Coastal Ecosystem Curriculum:

Sandy Beach Monitoring Teacher Handbook

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Gulf of the Farallones
National Marine Sanctuary

Acknowledgments

This project would not have been possible without the effort from many people and organizations. We would like to thank everyone for their valuable contributions.

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The sandy beach advisory committee includes the following people:

Sarah Allen	National Park Service – Point Reyes National Seashore
Candice Brown	Exploratorium
Maria Brown	Farallones Marine Sanctuary Association
Cathleen Cannon	Lepus californicus
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Darren Fong	National Park Service – Golden Gate National Recreation Area
Trina Kvale	Golden Gate National Recreation Area – Ft. Funston
Jan Roletto	Gulf of the Farallones National Marine Sanctuary
Paul Wong	Gulf of the Farallones National Marine Sanctuary

Every member was helpful in giving guidance and suggestions to improve the project in a scientific and educational manner.

Finally, Jennifer Saltzman deserves thanks for developing this monitoring project. Her guidance on this handbook was also appreciated.

Sue Magdziarz
Education Specialist and Co-Project Developer
Farallones Marine Sanctuary Association
2001

Standards Covered at High School Level
from Science Content Standards for California Public Schools

The Sandy Beach Monitoring Project will help your students achieve the following educational standards. These standards are from the Science Content Standards for California Public Schools. Performance standards, indicated by bullets after each content standard, are specific for each activity.

Investigation and Experimentation

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. Students will:

a. Use appropriate tools and technology to collect data, analyze relationships, and display data.

- Students will know the correct procedure for monitoring sand crabs. They will be able to collect samples and record data without guidance from staff.
- Students will enter data into the computer, graph the trends, and calculate the density of crabs.
- Students will display and analyze the results from the entire year.

b. Identify and communicate sources of unavoidable experimental error.

- Students will record sources of error while monitoring, such as loss of sand during collection or loss of crabs when measuring.

c. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.

- Students will record uncontrolled conditions that cause errors in the data collection or recording.
- Students will evaluate the impact of the error on the data analysis (if some data are missing because the smaller crabs were lost when a wave emptied the sieve, the calculated abundance will be less than the actual abundance and the length frequency distribution will be shifted toward the larger crabs).

i. Analyze the locations, sequences, or time intervals that are characteristic of natural phenomena.

- Students will describe the seasonal cycle of the sand crabs in relationship to seasonal oceanographic conditions.

Biology/Life Sciences

6. Ecology. Stability in an ecosystem is a balance between competing effects. Students will:

b. Know how to analyze changes in an ecosystem resulting from changes in population size.

- Students will describe the population size of sand crabs and explain how the population changes along the beach and during the year.

c. Know how fluctuations in population size in an ecosystem are determined by the relative rates of birth, immigration, emigration, and death.

- Students will discuss the changes in the sand crab population. They will know the number of eggs a female carries and the life span of males and females.
- They will discuss why the females carry 50-45,000 eggs and what the pelagic life stages are.
- They will know the predators and parasites, which increase the death rate.
- They will understand how the chemical domoic acid can be passed from the crab's prey to the crab's predator.

Feedback and Evaluation of the Coastal Ecosystem Curriculum

Name (optional) _____
School/Organization _____
Mail Address _____
Email Address _____
Grade/Subject _____

Thanks for your interest in the Coastal Ecosystem Curriculum:Sandy Beach Monitoring Teacher Handbook. We would like your assistance in improving this curriculum. Your responses may be incorporated into future printings of this and other educational material. Please mail this form to: Education Coordinator, Farallones Marine Sanctuary Association, P.O. Box 29386, San Francisco, CA 94129.

What were your goals and objectives for using these materials?

Which activities did you use? How well did they work (rate 1-6, 6 is very well)? Do you have any suggestions for adaptations, extensions, or ways to improve the activities?

Evaluation continued on next page.

How useful was the background information?
not useful 1 2 3 4 5 6 very useful did not use

Did your students gain a better understanding about the coastal ecosystem? How did you evaluate your students?

Did you use the books and resources lists, website lists, or speaker lists? Were they useful? Please circle your response and comment.

books and resources lists: not useful 1 2 3 4 5 6 very useful did not use

website lists: not useful 1 2 3 4 5 6 very useful did not use

speaker list: not useful 1 2 3 4 5 6 very useful did not use

Do you plan to use this curriculum in the future? Why or why not?

Did this curriculum help you teach the California Standards? Which ones?
not useful 1 2 3 4 5 6 very useful does not apply

How can we further assist you? What type of supplemental information would you like? (please include your contact information)

Any other comments or suggestions

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1. Introduction

The sandy beach monitoring project is a long-term, baseline study. It offers high school students an excellent opportunity to learn about the sandy beach ecosystem as well as monitoring techniques and data analysis. The purpose of the project is to collect distribution and abundance data on the Pacific mole crab, *Emerita analoga*. This project requires at least one training session and monitoring at a beach three times per year. A significant time commitment is required from both the teacher (approximately 20 hours) and students (approximately 15 hours).

The overall goal of the project is to assess changes in the sandy beach environment that might affect the coastal birds that depend on the environment. The following questions will be answered through monitoring.

- What is the community of sand crabs? Described in terms of the crabs' size, gender, and reproductive status.
- What is the abundance of sand crabs? Described in terms of density.
- What is the distribution of sand crabs along a transect?
- How does the community of sand crabs change throughout the year?

You may choose to extend this project by adding a stewardship component. Your students may want to share their monitoring results with the community. They can do this in a variety of ways, including designing a kiosk, posting the information on the Internet, and presenting at Sanctuary symposiums.

This project is funded by the T/V *PUERTO RICAN* Oil Spill Restoration Fund. The *PUERTO RICAN* was a tanker vessel (T/V) that spilled 1.4 million gallons of oil into the Gulf of the Farallones in 1984. The oil injured and killed many birds in the area, including Common Murre, Cassin's Auklets, Pacific Loons, Western Grebes, Western Gulls, Eared Grebes, and Surf Scoters. The oil also washed onto beaches in the Gulf of the Farallones National Marine Sanctuary. This project is part of a curriculum that educates San Francisco Bay Area high school students about the local coastal ecosystem.

This handbook includes background information on the sandy beach environment as well as instructions on how to monitor sand crabs at a sandy beach. If you have any questions, please contact the education coordinator or the education specialist at the Farallones Marine Sanctuary Association (FMSA) at (415) 561-6625.

2. National Marine Sanctuaries

(Excerpted from *A Tour of the Sanctuaries*, brochure published by NOAA.)

In 1972, in response to a growing awareness of the intrinsic environmental and cultural value of our coastal waters, Congress passed the Marine Protection, Research, and Sanctuaries Act. The Act authorizes the Secretary of Commerce to designate discrete areas as National Marine Sanctuaries to promote comprehensive management of their special conservation, recreation, ecological, historical, research, educational, or aesthetic resources. National Marine Sanctuaries may be designated in coastal and ocean waters, in submerged lands, and in the Great Lakes and their connecting waters. Since the Act was passed, thirteen National Marine Sanctuaries have been designated (Figure 1). National Marine Sanctuary Program(NMSP) is administered by the National Ocean Service (NOS) of the National Oceanic and Atmospheric Administration (NOAA) in the US Department of Commerce. The mission of the Sanctuary Program is to manage ocean, coastal, and Great Lakes areas of special national significance to protect their ecological and cultural integrity for the benefit of current and future generations.

These protected waters provide a secure habitat for natural processes to occur, serve as a safe haven for species that may be threatened or endangered, and protect historically significant shipwrecks and prehistoric artifacts. They serve as natural classrooms and laboratories for school children and resources alike. Sanctuaries are also cherished recreational spots for diving and sport fishing, and support valuable commercial industries such as fishing and kelp harvesting. Thus, part of the challenge of managing these areas is balancing environmental protection with sustained economic use. Sanctuary management policies, practices, and initiatives ensure that human activities affecting Sanctuaries are compatible with long-term protection of Sanctuary resources.

Gulf of the Farallones National Marine Sanctuary

The Gulf of the Farallones National Marine Sanctuary (GFNMS) encompasses 948 square nautical miles (3251 km^2) of nearshore and offshore waters off the California coastline west of San Francisco, from Half Moon Bay to Bodega Head (Figure 2). Designated in 1981, the Sanctuary consists of the offshore marine region surrounding the Farallon Islands, as well as the nearshore areas of Bodega Bay, Tomales Bay, Drakes Bay, Bolinas Bay, Estero de San Antonio, Estero Americano, Duxbury Reef, and Bolinas Lagoon. This spectacular environment is home to a fascinating array of plants and animals. GFNMS supports 20% of California's breeding harbor seals and the largest concentration of breeding seabirds in the contiguous United States. Thirty-six species of marine mammals, including endangered blue and humpback whales, live in, feed in, or migrate through the Sanctuary waters. A complete spectrum of marine habitats including estuarine, intertidal, pelagic, and deep oceanic environments can be found within the Sanctuary.

Within GFNMS are habitats, nurseries, and spawning grounds for commercially valuable species such as Dungeness crab, Pacific herring, and rockfish. The area is the most heavily used fishing ground on the contiguous West Coast of the United States, supporting many large commercial fisheries based out of San Francisco and Bodega. Also contained within the Sanctuary boundaries are the West Coast's busiest shipping lanes. Whale watching, bird watching, and offshore excursions are other uses of the Sanctuary that are steadily growing in popularity. The Sanctuary also serves to protect beaches, bays, and lagoons within its boundaries as areas of public recreation and access to the marine environment. Successful management of the Sanctuary depends on a careful balance of multiple use.

The Gulf of the Farallones National Marine Sanctuary's resources are managed and protected through research and education programs, as well as through regulations. Specific regulations for the Sanctuary include:

- prohibition of oil and gas exploration and development activities;
- prohibition of discharges;
- prohibition of seabed alteration or construction;
- prohibition of oil tankers, barges, and merchant vessels within two nautical miles of the Farallon Islands, Bolinas Lagoon, and Areas of Special Biological Significance;
- requirement of aircraft to maintain an altitude of at least 1000 feet within one nautical mile of biologically sensitive areas to avoid disturbing marine mammals and seabirds; and
- prohibition of damaging or removing historical or cultural resources.

