The Sandy Beach Habitat

Seashore habitats vary greatly, from mudflats to gentle, wave-lapped protected beaches to headlands exposed to the pounding fury of storms. Some are places of oozing mud, some are solid rock, and some are made of shifting sand. Along the shores, animals, algae, and plants have traits that allow them to survive in those specific conditions. Some shores, especially mudflats, are among the most productive and prolific environments on Earth. Others, especially rocky shores, are among the most diverse. But the shore most often pictured in the mind's eye, the wind-swept sandy beach, is the closest that the seashore comes to being a desert.

The sandy beach is a harsh physical environment. The sand shifts. There isn't much food produced at the beach. Waves crash. The *tide* rises and falls. The sandy beach begins underwater in the *subtidal* region, continues up through the crashing waves of the *surf zone*, into the *swash zone* where the waves cover and uncover the sand regularly up to the high tide line, and extends to the cliff or ssand dunes that border the sandy beach. Specialized animals inhabit this turbulent and varied habitat. This unit will cover the physical habitat and the biological community of the sandy beach specific to the Gulf of the Farallones National Marine Sanctuary (NMS). The Sanctuary protects and manages the sandy beach up to the mean high tide line.

Waves

Ocean waves are created by the force of the wind blowing across the surface of the water. The size of waves reaching the shore is determined by how fast the wind blows, over how long a time and distance it blows (called *fetch*), and from what direction it crosses the shore. Though wind speeds are not significantly different on the Atlantic and Pacific coasts of North America, the fetch, prevailing wind direction, and track of the storms towards the shore combine to create the highest energy beaches along the Pacific coast.

Sandy beaches exposed to high-energy, crashing waves are nearly uninhabitable, but given any amount of protection the number of organisms able to make a living there greatly increases. There are several ways that beaches can gain protection from ocean waves. Offshore islands, sand bars, and kelp beds all act to deflect and dampen the power of waves approaching the shore. Such protected beaches typically have smaller waves, more *organic* material mixed in with the sand, and more organisms living there. In the Gulf of the Farallones NMS, the beaches range from sand only to sand with cobbles or boulders, backed by bluffs or sand dunes.

Prevailing sea conditions are reflected in the appearance of the beach. Its slope and size of sand particles indicate the power of the waves that strike it. Steep slopes and coarser grains mean big waves. The high-energy beach is cleaned of the fine sediment, because water with higher velocity carries away small sediment. Wide, gradually sloped beaches have finer sand grains and smaller surf. The low-energy beach allows more organic material to accumulate and finer grains to hold more water in the sand at low tide. The lower velocity water cannot hold the sediment and deposits the sediment along the shore. Beaches change appearance with the season. Bigger waves of the winter storms pull sand offshore to form bars, leaving behind only the larger gravel or cobble. When the gentler seas of summer return, sand is redeposited on the beach, and the offshore bars diminish.

It has been estimated that the energy contained in an average wave front approaching a beach is equivalent to a line of automobiles, side by side, revving their engines at full throttle. There is little wonder that the size and character of waves are the primary physical feature that determines how beaches look and what lives on them. For example, the shape of the shell of clams and crabs reflects the pounding surf.

Sand

Quartz is the most common mineral on Earth. It is found in most types of rocks, and it is nearly insoluble in water. Not surprisingly, it is the most common constituent of sandy beaches. The sandy beach is composed of many other minerals as well, each with slightly different densities and colors. Sand is sorted across the beach by wind and waves which create distinct and intricate bands in the sand. Indeed, nearly every solid material on Earth, whether from non-living sources (abiogenic), such as rocks, or from living organisms (biogenic), such as shells and corals, is worked into sand. The beaches of New England are still transporting and sorting the sediment from the glaciers that retreated thousands of years ago. In volcanically active areas like Hawaii, the beaches may be dark black; the sands are the eroded remains of lava flows. In Florida, the white debris of coral reefs and calcium-shelled microorganisms are the most significant contributor to the sand.

Though sands may be produced right at the shore where waves crash against headlands and reefs, the great bulk of the beach sand around the world comes from the interior of the continents. As mountains are weathered, their fragments are brought down rivers and eventually deposited where the river currents slow down abruptly after emptying into the ocean. The sandy beaches of the Gulf of the Farallones NMS are made up of sediment weathered from terrestrial rocks.

