Coastal Awareness:

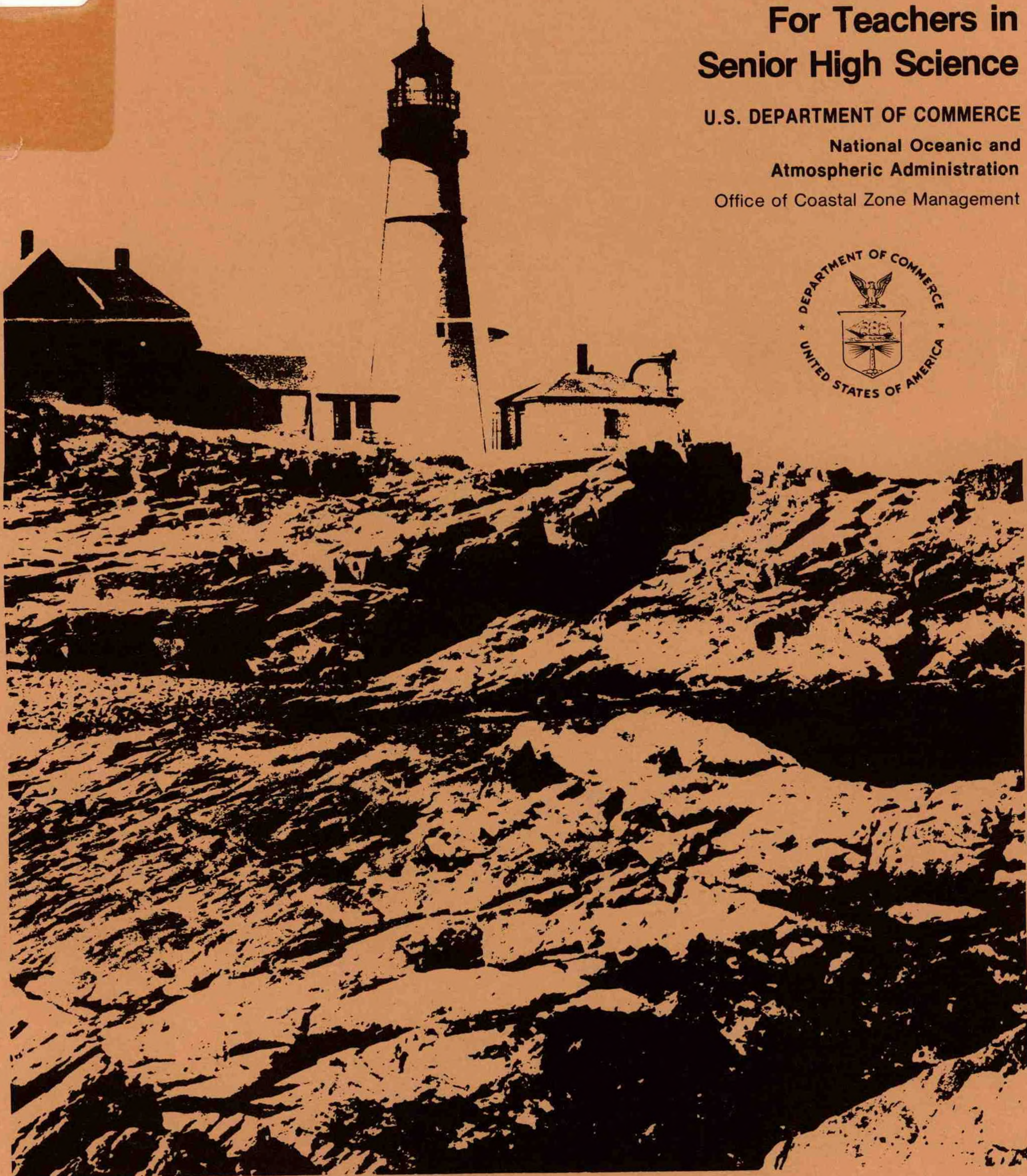
A Resource Guide For Teachers in Senior High Science

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

Office of Coastal Zone Management

DEPARTMENT OF COMMERCE • UNITED STATES OF AMERICA



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FOREWARD

This series of Resource Guides on Coastal Awareness in Science was developed for elementary, junior high and high school teachers who would like to instill in children and young adults an appreciation of the ecologic value of the coast. Each of the Guides contains concepts, and activities which could be used in a week long unit on Coastal Awareness. The purpose of this guide is not to present a definitive work on coastal ecology, but to entice teachers to explore ecological aspects of coastal awareness. A more complete understanding of the coast requires study of the interactions of ecology with economics, humanities, and government.

As state governments develop coastal management programs, citizens must make choices as to the most important uses of the coast. An understanding of coastal ecological processes will aid students as they participate in future decision making.

The Coastal Awareness Series in Science includes:

Coastal Awareness in Elementary Science
Coastal Awareness in Junior High Science
Coastal Awareness in Seniro High Science

These are available from the Office of Coastal Zone Management, National Oceanic and Atmospheric Administration, 3300 Whitehaven Street, N.W., Washington, D. C. 20235.

Robert W. Knecht
Assistant Administrator
Office of Coastal Zone Management

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Joan Froede of the University of Colorado, Institute for Equality in Education, contributed substantially to the Guides. John Evans from RRD and Bill Welsh of the National Oceanic and Atmospheric Administration illustrated the text. Joann Dennett of RDD contributed to the production of the Guides and Linda Sadler of the Office of Coastal Zone Management provided support and assistance.

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THE CHARACTER OF THE COAST

THE COASTS

The shore lines of the United States--where the land meets the sea--measure more than 140,000 km (88,000 mi). If straightened, they would stretch more than three times around the equator of the earth. Our nation's coasts include the sea shores of the continental United States, Alaska, Hawaii, four Atlantic island groups, and nine Pacific island groups. The Great Lakes and all the sounds, bays, creeks, and rivers washed by tidal waters are also included.

What are the special characteristics that define a coast, that make coasts valuable and vulnerable to human activities? Why and how should we protect this vital area of our nation?

The coast is a place of untold natural resources. It is a place to which one can escape, a place to play, to be serene, to be inspired. In near-shore ocean waters fish can be caught for sport or for food, and the coast itself can be a significant agricultural area. Each coast has a different history, different pressures, and different problems. Yet, in a physical sense, many of their problems may be similar.

Pollution is one such common problem. The Great Lakes are the largest fresh water resource in the world. Pollution of these lakes, which began in the 1800's, has continued steadily: forests were cleared, disrupting the natural balance, and increases in population, industry, commerce, and recreation continue to encroach.

The development that has plagued the Great Lakes for a century is only just beginning in Alaska. But changes come quickly where the margin for life is narrow, and in the frigid waters of the Bering Sea there is little room for error. The Bering Sea is literally the "fish basket" of the northern hemisphere. It supports a surprising variety of life, including one of the largest marine mammal populations of the world, what may well be the world's largest clam population, one of the world's largest salmon runs, some of the largest bird populations per unit area, the world's largest eelgrass beds, and unusually high numbers of bottom-dwelling fish.

Any coast consists of two primary elements: the water and the land. The area where these meet--the coast--has unique characteristics due to periodic inundation and continual changes in salinity. The biological composition of the coasts is often in delicate balance.

The science student concerned with the coastal zone will want to investigate both the water and the land as well as their interaction. Coastal waters are generally rich in nutrients that have been carried from the land by the rivers and streams. Near-shore coastal waters are particularly productive. These waters are a basic resource; they are affected by a variety of factors--the forces that cause tides, the winds that augment the waves, and the activities of human beings, including exploration and exploitation.

THE SHORE

There can be other definitions, but for our study, we define the shore as the narrow strip between the high-water and low-water marks of spring tides. Thus, there are regular, yet extremely variable local environments. First, the sea covers and uncovers the coastal area twice daily. Temperature ranges may be great within a single day. The salt concentration may vary greatly. The extent to which this intertidal zone is uncovered at low tide depends on the sharpness of its slope which in turn depends on a variety of factors including the nature of the land, its configuration, and the action of the tides, currents, and rivers.

The three basic types of shore are rock, sand, and mud. They are often mixed together. The waves have the greatest influence on molding the shore as they break against the land, washing away loose materials, eating into hard rocky coasts, and sometimes forming an abrasion platform at the base of high cliffs. Powerful crosscurrents deposit banks of sand that have been formed by the disintegrating rocks. Mud flats occur at the mouths of rivers or in sheltered creeks and inlets where the sediment brought from the land is deposited. Ice, weather, and the elements all work to help form the shore.

Plants and animals are other factors in coast building. Plants may act to bind sand and mud together into dry land. Encrusting animals may serve to protect rocks or to destroy them. Light plays a significant role in this environment, affecting growth of vegetation which, in turn, affects animal growth and survival.

Estuaries, too, affect the shore environment. Dilution by fresh water will occur at the mouths of rivers, while increased concentrations of salt will occur as a result of evaporation during the summer.

OCEAN IN MOTION: WIND, WAVES, CURRENTS AND TIDES

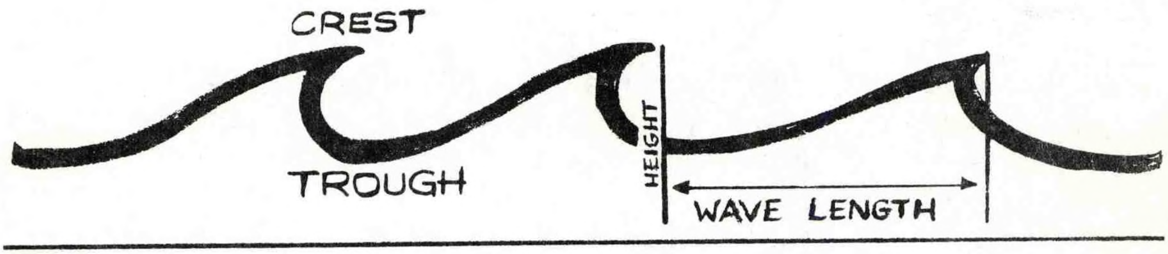
Wind generates waves. The wind, blowing irregularly, causes significant pressure differences that deform the water's surface, creating wave crests of many heights. The wind then pushes against these crests, supplying energy to the waves as they grow and become more regular in height and length. Wave growth depends on four factors: wind velocity, distance of open water over which the wind has blown (called the "fetch"), duration of the wind, and the state of the sea (waves that were present when the wind started blowing).

The wind also plays a part in coast formation. In addition to their indirect effect through action on the water, powerful winds can cut into rock, tearing away gravel that slides to the water's edge. They may also pick up grains of sand and pile them into dunes.

WAVES

Waves are the sculptors of the coasts. Forceful or gentle, loud or lulling, they combine two distinct types of motion. One is the circular motion of the water molecules within the wave, the up and down motion of the droplets. The other is the advancing movement. The actual water molecules have no horizontal motion as the wave advances through the ocean.

Waves are described by their height, length, velocity, and period. Period is the number of seconds it takes for two successive crests to pass a stationary point. Height is the vertical distance from the crest (high point) to the trough (low point) and length is the distance from one crest to the next. Period, length and wind velocity are interrelated. Wave height, however, is not related to these factors. The height of a wave in meters is usually about one-tenth the wind's speed in kilometers per hour.



As they move away from the winds that started them, waves tend to expand laterally and to become lower, more rounded, and more symmetrical. They then move in groups of similar size, called "wave trains"; the individual waves are called "swells." Once a wave train has formed, it will continue to travel over the sea until it either breaks on a shore or is flattened by opposing winds or wave systems. (In these materials, we will be concerned in particular with the breakers because of their effect on the coastal area.) As a swell approaches the beach, the topography of the ocean bottom takes effect. Depending on wave length and bottom contour, waves may break at depths from one-half to three times their height.

The bottom slope is the key determinant not only of the depth at which a wave breaks but also of the manner in which it breaks. A steep bottom results in a wave that retains all its energy until the last possible moment, when the crest peaks up suddenly and plunges violently forward into the trough. As the crest folds over it becomes concave, creating a "tube" or tunnel of air on the shoreward face. These are known as "plunging waves." Hollow plunging waves are the most challenging for surfers because their steepness makes for a very fast ride and it is often possible to crouch under the falling crest--to be "locked in the tube." The plunging waves that curl over the dangerously shallow coral reefs of Hawaii's "Banzai Pipeline" are a famous example of this kind of wave.

A gradually shoaling bottom results in a wave that releases its energy more slowly. When a crest finally becomes unstable, it rolls down or spills into the trough and the wave face remains gently sloped. It is these "spilling waves" that display white water at the crest.

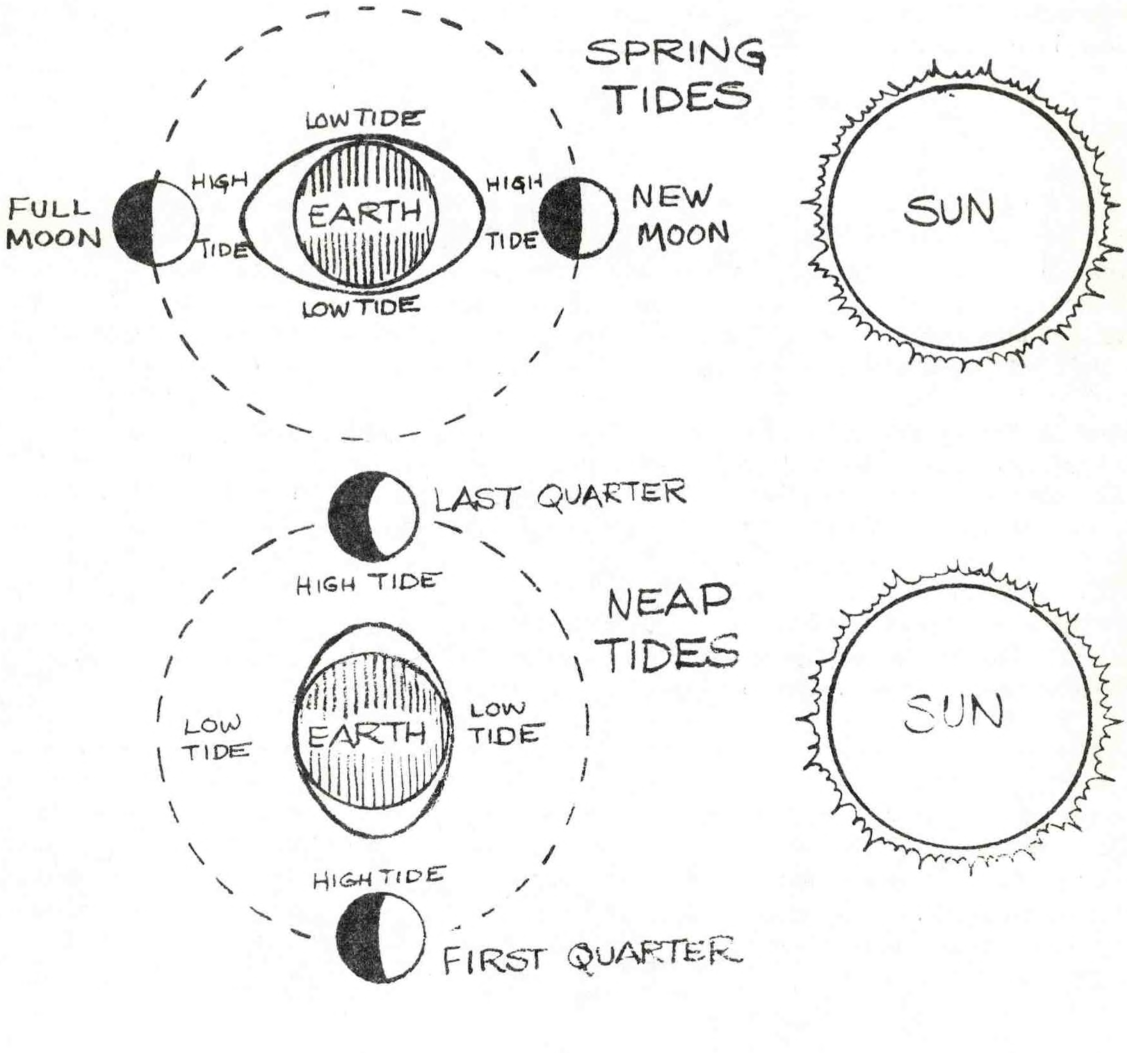
Irregularities in the ocean bottom tend to make waves spill rather than plunge. Even long-period waves break as spillers on a flat sloped beach, but any suddenly shallow spots will cause most waves to "suck out" and plunge, regardless of their periods. Most surf zones are in a state of constant change.

Wind is not the only generator of waves. Earthquakes on the land or under the sea may cause a drastically low tide that is followed by destructive giant waves (sometimes called tsunamis) hurling relentlessly against the shore.

