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<http://limpetsmonitoring.org/index.php>

LiMPETS Long-term Monitoring Program and
Experiential Training for Students
STUDENT SCIENTISTS ON OUR SANCTUARY SHORES

Did You Know?

Mole crabs are important prey for shorebirds, sea-birds, fishes, and marine mammals.



The Sandy Beach Monitoring Program is an in-depth education and monitoring program for middle and high school students, educators, and volunteer groups. Participants are trained to survey the distribution and abundance of the Pacific mole crab (*Emerita analoga*) at monitoring sites along the coast of California. Mole crabs are among the most important herbivores on beaches along the west coast of North and South America and are an important link in the sandy beach food web.



The Sandy Beach Habitat: People love to visit California's beaches for recreation and the beauty of the scenery. However, the sandy shore is often overlooked for the diversity of life that it supports. Although it may not be obvious at first glance, the constantly moving sand on the beach forms a very rich and productive intertidal habitat, particularly in California. In fact, thousands of mobile animals live along every foot of the shoreline.

Glossary

LiMPETS	Long-Term Monitoring program and Experimental Training for Students
beach wrack	Kelp, algae, and plants washed on shore and deposited on the beach
calipers	An instrument used to measure thickness
carapace	A protective, shell-like covering
Emerita analoga	Scientific name for the mole crab or sand crab
gills	used for breathing oxygen from water
primary (short) antennae	The antennae use for funneling water to the gills
secondary (large) antennae	used for filtering plankton from the water for food
subtidal region	The lowest part of the sandy beach always covered by water
surf zone	The area of the beach where waves crash
swash zone	The area of sand that is covered and uncovered by waves up to the high tide line
telson	The rearmost segment of the body of a sand crab
thoracic legs	the back legs used for digging and swimming
uropods	The sixth and last pair of limbs of lobsters and sand crabs, forming part of the tail fan
wrack line	The highest reach of the tide on shore where ocean debris is left

Mole Crab Coloring Page

Name _____

1. Label (and color) the mole crab drawing using some of the following terms: chelipeds, thoracic legs, eye stalks, uropods, carapace, abdomen, telson, primary antennae or secondary antennae.

2. If mole crabs are "crabs", where are the big "claws"? On other types of crabs, the crushers and pinchers are located on the first pair of legs. But in mole crabs, these claws are absent. Why?

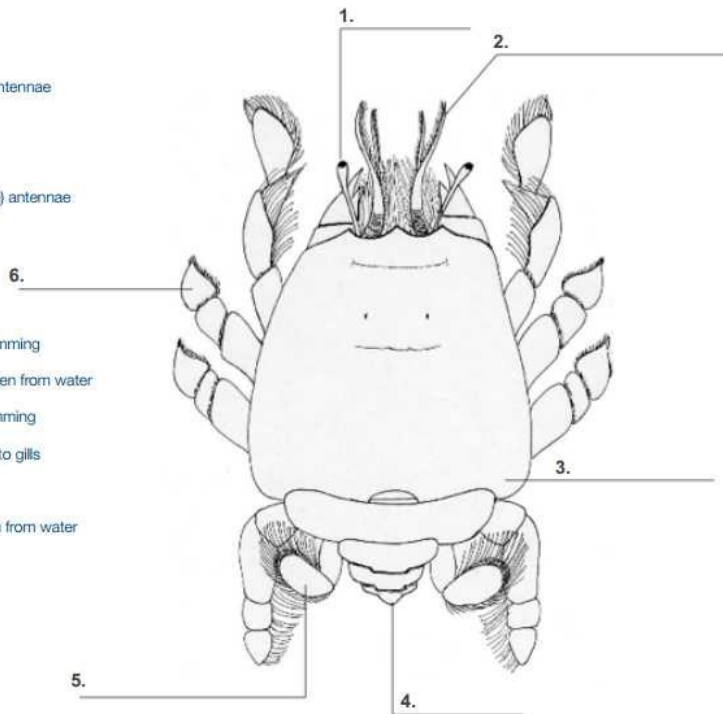
3. Match the body part with its corresponding function:

BODY PART

- Carapace
- Primary (short) antennae
- Uropods
- Thoracic legs
- Secondary (large) antennae
- Gills

FUNCTION

- Digging and swimming
- "Breathing" oxygen from water
- Paddles for swimming
- Funneling water to gills
- Protection
- Filtering plankton from water



The animals that live in this turbulent habitat are highly specialized. There is little to attach to or hold onto at the sandy beach, so the ability to move quickly to keep above the waterline or to burrow in the sand to avoid crashing waves is a common adaptation among beach organisms. Most beach animals survive by obtaining food from the organic material that washes in with each wave.

Beach Dynamics

The sandy beach is a harsh environment. Crashing waves, the daily ebb and flow of the tides, and the action of currents keep coastal ocean waters in constant motion. This water movement also carries the sand below it, changing the beach slightly with each wave and noticeably over seasons. Taken altogether, these physical forces create a very dynamic habitat.

It has been estimated that the energy contained in an average wave front approaching a beach is equivalent to a line of cars, side by side, revving their engines at full throttle. Not surprisingly, it is the waves that primarily determine how beaches look and what lives on them.

A sandy beach can change appearance seasonally. In the winter and spring, large waves can move most of the sand off the beach face leaving behind the larger gravel or cobble. The sand is pulled into the surf zone, where it forms sand bars. When the waves are smaller, sand is moved gradually back on to the beach face. California beaches are often widest and sandiest in the late summer and fall and narrowest and rockiest in the winter and spring months.





The day-to-day appearance of a sandy beach may not change much, but it is always in motion. No sand 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 current.

The sand that makes up beaches is eroded from inland rocks, flows down creeks and rivers, and then is deposited at the mouth, forming sandy beaches. Longshore currents generated by waves pick up sand grains from these larger deposits and move them along the coast to form more beaches. The sand itself is primarily made up of quartz, which is found in most types of rocks. There are other minerals as well, plus small pieces of shell and sea urchin spines.



of crabs/core. These data can then be used to estimate population sizes of mole crabs at a particular location compared across time at the same location and between different beaches.

Scientists use different methods to estimate population sizes for other organisms based on the environment where the organisms live. For example, think about scientists trying to estimate the population size of a certain type of fish. Using cores in the ocean will not work very well.

Different types of environments present unique challenges for estimating populations sizes. For example, think about the different methods required to sample organisms that live in the ocean, deep in the mud, in dark caves and so on.

Additionally different types of organisms present challenges based on their lifestyle characteristics. For example, think about the different methods required to research the population sizes of particular species of birds, fish, insects, and mammals with large ranges (e.g. wolves). Both different environments and different lifestyle characteristics of organisms create the need for various sampling methods. These challenges allow scientists to be innovative and creative in their work as they design new ways to estimate population sizes or modify existing methods that will work in their particular sampling environment.

b) Application for LIMPETS Sandy Beach

Monitoring:

Baseline data concerning the life history patterns and population dynamics of mole crabs allow scientists to know what is normal for the organism under natural conditions and to be able to track changes over time.

If scientists understand the life history patterns and population dynamics of mole crabs under natural conditions they have developed a baseline.

Scientists can then compare future data collection for mole crabs against the baseline data to determine if something about the organism has changed over time. Gathering baseline data requires repeated samples in a variety of locations where the organism lives year after year. This is where your class data comes in. The data you collected as a class can be used to contribute information to what we know about the 'the baseline' for mole crab populations in California.

5. POPULATION SAMPLING TECHNIQUES:

There are many ways that scientists can estimate the population size of an organism. As mentioned above in the case of Pacific mole crabs, transect lines and cores are used to collect crab data in standardized ways. Abundance is calculated as the

Life at the Sandy Beach

One of the main obstacles that sandy beach organisms face is the lack of stable ground to hold onto. They must swim or burrow, lest they be swept away. Burrowing also is the primary means of escaping predators. Also difficult is that very little food grows in the sandy beach habitat

Photosynthesis is limited to microscopic algae in the top few centimeters of the sand. Some beach animals survive by eating these minute algae particles. However, most sandy beach organisms depend on the waves to bring them food.



