Coastal Awareness:
A Resource Guide For Teachers

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
Office of Public and Constituent Affairs

Prepared by:
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Michelle A. Crockett
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FOREWORD

This Resource Guide on Coastal Awareness 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. The guide contains concepts and activities which could be used in a 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 interaction of ecology with economics, humanities and government.

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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 eel grass 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

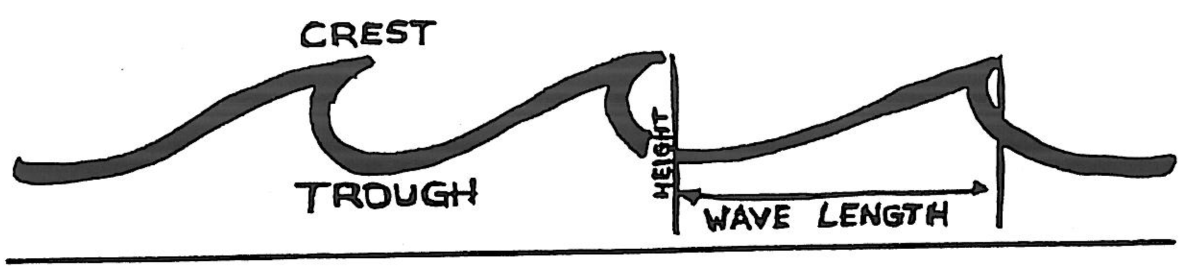
Wind generates waves. The wind, blowing irregularly, causes significant pressure differences that deform the water's surface, creating wave crests of many heights. The wind then pushes against these crests, supplying energy to the waves as they grow and become more regular in weight and length. Wave 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

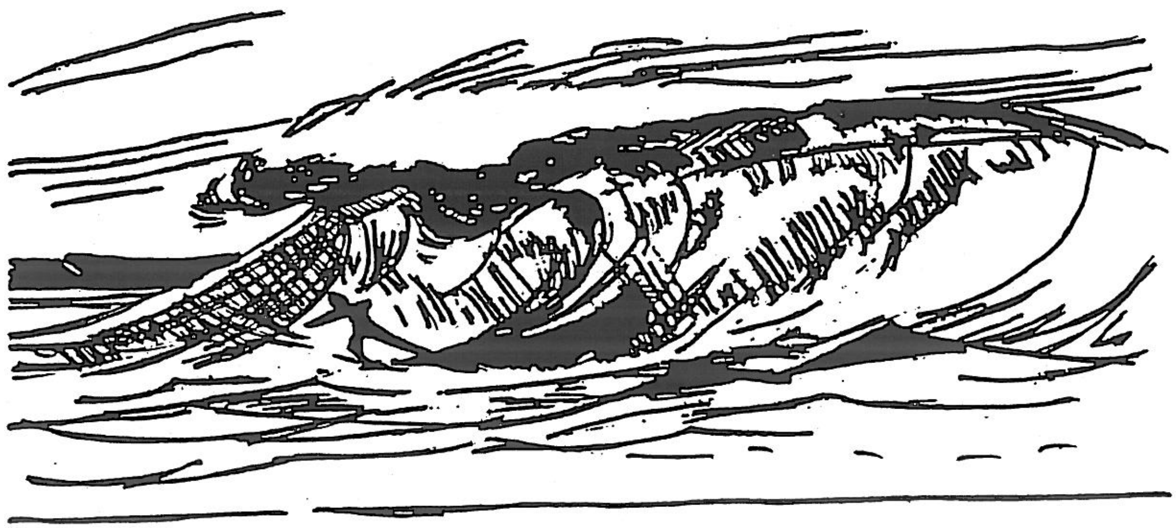
Waves are the sculptors of the coasts. Forceful or gentle, loud or lulling, they combine two distinct types of motion. One is the circular motion of the water molecules within the wave, the up and down motion of the droplets. The other is the advancing movement. The actual water molecules have no horizontal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

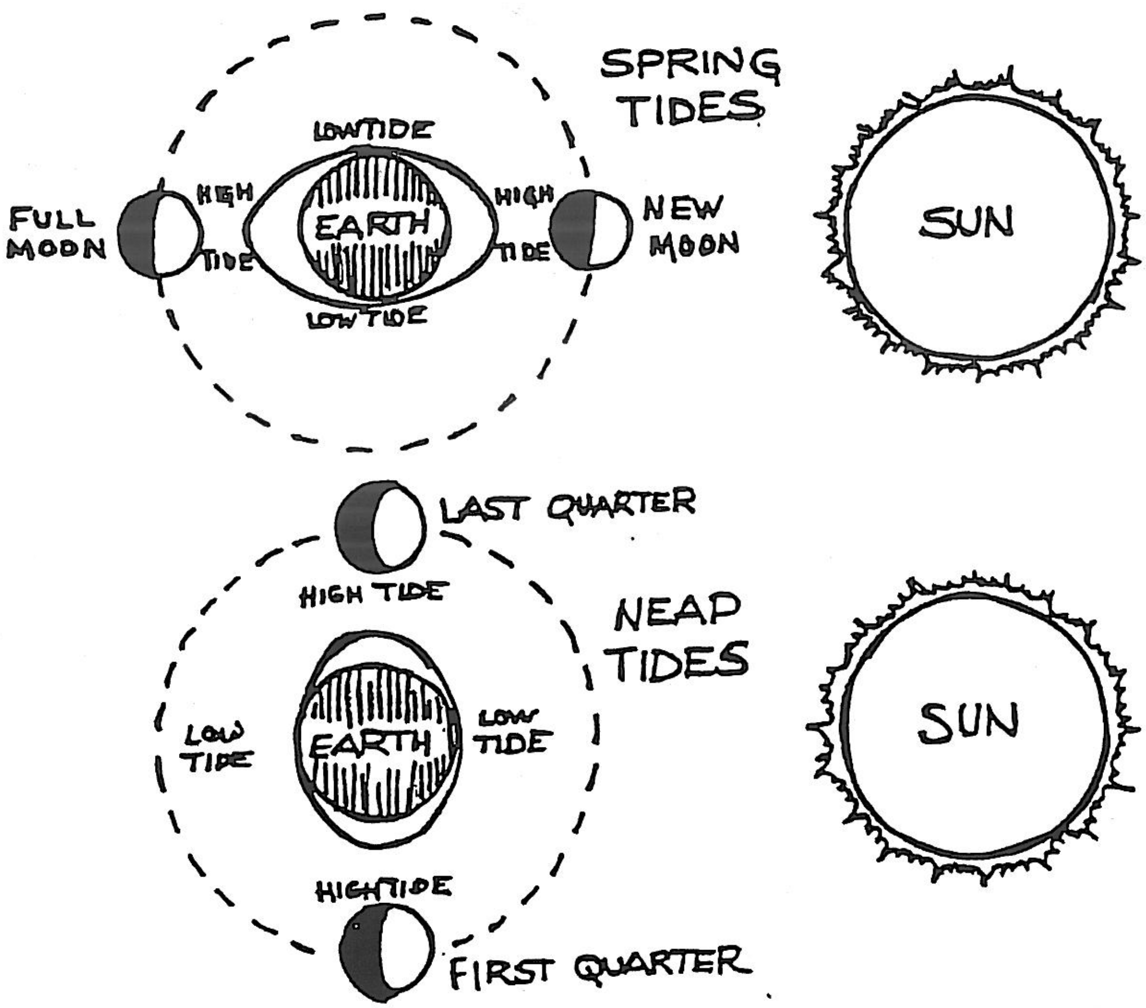


A gradually shoaling bottom results in a wave that releases its energy more slowly. When a crest finally becomes unstable, it rolls down or spills into the trough and the wave face remains gently sloped. It is these "spilling waves" that display white water at the crest. Irregularities in the ocean bottom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

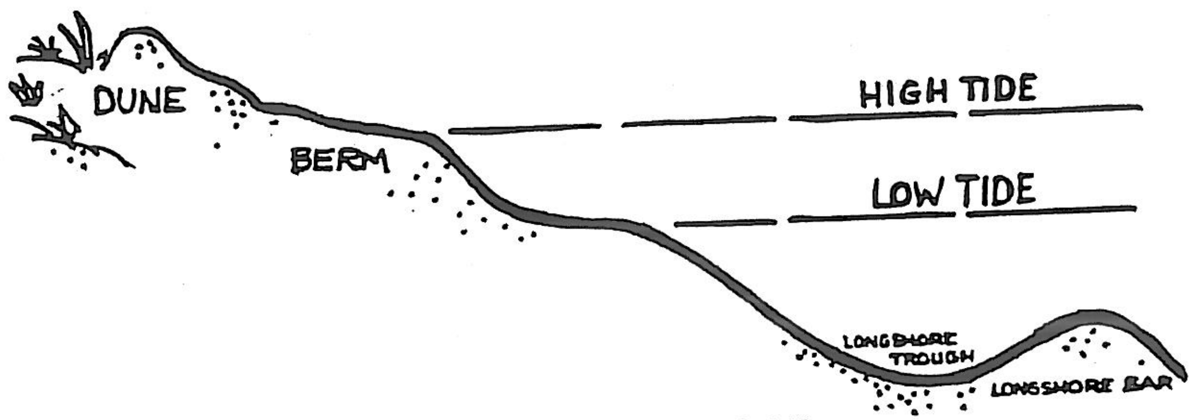
As the Gulf Stream moves north it trends increasingly toward the right (to the east) because of the Coriolis effect. By the time it reaches 40 degrees North latitude, it is flowing due east across the Atlantic, has lost considerable speed, and has widened; it has also cooled down. Currents similar to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

Although sandy beaches differ in many ways, they also share certain characteristics. 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.

