Sandy Beach Monitoring Project

Teacher Handbook

Farallones Marine Sanctuary Association
Gulf of the Farallones National Marine Sanctuary
San Francisco, California

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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A special thanks to Jenny Diehl. She shared her expertise on sand crab monitoring and background information about the sand crab.

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
Vic Chow	Bodega Marine Lab
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

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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.

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 monitor the distribution and abundance of 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. A website at www.sandcrabs.org was designed specifically for this project. Students and teachers can enter and graph the data and learn about sand crabs at the website.

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 Murres, 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). The National Marine Sanctuary System 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 (NMS) 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. Gulf of the Farallones NMS 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 Gulf of the Farallones NMS 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

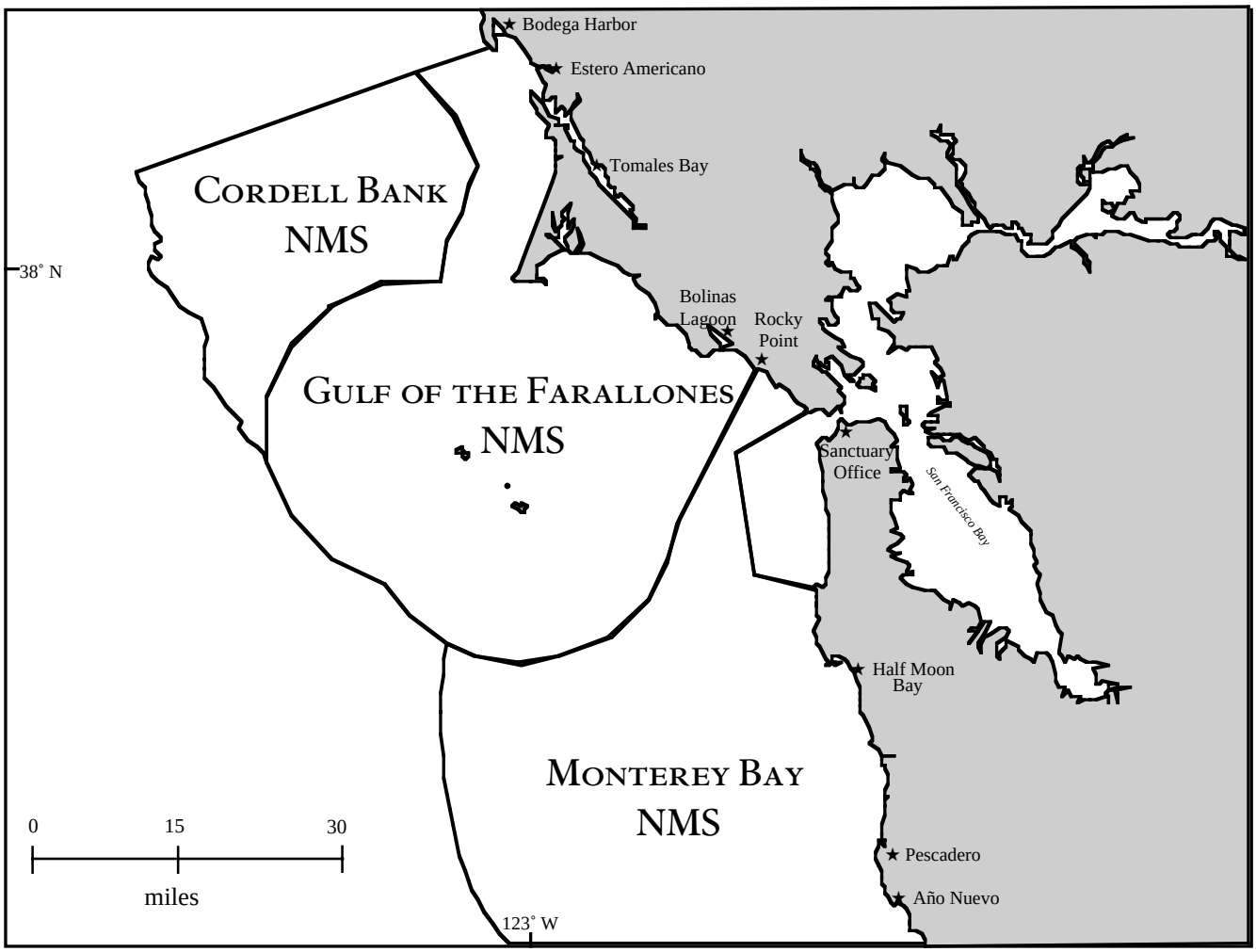


Figure 2. Boundaries of the three Sanctuaries managed by the Gulf of the Farallones NMS office.

3. Sandy Beach Monitoring Background

The sandy beach habitat is an interesting place to study and easily accessible for high school students. Researchers have examined longshore currents, beach slope, sand composition, beach wrack, and species zonation, just to name a few topics. The specialized animals that live in this habitat have also been studied, especially shorebirds, clams, worms, and crabs. The shifting sand and the tidal change in sea level make the sandy beach habitat a harsh place to live. The animals living in the sand have adaptations to help them survive.

All animals depend on either other animals or algae for food. If one species is harmed, the effects can resonate throughout the entire food web. For example, coastal birds and sea otters are predators of 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. People can also alter the food web. If there is an oil spill, it can contaminate the animals living on the beach as well as indirectly impacting predators.

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.

People use sand crabs in a variety of ways. Fisherman use sand crabs as bait and children enjoy discovering sand crabs while playing at the beach. Sand crabs have been used as indicators of the pesticide DDT as well as the neurotoxin domoic acid. Domoic acid is produced by diatoms, a type of phytoplankton. When sand crabs eat toxic plankton, crabs 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, predators may 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 will provide baseline abundance and distribution patterns about the sand crab. The data will be given to the Sanctuary for management purposes and for reference in the event of an oil spill. Natural resource managers can compare the density of sand crabs before and after an oil spill. They can use the parasite information to help explain mortality events in birds and otters. The results 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 habitat. The teacher should introduce topics related to this project and allow the students to discuss them. This project can lead to a discussion of marine conservation. The following are sample 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.

- 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?

  Long-term monitoring provides a long dataset which includes the natural fluctuations. Analysis of a long dataset can describe the natural cycles of populations. In addition, the impact of man-made impacts and natural catostrophic events can 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 the sandy beach (e.g. oil spills, development, harbors, etc.) How do all these events or developments 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 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 not needed?

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 because of physical factors such as waves or biological reasons such as protection from predators.
Baseline data	data 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 collected 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 provide 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. *Puerto Rican*	This project is funded by the *T/V Puerto Rican* Oil Spill Restoration Fund. In 1984, the *Puerto Rican* spilled 1.4 million gallons of oil off the San Francisco coast, killing thousands of seabirds.
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. Objectives	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.
6. 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.

7. World Map — This species of sand crab lives along the eastern edge of the Pacific Ocean in both the northern and southern hemispheres.

8. Female with eggs — Reproduction occurs from February through October. Females carry the eggs for about one month. Female crabs attach their eggs to the *pleopods* found under the telson.

9. Pelagic larval — 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.

10. 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.

11. 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.

12. 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.

13. Spiny mole crab (J. Hall) — You may find the much larger spiny mole crab (*Blepharipoda occidentalis*) in the subtidal zone. It can grow 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.

14. Shorebirds — Shorebirds are predators of the sand crab. Sanderlings and Willets use their beaks to dig into the sand to find sand crabs.

