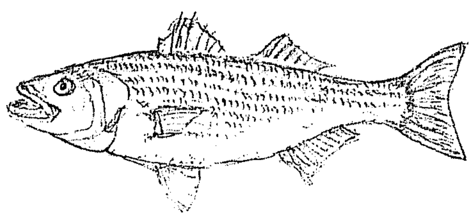
The winter and summer flounders are among the most sought after commercial and sport species of coastal waters. The winter flounder (or lemon sole) is found on all coasts of the state but the larger summer flounder (plaicefish or fluke) rarely is found north of the outer coast of Cape Cod.

Winter flounder are true products of the coast entering bays and estuaries to spawn: eelgrass beds are important nursery grounds for them. Summer flounder, especially in the northern part of their range, spawn well offshore.

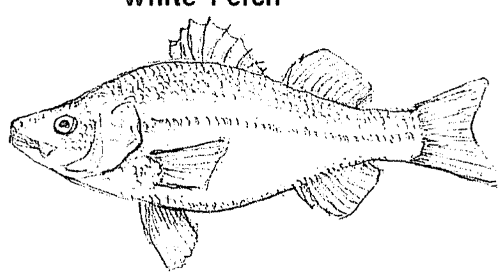
During their adult life both species spend many months of the year in shallow waters, where they feed on small fish, crustaceans, and worms. The winter flounder, not being so vigorous, includes less fish then the summer flounder in its diet.

The winter and summer flounders are especially dependent on the environmental condition and productivity of near shore waters. Pollution, dredging, increased sedimentation, thermal discharge, and displacement of coastal ecosystems, particularly subtidal flats and eelgrass beds, by shoreline construction have a negative effect on flounder populations.

Striped Bass



White Perch



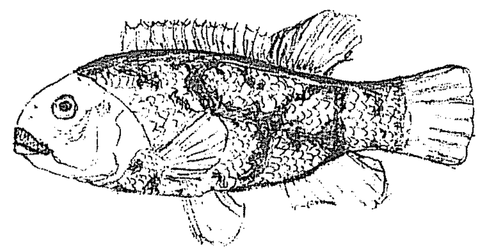
These two closely related fish are of great interest for their commercial and sport value. Both species are anadromous—living most of their life in salt water, but migrating up coastal rivers to fresh or brackish water to spawn.

The striped bass grows to large size, with occasional records of fish over five feet and weighing more than 90 pounds. Bass are strong swimmers, able to move through shoal riffs and breakers in pursuit of food. They feed on many forms of fish as well as crustaceans, squid and worms. The outer shore of Cape Cod and Nantucket are prime Massachusetts areas for striped bass with the beaches and bays north of Cape Ann to the Merrimack Estuary another major area. they are also found in Plymouth Bay and Buzzards Bay. The bass is a near shore fish dependent on Coastal ecosystems throughout its life.

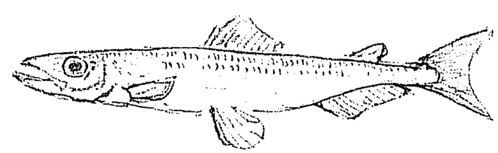
White Perch are small relatives of striped bass. they are decidedly inshore fish found often in upper estuaries, salt ponds and brackish bays. Perch are located around Cape Cod, Buzzards Bay, and the "Islands," and are found less frequently north of the Cape.

Striped bass and white perch are particularly susceptible to degradation of near shore and estuarine waters. Spawning activity and larval survival are seriously affected by sedimentation, toxic and oxygen reducing pollutants and thermal discharges in estuarine waters. Reduction of the productivity of such systems as salt marsh, eelgrass and tidal flats will also limit food supplies for young and adults.

Tautog



Smelt



These fish are coastal creatures of the near shore. Tautog are found rarely more than three or four miles from shore in their northern range and further seaward in their southern range. Smelt are hardly ever found more than one mile out. Both species are dependent on coastal environments for their entire life cycle.

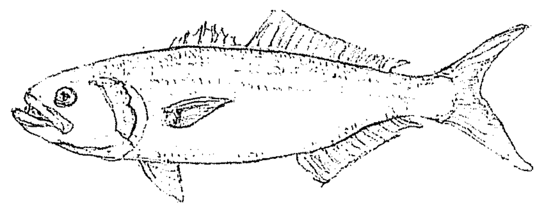
Tautog, a fish mostly important for sport, range from the North Shore to Cape Cod and Buzzards Bay. They are most abundant along the southern shores of Massachusetts. The waters off steep, rocky shores are the tautog's preferred habitat, though they also frequent areas over clean sandy bottoms. Tautog feed on invertebrates such as mollusks and worms. Blue mussels are their major food source. They often use eelgrass beds for resting and feeding, and suffered a reduction in population during the eelgrass decline in the 1930's.

Smelt are anadromous fish that move just above the salt water zone in estuaries to spawn. Though they are small (8 to 11 inches) smelt are voracious predators. They feed on small crustaceans, fish larvae and eggs.

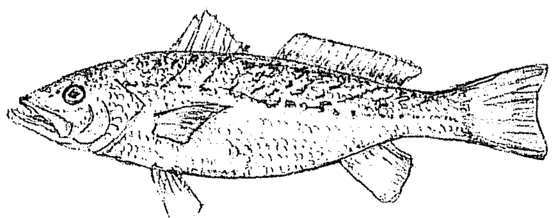
Smelt are harvested commercially and for sport. They are netted in April and early May at the mouths and in lower estuaries, where they appear in dense schools during their spawning run.

Because tautog and smelt are predators, they are adversely affected by any reduction in their food that is produced by the coastal ecosystems. Smelt are particularly vulnerable to upstream, penetration of salt water that is lethal to their eggs. Sedimentation of their spawning grounds is also a problem. Tautog suffer from the disturbance of mussel beds, sub-tidal flats, and eelgrass, from dredging and filling, and pollution from sediment and petroleum spills.

Bluefish



Weakfish



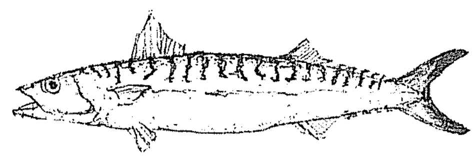
These two fish are important in Massachusetts for sport and to a lesser extent for commercial fishing. Because the center of their range lies south of Cape Cod, their appearance in large numbers along the Massachusetts coast is sporadic.

Like the bluefish, weakfish are voracious predators feeding on crustaceans, mollusks, worms, and, during their adult life, feeding mostly on other fish such as menhaden, scup, herring, and silversides. Weakfish schools are usually found during warm months in Buzzards Bay and along Cape Cod, except during rare summers when they may reach parts of the North Shore. They prefer shallow bays and coves and may enter estuaries, at least as far as the brackish water reaches.

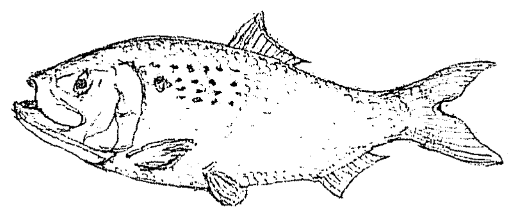
The bluefish is a much larger and stronger predator that prefers, during its adult life, areas offshore where tidal currents and rips are strong. It is often located in waters where striped bass are found. Its diet, except for its early life, is concentrated on other fish species. Young bluefish (snappers) are common summer inhabitants of lower estuaries, where they appear in large schools to feed on small crustaceans, mollusk larvae and the fry of other fish.

Both weakfish and bluefish are dependent on the products of shallow coastal waters and estuaries, and thus are indirectly affected by any reduction in the populations of their food species. Disturbance or loss of saltmarsh, tidal flat, and eelgrass beds, especially, are threats to the well-being of weakfish and bluefish.

Mackerel



Menhaden



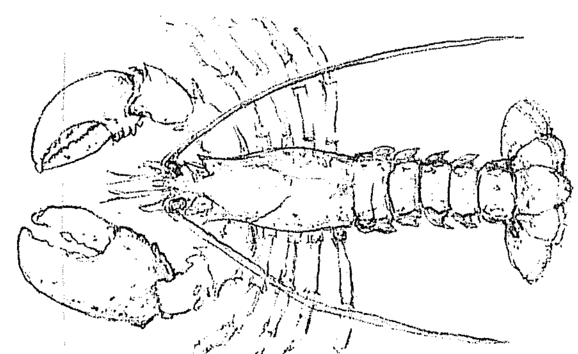
Menhaden (Pogy) are commercially very important for oil, fertilizer and fish meal. They appear near the coast in vast schools from Cape Cod northward during late spring and early summer, with the greatest populations occurring during the summer months. Menhaden are warm water fish that often seek their planktonic food in shallow waters. Their food is sieved from the water while they swim with open mouths. While of no importance directly to sport fishing, they are a valuable food source for many coastal and open ocean gamefish such as bluefish, weakfish, cod, tuna, and swordfish.

Mackerel, like the menhaden, are visitors to the Massachusetts coast, usually appearing in summer and fall. They are most consistently found from just north of Cape Ann along the inner Georges Bank south to Cape Cod Bay and the Nantucket Shoals. When young, these fish feed on minute planktonic animals, larvae, and eggs. As they mature, their diet shifts to fish, small crustaceans, mollusks, and their larvae, as well as bottom organisms such as marine worms.

Mackerel are a schooling species that are very important commercially and are sought after for sport. Since they are also a food source for larger commercial and sport fish such as striped bass and bluefish, they have a double role in the production of coastal resources.

Both menhaden and mackerel are sensitive to the quality of near shore environments. The productivity of coastal ecosystems provides a major part of the base of their food supply. Reductions of that productivity through pollution, dredging and filling, and sedimentation adversely affect these two valuable fish. Since both species are attracted to and held in coastal waters by the presence of their food, reductions in their food supply means not only a loss in menhaden and mackerel, but a break in the ecological links between primary coastal producers and important sport and commercial fish.