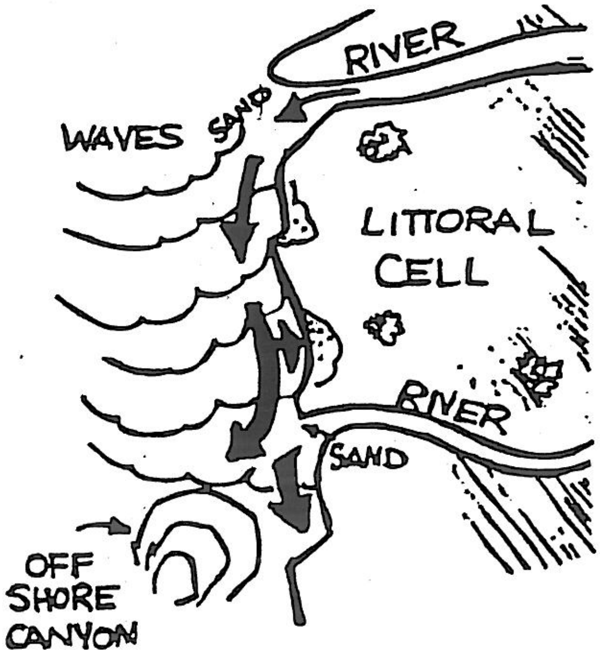


A TYPICAL SANDY BEACH

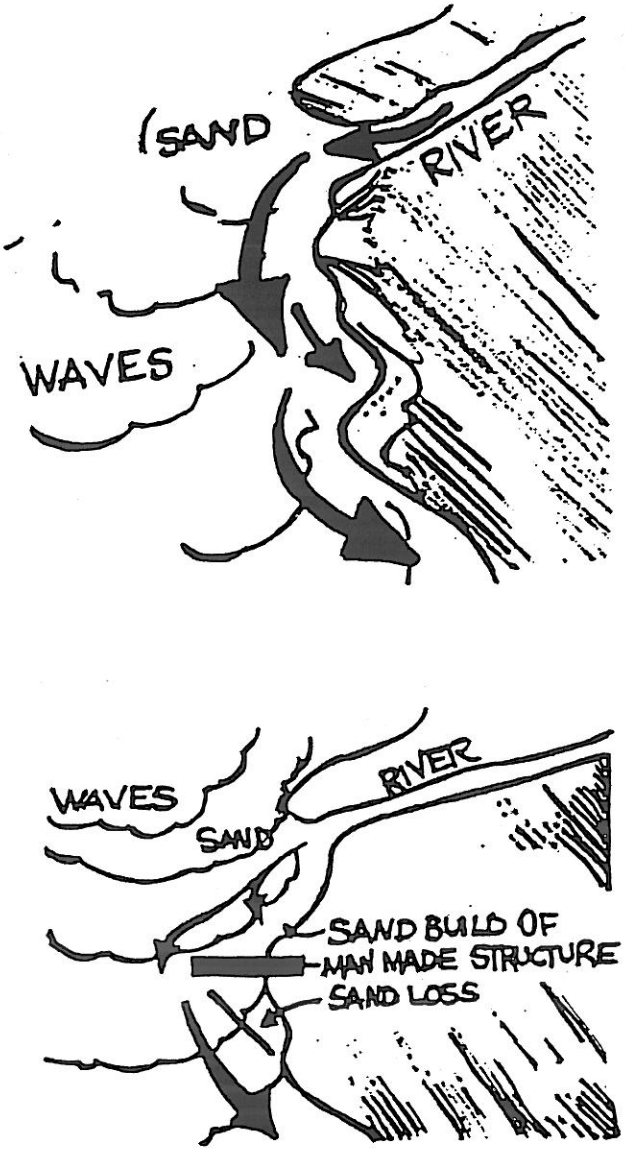
The texture of the sand plays a role in the kind of beach that will be built, because the slope of the beach relates directly to the particle size of the deposited material. The coarser the particles, the more the waves sink into the beach, depositing their load of sand. Since coarse sand does not pack 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

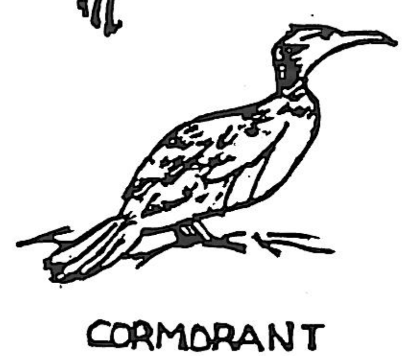
Ocean beaches are moving, active places that gain and lose sand continuously. Beach sand is transported by waves, wind, and wave currents in three kinds of movements: offshore, on-shore, and longshore. When put into suspension by wave action, sand can move laterally along the shore in long-shore currents 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 beach front modifications are undertaken.

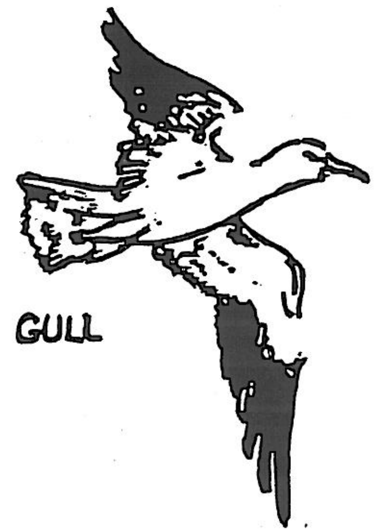
The long stretches of sun-baked sand and the breaking waves that delight vacationers are also what make sand beaches among the most barren of coastal environments. Because of its shifting nature, the sand offers a poor substrate for anchoring plants. Thus, beaches essentially lack the producers in the food chain and the few animal residents of the sand must depend on small wave-borne 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.

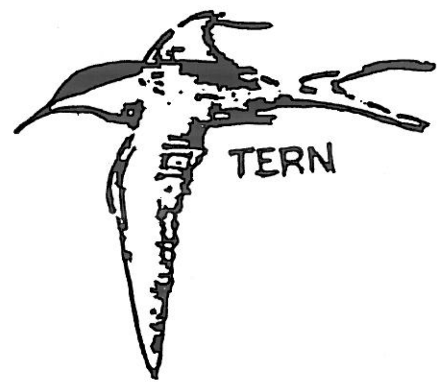
Sand beaches are superb places for bird watching. Some birds are full-fledged swimmers and obtain their food from the ocean and the near-shore ocean bottom. Others parade incessantly up and down the beach at the water's edge in search of food. The specific kinds of bird inhabitants vary from one part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

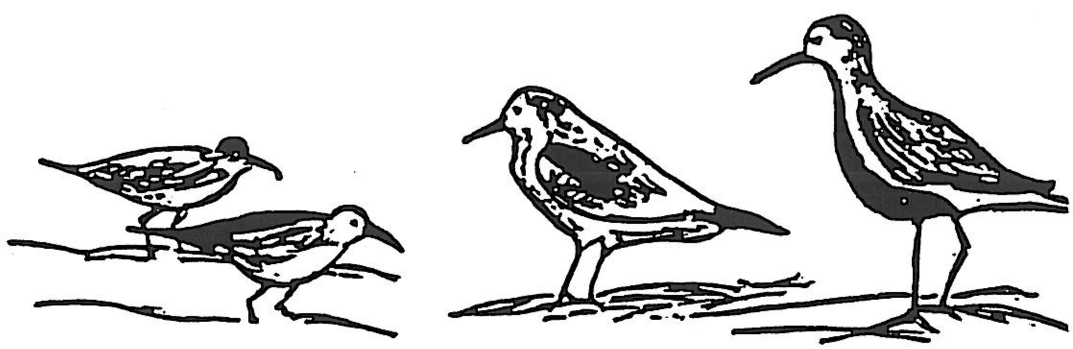


Medium-sized birds that are flying across the surface of the water or riding on it are likely to be gulls, terns, or cormorants. The cormorant is a dark bird that dives and disappears for a considerable time while swimming in search of food. Gulls and terns do not swim under water. Terns can be seen 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.

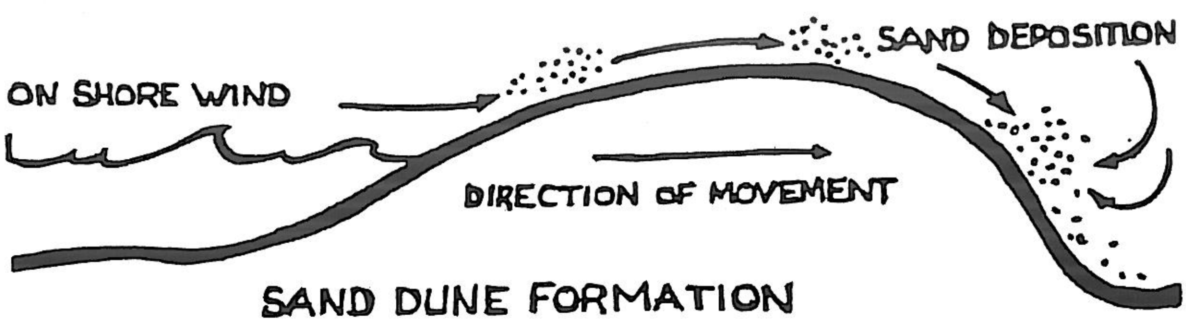




SHORE BIRDS

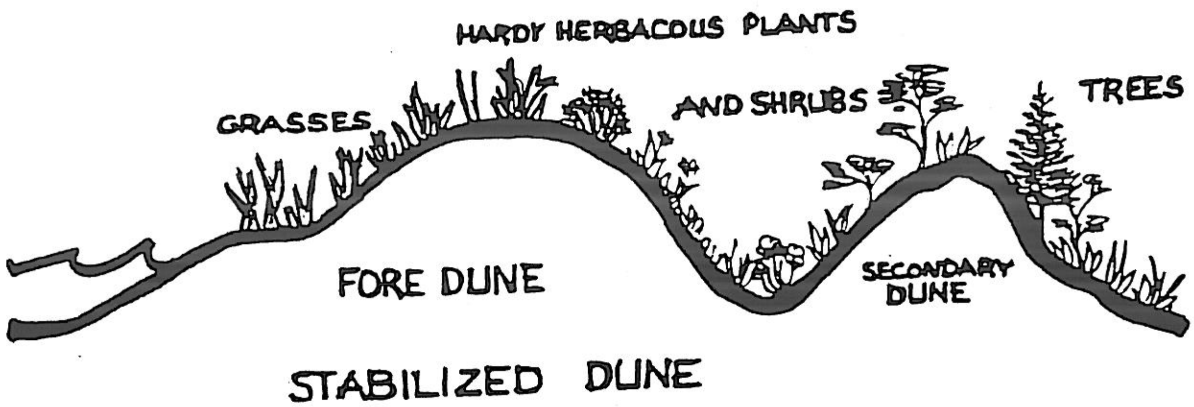
SAND DUNES

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



SAND DUNE FORMATION

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.



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 under-pinnings 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 6 m (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).

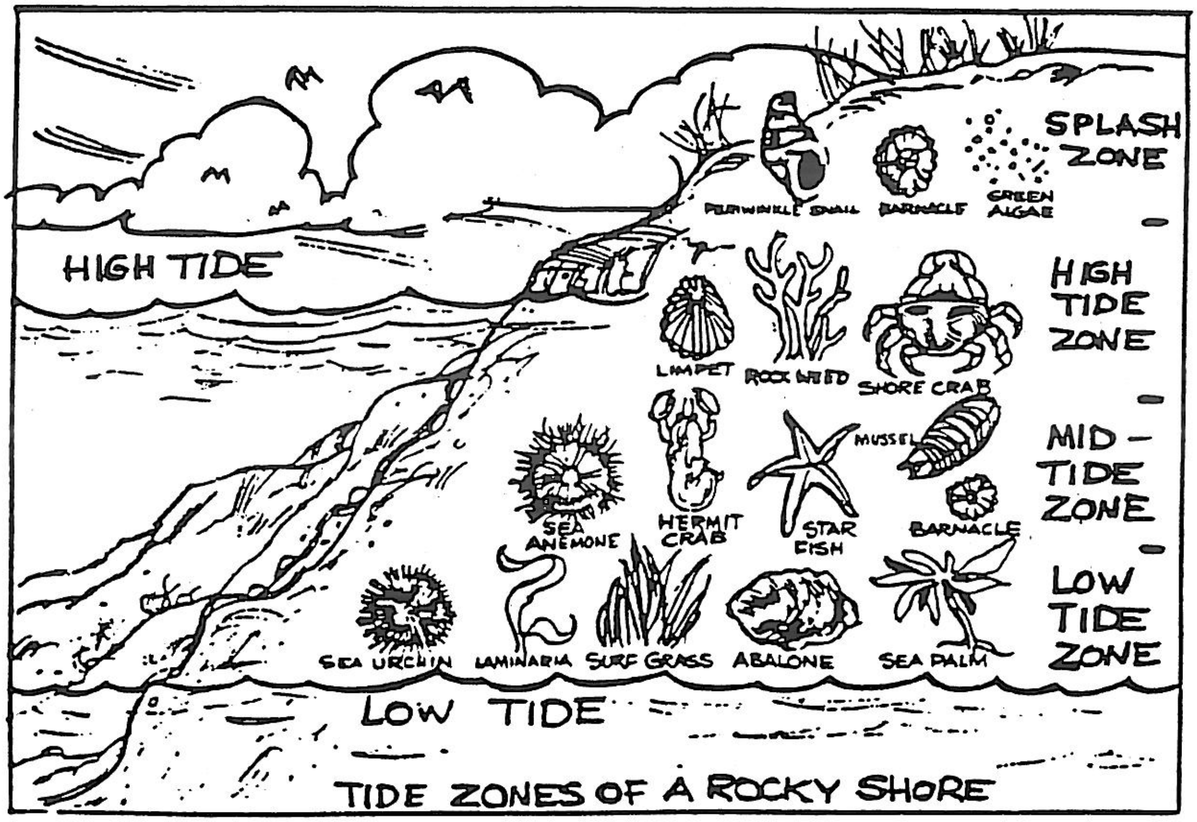
Even though the glass beacon on Tillamook Rock light house on the coast of Oregon is some 42 m (140 ft) high, a grating had to be installed over the glass to protect it from rocks tossed up by the pounding seas. Of course, not all rocky coasts are as exposed as Tillamook Rock. Offshore islands, reefs,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



Turbulence governs the life of organisms living between tide marks 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 tide marks. 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.