TIDES

The tides are important in determining the character of the coast. Tides result from the effect on the waters of the gravitational attraction among the sun, moon, and earth.

The masses of the earth and the moon exert a gravitational pull on each other that affects every particle on earth, including water. The force is greatest on those particles nearest the moon, but it is much smaller than the earth's force. Although the force required to pull water vertically off the earth would be great, a much weaker force can pull the water horizontally, in effect sliding it across the face of the earth. Water is drawn toward the point directly "below" the moon, and high tides occur when water piles up in this way. Identical forces cause comparable effects on the side of the earth farthest from the moon. In both cases, the water moving into the high tide is being drawn away from another region of the earth. Thus, there are high tides on opposite sides of the earth on a line directly extended between the moon and the earth, and there are low tides midway between the two high tides, in the area from which water for the high tides was drawn.



Due to the changing position of the moon, a tidal pulse sweeps around the surface of the earth, causing secondary waves that move across the oceans. In mid-ocean the secondary waves may be only as high as 1 meter, but where the water is shallow these sea waves become much higher. The increased height is the result of a tremendous friction force which slows the wave down. When such tidal pulses move through narrow channels, the water is "bottled up." The highest tides occur in these narrow channels; a well known example of such tides is the Bay of Fundy between Nova Scotia and New Brunswick in Canada.

Because the earth and the moon move orbitally (the earth around the sun and the moon around the earth), both the timing of the tides and their range vary in response to these gravitational forces. The greatest difference between high-water and low-water is found at the "spring" tide, when sun and moon exert their force in the same direction during the new or full moon. The highest tide is during the new moon when the moon is in line with the sun, with the earth between them, and the gravitational pull is all in the same direction. The smallest, or "neap" tide occurs when the high-water mark is at its lowest, and the low-water mark is at its highest.

CURRENTS

The forces that keep the great mass of ocean water in motion are many and varied; important among them are the heat of the sun and the rotation of the earth.

As the sun warms the surface water at the equator, the water expands and raises the surface just enough to cause a gentle slope. Water at the equator therefore runs downhill to the poles. The heavier polar cold water sinks and spreads slowly along the bottom of the ocean toward the equator. This interchange of warm equatorial waters with cold polar waters is complicated by a variety of additional forces. For example, the earth's motion toward the east affects the water on the surface of the earth both directly, by causing waves to pile up, and indirectly, by creating winds. The spin of the earth also results in the Coriolis effect -- the tendency of water (or any moving object) to turn slightly to the right in the northern hemisphere and slightly to the left in the southern. Consider the Atlantic Ocean waters in the region just north of the equator, where the Gulf Stream originates. Heated by the tropical sun, the salt concentration of the water steadily increases as a result of constant evaporation. Meanwhile, the trade winds (a consequence of the earth's spin) continually blow over the warm, salty waters, pushing the surface waters in a westerly direction toward the north coast of the South American continent. The waters then move toward the Caribbean Sea and on, northwesterly, into the Gulf of Mexico where they pile up, raising the surface level. Following its natural tendency to seek equilibrium, the water drops into the Florida Straits, the only possible egress. From there the Gulf Stream runs northward along the coast.

As the Gulf Stream moves north it trends increasingly toward the right (to the east) because of the Coriolis effect. By the time it reaches 40°N latitude, it is flowing due east across the Atlantic, has lost considerable speed, and has widened; it has also cooled down. Currents similar to the Gulf Stream move the waters of the Pacific, Indian, and other oceans.

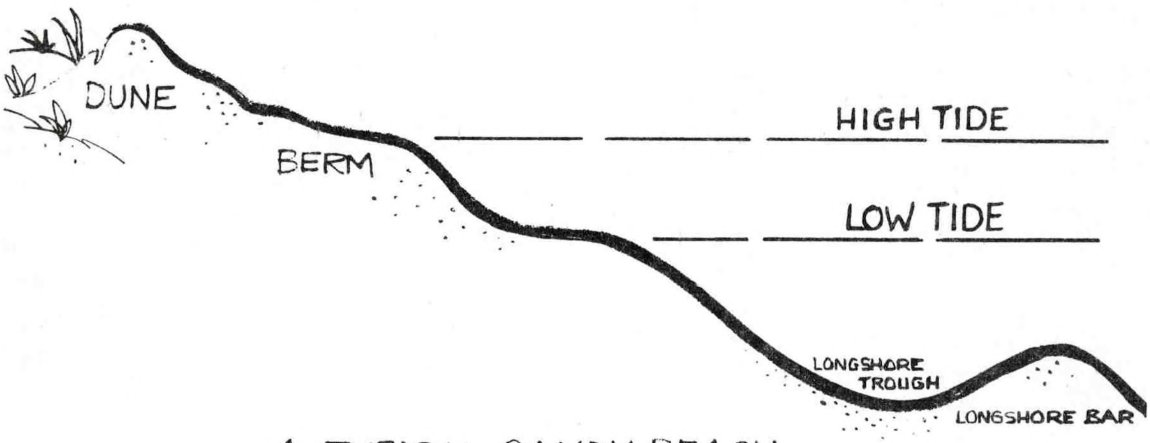
Other factors affecting water currents include ice floes moving from polar seas on the cold currents. As the ice moves southward it cools the water. Since cool water is heavier than warm water, it sinks and is then replaced by warm water near the surface.

The most economically important currents are upwellings of cold bottom water. This vertical motion brings to the surface an unusually heavy concentration of nutrients. When offshore winds drive surface waters out to sea, they are replaced by the upwelling nutrient-rich deep water. Mineral-rich waters from the land add to the nutrient supply. This upwelling supports a rich growth of phytoplankton, the start of a complex food chain, and makes possible intensive commercial fisheries such as those off the coast of Peru and the Grand Bank off the coast of Newfoundland, Canada.

THE SANDY BEACH

Of all the coastal elements, sandy beaches probably have the highest recreational value. These beaches vary considerably from one part of our

country to another. They have different sand, different waves and winds, and different dunes and other inland formations. They are composed of grains as diverse as the black lava sands of Hawaii, the golden sands of Lake Michigan, the white coral sands of Florida, and the seemingly endless sandy expanse from San Diego to Los Angeles. Florida's popularity as a vacation land almost certainly is in large part due to the fact that so much of its coastline is sandy ocean beach.



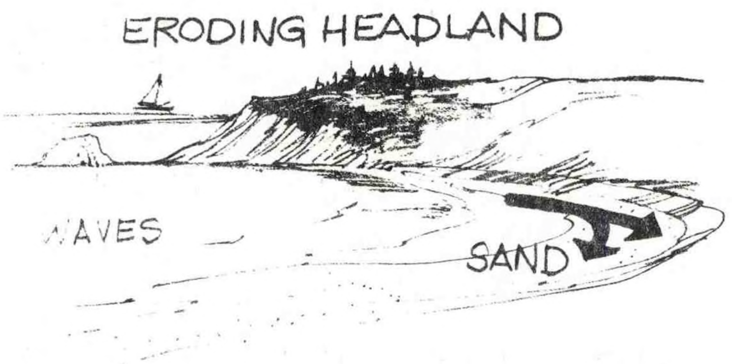
A TYPICAL SANDY BEACH

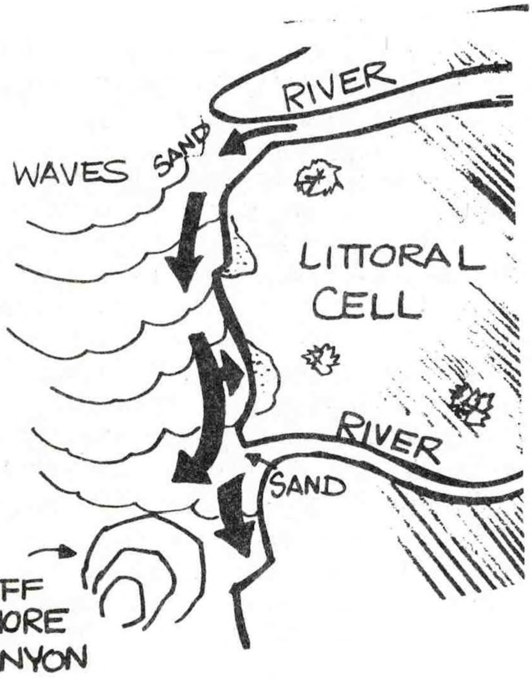
Although sandy beaches differ in many ways, they also share certain characteristics. A cross section of almost any sandy beach in early summer would probably reveal a structure like that shown above. Waves moving on-shore break on the longshore bar and roll up onto the beach. Each wave moves sand from the longshore bar and slowly, almost imperceptibly, a longer more sloping beach is created. Then, as the season changes, blustering winter winds and heavy seas begin to attack the sloping summer beach. The winter waves are higher, steeper, and closer together than those of summer. Sometimes sand is carried away from the berm and even from the dunes or other land areas behind the berm. This pounding winter wave action generally deposits some sand on the berm, but it carries away far more sand and deposits it in longshore bars, setting the scene for another yearly cycle.

The texture of the sand plays a role in the kind of beach that will be built, because the slope of the beach relates directly to the particle size of the deposited material. The coarser the particles, the more the waves sink into the beach, depositing their load of sand. Since coarse sand does not pack down and is easily moved around, steep beaches result. When the particles are finer the sand packs down more tightly; the waves do not sink in, and their action leaves a harder, smoother, and gentler slope.

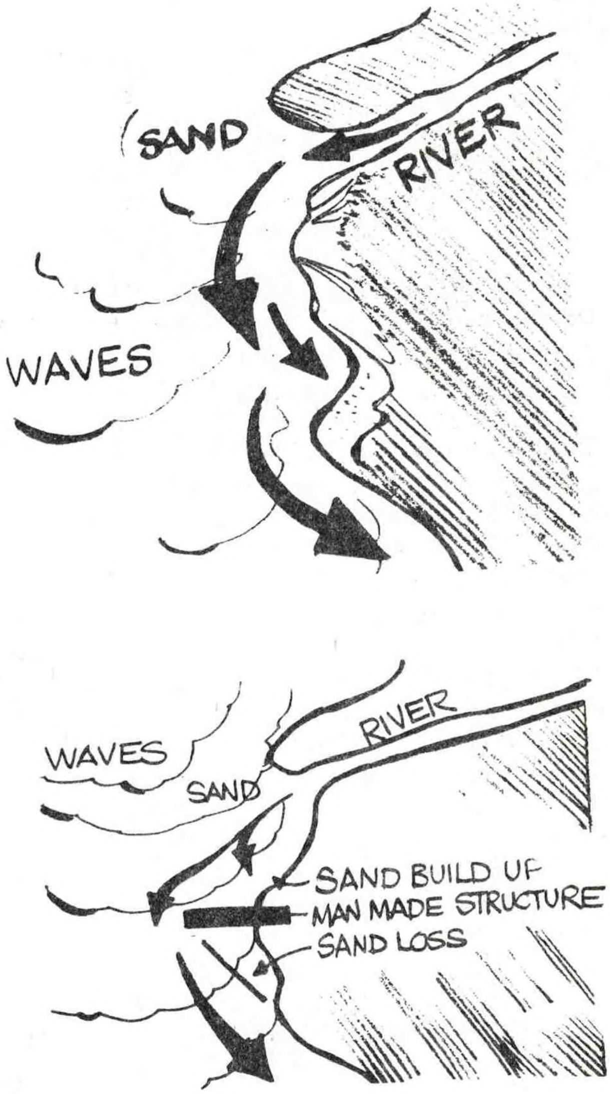
Waves and wind thus work endlessly building, shaping, and reshaping beaches. Large particles grind against each other, creating progressively smaller fragments. The largest of these are dropped on the beach and smaller less dense particles are carried out to be deposited in quieter, deeper regions of the ocean.

Regardless of the season, the markings on sandy beaches are intriguing. The graceful swash marks left by an ebbing morning tide are composed mostly of detritus -- fragments of once living things --that are not only a source of food for many beach inhabitants but are also a treasure trove for human beach explorers. Parallel ridges and troughs, called ripple marks, are often seen on sandy beaches: if the ripple marks are in dry sand they were caused by wind, but if they are lower down on the beach they were caused by moving water. Whether caused by wind or water, the process of ripple formation is essentially the same. When wind or water moving over the sandy surface meets an obstacle in the surface it turns downward, excavating a trough. The sand thus thrown up creates another obstacle and the wind or water then creates another trough.





LITTORAL CELL



LONGSHORE MOVEMENT

Ocean beaches are moving, active places that gain and lose sand continuously. Beach sand is transported by waves, wind, and wave currents in three kinds of movements: offshore, on-shore, and longshore. When put into suspension by wave action, sand can move laterally along the shore in longshore currents at the same time that it is being moved offshore and returned onshore. Sand movement along the shore occurs within relatively distinct sections of the coast, sometimes called "littoral cells." The boundaries of a cell extend from the place where sand is introduced onto the shoreline (generally by a stream) to the place where it is swept out to the sea. Where beach indentations in the coast are isolated from the general sand movement of the "cell" within these areas, shore erosion and onshore currents can supply sand to smaller "pocket" beaches.

Human activity often has had disastrous effects on the natural supply of sand to beaches. Reducing high water runoff from rivers seriously reduces the sand supply available since it reduces the erosion along river banks. Improper construction of groins, jetties, and breakwaters can change the distribution of sand by longshore currents, causing excessive sand build-up in some places and sand loss in others. The biological production of shorelines is also affected when normal water circulation patterns are changed. Careful study is needed before any major beachfront modifications are undertaken.

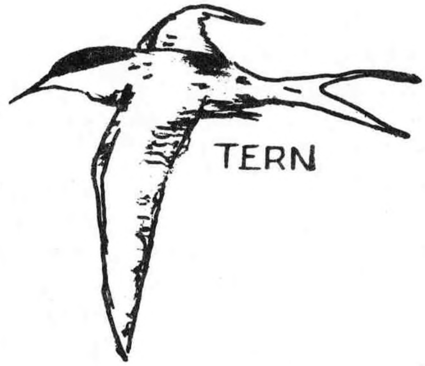
The long stretches of sun-baked sand and the breaking waves that delight vacationers are also what make sand beaches among the most barren of coastal environments. Because of its shifting nature, the sand offers a poor substrate for anchoring plants. Thus, beaches essentially lack the producers in the food chain and the few animal residents of the sand must depend on small waveborne particles for food. Usually such residents are tiny crustaceans or mollusks which live in the moist upper surface of the beach close to the water line and filter the food from the retreating waves. Other crustaceans and sand hoppers inhabit the upper beach, feeding at night along the tide line. Each sunrise they dig new burrows often peppering the sand with their holes.

Sand beaches are superb places for bird watching. Some birds are full-fledged swimmers and obtain their food from the ocean and the near-shore ocean bottom. Others parade incessantly up and down the beach at the water's edge in search of food. The specific kinds of bird inhabitants vary from one part of the country to another, but certain general kinds can be recognized. Medium-sized birds

PELICAN

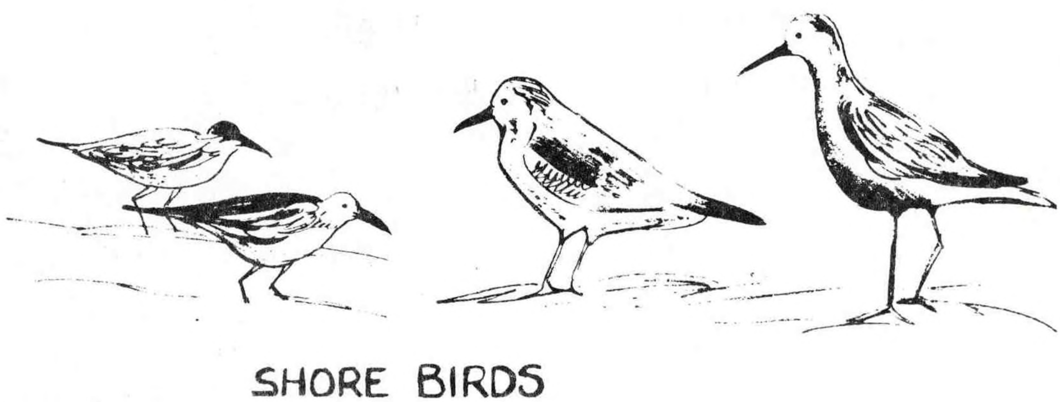
CORMORANT

that are flying across the surface of the water or riding on it are likely to be gulls, terns, or cormorants. The cormorant is a dark bird that dives and disappears for a considerable time while swimming in search of food. Gulls and terns do not swim under water. Terns can be seen flying over the water and diving into it to catch small fish, but gulls are less likely to dive for their food. Gulls, either singly or in groups, can also be seen on the beach itself in search of food. A group of large birds flying gracefully in formation just above the surface of the water is probably a flock of pelicans.