15. Surfperch (T. Chess) — Other predators include surfperch (sand crabs make up 90% of its diet), ...

16. Surf Scoter	. . . Surf Scoters, and...
17. Sea otter (R. Stallcup)	. . . sea otters.
18. Safety	The most important thing when you are monitoring at the beach is your safety. Please watch the water and follow these safety guidelines.
19. What not to wear	Dress appropriately for monitoring. The beach is often cold and we will be there for a couple of hours.
20. Dress Appropriately	You will want to wear many layers. A couple of people from each group will be getting into the water up to the knees, so bring boots or a change of clothes.
21. 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.
22. Sample set-up	This is a group that monitored at Stinson Beach. Each row of flags represents a separate group of students.
23. 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.
24. Transect	A sample is collected by pressing the sampling tube 10 cm into the sand and carefully picking up the sand.
25. Sampling	After a sample is taken, the sand is placed into the stacked sieves.
26. Rinsing	Water is then poured over the sand. The sand will fall through the sieves...
27. Crab in sieve	and the crabs will be caught in the sieves.
28. 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.

29. 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...

30. 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.

31. Size Classes — As you can see, there are a wide range of sizes. Females can grow up to 35 mm. 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.

32. 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.

33. 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.

34. 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.

35. 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.)

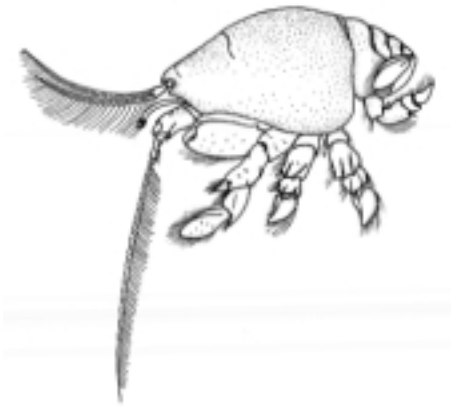
36. Data sheet 1 — This is the sampling conditions data sheet. Let's review it. (The teacher should now review this data sheet with the class. Explain that this gives weather conditions on the monitoring day. This information may be able to help explain some types of observer biases or other variables. This data sheet is also used to record information on the location of the transects.)

37. Online Databese — One part of this project is the field work and just as important to the project is analyzing the data back in school. Back in the classroom, you will enter your data online at sandcrabs.org. Each group will enter their data sample by sample.

38. Graph of data	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)
39. Acanthocephalan Parasites	An addition to the project is the investigation of parasite load on your beach. Acanthocephalan parasites are spiny-head worms that use the sand crab as an intermediate host. The parasites do not harm the crab, but they have killed animals higher up in the food web such as Surf Scoters and Sea Otters.
40. Parasites	Your class can collect crabs at the beach to dissect them and look for parasites. They are found in the midgut of the crab and they look like little white footballs.
41. 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.
42. 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.

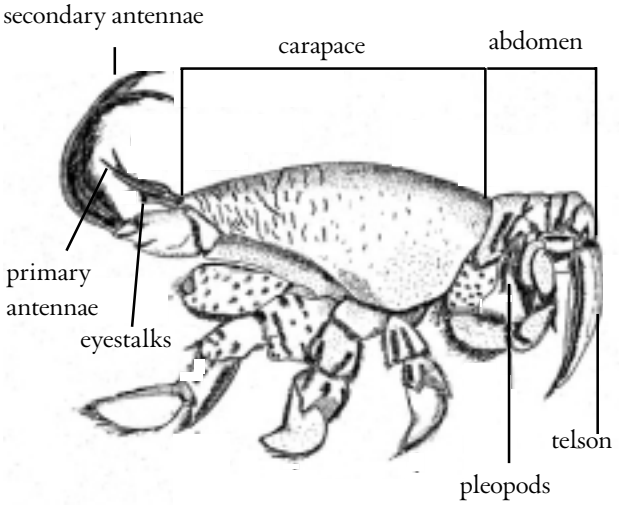
The crab spends most of its time buried in the sand. It has five pairs of legs that allow it to swim, crawl, and burrow, which are all done backwards. Its eyestalks reach above the sand. The first pair of antennae reach above the sand for respiration, and the second pair, resembling feathers, are extended 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 curlews, 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.

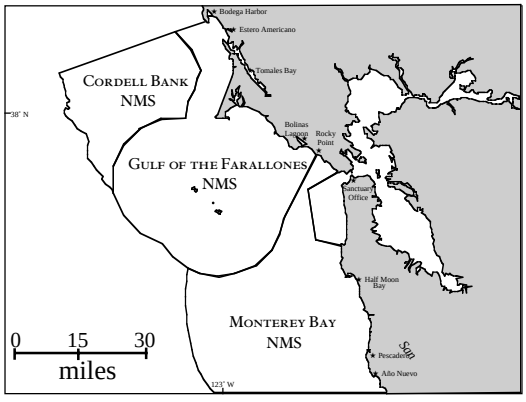
Sand crabs are known to carry parasites. They are an intermediate host of parasitic worms. These parasites are passed onto the predators of sand crabs. Sea otters and birds can eat many crabs per day, and the ingested parasites have been known to kill these predators.

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



www.sandcrabs.org

7. Monitoring Procedures

A. Overview

This monitoring procedure was developed for a high school students in the San Francisco Bay area. 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 allows 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.

These procedures were designed 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 the Farallones Marine Sanctuary Association (FMSA).

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 collected at predetermined locations along the transects. 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 collected. If there is a high abundance of crabs (>10 crabs per sample), samples should be taken at every meter and 10 samples will be collected. The protocols in this handbook have been written as if there is a high abundance of crabs and 10 samples are collected. Students will measure and record the carapace length of each crab. 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 into 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 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 (Figure 3). 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 (figure 3).

- 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 50 m line at the zero-zero mark and run the line parallel to the shore to mark the survey area.
- Once this is stretched out, each group should measure the distance to their assigned random number location. The 50 m line should be marked at every meter.
- Once the group is at the correct location, they should stretch out their measuring tape to mark their transect. A 10-20 m rope 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 50 m line, and the measuring tape is stretched perpendicular to the 50 m line 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.