Sediments are classified by particle size. Fine particles barely visible to the eye are called *mud*, particles more than 1/8" across are called *gravel,* and those particles intermediate in size are called *sand.* Where the sediments get deposited depends on the speed of the water carrying them. It takes more energy to carry larger particles. Therefore in very high surf zones, only gravel or cobbles may be left on shore. The smaller particles are easily resuspended and carried away by the water. The smaller particles of mud can only settle in calm water, such as inside bays or well offshore on the deep-sea floor. Wave action prevents their accumulation on open ocean beaches. On most beaches around the world, the energy of waves and currents is such that the average particle size is in that intermediate range called sand.

There may be little visible change in the day-to-day appearance of a sandy beach, but it is always in motion. No grain stays in one place for very long. Each *breaker* lifts millions of grains from one spot and deposits them at another. When the prevailing wave direction strikes the beach at an angle, sand grains are deposited by the receding backwash a short distance down the beach in the direction of the prevailing wind. This is called longshore transport. Though each movement of sand may be small, the overall movement of the sand is large. With an average of 8,000 waves per day and the 0.5 cm lateral movement of a sand grain with one wave, a sand grain is transported 40 meters in a day. Over the course of a year, sands may be moved considerable distances along the coast. If it were possible to watch individual grains, beaches would be seen, not as static geographical features, but as rivers of sand.

Where does the sand go? Most of the sand is transported along the shoreline, although some is moved across the continental shelf. There are deep-sea canyons that cut into the continental shelf along most shorelines. Longshore transport of sand continues until it reaches such a canyon, and then the sand is channeled down the canyon onto the deep-sea floor.

The average sand grain is 2.5 times as dense as seawater, but 2,000 times as dense as air. Consequently, only smaller grains are moved by the wind into dunes above the reach of the waves. Dune sand is noticeably different in appearance than beach sand. Air-borne grains are more rounded from abrasion, and their surface is frosted like old bottles on the beach. Their surfaces show the effects of sand blasting. In sharp contrast to this, sand grains that have only been carried by water are sharp-edged and clear. Each grain is surround by a film of water that clings to it by surface tension. On the beach, even in the midst of crashing surf, this water envelope keeps the grains from rubbing against each other. Wet sand grains are almost indestructible.

The amount of water that can be retained and held by beach sand depends on the size of the sand grains. Finer-grained sand holds more water than coarse-grained sand, but on average sand holds water in a volume equal to its own. That is, an average beach is half water and half sand. For this reason, when the tide is out and the beach is exposed to the Sun, only the upper few centimeters actually dry out. Conditions just a few inches below the surface do not change much in terms of wetness, temperature, or salinity. Even during rains, the flow of freshwater across the beach does not dilute the water held within the sand. Freshwater is less dense than saltwater and remains above it as it flows out to sea. Though the rigors of life are great in the sandy beach environment, as evidenced by the few species adapted to them, there are clear benefits for those animals that have adaptations. Surrounded by sand, they are not subjected to the desiccating stress of sunlight and air that species living on firm, but impenetrable, rocky shores must endure.

Tides

Tides are the periodic rise and fall of the sea level, resulting from the gravitational attraction and motions of the Earth, Moon, and Sun. Although most easily observed at the shoreline, the tidal forces impact the entire Earth. Along the California coast, there are *mixed semidiurnal tides*. Semidiurnal refers to two highs and two lows each tidal day, while mixed means that the heights of the tides during one tidal day are uneven.

The maximum *tidal range* along the coast of the Gulf of the Farallones NMS is about 3 m (9 feet), and the maximum tidal current is about 5 knots. When the Moon and Sun are aligned with the Earth during a new moon or a full moon, their gravitational pulls are combined. The result is more extreme tidal heights. These are called spring tides, and the tides are at its highest and lowest levels. When the Moon and Sun are at right angles with respect to Earth (the first and third quarter moons), the tidal range is the lowest. A tidal day is about one hour longer than the 24-hour day of the Sun, because the Moon revolves around Earth which is rotating. The tides come a little later each day.

Tides can be predicted quite well based on local observations of at least 19 years, the time period that covers most of the major tide-generating configurations of the Earth-Moon system. Once the tides are formed by the astronomical factors, tides are modified by the sea floor, coastline, and weather. Tide tables are predictions and cannot account for weather conditions. Tidal predictions are easily accessible in the newspaper or on the Internet. The National Atmospheric and Oceanic Administration distributes regional tide tables each year. Tide books for the Gulf of the Farallones NMS are available for free at the Sanctuary office.