Farallones Marine Sanctuary Association

The Farallones Marine Sanctuary Association (FMSA) is a non-profit, membership organization incorporated on May 25, 1995. FMSA is a cooperating association and was established to provide financial and programmatic support to the Gulf of the Farallones National Marine Sanctuary and the areas it manages. This includes the Cordell Bank National Marine Sanctuary and the northern part of the Monterey Bay National Marine Sanctuary. FMSA's goals for the Gulf of the Farallones National Marine Sanctuary and the area that it manages include:

- to increase the awareness and appreciation of the area;
- to educate the San Francisco Bay Area residents and visitors about its resources;
- to increase stewardship;
- to increase research and monitoring of resources;
- to maintain a cadre of trained individuals to respond to environmental emergencies.

Figure 1. The National Marine Sanctuaries of the United States

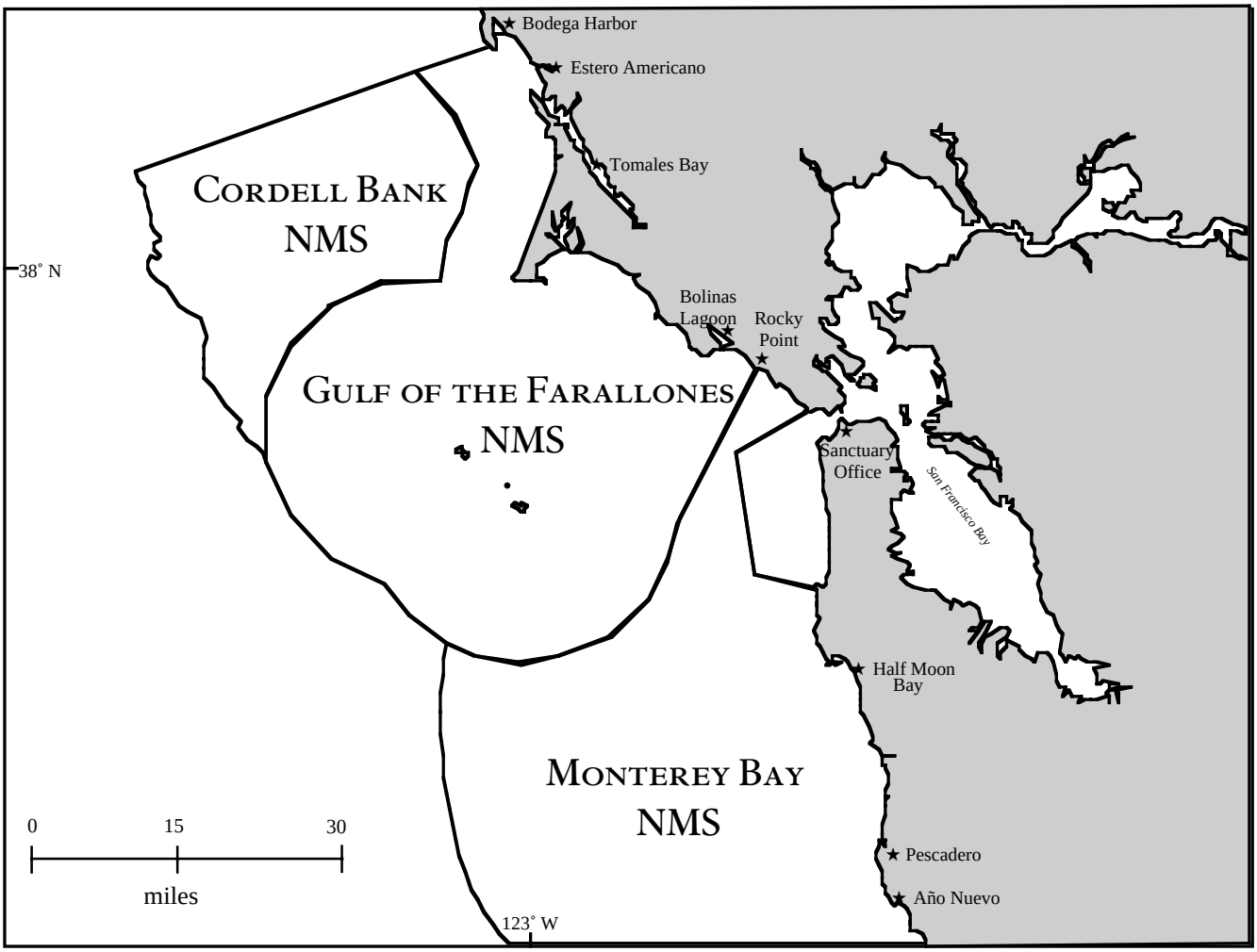


Figure 2. Boundaries of the three Sanctuaries managed by the Gulf of the Farallones NMS office.

Glossary of Terms
Sandy Beach Monitoring

Aggregation	a high density of sand crabs. Sand crabs are not distributed evenly across a beach. This means that at one location you may not find crabs, while a few feet away you may find hundreds. The reason for these aggregations is not clear. It may occur becauseof physical factors such as waves or biological reasons such as protection from predators.
Baseline data	data that is collected over a long period of time. This type of data can provide information on natural fluctuations over time. A change in the environment may be detected in an analysis of many years of data.
Carapace	the section of the exoskeleton that is on the dorsal side of a sand crab. This part of the sand crab will be measured.
Exoskeleton	hard external skeleton that encloses the body of an animal. Most arthropods have this type of covering. It doesn't grow, so an animal, such as a sand crab, sheds its exoskeleton (molts) and replaces it with a larger one in order to grow.
Larvae	pre-adult life stages of an animal that do not resemble the adult form.
Molting	shedding an exoskeleton. An animal sheds its exoskeleton as it grows and replaces it with a new one.
Ovigerous	the state in which a female is carrying eggs.
Plankton	organisms that have little to no control over the direction they travel in the ocean, they drift in the open water. Sand crab larvae are planktonic.
Pleopods	abdominal paired appendages. A female sand crab uses 3 pairs of pleopods to hold on to her eggs. The pleopods resemble short threads and can be seen when the telson is gently lifted from the crab's body.
Primary antennae	the antennae on a sand crab that are used for respiration. A crab extends these antennae above the surface of the sand to get oxygen from the water.
Recruits	sand crabs that have recently settled on the beach. A recruit's carapace is less than 9 millimeters long. At this size it is not possible to determine if the crab is male or female. They are called recruits, because they are recruited from the plankton to the beach.
Secondary antennae	the antennae on a sand crab that are used for feeding. When a wave returns to the ocean, a crab unfurls its secondary antennae and collects plankton from the water. It then pulls the antennae to its mouth parts which scrape off the plankton.

Swash zone	the area of the beach that falls between the highest and lowest point of the waves at any given time. The extent of the swash zone changes with the tide.
Telson	the part of the sand crab that looks like a tail and folds under the crab. It is used to help the crab swim backwards, and eggs can be found underneath the telson on female crabs. The telson is lifted to determine the gender of a sand crab.
Transect	a line that is used in monitoring. In this project, it is a line perpendicular to the ocean and the samples are taken along it.

Introduction to Sandy Beach Monitoring Slide Show

Slide # & Topic (photographer)	Script *(italicized words in glossary)*
1. Title slide	The sandy beach monitoring project is designed to give you the opportunity to participate in a monitoring project. One of the goals of the project is to collect *baseline data* on sand crabs. Baseline data provides information over a long period of time. This can be helpful in the future and will allow comparisons to past years if a drastic change occurs. The information from this project will be given to the Gulf of the Farallones National Marine Sanctuary for management purposes and for reference in the event of an oil spill. With this data, they can compare the number of sand crabs before and after an oil spill at a beach the students have monitored.
2. Local Sanctuaries	You will be working with the Farallones Marine Sanctuary Association which is a non-profit organization that supports the Gulf of the Farallones National Marine Sanctuary. There are three National Marine Sanctuaries off of the coast of the San Francisco Bay Area. Sanctuaries are federally designated to protect the resources of the marine environment.
3. Objectives text	The main goal of the project is to describe the sand crab community at a beach. This is done by recording the size, gender, and reproductive status of the crabs that are collected. The abundance of crabs will be described in terms of density along the beach. We will investigate the distribution of crabs along transects that are perpendicular to the shoreline. By monitoring at different times of the year, we can observe changes in the community between seasons.
4. Sand crabs in a container	Here are the sand crabs that we will be monitoring. They are also called the Pacific mole crab, and their scientific name is *Emerita analoga*.
5. Swash zone	Crabs can be found onshore between April and October. They live on sandy shores in the *swash zone*. The swash zone is the area from the highest point of the waves to the lowest point, at any given time. This means that the location of the crabs changes with the tide. The crabs tend to live in *aggregations* along the beach. One location may not have any crabs and a few feet away there may be hundreds. The crabs burrow backwards into the sand and live just a few centimeters beneath the sand.

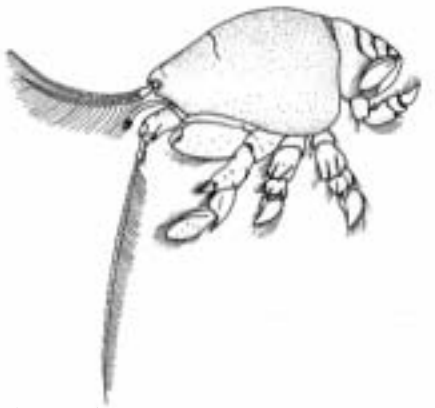
6. Text	This species of sand crab lives along the eastern edge of the Pacific Ocean in both the northern and southern hemispheres.
7. Spiny mole crab (J. Hall)	You may find the much larger spiny mole crab (*Blepharipoda occidentalis*) in the subtidal zone. It can grpw to 6 cm in length and feeds on dead *Emerita*. While walking along the beach, you may find molts from both of these crabs. As they grow, they shed their exoskeleton and grow a new one. You may even collect some crabs that have recently molted and have a soft shell.
8. Pelagic larval crabs	Reproduction occurs from February through October. Females carry the eggs for about one month. Once the eggs hatch, the *larval* forms are *planktonic* and they drift in the ocean for about 4.5 months. They go through 8-11 developmental stages and may drift far off shore. In the early summer and fall, the larvae that are fortunate enough to drift back near the shore begin to settle on a beach. Sand crabs are between 4 and 8 mm in length at the time they settle on the beach and are called *recruits*. At this size it is not possible to determine if a crab is male or female. Once a crab reaches 9 mm in length, its gender can be determined.
9. Adult crab	Adult female crabs can be up to 35 mm in length and males can reach 22 mm. They have two sets of antennae. The *primary antennae* stick above the sand and are used for respiration. The *secondary antennae* are used for feeding. The *carapace* is the hard covering on the top of the crab. That is the part that you will measure to determine the size of the crab. Female crabs attach their eggs to the *pleopods* found under the telson.
10. Wave	In the winter months, storms move sand off of the beach and into offshore sand bars. The crabs move with the sand, and that is why we won't be monitoring during the winter. When the gentle waves of spring return, the sand and crabs are moved back on to the beach.
11. Dinoflagellates	Sand crabs are small animals and they eat very small organisms. The crabs burrow backwards into the sand, facing the ocean. When a wave is returning to sea, the crabs unfurl their secondary antennae to filter the plankton, such as these dinoflagellates, out of the water.
12. Shorebirds	Shorebirds are predators of the sand crab. Sanderlings and Willets use their beaks to dig into the sand to find sand crabs.
13. Surfperch (T. Chess)	Other predators include surfperch (sand crabs make up 90% of its diet), ...
14. Surf Scoter	Surf Scoters, and...