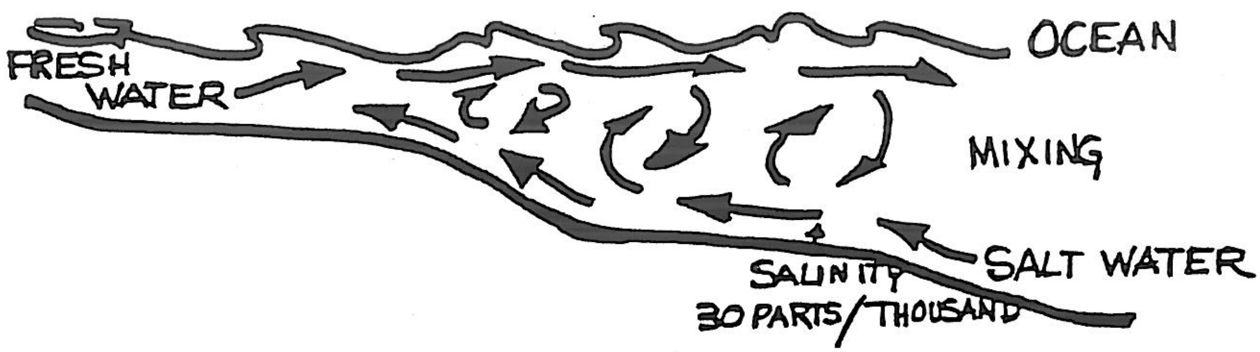
Before visiting your coast consult a local publication which describes in some detail the organisms present and their distribution. Living organisms should be observed where they are found, not collected. Disturbing the shore line in any significant way is to be avoided at all costs.

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.

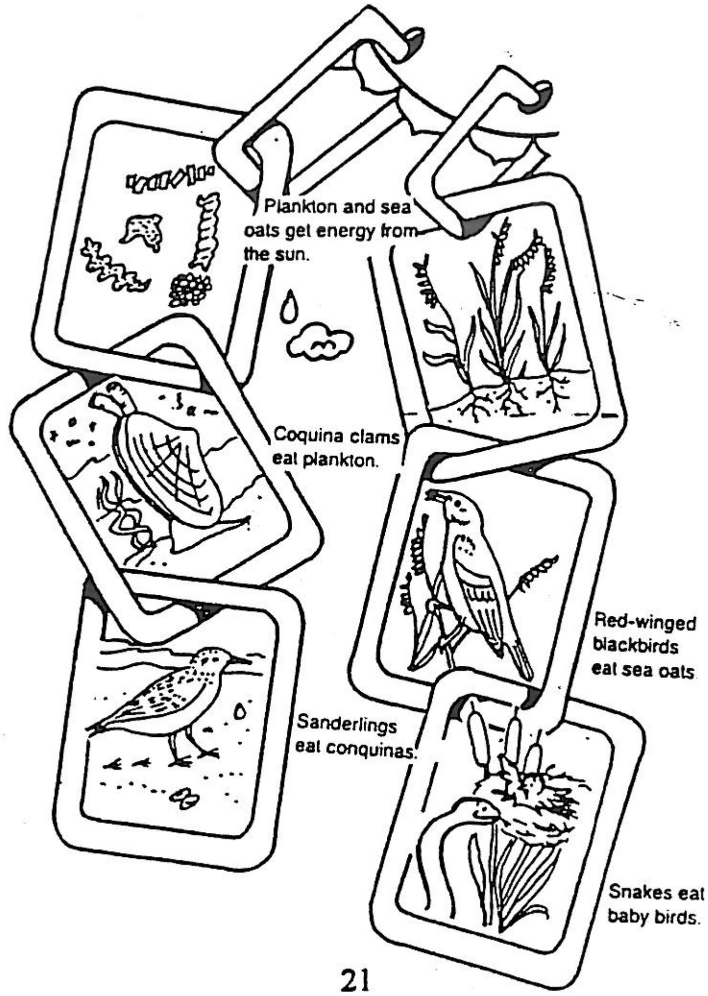


GENERALIZED CIRCULATION IN AN ESTUARY

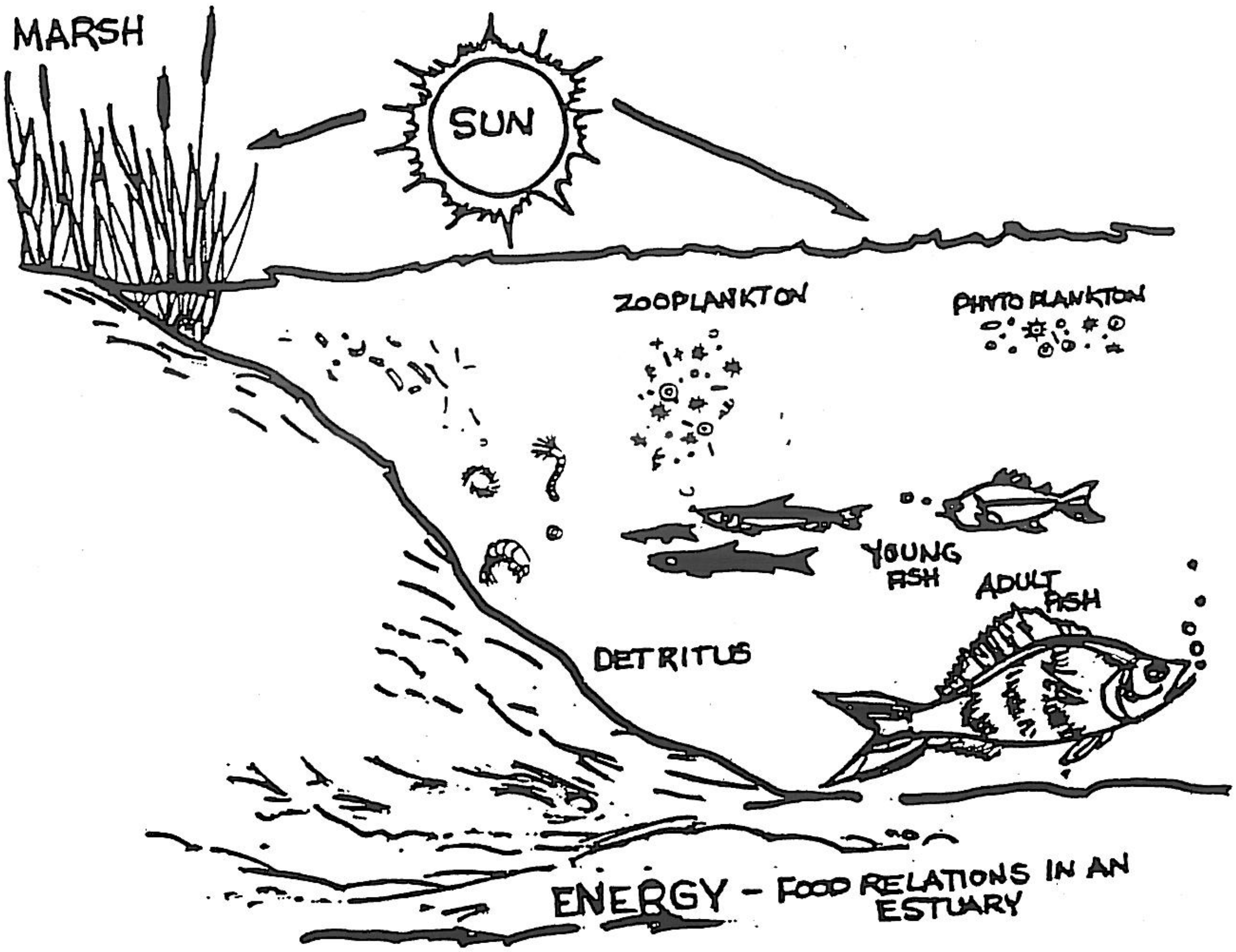
The food chains in estuaries include two distinct populations of primary producers -- phytoplankton and rooted aquatic plants at the edges of the estuary. The abundant zooplankton present include larvae of most of the organisms that live in the estuary. The behavioral patterns of many species of zooplankton 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.

