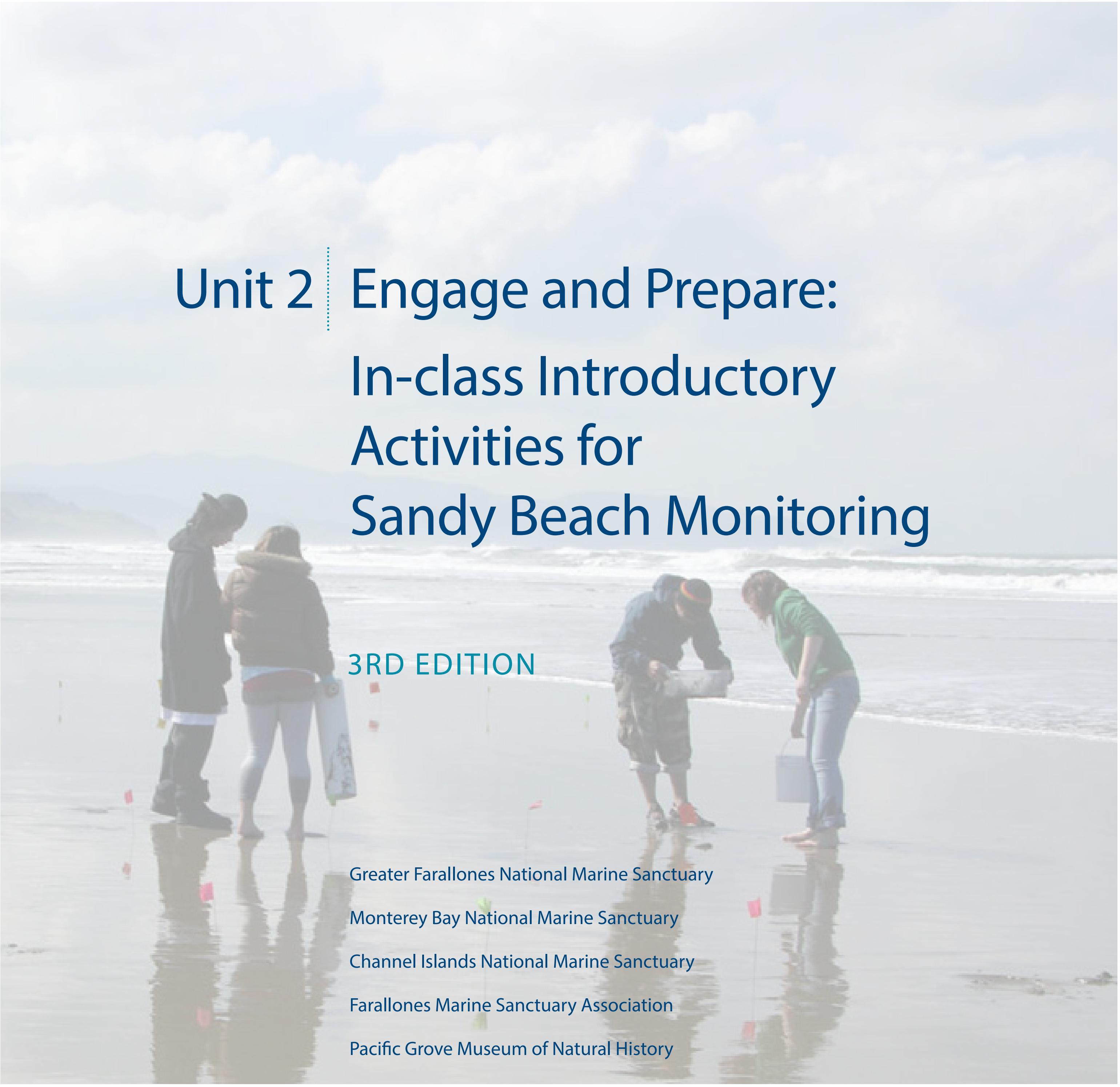
LiMPETS Sandy Beach Monitoring Program:
Curriculum Guide

National Marine Sanctuaries



Unit 2 | Engage and Prepare:

In-class Introductory Activities for Sandy Beach Monitoring

3RD EDITION

Greater Farallones National Marine Sanctuary

Monterey Bay National Marine Sanctuary

Channel Islands National Marine Sanctuary

Farallones Marine Sanctuary Association

Pacific Grove Museum of Natural History

LiMPETS Long-term Monitoring Program and Experiential Training for Students

LiMPETS Curriculum

The LiMPETS curriculum was created by the Farallones Marine Sanctuary Association and updated by the Pacific Grove Museum of Natural History in partnership with many generous individuals and organizations. We would like to thank everyone for their countless and valuable contributions to this project.

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Unit 2 | Engage and Prepare: In-class Introductory Activities for Sandy Beach Monitoring

Using the LiMPETS Curriculum

The LiMPETS curriculum was designed for a broad range of participants; middle school and high school students, college undergraduates, environmental education organizations, and community groups. We encourage you to adapt and customize this curriculum to suit the needs of your unique class or group. However, there are some essential elements that are required in order to participate. At minimum, teachers or group leaders should set aside three days to conduct the essential elements of the program: one day for classroom preparation, one day for monitoring, and one day for data entry and assessment.

The following outlines both the required and optional elements of this curriculum:

Unit 1: Getting Started (required reading for teachers and group leaders)

Unit 2: Engage and Prepare: In-class Introductory Activities for Sandy Beach Monitoring

- ACTIVITY: The Essentials of LiMPETS In-class Preparation (required)
- ACTIVITY: Monitoring Mole Crabs in the Classroom (suggested)
- ACTIVITY: Investigating the "Crab" in Mole Crabs (optional)
- ACTIVITY: Sandy Beach Food Chain, Trophic Levels, and Biomagnification Game (optional)
- ASSESSMENT: Student Pre- and Post-Monitoring Reflection (optional)

Unit 3: Investigate and Archive: LiMPETS Sandy Beach Monitoring and Data Entry

- ACTIVITY: LiMPETS Sandy Beach Monitoring (required)
- ACTIVITY: Data Entry (required)
- ACTIVITY: Extension to Monitoring — Acanthocephalan Parasite Investigation (optional)

Unit 4: Analyze and Interpret: Data Analysis Activities for the Classroom (optional)

- ACTIVITY: Visualizing Data from a Great Day at the Beach
- ACTIVITY: Exploring Trends in Mole Crab Abundance Over Time

Unit 5: Communicate: Effectively Communicating Science and Taking Action In Your Community (optional)

- ACTIVITY: Student Pre– and Post–Monitoring Reflection
- ACTIVITY: Communicating Science Through Posters and Oral Presentations
- ACTIVITY: Taking Personal Action to Protect the Ocean — Us Vs Them

The LiMPETS curriculum is aligned with the Next Generation Science Standards and Common Core Standards for grades 6–12. It is also aligned with the Ocean Literacy Principles and Concepts, which identifies the content knowledge that an ocean literate person should know by the end of 12th grade, www.oceanliteracy.org.