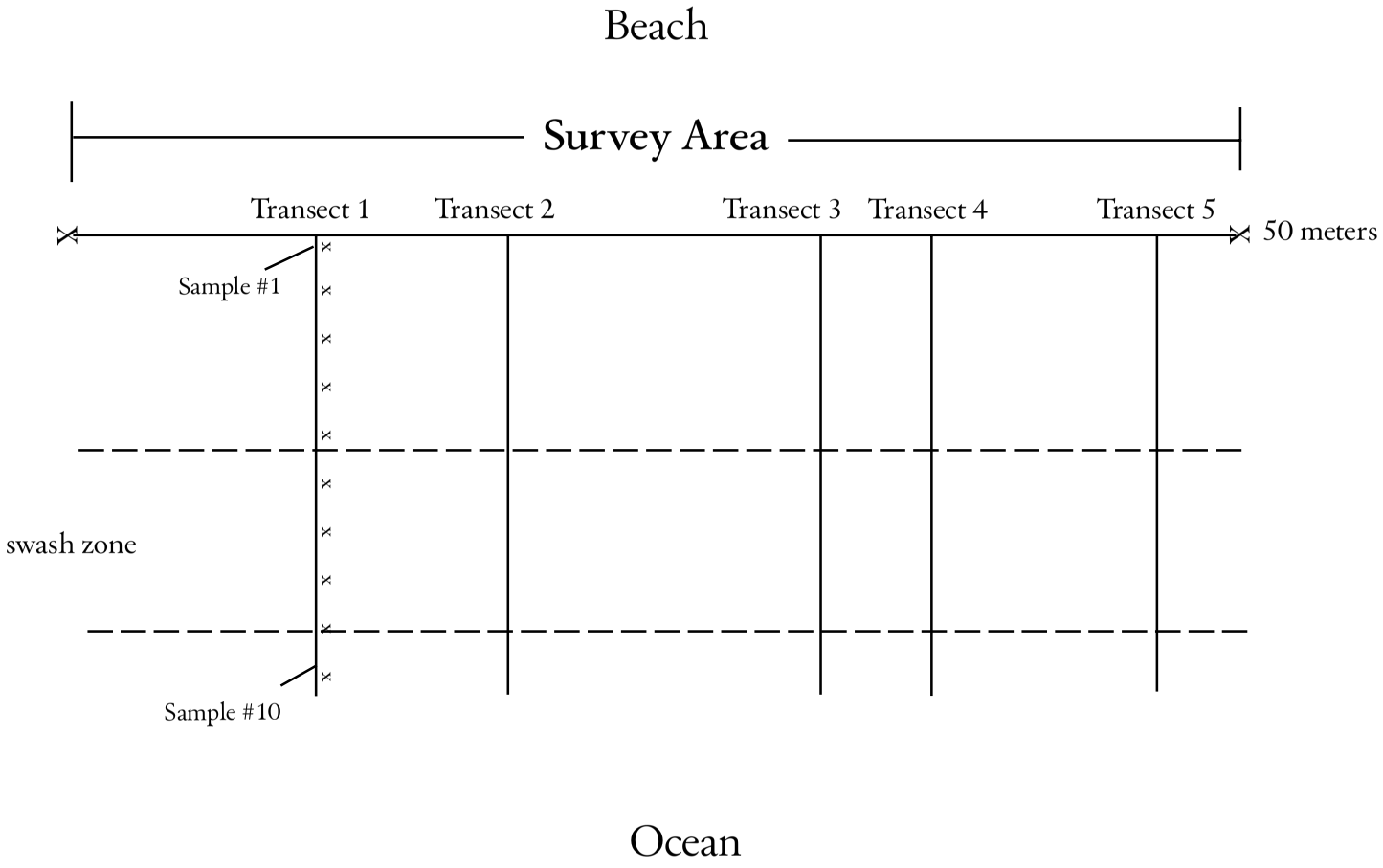


Figure 3. Diagram of transect layout. Transects are randomly selected and are at least 5 m apart.

- 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.
- 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

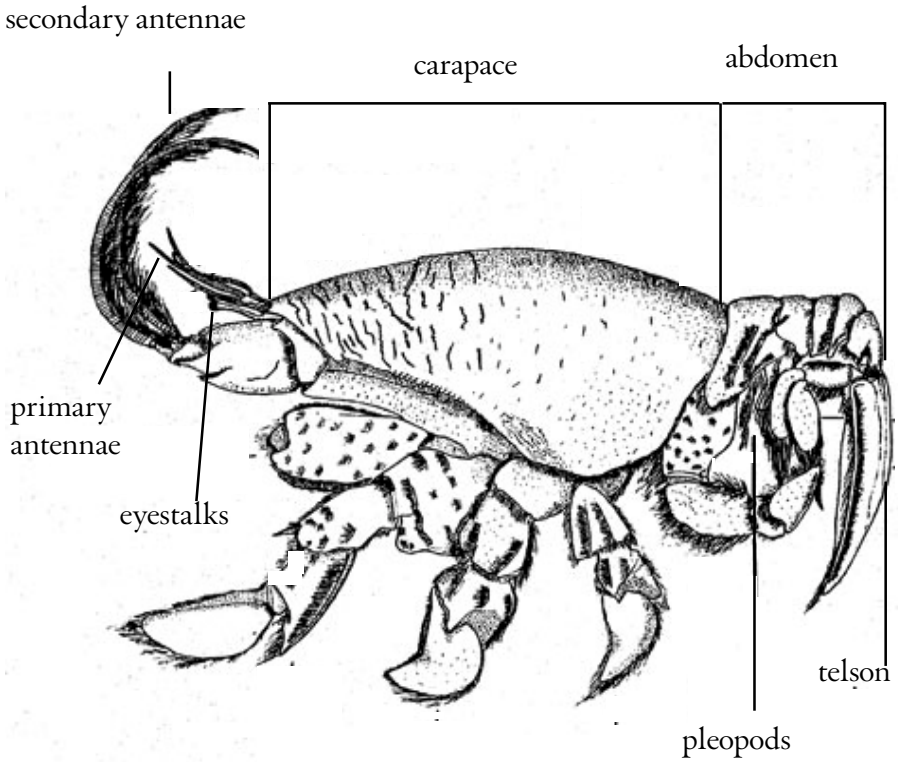
Sampling should occur quickly to avoid disturbance and loss of active animals from sampling area.

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. To collect a sample in the swash zone, it is 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 4) 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 (Figure 5).
  - 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.



Female *Emerita analoga*

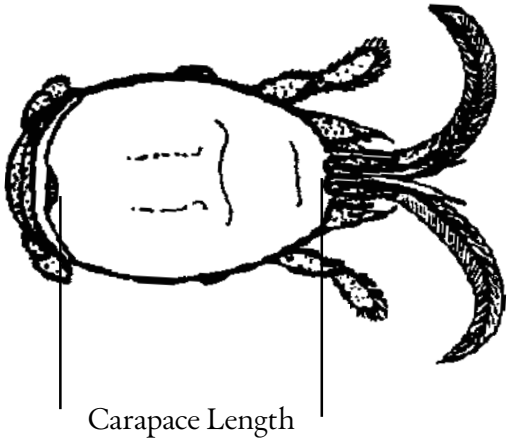


Figure 4. Top picture: diagram of a female Pacific mole crab. Females carry their eggs with their pleopods which can be seen under the telson or tail. Bottom picture (Dugan *et al*, 1990): dorsal view of a sand crab. The carapace is the hard covering, exoskeleton, covering the thorax. Students will measure and record the length of the carapace to the nearest millimeter using calipers.