Lobster



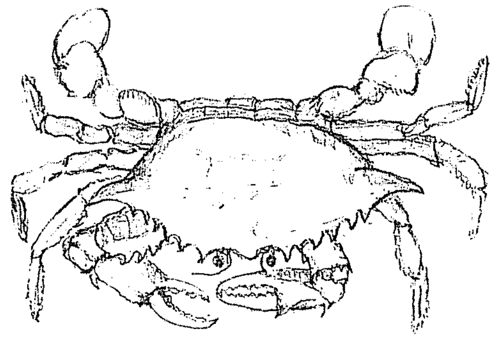
The lobster is the most commercially and culturally important crustacean of the Massachusetts coast. It is sought after by commercial fishermen, and each year thousands of people purchase permits for their personal lobster pots and buoys. The lobster lives from inshore areas, where water depth may be as shallow as ten feet, to many miles off the coast where it is found in sea bottom canyons hundreds of feet deep.

The female lobster carries the eggs with her until they hatch. Young lobster larvae are free swimming in the surface layers until they grow and physically change to the point where they resemble the adult. They then settle to the bottom where they live out their lives. Growth rate is influenced by water temperature, being faster in warmer water. However, at any temperature the lobsters' growth is slow. On the average, it takes about three years for a lobster to reach six or seven inches in length.

Lobsters feed on live animals but are limited generally to small fish and slow moving organisms such as clams, sea urchins, worms, and crabs.

The lobster is a declining resource. Overfishing in recent decades has severely reduced the population, and scarcity and higher fishing costs, plus high market demand have driven prices up. Inshore populations are particularly diminished, and fishermen have in many cases abandoned the earlier pot (trap) methods of inshore capture to trawl for lobsters in the deep offshore habitats.

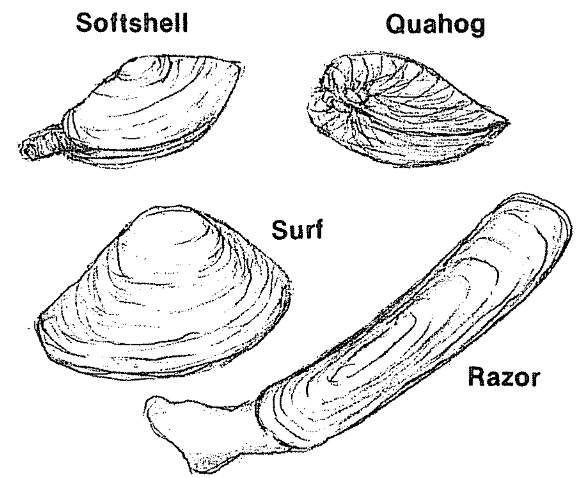
Blue Crab



The blue crab is a common and important commercial and recreational species of the southern coasts of Massachusetts. During the warmer months it can be found in estuaries, tidal creeks, salt ponds, bays, and on sub or intertidal mud flats. The blue crab spawn all through the summer and early fall, though the peak of spawning is in August and September. Crabs move offshore to mate. The young seek estuaries where the brackish water is essential for their survival and maturation. Blue crabs grow rapidly and reach maturity in one to one and a half years. During their growth, they shed their hard outer skeleton several times. It is during this shedding that crabs are considered especially desirable because their new skeleton is soft and the entire crab may be eaten. "Softshell crabs" are vigorously sought after for market and sport.

The blue crab is important in the estuarine food chain. It is fed on by many species of fish throughout its entire life cycle. Because this species relies on the detrital production of the near shore waters and low salinities to mature, it is adversely affected by losses or degradation of salt marshes, estuaries, and other productive ecosystems. The young are particularly vulnerable to changes in salinity that may occur from alteration in the yearly pattern of flows of freshwater and its mixing with salt water.

Clams



These clams, excepting the surf clam are all creatures of the "flats". They are important commercially and are eagerly sought by recreationists. The surf clam is found off open sand beaches where the high energy of waves is a common condition.

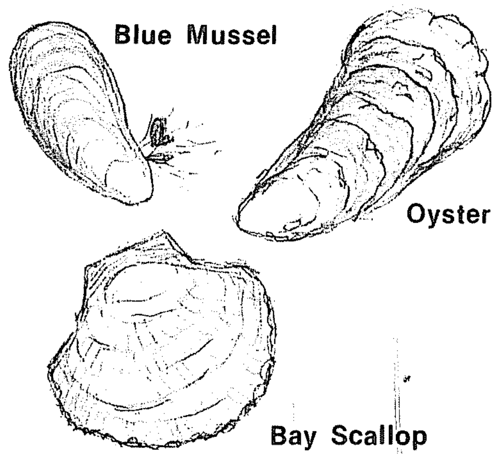
The softshell clam is the most significant in terms of total catch and in common use. It prefers mud or sandy-mud intertidal environments. This clam is the usual species used for steaming and frying.

The quahog (hardshell, cherrystone) is found in somewhat sandier habitats then the softshell, usually in the subtidal zone. It is a favorite clam for stews and chowders. Quahogs are commercially harvested by raking or hydraulic dredging, the latter technique creating a larger disruption of the clams' substrate.

Razor clams are intertidal sandflat inhabitants. Never as abundant State-wide as quahogs and softshells, they are nonetheless prized for chowders and frying. There is only a small commercial harvest of razor clams but local "flats" often provide excellent recreational clamming.

The surf clam is important for chowder and cut bait. Its habitat is one of the most physically rigorous of all coastal organisms of the open wave churned coasts along the true sand beaches. It is subtidal in location, and its population, in any single area, may fluctuate widely.

All clams are dependent on a supply of plankton and detritus transported to them by tides, currents, or waves. Reductions of primary productivity in ecosystems such as saltmarsh, rocky shores, eelgrass beds, and the intertidal flats adversely affect clam production. Some pollutants such as pesticides and metals may be lethal to clams—especially immature forms. Oil spills occasionally smother their habitats. Other forms of pollution, such as domestic wastes may not destroy clams, but the accumulation in clams of harmful bacteria from such pollution may render them unsafe for human consumption.



Scallops, oysters and, to a lesser extent, blue mussels are highly prized coastal mollusks. The bay scallop is the most commercially significant of these three bivalves, though oysters would certainly be important were there more of them in Massachusetts.

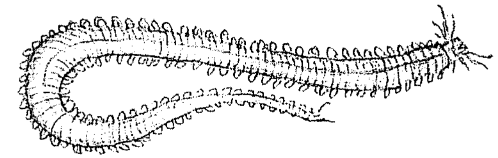
Bay scallops are subtidal, shallow water organisms with a strong dependence on eelgrass beds for their survival. They are found typically in salt ponds, mouths of estuaries, and quiet, shallow bays. The bay scallop is a mid-Atlantic animal that is rarely found north of Cape Cod.

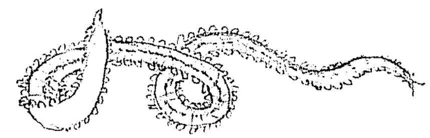
Oysters are exclusively estuarine and salt pond organisms. They are adapted to fluctuating salinities but do not persist in true marine salinity or freshwater. They require clean, rough substrates such as shell, shell fragments or coarse gravel. Oysters become fixed to their substrate once the young (spat) have attached themselves. They are relatively slow growing, taking up to three years to reach marketable size. Other than small, local populations scattered in rivers and salt ponds, only Wellfleet retains a population sufficient to support consistent commercial harvest. All other important oyster areas have been lost to persistent environmental degradation and earlier periods of overharvest.

Blue mussels, a very abundant intertidal animal, are found in dense colonies in a variety of environments. Rocks, course gravels, and sands, and constructed surfaces such as pilings, seawalls, and jetties are suitable substrates. Mussels are of considerable importance in European cuisine but have only limited appeal in North America.

As is the case with other bivalve filter feeders, mussels, scallops, and oysters must rely on other ecosystems than their own to supply their food. Damage to those ecosystems is degrading to these valuable mollusks. Some salinity changes in estuaries—particularly upstream penetration of seawater may reduce oyster populations because higher salinity favors the oyster drill, a very active predator. All three of these mollusks may be disturbed and killed by dredging and spoil disposal activities. Pollution also may reduce their numbers or prevent safe human use of them for food.

Clamworm





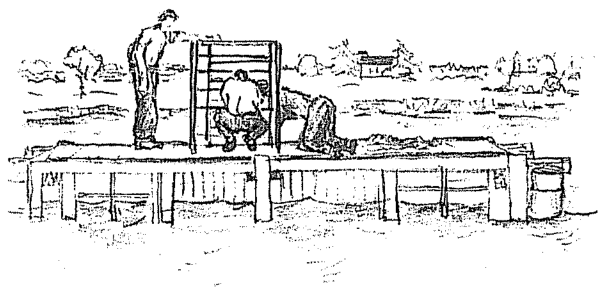
Bloodworm

These worms, commercially harvested and used by sport fishermen, are especially prized as live bait. They are a natural and preferred food for many small and large fish that forage for them on the subtidal and intertidal flats. The worms are usually found in mud or sandy-mud substrates, the common environment of the softshell clam. Both species may reach lengths of three feet but are usually found between 6 to 15 inches long.

Clamworms and bloodworms are burrowing animals, retreating below the mud surface at low tide to escape drying heat from the sun and changes in salinity. They are also sensitive to bright light and thus tend to emerge from their burrows for feeding on very cloudy days or at night.

Clam and bloodworms are vulnerable to the same environmental impacts as are clams and mussels. They are often stressed by salinity changes from changes with the pattern of salt and freshwater flows along the "flats" in estuaries or salt ponds.

Aquaculture



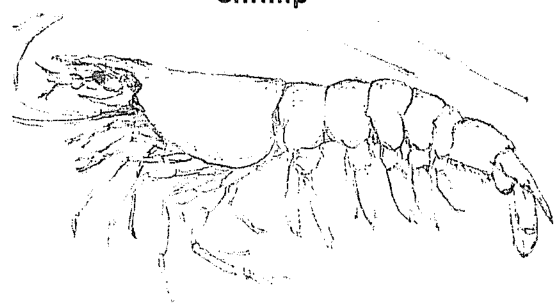
Research and development to artificially improve the production level of commercially important marine organisms has been undertaken world-wide. This management technique, called aquaculture, has focused on coastal biota, mostly mollusks and crustaceans. Clams, oysters, and lobsters claim most of the experimental attention in New England.