Middle School Curriculum Alignment

Activity	Next Generation Science Standards	Common Core Standards	Ocean Literacy Principle
The essentials of LiMPETS In-Class Preparation	Practices obtaining, evaluating, and communicating information Core Ideas LS2.A: interdependent relationships in ecosystems LS2.B: cycle of matter and energy transfer in ecosystems LS2.C: ecosystem dynamics, functioning, and resilience LS4.D: biodiversity and humans LS4.C: adaptation ESS2.C: the roles of water in earth's surface process ESS3.C: human impacts on earth systems Crosscutting Concepts stability and change	RST 2: determine the central ideal or conclusions of a text RST 4: determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context	2.D: sand is redistributed by waves and coastal currents seasonally 5.H: tides and waves cause zonation patterns along the shore
Investigating the "Crab" in Mole Crabs	Practices planning and carrying out investigations Core Ideas LS4.B: natural selection LS4.C: adaptation Crosscutting Concepts structure and function		5.D: ocean biology provides unique examples of life cycles and adaptations
Sandy Beach Food Chain, Trophic Levels, and Biomagnification Game	Practices developing and using models Core Ideas LS2.A: interdependent relationships in ecosystems LS2.B: cycle of matter and energy transfer in ecosystems LS2.C: ecosystem dynamics, functioning, and resilience Crosscutting Concepts energy and matter		5.D: ocean biology provides unique examples of life cycles and adaptations 6.A: the ocean affects every human life 6.E: human development and activity leads to pollution (point source, non-point sources, and noise pollution)
Student Reflection		W 3: write narrative to develop real or imagined experiences or events using effective technique, relevant descriptive details, and well-structured event sentences	6.G: individual and collective actions are needed to manage ocean resources for all

High School Curriculum Alignment

Activity	Next Generation Science Standards	Common Core Standards	Ocean Literacy Principle
The essentials of LiMPETS In-Class Preparation	Practices obtaining, evaluating, and communicating information Core Ideas LS2.C: ecosystem dynamics, functioning, and resil-ience LS4.C: adaptation LS4.D: biodiversity and Humans ESS2.C: the roles of water in earth's surface processes ESS3.C: human impacts on earth systems Crosscutting Concepts stability and change	RST 2: determine the central ideal or conclusions of a text RST 4: determine the mean-ing of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scien-tific or technical context	2.D: sand is redistributed by waves and coastal currents seasonally 5.H: tides and waves cause zonation patterns along the shore
Investigating the "Crab" in Mole Crabs	Practices planning and carrying out investigations Core Ideas LS4.B: natural selection LS4.C: adaptation Crosscutting Concepts structure and function		5.D: ocean biology provides unique examples of life cycles and adaptations
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Student Reflection		W 3: write narrative to develop real or imagined experiences or events using effective technique, relevant descriptive details, and well-structured event sentences	6.G: individual and collective actions are needed to man-age ocean resources for all

The Essentials of LiMPETS In-Class Preparation

OBJECTIVE: Your students should be familiar with the how, what and why of monitoring before they go to the beach. Preparation is both key to quality data collection and to an exciting and meaningful student experience. The following are, at minimum, the required elements of training that will help engage and prepare your students in-class for a successful day in the field.

ACTIVITY TIME: 45–60 minutes

GRADE LEVEL: 6–college

LIMPETS WEB RESOURCES:

- Species Monitored Pages, http://limpets.org/sb_species.php
- Student Resources Pages, http://limpets.org/student_resources.php

MATERIALS: Note that the fact sheets and crossword puzzle are also available on the "Student Resources" page of the LiMPETS website.

- LiMPETS Introductory Prezi: Teachers and group leaders receive the password for the LiMPETS Teacher Portal during the LiMPETS Workshops. Prezis are updated annually, and the script is in the Teacher Portal.
- LCD projector, computer, and projection screen
- Sandy Beach Fact Sheet (grades 6–college)
- Pacific Mole Crab Fact Sheet (grades 6–college)
- Field Sampling Techniques: Fact Sheet (grades 9–college)
- LiMPETS Sandy Beach Crossword Puzzle (grades 6–12)

BACKGROUND: You may wish to review Unit 1, "Why Monitor" and "Sandy Beach Habitat", as well as the script for the LiMPETS Introductory Prezi.

PROCEDURE:

- Assign any of the student fact sheets (e.g. Sandy Beach Fact Sheet) for homework or in-class prior to the Prezi.
- Allow approximately 45 minutes of class time to give the Prezi to your students.
- Assign the crossword puzzle for homework to reinforce learning.

EXTENSION ACTIVITIES:

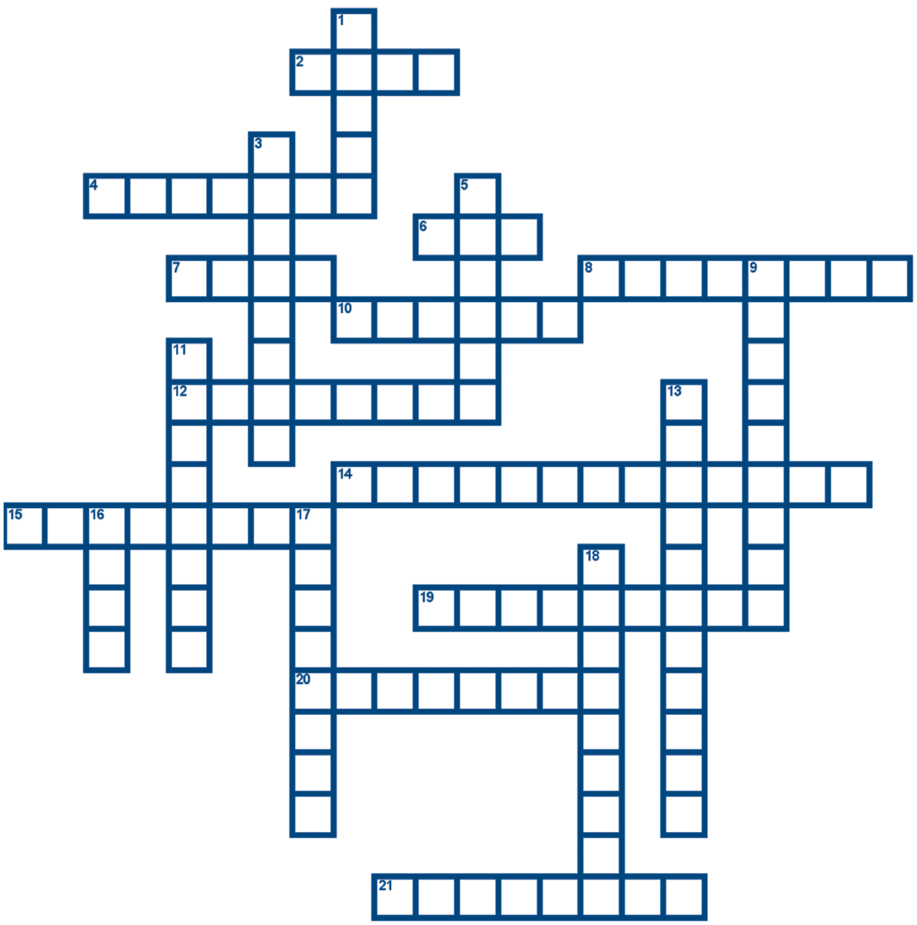
- You may ask students to visit the LiMPETS website, http://limpets.org, to review the "Species Monitored" pages and conduct additional web research on the Pacific mole crab.
- Students can create their own crossword puzzles using a series of "words" and "clues." Many free online puzzle makers exist and can be found with a simple Google Search.

ASSESSMENT: Students complete the Pre-Monitoring Reflection questions on page 29.

AMY DEAN

LiMPETS Sandy Beach Crossword: beaches, mole crabs, and more!