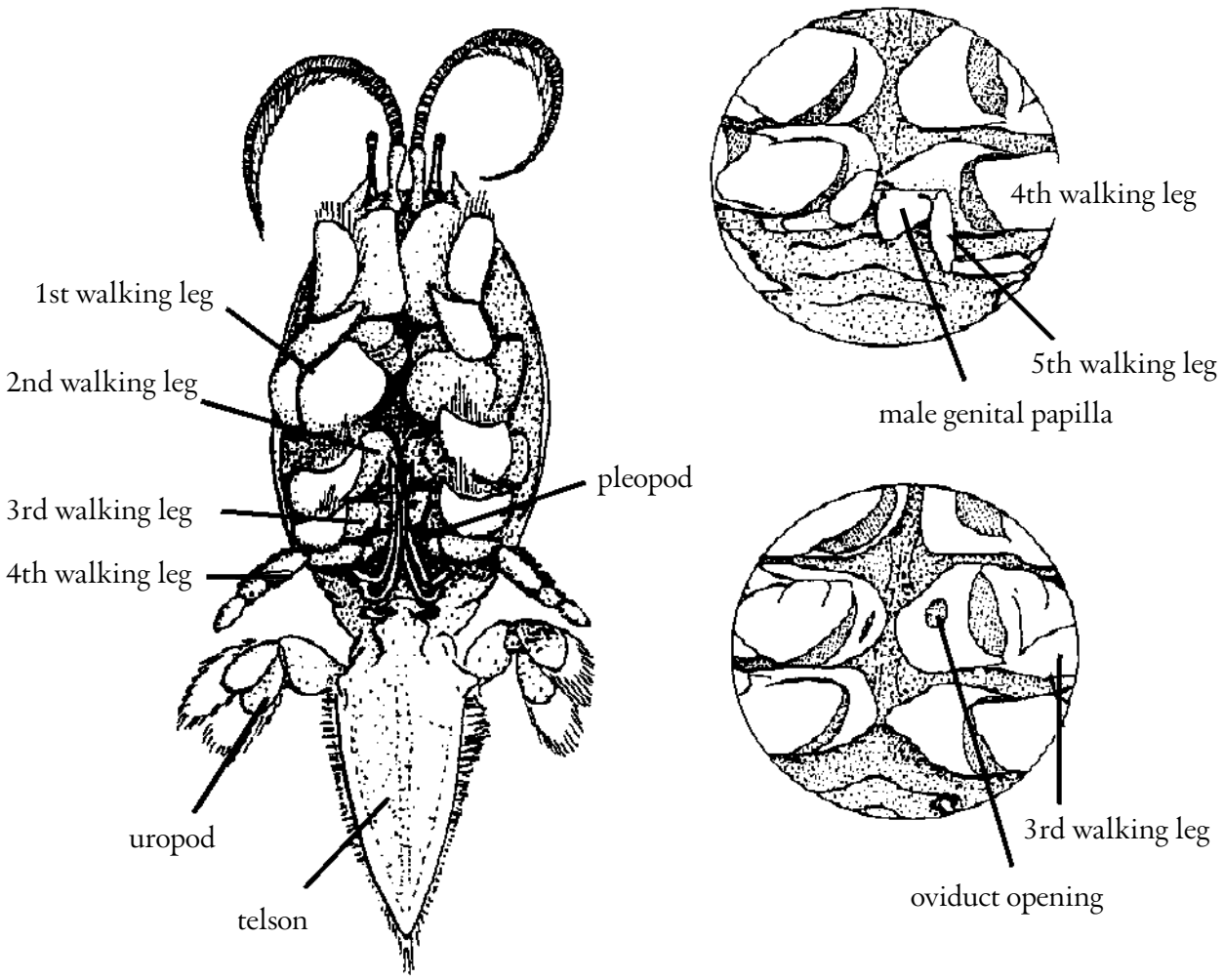


Figure 5. Ventral view of sand crab (Dugan *et al*, 1990)

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 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. 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 collecting the sand and crabs
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. You may want to assign two students to this task.

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.

Sampling Conditions: Data Sheet 1

Beach Name			Date	
School			Start Time	
Recorder			End Time	
Observors				
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				
Latitude		Longitude		

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:

Figure 6. Sampling Conditions Data Sheet

Sand Crab Data: Data Sheet 2

page _____ of _________

Beach name ____________________ Recorder ____________________

School name ____________________ 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. Use these codes: F=female   FE=female with eggs   M=male   R=recruit (<

Also note any crabs that have a soft shell by adding SS.

An example would be: for a 22 mm female with eggs that has a soft shell = FE 22 SS

If you start in the water, begin with sample #10; if starting on the shore, begin with sample #1.

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								

Figure 7. Sand Crab Data Sheet

Date ________ **Transect #** ________ **Random Location #** ________ **page** _____ **of** ________

Record the gender and size of each crab. Use these codes: F=female FE=female with eggs M=male R=recruit (< 9mm)

Also note any crabs that have a soft shell by adding SS.

An example would be: for a 22 mm female with eggs that has a soft shell = FE 22 SS

If you start in the water, begin with sample #10; if starting on the shore, begin with sample #1.

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

Sample Sand Crab Data: Data Sheet 2

page 1 of 4

Beach name	Doran	Recorder		Jane Lee
School name	Bay High	Team Members		Kim Jones
Date	7/25/01			John Smith
Transect #	2			Chris Black
Random Location #	13	# of Samples Along Transect	10	
Interval Width	0.5 meter	Water Depth at Last Sample	0.25 meters	

Record the gender and size of each crab. Use these codes: F=female FE=female with eggs M=male R=recruit (<
Also note any crabs that have a soft shell by adding SS.
An example would be: for a 22 mm female with eggs that has a soft shell = FE 22 SS
If you start in the water, begin with sample #10; if starting on the shore, begin with sample #1.

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							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**
Circle a zone:								
Dry or (Swash)								
Sample Number								**Tally**
Circle a zone:								

Figure 9. Completed Sand Crab Data Sheet

Data Entry Tally Sheet: Data Sheet 3

Beach name _____ Date _____

Transect # _____ Sample # _____

Tally the number of crabs by size and gender for ONE sample only

Size (mm)	Female	Female with Eggs	Male	Recruit	Totals
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 Entry Tally Sheet: Data Sheet 3

Beach name: Doran Beach Date: 8/4/02

Transect #: 3 Sample #: 2

Tally the number of crabs by size and gender for ONE sample only

Size (mm)	Female	Female with Eggs	Male	Recruit	Totals
4					
5					
6					4
7					17
8					9
9					
10					
11					5
12					18
13					14
14					10
15					1
16					
17					
18					6
19					7
20					
21					3
22					4
23					5
24					3
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
Totals	0	0	0	0	106

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 April Devitt at adevitt@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.

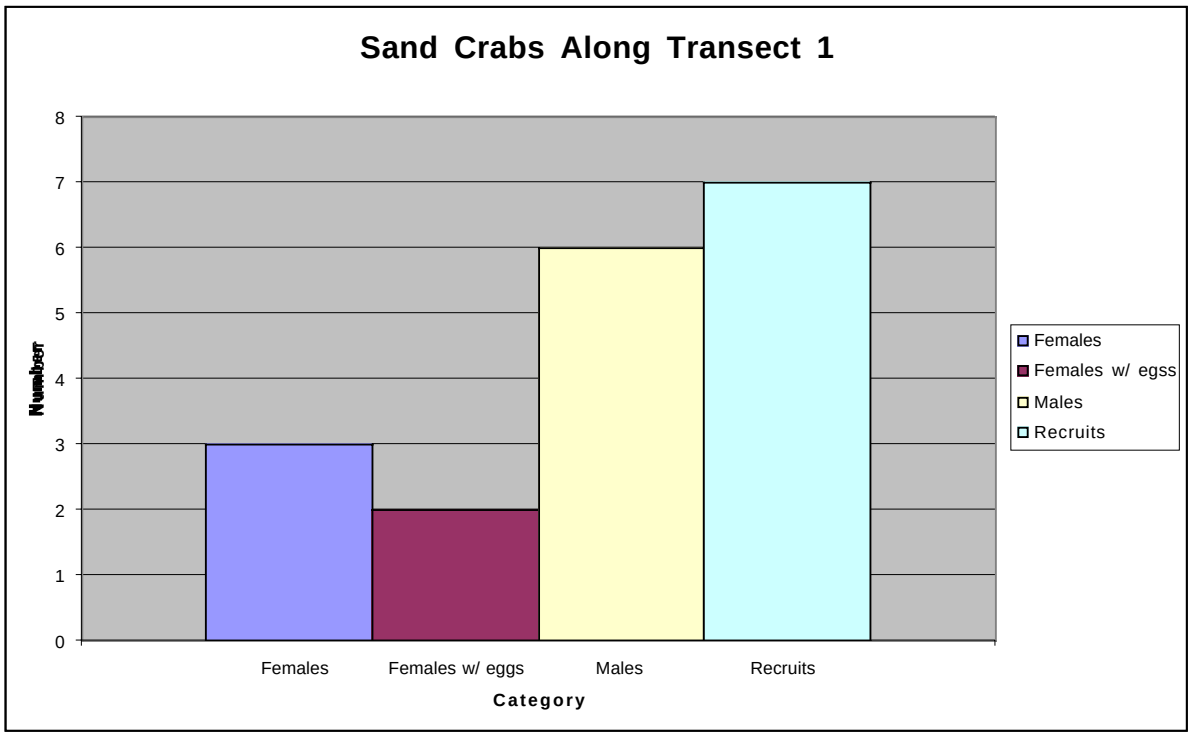


Figure 12. Sample graph of number of crabs found along a transect.