15. Sea otter (J. Roletto)	sea otters.
16. Sampling scheme	Now, let's move on to what you will be doing at the beach. This figure shows how we will set up the sampling area. First, a 50 m rope will be laid onto the sand, parallel to the shoreline. This is the sampling area, and the rope is marked at each meter. Each group will be assigned a random number, and that is where they will collect samples. You will stretch out the group's 10 m rope perpendicularly to the 50 m survey area rope.
17. Sample set-up	This is a group that monitored at Stinson Beach. Each row of flags represents a separate group of students.
18. Equipment	Here you can see some of the equipment you will be using. A sampling tube will be used to collect the sand. There are two sieves that are used to separate the crabs from the sand. One sieve has a larger mesh than the other so that a wider range of sizes of crabs can be collected.
19. Setting up a transect	Once you are standing at the spot that corresponds to your random number the rope should be laid out perpendicular to the survey area rope. The flags are placed one meter apart from each other. The lowest flag along the transect should be where the average height of the water is 0.25 m. You can estimate this by going to where the water level is at the middle of your calf. The highest flag along the transect should be placed approximately 5 m above the swash zone. Once the flags are in place, the rope should be removed.
20. Transect	A sample is collected by pressing the sampling tube 10 cm into the sand and carefully picking up the sand.
21. Sampling	After a sample is taken, the sand is placed into the stacked sieves.
22. Rinsing	Water is then poured over the sand. The sand will fall through the sieves...
23. Crab in sieve	and the crabs will be caught in the sieves.
24. Measuring	Next, each crab must be measured. The entire crab isn't measured, just the carapace. The carapace is the outer covering of the crab.
25. Carapace length	This is a diagram of the points between which you should measure. Start at the points between the eyes and measure to the notch at the back of the carapace. You will use calipers to measure the carapace to the nearest millimeter. If the carapace is under 9 mm, the gender cannot be determined and it is called a recruit. If the carapace is 9 mm or larger...
26. Lifting telson	You must determine the gender of each crab. This can be done by gently pulling the *telson* (the tail-like part) away from the underside of the crab.

27. Female with eggs	This is a female that is carrying eggs. Females can produce one clutch per month of 50-45,000 eggs. If the orange eggs were not present, you would have to look more closely to determine each crab's gender.
28. Male vs. Female	If an adult female is not carrying eggs, you will be able to see the pleopods under her telson. There are six pleopods and they resemble short threads. When a female is carrying eggs, she attaches them to the pleopods. If you lift the telson on an adult crab ($\geq$ 9mm) and do not see any pleopods, the crab is a male. Make sure to look carefully, especially on the smaller crabs, because sometimes the pleopods are hard to see. Be sure to ask for help if you are unsure.
29. Group of students	Each group will have 4-5 students. Each person will have a responsibility. It is important that your team works together. You can switch jobs with your team members, but remember that this project does require team work and everyone should be actively involved.
30. Data sheet 2	This is the data sheet on which the information about each sample will be recorded. It requires some explanation, so we will now review this data sheet. (The teacher should now review the data sheet and explain the main points—fill out the top portion of the data sheet, explain the code, explain the zones, explain how to record each sample, and explain the tally column.)
31. Data sheet 1	This is the sampling conditions data sheet. Let's review it. (The teacher should now review this data sheet with the class. Explain that this gives weather conditions on the monitoring day. This information may be able to help explain some types of observer biases or other variables. This data sheet is also used to record information on the location of the transects.)
32. Graph of data	One part of this project is the field work and just as important to the project is analyzing the data back in school. You will be entering your data into the computer, which will graph the abundance and length frequency for you. This graph shows the size frequency of the collected crabs. How many crabs were 15 mm long? (2 males) How many were 33 mm long? (3 females with eggs)
33. Final Projects	After the monitoring is complete, there are many other things you can do. Here are a few ideas.
34. Future additions	In the future, the Gulf of the Farallones National Marine Sanctuary and the Farallones Marine Sanctuary Association would like to add these projects. It may be possible to work with a university and have the crabs that you collect help them with their research.
35. Beach	We hope that through this project you will gain an appreciation for the sandy beach ecosystem.

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. Animals have to deal with crashing waves, changing tides, a beach that changes seasonally, and marine and terrestrial predators. The animals that live in this environment are buried in the sand. They all have adaptations that help them survive in the sandy beach ecosystem. It is in this environment that the Pacific mole crab can be found.



The Pacific Mole Crab

The Pacific mole crab (*Emerita analoga*), also known as the sand crab, is a common inhabitant of 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 live in the swash zone of the sandy beach intertidal zone. The swash zone ranges from the lowest to highest reaches of the waves at any given time. Because the swash zone changes with the tide, so does the location of the sand crabs.

Description

The sand crab is small in size, growing up to 35 mm long and 25 mm wide. It is gray or sand colored and does not have claws or spines. Like other crustaceans, they 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 major differences. Females are larger with a carapace length of 14-35 mm, and the males reach 10-22 mm. If a female is carrying eggs, they will be found under the telson and will be a bright-orange mass. If a female is not carrying eggs, the pleopods to which she attaches eggs will be visible on the underside of the crab when the telson is lifted. There are three pairs of pleopods, and they resemble short threads.

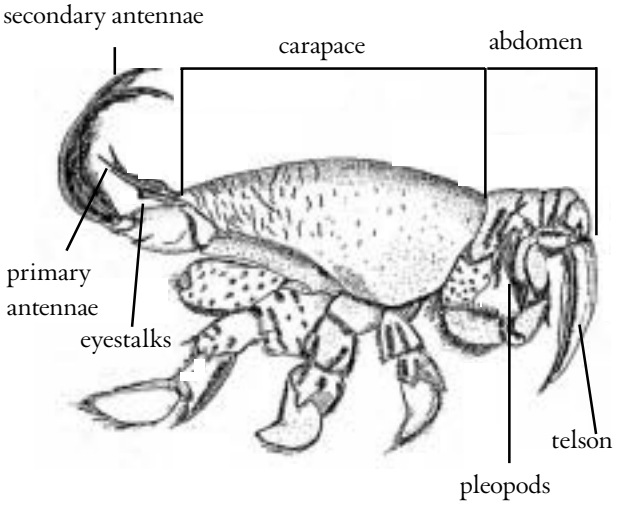
The crab spends most of its time buried in the sand. It has five pairs of legs that allow it to swim, crawl, and burrow, which are all done backwards. Its eyestalks reach above the sand. The first pair of antennae reach above the sand for respiration, and the second pair, resembling feathers, are extended when the crab feeds. The antennae collect small organisms, mostly dinoflagellates, then they are pulled into the body, and the food is scraped off. The food size ranges from 0.004 mm to 2 mm in diameter.

Emerita resembles another species of sand crab that live along the shore, the spiny sand crab, *Blepharipoda occidentalis*. This crab lives deeper in the subtidal zone and can reach 6 cm in length. The adult *Blepharipoda* feed on dead *Emerita*.

Natural History

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

During the reproductive season (February-October), females can produce one clutch per month of 50-45,000 eggs, which take approximately 30 days to develop. Once the eggs hatch, the larvae are plank-



Female *Emerita analoga*

tonic for about 4.5 months. They go through 8-11 larval stages, and during this time may drift far offshore. When they near the end of their larval stage, they hopefully return to nearshore waters. When the larvae settle onto the beach, it is called recruitment, and the crabs are considered "recruits." Recruitment can occur year-round, but large numbers of recruits are found in early summer and in the fall. The crabs move up and down the beach with the tides. Crabs move when the water rushes over the sand. Crabs also move down the length of a beach with longshore currents. These currents are created because waves approach a beach at an angle. As a wave returns to sea, it takes sand and crabs with it. The next wave goes in at an angle farther down shore and deposits the crabs in a new location.

Sand crabs are not distributed uniformly across a beach. Females are found lower in the intertidal zone than males and recruits. The crabs form large aggregations along the shore that are not uniformly spaced. Scientists have proposed biological reasons for this, such as predator avoidance and an advantage for mating. Physical reasons, such as 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 vary drastically from year to year, depending on environmental factors.

Predators and Parasites

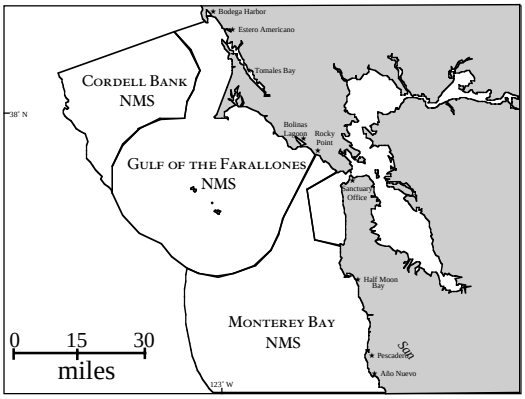
The main predators of the sand crab are fish, water birds, and shorebirds. Fish provide the greatest threat, and this may explain why sand crabs are mostly in the upper intertidal zone. The barred surfperch is a very common fish in the surf zone, and sand crabs have been found to make up 90% of its diet. The California corbina is another fish that eats sand crabs. Shorebirds, including sandpipers, Sanderlings, godwits, Blackbellied Plovers, Willets, and curlew, have been seen feeding on crabs within the swash zone. The Surf Scoter, a water bird, also feeds on sand crabs. The sea otter is a mammalian predator.