Estuaries, bays, and salt ponds are commonly the environments chosen for aquacultural experiments because they provide naturally high productivity of detritus and plankton. To date, most aquaculture has consisted of placing artificial substrates or containers in idealized environmental situations. High populations of the selected animal are put in the containers, or induced to naturally colonize on carefully prepared substrates. In each instance, the man-made habitat is maneuvered to place the organisms in the most favorable growing conditions with respect to food supply, salinity, or other chemical and physical factors. In some cases, available natural food may be supplemented with other "feed" in order to hasten growth or allow for higher population density in the cultured environment. Aquacultural devices are also made to facilitate easy harvest of mature organisms.

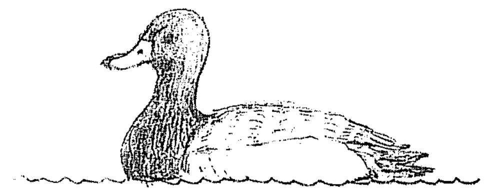
In some instances, particularly with large mobile organisms such as lobsters, aquaculture may only rear them until they are sizable enough to fend for themselves in natural conditions. This approach overcomes the high risks and low survival rate of the very young which is often the limiting condition in restoring or enlarging commercial harvests.

Aquacultural success will improve when problems of environmental degradation are relieved and when natural factors such as disease and predation can be consistently controlled. Given the ideal location for aquaculture in estuaries, there are risks incurred from direct effects of toxic or contaminating forms of pollution that tend to concentrate in the estuarine or salt pond areas. Salinity changes may also result from upstream water use or shoreline construction that change the amount or pattern of fresh water flow reaching the estuary or pond. Natural diseases or predators are encouraged by the high concentration of their hosts and prey and sometimes take a heavy toll from managed populations.

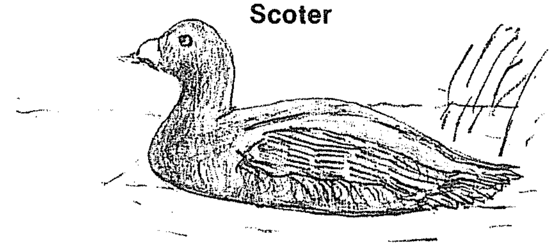
Shrimp



Greater Scaup



Scoter



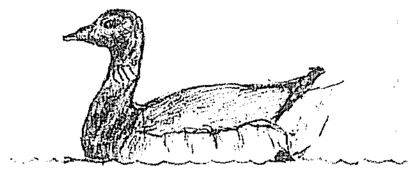
Scaup (bluebills) and scoter (coots) are open water duck that dive for their food. Both species nest in Northwestern Canada and Alaska and winter in part along the Atlantic coast from Massachusetts to the Carolinas.

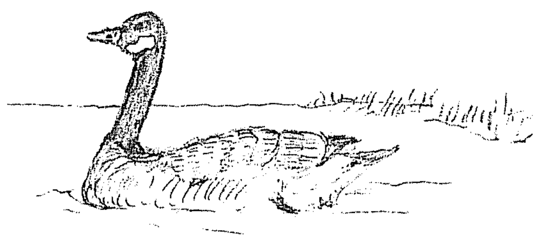
The greater scaup is both a freshwater and salt water bird. On the coast, estuaries and larger salt ponds are preferred feeding and resting areas. In those environments the scaup find their required food that includes about half animal life and half vegetable. Greater scaup feed on aquatic insects, crustaceans, and mollusks such as mussels and small oysters. Plant materials sought after are sedges, cordgrass and eelgrass. In many instances individuals living on coastal waters may have an exclusive animal diet.

Scoter are almost exclusively birds of salt water, often appearing well off the coast in calm weather. Their usual feeding and resting areas are close to shore and in estuaries where there is an abundance of mussels, clams, scallops, oysters, and crustaceans that make up the animal diet of this bird. The most effective method of seeing scoters is to observe their near shore low flights that carefully follow the shape of the shoreline.

Both scoters and scaup are sought after by hunters though not to the same degree as other ducks and geese. These birds have been affected by the destruction of various shellfish beds through sedimentation, dredging and fishing.

Brant





Canada Goose

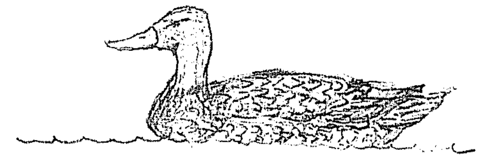
Brant and Canada geese are regular visitors or residents of the coastal waters of Massachusetts. They are especially valued by waterfowl hunters and are important animals in the natural history near shore waters, estuaries and salt ponds.

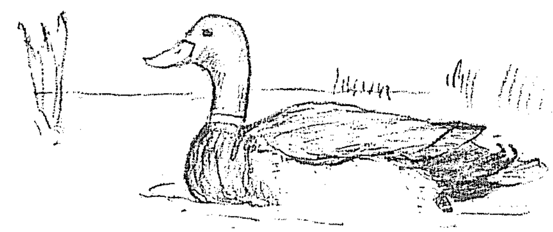
Brant are birds of the far north, nesting in the subarctic regions of Greenland and Canada. They winter from the Massachusetts Coast southward to North Carolina. Brant are almost exclusively birds of salt water. They can be seen flying in undulating lines often only a few feet above the waves. In their Massachusetts and southern range, brant rely heavily on eelgrass for food. They move inshore at the low tide when shallower eelgrass beds are within reach of the birds.

The Canada goose, a very large bird sometimes weighing over 12 lbs. and a wing span of up to 6 feet, is attracted to the marshes and salt ponds of the coast. Canada geese nest throughout the northern part of the continent with most of the Massachusetts birds coming from around Hudson Bay and the Canadian Maritime Provinces. Occasionally this bird may nest in Massachusetts but the breeding population is local and very small. Canada geese feed on land and gleaners in harvested grain fields and they will enter shallow coastal waters and marshes to feed on insects, mollusks, and crustaceans as well as green plants.

The most serious threats to the Brant and Canada goose in Massachusetts is the destruction of their winter feeding grounds and nesting places. Brant are particularly vulnerable to the loss of eelgrass, while Canada Goose are adversely affected by reductions or destructions in salt marsh, tidal flats and salt ponds. Oil spills are very damaging to both species. Hunting reduces their numbers and, if not carefully regulated can be an important limiting factor in the maintenance of population levels. Pollution from pesticides has been a problem, though restrictions on the use of some pesticides like DDT have reduced this danger.

Black Duck





Mallard

These closely related species are permanent residents and migratory visitors to the Commonwealth. They are found from the coast inland whereever shallow water and food are plentiful. Marshes, tidal creeks, and salt ponds are favorite coastal areas for these birds.

Black ducks are more prevalent in salt and brackish waters than are mallards. Animal food, such as mollusks and crustaceans figure prominently in their diet, sometimes making up as much as 25% of the food of this otherwise vegetarian bird. Black ducks prefer eelgrass among coastal plant species though they also seek out other plants and their seeds such as bulrish, burdock, and pondweeds that are found in fresh or brackish waters near the coast. Cultivated grains also are important to their diet when they are available. They nest in a variety of habitats along ponds and streams such as shrub thickets, grassy areas, or the edges of marshes and swamps.

The mallard or greenhead is the most widespread duck species in the world. It is common throughout most of North America and is a permanent resident of Massachusetts.

The mallard much prefers fresh over salt water environments though it can frequently be found feeding and resting in brackish water in estuaries and salt ponds. To a great degree the food of the mallard is similar to that of Black ducks but usually contains less than 10% animal life. Mallards generally nest on the rather open grassy edges of ponds, sloughs, and freshwater marshes. On the coast they will sometimes nest along "fresher" salt ponds.

The most significant threat to the mallard and Black duck has been the steady loss of their habitat. Draining and filling of marshes and swamps in Massachusetts and elsewhere has limited nesting and forced populations to concentrate in fewer feeding and resting areas. Fortunately, in Massachusetts, protective legislation for coastal and inland wetlands, has helped to retard habitat loss as has the establishment of National Wildlife Rufuges at the Parker River-Plum Island Marshes and on Monomoy Island.

Pollution (particularly occasional oil spills) and hunting also limit populations, though increasing constraints on the allowable harvest of black ducks has reduced some of the risks from hunting.

The grey seal is a threatened species that frequents Muskeget Island off Nantucket.

THREATENED SPECIES

Beach Meadow Vole

The beach meadow vole is found only on Muskeget Island off Nantucket. Its distribution on the island is limited to perennial grass habitats where it digs and tunnels in sandy substrates. Like most small rodents, the beach meadow vole's population fluctuates naturally from year to year and seasonally depending on breeding success and habitat conditions. It is capable of bearing several litters of five to seven young annually.

Protection for this rare and threatened species is partially accomplished because all of Muskeget Island is a refuge for nesting terns. However, predation by house cats and storm damage to the vole's habitat are limiting factors in its existence. It is important that continued protection be given to Muskeget Island and house cats removed from the island.