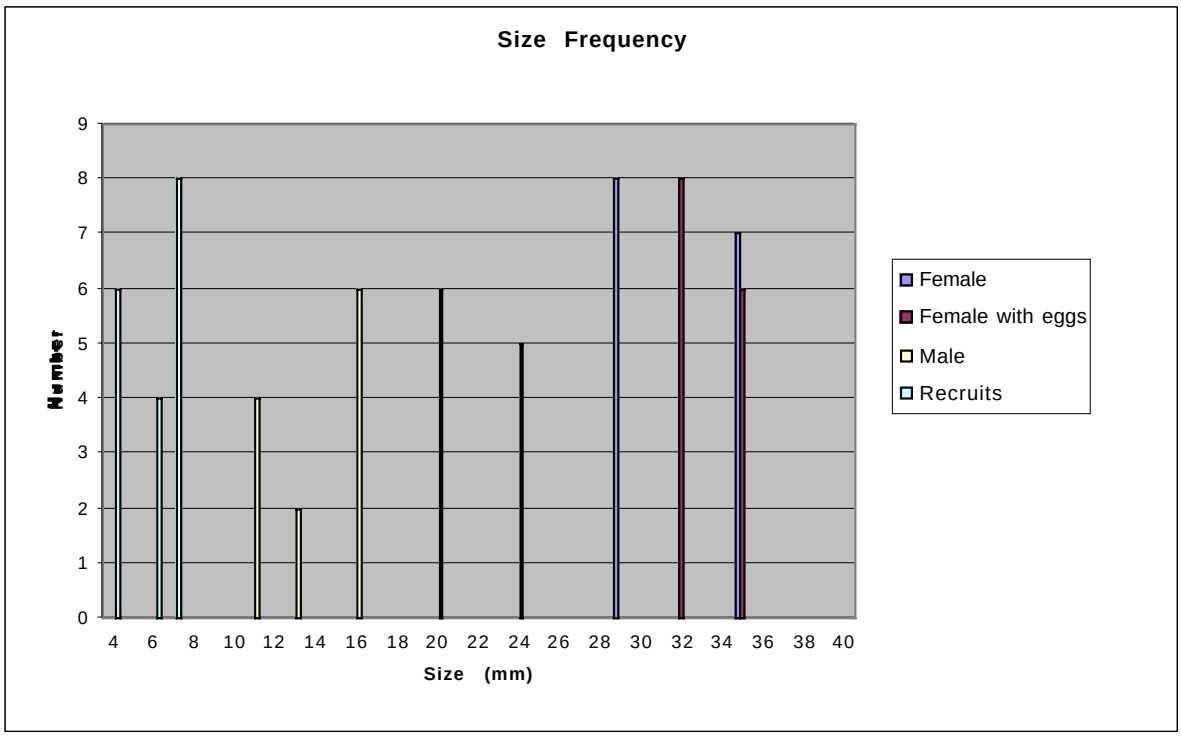


Figure 13. Sample graph of size frequency of crabs found along the survey area.

9. Data Analysis

Your students will need to interpret the data they collect in order to characterize the sand crab population at their beach. Organizing the raw data will allow students to identify any existing patterns, and to understand the distribution and abundance of sand crabs on a larger scale. To better visualize the data, students should begin by graphing the data. As they do, they may develop questions that could be tested using the information in the database. Skill level and the amount of time available for the project will dictate the ways by which students describe the data.

A. Graphing

Following data entry, students can generate graphs to display their results. The online system does not require a username and password to view the results. In the results section, students can select graphs for crab distribution along the beach, size fequency, and sex frequency. Students can compare their results to those of other schools monitoring beaches along the Gulf of the Farallones. At the future website, limpets.noaa.gov, the data will be part of a comprehensive dataset for beaches near the five National Marine Sanctuaries along the west coast.

If necessary, spend some time reviewing line graphs and histograms (bar graphs) with your students. You can use the student worksheet, *Analyzing the Data*, to guide your students in interpreting the graphs. When graphing distribution along the beach, each transect is presented as a different colored line. Students should keep in mind Sample Number 1 represents the high end of the beach, and Sample Number 10 represents the low end of the swash zone, in the water. Size frequency and sex frequency are presented as histograms for all crabs collected in a survey. For examples of these graphs, see Figure 12 and Figure 13. The bars represent categories of discrete data: sex or size (mm). For example, in Figure 12, there are four sex categories: females, females with eggs, males, and recruits (non-sexed crabs). The recruit category had the highest number of crabs: 7. Students can visually interpret the graphs to make comparisons between sampling events, or you can guide them to employ simple statistical methods to make more robust comparisons.

B. Statistics

A critical part of ecological investigation is statistical analysis. Statistical tests evaluate significant differences or similarities between data. They are used to draw conclusions about the patterns in the data with a higher level of confidence than using simple visual analysis. Explain to your students that one can measure a difference in nature, but the difference can be due to chance variation, and not representative of actual conditons. To reinforce this idea with your students, have them all flip a coin 10 times. Simply by chance, their results can differ from 5 heads and 5 tails. When sampling a sand crab population, you could not be 100% certain of conditions unless you were to census every crab. However, statisitics allows us to estimate with 95% certainty (P = 0.05) what is happening in the natural environment. A common factor in statistical tests is the null hypothesis, which assumes there is no effect or difference between treatments. The researcher is looking for a difference. Your students can explore the following questions using Chi Square analysis. Sample tables and examples are included for clarification.

For a Chi Square Tutorial, visit http://www.georgetown.edu/faculty/ballc/webtools/web_chi.html

B1. Is the sand crab sex ratio even or skewed?

Students can use the **Chi Square (χ^2) Test for Goodness of Fit** to compare the frequency distribution of their data with a theoretical expected distribution. The Chi Square Test examines the differences between distributions of discrete data, not percentages. When testing for a skewed sex ratio, the expected frequency distribution is 1:1, or 50 percent males : 50 percent females.

Null hypothesis:

The **observed** frequency distribution (ratio) is equal to the **expected** frequency distribution (ratio).

Formula: $\chi^2 = \sum (o - e)^2 / e$

For the different distributions to be compared, square the difference between the observed value (*o*) and the expected value (*e*), and divide this square by the expected value. The figures calculated for each category are then summed to obtain χ^2.

Calculation Table:

	MALES	*FEMALES*	
observed (obs.)			
expected (exp.)			
obs. – exp.			
(obs. – exp.)2			
(obs. – exp.)2 / exp.	+		=χ2

Degrees of freedom:

The degrees of freedom (d.f.) is equal to the number of categories (columns) minus 1.

Interpretation:

You will now compare the calculated χ^2 to a critical value from the χ^2 Table. χ^2 tables can be found at the following web addresses. A probablity level of 0.05 should be used.

- http://www.ento.vt.edu/~sharov/PopEcol/tables/chisq.html
- http://bmj.bmjjournals.com/collections/statsbk/apptabc.shtml
- http://www.richland.cc.il.us/james/lecture/m170/tbl-chi.html

If the value calculated for χ^2 is **equal to or greater than** the critical value given in the χ^2 Table, for the appropriate degrees of freedom, the null hypothesis can be rejected. If the calculated χ^2 value is **less than** the critical value, the null hypothesis cannot be rejected, indicating there is no statistically significant difference between the ratios.