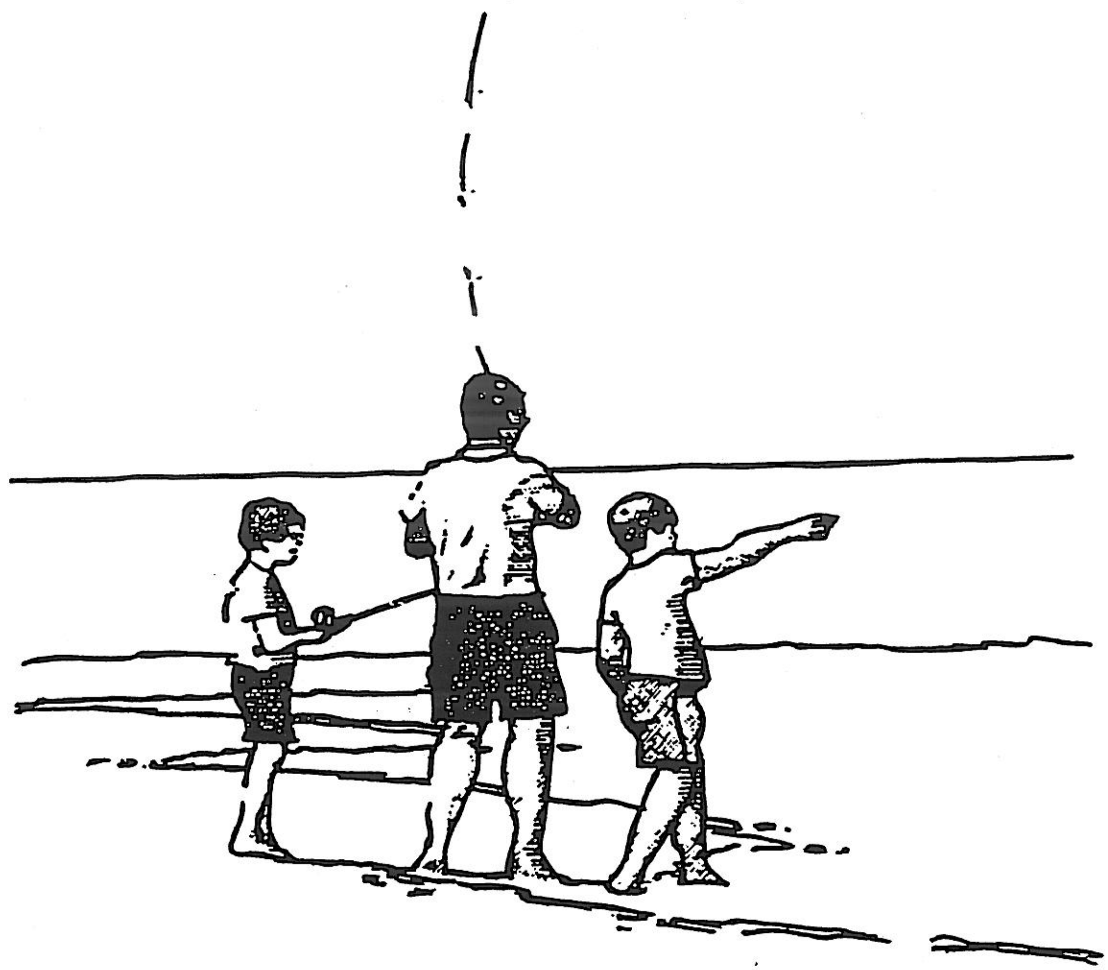


Some populations of striped bass spawn near the interface of fresh and low-salinity water, others move farther into the rivers, and some populations are even adapted to fresh water. In an estuary, eggs and larvae drift downstream.

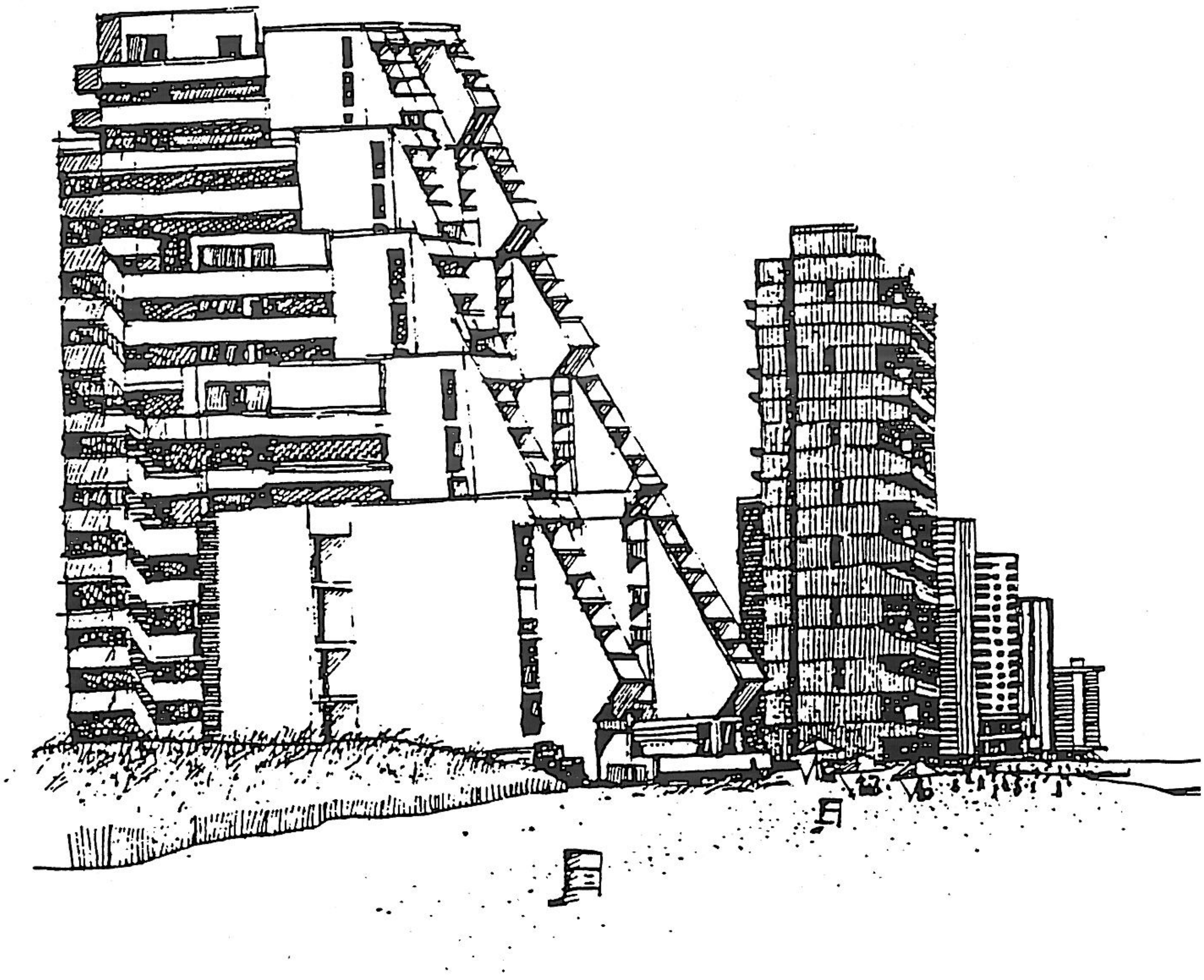


The developing fish feed throughout the system until they are adults and the cycle begins again. Anadromous fish, such as the shad or salmon, spend their adult lives in the open ocean but return to fresh water to breed.

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, bulrushes, 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.

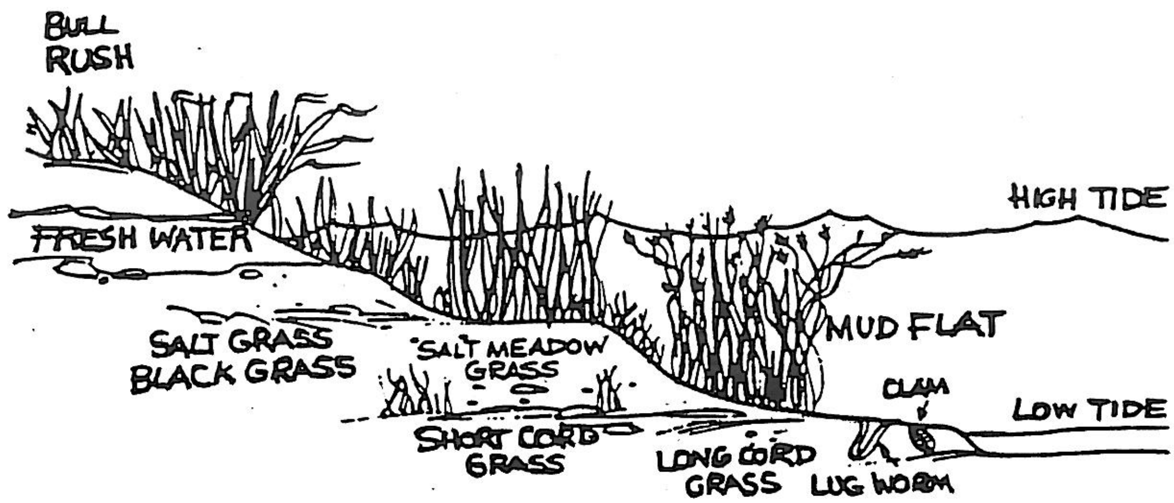
Marshes at the mouths of estuaries, usually found in the lee of coastal spits, are the next most maritime of the salt marshes. The coarse-grained soils of these marshes are subject to stronger saline influence than those of marshes further up the estuary.

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.

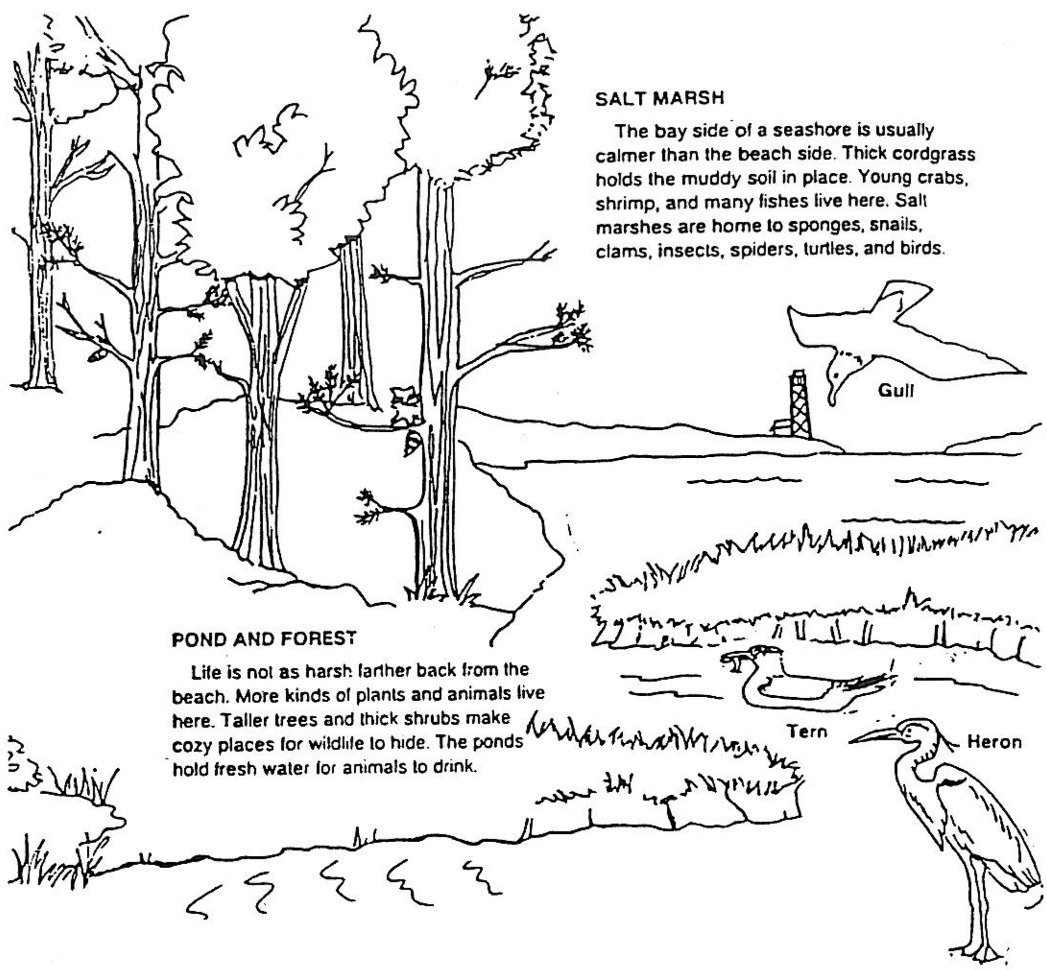
Grasses are the most prominent plants in salt marshes. Cord grass in a long and a short form, is the grass most likely to live in marsh areas covered by water at high tides. Other salt- tolerant plants and plants tolerant to salt spray make up the upper edges of the marsh and vary with the locality.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