Food Web

Very little food is produced in the sandy beach habitat. What primary productivity occurs in the sand comes from the microscopic algae in the top few centimeters of the sand. There are a few species of algae living between the sand grains near the surface, but the their total mass is very small. On protected beaches where the sand is much finer, more compact, and more stable, *diatoms* and *dinoflagellates* migrate vertically through the upper centimeters of the beach to capture sunlight at low tide. They serve as the productive base to the more complex *food web* of muddier backwater shores.

Without much primary production occurring in the sandy beach habitat, organisms depend on food produced in other habitats. Sandy beach organisms depend on organic debris called *detritus*, that is an important source of food in other marine habitats as well. Kelp, other macroalgae, and plants are washed to the shore and deposited on the sand. Called beach wrack, it is a valuable food source for many animals. The beach acts just like the sand filter bed in a sewage treatment pond, or, on a smaller scale, the sand filters in home aquaria. The rolling wave action maintains a very high oxygen level which allows bacteria to live well down into the sand. Bacteria breakdown 95% of all the organic matter deposited by the waves. Because the detritus does not build up in thick deposits, there are few sand-ingesting worms or other animals adapted to ingest the substrate directly to remove the digestible organic matter mixed in with the sand. This is a common feeding strategy in muddier substrates or in earth worm-rich backyards.

Another source of food is *plankton* and organic particles (detritus) kept suspended in the water by wave action. In the spring and summer when the upwelling of cold, nutrient-rich waters along the Pacific coast is at its highest, waves may be turned dark green indicating the presence of dense concentrations of phytoplankton.

When prevailing westerly winds slacken or shift, the surf may carry a brown froth that is often mistaken for pollution. This foam is merely the concentrated remains of dinoflagellates that have become trapped nearshore by the periodic cessation of upwelling and the associated currents that normally move the organisms away from the shore during the most productive seasons.

The sandy beach habitat provides little shelter or cover to avoid predation. During low tide, shorebirds, small mammals, and insects prey on sand crabs and other animals in the swash zone. High tide brings in another group of predators; fish, crabs, shrimp, and worms feed on the animals in the sand. Many shorebirds have camouflage for protection.

Life Cycle

The most difficult obstacle that sandy beach organisms face is the lack of a stable substrate on which to hold. The surface of the sand is constantly pounded, stirred, and shifted by waves to a depth of at least several inches. There is no means of attachment, there is continual abrasion by swirling sand, and life is nearly impossible. The solution, solved by only a handful of species, is to live in, not on, the sand. It is a swim, burrow, or be swept away habitat. Burrowing beneath the sand protects animals from predation, wave impact, *desiccation*, and extreme temperatures. Yet, life in the sand presents the problems of finding food and adequate oxygen.

Many species living on sandy beaches go through free-swimming larval stages and are carried by ocean currents as part of the plankton. This means that populations are able to move up and down the coast easily in response to favorable conditions. It also means that populations in any one area are not very stable and may fluctuate widely from year to year. Most sandy beach species only live 1-2 years, which makes annual variation more likely. Some clams are a notable exception to this pattern, however. For them, a long life span provides greater population stability, though it doesn't allow for rapid re-population if an environmental or human-caused calamity strikes. This is especially significant for some of the most commercially desirable large clams which live for 50 years or more.

Above the Waves

The highest reach of the tide is called the wrack line. It is the place where ocean debris is left onshore. The beach wrack reflects what lives just offshore and gets uprooted by big storm waves – sponges, olive shells, sand dollars, skate egg cases, plants, and algae. Kelp and other algae are the biggest contributors to the wrack in the Gulf of the Farallones region. Beach wrack also contains the drifting debris of the whole ocean – the dead and dying remains of fish, birds, and the formless masses of jellies. The flotsam and jetsam of merchant vessels, uprooted trees, and anything that floats and drifts at sea lands on sandy beaches.