Sand crabs are known to carry parasites. They are an intermediate host of parasitic 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 have been known to kill these predators.

Sand crabs are used by humans in a variety of ways. They are used as bait by fishermen. In southern California, approximately two million *Emerita* were taken for bait in one year. They have also been used to indicate levels of DDT and domoic acid in the waters off of California. Domoic acid is a neurotoxin produced by diatoms, a type of phytoplankton. When sand crabs eat the toxic plankton they become toxic to birds, otters, and fish that eat them.

Monitoring of Sand Crabs

The Farallones Marine Sanctuary Association is coordinating a sandy beach monitoring project. Through this program, San Francisco Bay Area high school students monitor the Pacific Mole Crab along the shores near their schools. The project is funded by the Gulf of the Farallones National Marine Sanctuary through the T/V *PUERTO RICAN* Oil Spill Restoration Fund. The *PUERTO RICAN* was a tanker vessel that spilled 1.4 million gallons of oil into the Gulf of the Farallones in 1984. The oil injured and killed many birds and washed onto beaches in the Gulf of the Farallones National Marine Sanctuary. This project is part of a curriculum that educates San Francisco Bay Area high school students about the local ecosystem. If you would like information on this program, please contact us at (415) 561-6625 or visit our web site at www.farallones.org.



6. Sandy Beach Monitoring Background

The sandy beach ecosystem is an interesting place to study. Researchers have examined a variety of aspects of this area. Research has been done on zonation, beach wrack, longshore currents, and sand composition, just to name a few topics. The organisms that live in this ecosystem have also been studied. These include shorebirds, clams, worms, and crabs.

All of the organisms have adaptations to help them survive in this harsh environment. It is important to remember that there are interactions between the different species. For example, the coastal birds and sea otters are predators of the sand crabs. The sand crabs feed on the plankton in the water. If sand crabs eat toxic plankton or become infested with parasites, this can affect the Surf Scoters and sea otters that eat them. All animals depend on either other animals or algae for food. If one of the species is harmed, the effects can resonate throughout the entire food web. People can also alter the food web. If there is an oil spill, it can contaminate the animals living on the beach and that can then affect their predators as well.

The Pacific mole crab (*Emerita analoga*), also known as the sand crab, is a common inhabitant of the sandy beach. These crabs have been a focus of research for many years. Scientists have investigated the longshore movements of the crabs along a beach, the migration and aggregation of the crabs, egg production, and molting cycles.

Sand crabs are used by people in a variety of ways. They are used as bait for fishing and entertain children playing at the beach. Sand crabs have been used as indicators of the pesticide DDT as well the neurotoxin domoic acid. Domoic acid is produced by diatoms, a type of phytoplankton. When sand crabs eat toxic plankton, they become toxic to birds, otters, and fish that eat them. Both DDT and domoic acid can harm and sometimes kill marine animals. By using sand crabs to indicate the presence of either of these, scientists can be prepared to treat animals affected by the toxins. Agencies that regulate the harvesting of shellfish need to know when domoic acid may be at a level that threatens humans who eat shellfish.

Sand crabs are also hosts to parasitic worms. These parasites are passed on to the birds and sea otters that eat the sand crabs. Because the crabs are small, these predators can eat many per day, and eating many parasite infested crabs may lead to death for birds and sea otters. By monitoring sand crabs and investigating their parasite load, more can be learned about the parasite's life cycle and predictions of bird and sea otter mortality may be possible.

The Sandy Beach Monitoring Project offers students the opportunity to experience the scientific process first hand. They will learn how to monitor, collect data, and analyze their results. They will be the scientists that conduct the monitoring and data analysis from start to finish.

The data collected are meant to provide baseline abundance and distribution information about the sand crab. The information will be given to the Sanctuary for management purposes and for reference in the event of an oil spill. With this data they can compare the density of sand crabs before and after an oil spill. They can use information on the parasites to help explain mortality events in birds and otters. The information will also be shared between the schools that are participating in the project. This will allow students to experience another component of the scientific process, communicating with their peers. Before monitoring, it is important to discuss with the students why they are monitoring and how this project fits into the bigger picture of the sandy beach environment. The teacher should introduce topics

related to this project and allow the students to discuss them. This project can lead to a discussion of more general topics on marine conservation. The following are just a few topics for discussion.

• Why monitor sand crabs?
They are part of the food web. As filter feeders they can accumulate toxins, such as DDT and domoic acid. These are then passed along to their predators. Sand crabs would be severely affected by an oil spill that reaches the sandy beach environment.

• What do the data tell us?
The data provide baseline information about the density of sand crabs on a beach. This information can be helpful if there is an oil spill. Since the crab density will be known it may be possible to determine how long it takes for the population to recover from an oil spill.

• Why long-term monitoring?
If monitoring occurs over a long period of time, it may be possible to determine natural fluctuations in the density of sand crabs on a beach. From this it may be possible to determine if a population is low because of another reason. This could lead to determining if there is a higher level than normal of DDT or domoic acid present. The source of the toxin may be investigated.

• How do humans affect the sandy beach environment?
Ask the students how they impact the environment when they visit the beach. Also, have them discuss how humans in general may affect it, i.e. oil spills, development, harbors, etc. How do all these things affect the environment and the animals that live there? Have them weigh the pros and cons of development. Lead a debate or town hall meeting on a specific development project that has occurred at a beach near your school.

• How can you become a steward of the sandy beach environment?
After the students list all of the negative ways that people impact the sandy beach environment, make sure they discuss the ways that people address these impacts. Are there any local programs that protect or clean-up the beach? For example, Adopt-a-Beach, coastal clean-up day, or the Sanctuary's volunteer program Beach Watch are such programs. How can the students get involved in protecting a local sandy beach?

• How can you become a steward of the marine environment?
Have the students look beyond the sandy beach to the entire marine environment. What are some threats to the health of the oceans? How can they help to protect the marine environment?

• Why are National Marine Sanctuaries important?
Discuss the National Marine Sanctuary program. Which is the closest Sanctuary to their school? Why are there Sanctuaries? How do they protect the marine environment? What would happen if there were no Sanctuaries? Will there ever be a time when Sanctuaries won't be needed? When all parts of the ocean are treated with respect and not exploited. What can your students do to reach the goal of making Sanctuaries obsolete?

7. Monitoring Procedures

A. Overview

This monitoring procedure was developed for a group of 20 students. If there are more students in your class, you can add more transects to increase the sampling area. You may also establish another sampling area that is at least 50 m from the first. Another option is to have some students measure the beach profile. Protocols for this are in the coastal ecosystem curriculum developed by FMSA.

Students will monitor sand crabs at a sandy beach throughout the year. They will learn about quantitative sampling and the importance of good record keeping. By sampling quantitatively, the exact amount of area studied will be known. This eliminates a variable and makes the results more meaningful and allow for comparison between transects and days. This will also make it easier for another group to duplicate the procedures at another site and allow comparison between the two sites. At least three sampling dates should be scheduled each year. By monitoring at different times of the year, the seasonal cycle of the crabs may be observed.

FMSA staff may be available to visit your class prior to the monitoring dates. This will give the students an introduction to the project. A training session at the beach may be scheduled to ensure that the students are familiar with the procedures. This will offer the students the opportunity to practice collecting crabs, measuring and identifying gender, and completing the data sheets.

On the monitoring days, a survey area will be setup with a 50 m line that runs parallel to the shore (Figure 3). Along this line, 5 transects will be marked that are perpendicular to the line. Sampling will occur along each transect. Samples will be taken at predetermined locations along the transects. At least 10 samples will be taken along each transect. The number of samples will depend on the beach and the conditions of the day. If there is a low abundance of crabs (< 10 crabs per sample), samples should be taken every 0.5 meters and 20 samples will be taken. If there is a high abundance of crabs (>10 crabs per sample), samples should be taken at every meter and 10 samples will be taken. The protocols in this handbook have been written as if there is a high abundance of crabs and 10 samples would be taken. Students will measure and record the carapace length of each crab. See figure 5 for a diagram of a sand crab and notice the carapace. Students will also record the gender of the crab and will record if the females are carrying eggs (ovigerous). The data for each sample will be recorded separately.

After monitoring, the data will be entered into a spreadsheet and analyzed. The density of crabs along a transect, or over time, will be graphed along with other statistics.

B. Pre-Monitoring

Before monitoring can begin, you and your students must prepare the equipment. A beach must be chosen, and any permits that are required must be obtained. The following will help you prepare for the monitoring day.

Equipment

The following list will accommodate five groups of students, each working on their own transect.

- (5) 7 inch diameter, 24 inch tall galvanized stove pipes
- 1 roll of duct tape
- (10) 6 quart clear plastic boxes
- heavy duty scissors to cut the plastic boxes
- small hack saw to cut the plastic boxes
- 1/4 inch hardware cloth (metal mesh)
- 1/8 inch hardware cloth (metal mesh)
- wire cutters to cut the hardware cloth
- Pop-rivet gun
- 100 aluminum rivets (1/8", 3mm)
- 100 aluminum washers (1/8", 3mm)
- small power drill with 9/64" drill bit
- 5 plastic calipers (metric)
- 5 clear containers to hold crabs
- (2) 5 gallon buckets
- (5) 2 gallon buckets
- 5 clipboards (with rubber bands to hold the paper down)
- data sheets (can be printed on waterproof paper)
- 5 pencils
- 50 flags for marking the transects
- measuring tape (metric if possible)
- 50 m survey line (rope)
- meter stick
- compass
- rubber boots (optional)
- safety goggles (for cutting hardware cloth and boxes)
- GPS (optional)
- change of clothes (optional)

Students are likely to get wet during monitoring. They may want to bring a change of clothes. They can also wear a set of rubber boots to help them stay dry.