A TYPICAL SALT MARSH

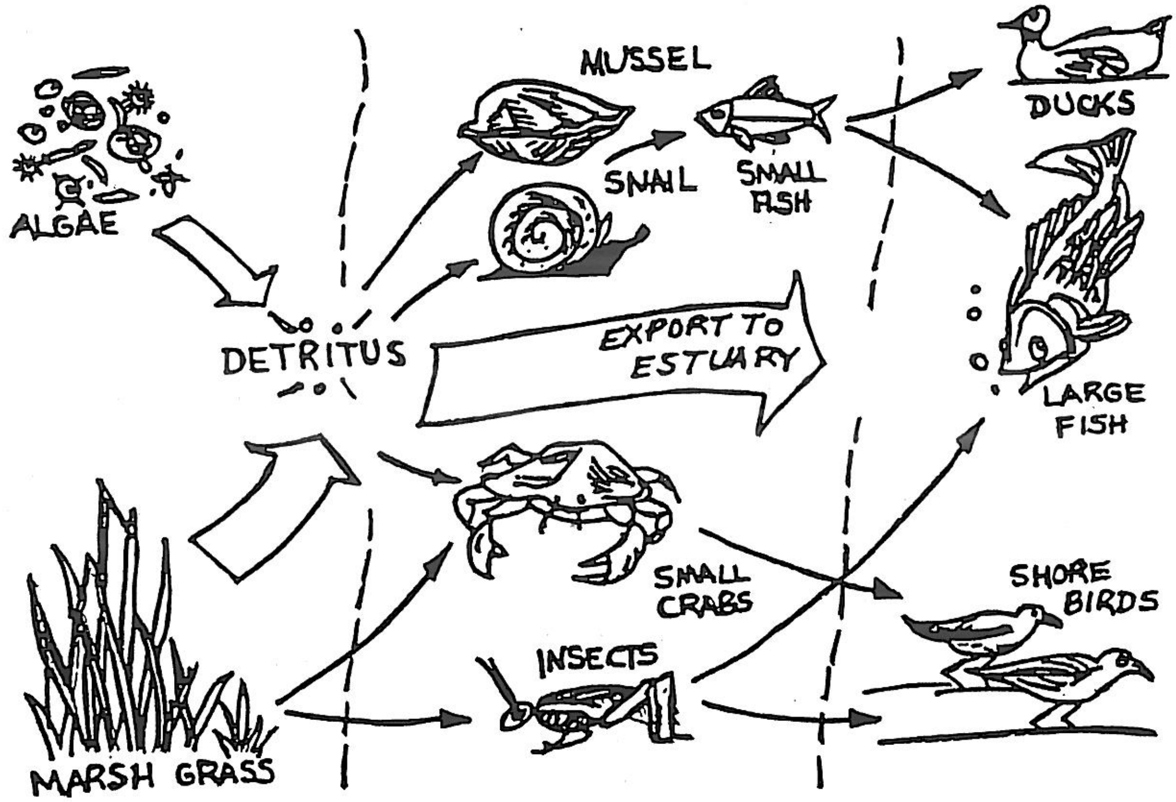
Fish come in with the tide to feed on the abundant small forms of life that occupy the marshes. Birds are prevalent in marshy areas. Some, such as the marsh wrens, swallows, ducks, geese, herons, and rails nest in or around marshes and get most of their food from them. Mammals such as raccoons, mice, 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 photo-synthesis.



FOOD CHAIN

The food chain of nature is complex. Each step up the chain involves 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. People are at the top of the 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

COASTAL ZONE AWARENESS ACTIVITIES FOR ELEMENTARY STUDENTS

The activities included were chosen because they will provide students first-hand experiences with natural phenomena. Such experiences are the basis for learning -- they are thought-provoking and provide ideas to share through speech and writing. Students may even wish to seek out books or other secondary sources of information that will add to their own findings. The purpose of these suggestions is not to have children learn all about coasts but rather to provide an experiential background that will be the basis for a lifelong interest in coastal processes.

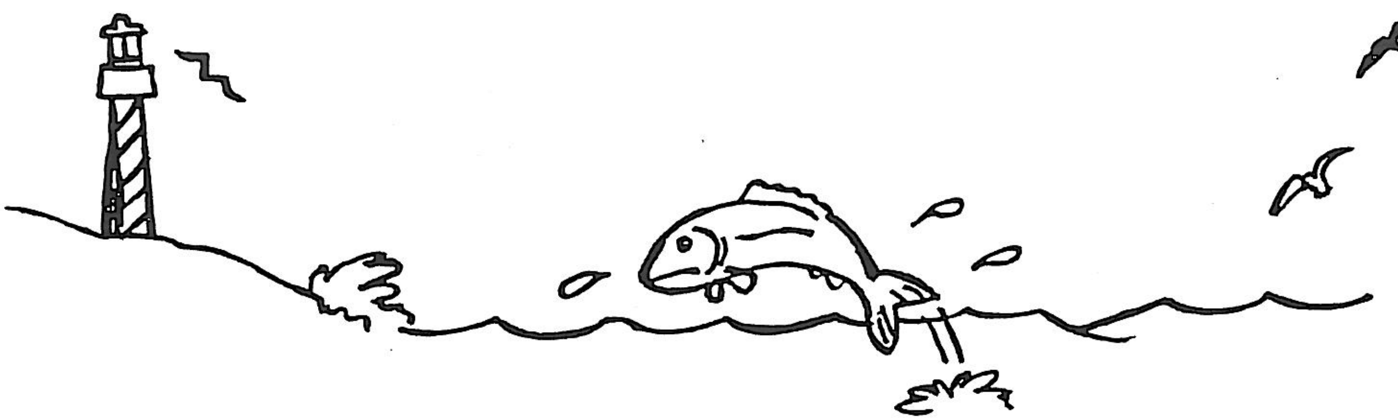
When visiting a beach or shore students should be encouraged in a positive way to leave the area in the same shape they found it. When any microhabitat, such as a rock or log, is moved, it should be replaced as it was found. If organisms are living under it they may depend on that object for survival. Children should be helped to understand why they should not collect living things but only observe them.

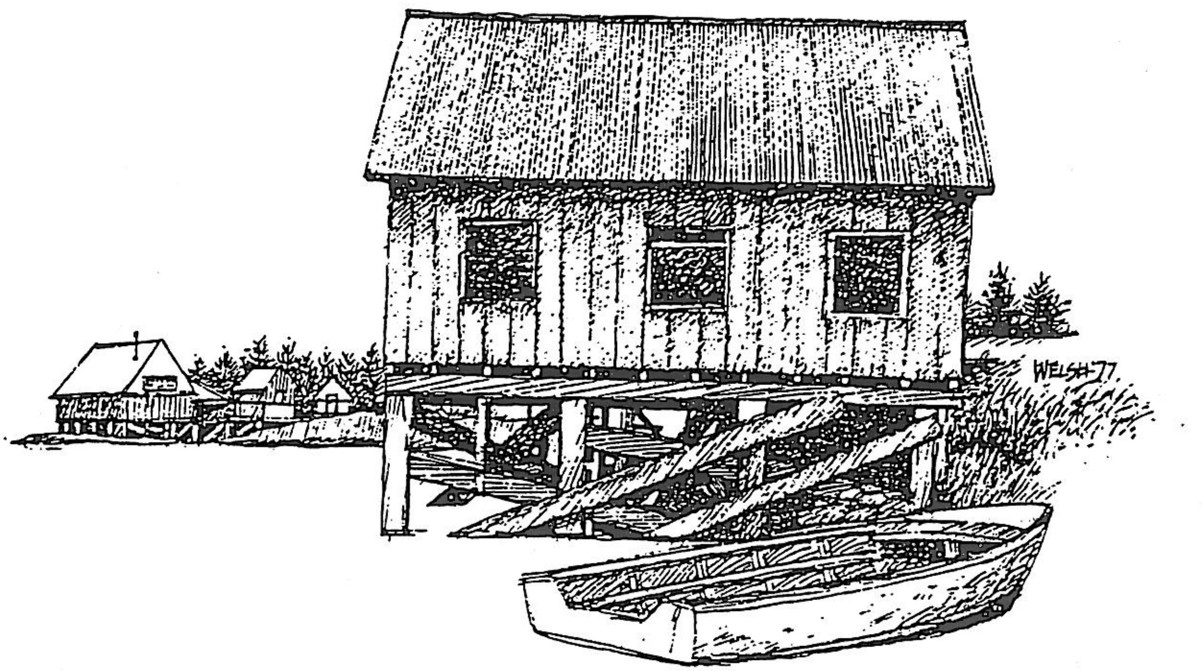
What FLOATS?

Have children collect natural objects along the shore, put them in water, and observe whether they float or sink. They should try as many different kinds of substances as they wish but should also experiment with different shapes of the same substance. The more such experiments each child attempts, the better the experience will be. In a group discussion after the experiments see if the children can develop some generalizations about floating and sinking. Avoid summarizing their experiences for them since this would probably not significantly add to their long-term learning. Have students who cannot visit the coast collect and bring objects to the classroom and substitute containers of water for the coastline.

FRESH WATER OR SALT?

In the classroom students can discover some of the differences between the properties of fresh and salt water. Some or all of the following manipulations can be included. Compare the level at which different objects float in fresh and salt water and the time it takes them to sink. Place a drop of colored fresh water in a container of fresh water and a drop of colored fresh water in a container of sea water. Observe and discuss the difference in the results.





AT THE BEACH

At the coast there are many things for children to do. They should close their eyes and listen to the sounds waves make as they break on the beach. Do they make the same sounds on sandy beaches and rocky beaches? Do the waves sound near or far away. Have the children describe what sea air smells like. How far away from the beach can they smell it? They can look for bird footprints in the sand. Are there more tracks near the water's edge or farther up on the beach? Can they guess the size of the bird that made each kind of print? Let the children make a drawing of a bird footprint or help them make plaster casts of bird footprints to take home. In a class discussion period make a list of the different kinds of birds the children saw at the beach. See if they can remember and mimic the kinds of sounds each one made. Help the children make a plant collection of the different kinds of water plants they found washed up on the open beach. What is the biggest one they found? The smallest? Where do they think they came from?