Potentially, the wrack constitutes a plentiful source of food. But since it sits at the highest tide mark, it is out of reach for most of the intertidal community. There are a few species, however, that take advantage of this rich food source. One of these species is the commonly called beach hoppers or sand fleas which are small shrimp-like amphipods that feed on the beach wrack. They have gills that function almost like lungs yet must be kept wet to function. The beach hoppers must avoid direct contact with the water, because they will drown if submerged. They are able to get enough moisture from the damp sand to keep their gills functioning. During the day, beach hoppers burrow head first deep beneath the high tide line, often under the beach wrack. The burrows are plugged for disguise and protection. An open burrow is an abandoned one. Even though a great deal of work is invested in the burrow's construction, it lasts only one day – until the waves of the next high tide wash over it. At night, on a falling tide, beach hoppers swarm out to feast on the organic debris of the wrack. Their chief diet is the rotting kelp. To protect their eggs, the females carry them in a brood pouch found on the underside of their body. Beach hoppers can be very prolific, sometimes existing in densities of hundreds per square meter. They are prey for many shorebirds and beetles.

Probably the most familiar birds on the sandy beaches of the Gulf of the Farallones NMS are the little Sanderlings. These are the birds that move like little wind-up toys, darting back and forth at the edge of the crashing surf. With their bodies held motionless and their feet a blur, Sanderlings seem as anxious to avoid getting wet as they do to snatch an exposed mole crab or worm. Sanderlings aren't equipped to probe deep into the sand, so they try to find prey as it is stirred up by the waves and before it can re-burrow. The larger Willets have longer bills and longer legs and are less concerned about getting wet. They wade into the retreating surf to forage. With their longer bills, they are less restricted to finding loosened prey at the sand surface. The tips of their bills are sensitive and are able to detect tiny vibrations that indicate the presence of prey deeper in the sand. Willets and other long-billed probers like Marbled Godwits actually feel the sand for food with their bills.

Higher on the beach, small Snowy Plovers chase about in the dry sand and beach wrack to snatch flies, other insects, and beach hoppers on the beach wrack. On gravelly beaches too coarse to probe with their beaks or where thick lines of kelp cover hordes of beach hoppers, there is a group of shorebirds adapted to flip over rocks and debris in search of food. These small shorebirds are aptly named turnstones. The most noticeable birds of the beach and certainly the loudest are the ubiquitous gulls. These scavengers are opportunists that feed on most any food item tossed on the shore – whether by a wave or picnicker.

In the Swash Zone

On an exposed beach, perhaps only five or six species of animals will be found burrowing in the sand. If a beach has some protection, the number may reach 20-25 species, and the total *biomass* may be 20 times greater. Fine sand on protected beaches is better for burrowing, retains more water, and has more organic matter to provide food for deposit feeders. The swash zone is one of the most physically harsh environments, because the waves are crashing, and the water comes and goes several times per minute.

Commonly called the sand crab or mole crab, *Emerita analoga,* is the epitome of burrowing efficiency. While other crabs are able to move in any direction, the sand crab can only move backwards. Its legs move sand in one direction to bury itself quickly. Its rear legs are modified as paddles, which gives it very good swimming capability, an essential skill when it is stirred out of the sand by crashing waves.

The sand crab burrows tail first into the sand, with its head near the surface facing seaward. Only its eyes and antennae are held above the sand. When the wave recedes, its large antennae are unfurled to form a "V" through which the backwash is sifted. The antennae are feather-like with numerous fine projections. Around the mouth, modified appendages act as bottlebrushes, scraping and cleaning the antennae several times during each wave. The most common food items are phytoplankton, though small pieces of macroalgae and sand may be trapped. The straining capacity is so refined that sand crabs are even able to trap bacteria.

Population densities of the sand crabs are sometimes so great that individuals may be touching one another. They are usually segregated by size with the larger ones nearer the ocean and the smaller ones higher up in the intertidal zone. Since females are larger than males, there is a corresponding segregation of the sexes as well. The entire population moves up and down the beach with the tides, with the greatest concentrations nearest the breakers. They also move along the length of the beach if longshore currents are present.

Sand crabs live 2-3 years and are able to reproduce during their first year. The bright orange eggs are carried on the female's underside. They spend four months as planktonic *larvae*, and they can be carried great distances by currents. Consequently their distribution is highly variable and their range is great (Alaska to Chile).

The sandy beach habitat provides little shelter to avoid predation. During low tide, shorebirds are the principal predators of sand crabs, while during high tide fish take over this role. Shorebirds are not as significant a threat, because the larger bird species best able to catch them, such as willets and godwits, tend to spread out as they feed and consequently pass over populations quickly. Fish, especially surfperch, are a more significant threat. In fact, predation from the sea is probably the major evolutionary factor that propelled these crabs to adapt to the rigors of life at the leading edge of the surf. Humans use sand crabs as bait.