JAIME HALL

Scurrying Sanderlings probe for invertebrates in the swash zone and the wrack.

ABOVE THE TIDES: Probably the most familiar birds of the sandy beach are the little Sanderlings. These are the birds that dart back and forth at the edge of the crashing surf, trying to grab an exposed sand crab or worm. Sanderlings' bills are not designed to probe deep into the sand, so they try to find prey as it is stirred up by the waves. Larger Willets and Godwits with longer bills are less restricted. The tips of their bills are sensitive and are able to feel tiny vibrations that indicate prey deeper in the sand.

crabs: Abundance of mole crabs = # of crabs / core

4. DATA ANALYSIS:

The goal of data analysis is to make graphs and look for patterns in your data. Your analysis revolves around the questions you are asking and the independent and dependent variables you are testing.

By analyzing your data, you are looking for ways that the independent variables that you test (e.g. water temperature) affect the dependent variables (e.g. crab size) that you are interested in researching.

a) Baseline Data: Analyzing data and looking for patterns allows scientists to find evidence to support or refute their hypotheses. This evidence is not conclusive (in other words, it's not the final answer) but adds to the knowledge base that scientists have about a particular organism. An accumulation of evidence and information about an organism (e.g. life history patterns, population dynamics) allows scientists to establish baseline data about a population of organisms.





a) Calculating Abundance: In order to be able to compare samples of the same type of organism from research projects conducted by different groups of scientists, there needs to be a common way to standardize data — or calculate how much of a particular organism there is in a particular location. We call this calculating abundance.

Abundance can be calculated in many ways. A common abundance calculation (e.g. for crabs) = # of crabs/area sampled.

b Application for LiMPETS Sandy Beach Monitoring:

In the case of mole crabs, scientists often report findings by core. Therefore in the case of mole

The highest reach of the tide is called the “wrack line,” where debris from the ocean is left onshore. While kelp and other algae are the biggest contributors to the wrack on California beaches, the dead and dying remains of fish, birds, and jellies can also be found among the wrack. Small shrimp-like amphipods, commonly called beach hoppers, feed on this nutrient-rich debris. Beach hoppers have gills that function almost like lungs yet must be kept wet from the damp sand to function. During the day, beach hoppers burrow headfirst deep beneath the high tide line, often under the beach wrack. At night on a falling tide, beach hoppers swarm out to feast.

Higher on the beach, above the wrack, small Snowy Plovers, a threatened species, chase about in the dry sand and beach wrack to catch insects and beach hoppers. The most noticeable birds of the beach, and certainly the loudest, are the ubiquitous gulls. These scavengers are opportunists that feed on almost any food item tossed on the shore, whether by wave or picnicker.

THE SWASH ZONE: In the area where the waves wash in and out, organisms must have a different strategy for obtaining food. Most of these animals, such as clams and crabs, filter feed, straining the ocean water for plankton and detritus. In the spring and summer when upwelling of cold, nutrient-rich waters along the Pacific coast is at its strongest, waves turn dark green indicating very abundant phytoplankton and lots of food for filter-feeders.

One of the most common animals in the swash zone is the Pacific mole crab (a.k.a. sand crab), *Emerita analoga*. It is the epitome of burrowing efficiency. The sand crab can only move backwards, perfect for digging down into the sand. In fact, it can completely bury itself in about in 1–7 seconds! Its rear legs are modified as paddles, which gives it very good swimming capabilities, an essential skill when it is stirred out of the sand by crashing waves. After being dislodged, the sand crab burrows end-first into the sand, with its head near the surface facing seaward, leaving only its eyes and antennae above the sand. When a wave recedes, the crab's large, feathery second antennae are unfurled to form a "V," through which the backwash is strained for phytoplankton.