The bottoms of the plastic boxes need to be removed so that the mesh can be put into the box to make it a sieve. Safety goggles should be worn when cutting the mesh and the plastic boxes. Use the heavy duty scissors to punch a hole in each box and then use the scissors and the small hack saw to cut out the bottom of each box. A piece of hardware cloth will replace the plastic bottom of the box. Cut the hardware cloth so that it is larger than the hole in the box. It should be placed on the inside of the box and the sides folded so they rest against the sides of the box. Drill two holes on each side of the box. Each hole should be placed so a rivet can pass through the box and the mesh. Insert a rivet into one of the holes. Push the rivet through the box and the mesh. Hold a washer on the inside of the box and use the pop-rivet gun push the rivet through the washer. The washer holds the mesh in place. Five boxes should have the small mesh and the other five should have the large mesh placed inside them.

Cover one end of the stove pipe with duct tape. This will be the top end where the students hold as they push the tube into the sand. Mark a line around the tube 10 cm above the end without duct tape. This will show the students how far to push the tube into the sand. Permanent marker or duct tape may be used

to mark the stove pipe. The tape or ink may come off in the water, so be prepared to remark the line in the field. Make sure any duct tape that does come off while sampling is not left at the beach.

The 50 m rope will mark the survey area. Mark the rope with duct tape at each meter. The random numbers will correlate with the markings on the rope.

Choosing a Beach and Survey Area

There are many factors that must be considered when choosing a site for monitoring. FMSA and Sanctuary staff will be available to help with this selection. Things to include are:

- Is it a safe beach for students to be in or close to the water?
- Is it easily accessible while carrying the monitoring equipment?
- Is it close enough to the school to allow two hours at the beach in addition to the driving time?
- Is the beach in a National Marine Sanctuary?
- Do you need to get a permit(s) to sample?
- Are crabs present?

The teacher is responsible for choosing a beach and the survey area that will be monitored. This will require the teacher to scope out the site in advance of training the students. The number of sand crabs at a beach can vary dramatically from year to year, depending on environmental conditions, so make sure that crabs are present at your chosen beach. Take a few samples at the beach to determine the presence or absence of crabs. Make sure to schedule the sampling days at the right time of the year. The crabs are moved offshore by winter storms from December to February and won't be found on the beach. Choose a location at your beach that is a distance from the most highly visited areas, so there will be at least 50 m available when you monitor. Monitoring does not need to occur at a low tide, but it is easier to sample if the tide is receding.

Permits

Before sampling, make sure to find out if any permits are required at the beach you have chosen. You will need to get a permit from the California Department of Fish and Game. If you are working on a beach in a National Park, you will also need to obtain a permit from the park. Golden Gate National Recreation Area and Point Reyes National Seashore are two local National Parks. Make sure to request the application well in advance of when you want to monitor. It may take months to complete the application process and get the permit.

Random Numbers

Before sampling, you need to determine the locations of the five transects using a random number table (Appendix 1). These numbers will be different for each monitoring day. The numbers will be from 0 to 50, the length of the survey area. Adjust the random number list according to the length of your area. From the random number table, randomly select the first number. This number will correspond with a meter mark on the 50 m survey line and will be the location of one of the transects. Following the row on the table, use the next 4 numbers for the locations of the other 4 transects, as long as they are at least 5 digits apart from the other selected numbers. The numbers should be chosen prior to the monitoring day.

Safety Issues

It is important to review safety issues with your students prior to going to the beach. Please remind them of the following:

1. Safety is the number one priority while at the beach.
2. Do not turn your back to the waves even while sampling.
3. Do not sample if there is heavy surf and conditions look unsafe.
4. Use common sense.
5. Explain the dangers of rip tides, currents, and sneaker waves.
6. Make sure the students know the beach can be a dangerous place, and they should be alert for hazards at all times.

C. Sampling Protocols

Five transects will be set-up and at least ten samples collected along each transect. The following explains the procedures for monitoring.

Marking the transects

Five transects will be marked along a 50 m line that is parallel to the shore. The 50 m line should be placed at the same location each monitoring day. To ensure that this happens, the location of the start of the line should be recorded in relation to at least two permanent landmarks. The compass bearings for the beginning of the survey area should be recorded prior to the monitoring day by doing the following:

- Stand at the zero-zero mark (the place where the 50 m line will start).
- Find a permanent landmark that will be easy to find each time you monitor the beach (such as a tree or telephone pole).
- Use the compass to get the compass bearing to a landmark. Repeat this procedure for at least one other permanent landmark.
- Record this information and use it on monitoring days.

On the days that you are monitoring, follow these directions to mark the five transects.

- Locate the zero-zero spot of the survey area, using the compass bearings that were recorded on the station location data sheet.
- Put one end of the line at the zero-zero mark and run the line parallel to the shore to mark the survey area.
- Once this is stretched out, have each group measure the distance to their assigned random number. The line should be marked at every meter.
- Once the group is at the correct location, they can stretch out their measuring tape to mark their transect. A rope that has been marked at each meter can be used instead of a measuring tape.
- The sampling zone should begin at 5 m above the top of the swash zone and continue to 0.25 m water depth. (This may vary depending on the day's conditions.)
- One end of the 10 m measuring tape (or rope) is placed at the parallel line, and the measuring tape is stretched perpendicular to the survey area line and toward the water. The measuring tape or rope is moved down the beach and is placed with one end 5 m above the top of the swash zone and the other end at 0.25 m water depth.

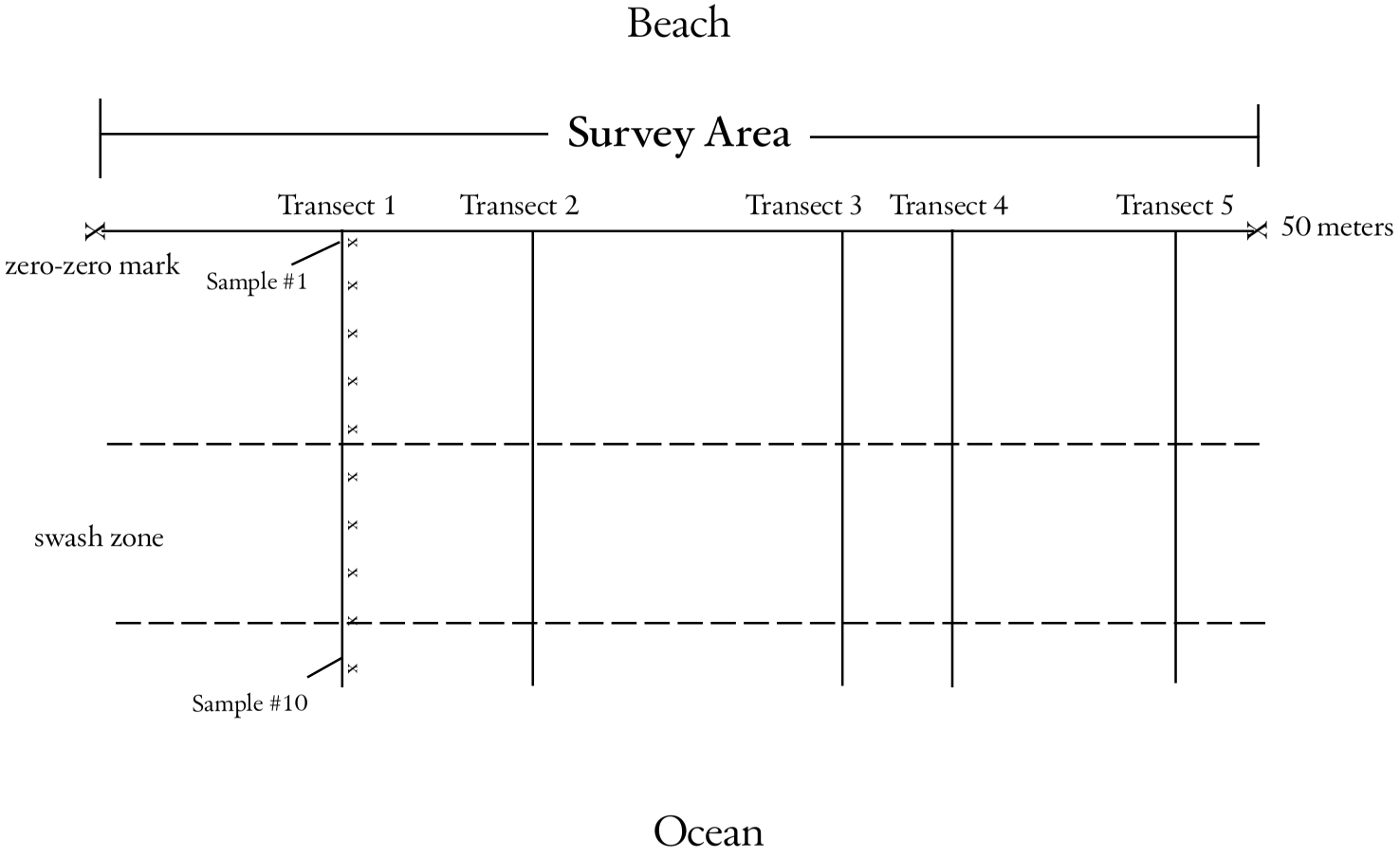


Figure 3. Diagram of transect layout. Transects are randomly selected and are at least 5 m apart.

- At each meter, a flag should be placed to indicate where each sample will be taken. If crabs are not very dense (< 10 per sample), the sample interval width along the transect needs to be adjusted to taking samples every 0.5 m. Once all the flags are in place, the measuring tape can be removed. Please refer to Figure 3 for an example of the layout.
- Each sample should have a sample number (#1-#10). The sample collected at the highest location on the beach is #1 and the one taken at the lowest location is #10. Sampling can begin with #1 or #10, just make sure to record the results accurately on the data sheet and be consistent throughout the year. On a falling tide, start sampling at # 1, and on a rising tide, start sampling at #10.

Collecting a sample

Sampling should occur quickly to avoid disturbance and loss of active animals from sampling area.

To collect a sample:

- Hold on to the duct taped end of the sampling tube.
- Push the tube in gently to avoid injuring any crabs.
- Press the tube 10 cm into the sand, using the marker on the tube as a guide. Push the tube over and, at an angle, lift the sand in the tube. If the sample is taken in the swash zone, it may be easier to take the sample when the water has receded or while it is receding.
- Use one hand to hold the tube and one hand to keep the sand in the tube.
- Use a bucket to transport the sand if needed.
- Pour the sand into the sieves. Two mesh sizes are recommended in order to catch the maximum number of crabs. Place the larger mesh sieve on top of the smaller mesh sieve. The larger crabs will be caught in the large mesh and the small crabs will be caught in the small mesh.
- Shake the sieve to remove the sand – adding some water will make this go more quickly.
- Place all sand crabs into a small container with some sea water.