Name ______________________________



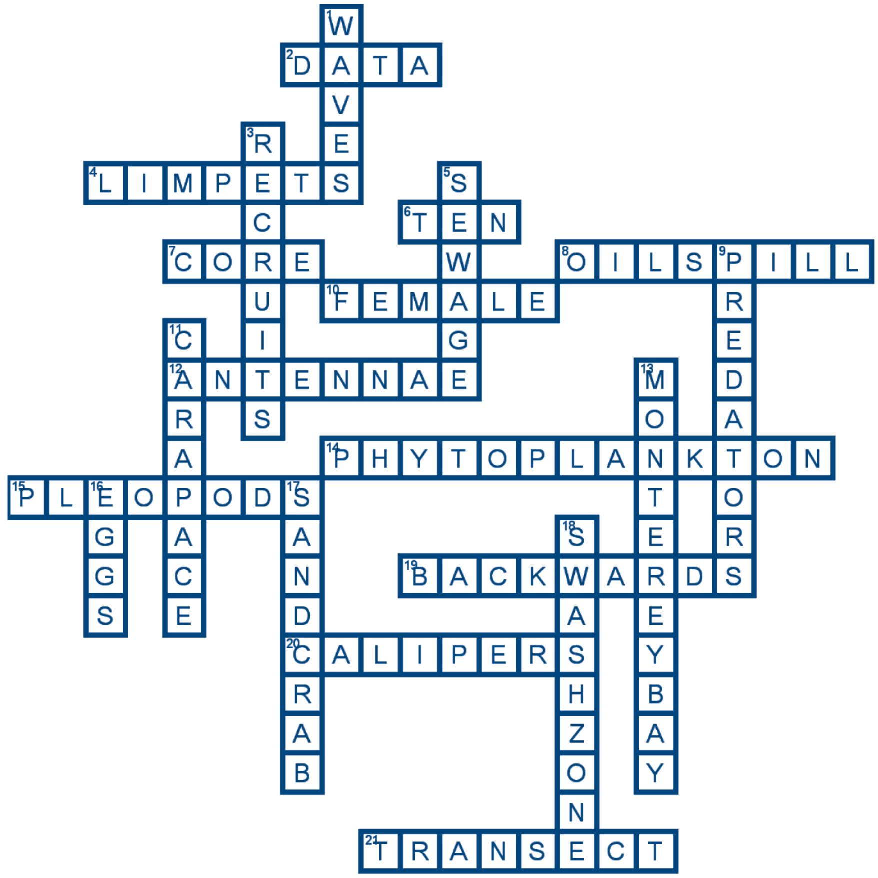
Across →

2. You are helping to collect important, long-term ____ for the sanctuaries
4. Monitoring program acronym
6. Number of legs of mole crabs, crabs, lobsters, and shrimp
7. Scientific tool, for collecting a sample of sand
8. Human-caused threat to beaches
10. Gender of crab that grows biggest
12. Receives radio signals OR feathery appendage for collecting food
14. Favorite food for mole crabs
15. Egg carriers, in females
19. Mole crabs move in this direction only
20. Scientific tool, for measuring
21. A line along which scientists collect data

Down ↓

1. When monitoring, never turn your back to the _____
3. Crabs that just settle on the beach, from the plankton
5. Another human-caused threat to beaches
9. Shorebirds, surfperch, and surf scoters….for mole crabs
11. Don't measure the entire crab — just this
13. National Marine Sanctuary in California
16. Bright orange mass, in females
17. a.k.a. the Pacific mole crab
18. Beach zone covered and uncovered by waves

Crossword Answers



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The Sandy Beach Habitat: Fact Sheet


NOAA

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. 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.

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.

CHAD KING

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

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.

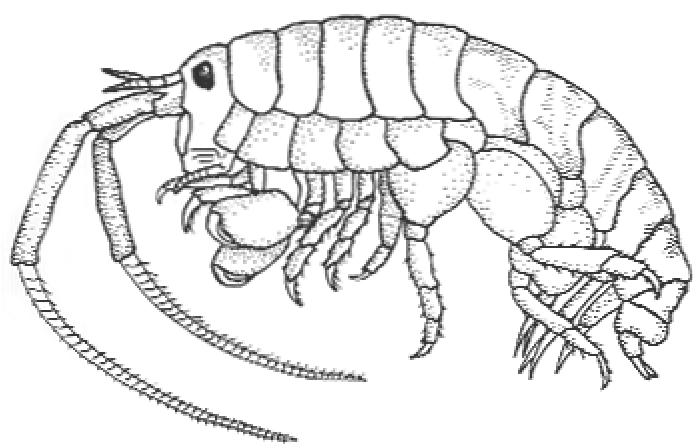
ABOVE THE TIDES: Probably the most familiar birds of the sandy beach are the little Sanderlings. These are the birds that dart back and forth at the edge of the crashing surf, trying to grab an exposed sand crab or worm. Sanderlings' bills are not designed to probe deep into the sand, so they try to 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.

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 head-first deep beneath the high tide line, often under the beach wrack. At night on a falling tide, beach hoppers swarm out to feast.

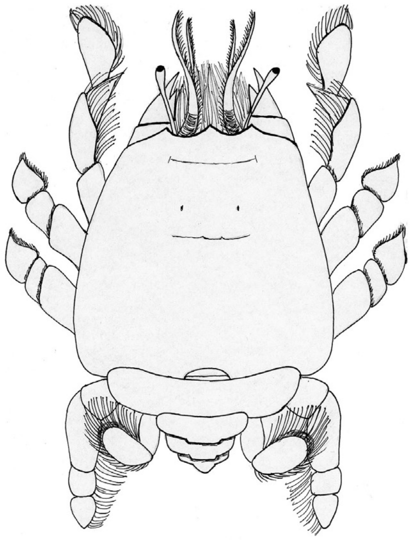
Higher on the beach, above the wrack, small Snowy Plovers, a threatened species, chase about in the dry sand and beach wrack to catch insects and beach hoppers. The most noticeable birds of the beach, and certainly the loudest, are the ubiquitous gulls. These scavengers are opportunists that feed on 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.



During the spring and summer, populations of beach hoppers can eat most of the fresh wrack on the beach in just one night.



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 surfperch 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.

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.

CA COASTAL COMMISSION

"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.

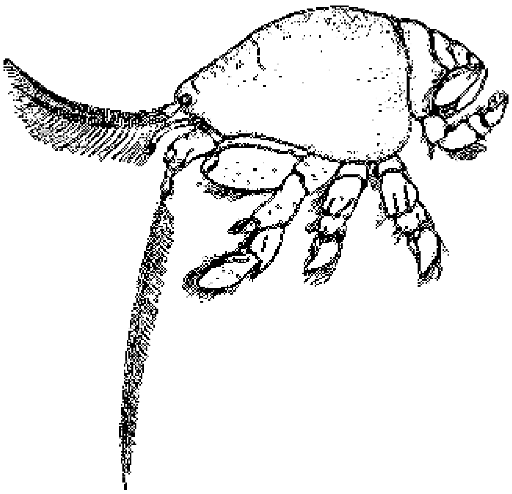
Marine debris comes from two main sources, the land and the ocean. Trash is dumped overboard by ships at sea, carried by rivers and storm drains from inland areas, and deposited directly on beaches by visitors. Regardless of its origin, much of this debris ends up on beaches and can pose a threat to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

Human activites such as burning fossil fuels and deforestation, have lead to a rapid increase in atmospheric carbon dioxide levels. The ocean absorbs approximately 1/3 of the atmospheric carbon dioxide from human activities, or anthropogenic carbon dioxide. Carbon dioxide acts as a weak acid when it dissolves in seawater. The dissolution of anthropogenic carbon dioxide into the ocean is changing ocean chemistry and making it difficult for some organisms to live.

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 that can negatively impact them.

The Pacific Mole Crab: Fact Sheet



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.

The Pacific Mole Crab

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.

Description

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 bright-orange 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. 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.

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 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 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.

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.

Field Sampling Techniques: Fact Sheet


AMY DEAN

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.

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.

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.

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.

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 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.

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 # 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.

Monitoring Mole Crabs in the Classroom

OBJECTIVE: To engage students in a hands-on activity that will introduce them to some of the sandy beach monitoring techniques used in LiMPETS. Students will learn to determine life stage and sex and accurately measure mole crabs with calipers.

ACTIVITY TIME: 10–20 minutes

GRADE LEVEL: 6–college

LIMPETS WEB RESOURCES:

- Sandy Beach Methods, http://limpets.org/sb_methods.php
- Species Monitored Page, http://limpets.org/sb_species.php

MATERIALS:

- Plastic calipers (1 per group of 2–4 students)
- Mole crab cards
- Data sheets, http://limpets.org/sb_data.php (optional)

BACKGROUND: At the beach, students should determine the size and sex of all mole crabs in their samples as accurately as possible. Practice beforehand is key to success. The size is determined by measuring the length of the carapace (to the nearest millimeter) with a caliper. The sex is determined by carefully lifting the telson. Females are identified by the presence of modified legs, or pleopods, under the telson. Ovigerous (egg-carrying) females are identified by an orange mass of eggs. Males lack both pleopods and eggs. Sex cannot be determined if crabs are less than 10 mm. These crabs are called "recruits."