b) Application for LIMPETS Sandy Beach Monitoring:

Let's say that your class is sampling at a beach that is 1 mile long. You want to know how many mole crabs are on the beach and you take 1 core to determine this information. You find 15 crabs in that core. You decide to take 4 more cores just because you have extra time and this is what you find: Core 2 = 3 crabs, Core 3 = 1 crab, Core 4 = 2 crabs, Core 5 = 4 crabs. You can now determine that Core 1 with 15 crabs is not consistent with what you found in other cores. This doesn't mean that you shouldn't use this sample, by all means it should be included; however, in order to get a representative sample, you need to sample several times in one location.

3. STANDARDIZING DATA:

Calculation made with data that takes into account the size of the area where the samples were collected and provides a way for scientists to compare samples across locations and research projects. For example, if you collected 100 crabs, it is important to note the amount of area you sampled within — did you catch 100 crabs along 10 m of beach, 100 m of beach? The size of your study area can make a big difference when trying to determine the population sizes of a particular organism.

2. REPLICATION:

Taking more than one sample in a given sampling area. Scientists take more than one subsample (described above) in a given location in order to make sure that their samples represent the actual number of organisms in a given area and that the number they got didn't happen just by chance.

a) Representative Sample:

By using the tools and techniques described above, scientists collect data from multiple samples in one location. Together these samples constitute a representative sample, in that it accurately represents what is happening in a given area. When a representative sample is obtained, this information can then be applied to the rest of the sampling area.



CHAD KING

Willets (*Catoptrophorus semipalmatus*) foraging for mole crabs on Asilomar Beach.



BEYOND THE TIDES: Though unseen by those of us on the beach, there are several fish species that live in 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,” these fish create surf-like action to blow away the sand and expose their prey. Some fish such as surperch and sand eels feed just behind the leading edge of the breaking waves, taking advantage of the dislodging force of the fast-moving water to grab crabs and worms otherwise unobtainable.



Female mole crabs can produce up to 50,000 eggs at one time.

b) Purpose of Tools:

Different tools all serve a slightly different purpose with the common goal of providing a standardized way to conduct field sampling. Transects are simply lines of a known length (e.g. a measuring tape) laid out across the sampling area. Transects serve as a baseline for placement of other types of sampling tools such as cores. Each of these tools (e.g. quadrats, nets, cores) is of a known size so that scientists can determine how much of an area was sampled.



c) Application for LiMPETS Sandy Beach Monitoring:

Your goal is to determine the amount of crabs present at your sampling location, which is often a large beach. Think of how challenging it would be to count all of the crabs on the entire beach! To avoid this time consuming (and nearly impossible) task, you will subsample a smaller, 50-meter section of the beach using transects and cores.

Field Sampling Techniques: Fact Sheet

What do field scientists do — and why do they do it? Scientists have specialized methods or techniques that they use to gather data in the field about individuals, populations or communities. Good scientific technique is essential and must produce results that are both unbiased and representative of what is happening in the entire study area. This fact sheet serves as an overview of some of the common sampling techniques used by scientists to gather accurate and standardized data about populations.