There are not many predators down in the sand, but there are a few. The most effective are probably the moon snails, *Polinices* and *Natica.* These large snails (10-15 cm across the shell) have an immense foot which when fully extended nearly envelopes its own shell. It can only be withdrawn after a slow process of discharging water. The moon snail creeps just below the surface of the sand searching for prey, primarily clams. Other in-sand predators include several species of the segmented polychaete worms including *Euzonas* and *Nepthys.* They are more common on protected beaches, but sometimes abundant on exposed shores as well. Though small, they are effective predators.

Clams are the dominant *filter feeders*, meaning that they filter the water for plankton and detritus. The fast burrowing razor clam, *Soliqua,* has a shell that is long and very fragile, not at all what one would expect for an animal living in the tough surf. Long siphons are projected up to the surface of the sand to pump water and food. The razor clam is able to burrow fast enough to reposition itself within the short time between one crashing wave and the next (an average of 7 seconds). The Pismo clam, *Tivela,* of southern California is massively built with a thick, strong, and smooth shell. This allows it to easily withstand the force of breakers. These clams cannot survive in quiet water; they require the high oxygen content of the surf. Unlike relatives adapted to quieter habitats, the siphon of the Pismo clam has filter-like projections across the opening that keep out sand.

Between the Sand Grains

The most diverse and abundant organisms of the sandy beach habitat are too small to be seen with the naked eye. Because the sand holds water even when the tide is out, the minute spaces between the grains of sand are able to support a complex community of microorganisms that swim within the protective film of the water that surrounds each grain. These are single-celled protozoans, nematodes, flatworms, larvae of other worms, and several crustaceans. Most of the major invertebrate groups have members which live in the *interstitial* water that surrounds each sand grain. This community is known as the interstitial fauna.

Many of the animals are small, specially adapted members of groups that are larger in other habitats – 2 mm sea cucumbers, 2 mm snails, and 0.3 mm polychaete worms. The single-celled protozoans found here, however, are often larger than their microscopic relatives found in other habitats. All species tend to be long and flat, which makes it easier for them to stay wrapped within the film of each grain. They also tend to have simplified bodies. At this size there is no need for complex digestive tracts or respiratory, circulatory, or excretory organs. Diffusion through their body walls is adequate to transport gases, food, and waste. Most have some mechanism for holding on to their one-grain world such as adhesive glands, hooks, or claws. The interstitial copepods do not have the large antennae that their free-swimming relatives use to dart about in the ocean. There is no room for that kind of locomotion. Instead, interstitial copepods wriggle. Nematodes are the most common animal here. One study identified 70 different species in a 50 cm^2 plot (less than 3 inches per side). It has been estimated that as many as one million animals may live in a square meter of sand!

There are three feeding strategies in the interstitial space: herbivores feeding on the *benthic* diatoms, deposit feeders ingesting detritus brought in by the waves, and suspension feeders that filter the water for plankton between the grains of sand. Though they are all microscopic in size, the interstitial fauna are so abundant that it accounts for the majority of the oxygen used and the carbon dioxide produced on the beach. Predators of the interstitial fauna include young flatfishes as well as shrimp and polychaete worms.

Beyond the Tides

Though unseen by the beach stroller, there are several fish species that are also a part of the sandy beach habitat. Skates, rays, and other flatfish patrol for prey just beyond the waves. When the tide is in, they have access to the intertidal crabs, clams, and worms. By flapping their "wings," they create their own surf-like action to blow away the sand and expose their prey. Some fish have adapted to feed just behind the leading edge of the breaking waves. Surfperches and sand eels take advantage of the dislodging force of the waves to grab crabs and worms otherwise unobtainable.

Though the empty shells of dead sand dollars are often washed up on beaches, the living animals are only found below the low tide. Sand dollars, with flat shells and short spines, are relatives of sea urchins and sea stars. They are able to work their way into the sediment and can even right themselves and re-burrow when turned upside down by a passing wave. Sand dollars feed by trapping detritus in mucous between their spines and carrying it to their mouths by the action of tiny hairs (cilia).