Sand pipers and plovers are the smaller birds that run up and down the beaches, carefully avoiding the breaking waves. They are generally long-legged, small to medium in size, and inconspicuous in color. Their food consists of animal and plant fragments that have been cast onto the sand by waves and the tiny animals that live in the upper surfaces of the sand.

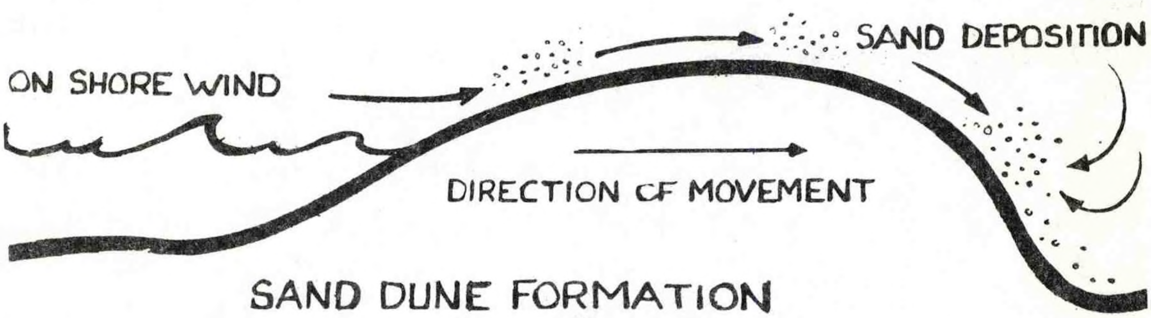

GULL


SHORE BIRDS

SAND DUNES

Sand dunes form when large amounts of sand are blown inland from a constant source of supply such as a beach. Where the wind is slowed by a log or clump of grass, it drops its load of sand, and a mound slowly builds up. As the mound grows, more sand is deposited behind it; growing larger and higher, the mound becomes a small hill, a ridge, and finally a dune. Wind-blown sand blowing up the face and falling down the crest gives the dune its characteristic shape -- a long sloping windward side and a steeper slope on the lee side. If nothing interferes with the wind or anchors the sand, the dune creeps inland as the wind moves sand from the windward to the lee side. The rate at which a dune advances can vary from a few centimeters to many meters per year. A fast-moving dune can bury everything in its path.

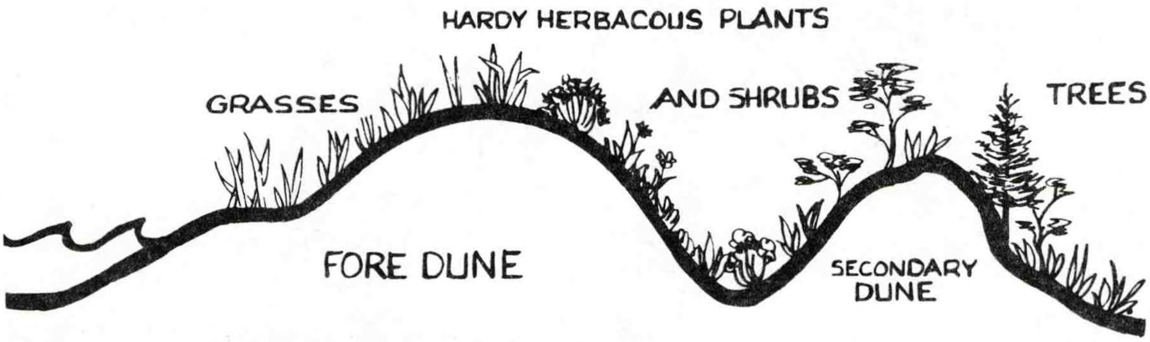
The movement of sand dunes may be slowed by the invasion of pioneer plants that can root and grow in the shifting sands; often it is grasses, such as Marran grass -- or Poverty grass-- which begin the stabilization process. After the clumps of grass have become established, shrubby plants can take root on the lee face of the dune. Protected from the wind



SAND DUNE FORMATION

and with their roots close to the water table, these shrubs often form dense thickets, providing shelter and food for small mammals and birds.

Dune life tends to progress from that of bare sand to dense woodland, but this progression can be halted and hundreds of years of growth destroyed in a very short time. Hurricanes, fires, or construction (the building of homes, cottages, or roads) can disrupt the stability that took so long to establish. When a break in the vegetation mat occurs, the wind can quickly charge through it, tearing at the roots of nearby plants. As successive clumps of plants are exposed, more and more sand is released, and the dune begins to move again.



STABILIZED DUNE

ROCKY SHORES

Rocky shores are the coastal areas where the confrontation of land (continent or island) with the ocean is most evident. Here the rocky underpinnings are ceaselessly attacked by moving water, sometimes on a spectacular scale. For example, on our Pacific shores, where wind-driven waves can build up over almost 10,000 km (6,000 mi) of open ocean, the surf is as violent as anywhere in the world. Even normal winter storms generate 6m (20 ft) waves that break against the shore with a shock equivalent to an automobile striking a wall at about 145 km/h (90 mph).

Even though the glass beacon on Tillamook Rock light house on the coast of Oregon is some 42 m (140 ft) high, a grating had to be installed over the glass to protect it from rocks tossed up by the pounding seas. Of course, not all rocky coasts are as exposed as Tillamook Rock. Offshore islands, reefs, and headlands provide protection from the pounding surf when they are in the direction of the prevailing winds.

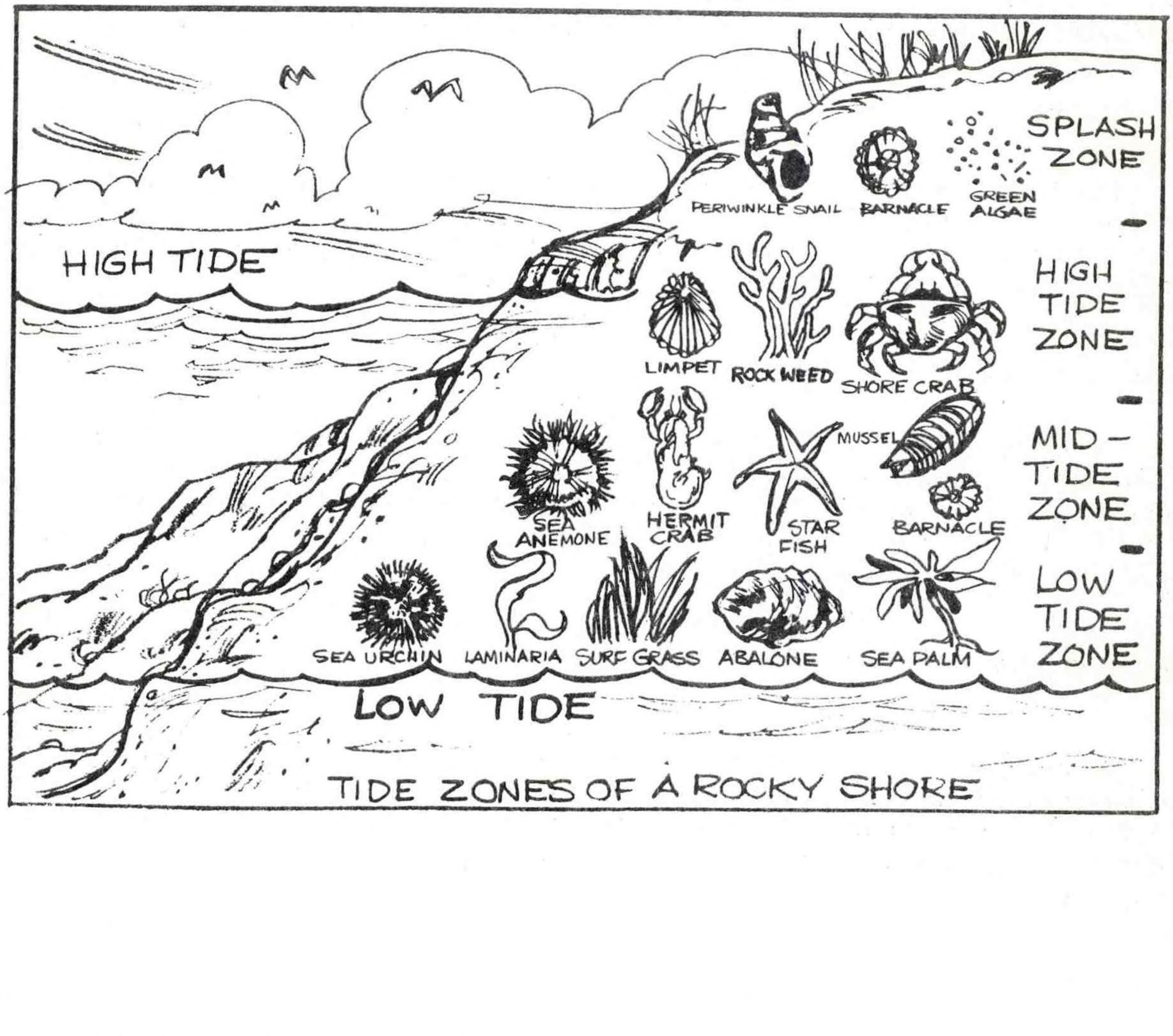
The composition of the rocky shores of the United States varies significantly from one place to another. In the northeastern United States, shorelines are made up largely of metamorphic and intrusive igneous rocks, but those on the southern Atlantic coast might be sandstone, coarse shell gravel, or coral. Continental Pacific coasts are largely sedimentary rock, and the Hawaiian coasts are igneous rock. The shores of the Great Lakes have rocky coasts, some of which are formed by older sedimentary rock and others by ancient metamorphic rock. Since the nature of the rocky substrate, the rate at which it erodes, the forms produced by erosion, and the mineral content released are so variable, it is not possible to deal with these factors in a publication of this nature. Teachers who want to explore the rocky coast should research their coastal zones in one of the publications cited in the bibliography.

The kind of biological communities that will live on any particular rocky coast is determined largely by the degree of exposure to open surf, and by the extent of tidal exposure. Life forms can vary significantly from one side of an island or a headland to the other because conditions which regulate life are so different. Regardless of their exposure to violent surf, rocky shores are much more active biologically than sandy ones, for they offer a solid, unmoving (albeit hazardous) place where both plants and animals can attach and survive. Thus, rocky shores are better than sandy ones for providing opportunities to observe a wide assemblage of marine organisms.

Significant differences in the appearance of the marine shoreline are evident at high and low tides. A careful observer can see the orderly progression of plants and animals. These species lie in horizontal "belts" across the shore, one strip above another.

In many places, these strips (or zones) are brightly colored by the resident organisms and therefore sharply delineated; a view of them from the shore is often startling. On other coasts such zones may be less obvious and more difficult to distinguish, but they are rarely absent.

Local zonation may vary considerably. Zones of a rocky face directed seaward will differ from zones facing the land or from those at right angles to the shore. Zones on a smooth, sloping rock surface may be immediately apparent whereas a shore of broken rock lying at random angles may seem not to have a pattern of zones at all. Similarly, the zones found on sunlit slopes are noticeably different from those in areas shaded by overhanging rock.



TIDE ZONES OF A ROCKY SHORE

Adapted from Marine Advisory Publications

Turbulence governs the life of organisms living between tidemarks on rocky coasts. Even when the ocean surface appears to be calm, there is usually a swell which explodes when it strikes the coast. Animals that live there seem to prefer this turbulence, and the highly aerated water it produces is crucial to their existence.

Organisms living near the upper tide mark must be able to resist desiccation during low tides. Many intertidal organisms have developed anchoring methods that keep them in place even during storms which batter them for hours on end. By and large, it is the adaptation of such organisms to life under very special conditions that governs intertidal zonation.

The extreme variations found in coastal areas in the United States make it difficult to recognize the zones between tidemarks. The following definitions of the intertidal subdivisions may therefore be helpful.

SPLASH ZONE

The splash zone is the area of transition between water and land. Although it is affected by spray, it is covered by water only at the highest tides or during storms. Animals that might inhabit this area are the periwinkle snail and the pill bug.

HIGH TIDE ZONE

Where the high tide zone is most fully developed, barnacles form a dense, almost continuous sheet on the rocks. Often this sheet has a sharp upper limit which is a very conspicuous part of the shore line. On some shores limpets are present with the barnacles. Rock weed can be found in the lower edges of this zone.

MID-TIDE ZONE

Each day the mid-tide zone is usually uncovered twice (at low tide) and covered twice (at high tide). Animals found here are seldom found in the deeper waters that are not as affected by tidal fluctuation. Sea anemones, star fish, mussels, and hermit crabs are frequently found in this zone.

LOW TIDE ZONE

Only during the very lowest tides, once or twice a month, is the low tide zone exposed to view, and then only briefly. Animals found in this zone can also be found in deeper water. The animal and plant populations of this zone are large and varied. In cold temperate regions, these populations consist of forests of the brown algae with animals and an undergrowth of small plants on their holdfasts. Coral reefs commonly include or encompass the upper edge of the rich growth that extends down the reef face below low-water level. In warm temperate regions the low-tide zone may support dense colonies of tunicates and other ascidians, as well as dense growths of red algae.

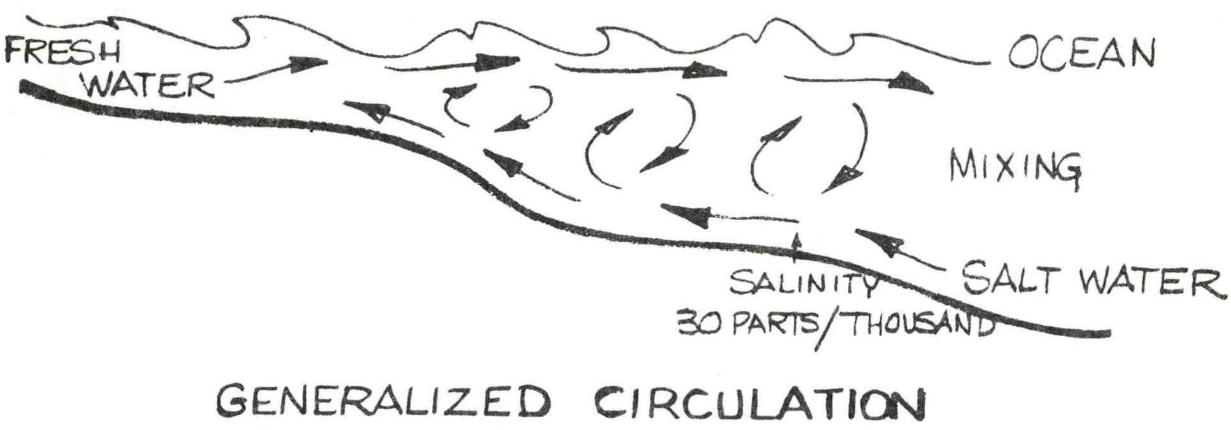
Before visiting your coast consult a local publication which describes in some detail the organisms present and their distribution. Living organisms should be observed where they are found, not collected. Disturbing the shore line in any significant way is to be avoided at all costs.

Remember that rocky coasts can be dangerous places to observe, especially at low tide when the tendency is to walk out as far as possible. Even on relatively calm days unpredictable large swells may develop, so careful watch should be maintained.

ESTUARIES

An estuary is a partially enclosed body of water connected to the open sea; thus, the seawater is diluted by fresh water draining from the land. An estuary is the site of forceful interaction between sea, land, and air.

Along the coasts of the United States there are almost 900 estuaries of many different types. Along the Atlantic coast there are drowned-valley estuaries, exemplified by Chesapeake and Delaware Bays. Estuaries that developed behind barrier beaches are found at Ocean City, Maryland, and at Biscayne Bay, Florida. In contrast, the estuaries along our northwest Pacific coastline are majestic glacier-gouged fjords, where the rivers are contained by steep rocky slopes. Earthquakes, land shifts, and other violent actions have created estuaries such as San Francisco Bay.