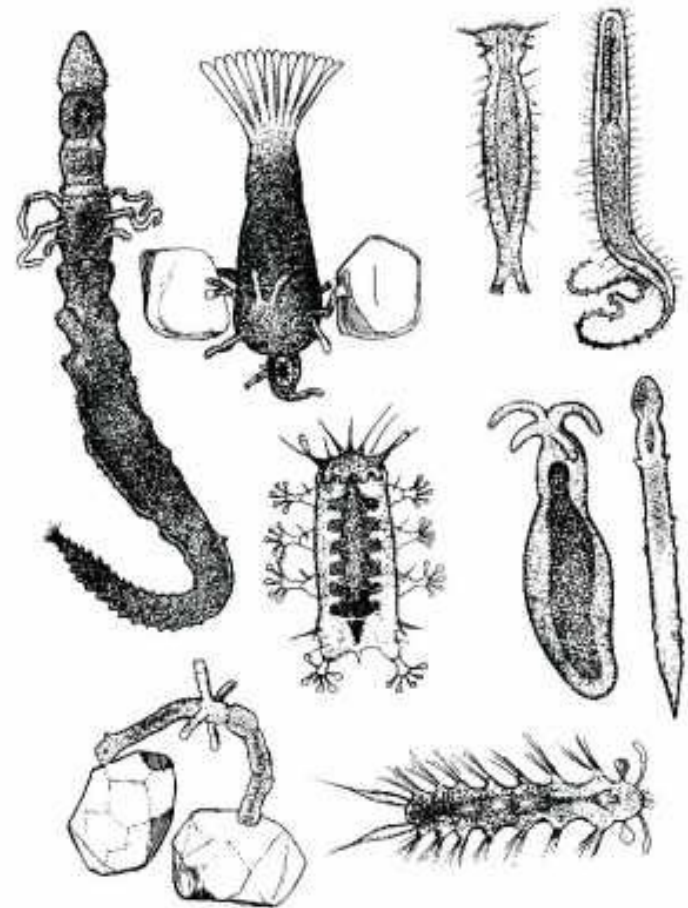
1. SUBSAMPLING:

Taking smaller samples as a subset of a larger potential sampling area. Scientists use this technique in order to get an idea of how many organisms exist without having to sample the entire area where the organism is found.



a) Tools Used:

Scientists use different tools such as transects, quadrats, nets, and cores to subsample an area.



Interstitial fauna.

Human Impact

More people use sandy beaches than any other type of seashore. Unfortunately, beaches suffer from a number of impacts caused by humans.

Major impacts to beaches include coastal armoring, marine debris and pollution. “Coastal armoring” is the building of seawalls and other structures to prevent the natural erosion of coastline.

However, these structures can potentially damage or alter local coastal habitats and deprive beaches of sand. Coastal armoring within the boundaries of national marine sanctuaries is strictly regulated, because it is very hard to correctly predict how the sand and water will flow around the new structure.

Marine debris comes from two main sources, the land and the ocean. Trash is dumped overboard by ships at sea, carried by rivers and storm drains from inland areas, and deposited directly on beaches by visitors. Regardless of its origin, much of this debris ends up on beaches and can pose a threat to many organisms who may eat or become tangled in the debris.

The pollution of water along our beaches is also a persistent problem in the United States. Sewage spills and oil spills are both common culprits.



Monitoring Sand Crabs

When scientists study the sandy beach ecosystem, sand crabs are often the focus. Sand crabs tend to be abundant and relatively easy to find, making them ideal to understand population dynamics on the beach. As one of the largest filter-feeding herbivores on the beach, they form a vital link in the food chain from ocean to sand crab to predator, giving us a picture of the overall health of the shore. Furthermore, by collecting long-term data on sand crab abundance, we can track fluctuations over time that can possibly be linked to environmental or human-caused phenomena. Lastly, for our sanctuaries, monitoring sand crabs is important in case of an oil spill. We can compare sand crab data from before and after the spill to understand the impact the oil had on the beach and to help us restore the shore to its original conditions.

Sewage typically comes from sewer overflows and malfunctioning sewage treatment plants. Oil can come from many sources, including land runoff, poor vessel maintenance and vessel spills. The toxic chemicals in oil kill many animals and may pollute a sandy beach for many years.

The sandy beach is a dynamic environment that is home to many creatures uniquely adapted to survive in harsh conditions. Life exists on all areas of the beach, from above the reach of the tide, through the swash, and down into the ocean. In order to conserve and protect these threatened ecosystems, we must understand the ecological value of beaches and try to limit our human actions



In November 2007, the M/V *Cosco Busan* struck the San Francisco Bay Bridge. The collision tore a 200-foot hole in its hull and spilled 58,000 gallons of heavy fuel oil into San Francisco Bay.