PROCEDURE:

- In preparation for the activity, make color copies of the mole crab cards. Cut photos and paste each photo in the left column to the adjacent photo in the right column (back to back). Each card should show a dorsal and ventral photo of a mole crab on opposite sides of the card. Each student group should have one set of cards.
- Divide class into groups of 2–4 students each.
- Give each group one caliper and a set of mole crab cards.
- Explain to students that they will practice measuring and sexing mole crabs. Demonstrate how to use and read calipers accurately.
- Optional: Put the cards into various numbered containers or sieves to simulate samples 1–10 along the transect. Label containers #1–#10. Students can practice recording their findings on the sand crab data sheet, http://limpets.org/sb_data.php.

EXTENSION ACTIVITIES:

- Ask students to visit the LiMPETS website, http://limpets.org, to review the "Species Monitored" pages and conduct additional web research on the Pacific mole crab.
- If you plan to have your students complete a scientific paper, poster or oral presentation, you may decide to give students a 'question' or a choice of 'questions' to focus on that you have pre-determined. Sample questions are listed in Unit 5 – Communicating Science Through Posters and Oral Presentations.

ASSESSMENT:

- Ask students to compare the accuracy of their measurements with other groups.
- Ask students to complete the Student Reflection 'anticipation questions' on page 29.
- If students will be required to write up a lab report for their LiMPETS investigations at the beach, ask students to write a draft of their "Methods" section prior to monitoring.

Mole Crab Card Answer Key:

1-F35; 2-F18; 3-F28; 4-FE25; 5-M12; 6-M18; 7-M15; 8-R7


1


1


2


2


3


3


4


4


5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8


8

Investigating the "Crab" in Mole Crabs

OBJECTIVE: Students will understand how the anatomy of mole crabs illustrates the complementary nature of structure and function.

ACTIVITY TIME: 20–30 minutes

GRADE LEVEL: 6–8

LIMPETS WEB RESOURCES:

- Species Monitored Pages, http://limpets.org/sb_species.php

MATERIALS:

- Mole Crab Coloring Page and Answer Sheet
- Colored pencils, markers, or crayons

BACKGROUND: Mole crabs certainly don't look (or act) like your typical crab. They lack pinchers, are egg-shaped, and move backwards. So, ARE mole crabs really crabs? What structures and features are different and why?

Because mole crabs are adapted to burrowing on sandy beaches, their body shape and structure is somewhat different than other crab-like crustaceans. Like true crabs, shrimps, and lobsters, mole crabs have ten legs and are classified as decapod crustaceans. However, mole crabs are more closely related to hermit crabs than they are to "true crabs." Pacific mole crabs (family Hippidae) have an egg-shaped body, they have no claws on their first pair of legs, and they have a long telson that is wrapped under the body.

Unlike most other decapods, mole crabs cannot walk or crawl. Instead, they use their legs to dig into the sand or to swim. They have two pair of antennae to gather food and oxygen. The smaller, primary antennae are used to funnel water down to the gills for respiration. The larger, plumose secondary antennae are used for filter-feeding. When the crab is not feeding, it tucks these antennae up under its carapace. Mole crabs have four big pairs of legs and a pair of modified paddles (called uropods) that it uses to swim. A fifth pair of tiny legs is tucked up under the carapace.

PROCEDURE:

- In preparation for the activity, make copies of the Mole Crab Coloring Page.
- Give students the LiMPETS Introductory Prezi and review mole crab anatomy prior to this activity.
- Ask students to complete the Mole Crab Coloring Page in-class or for homework.

SCIENTIFIC CLASSIFICATION

Kingdom: Animalia

Phylum: Arthropoda

Subphylum: Crustacea

Class: Malacostraca

Order: Decapoda

Infraorder: Anomura

Family: Hippidae

Coloring Page Answer Key (for activity on next page):

1. 1-eye stalks; 2-primary antennae; 3-carapace; 4-telson; 5-uropods; 6-thoracic legs
2. The "claws" on true crabs are used for crushing and tearing of food. Mole crabs are filter-feeders and use their antennae to collect food; therefore claws are unnecessary.
3. Carapace-protection; primary antennae-funneling water to gills; uropods-paddles for swimming; thoracic legs-digging and swimming; secondary antennae-filtering plankton; gills-"breathing" oxygen from water.

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 it's corresponding function:

BODY PART

Carapace

Primary (short) antennae

Uropods

Thoracic legs

Secondary (large) antennae

Gills

FUNCTION

Digging and swimming

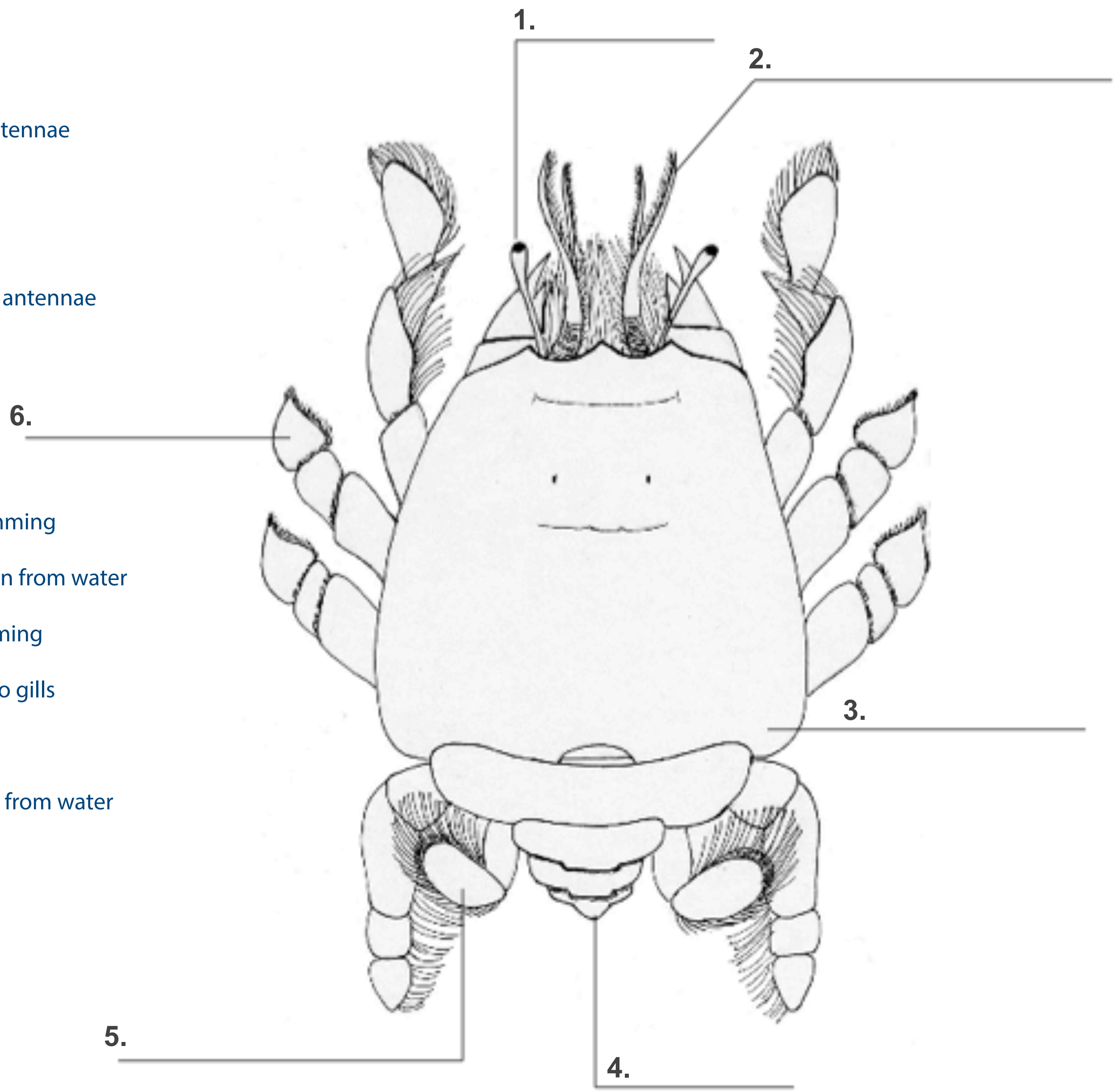
"Breathing" oxygen from water

Paddles for swimming

Funneling water to gills

Protection

Filtering plankton from water



Sandy Beach Food Chain, Trophic Levels, and Biomagnification Game

Author: Gillian Ashenfelter

OBJECTIVE: Students will understand food chains, trophic levels, and accumulation of toxins in a marine ecosystem. Students will learn that trophic levels depend on one another and that small amounts of toxins in organisms at one trophic level can biomagnify as they are passed to higher trophic levels. Students will be active and engaged in a team challenge.

ACTIVITY LENGTH: 30–45 minutes

GRADE LEVEL: 6–9

WEB RESOURCES:

- LiMPETS Species Monitored Pages, http://limpets.org/sb_species.php

BACKGROUND: Mole crabs, or sand crabs, play an important ecological role in sandy beach habitats. On many sandy beaches, mole crabs serve as the main prey for shorebirds, fishes, and mammals. Mole crabs consume phytoplankton and detritus. In this activity, phytoplankton, mole crabs, and Sanderlings (shorebirds) represent a simple sandy beach food chain with three trophic levels.

In addition to food webs and trophic levels, this game introduces students to the concept of biomagnification. Biomagnification refers to the tendency of pollutants to concentrate as they move from one trophic level to the next. This is a concern in coastal ecosystems such as sandy beaches because even small concentrations of chemicals in the environment can find their way into organisms in high enough dosages to cause problems.

The toxin used to demonstrate biomagnification in this game is DDT. This pesticide is known to cause neurological defects and is found in our oceans. In a study testing mole crabs from beaches in central California, every mole crab sample from every beach in the study revealed DDT contamination (Dugan et al., 2005). DDT (dichlorodiphenyltrichloroethane) is an organochlorine insecticide used to control mosquitoes and other insects. DDT is very toxic, very persistent in the environment, and bioaccumulates in many animals to a large degree. DDT commonly degrades to DDE (dichlorodiphenylethylene) in the environment. DDT was banned from use in the United States in 1972; however, it is still found in the environment and it is still used in other parts of the world. DDT is on the list of 12 persistent organic pollutants that are slated for total elimination by the Stockholm Convention on Persistent Organic Pollutants (USGS).

MATERIALS: The following materials are required for a class that can be separated into 5 groups of students. Adjustments may be necessary, depending on class size.

- A cleared space in the classroom (students can help move desks).
- Cards for game play. If different color paper is available, use yellow for sun, purple for nutrients, green for phytoplankton, brown for mole crabs, and grey for Sanderlings.
- 12 copies of the nutrient page cut into individual cards. Phosphates and nitrates (PO_4^-, NO_3^-) are nutrients on all cards. Some cards also include the pesticide DDT ($C_{14}H_9C_{l5}$).
- 4 copies of the phytoplankton page cut into individual cards.
- 4 copies of the sun page cut into individual cards.
- 2 copies of the Pacific mole crab page cut into individual cards.
- 1 copy of the Sanderling page cut into individual cards.
- Copies of the student worksheet (pages 22–23) for each student or team.

PROCEDURE AND GAME RULES:

- Review the following vocabulary with the students: Pacific mole crab, phytoplankton, nutrient, food chain and trophic level.
- Once the room is cleared, desks moved away, scatter cards (nutrient, sun, phytoplankton, mole crab, sanderling) on the floor.
- Divide students into 5 groups and explain how the game is played.
- Tell students that each group is trying to collect enough food to 'feed' a Sanderling. The goal is to collect one Sanderling.
- Team members rotate being the 'gatherer.' Only one team member may be out gathering at a time.
- The 'gatherer' collects cards from the floor and must begin by collecting resources that phytoplankton need in order to photosynthesize – sunlight and nutrient cards. The 'gatherer' must first collect one sun card and three nutrient cards from the floor. Then, he/she is allowed to collect one phytoplankton card before returning to their group with the cards stacked together, phytoplankton on top. The 'gatherer' sits down and another student gathers a sun card, 3 nutrient cards, and a phytoplankton card.
- This is repeated until the group has 3 of these "phytoplankton" stacks. Then, a new gatherer can stack those, collect a mole crab card from the floor, and place that card on top of the stack of "phytoplankton." The process repeats until the group has collected 3 stacks with mole crabs on the top.
- Then, a new gatherer can stack those, collect a Sanderling card from the floor and place it on top of the stack of "mole crabs." The first team to accomplish this wins!
- The winning team's stack of cards should have the following: one Sanderling card, 3 mole crab cards, 9 phytoplankton cards, 9 sun cards, and 27 nutrient cards.
- Remind students that they cannot take another teams cards, nor take cards out of the hands of other students. They may walk quickly, but not run. All students should have a turn being the gatherer of cards.

ALTERNATIVE GAME: (seated at desks, with no running):

MATERIALS: The following is required for a game that includes 24 students divided into 4 groups of 6. Adjustments may be necessary, depending on class size.

- Tables or lab benches to accommodate a group of 6 students (students can help move desks).
- Cards for game play. If different color paper is available, use yellow for sun, purple for nutrients, green for phytoplankton, brown for mole crabs, and grey for Sanderlings.
- 21 copies of the nutrient page cut into individual cards. Phosphates and nitrates (PO_4^-, NO_3^-) are nutrients on all cards. Some cards also include the pesticide DDT ($C_{14}H_9C_{l5}$).
- 7 copies of the phytoplankton page cut into individual cards.
- 7 copies of the sun page cut into individual cards.
- 3 copies of the mole crab page cut into individual cards.
- 1 copy of the Sanderling page cut into individual cards.
- One die for each group of 6 students.
- Copies of the student worksheet (pages 22–23) for each student or team.

PROCEDURE AND GAME RULES:

- Review the following vocabulary with the students: Pacific mole crab, phytoplankton, nutrient, food chain, and trophic level.
- Divide students into groups of six. Within each group, students should pair off into three teams.
- Explain how the game is played.
- Tell students that each group is trying to collect enough food to 'feed' a Sanderling. The goal is to collect one sanderling.
- Place cards in piles on the table. Each group of 6 students needs a stack of: 3 sanderling cards, 9 mole crab cards, 27 phytoplankton cards, 27 sun cards, 81 nutrient cards and 1 die.
- Teams of two take turns rolling the die. The number

they roll is the number of nutrient or sun cards they are allowed to collect in one turn.

- Once a team accumulates 3 nutrient cards and 1 sun card, they can take a phytoplankton card and place it on top of that pile.
- This is repeated until the group has 3 of these stacks. Then, the team can stack those and put a mole crab on that stack. The process repeats until the group has collected 3 stacks with mole crabs on the top.
- At this point, a team can stack those, collect a Sanderling card from the table and place it on top of the stack of "mole crabs." The first team to accomplish this wins!
- The winning team's stack of cards should have the following: 3 mole crab cards, 9 phytoplankton cards, 9 sun cards, 27 nutrient cards.
- Remind students that they cannot take another teams cards, nor take cards out of the hands of other students.