Using Tide Tables

Please 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 lowest 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
Day of Week	TH	0906	5.6		(2 high tides and
		1524	-0.4		2 low tides)
		2136	4.4		

The time is based on the 24 hour 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 that 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
		4.0
18	0406	0.0
SU	1042	5.2
	1706	0.1
	2312	3.7
19	0454	0.3
MO	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 commercial 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 freshwater, 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 degrees C. At every 5 degree 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:

Wave length = velocity x period cm = cm/s x s

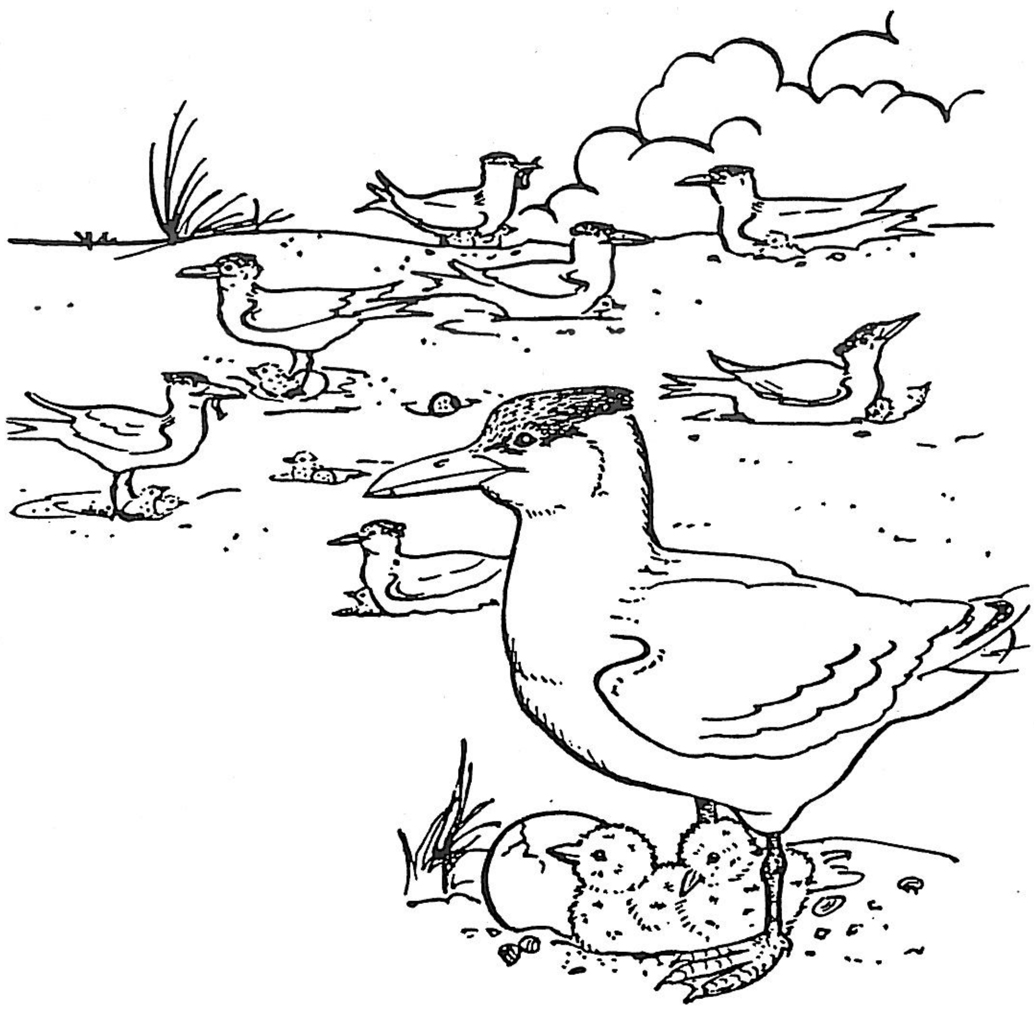
Measuring Turbidity

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 turbidimeter.

Shine a light through the wood onto the surface of the photo cell. Set the selector of the VOM on R x 1, Q, 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 Q or R scale, use semi-log pacer.

Bird Prints and Behavior

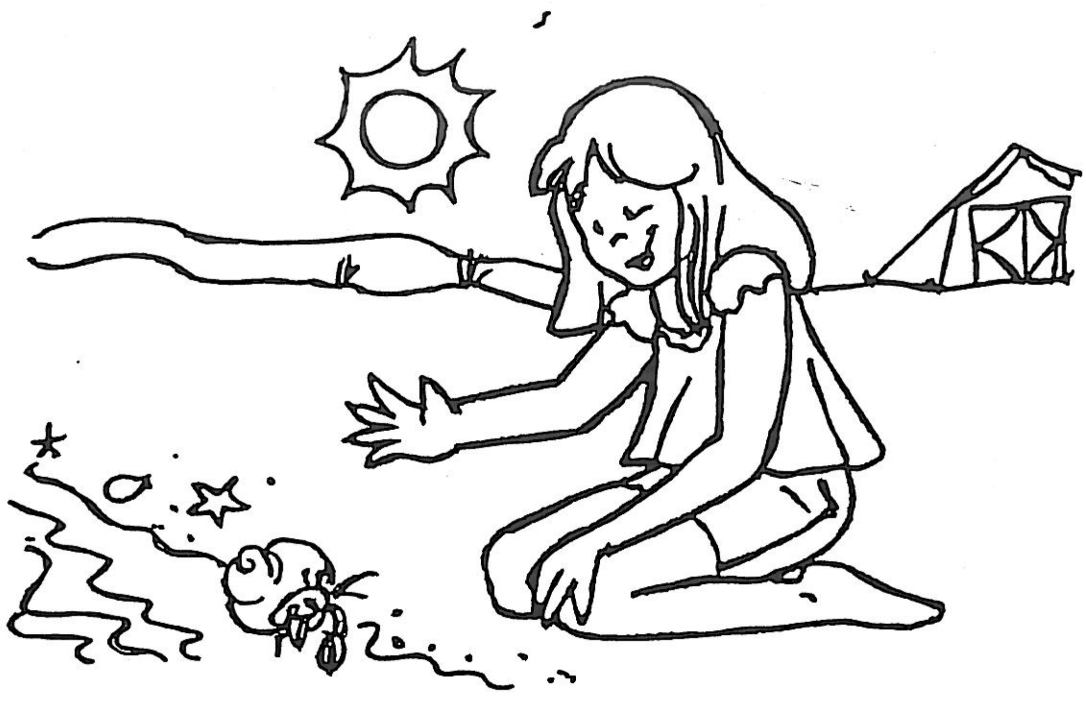
Walk along a sandy beach looking for the footprints of birds. On an ocean beach this is most productive on a receding tide. Make sketches or plaster of paris casts of the footprints. Take your sketches to the classroom and see if you can find out what kinds of birds made the prints.

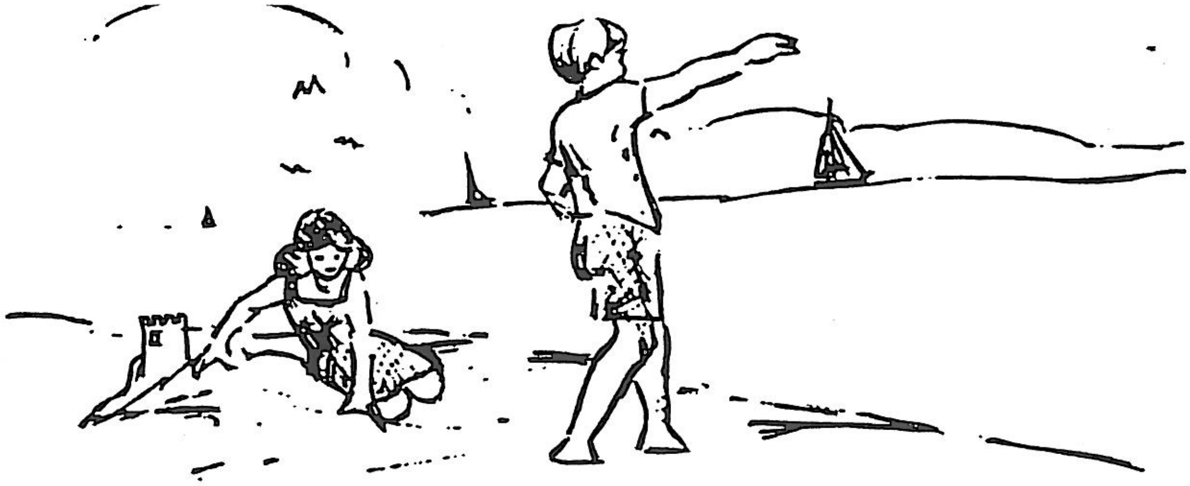


COASTAL AWARENESS ACTIVITIES FOR MIDDLE AND JUNIOR HIGH SCHOOL STUDENTS

Two elements are common to all activities suggested in this collection: each requires a concrete experience as a basis for learning, and each requires an action on the part of the learner. A range of activities is offered: some must be pursued at the seashore, others in fresh water environments, and still others in the classroom. Teachers are encouraged to offer the widest possible selection of activities to their students. Since some of these activities involve children working at or near the water's edge, students must be instructed in how to behave in these potentially dangerous coastal areas. They must be instructed not only for their own safety but for the protection of the environment.

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





Beach Art

Make a sculpture or another art form from litter you collect at the beach. Take a picture of it to display in the classroom or at home. How should you dispose of your art work?

Measuring Sand Dunes

Make a clinometer (an instrument used to determine inclination or slope) by gluing a soda straw along the straight edge of a protractor and attaching a weighted string to the zero mark in the middle on the straight edge of the protractor. You also will need a stick that comes up to your eye level from the ground. Plant the stick at the top of a dune. From the bottom of the dune, sight through the straw to the top of your stick (the curve of the protractor will be on the underside of the straw). Note the angle of the string hanging down over the curved side of the protractor. Subtract this number from 90 degrees (vertical) to find the angle of the dune. Measure the front and back angles of the dune. Which is the steeper? Which would slide more easily? Can you pile sand from that dune at a steeper angle than the back slope?

Ideas for Coastal Observations

Visit a rocky beach at low tide. Take along pieces of fresh shrimp or fish and feed small crabs or anemones; describe how they respond. How many other kinds of living things can you see in the tidal pool?

At low tide, put some mud from a tidal flat on a piece of window screen and wash it gently with water. Describe what you see. Look at some dock pilings while the tide is still out. How is the part that is covered at high tide different from the continuously exposed part? Describe any living things you see on the piling.

Put a stick in the sand where you think the high tide will just reach it but not wash it away. Watch to see what happens.

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
and Day of Week		0906	5.6	(2 high tides
	TH	1524	-0.4	2 low tides)
		2136	4.4	

The time is based on the 24 hour 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 that 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
		4.0
18	0406	0.0
SU	1042	5.2
	1706	0.1
	2312	3.7
19	0454	0.3
MO	1136	4.9
	1800	0.4
20	0006	3.4
TU	0548	0.6
	1230	4.5
	1900	0.7

Using the information on the previous page answer the following questions.

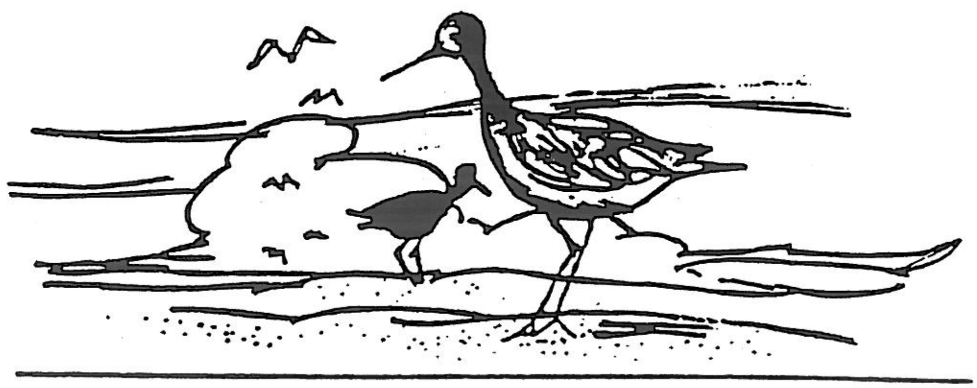
1. What day of the week will have the highest tide?

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?

Have the children try to make a sand castle that the waves cannot wash away, using materials from the beach to make it as strong as possible. Ask them to describe what a wave does to the hole they dug in the sand.



Make a "Treasure Chest" of things the students found on the beach. See if they can guess where each kind of treasure came from -- and how? Make a classroom display of the treasures collected at the beach. Invite other classes to view the collection.