Measuring crabs and recording data

- The carapace length (Figure 5) should be measured to the nearest millimeter for each crab.
- Record the length of each crab on the data sheet. Make sure to keep the data from each sample separate.
- The gender of each crab should be determined and recorded.
  - A female crab can be identified by the pleopods that are visible when the telson is lifted. There are three pairs of pleopods, and they resemble threads. (See figure 4)
- A female crab with eggs (ovigerous) can be identified by the eggs found when the telson is lifted. The eggs appear as a bright orange mass. (Appendix 3 photo)
  - A male will not have pleopods or eggs.
  - A crab that has a carapace length of less than 9 mm is considered a recruit, and the gender cannot be determined.
- Record any other animals that are found in the samples on the data sheet.
- Return the animals to the water, away from the transects so the crabs won't be counted in another sample.

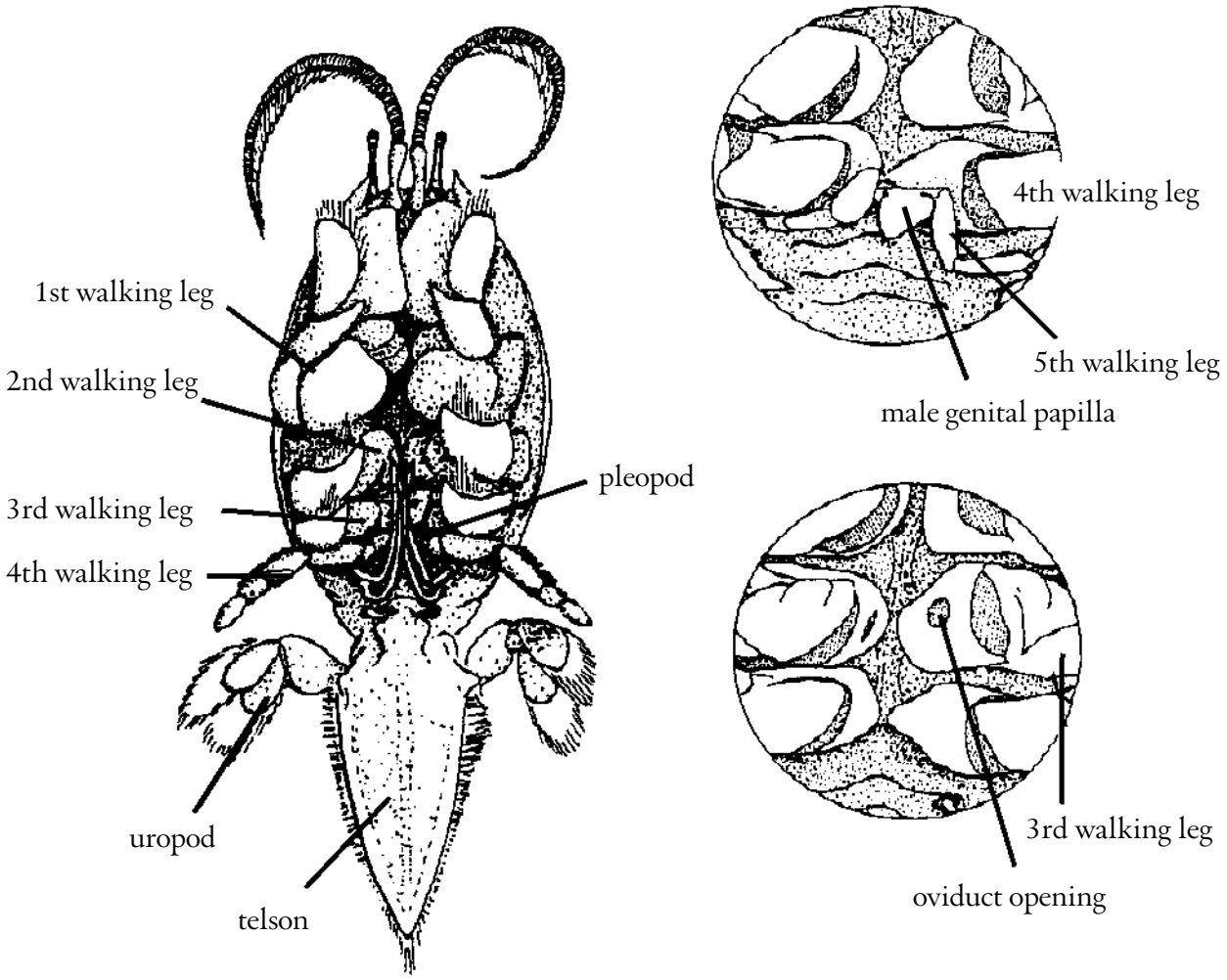


Figure 4. Ventral view of sand crab (Dugan 1990)

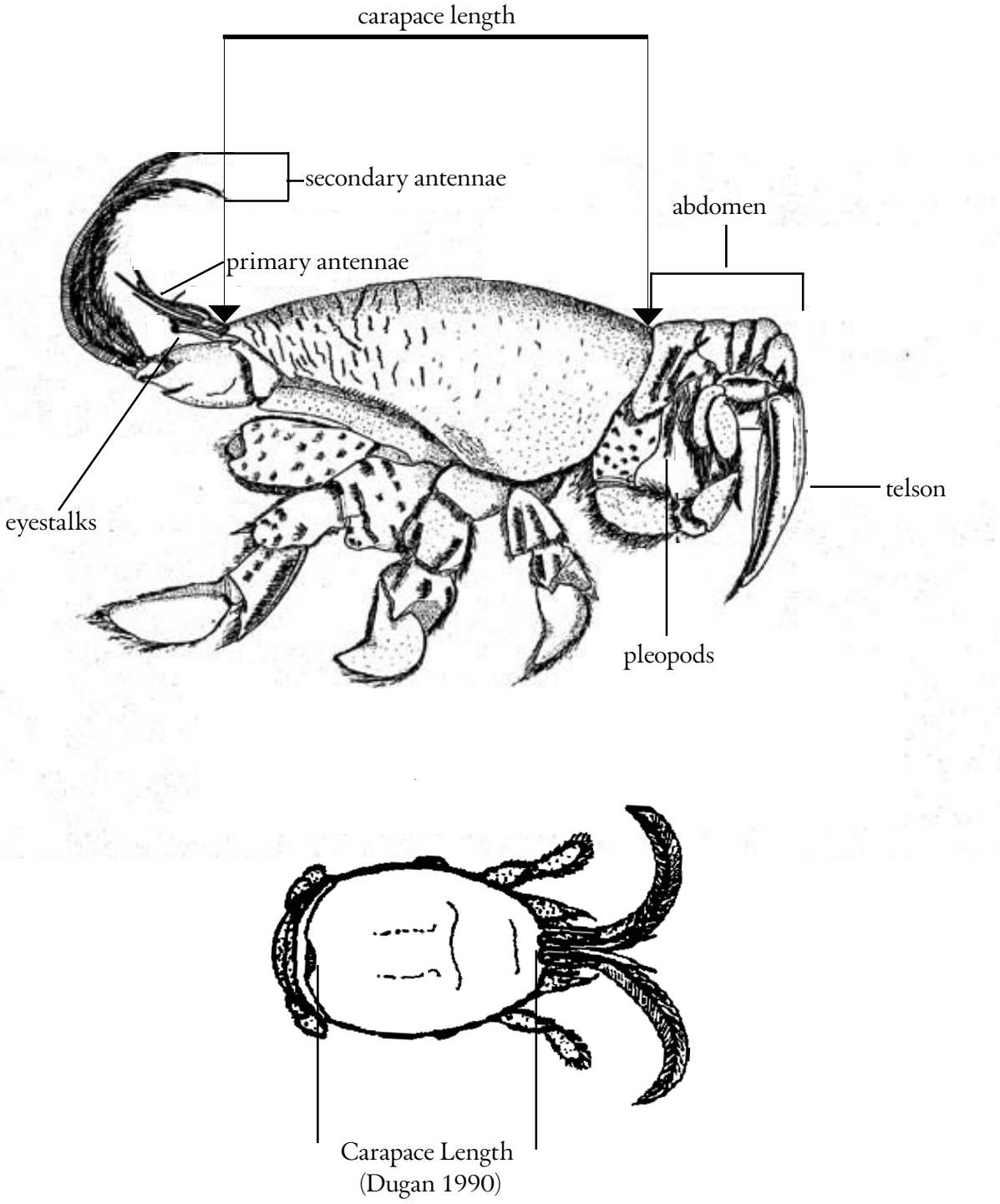


Figure 5. Top picture: diagram of a female Pacific mole crab. Females carry their eggs with their pleopods which can be seen under the telson, or tail. Bottom picture: dorsal view of a sand crab. The carapace is the hard covering, exoskeleton, covering the thorax. Students will measure and record the length of the carapace to the nearest millimeter using calipers.

D. Training Day

A training day should be scheduled prior to the monitoring day. This may consist of classroom and/or field training. FMSA staff may be available to train your students in the classroom and in the field. Prior to the training session, discuss the project with the students, and make sure they understand the goals of the project as well as the goals for the training day.

If you decide to do a training in the field, the data sheets and sand crab natural history should be reviewed in the classroom, before going into the field. The sampling technique and crab identification should be emphasized while in the field. At the end of the training day the students should be able to:

- collect sand crabs with a sampling tube and use the sieves,
- identify recruits, males, females, and ovigerous females,
- measure the carapace length with calipers,
- mark a transect, and
- complete the data sheets.

Student Groups

Before going to the beach on the training or monitoring days, the students should know that they will be working in groups. They should know the responsibilities of each task to be done in the group. By the end of the training they should be prepared to do any of the necessary tasks. The recommended group size is four students.

Person 1: in water taking the samples
Person 2: helping with the samples, carrying an extra bucket, helping with sexing and sizing
Person 3: in charge of the sieve – sexing and measuring size of crabs
Person 4: recorder

E. Monitoring Day

Prior to going to the beach, make sure to select the five random numbers for the locations of the transects. Inform each group of their random number before leaving for the beach.

Record the observational information on the sampling conditions data sheet.