ASSESSMENT:

- After playing the game (but before collecting the game cards), hand out the student worksheet and have students work with their team members to answer the questions. Discuss as a whole class.

ANSWER KEY:

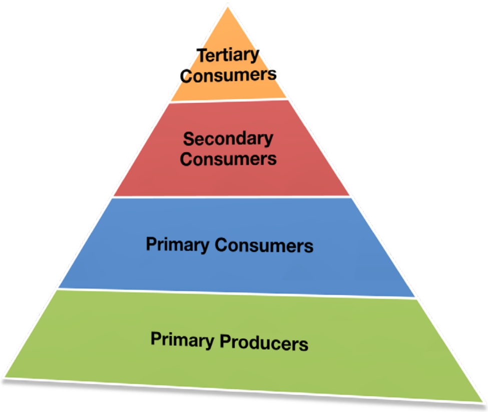
1. Sun > Nutrients > Phytoplankton > Mole Crabs > Sanderling
2. A nutrient-limited ecosystem would directly impact the phytoplankton. Phytoplankton need nutrients to grow and reproduce. When nutrients are in limited supply, you would expect to have less phytoplankton than normal in the ecosystem. The mole crabs and Sanderlings would have less to eat, as a result. Alternatively, when there are too many nutrients, phytoplankton can increase their numbers at an incredible rate — this population explosion is known as a bloom.
3. If mole crab populations declined, Sanderlings would have less to eat. With less food to eat, the birds' growth and reproductive success would be affected, and you might expect to have fewer Sanderlings as a result. With a decline in mole crabs, you might also expect to have more phytoplankton. Why? Because not as much is being consumed by the mole crabs.
4. Level 3 (Sanderlings) required the most energy/nutrients because it is a predator. To attain one Sanderling you needed to acquire 27 nutrient cards and 9 sun cards. Trophic level 1 (phytoplankton) required the least amount of nutrients and energy. Each phytoplankton needed 3 nutrient cards and 1 sun card.
5. Answers will vary. Each group should have approximately 7 total nutrient cards that have DDT on them. Approximately 2 per mole crab and less than 1 per phytoplankton card.
6. The higher an animal is on the food chain, the greater the concentration of DDT in their body as a result of a process called biomagnification. This is important to consider when we eat seafood where food chains tend to be very long and top predators can build up lots of chemicals in their tissues. It is also important to realize that a small amount of pollution diluted in the ocean doesn't always stay diluted but, rather, can biomagnify in organisms.

REFERENCES:

- "Biomagnification Definition Page." USGS Toxic Substances Hydrology Program. Web. 10 Aug. 2010. http://toxics.usgs.gov/definitions/biomagnification.html.
- "DDT Definition Page." USGS Toxic Substances Hydrology Program. Web. 10 Aug. 2010. http://toxics.usgs.gov/definitions/ddt.html.
- Dugan J.E., Ichikawa G., Stephenson M., Crane D.B., McCall J., Regalado K. (2005). Monitoring of coastal contaminants using sand crabs. Final Report. Central Coast Regional Water Quality Control Board, San Luis Obispo, CA, USA.

Sandy Beach Food Chain, Trophic Levels, and Biomagnification Game

Name ____



1. Diagram the food chain you just constructed.

2. Explain what could happen if there were too few nutrients? Which organisms would grow faster if there were too many nutrients?

3. Explain what could happen if the mole crab population declined — who could be affected?

4. The trophic level of a plant or animal is determined by the position it occupies on the food chain. Simple food chains start at trophic level 1 with primary producers, move to primary consumers at level 2, and secondary consumers at level 3. In this game, which trophic level required the most total nutrients/energy to survive? Which trophic level requires the least? Give specific examples using the results (# of cards/ energy needed to feed a mole crab, Sanderling, etc.) from your game.

5. Look closely at your nutrient cards. Not everything on that card is good for those that eat it. Phosphate and nitrate (PO_4^-, NO_3^-) are nutrients that are needed by the phytoplankton to grow, but DDT ($C_{14}H_9C_{l5}$) is a harmful chemical.

   DDT has been used as a pesticide and is still found in the coastal waters of California. DDT can cause bird eggs to crack easily and can lead to brain development problems.

   Separate out the nutrient cards from your stack of cards. Count how many of your nutrient cards have DDT ($C_{14}H_9C_{l5}$).

   Record your answers in the table below:

Table 1. Amount of DDT found in various trophic levels.	
Total amount of DDT cards = amount found in one sanderling (A)	
Divide the total number of DDT cards by 3 to get the average amount of DDT per sand crab (A/3)	
Divide the total number of DDT nutrient cards by 9 to get the average amount of DDT per phytoplankton card (A/9)	

6. What happens to the levels of toxins as they move from one trophic level to the next? Explain why this is important to understand for both wildlife and human health? Hint: What trophic level are humans?

SANDY BEACH FOOD CHAIN GAME: NUTRIENT CARDS

PO_4^{-3}

NO_3^-

PO_4^{-3}

NO_3^-

PO_4^{-3}

NO_3^-

PO_4^{-3}

NO_3^-

PO_4^{-3}

NO_3^-

PO_4^{-3}

NO_3^-

PO_4^{-3}

NO_3^-

PO_4^{-3}

NO_3^-

PO_4^{-3}

NO_3^-

PO_4^{-3}

NO_3^-

$C_{14}H_9C_{15}$

PO_4^{-3}

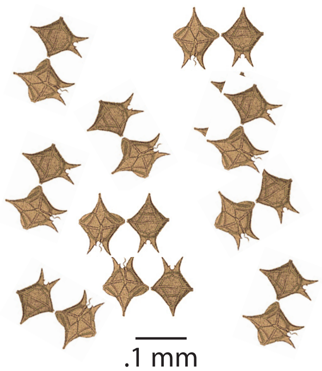
NO_3^-

$C_{14}H_9C_{15}$

PO_4^{-3}

NO_3^-

$C_{14}H_9C_{15}$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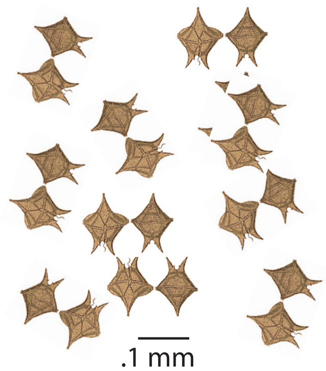
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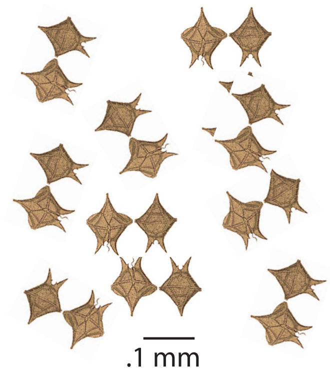
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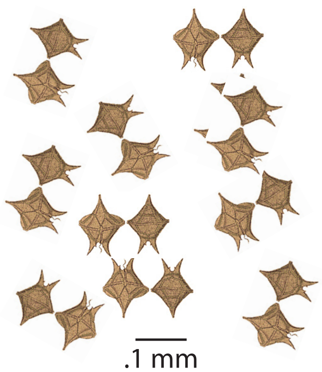
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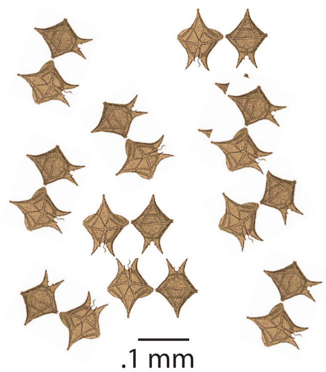
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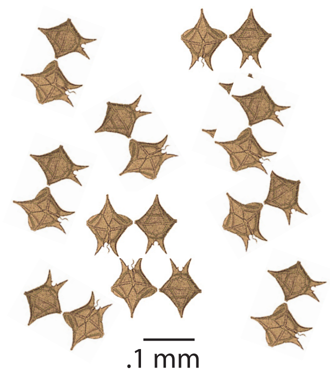
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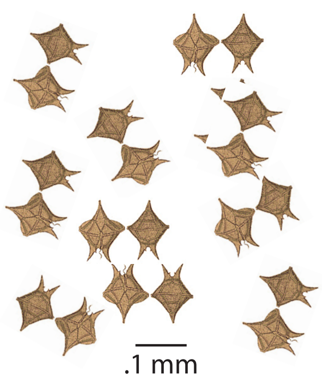
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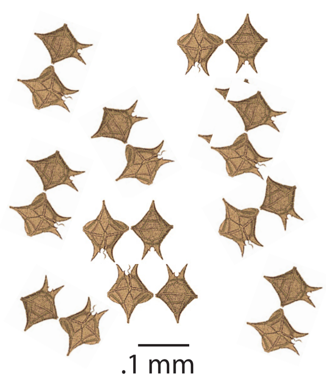
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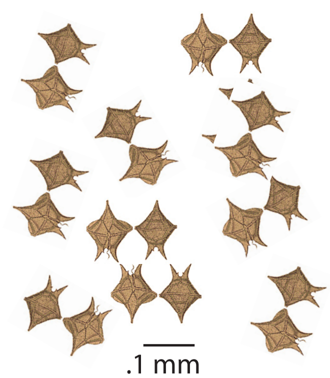
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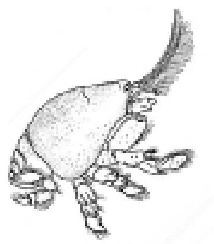
SANDY BEACH FOOD CHAIN GAME: PACIFIC MOLE CRAB CARDS