Ipswich Sparrow

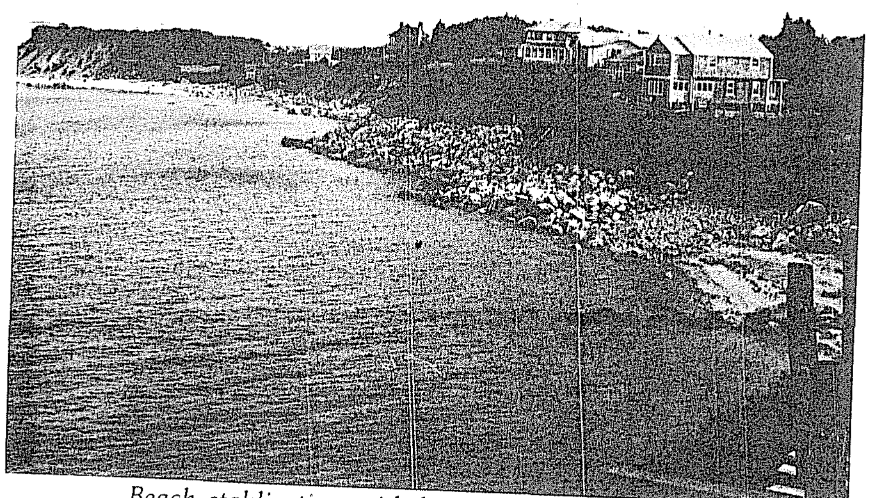
This sparrow is a winter resident in Massachusetts. The Ipswich sparrow's breeding range is restricted to Sable Island off Nova Scotia. Its wintering range is from Nova Scotia to Georgia where it lives among coastal sand dunes, particularly the primary dunes fronting the beach.

Destruction of the Sable Island breeding areas from storm erosion and loss of dune habitats in the bird's winter range from shoreline development have caused a decline in numbers. Oil exploration in the Sable Island area also threatens this species.

Protection is offered through the establishment of National Wild Refuges and National Seashores. Further protection could be achieved by enlarging the "Refuge" and "Seashore" systems and the preservation of sand dune environments through development control. Preservation of the Ipswich Sparrow breeding grounds by the Canadian government is also essential.

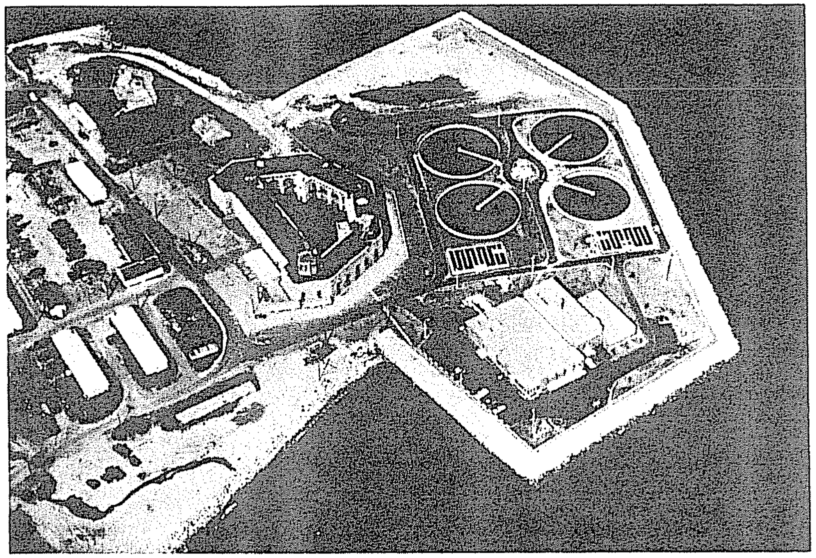
Beach nourishment project, Scituate *Courtesy Army Corps of Engineers, NE Division*

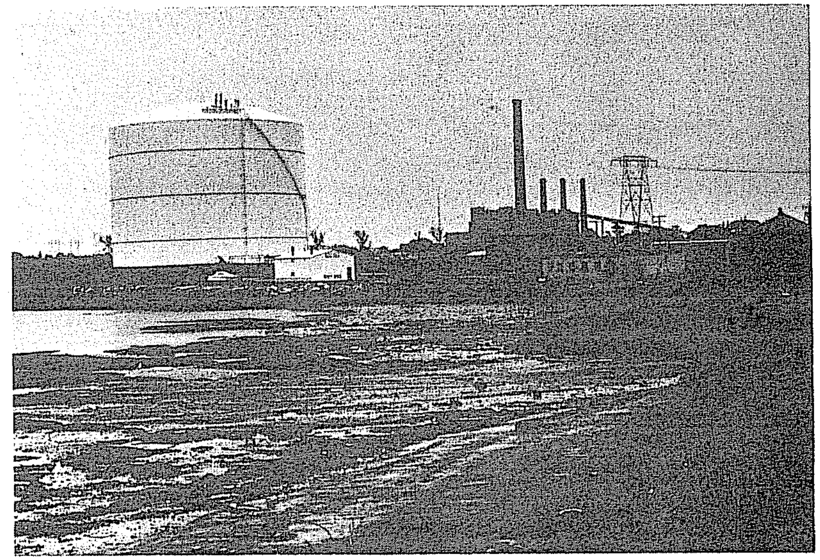
Decaying wharf *Newburyport*

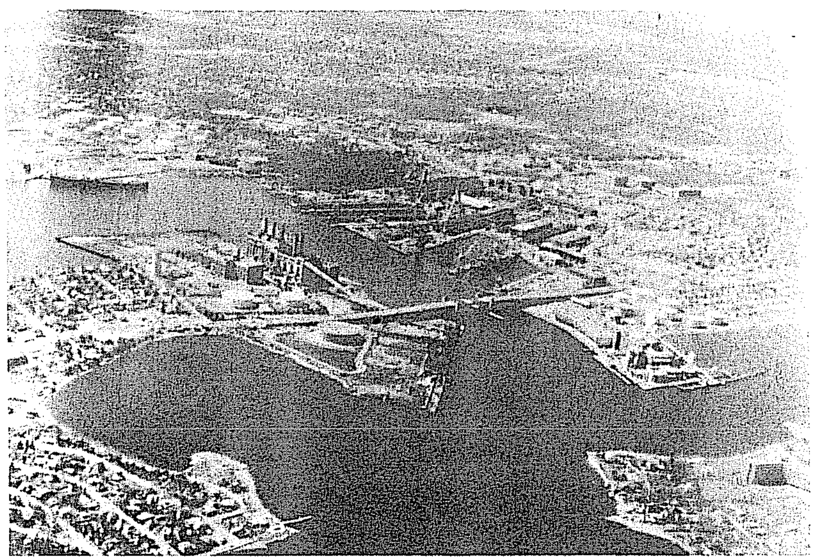


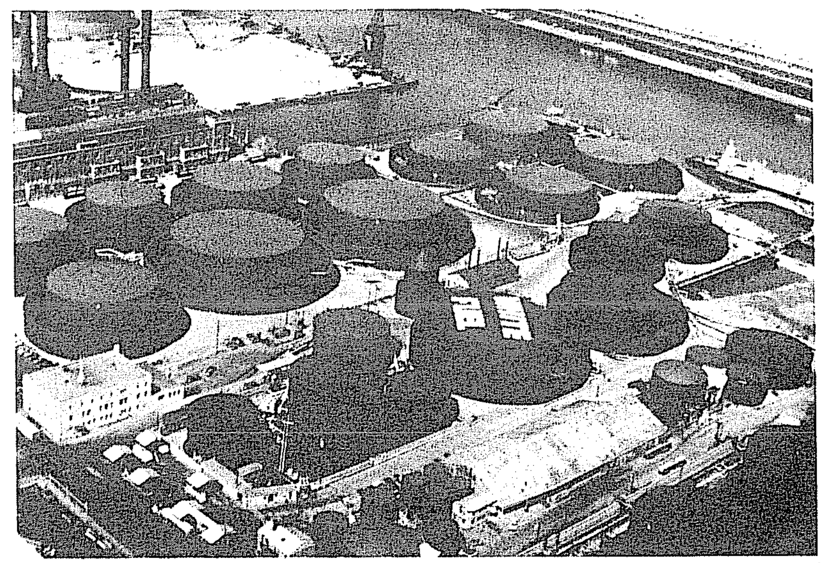
Beach stablization with boulders *Plymouth*