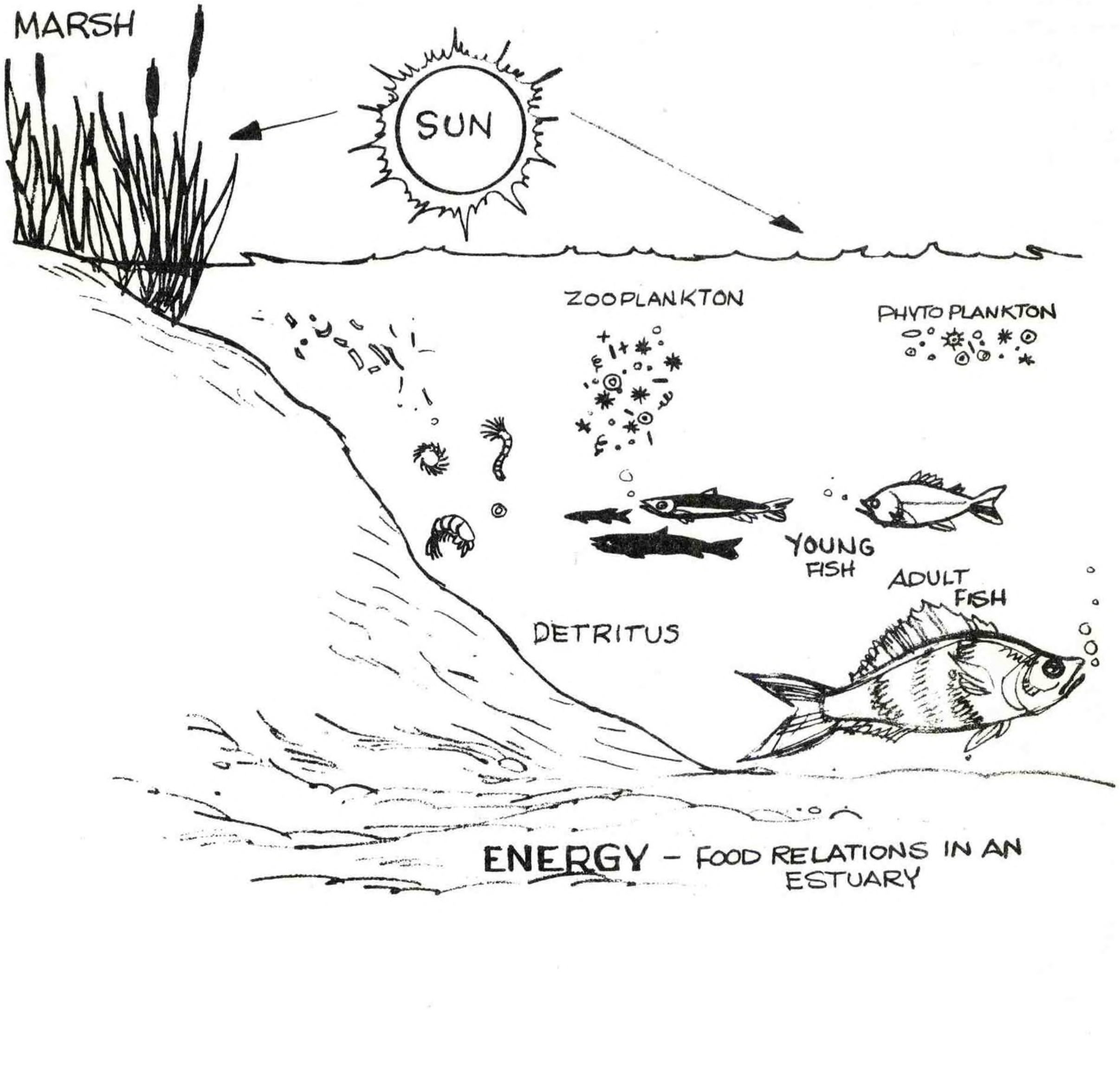


GENERALIZED CIRCULATION
IN AN ESTUARY

Despite some very apparent differences, some characteristics appear to be common to estuaries: fresh water at the river end, salt water at the ocean end, and a mixing system between them. In most estuaries the salinity gradient ranges from 30 to 35 parts of salt per thousand parts of water at the ocean end and to zero salinity at the river end. Water samples from estuaries usually show that deep waters are more saline than shallow waters -- that is, a vertical gradient of salinity exists. This gradient not only moves up and down the estuary with the ebb and flow of the tide but also responds to high and low flows of river water. The net transport of the less salty water at the top is seaward, while the saltier water moves inland along the bottom. Thus, a stratified system, with a distinctive pattern of circulation evolves, resulting in the movement of surface organisms toward the sea and of bottom organisms toward the river.

Although the circulation patterns in estuaries have many characteristics in common, different estuaries may have significantly different flow patterns. For example, in the delta of the Mississippi River, the volume of fresh water is so great that the fresh water overruns the salt water of the Gulf of Mexico and a tongue of less saline water extends far out into the salty Gulf of Mexico. In Chesapeake Bay, where the outflow of fresh water and the saline tidal inflow are nearly equal, a distinct salinity gradient is formed and the water stratifies within the estuary. A variety of other factors (such as the nature and slope of the bottom, and the force of prevailing winds, the amount and timing of rainfall) also affect the circulation and salinity of estuary waters.

Rivers flowing into estuaries carry with them erosion products and detritus which tend to settle out as the current slows in the estuary. As they near the bottom, these sediments tend to be carried inland with nutrients carried in from the ocean; this creates a kind of nutrient trap that makes estuaries highly productive eco-systems. At the same time, the constant input of solid material from the river outflow contributes to the filling of the basin or to the creation of a delta extending into the sea. Unfortunately this deposition of solids also serves to trap contaminants such as heavy metals, pesticides, pathogenic bacteria, and toxins. Increasing densities of industry and population along coasts could thus produce unforeseen but far-reaching and permanent detrimental effects on the biological production of estuaries.



ENERGY - FOOD RELATIONS IN AN ESTUARY

The food chains in estuaries include two distinct populations of primary producers -- phytoplankton and rooted aquatic plants at the edges of the estuary. The abundant zooplankton present include larvae of most of the organisms that live in the estuary. The behavioral patterns of many species of zooplankton keep them within the circulation pattern of the estuary and prevent them from being washed out to sea.

Benthos (bottom-dwelling species) are usually more abundant in estuaries than in either fresh or salt water environments. These species are quite diverse, ranging from annelid worms through a variety of crustaceans and mollusks. Many feed by various filtering processes, an effective way of trapping the nutrients flowing through the estuary. Oysters and clams are the most commercially valuable of these filter feeders harvested by man.

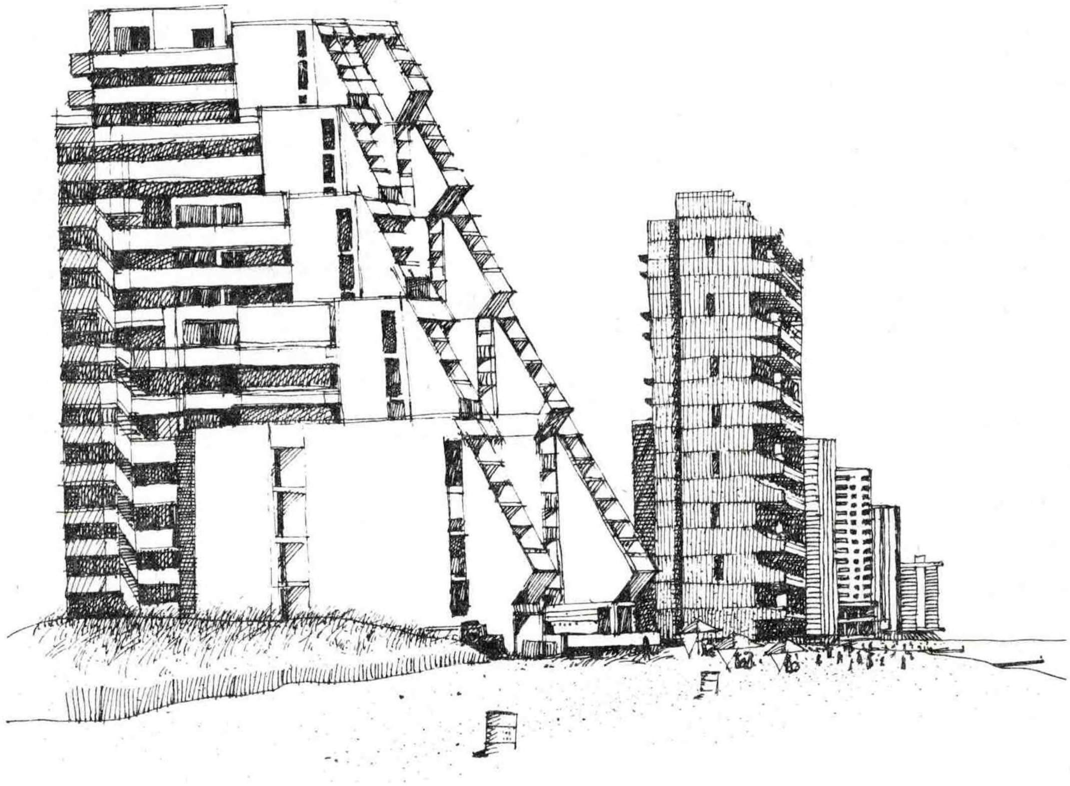
The benthic populations range from fresh to marine environments, but the most dense beds are often near the center of the estuarine system. The distribution of the oyster, for example, seems to be controlled primarily by three factors: the upstream limit is set by the maximum flow of fresh water from the river; the downstream limit is set by predators and parasites which are found only in high salinities; and the lateral limit depends on the presence of a relatively firm channel shoulder.

Among our coastal fishes the most commercially valuable species are either partly or entirely dependent on estuarine environments. Fish use estuaries in many different ways. Some populations of striped bass spawn near the interface of fresh and low-salinity water, others move farther into the rivers, and some populations are even adapted to fresh water. In an estuary, eggs and larvae drift downstream. The developing fish feed throughout the system until they are adults and the cycle begins again.

Anadromous fish, such as the shad or salmon, spend their adult lives in the open ocean but return to fresh water to breed. Shad also use the estuary as a nursery for the first summer before the young fish move to the ocean. In contrast, the croaker, which also depends on the waters of estuaries for reproduction, spawns at the entrance to the estuary and the young are transported upstream to the plankton-rich, less saline part of the estuary, where they develop before returning to the ocean.

Open ocean fish, such as the bluefish, whose early life histories are totally marine, migrate into estuaries as adults to feed on the abundant food available there.

These varied patterns of estuarine use are concurrent as each species follows its own seasonal and reproductive sequence. Thus an estuary may include the regular or occasional presence of several hundred species of fish. The low-salinity portion of the estuary is of exceptional importance since it receives the eggs, larvae, and young of fish with different kinds of spawning patterns. Although this aspect of the estuary is highly valuable, its value is not obvious because these stages in the life cycle of fish are not immediately recognizable. Since many large cities are located near estuaries close to the head of navigable waters, this potential impact merits special attention.



MARSHES

Marshes are broad wet areas where grasses grow in abundance. When they are located along the margins of ponds, streams, or rivers, they are freshwater marshes. When they are found on ocean coasts or along the banks or margins of estuaries, they are salt water marshes. Salt water marshes are the nurseries of the sea. They are the most productive land on earth, producing three times more than the best wheat lands.

Biologically, marshes are transitional between wet and dry areas, and they are usually very productive in terms of the biomass they can support. If undisturbed by nature or man, most marshes gradually fill with detritus and are eventually invaded by dry land plants.

In freshwater ecosystems, marshes contain such water-tolerant species as cattails, bullrushes, horsetails, arrowgrass, flowering rushes, buttercups, crowfoot, and many types of grasses. These marshes are also homes for many aquatic insects, amphibia, crayfish, isopods, birds, and aquatic mammals; when they are associated with permanent bodies of water, they may serve as nurseries for young fish. Lake St. Clair (a very wide area in the isthmus connecting Lake Huron with Lake Erie), which has extensive marshy areas built on the silt deposited from Lake Huron, is one of the most productive freshwater fisheries in the world.

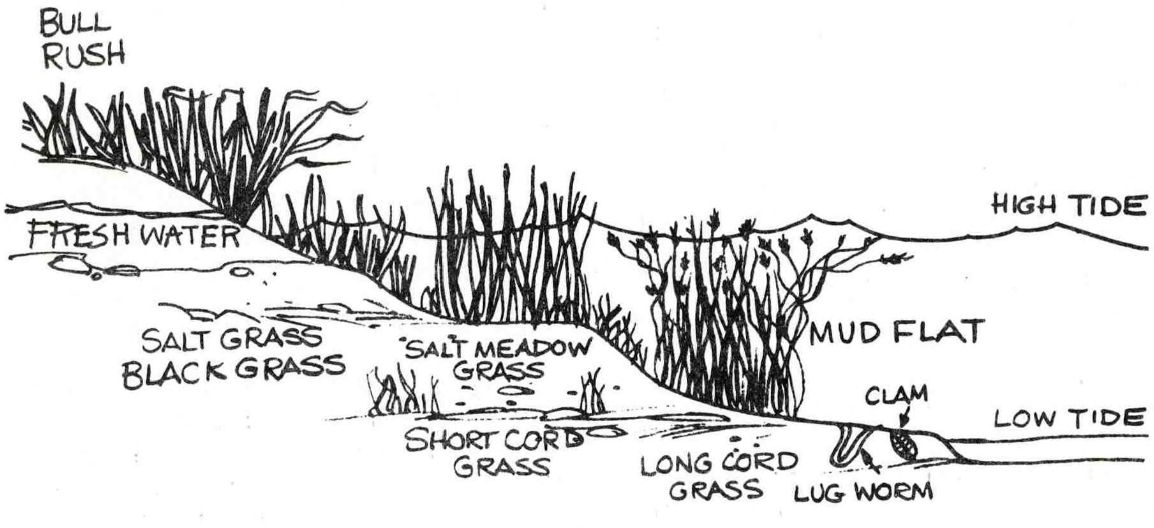
Salt water marshes can best be classified by their relation to the land or the ocean. Of all salt marshes, the most maritime (bearing the closest relation to the ocean) are those that develop on relatively open coasts. They are bathed in sea water at almost full strength since the freshwater drainage from land is usually minimal. These marshes are usually rich in algae, including free-living species and tiny forms of the brown algae derived from normal forms that are attached to rocky shores near the marshes.

Marshes at the mouths of estuaries, usually found in the lee of coastal spits, are the next most maritime of the salt marshes. The coarse-grained soils of these marshes are subject to stronger saline influence than those of marshes further up the estuary. As their distance from the ocean increases toward the middle and upper reaches of the estuaries, the marshes tend to become progressively more terrestrial since the water becomes progressively fresher.

Despite the wide range of conditions in the United States under which salt marshes exist, some general statements about their formation and the distribution of organisms within them can be made. Salt-marsh formation usually starts in an area that is subject to twice-daily salt water (tidal) inundation. Salt-marshes are replaced by freshwater marshes at the upper level of tidal influence, where tidal inundations occur only a few times a year. Between these two extremes, plants and animals thrive according to the range of conditions they can tolerate - conditions that are dominated by the tides at the lower levels--and almost independent of them at the upper levels.

Some factors of crucial importance to the survival, growth, and reproduction of organisms in the intertidal zone are the intensity and frequency of mechanical disturbance due to tidal movement; the vertical range over which the tide operates, which determines flooding depths and the vertical extent of the marsh; the form of the tidal cycle, which determines both the frequency and the length of submergence and emergence; and the water quality, which determines, among other things, the amount of light reaching submerged growths and the salinity to which they are subjected.

Grasses are the most prominent plants in salt marshes. Cord grass in a long and a short form, is the grass most likely to live in marsh areas covered by water at high tides. Other salt-tolerant plants and plants tolerant to salt spray make up the upper edges of the marsh and vary with the locality.