Take the class to visit a rocky beach at low tide. Have pieces of shrimp or fish to feed pieces of food to small crabs or anemones and ask the children to describe how they responded. How many other kinds of living things did they see in the tidal pool?

In the classroom have the students put some sand and some soil in a container of water and stir it. Let the sand and soil settle and then ask them to describe which is on top and which is on the bottom. Have them do it again and compare the results. Ask them why they think layering occurs. Take the class on a walk along the edge of a marsh. In the classroom discuss and list the kinds of birds they saw and heard. How does this list compare with the list they made after their visit to the beach?

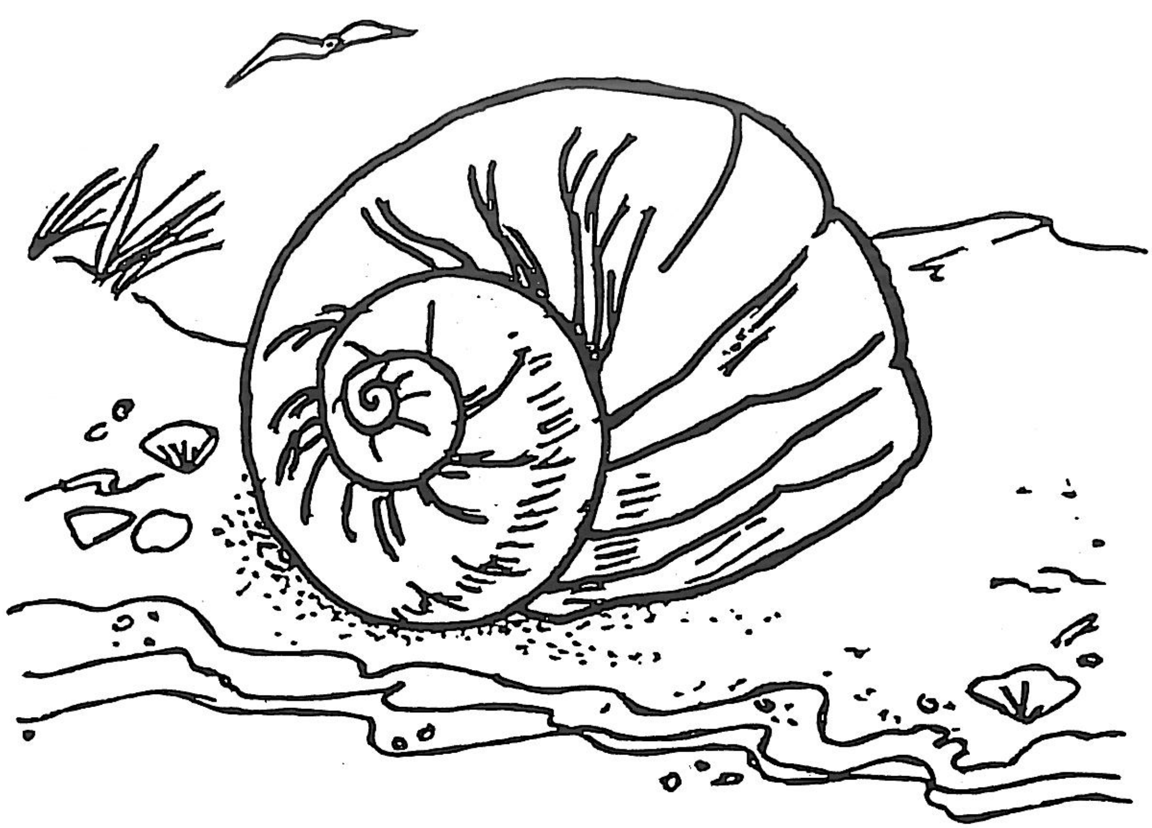
At low tide, have the children put some mud from a tidal flat on a piece of window screen and wash it gently with water. Have them describe what remains on the screen. Have them look at dock pilings while the tide is still out. How is the part that is covered at high tide different from the part exposed at low tide? Have them describe any living things they see on the pilings.

At low tide make a map of a small section of coastline. Include rocks, curves in the beach, and the location of logs and other things that are lying on the beach. Make another map of the same place at high tide. Compare the maps.

Have the students put a stick in the sand where they think the high tide will just reach it but not wash it away. Watch to see what happens. Can they make a more accurate guess the next time? In the classroom, put some brine shrimp eggs in fresh water and some in salt water and have the children observe the containers for a few days. Ask them where they think brine shrimp live. Let them use a microscope to observe the brine shrimp when they start to swim.

Take the class on a trip to a local market. How many kinds of coastal organisms are for sale? How many people handled them before they reached the store?

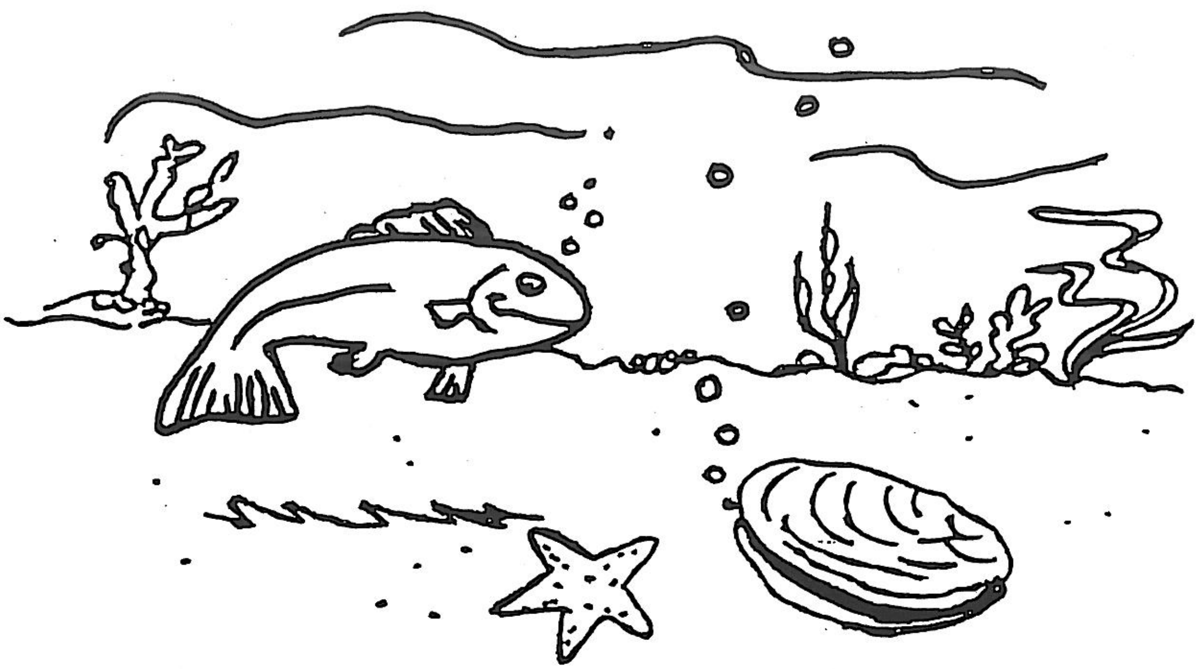
Have the children put a rock in the sand just below where the waves are washing up on the beach. (Do this only if the waves are small and not dangerous.) After each wave goes out have them look at the sand around the rock and describe what is happening. Have the class observe the groups of small birds that peck the sand just above the wave line. Have them discuss whether the group has a leader, what the birds are pecking and how they avoid getting wet.



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.

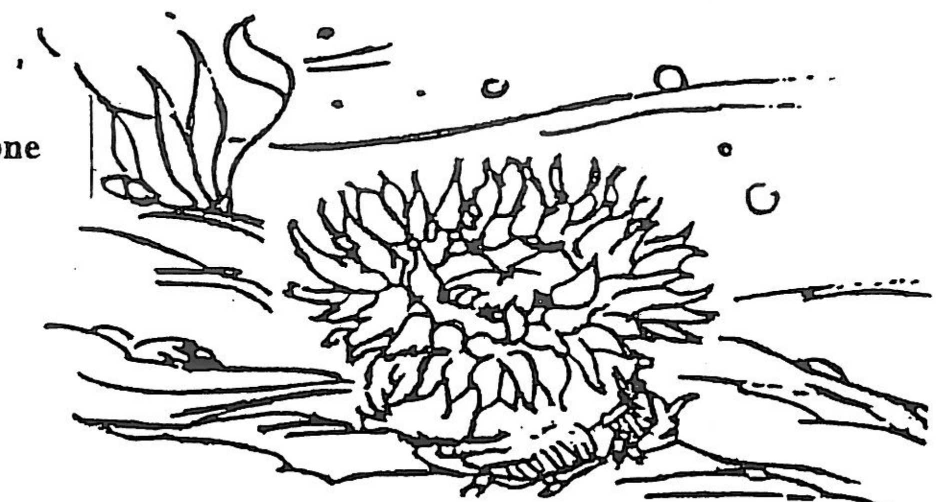


Anemone Behavior

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 shoe box 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. 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.

Sea Anemone



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 seashore 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
and Day of Week		0906	5.6	(2 high tides
	TH	1524	-0.4	2 low tides)
		2136	4.4	

The time is based on the 24 hour 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 that 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
		4.0
18	0406	0.0
SU	1042	5.2
	1706	0.1
	2312	3.7
19	0454	0.3
MO	1136	4.9
	1800	0.4
20	0006	3.4
TU	0548	0.6
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1. What day of the week will have the highest tide?

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4. Using the 12 hour clock what is the best time to visit the beach on Sunday during high tide? At high tide make a map of a small section of coastline. Put in rocks, curves in the beach, and the location of logs and other things that are lying on the beach. Make another map of the same place at low tide. Compare your maps. Put a rock in the sand just below where the waves are washing up on the beach. Do this only if the waves are small and not dangerous. After each wave goes out look at the sand around your rock and describe what is happening.

Beach Currents

Is there a beach current? You can often determine the direction of beach currents by observing the direction taken by floating objects thrown into the surf. Brightly colored objects--balls or balloons partially filled with water--make good objects to observe.

Do the currents along your beach run parallel to the coast? Are they influenced by curving coast lines or headlands? Can you measure the rate at which the current is moving? Mark off in the sand 50 or 100 steps and time how long it takes your object to move that distance.

Sand in Motion (Erosion)

Which way is the sand moving? Plant a stake in the sand midway between the highest wave mark and the low point of wave recession. Does sand accumulate on one side of the stake? Is it washed out from another side? Can you decide in which direction sand is being moved?

Measuring Tidal Change

Mark a stake in centimeter intervals, and when you arrive at the beach drive it into the sand so that the water covers the lower part of the stake after the waves have receded. Watch the water level on the stake. Is the tide coming in or going out? Can you measure the vertical distance (up the stake) traveled by the water during your stay at the beach?

Oil Spills

How would a small oil spill affect your coast? You can use non- polluting material to represent drops of oil. Pick a dock or some prominence that extends out into the water as the place to have your "oil spill."

Throw your simulated oil drops (leaves, shavings, or sawdust) into the water and watch what happens. What factors determine where your spill reaches the coast? How big an area is affected? Which animals and plants collect the most "oil"? How would your oil spill affect recreation in your area?