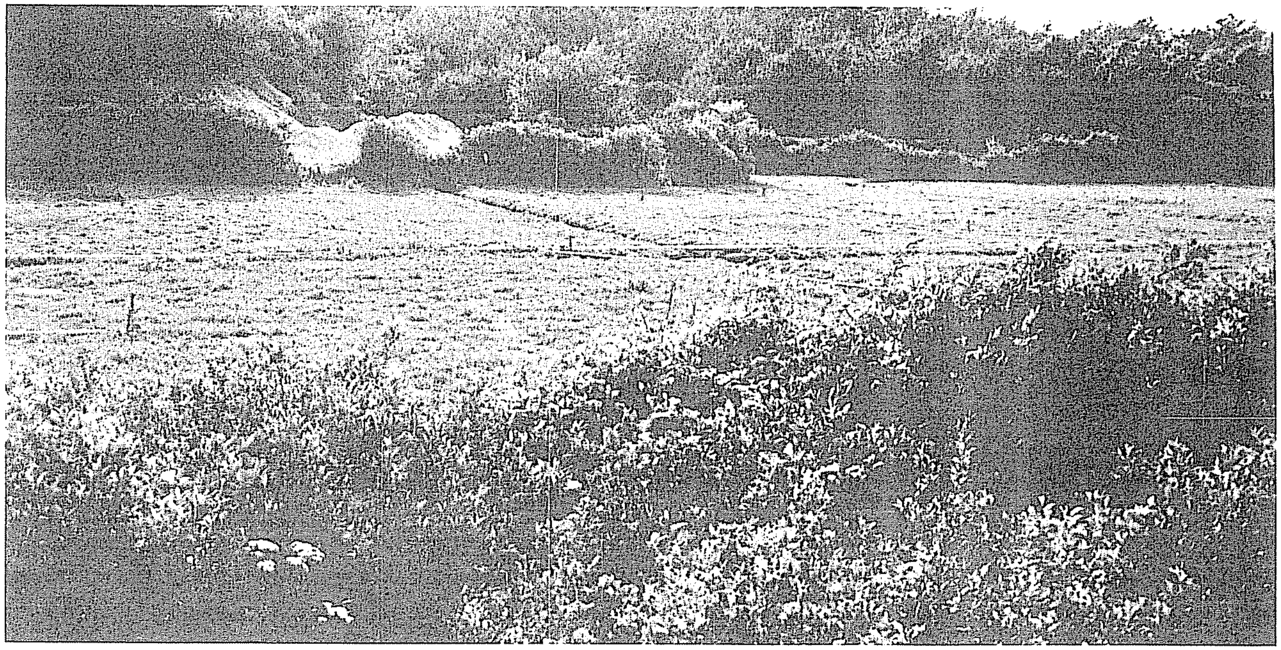
Groins for beach stabilization *Dennis*


Sewage plant   Fall River   Courtesy CZM Office

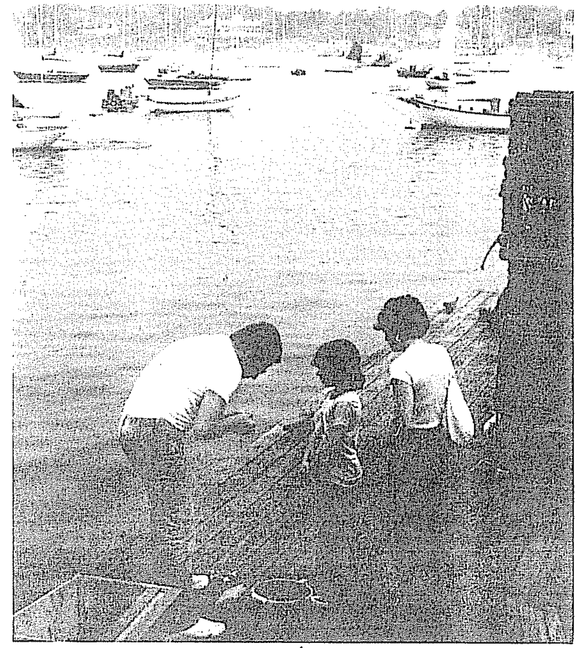

Tidal flat with oil storage. Power plant in distance   Nahant


Power plant and oil storage tanks   Quincy

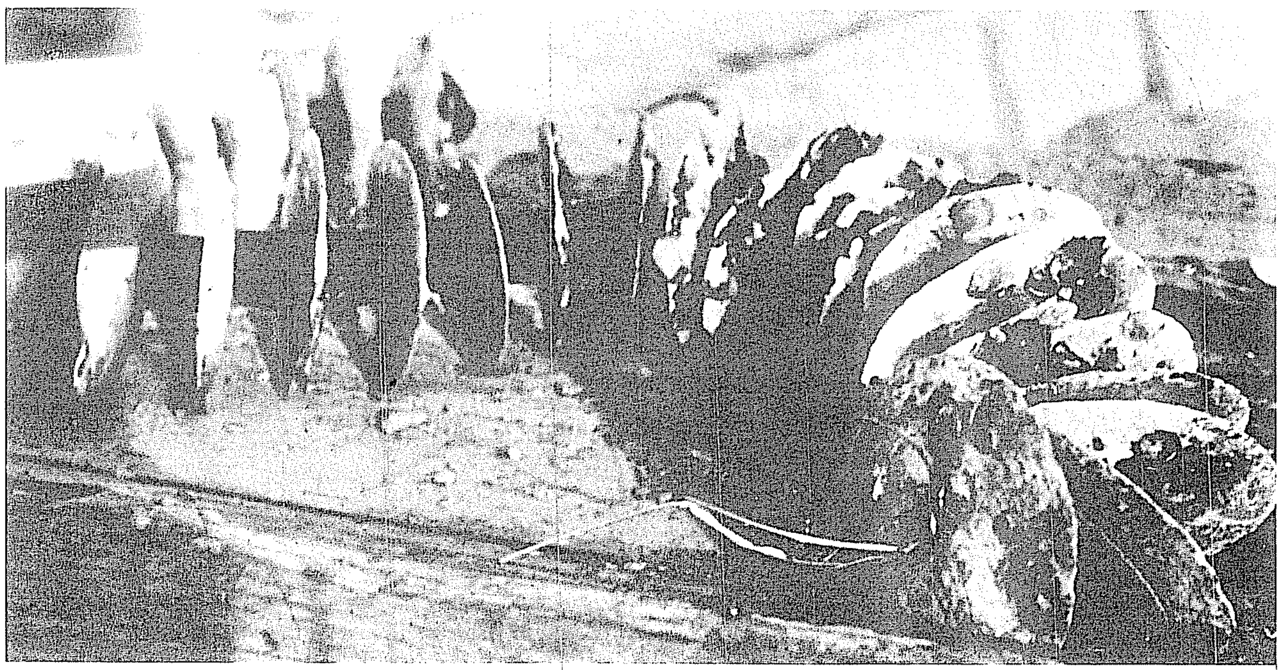

Oil storage tanks   City Pt. South Boston   Courtesy CZM Office



Cranberry bog   Manomet



Fishing with hand lines   Marblehead



Oyster aquaculture experiment   Wellfleet

Clamming flats   Sandy Neck   Barnstable

IV. PLANNING AND RESEARCH FOR COASTAL ZONE MANAGEMENT

Coastal areas, a major concern of planners, are distinguished from the remainder of the state for two principal reasons. First, the coast has diverse and particular high-quality physical and biological resources. Second, the coast experiences intense and diverse resource demands from uses which are not always mutually compatible or supportive of productive ecosystems.

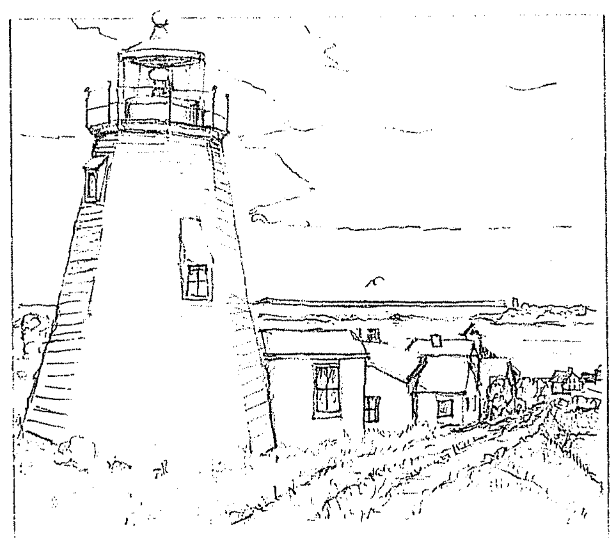
All manner of resource uses focus on the coastal areas, legitimately pursuing their own respective goals, each inadvertently levying costly impacts on the others, and, most importantly, producing in the aggregate a growing negative effect on coastal ecosystems. Issues for management do not evolve from any special or unusual coastal uses, but rather from the concentration of use effects. Not all problems are caused directly by coastal uses. For example, much and perhaps most of the pollution of estuaries results from actions upstream--often many miles. The dwindling numbers of such important fish as cod and haddock in the near-shore area is the result of massive over-harvest in the oceans by domestic and foreign fleets.

The episodic "red tides" often begin outside coastal ecosystems but their toxins reach the shore, diminishing for a period the potential harvest of shellfish.

Solutions to such problems are ûnlikely to be found in any direct management of the coastal zone. But they illustrate the importance of maintaining a close coordination between research and management activities on the coast and those related to inland areas and the ocean.

Planning for use and protection of most coastal resources will, however, be a question of how to accomodate, effectively and equitably, the needs of all kinds of coastal resource users. This question may be more pertinent in high-use areas but it is not in fact or principle limited to those areas. Virtually every mile of coastline is today subject in some degree to conflicting uses and ecosystems. degradation.

Since it is the productive and protective capacities of the coastal ecosystems that produce most of the coastal resources, management efforts must give these systems highest priority. Identification of the most productive ecosystems is a needed first step. Preservation of the state's established and thriving salt marsh, tidal flat, eelgrass, dune, and rocky shore ecosystems will provide a solid beginning for the overall productivity along the coast. The Coastal Zone Management program is currently engaged in research leading to this end. Specific studies of salt marsh ecosystems and evaluation of their relative production



coupled with the use of high and low altitude aerial photography will ÿield an inventory of critically important salt marsh communities. Similar research efforts are being directed at tidal flat and eelgrass systems.

Despite the reliance of many coastal towns on the fisheries resource, there is insufficient knowledge of critical coastal habitats supporting this resource. Research required to describe and evaluate these habitats in relation to fish species is already under way. These studies recognize species that are important commercially and for recreation and those species that are vital links in the food chain of the larger fishes. Particular concern is shown towards those species that require estuarine, salt pond, and tidal marsh creek habitats.

Accurately describing both large and small systems of ocean and coastal currents is essential to the management of the coastal zone. The circulation patterns tell much of the story of where both beneficial and harmful materials go once they reach the coast. The answer to this question is being sought by research. Findings will be used to better understand the physical and chemical conditions influencing the success of high productivity ecosystems. They will also give insight into the ability of the coastal water to transport and dilute harmful substances.

Coastal erosion is a perennial human concern. Research is needed to help define the nature and extent of the erosion process in Massachusetts. The focus of such investigation investigations would not solely be to provide a basis for erosion control. It would also be interested in the importance of erosion in the natural development of the total coastline and the role erosion plays in enlarging or limiting the growth of productive ecosystems.

ALGA (pl. algae): The simplest of all green plant forms, having neither roots, stems, nor leaves. Algae range in size from microscopic single cells to branching forms one hundred feet or more in length. Larger marine forms are known as seaweeds.

BARRIER BEACH: A bar, parallel to the shore, whose crest rises above high water.

BARRIER ISLAND: A detached portion of a barrier beach between two inlets.

BERM: A nearly horizontal upper part of the beach or one sloping away from the ocean.

BIVALVE: Possessing two valves, or shells. Bivalve molluscs include oysters, clams, and similar animals.

BRACKISH: Used to describe waters that are mixtures of fresh and salt water. Coastal marshes and estuaries generally contain brackish, or moderately salty, water.

BREAKWATER: A structure, usually of rock or concrete, protecting a shore area, harbor, anchorage, or basin from waves.

CHLOROPHYLL: A group of pigments that produces the green color of plants; essential to photosynthesis, q.v.

COMMUNITY: All the plants and animals in a particular habitat that are bound together by food chains and other interrelations.