A TYPICAL SALT MARSH

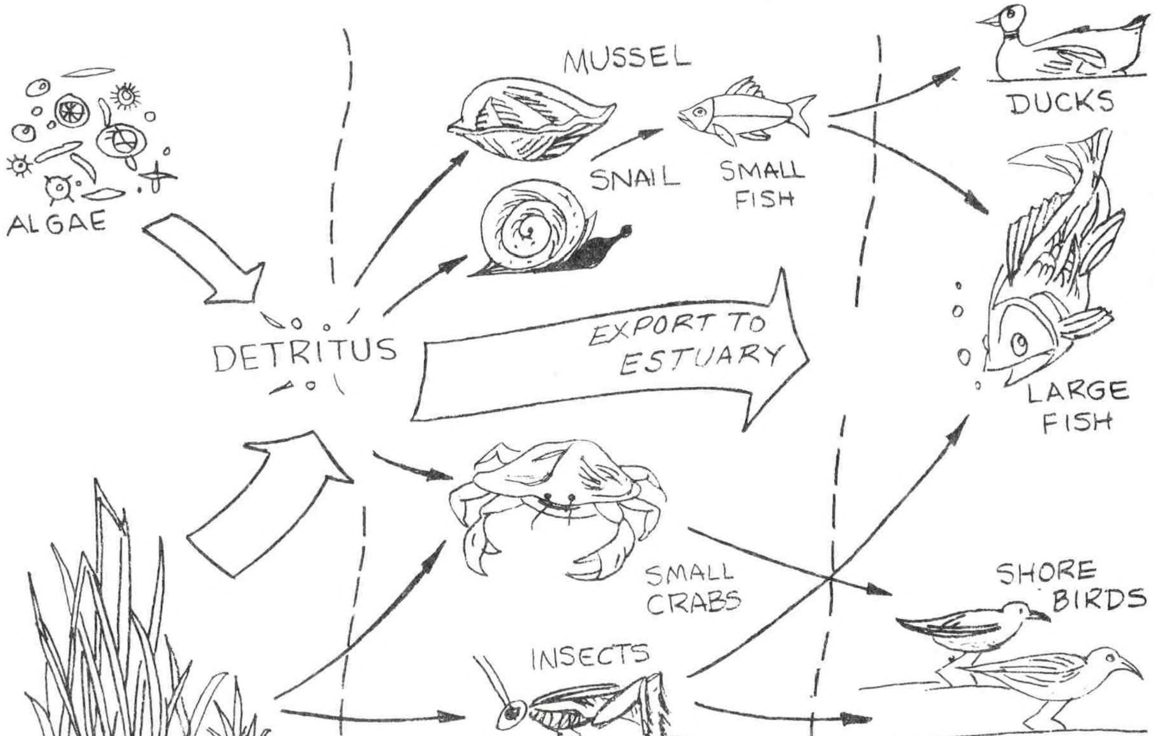
Animals are widely distributed in salt marshes and the adjacent mud flats, although their distribution patterns are not as obvious as those of the plants. Mud flats are occupied by burrowing creatures such as marine worms and clams, which are fed on in turn by other organisms. Fish come in with the tide to feed on the abundant small forms of life that occupy the marshes. Birds are prevalent in marshy areas. Some, such as the marsh wrens, swallows, ducks, geese, herons, and rails nest in or around marshes and get most of their food from them. Mammals such as raccoons, mice, rats and, less often, otters and mink inhabit marshes and feed on other organisms that live there. Marshes are also crucial stopping and feeding stations for flocks of migratory birds.

Marshes are rich in numbers of species as well as numbers of individuals. Species with aquatic larvae, such as mosquitos, gnats, and dragonflies are well represented. Other species, such as grasshopper and cricket, enter the marshes to feed.

In a terrestrial grassland, energy conversion relies on direct consumption of green plants. In contrast, energy conversion in salt marshes relies on decay as the chief link between primary and secondary productivity. Only a small proportion of marsh grass is grazed while it is still alive. Not only is the role of phytoplankton in energy production in marshes less than it is in open water, but also cloudy water or turbidity may diminish algae productivity by reducing the amount of light available for photosynthesis.

The food chain of nature is complex. Each step up the chain involves a a decrease in the number of organisms and an accompanying increase in the amount of food they consume. At the bottom of the food chain, 1000 pounds of phytoplankton will result in 100 pounds of insects and small animals. In turn 100 pounds of insects result in 10 pounds of fish, ducks and birds.

Although it is not shown on this diagram, people are at the top of this steadily narrowing food chain. As in the other steps, it takes 10 pounds of ducks or fish to produce a one pound gain in human beings.



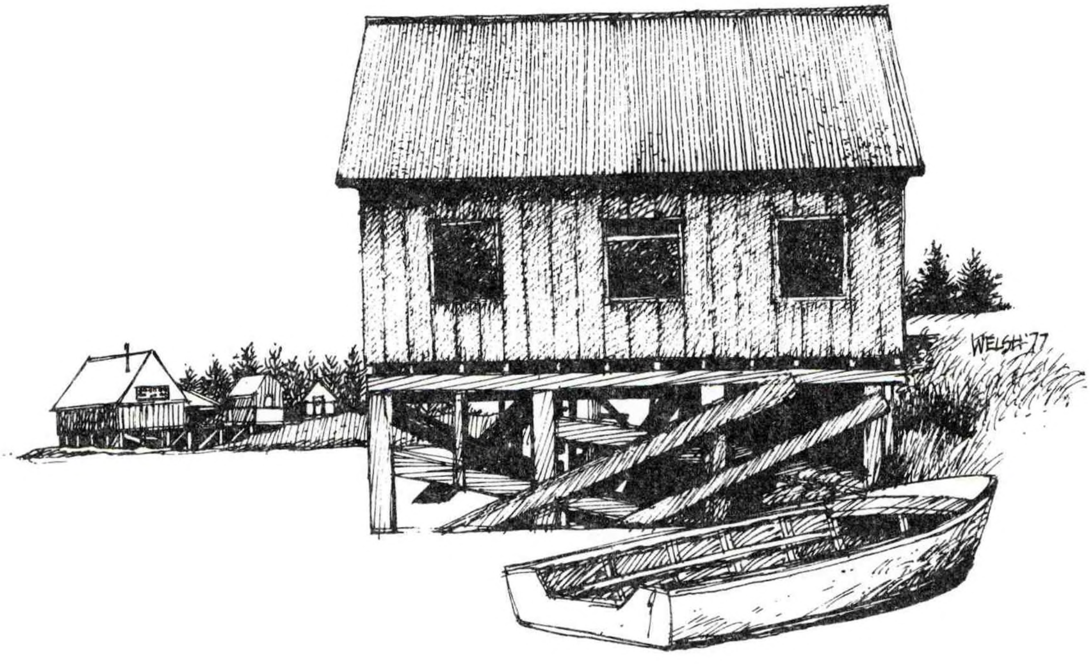
ENERGY CONVERSION IN A SALT MARSH

ACTIVITIES

COASTAL ZONE AWARENESS ACTIVITIES FOR HIGH SCHOOL STUDENTS

This collection of suggestions for activities is designed for high school students. Some of these activities can be carried out in the classroom and others in any aquatic environment; some require access to a marine environment. The activities suggested range in difficulty from the relatively simple to the fairly complicated. Some require a high order of cognitive processes for understanding; thus there should be a fit with student skills at a variety of grade levels.

Teachers will note that the suggestions are written mostly as directions for students rather than for teachers. This is largely a space-saving device, but it does allow for more rapid skimming of ideas to see what is available and suitable to your environment.



Anemone Behavior

If you live in an area where anemones are plentiful and the state authorities allow it, taking an anemone temporarily for experimentation and returning it to the water can be a rewarding experience. A single anemone can be kept in a plastic shoebox aquarium with an air stone for as long as a week. The temperature of the water in the shoe box should be maintained at the temperature of the water where the anemone was collected.

sea anemone

There are many things you can do to learn about anemones. Place a piece of raw shrimp or fish (about pea size) in a nylon mesh bag made from a stocking. Put the nylon bag on a piece of thread and let the anemone eat it. Look at it the next day. Feed your anemone a small piece of food that was cooked in food dye. Record what happens.

If you give your anemone a choice of sand, small rocks, or big ones, where will it anchor? Try placing a checkerboard pattern on the bottom (or, if the bottom is clear plastic, place the pattern under the box) of your shoe box aquarium. The squares should be at least as large as the anemone. Where will the anemone anchor, on a light or a dark square?

Can your anemone tell food from non-food? Attach pieces of real food and inert (non-poisonous) materials to threads and carefully lower them into the water, near the anemone. What happens?

Return your anemone to the ocean carefully, to the place where it was collected.

Tidal Marsh and Flats

What proportion of a tidal marsh is exposed as mud or sand flats during low tide? Take photographs of such an area at high and low tides. Compare these and, by locating landmarks on a map, compute the area exposed by a low tide. How large is the exposed area compared to the area where the bottom isn't exposed?

Piling Organisms in an Estuary

Visit several areas in an estuary, from the mouth up into the river. During low tide observe and record the kinds of organisms that live on the pilings in each area. Take specific gravity readings at each location. Does the decreasing salinity affect the kind of organisms that can grow there? How is this indicated by your survey?

Using Tide Tables

People who live near oceans can plan exploratory trips to the sea shore more effectively if they know what the tidal level will be when they get there. If you want to go to see the animals that live at the lower level of the intertidal zone then you should visit the shore when the tides are at their lowest ebb. You can find this information by getting a tide table for your local area. Reading a tide table seems difficult at first so practice on the sample below which was taken from a table constructed for Breakwater Harbor, Delaware. Tide tables give you six kinds of information:

OCTOBER 1970

Month	*Time*			*Year*	
Date	16	0236	-0.5		*Height of tide (2 high tides and 2 low tides)*
		0906	5.6		
Day of Week	TH	1524	-0.4		
		2136	4.4		

The time is based on the 24 hr where 0000 is 12 o'clock midnight and 1200 is 12 o'clock noon. So 0236 would be 2:36 AM and 1524 would be 3:24 PM. The height of the tide is related to the mean low water level. A number preceded by a minus sign means the water level will be below mean low water. No minus sign indicates the height of the water above mean low water.

17	0318	-0.3
SA	0954	5.4
	1612	-0.2
	2224	4.0
18	0406	0.0
SU	1042	5.2
	1706	0.1
	2312	3.7
19	0454	0.3
M	1136	4.9
	1800	0.4
20	0006	3.4
TU	0548	0.6
	1230	4.5
	1900	0.7

Using the information above answer the following questions.

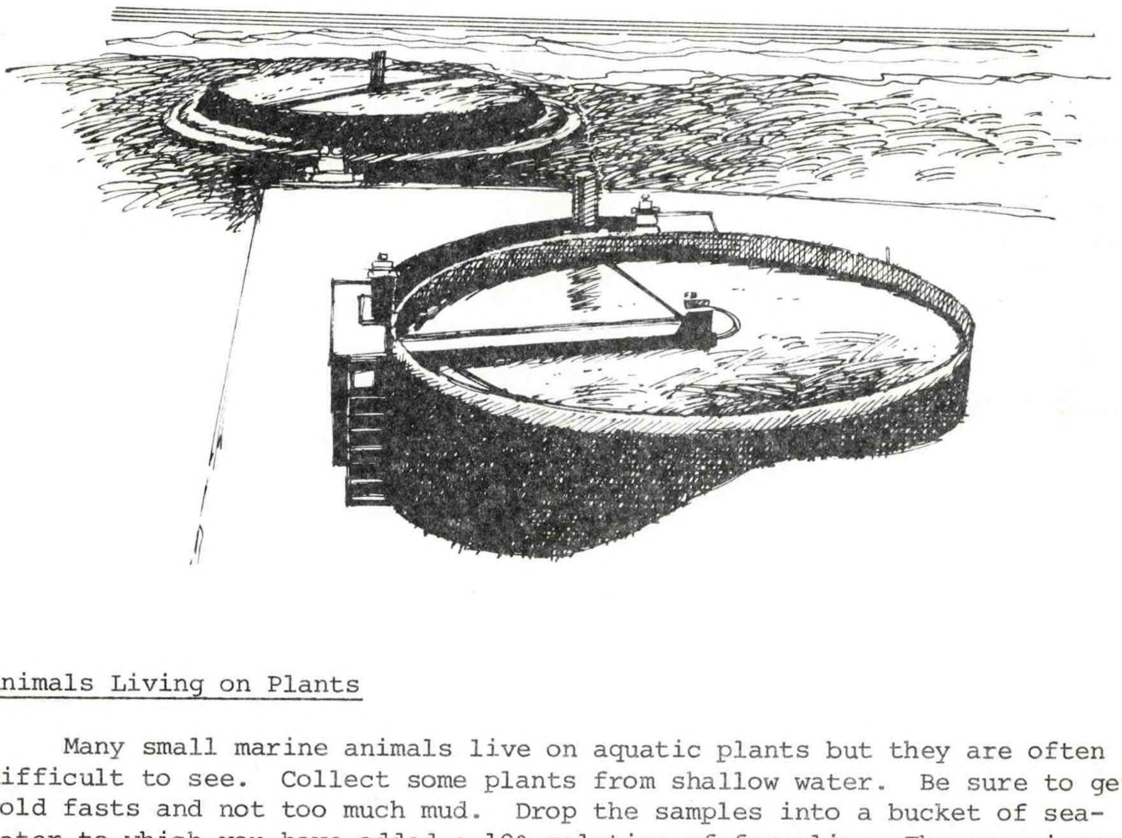
1. What day of the week will have the highest tide?
2. On which date will the high tide be the lowest?
3. Which day would be best for looking for organisms farthest down the beach?
4. Using the 12 hour clock what is the best time to visit the beach on Sunday during high tide?

Plant Cells and Salt Concentration

Collect a living piece of marine algae such as sea lettuce *(Ulva)* and a freshwater plant, such as Anacharis. While observing their cells through a microscope, flood each one alternately with fresh water, then salt water. Note and compare the responses of the cells to each condition. What explanation can you give for these different responses?

Oceans As Places for Waste Disposal

Who controls the manner of disposal and amounts of wastes that are emptied into your coastal waters? Does your local Board of Health have this authority? Are there state and federal laws that are applicable also? Write a brief report about how waste discharge in your area is monitored and controlled.



Animals Living on Plants

Many small marine animals live on aquatic plants but they are often difficult to see. Collect some plants from shallow water. Be sure to get hold fasts and not too much mud. Drop the samples into a bucket of sea-water to which you have added a 10% solution of formalin. The organisms will leave the plants and fall to the bottom of the bucket. Quickly remove the plants and collect the organisms from the bottom of the bucket using a glass tube. Examine and record what you see under a binocular microscope. What animal phyla are represented?

Crustacean Growth Curves

Keep a commonly available crustacean (freshwater or marine) in an aquarium; the length of time it should be held varies according to the growth rate of the organism. Collect the molted exoskeletons as they are shed, being sure to note the date of each molt. Make a display that shows the growth of one or more aspects of the exoskeleton, such as the width of the carapace or the length of a front claw.

Beach Hopper Population Count

Count the number of beach hoppers in a square meter at several (four or more) locations on a beach. Calculate the average number of hoppers per square meter. Calculate the area of the beach within one kilometer of your sample, and the number of hoppers on that section of beach.

Fresh Water from a Marine Beach?

Dig a hole about one meter in diameter and about 30 to 40 cm deep in a sandy beach. Choose a sunny spot, where the tide will not wash in for several hours. Place a collection container at the center of the bottom of the hole. Cover the hole with a piece of heavy clear plastic that extends well beyond the edges of the hole in all directions. Anchor the plastic with heavy rocks in such a way that it sags into the hole but does not touch the bottom or sides of the hole. Seal the edges with sand. Place a rock in the center of the plastic, over the container. After several hours, or longer if you have time, look for moisture on the underside of the plastic and in the container. Taste the water. Could you drink it? What is its source? Explain.

(This activity can also be carried out on a freshwater beach.)

Seasonal Changes in Sandy Beach Structure

What effect do changes in seasons and the accompanying changes in storm patterns have on the shape and profile of the beaches in your coastal zone? Locate a beach to study. During a low tide, photograph the beach profile and note the position of objects above the normal high tide line. Repeat this process several times during the year. Make a display of your findings.

Coastal Productivity

Why do people congregate to fish at some places along the coast but not at others? Are these places more productive biologically? Survey the people that are fishing. Ask them why that place (or those places) are superior to others. Talk to as many people as you can, preferably on more than one occasion. What factors can you identify that make the fish more plentiful in some areas than in others?

Feeding Habits of Marine Fish

Make arrangements with a cannery, sport fishing boat, or fisherman you know to save the digestive tracts of specific kinds of fish. Examine the contents of the digestive tract for the remains of food organisms. Keep a careful record of food preferences of fish by species.

Survey of a Tidal Pool

Carefully divide the area of a tidal pool into one-meter squares. Draw a diagram with squares, like the pool. Count the organisms. Note the kinds of organisms in each square and locate these in the proper square of your drawing of the pool. Measure and record water depth, temperature, salinity, and oxygen concentration at the location where each organism is most prevalent.

What conditions do you think each of these organisms prefers?

Coastal Model

Get a topographical map of part of the coast in your area. Maps can be obtained from the Geological Survey, U.S. Department of Interior. Using the data on the map, make a plaster of paris model of some segment of your coastline. Include segments of the continental slope, the fore coast and the back coast. Local hydrological charts would also be of value in constructing that area below the water line. Mark in some special color the areas that are used extensively by people.

Soil Profiles in Coastal Areas

A soil profile is a kind of historical record of the ecological events that occur in a particular area. The profile is an accurate drawing of a carefully excavated hole. The side that you draw should be vertical and smooth. Sketch in each layer you can identify. Keep careful notes as to the width of each layer, particle sizes, color, and composition, the presence of organic matter or shells, and other interesting elements of each layer. Make profiles of sparse dune grassland, dense dune grassland, and open beach, and compare the profiles.

What features are different? The same? What can you infer about the history of the area? Carefully fill your holes when you are done.