Example:

You want to know if there are more male or female sand crabs at your study beach on a given date. You randomly sample the beach, and record 52 males and 64 females. Your null hypothesis is that the sand crab sex ratio is 1 : 1 (the number of males is proportionately the same as the number of females). To obtain the theoretically expected values, sum the two observed values (52 + 64 = 116) and divide by two (116 / 2 = 58).

Arrange the calculations in a table like this:

	MALES	*FEMALES*	
observed (obs.)	52	64	
expected (exp.)	58	58	
obs. – exp.	6	6	
(obs. – exp.)2	36	36	
(obs. – exp.)2 / exp.	0.62	0.62	
$\chi 2$ =	0.62 +	0.62	1.24

There are two categories (males and females), so the degrees of freedom is 1. The χ^2 Table at this d.f. and the probability level of 0.05 shows the critical value is 3.84. Since the calculated χ^2 value (1.24) is less than the critical value (3.84), you do not reject the null hypothesis. Although you collected more females than males, you cannot conclude that a significant difference exists between the number of male and female sand crabs on the sampling day. It is likely that the observed difference is the result of random variation in your collection.

B2. Do sand crab sex ratios vary significantly by season or location?

To test for a seasonal difference or a difference between beaches, students can use the **Chi Square (χ^2) Test of Independence**. This test can determine whether two or more frequency distributions are the same, and requires a contigency table to calculate the expected values.

Null hypothesis:

The frequency distribution of Sample A is equal to the frequency distribution of Sample B.

Contigency Table:

		males	*females*	Row Totals
Fall	observed			
	expected			
Spring	observed			
	expected			
Column Totals				

Degrees of freedom:

The d.f. is equal to (the number of columns minus 1) multiplied by (the number of rows minus 1).

Example:

You want to know if the distribution of sand crabs at your beach differs between Fall and Spring. The null hypothesis is # Males : # Females in the Fall is equal to the # Males : # Females in the Spring. You observe 72 males and 45 females in the Fall, and 15 males and 88 females in the Spring, and record this observed distribution in a contingency table as follows.

In this case, the expected distribution is not obvious, but must be calculated from the data. You calculate each expected value by multiplying its row total by its column total, and dividing by the grand total. For example, to determine the expected value for the Fall for males, (117 x 87) / 220 = 46.3. This calculation must be done for each row and column category.

		males	*females*	Row Totals
Fall	observed	72	45	117
	expected	46.3	70.7	
Spring	observed	15	88	103
	expected	40.7	62.3	
Column Totals		87	133	220

Now, you must calculate (obs. - exp.)^2 / exp. for each set of values and then total them to determine χ^2.

	FALL		SPRING		
	males	*females*	*males*	*females*	
obs. - exp.	25.7	-25.7	-25.7	25.7	
(obs. - exp.)^2	660.5	660.5	660.5	660.5	
(obs. - exp.)^2 / exp.	14.27	+ 9.34	+ 16.23	+ 10.6	50.44=χ^2

The sum of these calculations is χ^2, or 50.44.
The degrees of freedom for the test is (2-1) x (2-1) = 1. Consulting a χ^2 Table at the 0.05 level and 1 d.f. results in a critical value of 3.84, which is much smaller than the calculated χ^2 of 50.44, so you can reject the null hypothesis that the ratios are equal. There are different sex ratios in Fall and Spring; there are significantly more females in the Spring.

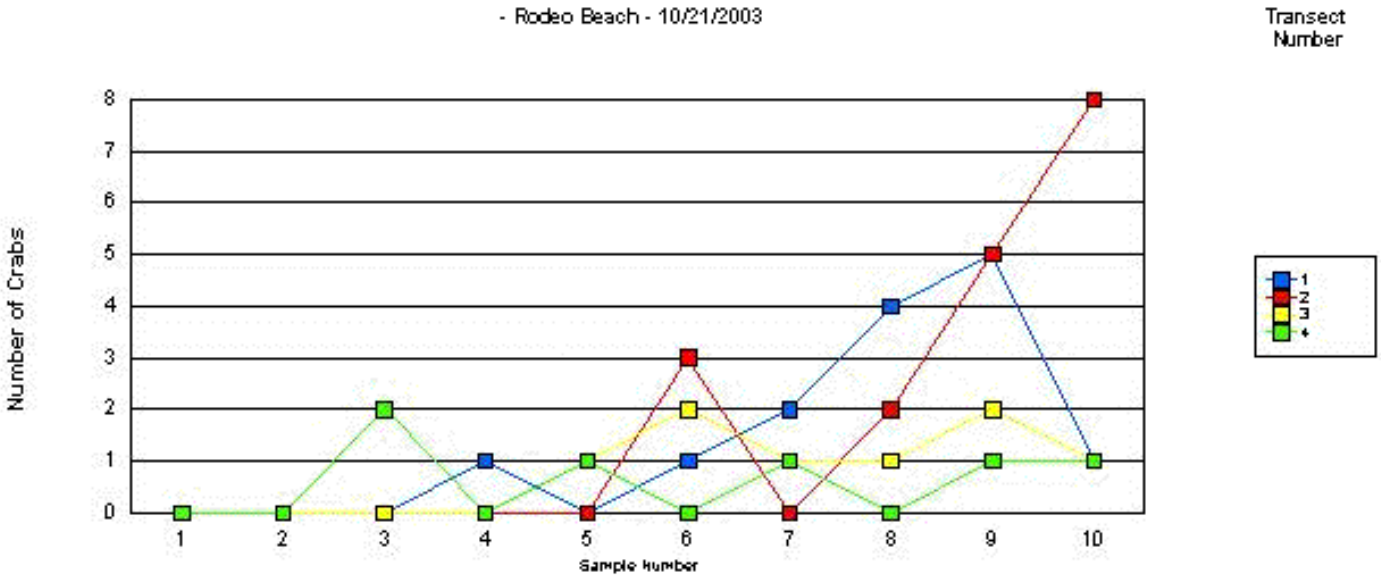
Other Comparisons
The same test could be used to investigate differences between two or more beaches. In addition to comparing the ratio of females to males, students could also compare the ratio of adults to juveniles.

Name _____ Date _____

Got crabs, now what?
Analyzing the Data

The purpose of a graph is to organize and present data so that it can be quickly and easily understood. A line graph depicts all data points. A histogram, or bar graph, distributes the data into different categories along the x-axis (bottom of graph). The bars show the number of items that fall into each category, or class, along the y-axis (side of graph).