Locate the station location for the survey area using the recorded compass bearings. Place the 50 m line parallel to the shore. Once each group has located their random number along the 50 m line, they can mark their transect, and put flags at every meter to indicate sample locations. They should collect at least ten samples, record all of the information on each crab collected, and return the crabs to the water. Refer to the sampling protocols in section C for detailed instructions.

After each group has collected all of their samples along their transect, make sure they pick up all the equipment. Collect and review all of the data sheets to make sure they are all complete before leaving the beach.

F. Data Sheets

There are two data sheets that the students will use in the field. Information on the sampling conditions and the sand crab data will be recorded. Please make sure that the students fully complete each data sheet while they are at the beach. This will ensure quality data and make data analysis much easier.

Sampling Conditions Data Sheet Instructions

This data sheet is used to record information about the conditions on the monitoring day (Figure 6). This information can sometimes help explain the data. It may also explain any observer bias due to weather conditions.

1. Beach name: Record the name of the beach at which you are monitoring.
2. School name: Record the name of your school.
3. Recorder name: Record the name of the person who is recording the information.
4. Observer name (s): Record the name of anyone who is helping the recorder.
5. Date: Record the date on which the monitoring takes place including month, date, and year.
6. Start time/end time: Record the time that monitoring starts and ends.
7. Approximate tidal height: In order to determine the approximate tidal height, refer to a tide chart and estimate the height at the time that your group *started* monitoring.
8. Rising/falling tide: Note if the tide is rising or falling. It is recommended to conduct your sampling during a falling tide.
9. Wind speed: Use the anemometer to measure the wind speed in mph.
10. Beaufort Wind Scale: Refer to the Beaufort Scale in Appendix 2 and determine the conditions on the day that you are monitoring.
11. Approximate Visibility: Estimate the visibility during monitoring, and circle the appropriate choice.
12. Cloud Cover: In order to estimate the cloud cover, it is easier if the sky is divided into quarters. Estimate the cloud cover in each quarter, not counting the sky that falls within a thumb's height above the horizon. Add the value for each quarter, and divide by four to get an average. Circle the appropriate choice on the data sheet.
13. Approximate Air Temperature: Estimate the air temperature, or bring a thermometer.
14. Latitude: Use a map or GPS unit to determine the latitude.
15. Longitude: Use a map or GPS unit to determine the longitude.
16. In the table, record the following:
    - the random number chosen for each transect (random location number),
    - the name of the person recording the data for each transect,
    - the distance in meters above the swash zone,
    - the depth of the water at the location at which the last sample (the lowest one) was taken
    - the distance between each sample (sampling interval)
17. Station location description: The students should describe the location of the survey area.
18. Notes/unusual observations: Record anything that may have an affect on the data.

Sand Crab Data Sheet Instructions

This data sheet will be used to record the number, size, and gender of the crabs found in each sample. Please refer to Figure 7 for a sample of this data sheet. See Figure 9 for a completed sample data sheet.

1. Beach name: Record the name of the beach you are monitoring.
2. School name: Record the name of your school.
3. Record the page number. Make sure the data sheets for each transect are kept together with the page numbers properly labeled.
4. Date: Record the date your group is monitoring including month, date, and year.
5. Transect #: Record the number of your transect.
6. Random Location #: Record the random number that was chosen to determine the location of the transect.
7. Interval width: Record the distance between the samples.
8. Recorder: Write down the name of the person who is recording the data.
9. Team Members: Write down the name of each person in the group.
10. # of samples along transect: Record the number of samples that were taken along the transect.
11. Water depth at last sample: Use a meter stick to measure the water depth at the place where the last sample was taken.
12. For each sample, circle the correct location. Was it collected in dry sand (D) or the swash zone (S)? *If you start in the water, begin with sample #10; if you start on the shore, begin with sample #1.*
13. For each sample, record the size (carapace length) and gender of each crab. Use the code on the data sheet and measure to the nearest millimeter. F=female, FE=female with eggs, M=male, and R=recruit(<9 mm). Also note any soft shell crabs by recording SS.
14. In the tally column, add the number of crabs for each category. For example, write 3 F, 2 M, and 5 R if you collected 3 females, 2 males, and 5 recruits. This is an optional step in the field, but will make the data entry process easier. Or, you can use the data entry tally sheet in the classroom.

Data Entry Tally Sheet Instructions

This data sheet will be used back in the classroom to make entering the data into the online database easier. This data sheet will help you tally the sizes of all of the crabs found in one sample, which is useful when there were alot of sandcrabs collected (>30 crabs). See Figure 10 for a sample of this data sheet and Figure 11 for a completed sample.

1. Beach name: Record the name of the beach you monitored.
2. Date: Record the date your group monitored including month, date, and year.
3. Transect #: Record the number of your transect.
4. Sample #: Record the sample number.
5. It is easiest to go through the sample crab by crab and record the size with a tally mark in the appropriate group (Females, Females with eggs, Males, and Recruits).
6. Although the database will total the numbers automatically, it is a good idea to total the numbers on this sheet to double check your data entry work.
7. Total the number of crabs for each size group.
8. Total the number of crabs found in the sample.

Data Sheet 1: Sampling Conditions

Beach Name _____ Date _____

Recorder _____ Start Time _____

Observors _____ End Time _____

Approximate Tidal Height _____ Tide: rising / falling (circle one)

Wind Speed _____ Maximum Beaufort Wind Scale _____

Aproximate Visibility (circle one) <300 feet <1/4 mile < 1 mile > 1 mile

Cloud Cover (circle one) 0 1-25% 26-50% 51-75% 76-100%

Approximate Air Temperature _____

Transect Number	Random Location Number	Recorder's Name	Distance Above Swash Zone	Depth of Last Sample (m)	Sampling Interval (m)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Station Location Description:

Notes/Unusual Observations:

Figure 6. Sampling Conditions Data Sheet

Data Sheet 2: Sand Crab Data

page ____ of ________

Beach name ______________________ Recorder ______________________

Team Members ______________________

Date ______________ ______________________

Transect # ________ ______________________

Random Location # ________ # of Samples Along Transect ________

Interval Width ________ Water Depth at Last Sample ________

Record the gender and size of each crab. Also note any crabs that have a soft shell.
Use these codes: F=female FE=female with eggs M=male R=recruit (< 9mm) SS=soft shell

Sample Number								Tally
Circle a zone:								
Dry or Swash								

Sample Number								
Circle a zone:								
Dry or Swash								

Sample Number								
Circle a zone:								
Dry or Swash								

Sample Number								
Circle a zone:								
Dry or Swash								

Sample Number								
Circle a zone:								
Dry or Swash								

Sample Number								
Circle a zone:								
Dry or Swash								

Figure 7. Sand Crab Data Sheet

Date ________ Transect # ________ Random Location # ________ page ____ of ________

Record the gender and size of each crab. Also note any crabs that have a soft shell.
Use these codes: F=female FE=female with eggs M=male R=recruit (< 9mm) SS=soft shell

Sample Number								Tally
Circle a zone:								
Dry or Swash								

Sample Number								
Circle a zone:								
Dry or Swash								

Sample Number								
Circle a zone:								
Dry or Swash								

Sample Number								
Circle a zone:								
Dry or Swash								

Sample Number								
Circle a zone:								
Dry or Swash								

Sample Number								
Circle a zone:								
Dry or Swash								

Sample Number								
Circle a zone:								
Dry or Swash								

Figure 8. Second page of the Sand Crab Data Sheet

Data Sheet 2: Sample Sand Crab Data

Beach name Doran

Recorder Jane Lee

Team Members Kim Jones, John Smith, Chris Black

Date 7/25/01

Transect # 2

Random Location # 13

# of Samples Along Transect 20

Interval Width 0.5 meter

Water Depth at Last Sample 0.25 meters

Record the gender and size of each crab. Also note any crabs that have a soft shell.
Use these codes: F=female FE=female with eggs M=male R=recruit (< 9mm) SS=soft shell

Sample Number								Tally
1	M-14	M-13 (SS)	R-5					2 M
Circle a zone:								1 R
(Dry) or Swash								
Sample Number								**Tally**
2								0
Circle a zone:								
(Dry) or Swash								
Sample Number								**Tally**
3	M-14	F-25 (SS)	FE-33	F-30	FE-33			1 M
Circle a zone:								2 F
(Dry) or (Swash)								2 FE
Sample Number								**Tally**
4	FE-35	FE-33	FE-31					3 FE
Circle a zone:								
(Dry) or (Swash)								
Sample Number								**Tally**
5	F-30	F-31	F-28					3 F
Circle a zone:								
(Dry) or (Swash)								
Sample Number								**Tally**
6	F-28	FE-30	FE-29	FE-31	F-27	F-30		3 F
Circle a zone:								3 FE
(Dry) or (Swash)								

Figure 9. Completed Sand Crab Data Sheet

Data Sheet 3: Data Entry Tally Sheet

Beach name _____ Transect # _____

Date _____ Random Location # _____

Transect # _____ Sample # _____

Tally the number of crabs by size and gender for ONE SAMLPE ONLY

Size (mm)	Female	Female with Eggs	Male	Recruit	Totals
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
Totals					

Figure 10. Data Entry Tally Sheet

Sample Data Sheet 3:Data Entry Tally Sheet

Beach name _____ Transect # _____

Date _____ Random Location # _____

Transect # _____ Sample # _____

Tally the number of crabs by size and gender for ONE SAMLPE ONLY

Size (mm)	Female	Female with Eggs	Male	Recruit	Totals
4				𝍸 ||	7
5					
6				𝍸 𝍸 ||	12
7					
8					
9					
10					
11					
12					
13					
14					
15			||		2
16	𝍸 𝍸				10
17	𝍸 |				6
18			|		1
19			||		2
20					
21					
22					
23					
24	𝍸				5
25	||				2
26	|				1
27	|	𝍸			6
28					
29					
30					
31					
32					
33					
34					
35					
Totals	25	5	5	19	54

Figure 11. Completed Data Entry Tally Sheet

8. Data Entry

Once the monitoring is completed and the data have been recorded in the field, the data should be entered into a database for analysis. As of January 2003, to enter your data online, go to www.sandcrabs.org, and click on the data entry button. For a log on name and password, contact Shannon Lyday at slyday@farallones.org or at (415) 561-6625. Detailed data entry instructions are on the website. In the future, data entry will be at www.limpets.org or limpets.noaa.gov.