Handmade Hydrometer

For the body of the hydrometer, use a test tube or a slender wooden cylinder. Weight one end so that the tube floats vertically and is stable. Calibrate your hydrometer with known concentrations of salt water, ranging from 35 parts of salt per thousand of water down to fresh water. Make your markings so they are relatively permanent. Now compare your readings with a commercial hydrometer available from a tropical fish store. How can you tell which one is correct if they differ?

Salinity in an Estuary

Using the hydrometer you made or a commerical one, sample the specific gravity of an estuary at several places from the mouth up into the river. Knowing what you do about the relative density of sea water and fresh water, at what depths should you take your samples? Take a water sample from each place you make a measurement and take it back to the school laboratory. Evaporate 100 ml amounts from each sample and determine the percentage of salt. Find a way to compare this measure of salinity with your hydrometer readings.

Measuring Suspended and Dissolved Solids in Water

The turbidity (amount of suspended and dissolved solids in a body of water) has an effect on the amount of light that water will transmit. In this way, suspended and dissolved solids affect the rate of photosynthesis in bottom-dwelling plants.

The amount of suspended solids in a sample of water can easily be measured. First, weigh a round sheet of filter paper. Filter one liter of a water sample. Allow the filter paper to dry completely, in an oven if possible. Use a temperature low enough so the filter paper will not burn.

Re-weigh the filter paper. The difference in weight is the weight of the suspended solids that were in your sample. These values are usually given in parts per million or milligrams per liter. (Dissolved solids are measured the same way as salt, by evaporation.)

Take a series of water samples in an estuary, stopping at several places from the mouth up into the river. Measure the amounts of suspended and dissolved solids in each. What do your results tell you about the sources of dissolved solids in the estuary? This same process can be carried out where a river or stream enters a lake.

Temperature and Specific Gravity

Gradually reduce the temperature of a sample of sea water from room temperature to about 5°C. At every 5° change of temperature, use your hydrometer to measure the specific gravity. Plot your results on a graph, using the horizontal axis for temperature. Describe your results in terms of the effects of temperature on specific gravity.

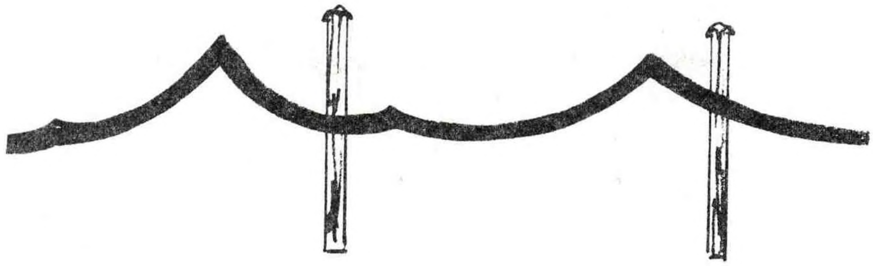
Measuring Wave Length

This activity should be conducted when wave size offers no danger to students. Wave length is the distance from the crest of one wave to the crest of the next. To find out wave length in a lake or ocean at a particular time, you need to measure two aspects of the wave motion: the velocity (or speed) at which the wave is moving through the water (meters per second) and the time in seconds it takes for two successive wave crests to pass a fixed point (period).

To calculate velocity, attach a 3-meter rope to two tall stakes and place the stakes in the water so that one stake is three meters closer to the beach than the other. The rope should be taut but not stretched, and at about water level. Measure the time it takes for a wave crest to travel from the first stake to the next. Do this at least five times; then compute an average velocity in centimeters per second. Now record the time between crests (from the time that one crest hits a stake until another hits that same stake). Do this for at least five successive waves. Calculate the average wave period in seconds. Find the wave length in centimeters by using the following equation:

$$\text{Wave length} = \text{velocity} \times \text{period}$$

$$\text{cm} = \text{cm/s} \times \text{s}$$

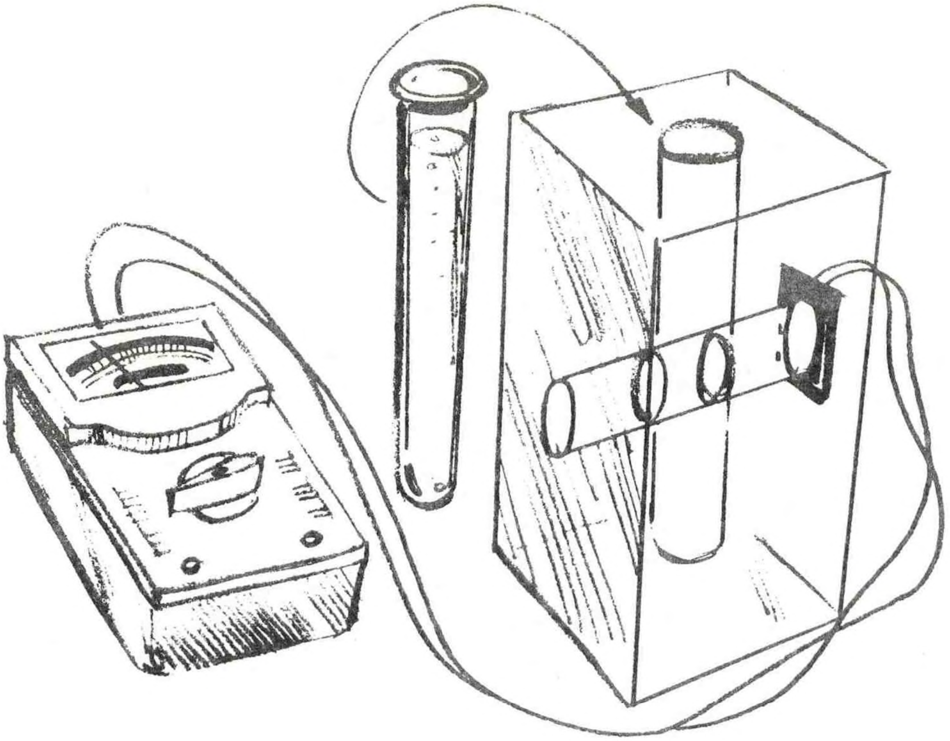


Measuring Turbidity

Make a photometer to measure turbidity of coastal waters. You can make a reasonably accurate photometer from readily available components for less than $10.00. You will need an inexpensive volt-ohm meter (VOM), a cadmium sulfide photo cell, and a block of soft wood (pine) about 15 cm long and 10 cm square. You will also need some test tubes to carry out your experiments. At one end of the block drill a hole that is centered and goes almost through the length of the wood. The diameter of the hole should be slightly larger than 2.6 cm so it will accommodate a large test tube. Next drill a hole at right angles to the first hole, and passing through it, so that the paths cross. The second hole should go through the wood from side to side. The diameter of this hole should allow the photo cell to fit tightly. Push the photo cell into one of the side holes a short distance and secure it with an epoxy cement. Attach the leads of the VOM to the leads of the photo cell and you are ready to test your turbidometer. Shine a light through the wood onto the surface of the photo cell. Set the selector of the VOM on R × 1, Ω, or R. The needle of the meter should deflect. An ideal bulb size for a light source is 75 or 100 watts. Determine the most effective distance of the light source from the meter by trial and error.

Now you are ready to introduce test tubes of turbid water into the turbidometer. The more turbid the water is, the less is the light that will reach your photo cell, and the less the needle will deflect.

Compare samples from different places along your coast. Graph your data. If you use the Ω or R scale, use semi-log paper.



Bird Prints and Behavior

Walk along a sandy beach looking for the footprints of birds. On an ocean beach this is most productive on a receding tide. Make sketches or plaster of paris casts of the footprints. Take your sketches to the classroom and see if you can find out what kinds of birds made the prints.

FURTHER RESOURCES

READING SUGGESTIONS

AMERICANS AND THE WORLD OF WATER. Harold L. Goodwin (ed.). University of Delaware Sea Grant College Program. 1977. Highly recommended.

*THE ART AND INDUSTRY OF SANDCASTLES. Jan Adkins. Walker Publishing Co. 1971. Grades 5-8 and all other readers. 29 pages. Informational.

Twenty-nine 11" x 15" hard-cover pages. This unique book cleverly combines the popular seaside occupation of sand castle building with the lives and times of ancient castle dwellers. The handsome monochrome illustrations show the sand castle builder and the how and why of castle construction; they help develop a vocabulary and a historical perspective in the process. Thoroughly enjoyable.

*THE BEACHCOMBER'S HANDBOOK OF SEAFOOD COOKERY. Hugh Zachary. John F. Blair, Publisher. 1969. For all readers. 208 pages. Informational.

More than a cookbook. This is a sincere commentary on seaside conservation. There is a recipe for just about any common marine animal including octopus. The line drawings are decorative. There is a serviceable index.

@ BILLY BUDD. Herman Melville. 1921. Penguin paperback.

* BOOK OF THE SEVEN SEAS. Peter Freuchen. Simon & Schuster, Inc. 1957. Grades 9-12. 512 pages. Informational.

A detailed book about the realm of the oceans of the world. Some of the topics included are the shape of the seas, battles at sea, and treasures of the seas. A highly specialized book for the mature reader who is motivated toward this subject.

@ THE CAINE MUTINY. Herman Wouk. Doubleday. 1951.

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* Adapted from Project COAST, Language Arts Activities to Supplement Coast Learning Experiences (Learning Experience No.5). One of a series of 86 learning experiences on Coastal and Oceanic Awareness available from Project COAST, 310 Willard Hall, University of Delaware, Newark, Delaware 19711.

*Reviewed in the essay by Joel W. Hedgpeth, "Images for a Sea People: Arts, Letters and Science of the Sea," in Harold L. Goodwin (ed.), Americans and the World of Water, Newark, DE: University of Delaware Sea Grant College Program, 1977.

@ CAPE COD. Henry David Thoreau. W. W. Norton. 1951.

@ CANNERY ROW. John Steinbeck. Viking. 1945.

*THE CHALLENGE OF THE SEAFLOOR. Adelaide Field. Houghton Mifflin Co. 1970. Grades 7-12. 133 pages.

The story of the development of the submarine with particular emphasis given to the scientific research vessel, the Alvin. Traces the development of Alvin and details its journeys. Closes on an ecological regard for the presentation of the sea. A high interest book for the student interested in mechanical means of underwater exploration.

"CLIMATOLOGY AND WEATHER SERVICES OF THE ST. LAWRENCE SEAWAY AND GREAT LAKES." U. S. Weather Bureau. Technical Paper No. 35. 1959.

*THE CURIOUS WORLD OF THE CRAB. Joseph J. Cook. Dodd, Mead & Co. 1970. Upper Middle School and others. 96 pages. Informational.

Illustrated mostly by black-and-white photographs. There is a chapter on crabs in general as crustaceans and 39 pages describing various crabs of the world. One chapter is devoted to a non-crab, the horseshoe crab (Limulus), as a living fossil and there is a short discussion on crab mythology. The last chapter deals with crabs as seafood for people.

DIRECTORY OF SHIPWRECKS OF THE GREAT LAKES. Karl E. Heden. Bruce Humphries Publishers. Boston. 1966.

@ *THE EDGE OF THE SEA. Rachel L. Carson. Houghton Mifflin Co. 1955. Upper Middle School-High School. 251 pages. Informational.

The plant and animal life environments of the coral reef, sandy beach, and rocky coast are explored in this book. The author attempts to develop an appreciation of sea and surf. Accurate scientific insights are written in a literary style. Labeled pencil sketches of marine plants and animals make this a reference and guidebook for interested people.

*A FIELD GUIDE TO THE SHELLS OF OUR ATLANTIC AND GULF COASTS. Percy A. Morris. Houghton Mifflin Co. 1951. Middle School-High School. 228 pages. Informational.

Primarily an identification guide to over 500 kinds of shells. Also tells about the life-styles of many sea animals. Provides information about emptying shells, recording finds, and classifying and associating different kinds of shells.

FISHES OF THE GREAT LAKES REGION. Carl Hubbs and Karl Lagler. Bulletin 26 (rev.). Bloomfield Hills, Michigan. Cranbrook Institute of Science. 1958.

FISHERIES AS A PROFESSION (A CAREER GUIDE FOR THE FIELD OF FISHERIES SCIENCE). American Fisheries Society. 1976.

*FRESH WATER FROM SALTY SEAS. David O. Woodbury. Dodd, Mead & Co. 1967. Grades 6-12. 96 pages. Informational.

All of the industrial methods of desalination that show promise are reviewed. Some of the technical passages may require studied reading. The book is indexed and contains about 35 photographs and drawings. David O. Woodbury is the author of more than 31 science books for children.

FRESHWATER FURY YARNS AND REMINISCENCES OF THE GREATEST STORM IN INLAND NAVIGATION. Frank Barcus. Wayne State University Press. Detroit. 1960.

GEOLOGY OF THE GREAT LAKES. Jack L. Hough. Urbana, Illinois. University of Illinois Press. 1958.

THE GREAT LAKES READER. Walter Havighurst. New York, New York. The Macmillan Company. 1966.

THE GLACIAL LAKES SURROUNDING MICHIGAN. Robert W. Kelly. Lansing, Michigan. Michigan Department of Conservation. December. 1960.

GREAT LAKES COUNTRY. Russell McKee. New York, New York. Thomas Y. Crowell Co. 1966.

*GREAT SEA POETRY. Willard Bascom, ed. Compass Publications, Inc. 1969. Upper Middle-High School. 119 pages.

Includes poems by Rudyard Kipling, A. A. Milne, John Masefield, Lewis Carroll, Matthew Arnold, Robert Browning, Oliver Wendell Holmes, Sir William Gilbert, John Gray, and J. Frank Stimson. The poetic nature of the sea becomes evident as one reads the descriptive emotion-filled lines. A glossary of special words and a gazetteer of places (listed by poem) is included.

@ HALF MILE DOWN. William Beebe. Harcourt, Brace. 1934.

*HARVESTING THE SEA. D. X. Fenten. J. B. Lippincott Co. 1970. Grades 4 and up. 58 pages. Informational.

A good reference for learning about the riches found in the sea (plants, animals, and minerals) and careers related to the harvesting of these riches. Photographs and sketches are good.

*HOMES BENEATH THE SEA: AN INTRODUCTION TO OCEAN ECOLOGY. Boris Arnov, Jr. Little, Brown & Co. 1969. Grades 7-9. 131 pages. Informational.

Each of the chapters deals with a different habitat in and near the sea: seashore, continental shelf, open sea, coral reef, and the high seas. The book contains well written passages but it suffers from poor organization. A book of this sort should have a bibliography; this one doesn't. The photographs are good.

*HOW TO KNOW THE AMERICAN MARINE SHELLS. R. Tucker Abbott. The New American Library. 1961. Grades 7 and up. 222 pages. Informational.

Abbott divides his reference book into two parts. In his Natural History section he discusses the mechanics of having shells as a hobby--collecting and cleaning shells, and organizing shell collecting clubs. In the Identification section he describes each type of shell in great detail and refers the reader to color plates included.

*ISLANDS: THEIR LIVES, LEGENDS AND LORE. Seon and Robert Manley. Chilton Book Co. 1970. Grades 10-12. 383 pages. Informational.

This book is a collage of island lore, love, lure, and legend. Perhaps it is for the teacher who would chuck it all and, if vicariously, sail to those remote insular specks that populate the ocean realm. The book is generously illustrated and contains more history than science.

LAKE ERIE. Harlan Hatcher. Bobbs Merrill Company, New York.

LAKE HURON. Fred Landon. Bobbs Merrill Company, New York.

LAKE MICHIGAN. Milo M. Quaife. Bobbs Merrill Company, New York.

LAKE ONTARIO. Arthur Pond. Bobbs Merrill Company, New York.

LAKE SUPERIOR. Grace Lee Nute. Bobbs Merrill Company, New York.

*THE LAST FREE BIRD. Harris A. Stone. Prentice-Hall, Inc. 1967. All grades. Fiction.

A plea to save our environment is made in this picture book for all ages. Beautiful water color illustrations.

*LIFE IN PONDS. Jean Gorvett. American Heritage Press. 1970. Middle School and up. 31 pages. Informational.

An introduction to the living things in a pond and how to fish and observe them. The common plants of freshwater ponds are attractively and accurately illustrated in color and very briefly discussed (about one page). There is one page on the smaller invertebrates, three nicely illustrated pages on mollusks, and an appealing eight-page section on insects. The reptiles are accorded one page, the amphibians three, fishes one, birds two, and mammals (the muskrat) one. The remaining five pages are divided into sections on worms, scavengers, parasites, aquariums, and record keeping. There is no bibliography or index.

*THE LIFE OF SEA ISLANDS. N. J. and Michael Berrill. McGraw-Hill Book Co. 1969. Grades 3 and up. 231 pages. Informational.