1. Look at the graph of sand crab distribution along Rodeo Beach on October 21, 2003.

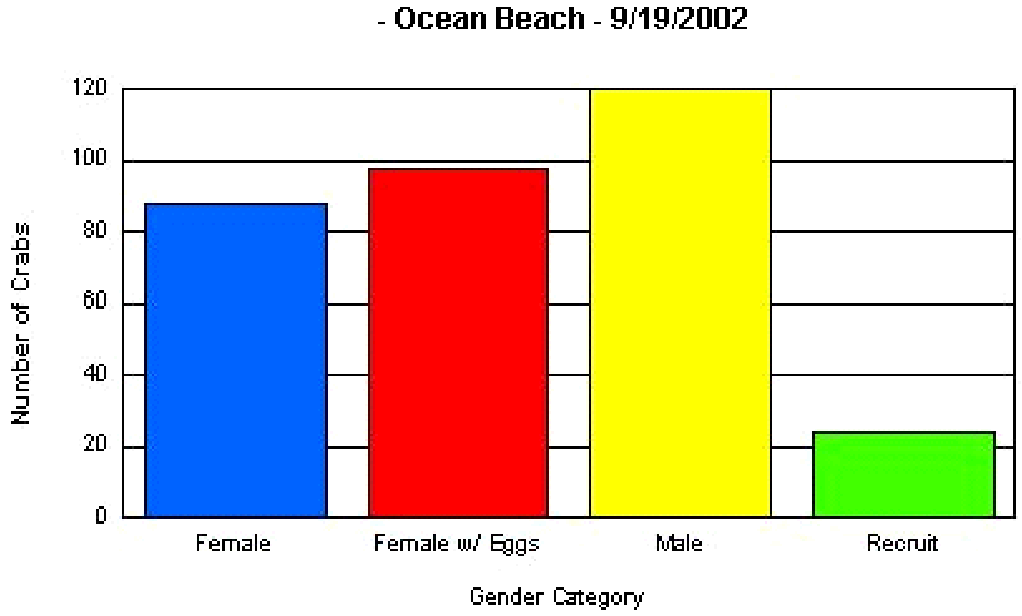


a) How many transects are shown?

b) Is there any pattern among the transects?

c) Describe the pattern from high (Sample 1) to low (Sample 10) swash zone?

2. Look at the graph of sand crab sex frequency at Ocean Beach on September 19, 2002.

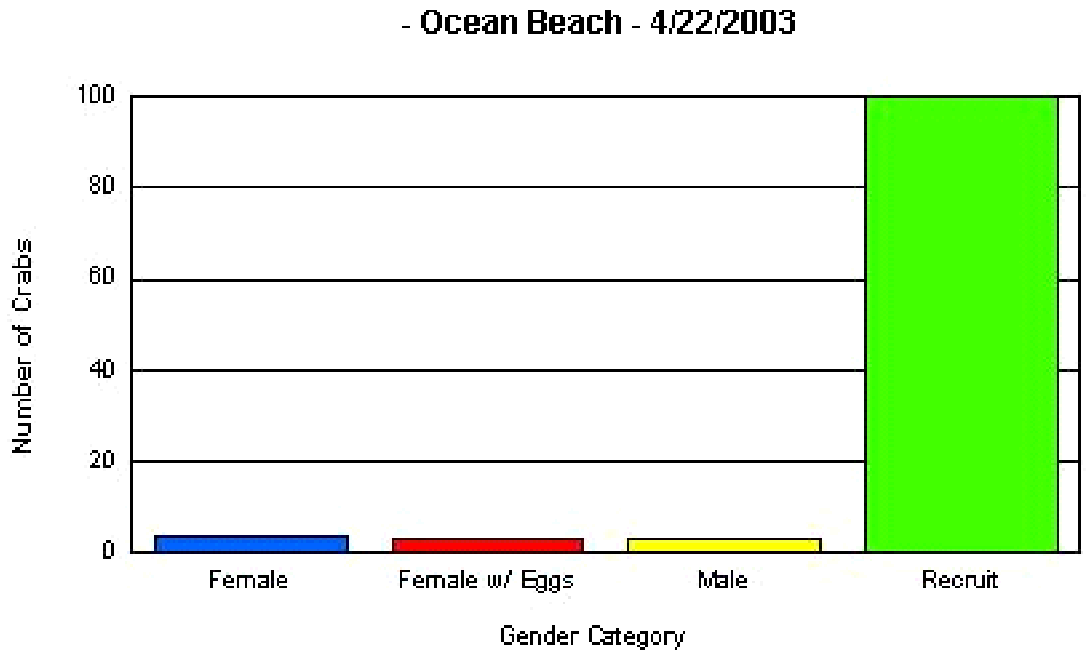


a) Which sex class is most abundant?

b) Which sex class is least abundant?

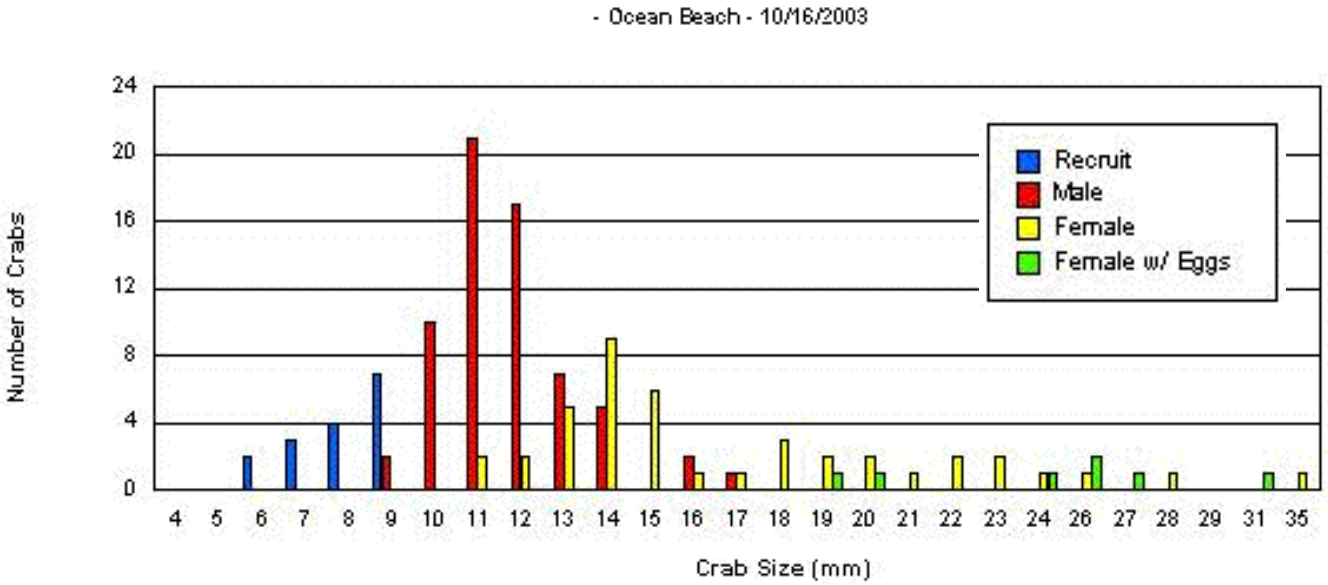
c) What is the difference between the number of males and all females?

3. Look at the graph of sand crab sex frequency at Ocean Beach on April 22, 2003.



a) How did the sex frequency of crabs change between seasons at Ocean Beach?

4. Look at the graph of sand crab size frequency at Ocean Beach on October 16, 2003.



a) Which size class is most abundant? How many crabs fall into this class?

b) Overall, do males appear to be smaller or larger than females?

c) What is the size range of females with eggs?

5. Make your own histogram.

a) Measure the height in centimeters of every member of your class, and record the data in the following table. Round to the nearest cm.

Females	Height (cm)	Males	Height (cm)

This is your raw data. To illustrate pattern, you need to simplify the data in a bar graph. First, determine:

- the maximum height (cm)
- the minimum height (cm)
- the difference between them (range)

Now you have a range of heights to group into categories, or classes, but how many should you have? Choose a number (between 5 and 10) that can be divided evenly or closely into the range.