CONSUMER: Any living thing that is unable to manufacture food from nonliving substances but depends instead on the energy stored in other living things. **See also** Decomposers; Food chain; Producers.

CONTINENTAL SHELF: A shallow portion of the sea floor adjoining continents and extending from the low-tide level seaward to a break in slope, generally 300 to 700 feet below sea level. Widths vary from less than a mile to several hundred miles.

CORIOLIS EFFECT: An apparent force acting on moving particles and resulting from the earth's rotation. It causes moving particles to be deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere, the deflection being proportional to the speed and latitude of the moving particle. The speed of the particle is unchanged by the apparent deflection.

CRUSTACEANS: The large class of animals that includes crabs, lobsters, shrimp, and similar forms. Crustaceans typically live in water and are characterized by jointed legs, segmented bodies, and hard external skeletons.

DECOMPOSERS: Living plants and animals, but chiefly fungi and bacteria, that live by extracting energy from the decaying tissues of dead plants and animals. In the process, they also release simple chemical compounds stored in the dead bodies and make them available once again for use by green plants.

DETRITUS: Particles of the decaying remains of dead plants and animals; an important source of food for many marsh animals.

DRUMLIN: Elongate oval hill formed of debris accumulated beneath a slowly advancing glacier. The long axis of the hill and steeper frontal slope mark the direction of movement of the subsequently vanished glaciers.

ENVIRONMENT: All the external conditions, such as soil, water, air, and organisms, surrounding a living thing.

EQUILIBRIUM BEACH: A beach where littoral currents supply an adequate quantity of sand or gravel during small-wave periods to replace that removed by beach erosion during storms. Equilibrium may be disturbed by human activities, such as jetty building, or the opening of new tidal inlets where sand is carried into lagoons to form tidal deltas, or a change of wave or current regime.

ESTUARY: A tidal river; the portion of a river affected by the rise and fall of the tide andt- and that contains a mixture of fresh and salt water.

FILTER FEEDERS: Animals such as clams and mussels that obtain food by filtering or straining it from the surrounding waters.

FLOOD TIDE: An usually high tide often caused by a combination of factors such as storms or a particular alignment of the sun, moon and earth.

FLYWAYS: Routes followed by migrating birds. In North America, ornithologists distinguish between the Atlantic, Mississippi, Central, and Pacific flyways.

FOOD CHAIN: The passage of energy and materials in the form of food from producers (green plants) through a succession of plant-eating and meat-eating consumers. Green plants, plant-eating insects, and an insect-eating fish would form a simple food chain. **See also** Food web.

FOOD WEB: A system of interlocking food chains. Since few animals rely on a single food source and since a given food is rarely consumed exclusively by a single species of animals, the separate food chains in any natural community interlock and form a web.

GLACIAL DRIFT: Sediment accumulated as a result of glaciation, under a glacier, at its margins or beyond, as glaciofluvial and glacial marine deposits.

GLACIAL TILL: A "boulder clay," an unsorted and unstratified sediment deposited directly by a glacier in moraines or drumlins and not reworked by meltwater.

HABITAT: The immediate surrounding (living place) of a plant or animal.

HYDROLOGIC CYCLE: The composite cycle of water exchange, including change of state and vertical and horizontal transport, of the interchange of water substance between earth, atmosphere, and ocean.

INTERTIDAL ZONE (littoral zone): Generally considered to be the zone between mean high-water and mean low-water levels.

INVERTEBRATE: An animal without a backbone. Insects and mussels are invertebrates, **see also** Vertebrate.

KETTLE HOLE LAKES: Bodies of water formed in depressions left by melted glacial ice blocks. Bogs often form in these depressions.

LARVA (pl. larvae): An active immature stage in an animal's life history, during which its form differs from that of the adult. The caterpillar, for example, is the larva of a butterfly; the tadpole is the larval stage in the life history of a frog.

LITTORAL CURRENT: A current moving parallel to the shore, usually developed by wave fronts that have an angular approach to the shore. The current causes shifting of beach sand along the shore.

MARSH: A treeless form of wetland, often developing in shallow ponds or depressions, river margins, tidal areas, and estuaries. Marshes may contain either salt or fresh water. Prominent among the vegetation of marshes are grasses and sedges.

MOLLUSCS: A major group of animals with soft, boneless bodies and, usually, shells. The group includes snails, clams, mussels, and oysters.

MORAINE: A deposit left by a glacier at its terminus (terminal moraine), along the side of a valley glacier (lateral moraine), down the glacier from the junction of tributaries (medial moraine), and as a thin glacial deposit over most of the glaciated area (ground moraine). Moraines are generally ridges, but a ground moraine may form a level plain.

MUD: Detrital material consisting mostly of silt and clay-sized particles (less than 0.06 millimeter) but often containing varying amounts of sand and/or organic materials. It is also a general term applied to any fine-grained sediment whose exact size classification has not been determined.

NUTRIENT: In the ocean, any one of a number of inorganic or organic compounds or ions used primarily in the nutrition of primary producers. Nitrogen and phosphorous compounds are examples of essential nutrients.

PANNE: A shallow depression containing water left by receding tides. The water is usually too salty to support vegetation, but sometimes mats of blue-green algae, stunted grasses, or showy flowers form. Pannes and creeks are the principal physical features of saltwater marshes..

PEAT: Partly decayed organic matter formed in boggy areas where high acidity and a lack of oxygen limits decomposition.

PHOTIC ZONE: Area penetrated by light.

PHOTOSYNTHESIS: The process by which green plants convert carbon dioxide and water into simple sugars. Chlorophyll and sunlight are essential to the series of complex chemical reactions involved.

PLANKTON: The minute plants and animals that float or swim near the surface of a body of water. The enormous quantities of plant plankton (phytoplankton) and animal plankton (zooplankton) in water provide an important food source for many aquatic animals.

PLEISTOCENE: Of or pertaining to the most recent epoch in the earth's geologic history, roughly the past one million years. The period includes at least four major retreats and advances of continental glaciers.

PRODUCERS: Green plants, the basic link in any food chain. By means of photosynthesis, green plants manufacture the food on which all other living things ultimately depend. **See also** Consumer.

PRODUCTIVITY: The rate at which living things in an ecosystem add to the amount of biological matter. Productivity is dependent on the interaction of the life and the environment.

RED TIDE: A red or reddish-brown discoloration of surface waters most frequently occurring in coastal regions, and caused by concentrations of certain microscopic organisms, particularly dinoflagellates. These organisms produce toxic substances which when ingested by filter feeders render them unfit for human consumption.

SALINITY: A measure of the quantity of dissolved salts in sea water. Formally defined as the total amount of dissolved solids in sea water in parts per thousand (0/00) by weight when all the carbonate has been converted to oxide, the bromide and iodide to chloride, and all organic matter is completely oxidized.

SAND: Loose material which consists of grains ranging between 0.0625 and 2.0 millimeters in diameter.

SEDGE: A kind of plant resembling the grasses. However, sedges usually have solid triangular stems in contrast to the round hollow stems of grasses. The floating mats of bogs are often composed of sedges.

SESSILE: Permanently attached to a surface.

SHRUB: A woody plant, usually less than twelve feet tall, having many stems rising from the ground.

SPAT: Immature oysters or scallops newly settled upon an available surface.

SPIT: A small, elongated point of land, mostly sand, extending into a body of water.

SUCCESSION: The gradual replacement of one biotic community by another, eventually leading to a more or less stable community.

SWAMP: A form of wetland characterized by moss and shrubs, or trees such as maples, gums, and cypresses. Swamps usually have better drainage than bogs. Sometimes they succeed marshes in shallow water basins, and they also may develop in sluggish streams and floodplains.

TERMINAL MORAINE: Debris deposited at the terminus of a glacier and forming a ridge remaining to mark a particular glacial stage after the glacier has melted back or vanished.

TIDAL FLAT: A sandy or muddy land covered and uncovered by rise and fall of the tides. Tidal flats are largest where land slopes are low and tidal range is high, as in northern Maine.

TIDAL INLET: A breach in a coastal barrier generally opened by a major storm and maintained by tidal flow.

VERTEBRATE: An animal with a backbone. The group includes fishes, amphibians, reptiles, birds, and mammals.

WATER TABLE: The upper level of the underground reservoir of water.

LIST OF ANIMALS AND PLANTS IN TEXT

VERTEBRATES

Fishes

Alewife	*Alosa pseudoharengus*
American Pollock	*Pollachius virens*
American Shad	*Alosa sapissima*
Atlantic Herring	*Clupea harengus*
Atlantic Silverside	*Menidia menidia*
Atlantic Sturgeon	*Acipenser brevirostrum*
Banded Killifish	*Fundulus diaphanus*
Blueback Herring	*Alosa aestivalis*
Bluefish	*Pomatomus saltatrix*
Cod	*Gadus callarias*
Cunner	*Tautogolabrus adspersus*
Four-spine Stickleback	*Apeltes quadracus*
Haddock	*Melanogrammus aeglefinus*
Mackerel	*Scomber scombrus*
Menhaden	*Brevoortia tyrannus*
Mummichog	*Fundulus heteroclitus*
Pipefish	*Syngnathus fuscus*
Rainbow Smelt	*Osmerus sturio*
Scup	*Stenotomus versicolor*
Sea Robin	*Prionotus carolinus*
Short-nose Sturgeon	*Acipenser brevirostrum*
Smelt	*Osmerus mordax*
Striped Bass	*Morone satillis*
Summer Flounder (Plaice)	*Paralichthys dentatus*
Swordfish	*Xiphias gladius*
Tautog	*Tautoga onitis*
Three-spine Stickleback	*Gasterosteus aculueatus*
Tomcod	*Microgadus tomcod*
Tuna	*Thynnus thynnus*
Weakfish	*Cynoscion regalis*
White Perch	*Morone americana*
Winter Flounder	*Pseudopleuronectes americanus*