It is best for the students to enter their data soon after monitoring so that it is fresh in their minds. To enter the data, break the students up into the transect groups that they were in. Data should be entered for each sample collected along the transect.

After the data have been entered, graphs can be made to display the results. Click on the results button to have the online database graph your results. There are three graphs to choose from: distribution along the beach, size distribution, and gender distribution. For examples of these graphs, see Figure 12 and Figure 13. The online system does not require a log on name and password to view the results. Students can compare their results with other schools monitoring beaches along the Gulf of the Farallones. At the future website, the data will be part of a network from beaches near five National Marine Sanctuaries along the west coast.

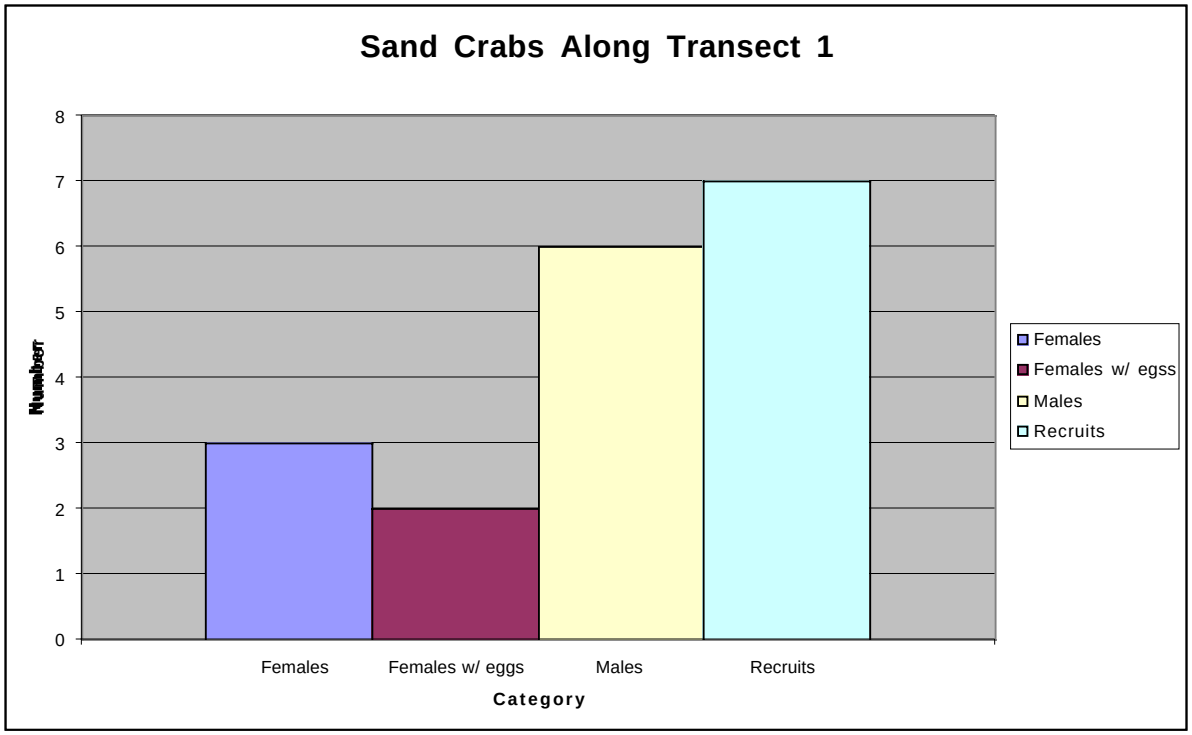


Figure 12. Sample graph of number of crabs found along a transect.

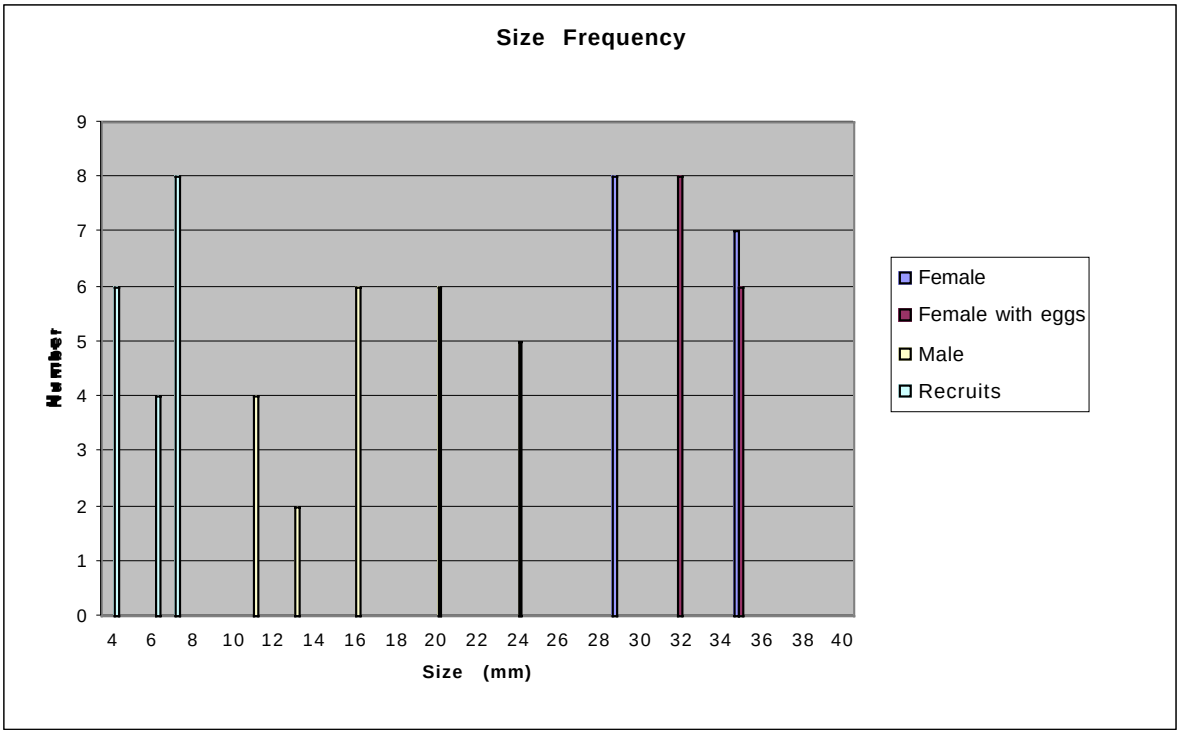


Figure 13. Sample graph of size frequency of crabs found along the survey area.

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Appendix 1

Random Number Table
(0-50)

1	6	45	44	38	22	36
3	40	42	9	20	39	15
6	21	44	10	4	48	37
27	7	17	15	25	2	25
48	15	28	20	37	20	42
20	29	15	6	49	45	23
9	1	8	45	35	0	48
11	34	27	11	10	21	40
29	19	14	4	43	24	45
2	12	13	34	47	4	19
21	43	47	37	40	16	28

Appendix 2
Beaufort Wind Scale

Beaufort Number or Force	Wind Speed			World Meteorological Organization Description	Estimating Wind Speed		
	Knots	mph	km/hr		Effects Observed at Sea	Effects Observed Near Land	Effects Observed on Land
0	under 1	under 1	under 1	Calm	Sea like a mirror	Calm	Calm; smoke rises vertically
1	1-3	1-3	1-5	Light Air	Ripples with appearance of scales; no foam crests	Small sailboat just has steerage way	Smoke drift indicates wind direction; vanes do not move
2	4-6	4-7	6-11	Light Breeze	Small wavelets; crests of glassy appearance, not breaking	Wind fills the sails of small boats which then travel at about 1-2 knots	Wind felt on face; leaves rustle; vanes begin to move
3	7-10	8-12	12-19	Gentle Breeze	Large wavelets;crests begin to break, scattered whitecaps	Sailboats begin to heel and travel at about 3-4 knots	Leaves, small twigs in constant motion; light flags extended
4	11-16	13-18	20-28	Moderate Breeze	Small waves 0.5-1.25 meters high, becoming longer; numerous whitecaps	Good working breeze, sailboats carry all sail with good heel	Dust, leaves, and loose paper raised up; small branches move
5	17-21	19-24	29-38	Fresh Breeze	Moderate waves of 1.25-2.5 meters taking longer form;many whitecaps; some spray	Sailboats shorten sail	Small trees in leaf begin to sway
6	22-27	25-31	39-49	Strong Breeze	Larger waves 2.5-4 meters forming; whitecaps everywhere; more spray	Sailboats have double reefed mainsails	Larger branches of trees in motion; whistling heard in wires
7	28-33	32-38	50-61	Near Gale	Sea heaps up, waves 4-6 meters; white foam from breaking waves begins to be blown in streaks	Boats remain in harbor; those at sea heave-to	Whole trees in motion; resistance felt in walking against wind
8	34-40	39-46	62-74	Gale	Moderately high (4-6 meter) waves of greater length; edges of crests begin to break into spindrift; foam is blown in well-marked streaks	All boats make for harbor, if near	Twigs and small branches broken off trees; progress generally impaired
9	41-47	47-54	75-88	Strong Gale	High waves (6 meters); sea begins to roll; dense streaks of foam; spray may reduce visibility		Slight structural damage occurs; slate blown from roofs
10	48-55	55-63	89-102	Storm	Very high waves (6-9 meters) with overhanging crests; sea takes a white appearance as foam is blown in very dense streaks; rolling is heavy and visibility is reduced		Seldom experienced on land; trees broken or uprooted; considerable structural damage occurs
11	56-63	64-72		Violent Storm	Exceptionally high (9-14 meters) waves; sea covered with white foam patches; visibility still more reduced		Very rarely experienced on land; usually accompanied by widespread damage
12	64 and over	73 and over	118 and over	Hurricane	Air filled with foam; waves over 14 meters; sea completely white with driving spray; visibility greatly reduced		

Appendix 3

Pictures

Sanderling (left) and Willet (right) feeding in the swash zone

The Surf Scoter is a predator of the sand crabs. It can be affected by the parasites that are transferred from sand crabs.

Example of a survey area. Each row of flags is a transect for a group of students. A sample is taken next to each of the flags.

Using sieve to separate crabs from the sand

Female sand crab with her telson pubbled back to expose the eggs

Measuring the crab's carapace length with calipers