Measuring Wind Erosion

Coat the top 10 cm of the sides of a short, square post (a four by four will work) with petroleum jelly. Sink the post into a section of sandy beach. Observe the post after 24 hours. On which side is the sand the highest? In which direction was the sand moving? What was happening to the beach--was it being built up or eroded? Does this pattern change from high tide to low tide, from day to day? What is the most sand that will collect by the post in one day?

Prints of Aquatic Plants

Buy some ozalid paper from a store that handles drafting supplies. It comes in a roll and you will have to cut it to the size you want in a dark room. Using glass, a piece of cardboard the same size as the glass, and masking tape to hold them together on one side, make a frame for exposing the paper. Then cut pieces of Ozalid paper to fit in the frame. Place a plant (or feather, or other material you collected from the beach) between the glass and the sensitive side of a piece of the paper. Press the cardboard against the paper, and hold the glass toward the sun. Red paper will take about 15-25 seconds of exposure, blue paper about 20-35 seconds, and black about 40-50 seconds. You may have to experiment to get the proper timing.

Remove the Ozalid paper from the frame in a shaded place. Roll into a cylinder, put it in a large jar containing a small open jar of concentrated ammonia, and cover the top of the large jar. The fumes from the ammonia will develop the print in 3 or 4 minutes. If prints are too pale, they were not exposed to fumes long enough; dark, heavy prints indicate excessive exposure. Use a fresh supply of ammonia each time you print; concentrated ammonia usually is available at drug stores. Household ammonia is not concentrated enough. Do not inhale the fumes from the jar.

Observing Barnacles

Take a plastic shoe box or similar container with you to a rocky seashore. Find a rock that has barnacles on it that will fit in your container. Cover the barnacles with sea water, sit back, and watch what happens.

What is the function of the four plates on the front of the barnacle? When the barnacle opens, what comes out? Make a shadow across the top of an open barnacle. What happens? What happens when you put a few drops of fluid from a crushed clam or piece of fish near an open barnacle? When you have finished, carefully put your barnacle rock back where you found it.

Watching Aquatic Organisms With a Look Box

A "look box" will allow you to look into the water, on the bottom, and to see things not easily seen from above the water. To make your look box, remove both ends from a large (#10) can, and tape clear plastic wrap across the openings, or use your imagination to design your own kind of look box. Bring extra plastic wrap and tape with you to the coast in case your box is damaged. The secret to seeing with such a box is to move slowly and carefully, and to be patient.

How many kinds of moving animals can you see? How many are attached? Are the fish in the open or hidden? What kinds of plants do you see, and are they just in some places or everywhere? Make a sketch of the things in the small area you are observing.

Hermit Crab Houses

Do hermit crabs on the coast near you prefer to live in particular kinds of shells? Take several containers with you to a section of the coast where hermit crabs live. Pick a single tidal pool and carefully pick up all the hermit crabs you can find. Sort them into containers by the kind of shell they have. You don't need to know the kinds of shell--only how they look. Count the number of crabs in each container and then release them.

Is one kind of shell preferred? Survey another pool to see if the choices are the same. Make a chart showing the shape of the shells and the numbers of crabs in each. Can you identify the kinds of shells used most often?

Populations on Pilings

Is there a pattern to the way animals and plants grow on pilings in salt-water estuaries? Find a place where you can examine the underwater portion of several pilings during low tide; the lowest tide is the best time. Carefully observe and record the kinds of organisms present on one piling and the vertical space they occupy--that is, which organisms are highest on the piling, which the next highest, and so on. Then examine one or two other pilings. What are the common characteristics with respect to distribution of living things on the pilings? What are the differences? What do you think affects the distribution of these living things?

Bird Behavior

Find a comfortable place to sit along the coast in an area where you can see more than one kind of bird. Watch the groups of small birds that are pecking in the sand just above the wave line. How do they keep from getting wet? Does the group have a leader? What are they pecking at? Can you find out? Watch one member of a particular species of bird for ten minutes or so. Look for and record the following kinds of things about that bird: the kind of bird; how it holds its body when it walks (horizontal, upright, in between); its gait (hop, run, or waddle); grooming (does it groom its feathers? How?).

Also note whether it raises its tail when it lands; whether it flies in a straight line, undulates (up and down), glides, soars, or flaps; and whether its wing beats are fast or slow. Does it get its feet wet, land on water, or land on bushes or trees? Observe several kinds of birds in this way and make a chart of your records to show the differences and similarities among the birds you watched.

Visit two or more types of coastal areas, such as a marsh and a rocky beach. What kinds of birds are found in each? Where are there more perching birds, wading birds, or swimmers? Identify as many of these birds as you can. Visit these places during more than one season. Do the kinds of birds present in each change with changing seasons?

Poke Pole Fish Survey

What kinds of fish live in rocky intertidal areas? You can find out what some of them are by going fishing with a poke pole. Make your poke pole from a 2-3 m (6-10 ft) pole of bamboo or some other material. Tape about 30 cm (12 in.) of heavy wire with a size 2 or 4 fishhook on the end of the pole; 15 cm (about 6 in.) of wire is attached to the pole and 15 cm hangs out, with the hook on the end. File the barb from the hook so that you can easily release fish without damaging them. This kind of fishing should be done at low tide, but if there are large waves you should stay away from the edge of the water. Bait the hook with mussel, shrimp, or pieces of other marine animals. Fish by putting the pole into deep pools or crevices in the rock. Try many pools; keep a record of the kinds of fish you catch and where you caught them. You should be able to release most of your catch unharmed--unless of course you are very hungry.

What Kind of Organism Was It?

Walk along the beach soon after high tide. Make a collection of the fragments of what were once living things. Examine each fragment very carefully. Try to answer some of the following questions about each one: Was it a plant or animal? What did it look like when it was living? How big was it? Where did it live? How did it get to where you found it on your beach? Can you trace the path it took?

Life on a Rocky Beach

Visit the beach at low tide, and take with you pictures or descriptions of plants and animals that are commonly found in that area. What kinds of organisms are most common high up on the shore, but within the tidal zone--plants or animals? What kinds of organisms are most common in the lowest level exposed by the receding tide? How would you name these areas if you used the prevalent organisms to identify each zone? Which organisms are best adapted to live for the longest period of time in the air? Are there more water plants in the higher or the lower zone?

Aquatic Coastal Inhabitants

Several students should cooperate in this project. Any coastal area that is occupied by visible inhabitants is suitable. Select a length of coast that can be easily examined in the time available. Use graph paper to help you sketch the coast before you begin the survey. Each time you find an organism, observe and examine it. Record its description (in words and/or pictures) along with the depth of the water where you found it or its location on the beach.

Beach Hoppers

If you were a beach hopper how far could you hop? To find the answer to this question measure your length (height), the length of a beach hopper, and the distance a beach hopper hops. Substitute these data in this equation: your height divided by x will equal the length of hopper divided by the distance that the hopper hops.

Clams

If you live near a sand or mud flat in an estuary, you can dig clams. You will need a shovel or trowel and a bucket without a bottom. Go to the flats and find the likely places to look for clams in your area, using clam siphon holes as indicators of good places to dig. First jump or bang on the surface of the flat so the clams will draw in their siphons; this way you will be less likely to injure any of them. Dig around a siphon hole but not too close to it to avoid breaking the clam's shell. When your hole starts to cave in, put your bucket in it so that the siphon hole is near the center and the bucket is buried almost to the rim. Dig with your hands now. When you locate a clam, loosen it carefully before you attempt to lift it out. (You may wish to wear gloves to protect your hands from broken shells and glass.) Remember to rebury each clam in the hole from which you took it. Now that you know and have followed the procedure for locating clams, see if you can answer the following questions: How far up the beach do clams live?

Can you predict the size or kind of clam from the size of its siphon hole?

Do little clams live closer to the surface than large ones? How many kinds of clams live in this tidal area? Do clams live alone or in groups? Remember to put each clam back in the hole where you found it. Be careful to leave an air hole.

"Rubbing It In"

Many weathered objects on beaches have attractive and complicated patterns. Use plain paper and crayons or charcoal pencil to make rubbings from weathered boards or ends of pilings.

Coastal Classroom Ideas

In the classroom, put some brine shrimp eggs in fresh water and some in salt water and watch the containers for a few days. Where do you think brine shrimp might live? Watch under the microscope as your brine shrimp swim. Make a trip to a nearby market. How many kinds of coastal organisms are for sale? How many people handled them before they reached the store?

In the classroom, put some sand and some soil in a glass container with water and stir the mixture. Let the sand and soil settle, then describe which layer is on top and which is on the bottom. Collect mud and sand from a marsh, beach, or river. Put sand and mud in a glass container with water, mix it, and let it settle. How many layers can you see? How are they different? What do you think causes this layering?

Carefully pour or siphon off the water. Examine a sample of each layer under the microscope. Describe and compare the particles. Are they dark or light, rough or smooth, sharp, thick or thin? How do mud particles differ from sand particles? Where do you think each might have originated? How do you think they got to where you collected them?

Make a Hydrometer

Take a stick (or pencil) and tie a weight such as a metal washer to one end, or screw a sharpened pencil into a metal nut. Place this "hydrometer" in a large container of fresh water. Mark the water line on the stick. Now repeat this experiment in a container of salt water. Is the water line on the stick different in salty and fresh water? What do you think causes the difference in the water line on the stick? Have a friend make a measured salt water solution. Now, try to guess the salinity of this solution.

How could you mark (calibrate) your hydrometer for a solution that is one-third as salty as sea water? A solution one-half as salty?

Density of Water

Which is more dense, salt or fresh water? Completely fill two containers (such as baby food jars of the same size) with water. Do not place lids on the jars. To one jar, add a drop of food coloring and one half teaspoonful of salt. Mix well. Cover the top of the salt water container with a piece of cardboard. Invert the jar and place it directly over the top of the fresh water container so that the openings are aligned and separated only by the cardboard. Now, carefully slide out the cardboard. Observe and record the movements of the colored water. Repeat the experiment, this time putting the food coloring in the fresh water and placing the fresh water container on top of the salt water container. Try it sideways too. What do you think happens when fresh river water flows into a salty ocean?

Salt in Rivers

To learn how to measure salinity in the classroom, carefully measure exactly 100 ml of sea water into a pyrex container. Weigh the container and the water. Evaporate the water.

Now weigh the contents and the container again. Subtract your second measurement from the first. Multiply the difference in weight by ten (to adjust the volume from 100 ml to 1,000 ml). This will give the salinity of your sample in parts of salt per thousand parts of water (%).

Teachers with a marine aquarium can allow students to use the aquarium water as "seawater" if they cannot get to the ocean. Alternatively, several samples of salt water of various concentrations can be set up by the teachers, and the students can determine which one is closest in salinity to sea water. Next, visit a salty river. How far up the river is the water salty? In the classroom, using a hydrometer (available at tropical fish stores), establish baseline readings for fresh water and for salt water (30% salt in water). Then, take a trip to a tidal river. Make a series of readings up the river from the ocean to see if you can find out how far up the river the water is salty. Consider the following questions: Does high or low tide make a difference in your readings? Can you tell when the water is one-half as salty as sea water? Does the depth at which you take the reading make a difference? How much of seawater is salt?

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 arachnids insects, and crustaceans

Barrier islands:
Low off shore 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 island 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, from islands or ridges near the surface of the sea in tropical areas (found only in Florida and Hawaii in the United Sates)

Crustacean:
Any mostly aquatic arthropod, typically with a hard shell covering the body; includes lobsters, shrimps, crab, 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 are 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'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

Tropic:
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