The Pacific Mole Crab:

The sandy beach environment is not an easy place for organisms to live.

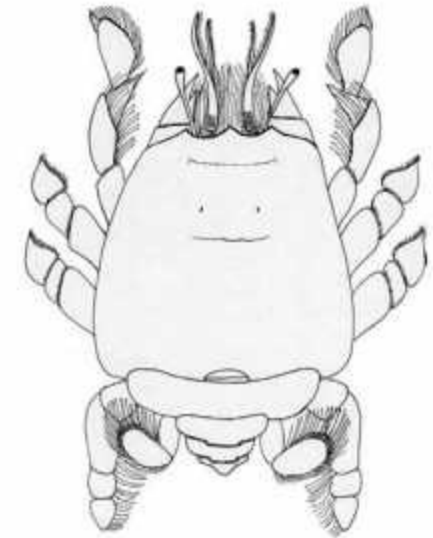
Unlike the rocky intertidal ecosystem, there is no solid material on which to attach. Sandy beach animals have to deal with constantly shifting sand, crashing waves, tides coming in and out, a beach that changes seasonally, and marine and terrestrial predators. The animals that live in this environment are almost always buried in the sand and have many adaptations to help them survive. It is in this habitat that the Pacific mole crab can be found.



fish that eats sand crabs. Shorebirds, including Sandpipers, Sanderlings, Godwits, Black-bellied Plovers, Willets, and Curlew have been seen feeding on crabs in the swash zone. The Surf Scoter, a water bird, also feeds on sand crabs. Sea otters are one of the few mammalian predators of sand crabs.

Sand crabs are known to carry parasites. In particular, they are an intermediate host of parasitic worms in the phylum Acanthocephala, known as spiny-headed worms. These parasites are passed onto the predators of sand crabs. Sea otters and birds can eat many crabs per day, and the ingested parasites can kill these predators.

Pacific mole crabs (*Emerita analoga*), also known as sand crabs, are one of the most important and abundant invertebrates on the sandy beach. They live along the Pacific coast from Alaska to Baja California in the northern hemisphere and between Ecuador and Argentina in the southern hemisphere. They inhabit the swash zone, which extends from the lowest to the highest reach of the waves at any given time. The swash zone is an especially harsh environment to inhabit on the beach because of the crashing waves and shifting sand.

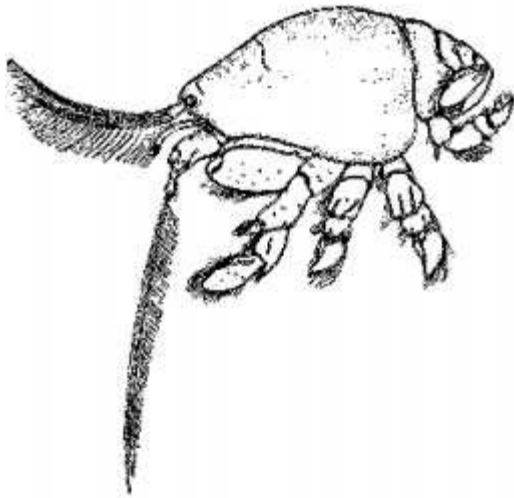


The sand crab is small in size, growing up to 35 mm (1.4") long and 25 mm (1") wide. It is gray or sand colored and does not have claws or spines. Like other crustaceans, sand crabs periodically molt, so the empty exoskeletons may be found on the shore. Males and females may look very similar at first glance, but there are some important

differences.

Females are larger, with a carapace length of 14–35 mm, while males reach 10–22 mm. If a female is carrying eggs, they will be found under the telson and look like a brightorange to dull-yellow mass, depending on the maturity of the eggs. If a female is not carrying eggs, the pleopods to which she attaches the eggs will be visible on the underside of the crab when the telson is lifted.

There are three pairs of pleopods, right below the fourth pair of legs, and they resemble short threads.