A very complete reference that discusses many islands and their origins, wildlife, and importance. Outstanding photographs and illustrations. A top-notch reference.

*THE LIFE OF THE MARSH. William A. Niering. McGraw-Hill Book Co. 1966. Grades 6-12. 232 pages.
Informational.

Maintains the high standards of the books in this series. One section describes the distribution of the eight types of wetlands in the United States. Another section describes the energy flow through wetland ecosystems. Contains about 200 illustrations, many in color. A glossary, appendices, a bibliography, and an index are included.

*THE LIFE OF THE OCEAN. N. J. Berrill. McGraw-Hill Book Co. 1966. Grades 6-12. 232 pages. Informational.

Discusses the wide variety of plants and animals found in different parts of the ocean. Beautifully illustrated with many photographs, many of which are in color. The appendix includes a section on starting and maintaining a marine aquarium. A glossary, bibliography, and index are also included.

*THE LIFE OF THE SEASHORE. William H. Amos. McGraw-Hill Book Co. 1966. Grades 7-12. 231 pages.
#208 Informational.

Describes the diverse kinds of marine shore life to be found in and around sandy beaches, tidal flats, rocky cliffs, etc. Richly illustrated in vivid color, including many of the author's photomicrographs. The book, like others in the series, describes life in terms of ecological patterns and relationships. There are five appendices, a glossary, a bibliography, and an index.

*THE LIVING SEA. Ritchard Read. Penguin Books, Inc. Middle School and up. 48 pages. Informational.

Very briefly introduces the organisms of the sea. Some are nicely illustrated in full color, including plankton, seaweeds, mollusks, crustaceans, fishes, and mammals. Very brief attention is given to vertical migration, food chains, food pyramids, geography, and evolution. There is a list of oceanographic expeditions, a list of suggested readings, and a one-page index. No. 11 of the Explorer Series. Paper cover.

LOG TRANSPORTATION IN THE LAKE STATES. W. G. Rector. A. H. Clark Company. Glendale, California. 1953.

@THE LOG OF THE SEA OF CORTEZ. John Steinbeck. Viking. 1951.

THE LONG SHIPS PASSING. Walter Havighurst. The Macmillan Company. New York, New York. 1942.

LORE OF THE LAKES. Dana Thomas Bowen. The Lakeside Printing Company. Cleveland, Ohio. 1948.

*MAGIC OF THE SEA. Max Albert Wyss. The Viking Press. 1968. All ages. 86 pages. Informational.

Superb photographs of the sea and its inhabitants are combined with essay and poems to make a moving essay about people and the sea. The influence of the oceans on human cultures is impressively developed. A handsome book.

*MAN EXPLORES THE SEA. Malcolm E. Weiss. Julian Messner. 1969. Upper Middle School and others. 110 pages. Informational.

The story of the three Sealab expeditions in which man lived for many days at the bottom of the sea and of other explorations of the ocean depths. Illustrated with black-and-white photographs. Glossary and index.

@MOBY DICK. Herman Melville. 1851. Penguin paperback.

*THE OCEAN WORLD. Peter Ryan. Penguin Books, Inc. 1973. Grades 7 and up. 48 pages. Informational.

The ocean itself and almost everything that affects it is covered by Ryan's short but informative book. A bit of history of the exploration of the undersea world is presented including pictures of an early diving bell and undersea saucers. A good introduction to the ocean's wealthy potential--oil, minerals, and hydroelectric power.

*OF MEN AND MARSHES. Paul L. Errington. The Iowa State University Press. 1957. Grades 8-12. 150 pages. Informational. #202, #208

This is a book of memories and philosophy by a man who rose from fur trapper to college professor. It describes marshes all over America, but dwells on the glaciated prairie marshes of the Dakotas. The 23 illustrations are excellent but do not have captions. There is no index. The author's knowledge of marsh ecology makes this a very worthwhile book.

@ THE OLD MAN AND THE SEA. Ernest Hemingway. Scribner's. 1952. Scribner's paperback.

@ THE OUTERMOST HOUSE. Henry Beston. Holt, Rinehart & Winston. 1928, 1949. Viking Compass paperback. 1962.

@ THE PEARL. John Steinbeck. Viking. 1947.

*POND LIFE: A GUIDE TO COMMON PLANTS AND ANIMALS OF NORTH AMERICAN PONDS AND LAKES. George K. Reid. Golden Press. 1967. Middle School and others. 160 pages. Informational.

Mostly a very usable manual for identification of a wide variety of common plants and animals of fresh water ponds, including birds and mammals. There is a very brief treatment of the physical features of a pond and of aquatic ecosystems, and a bibliography and five-page index. Useful for amateur pond watchers of all ages.

@ *THE SEA AROUND US. Rachel Carson. Franklin Watts. 1961. Golden Press. 1951. Grades 8-12. 259 pages. Informational. #214

Miss Carson's famous book is the winner of many accolades, including the National Book Award. In the book she describes the sea in three different ways: the mother sea, the restless sea, and the sea's relationship with man, i.e., man and the sea about him. The book conveys knowledge of the sea in a language that often rises to poetic elegance.

@ SEA OF CORTEZ. John Steinbeck and Edward F. Ricketts. Viking. 1941.

@ SEASCAPE AND THE AMERICAN IMAGINATION. Roger B. Stein. Clarkson N. Potter, Inc. (Crown Publishers). 1975.

*SEASHORES: A GUIDE TO ANIMALS AND PLANTS ALONG THE BEACHES. Herbert S. Zim and Lester Ingle. Golden Press. 1955. Grades 5-12. 160 pages. Informational.

About 460 forms of seashore life are described and illustrated in this book. It is attractive and authoritative. Its convenient hip-pocket size makes it a useful companion for anyone who frequents the beaches. There is an index with a list of scientific names of the plants and animals discussed.

@ SEASIDE STUDIES IN NATURAL HISTORY. Elizabeth C. Agassiz and Alexander Agassiz. Houghton Mifflin. 1866. 2nd ed. 1871. Facsimile reprint by Arno and New York Times as American Environmental Studies series, 1970.

@ THE SEA WOLF. Jack London. 1904.

SHIPS THAT NEVER DIE. Marine Historical Society of Detroit. Detroit, Michigan. 1952.

SHIPWRECKS OF THE LAKES. Dana Thomas Bowen. The Lakeside Publishing Company. Cleveland, Ohio. 1952.

"SOME SEA TERMS IN LAND SPEECH." Samuel F. Batchelder. The New England Quarterly (January-October) 1929, pp. 625-653.

A delightful compendium of nautical terms in the U.S. language.

@ TWO YEARS BEFORE THE MAST. Richard Henry Dana, Jr. Harpers. 1840.

@ TYPEE. Herman Melville. 1846. Penguin paperback.

@ *UNDER THE SEA-WIND. Rachel Carson. New American Library. 1941. Grades 7 and up. 157 pages. Fiction.

An obvious love and understanding of the interdependence and life of the sea is conveyed in Carson's book. She selects several animals of different species to follow closely as they affect and are affected by their environment. Beautifully written.

*VALLA: THE STORY OF A SEA LION. Dean Jennings. The World Publishing Co. 1969. Grades 9 and up. 172 pages. Fiction.

Conservation of a species and survival of the fittest are the main themes of this book. It follows the life of Valla, a sea lion, through natural interactions and competition with other species and through unnatural problems caused by man. Research about the sea lion is also dealt with. Some illustrations.

VEIN OF IRON. Walter Havighurst. The World Publishing Company. Cleveland, Ohio, 1958.

WINSLOW HOMER. Lloyd Goodrich. W & W Visual Library. 1973.

WHO'S MINDING THE SHORE? A CITIZEN'S GUIDE TO COASTAL MANAGEMENT. National Resources Defense Council. National Oceanic and Atmospheric Administration. 1976.

*THE WONDERFUL WORLD OF THE SEA. James Fisher. Doubleday & Co. 1970. Upper Middle School and up. 96 pages. Informational.

A comprehensive coverage of: the origins and physical features of the seas; the sea's living inhabitants and their contributions to evolution; and the role of the sea in war, transportation, and food production. There is a 22-page encyclopedia and a three-page index.

*THE YEAR OF THE SEAL. Victor B. Scheffer. Charles Scribner's Sons. 1970. Upper Middle and others. 200 pages. Fiction.

By interweaving the lives of seals and humans, the author achieves a sensitive and engrossing account of a year in the life of an Alaskan fur seal. The viewpoint of the wildlife biologist is dominant and the writing is clearly authoritative but warm-hearted and sensitive. Bibliography and index are included.

*THE YEAR OF THE WHALE. Victor B. Scheffer. Charles Scribner's Sons. 1969. Grades 7-12. 213 pages. Fiction.

Marine biologist Victor Scheffer wrote the story of a newborn sperm whale's first year of life. Straightforward scientific exposition is sandwiched in the fictionalized narration. The author has included six pages of reference notes and an annotated bibliography of seven whaling classics. There is an index also. This book won the 1969 Burroughs Medal.

*YOU CAN MAKE SEASIDE TREASURES. Louis Beetschen. Pinwheel Books. 1971. Middle School and others. 32 pages. Informational.

Describes a number of arts and crafts activities that can be done with sand and other items commonly found on beaches. Included are sand molding, making shell necklaces, painting pebbles, building sand castles, and collecting shells. Also includes games to be played at the beach.

LIST OF SUGGESTED FILMS

All films on this list (except where otherwise indicated), may be obtained without charge by writing to:

Motion Picture Service
Department of Commerce -- NOAA
12231 Wilkins Avenue
Rockville, Maryland 20852
(301) 443-8411

THE BIOLOGIST AND THE BOY. 14 minutes. An encounter between a biologist and a boy on the Gulf of Mexico. Discusses conservation and awareness.

ESTUARINE HERITAGE. 28 minutes. Shows threats to estuarine resources and stresses the importance of estuaries.

ESTUARY. 28 minutes. Stresses the value of the estuary and its uses for food resources and recreation.

THE GREAT AMERICAN FISH STORY. 28 minutes. A series of five films (each is 28 minutes long) which tells the story of the American fishing industry. The first film is an overview and the other four each concentrate on one area of the country -- The West, The Northeast, The South, The Lakes and Rivers. Every aspect of the fishing industry is covered from catching to cooking.

HURRICANE. 27 minutes. Shows warning methods for hurricanes. Emphasizes safety precautions for life and property. To obtain: Film Librarian, Public Relations and Advertising Dept., Aetna Life and Casualty, 151 Farmington Ave., Hartford, Conn. 06115. (203) 273-0123.

HURRICANE DECISION. 14 minutes. A hurricane awareness and preparedness film. Points out the dangers of storm surge, wind and inland flooding caused by hurricanes.

IT'S YOUR COAST. 28 minutes. Discusses coastal zone problems with people from Florida, Maine, Illinois and Washington. Land development, oil pollution, and beach erosions are discussed. Stresses the importance of the coast.

WATERMEN OF CHESAPEAKE. 28 minutes. A film about the impact of Chesapeake Bay on a large segment of America.

GAMES

THE THERMAL POLLUTION GAME. Educational Research Council of America, a board game for 4 players about the pollution over time of two rivers in "Central City."

DIRTY WATER. Judith Anderson, Helen Trilling, and Richard Rosen; Urban Systems, Inc., a board game for grades 4 to 12 for 2 to 4 players about the problems of maintaining an ecologically balanced lake.

WHERE TO OBTAIN DATA*

The following paragraphs give detailed information on the types of data available from different sources and show how to obtain it.

1. EARTH RESOURCES OBSERVATION SYSTEM (EROS)

Earth resource data can be obtained by writing to the EROS Data Center, a division of the Department of the Interior.

EROS
Data Management Center
Sioux Falls, SD 57190

The EROS Data Center will assist in locating imagery and photography to suit the particular needs of the user. The center's computerized storage and retrieval system is based on geographical coordinates (latitude and longitude), the date and time of day the photographs were obtained, and the scale of the photographs.

The requestor may provide the center with the latitude and longitude of the point of interest, or may define an area by giving latitude and longitude of a maximum of eight perimeter points. On receipt of a request the center staff will locate the area of interest and will prepare a listing of photographs from which the requestor can make the final selection.

EROS stocks Skylab photographs as well as LANDSAT (ERTS) photographs. The Skylab spacecraft operated at about half the altitude of LANDSAT. Consequently Skylab photographs contain more detail than LANDSAT.

If you elect to use Skylab photographs in your study, it is possible to help EROS speed up your order by quoting the specific photograph numbers of the scene you need. You can write to the following address for help.

Lyndon B. Johnson Space Center
Research Data Facility
Mail Code TF-8
Houston, TX

Include the names of prominent features in the area. City names, rivers, and mountains should be included as well as latitude and longitude. Research Data Facility personnel will check through their catalogs and provide you with photograph identification numbers that you can then send to EROS to obtain the copies you need.

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*National Aeronautics and Space Administration, What's the Use of Land? A Secondary School Social Studies Project (Jefferson County, Colorado, Public Schools), 1976, pp. 32-35. (For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price $1.45, Stock Number 033-000-00665-9).

At the time of writing the prices of black and white EROS photographs ranged from $1.25 to $9.00. Color reproductions cost about three times as much as black and white. For more details write to EROS at Sioux Falls, South Dakota.

Another outlet for EROS services is located in Bay St. Louis, Mississippi. At the National Space Technology Laboratories, anyone can obtain a wide variety of earth resources information and order photographs by writing to:
National Space Technology Laboratories
Bay St. Louis, MS 37520

2. U. S. GEOLOGICAL SURVEY

U.S. Geological Survey (USGS) maps are available from any regional Federal Center and from certain commercial stores such as sporting goods stores. The most common USGS maps are of an area 7½ minutes square or 15 minutes square.

3. SKYLAB EARTH RESOURCES DATA CATALOG

The Skylab Earth Resources Data Catalog prepared by NASA, provides a complete index of Skylab earth resources photographs and other data, plus direction on how copies can be obtained. It also provides a discipline-by-discipline review of possible uses of the Skylab photographs and data with appropriate illustrations.

In marine resources data, channels, shallow areas, river discharges of sediment, and other features of waterways often show up better from space than by any other means.

The environment data deal, in a broad sense, with man's environment. The data also proved particularly useful regarding specific environmental problems. Sources of water and air pollution often can be located and the spread of contaminants traced for long distances in a single photograph.

The Skylab Earth Resources Data Catalog is obtainable from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Price $12.50). The book number is GPO-3300-00586.

WHERE TO GET INFORMATION?

Federal Sources of Information

Numerous Federal agencies are involved in matters affecting the coastal zone. Many have special expertise and information that will be of use to citizens who are participating in the development of state management plans. For example they may have data that permits state information to be cross-checked or supplements it with a regional or national perspective. The following are some of the best sources of information.