Birds

American Golden Eye	*Glaucionetta clangula americana*
Black-backed Gull	*Larus marinus*
Black Duck	*Anas rubripes*
Black Skimmer	*Rynchops nigra*
Brant Goose	*Branta bernicla*
Canada Goose	*Branta canadensis*
Clapper Rail	*Rallus longirostris*
Common Tern	*Sterna hirundo*
Double-crested Cormorant	*Phalacrocorax auritus*
Greater Scaup Duck	*Aythya marila nearctica*
Herons	*Nycticorax nycticoras*, *Ardea herodias*
Herring Gull	*Larus argentatus*
Ipswich Sparrow	*Passerculus princeps*
Laughing Gull	*Larus atricilla*
Mallard	*Anas platyrhynchos platyrhynchos*
Marsh Hawk	*Circus cyaneus*
Mute Swan	*Cygnus olor*
Osprey	*Pandion halicetus cardinensis*
Pectoral Sandpiper	*Erolia melanotos*
Seaside Sparrow	*Ammospiza maritima*
Semi-palmated Sandpiper	*Ereunetes pusillus*
Sharp-tailed Sparrow	*Ammospiza caudacuta*
Song Sparrow	*Melospiza melodia*
Sparrow Hawk	*Falco sparverius*
Spotted Sandpiper	*Actitis macularia*
White-winged Scoter	*Melanitta fusca doglandi*

Mammals

Beach Meadow Vole	*Microtus breweri*
Meadow Mouse	*Microtus pennsylvanicus*
Muskrat	*Ondatra zibethica*
Rabbit	*Sylvilagus floridanus*

INVERTEBRATES Arthropods

Crustaceans

Acorn Barnacle	*Balanus balanoides*
Blue Crab	*Callinectus sapidus*
Fiddler Crabs	*Uca pugnax, pugilator and minax*
Ghost Shrimp	*Callianassa atlantica*
Gooseneck Barnacle	*Lepas fascicularis*
Green Crab	*Carcinides maenas*
Hermit Crabs	*Pagurus pollicarus and longicarpus*
Jonah Crab	*Cancer borealis*
Lobster	*Homarus americanus*
Mud Crab	*Panopeus herbstii*
Oyster Crab	*Pinnotheres ostreum*
Pea Crab	*Pinnixa chaetopterana*
Rock Crab	*Cancer irroratus*

Molluscs

Bay Scallop	*Argopecten irradians*
Channeled Whelk	*Busycon Canaliculatum*
Dog Whelk	*Thais lapillus*
Edible Mussel	*Mytilus edulis*
Gem Clam	*Gemma gemma*
Knobbed Whelk	*Busycon caricum*
Limpet	*Acmaea testudinalis*
Marsh Snail	*Melampus bidentatus*
Moon Snail	*Polinices heros*
Mud Snail	*Narcarius obsoletus*
Oyster	*Crassostrea virginica*
Oyster Drill	*Urosalpinx cinerea*
Periwinkle	*Littorina spp.*
Pond Snail	*Planorbis trivolvis*
Quahog	*Mercenaria mercenaria*
Razor Clam	*Ensis directus*
Ribbed Mussel	*Modiolus demissus plicatulus*
Rough Periwinkle	*Littorina rudis*
Soft-shell Clam	*Mya arenaria*
Surf or Sea Clam	*Spisula solidissima*

Echinoderms

Brittle Star	*Ophiopholis aculeata*
Common Starfish	*Asterias forbesi*
Green Sea Urchin	*Strongylocentrotus droehbachiensis*
Sand Dollar	*Echinarachnius parma*
Sea Cucumber	*Cucumaria frondosa*

Merostomates

Horseshoe Crab	*Limulus polyphemus*

Insects

Beach Flea	*Talorchestia spp.*
Greenhead Fly	*Tabanus nigrovittatus*
Mosquito (Salt marsh)	*Aedes solicitans*

Coelenterates

Moon Jelly	*Aurelia aurita*
Pink Jellyfish	*Cyanea capillata*
Plumose Anemone	*Metridium dianthus*
Sagartia Anemone	*Sagartia modesta*
Sea nemone	*Adamsia spp.*
Stalked Jellyfish	*Haliclystus auricula*

Annelids

Clam Worm	Nereis virens
Fringed Worm	*Cirratulus cirratus*
Lugworm	*Arenicola marina*
Parchment Worm	*Chaetopterus variopedatus*
Plumed Worm	*Diapatra cuprea*
Sand Worm	*Polycirrus eximius*
Trumpet Worm	*Pectinaria gouldii*
Tube Worm	*Spirorbis spp.*

PLANTS

Seed Plants

Alder (Speckled)	*Alnus rugosa*
American Beech	*Fagus grandifolia*
Arrowwood (Southern)	*Viburnun dentatum*
Bayberry	*Myrica pensylvanica*
Beach Grass	*Ammophila breviligulata*
Beach Heather	*Hudsonia tomentosa*
Beach Pea	*Lathyrus maritimus*
Beach Plum	*Prunus maritima*
Beach Wormwood	*Artemisia caudata*
Bear Oak	*Quercus ilicifolia*
Bearberry	*Arctostaphylos uva-ursi*
Black Cherry	*Prunus serotina*
Black Grass	*Juncus gerardi*
Black Gum Tree	*Nyssa sylvatica*
Black Oak	*Quercus velutina*
Blueberry	*Vaccinium spp.*
Bulrush	*Scirpus validus*
Cattail	*Typha latifolia*
Cord Grass	*Spartina alterniflora*
Cranberry	*Vaccinium macrocarpon*
Crowberry	*Corema conradii*
Duckweed	*Spirodela polyrhiza*
Dusty Miller	*Artemisia stelleriana*
Eelgrass	*Zostera marina*
Fly Honeysuckle	*Lonicera morrowi*
Golden Aster	*Chrysopsis falcata*
Golden Heather	*Hudsonia ericoides*
Grey Birch	*Betula populifolia*
Heather	*Calluna vulgaris*
Highbush Blueberry	*Vaccinium corymbosum*
Holly Tree	*Ilex opaca*
Indian Pipe	*Monotropa uniflora*
Japanese Black Pine	*Pinus nigra*
Jointed Glasswort	*Salicornia europaea*
Meadowsweet	*Spiraea latifolia*
Moccasin Flower	*Cypripedium acaule*
Partridge Berry	*Mitchella repens*
Pitch Pine	*Pinus rigida*
Plume Grass (Reeds, Phragmites)	*Pragmites communis*
Poison Ivy	*Rhus radicans*
Pussy Willow	*Salix discolor*
Quaking Aspen	*Populus tremuloides*
Red Cedar	*Juniperus virginiana*
Red Maple	*Acer rubrum*
Salt-meadow Cordgrass	*Spartina patens*
Salt-spray Rose	*Rosa rugosa*
Saltwort	*Salsola kali*
Sassafras	*Sassafras albidum*
Sea Blite	*Suaeda maritima*
Sea Lavender	*Limonium nashii*
Sea Rocket	*Cakile edentula*
Sedges	*Carex spp.*
Seabeach Orache	*Atriplex hastata*
Seabeach Sandwort	*Arenaria peploides*
Seaside Aster	*Aster linariifolius*
Seaside Goldenrod	*Solidago sempervirens*
Seaside Spurge	*Euphorbia polygonifolia*
Shadbush	*Amelanchier canadensis*
Spike Grass	*Distichlis spicata*
Staghorn Sumac	*Rhus typhina*
Sundew	*Drosera rotundifolia*
White Cedar	*Chamaecyparis thyoides*
Wild Rose	*Rosa virginiana*
Glasswort	*Salicornia spp.*

Algae

Blue-green	*Calothrix spp.*
Dulse	*Rhodymenia palmata*
Enteromorpha	*Enteromorpha intestinalis*
Irish Moss	*Chondrus crispus*
Kelps	*Laminaria spp.; Alaria esculenta; Agarum cribrosum*
Knotted Wrack	*Ascophyllum nodosum*
Rockweeds	*Fucus spp.*
Sea Laver	*Porphyra vulgaris*
Sea Lettuce	*Ulva lactuca*