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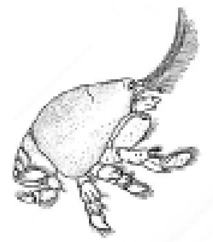

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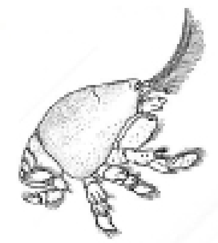

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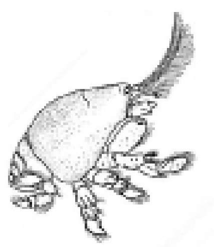

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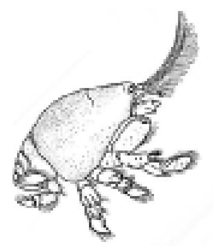

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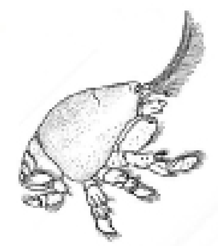

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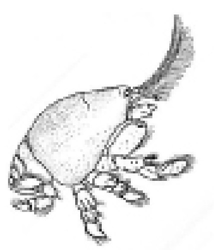

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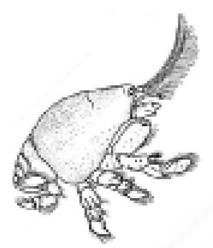

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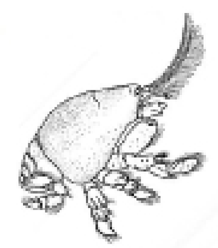

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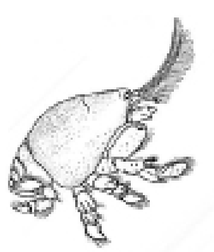

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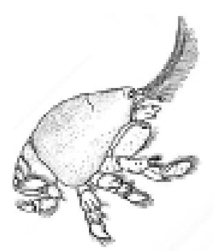

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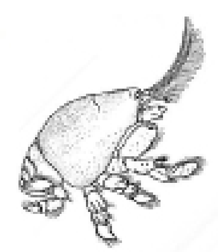

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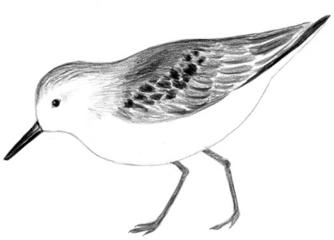

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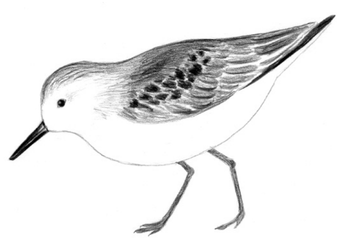

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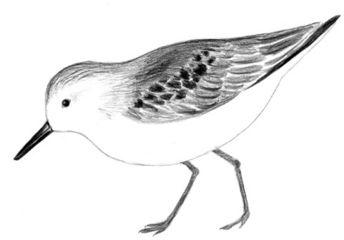

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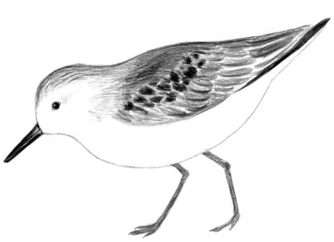

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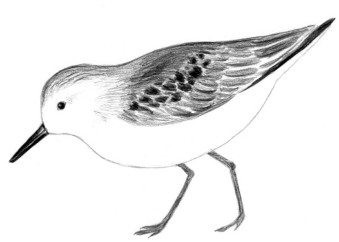

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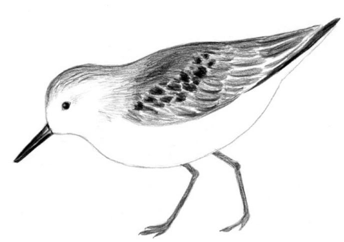

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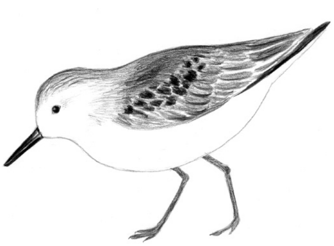

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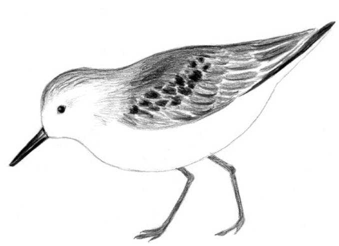

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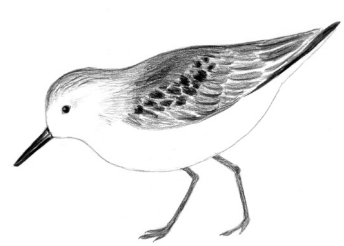

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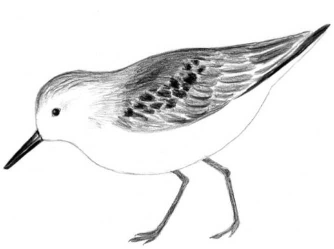

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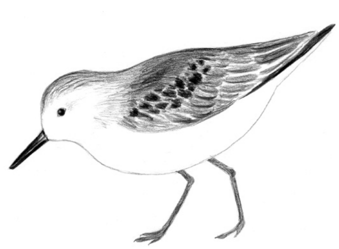

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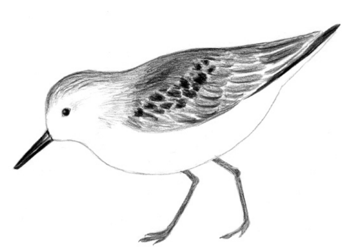