The crab spends most of its time buried in the sand. It has five pairs of legs that allow it to swim, crawl and burrow, all of which are done backwards. In fact, they are so well-

designed for burrowing that they can completely bury themselves in 1–7 seconds! The crab's eye stalks reach above the sand as do the first pair of antennae, which they use for respiration.

currents are created by waves that approach a beach at an angle. As a wave returns to sea, it takes sand and crabs with it. The next wave comes in at angle farther down shore and deposits the crabs in a new location.

Sand crabs are not distributed uniformly across a beach.

Females are often found lower in the intertidal zone than males and recruits. The crabs form large, unevenly spaced aggregations along the shore. Scientists have proposed biological reasons for these aggregations, such as predator avoidance and an advantage for mating. Physical reasons like water flow and wave shock have also been proposed. A combination of multiple factors may explain the aggregations. The number of crabs on a beach can also vary drastically from year to year, depending on environmental factors.

Predators and Parasites

The main predators of the sand crab are fish, water birds, and shore birds. Fish are the greatest threat, and this may explain why sand crabs are not often found in the low intertidal and subtidal zones. The barred surfperch is a very common fish in the surf zone, and sand crabs have been found to make up 90% of its diet. The California corbina is another

Natural History

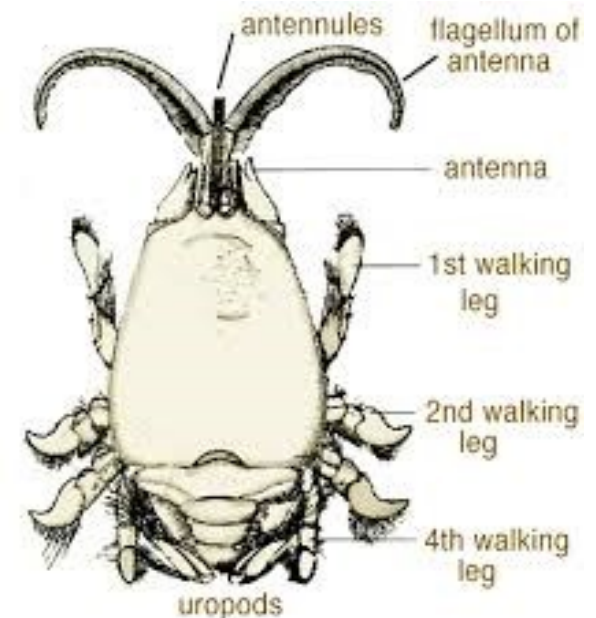
Sand crabs are usually found on the beach in large numbers from spring to fall. In the winter, storms may carry them offshore with the sand into sandbars. When the sand is transported back onshore in the spring, crabs come with it.

During the reproductive season (February–October), females can produce one clutch of up to 45,000 eggs per month, which take approximately 30 days to develop. Once the eggs hatch, the larvae are planktonic for about 4.5 months, where they go through 8–11 larval stages. During this time they may drift far offshore. When the crabs near the end of their larval stage they can return to the beach if they have been carried by the currents back to nearshore waters. When the larvae settle onto the beach, it is called recruitment, and these small crabs are considered “recruits.” Recruitment can occur year-round, but often, depending on environmental conditions, large numbers of recruits are found during spring and early summer and again in the fall.

Sand crabs move up and down the beach with the tides, using the action of the waves to carry them higher or lower in the swash zone, depending on the direction of the tide. Crabs also move down the length of the beach with longshore currents. These

The second pair of antennae resembles feathers and is extended when the crab feeds. Small organisms, mostly dinoflagellates and other phytoplankton, are collected on the antennae, then the antennae are pulled into the mouth and the food is scraped off.

The Pacific mole crab resembles another species of sand crab that lives along the shore, the spiny mole crab, *Blepharipoda occidentalis*. This crab lives deeper in the subtidal zone and can reach 65 mm in length. The adult spiny mole crabs feed on dead Pacific mole crabs.



Notes page:

Write down interesting facts you have learned about the sand crab.

Sketch page:

Sketch a detailed drawing of the sand crab.