Lichens

Lichens	*Cladonia spp.*

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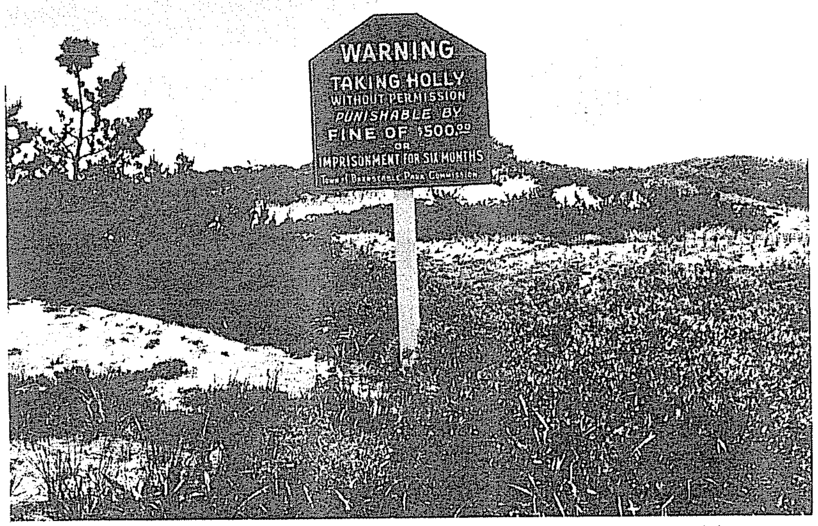
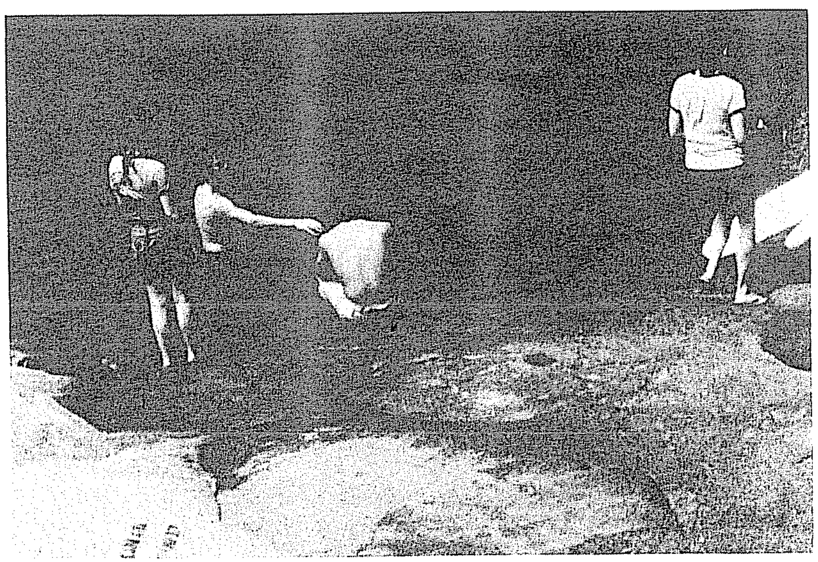
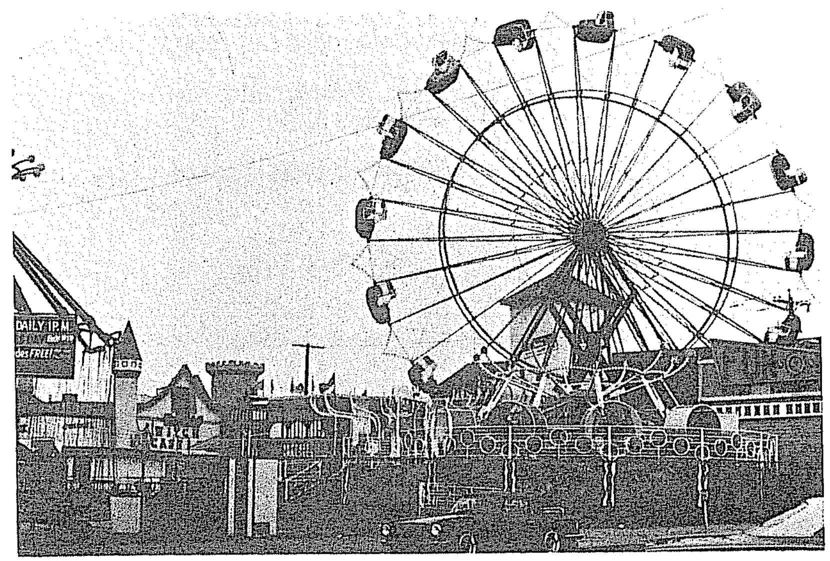


Dune vegetation   Sandy Neck   Barnstable

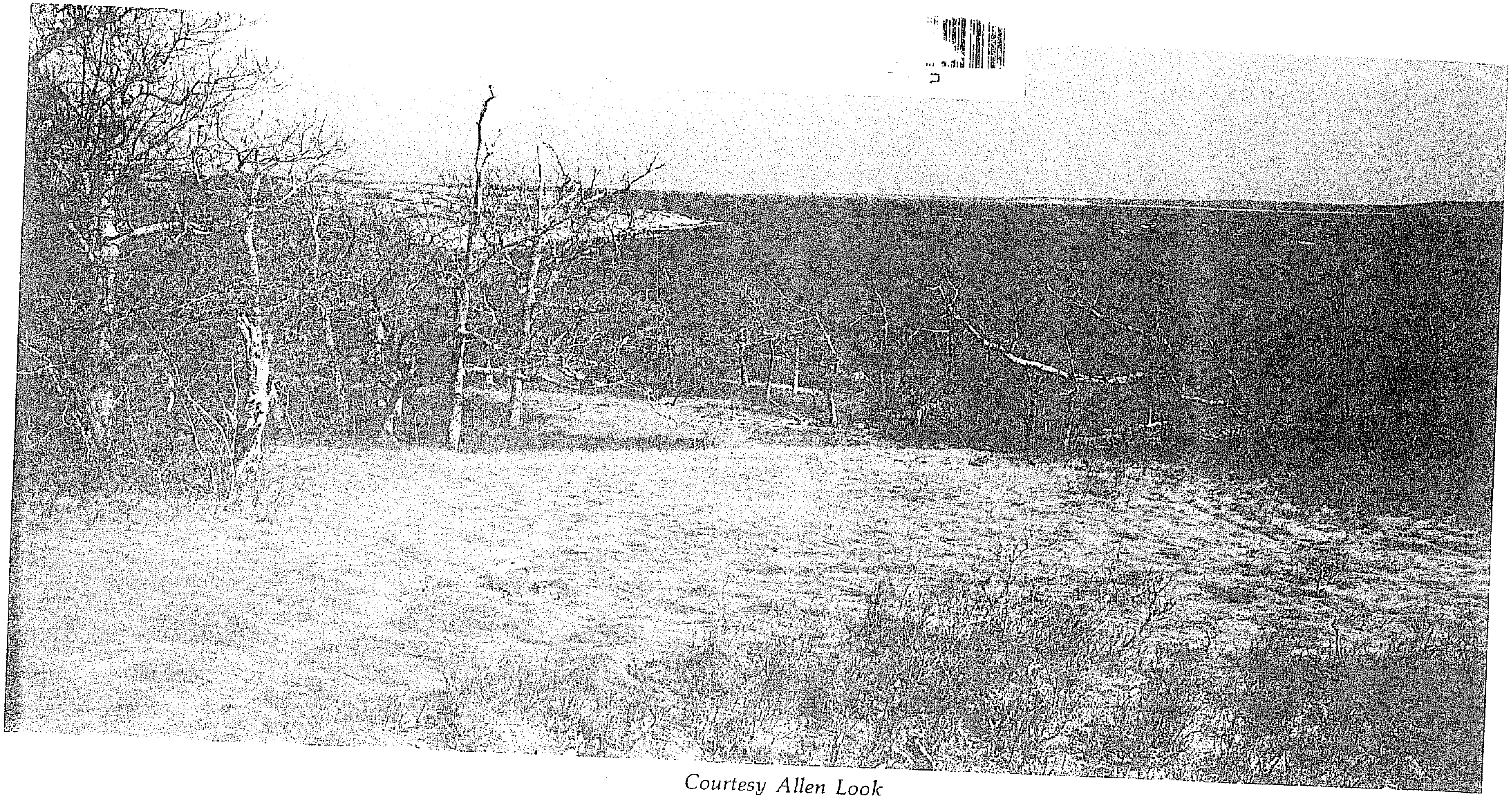
Road causes destruction of dune vegetation   Duxbury



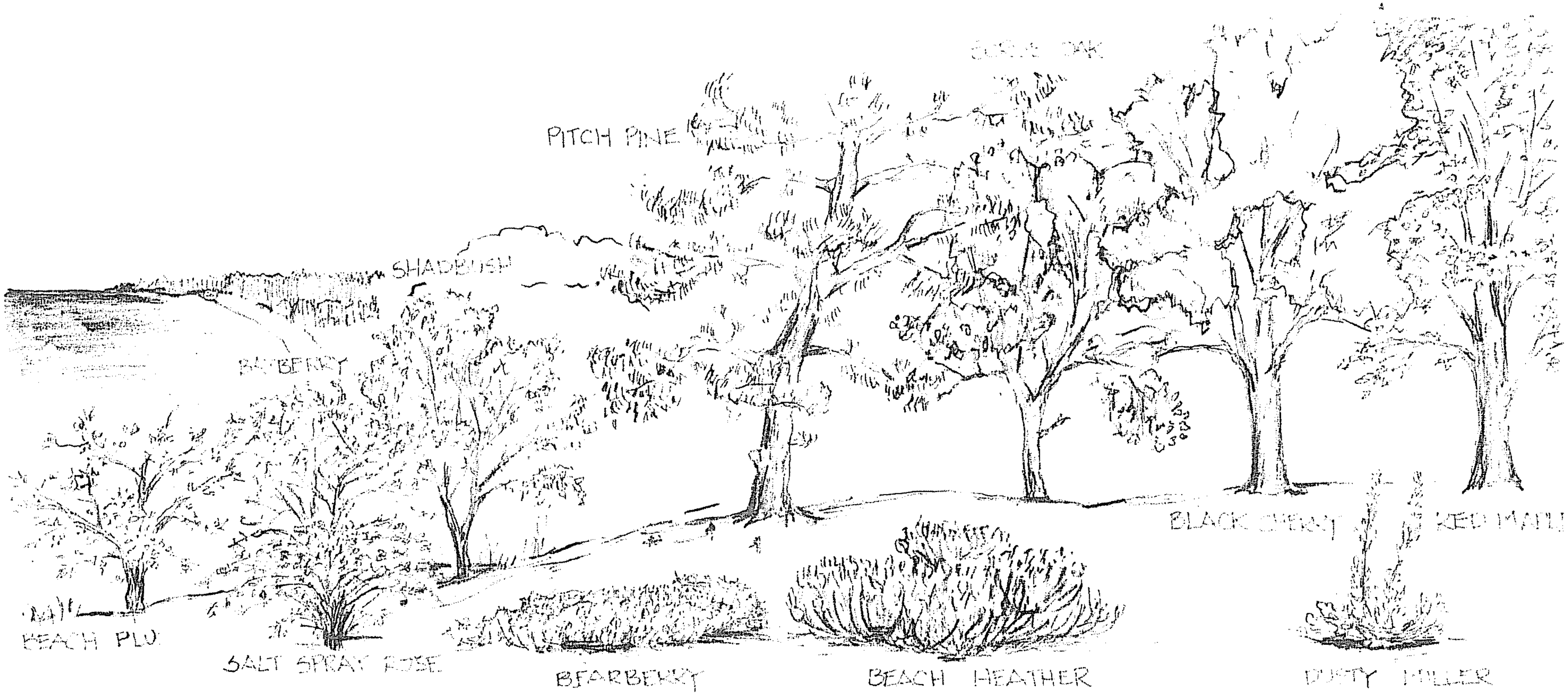
The problem of public access   Note no trespassing signs   Scituate



Salisbury Beach Amusement Park   Salisbury



Courtesy Allen Look



SOME TREES and PLANTS ASSOCIATED WITH THE MASSACHUSETTS COAST