Human Impact

The seashore is a major recreational site for people all over the world. Sandy beaches are the most visited of all shore types. They are often easy to get onto, they don't show much wear and tear from great crowds, and probably just as important – it is a place of relaxation and exploration. For these reasons, sandy beaches are often held as public property. In many states, even where private homes are built near the shore, the beach itself is kept open to public access.

As we have seen, beaches are in constant motion. Sand moves seasonally on and offshore. It also moves along the coast in the prevailing direction of wind and waves. A shoreline that moves 25 meters in 50 years gets noticed when it is near a man-made structure that becomes threatened by the moving shoreline. The problem becomes especially urgent when a home is built on such a beach. The first reaction has often been to build some sort of seawall to keep the beach from eroding away. However the change in the shoreline from the seawall often causes unwanted erosion and deposition in other areas.

Along Ocean Beach in San Francisco, a submerged sill traps sand along the beach. This man-made structure has been considered a success by some people in that it keeps the sand on the beach during the winter and has not disrupted the normal sand cycle in other areas. In contrast, a groin was placed north of the mouth of Bolinas Lagoon to protect the Lagoon. Not only has it trapped sand behind the groin, sand is also accumulating to the south of the groin at the mouth of the Lagoon. The water is slowed down by the groin and deposits the sediment it had been carrying along the shore. This sand inhibits water flow out of the Lagoon which increases the siltation within the Lagoon itself.

The sandy beach is a major deposition area for algae and all the other material floating at the surface. Plastic and garbage end up on the beach and may be mistaken for food by birds and other animals. Oil from spills ends up on the beach, potentially covering the animals and their food with toxic oil. Pollution reaches the sandy beaches and impacts the marine life there. Although the sandy beach is often a place of beauty, some human activities threaten the habitat.

Gulf of the Farallones National Marine Sanctuary

Through the Beach Watch program, the Gulf of the Farallones NMS monitors the beaches along its boundary with the help of volunteers. Every two to four weeks dedicated citizen scientists survey their beaches for marine life and human activity. Fluctuations in bird and marine mammal populations are detected in the long-term database. Volunteers find and report oil or tarballs and collect and preserve oil samples as evidence. The Beach Watch program provides additional eyes and ears for protecting the Sanctuary's sandy beaches.

Adapted from Project Ocean: Sandy Beach Habitat Guide

Glossary of Terms
Sandy Beaches

Algae (singular-alga)	photosynthetic, aquatic or marine organisms that resemble plants but have no seeds or roots, ranging from one-celled diatoms to multicellular seaweed called macroalgae. The largest macroalgae are kelp.
Beach wrack	debris from the ocean that is washed onto the beach. It can include kelp, shells, sand dollars, birds, and fish.
Benthic	associated with the sea floor; pertaining to organisms living in or on the sea floor.
Biomass	total weight of living organisms.
Breaker	a wave that is unstable and collapses or breaks along the shoreline.
Detritus	dead organic matter and the microscopic decomposers that live on it.
Diatoms	microscopic, single-celled *algae* which have silica (glass-like) valves and are abundant in upwelling waters. Some species live in the shallow waters on the sediment.
Dinoflagellates	microscopic, single-celled organisms. Both plant and animal traits. They have flagella which provides them some locomotion. Some species live in the shallow waters on the sediment.
Fetch	area and distance across which wind interacts with the water surface to generate waves.
Filter feeder	an animal whose feeding strategy is to filter water for food. Examples from the sandy beach are clams and sand crabs.
Food web	all feeding relationships in a community.
Habitat	the place where organisms live.
Interstitial	refers to the space between sediment particles.
Intertidal zone	area between the high and low tide.
Larvae	immature pre-adult stages of an organism, which do not structurally resemble the adults. Often have different diets and habitats than the adults.
Longshore current	current produced by waves landing on shore at an angle to the shore; responsible for moving coastal sediment and natural erosion along beaches.
Mixed tide	daily tidal pattern of uneven high tides and uneven low tides.

Organic matter that is produced by living organisms, a chemical compound with a backbone of carbon atoms.

Plankton drifting organisms that have no control over the direction they travel; they are at the mercy of the currents.

Subtidal the part of the continental shelf that is never exposed by low tide; area below the low tide zone.

Swash zone area where water rushes up the beach after the wave has broken.

Tide the periodic, rhythmic rise and fall of the sea surface.

Tidal range the difference in sea level height between high tide and low tide.

Semidiurnal tide daily tidal pattern of two high tides and two low tides.