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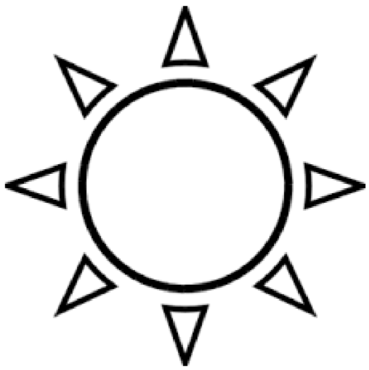
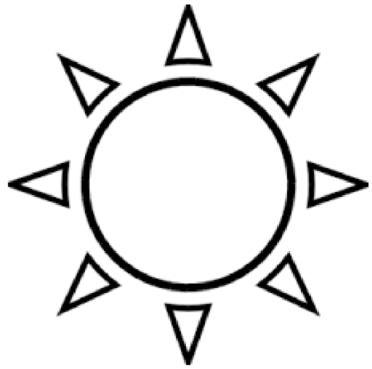
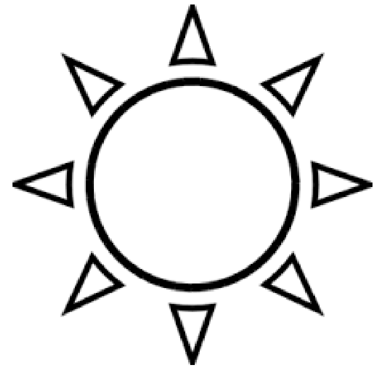
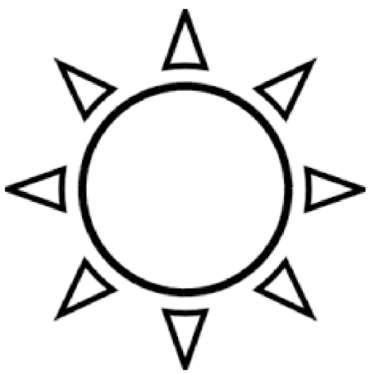
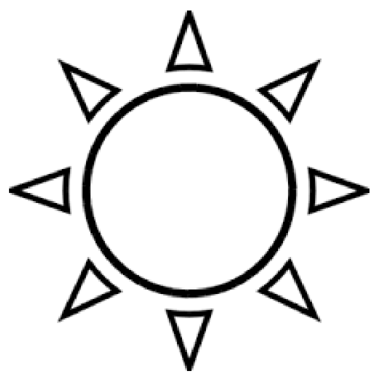
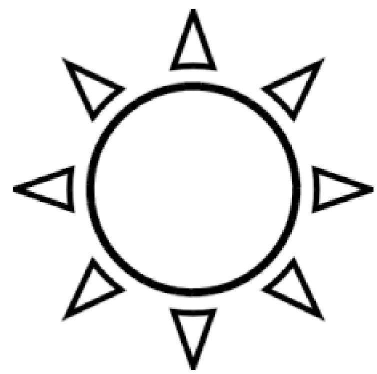
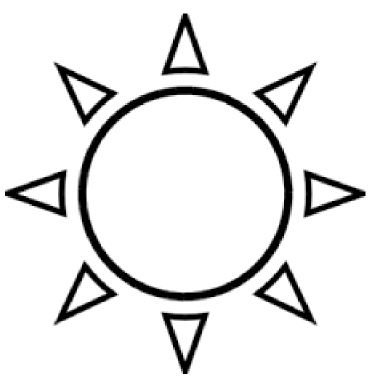
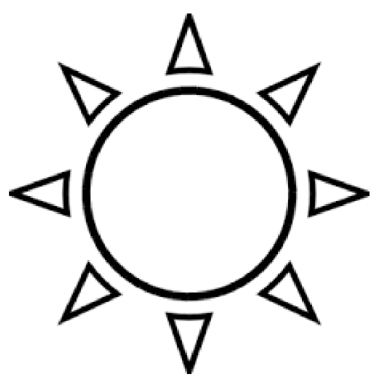
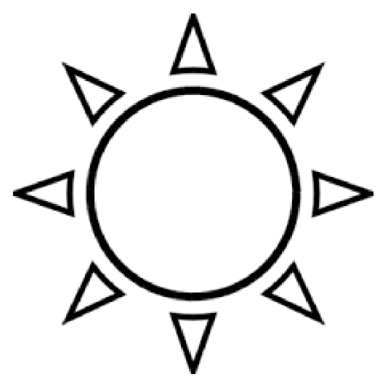
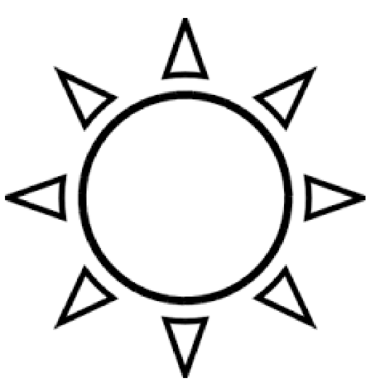
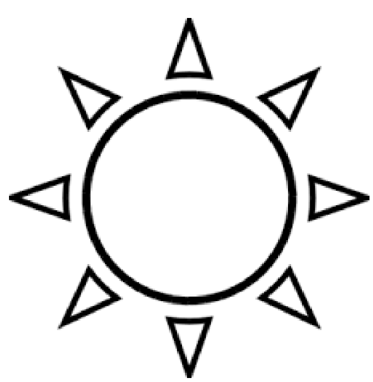
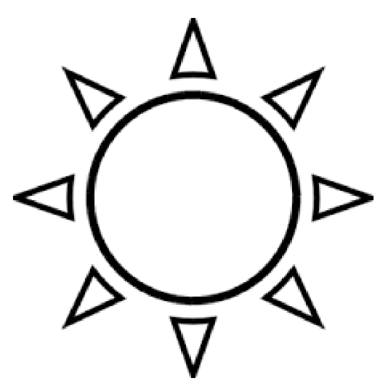

LiMPETS Sandy Beach Monitoring Student Pre- and Post-Activity Reflection

Author: Gillian Ashenfelter

OBJECTIVE: Students will take time to reflect about the value of collecting baseline data through a monitoring program such as LiMPETS. Students will understand that they are learning and providing a service.

ACTIVITY TIME: 15–20 minutes

GRADE LEVEL: 8–12

BACKGROUND:

The values of reflecting on service learning experiences are widely recognized, and literature abounds on the benefits to student learning (Learn and Serve Clearinghouse).

> "Reflection in service-learning provides students and teachers with a way to look back at their experiences, evaluate them, and apply what is learned to future experiences.
>
> Reflection is an important means by which students integrate prior knowledge and experiences with new experiences to develop critical thinking and problem solving skills."

If you have an interest in learning more about the value of reflection in service learning, the organization referenced in this activity has a large number of studies revealing the gains achieved through reflection.

PROCEDURE:

- After introducing students to the LiMPETS program and protocols, give them independent time to work on the pre-trip anticipation questions. This can be a homework assignment. Give students an opportunity to share their thoughts in class with other students if time allows.

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- After the trip, assign students the post-trip reflection questions to be done independently. Again, this can be a homework assignment. Give students an opportunity to discuss their thoughts with other students and facilitate a class discussion. In your discussion, be sure to point out the messy nature of field work and the importance of following protocols to the best of your ability in order to get reliable data.

REFERENCES:

- Learn and Serve America's National Service Learning Clearinghouse. Web. 10 Oct. 2010. http://servicelearning.org.

Reflections on Sandy Beach Monitoring

ANTICIPATION QUESTIONS:

1. What are you expecting this experience to be like? Do you think you will enjoy it?
2. What is the value of monitoring the population of an organism like the mole crab?
3. Why are California's national marine sanctuaries asking students to help gather data?
4. What value will this data have for future scientists?
5. Why is it going to be important for us to follow the procedures carefully when we go monitoring?
6. Do you think you might be interested in a career in the sciences or the environment? Why or why not?

POST-TRIP REFLECTION QUESTIONS:

1. How did this experience compare to your expectations?
2. How is gathering reliable and accurate data in the field (at the beach in this case) different from gathering reliable and accurate data in a classroom?
3. Students monitoring mole crab populations can be called 'service learning.' What do you think that means? Can you explain how monitoring mole crabs is a service learning experience?
4. If you were a teacher, would you take your students sandy beach monitoring? Explain.
5. After participating in 'real field research' through the LiMPETS program, are you more or less interested in science as a career? Why?