Office of Coastal Zone Management/NOAA
3300 Whitehaven Street, N.W.
Washington, D.C. 20235
(clearinghouse for specialized coastal zone technical information)

U.S. Fish and Wildlife Service
Washington, D.C. 20240
(can provide information on local waterfowl, game fish and endangered species)

National Marine Fisheries Service/NOAA
Page Building 2
3300 Whitehaven Street, N.W.
Washington, D.C. 20235
(data on commercial and sport fisheries)

Office of Sea Grant/NOAA
3300 Whitehaven Street, N.W.
Washington, D.C. 20235
(supports a large program of university research on ocean and coastal topics)

Department of Agriculture
Federal Soil Conservation Service and Cooperative Extension Agents
Washington, D.C. 20250
(can supply hydrological and soil data, also helpful in providing names of local experts and scientists)

State Coastal Management Program Managers

NORTH ATLANTIC REGION

Connecticut: Charles McKinney, Director, Coastal Area Management Program, Department of Environmental Protection, 71 Capitol Avenue, Hartford, CT 06115

Maine: Alec Griffen, State Planning Office, Resource Planning Division, 189 State Street, Augusta, ME 04333

Massachusetts: S. Russell Sylva, Assistant Secretary, Executive Office of Environmental Affairs, 100 Cambridge Street, Boston, MA 02202

New Hampshire: Larry Goss, Division of Regional Planning, Office of Comprehensive Planning, State Annex, Concord, NH 03301

New Jersey: David Kinsey, Chief, Office of Coastal Zone Management, Department of Environmental Protection, P.O. Box 1889, Trenton, NJ 08625

New York: Robert Hanson, Director, Division of State Planning, Department of State, 162 Washington Street, Albany, NY 12231

Rhode Island: Daniel Varin, Statewide Planning Program, Department of Administration, 265 Melrose Street, Providence, RI 02907

SOUTH ATLANTIC REGION

Delaware: David Hugg, Coastal Management Program, Office of Management, Budget and Planning, James Townsend Building, Dover, DE 19901

Georgia: James Dodd, Planning Division, Office of Planning & Budget, 270 Washington Street, S.W., Room 613, Atlanta, GA 30334

Maryland: Suzanne Bayley, Department of Natural Resources, Energy & Coastal Zone Administration, Tawes State Office Building, Annapolis, MD 21401

North Carolina: Ken Stewart, Department of Natural & Economic Resources, Box 27687, Raleigh, NC 27607

South Carolina: Wayne Beam, Wildlife and Marine Resources Department, 1116 Bankers Trust Tower, Columbia, SC 29201

Virginia: Don W. Budlong, Office of Commerce and Resources, 5th Floor, Ninth Street Office Building, Richmond, VA 23219

GULF/ISLANDS REGION

Alabama: Dr. Bruce Trickey, Executive Director, Coastal Area Board, General Delivery, Daphne, AL 36526

Florida: Dr. Ted LaRoe, Bureau of Coastal Zone Planning, Department of Environmental Regulation, 2562 Executive Center Circle East, Montgomery Building, Tallahassee, FL 32301

Louisiana: George A. Fischer, Secretary, Department of Transportation and Development, P.O. Box 44486, Baton Rouge, LA 20804

Mississippi: Jerry Mitchell, Mississippi Marine Resources Council, P.O. Drawer 959, Long Beach, MS 39560

Puerto Rico: Frank A. Molther (Acting), Department of Natural Resources, P.O. Box 5887, Puerto de Tierra, PR 00906

Texas: Ron Jones, Director, Texas Coastal Management Program, General Land Office, 1700 N. Congress Avenue, Austin, TX 78711

Virgin Islands: Darlan Brin, Virgin Islands Planning Office, P.O. Box 2606, Charlotte Amalie, St. Thomas, VI 00801

GREAT LAKES REGION

Illinois: Chris Shafer, Illinois Coastal Zone Management Program, 300 N. State Street, Room 1010, Chicago, IL 60610

Indiana: T. "Ted" Pantazis, State Planning Services Agency, 143 West Market Street, Harrison Building, Indianapolis, IN 46204

Michigan: Merle Raber, Coastal Zone Management Program, Department of Natural Resources, Division of Land Use Programs, Stephen T. Mason Building, Lansing, MI 48926

Minnesota: Roger Williams, State Planning Agency, Capitol Square Building, 550 Cedar Street, Room 100, St. Paul, MN 55155

Ohio: Bruce McPherson, Department of Natural Resources, Division of Water, 1930 Belcher Drive, Fountain Square, Columbus, OH 43224

Pennsylvania: George E. Fogg, Chief, Division of Outdoor Recreation, Department of Environmental Resources, Third & Reily Sts., P.O. Box 1467, Harrisburg, PA 17120

Wisconsin: Al Miller, Office of State Planning & Energy, One West Wilson St., B-130, Madison, WI 53702

PACIFIC REGION

Alaska: Glenn Akins, Policy Development & Planning Division, Office of the Governor, Pouch AD, Juneau, AK 99801

California: Joe Bodovitz, California Coastal Zone Conservation Commission, 1540 Market Street, San Francisco, CA 94102

Guam: David Bonvouloir, Bureau of Planning, Government of Guam, P.O. Box 2950, Agana 96910

Hawaii: Dick Poirier, Department of Planning & Economic Development, P.O. Box 2359, Honolulu, HI 96804

Oregon: Jim Ross, Land Conservation & Development Commission, 1175 Court St., N.E., Salem, OR 97310

Washington: Rod Mack, Department of Ecology, State of Washington, Olympia, WA 98504

SEA GRANT INSTITUTIONS

Pam Johnson and Linda Weimer have summarized Sea Grant activities and publications that are relevant to elementary and secondary schools. Write for Informal Survey of K-12 Publications. University of Wisconsin, Sea Grant College Program, 1800 University Avenue, Madison, WI 53706, July 1977. Information may also be requested directly from state Sea Grant Marine Advisory Services.

Alaska: Marine Advisory Service, 3211 Providence Avenue, Anchorage, AK 99504

Alabama: Resource Use Division, Cooperative Extension Service, Auburn University, Auburn, AL 36526

California: Marine Advisory Program, University of California, Davis, CA 95616

Connecticut: Marine Advisory Service, University of Connecticut, 322 N. Main Sreeet, Wallingford, CT 06492

Delaware: Marine Advisory Service, College of Marine Studies, University of Delaware, Newark, DE 19711

Florida: Marine Advisory Program, 3002 McCarty Hall, University of Florida, Gainesville, FL 32611

Georgia: Sea Grant Program, University of Georgia, 110 Riverbed Road, Athens, GA 30602

Hawaii: Sea Grant Programs Office, University of Hawaii, Spalding Hall, Room 255, 2540 Maile Way, Honolulu, HI 96822

Louisiana: Sea Grant Program, Coastal Studies Building, Louisiana State University, Baton Rouge, LA 70803

Maine: Cooperative Extension Service, Univ. of ME Marine Lab., Walpole, ME 04573

Maryland: Cooperative Extension Service, 1224 Symons Hall, University of Maryland, College Park, MD 20742

Massachusetts: MIT Sea Grant Program, MIT, Room 1-211, 77 Massachusetts Avenue, Cambridge, MA 02139

Michigan: Coordinator, Advisory Service, Michigan Sea Grant, 2200 Bonisteel Boulevard, University of Michigan, Ann Arbor, MI 48105

Minnesota: Marine Advisory Service, 325 Administration Building, University of Minnesota, Duluth, MN 55812

Mississippi: Sea Grant Advisory Service, Box 4557, Biloxi, MS 39531

New Jersey: Marine Science Center, Rutgers University, New Brunswick, NJ 08903

New Hampshire: UNH Sea Grant Marine Advisory Service, Kingsbury Hall, University of New Hampshire, Durham, NH 03824

New York: NY Sea Grant Advisory Service, Fernow Hall, Cornell University, Ithaca, NY 04853

North Carolina: Extension & Public Service NC State University, 133, 1911 Building, Raleigh, NC 27607

Ohio: Extension Wildlife Specialist, 232 B Howlett Hall, 2001 Flyffe Center, Ohio State University, Columbus, OH 43210

Oregon: Marine Advisory Program, OSU Marine Science Center, Newport, OR 97365

Pennsylvania: Urban Forest Wildlife Specialist, 11 Ferguson Building, Pennsylvania State University, University Park, PA 16802

Rhode Island: Marine Advisory Service, University of Rhode Island, Narragansett Bay Campus, Narragansett, RI 02882

South Carolina: Marine Resources Center, P.O. Box 12559, Charleston, SC 29412

Texas: Education & Advisory Services, Center for Marine Resources, Texas A & M University, College Station, TX 77843

Virginia: Dept. of Advisory Services, Virginia Institute of Marine Scinece, Gloucester Point, VA 23062

Washington: Washington Sea Grant Marine Advisory Program, University of Washington-HG30, Seattle, WA 98195

Wisconsin: Advisory Services, 420 Lowell Hall, 610 Langdon Street, Madison, WI 53706

RESOURCES FOR COASTAL STUDIES

CURRICULUM MATERIALS CATALOGS

A Catalog of Curriculum Materials for Marine Environment Studies: Elementary, Secondary. 38 pages, $1.00

A List of Books on the Marine Environment for Children and Young People. Annotated, 65 pages, $2.00

Audio-Visual Aids, Games, and Art for Marine Environment Studies. Annotated, 89 pages, $2.00

An Annotated Bibliography of Periodical Sources for Marine Environment Studies, Newsletters, Bulletins, Journals, and Magazines. 21 pages, $1.00

All these are available from Project COAST, 310 Willard Hall, University of Delaware, Newark, DE 19711

A Bibliography of Elementary and Secondary Marine Science Curriculum Projects and Education Materials. University of Rhode Island Marine Bulletin Series #15. 23 pages, New England Marine Resources Programs, Narragansett, RI 02882

A Partial Bibliography for Precollege Marine Science Educators. 94 pages, University of Maine Sea Grant. Orono, ME 04473

NON-SCHOOL ORGANIZATIONS

League of Women Voters
1730 M Street, N.W.
Washington, D. C. 20036

Brochures: Coastal Zone Management.1975
The Onshore Impact of Offshore Oil.1976
Energy and our Coasts: The 1976 CZM Amendments.1977

Florida 4-H
Florida Sea Grant
Florida Maine Advisory Program
University of Florida
Gainesville, Florida

Study: Interest in coastal states in developing marine education programs.

Call : Local Department of Agricultural Extension Service for information on local 4H marine education projects,

Marine Ecological Institute
811 Harbor Boulevard
Redwood, California 94063

Discovery marine voyages: Around San Francisco area, fee.

Jean-Michel Cousteau Institute
P. O. Drawer CC, Harbor Town
Hilton Head Island, South Carolina

Workshops: "Man and the Sea" in Savannah, Georgia and Charleston, South Carolina, fee.

Coastal Management Programs
Coastal States

Newsletter: Describes local coastal problems, issues and proposed solutions. For addresses see list of state coastal management programs in section on "Where to Get Information".

ASSISTANCE IN COASTAL AND MARINE EDUCATION

National Marine Education Association
546-B Presidio Boulevard
San Francisco, California 94120

Newsletter and Annual Conference: Contact Thayer Schafer, Exec. Secy. Membership $15

Sea World (Formerly, The Journal of Marine Education)
Sea World Communications
1250 Sixth Avenue
San Diego, California 92101

Magazine: Published quarterly, includes section on curriculum (included in $15 membership in National Marine Education Association).

Marine Education Materials System
Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

Microfiche copies of marine education materials; Inexpensive, ask for list of materials available.

Dr. Francis Pottenger
Curriculum Research and Development Group
College of Education, University of Hawaii
1776 University Avenue
Honolulu, Hawaii 96822

Coastal Studies Course: Designed for 11th and 12th graders, includes ecology, economics, and government and involves students in coastal issues and management systems. Write for information on the course and teacher training.

GLOSSARY

GLOSSARY:

Algae:
Simple aquatic plants, without true stems, leaves, or roots, that vary in size from microscopic, unicellular forms to multicellular forms more than 30.5m (100 ft) long

Arthropods:
Segmented invertebrates with jointed legs, including arcachnids insects, and crustaceans

Barrier islands:
Low offshore islands stretching parallel to the shore and separated from the mainland by a small body of water; in the United States found mainly on the Atlantic coast (from New Jersey south), along the Gulf of Mexico, and in the Pacific only in north Alaska and in an area along the coast of northern Oregon and southern Washington

Bay:
A wide inlet of water, indenting the shoreline and forming a protected area along the shore of a sea or lake

Bayou:
A marshy, sluggish tributary to a lake or river; from the Louisiana French version of the Choctaw word bayuk

Beach:
A shoreline area washed by waves and composed of sand or pebbles

Beach grass:
A strongly rooted plant common on sandy shores that helps to anchor and build the dunes

Berm:
A narrow shelf, path, or ledge typically at the top or bottom of a slope.

Breakwater:
A barrier constructed of large rocks or concrete to provide protection for beaches or harbors by breaking the force of wave action. Groins, jetties, and sea walls are all forms of breakwaters

Coast:
Land next to the sea; seashore

Coastal management:
The development of policies and regulations to insure wise control, development, and use of coastal resources

Coastal pond complex:
A land and water composite that consists of a barrier beach, sand dunes, marsh, and pond; small off-shore islands and freshwater streams and wetlands are sometimes included

Coastal resources:
Anything that gives a source of supply, support, or aid in maintaining the value of the coastal region. The value can be counted in various terms: monetary (oil, ports, fish), ecological (plankton, dunes, shorebirds), cultural (historic areas), aesthetic (scenic bluffs, clear blue water) or recreational (marinas, beaches)

Continental shelf:
The ocean floor along the coastline that is submerged in the relatively shallow sea; the sunlit, submerged land from the coast to the brink of the deep ocean

Coral reef:
A colony of marine animals with skeletons containing calcium carbonate that, massed together, form islands or ridges near the surface of the sea in tropical areas (found only in Florida and Hawaii in the United States)

Crustacean:
Any mostly aquatic arthropod, typically with a hard shell covering the body; includes lobsters, shrimps, crabs, and barnacles

Delta:
The area where river sediment is dropped at the mouth of a river flowing into an ocean or large lake; frequently triangular in shape made up of marshy areas, lagoons, and lakes

Detritus:
A sediment of small particles found on the ocean bottom made up of the remains of plants and animals and the disintegration of rocks; an important link in many food chains

Dock:
A platform extending into the water to which a boat is tied or where passengers and gear are loaded or unloaded

Downdrift:
Describes direction of sand movement with the prevailing current

Dune:
Elliptical or crescent-shaped mound of sand formed by wind action. The windward slopes of dunes are gentle, the lee sides steep. In crescent-shaped dunes the convex side faces the direction from which the wind is blowing. Sand blown up the windward side drops down the lee slope, causing the dunes to migrate slowly

Eelgrass:
A grasslike marine herb with ribbonlike leaves that grows on sand and mud-sand bottoms in shallow coastal waters

Estuary:
The zone where the fresh water of a river mixes with the salt water of the sea; rich in biological activity

Flood plain:
The flat area along a river that is subject to flooding at high water periods

Food chain:
A series of organisms in which members of one level feed on those in the level below it and are in turn eaten by those above it; there is a 10 to 1 loss in bulk as the food chain moves upward. It takes a 1000 kilograms of phytoplankton to make 1 kilogram of shark

Food web:
The interconnected food chains of a biological community

Groin:
Breakwater structure constructed outward into the sea or a lake to reduce drifting of beach sand along the shore

Harbor:
A sheltered area of water deep enough for ships to anchor or moor for loading and unloading; may be natural (bays) or artificial (within breakwaters)

Intertidal zone:
The area along the shoreline that is exposed at low tide and covered by water at high tide

Island:
A body of land completely surrounded by water and too small to be called a continent

Isopod:
Any fresh-water, marine, or terrestrial crustacean having seven pairs of legs and a flat body

Jetty:
A pier or structure projecting into the water to protect a harbor or deflect a current

Lagoon:
A body of brackish water separated from the sea by sandbars or coral reefs

Lake:
A large body of fresh or salt water completely surrounded by land

Littoral:
Pertaining to the shore of a lake, sea, or ocean

Mangrove:
A moderate-sized tree which grows on low, often submerged coastal lands, noted for the land-forming function of its intricate mass of arching prop roots which trap silt and debris floating in the water

Ocean:
The entire body of salt water (seawater) that covers almost three-fourths of the earth's surface

Oil rig:
A structure for drilling and pumping oil from beneath the ocean floor to the water's surface

Pier:
A fixed or floating platform attached to piles or posts over the water from the shore; may be used for mooring boats or ships, fishing, etc.

Pond:
A body of still water, fresh or salty, that is smaller than a lake; frequently constructed to hold water

Port:
A town or city located at a bay or harbor where waterborne transportation takes place; from the Latin for house door

Riprap:
Broken stone or other material piled along a shore to protect it from erosion by wave action

River:
A fairly large-sized natural stream of water flowing in a definite course from an area of higher elevation to lower elevation. The term "river" is sometimes used incorrectly to define narrow tidal inlets

Rocky cliff:
The high steep face of a rock mass that forms the most erosion-resistant areas along the shore

Salinity:
The measure of the quantity of dissolved salts in seawater

Salt marsh:
An area of low-lying, wet land with heavy vegetation that is washed by tidal action from the sea

Sand:
A mixture of tiny grains of different types of disintegrating rocks and shells found along beaches

Sandbar:
An off-shore shoal of sand resulting from the action of waves or currents

Sea wall:
A barrier constructed along the edge of a shore to prevent erosion from wind or wave action; sometimes called bulkhead or revetment

Seawater:
The water of the ocean which is distinguished from fresh water by its salinity

Seaweed:
Any plant growing in the sea, specifically marine algae like kelp, rockweed, and sea lettuce

Shore:
The space between the ordinary high water and low water marks

Shoreline:
Where the land and water meet

Sound:
A narrow passage of water forming a channel between the mainland and an island or connecting two larger bodies of water such as a bay and an ocean

Spit:
A narrow point of land extending into the sea or a lake formed by waves and currents; subject to shifting

Tide:
The twice-daily rise and fall of the waters of the ocean and its inlets produced by the gravitational attraction of the moon and sun

Tidal pool:
A small body of water along rocky shores left by the retreat of the tide; a unique environment for many plant and animal species that can withstand highly variable moisture, salinity, and temperature conditions as well as high winds and pounding waves

Trophic:
Having to do with nutrition

Wave-cut cliff:
The steep slope of the shore cut by wave action

Wetlands:
Areas such as fresh and salt-water marshes, bogs, or swamps that remain wet and spongy most of the time