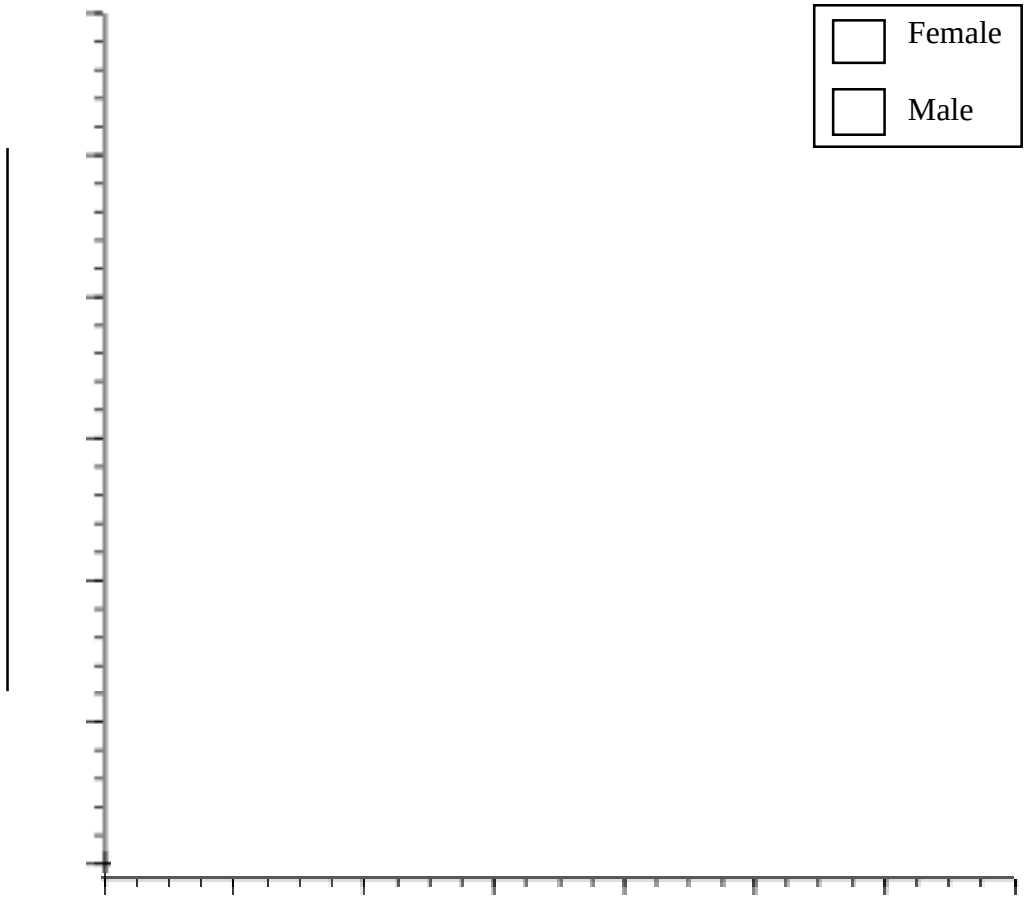
- number of categories _____

Next, divide the height range by the number of categories you have chosen to determine the interval, the size of each category. You don't want the interval to be too large.

- interval _____

Now you can label your graph, and plot your data. Remember to place the height classes from minimum to maximum along the x-axis (bottom), and the number of students along the y-axis (side). For each height class, draw a bar to represent how many students fall into that category. If you're feeling ambitious, draw one bar for females, and one for males in each height class - be sure to use two different colors or shadings.

(Title)



10. Final Assessment Options

Drawing conclusions completes the research process. You can choose from a number of ways to have your students do this. Regardless of the method, students should reflect on their experience, and communicate their observations to an audience (teacher, classmates, school community, etc.). Following are guidelines and suggestions for field journals, scientific papers, and poster and oral presentations.

Field Journal

Students can keep a field journal throughout the year to accompany sandy beach monitoring and other outdoor experiences. The purpose of a field journal is to help students develop a complete picture of a study, so that it can be understood within the context of the curriculum. Students record their observations prior to fieldwork, in the field, and during follow-up lab activities. They should describe any problems or ideas that occur during the research experience. Students can use a blank composition notebook or prepared worksheets as they complete the monitoring activities. If you choose to create a structured journal for your students, consider the following sample questions.

Slide Show and Training

- Where do sand crabs live?
- Draw a sand crab, and label the carapace.
- How can you tell the difference between a male and a female?
- Why might it be important to monitor sand crab populations?

Sampling

- Record the weather conditions.
- Describe your beach study area.
- What other animals are present, if any?
- Why do we sample along randomly assigned transects?
- What trends did you observe, if any?

Parasite Analysis

- How long does it take for the parasites to excyst in fresh water?
- What predators might sand crabs have?
- How can the parasites affect these animals?

Formulating a Question

Field journals can be used alone to reinforce learning, or as the preliminary step in the scientific process: formulating a question. As the field journal provides students with opportunities to record questions that arise throughout the study, it can serve as a catalyst for further investigation. Following the fall sampling event, encourage your students to sit in small groups or alone and develop some questions about what they have experienced in the classroom or field. Have the students share their questions with the group, and invite discussion. Group similar or related questions, and ask the students how they would go about answering them. Remind students that a research question must be testable. Ask them to consider what they could investigate given the parameters of the study: crab density and distribution along the beach, size frequency, and sex frequency for all beaches in the monitoring program. Work with the group to generate testable questions. If you like, the class can investigate these questions together, in groups, or

individually, and present their findings in the spring. Following are some possible questions that your students may pursue.

- Are sand crabs distributed evenly between high and low elevations?
- Does the distribution of crabs across the beach differ between fall and spring?
- Are there seasonal variations in the sex frequency and size frequency of sand crabs?
- Does the sand crab population have a skewed sex ratio?

Scientific Paper

When writing a scientific paper, students should recognize that the organization of the paper is patterned after experimental design. The research paper presents the question being asked, the materials and methods used to answer it, the results of the experiment, and the meaning and significance of the results. The student handout, ***Writing a Scientific Paper***, describes the sections each paper should include: Introduction, Materials and Methods, Results, Discussion. Tables and Figures can be included in the Results section, or placed at the end of the paper. The axes of the graphs generated by the database will be labelled automatically, but students should title all inserts so they can be referred to in the text of the paper.

Following the spring sampling event, there will be a limited amount of time for data analysis and write-up. Although the results and discussion sections cannot be completed until this time, have your students begin work on their research papers earlier in the year. The bulk of the introduction can be written prior to the first monitoring experience. Allow time for students to research and summarize background information on the Pacific mole crab so they will have a clear understanding of what is known about the animal before the field trip. Instruct students how to cite sources, and provide a bibliographic style for them to follow. After the field experience, students can brainstorm and formulate the question under investigation, and state it at the end of the Introduction. The Materials and Methods section can be completed at this point, as the same protocol will be employed in the spring. Once they have entered their data, students can begin to generate the relevant graphs and summarize these results. In the spring, students can conduct statistical tests, if applicable, finish the Results section, and interpret the results in the Discussion.

Poster Presentation

A scientific poster incorporates design elements into a visual presentation of information, and allows students to communicate their research to a larger audience. The student handout, ***Creating a Scientific Poster,*** describes the format used to present research. If students are working in groups, posters provide the best forum for group exchange of information. Students can use posters to present their findings to one another, to other classes, and to parents.

Oral Presentation

In addition to a visual presentation of information, an oral presentation provides students with the opportunity to practice their public speaking skills. The student handout, ***Preparing and Presenting a Scientific Talk***, provides guidelines for the oral presentation. Depending on available resources, students can produce handouts, overhead transparencies, slides, or a Powerpoint presentation to aid them in their talk. The printed information should be clear and concise, and reflect the key points of the study. Provide your students with a time limit for the talk - ten minutes is sufficient.

Writing a Scientific Paper

What is a Scientific Paper?

A scientfic paper is a written research report that follows a strict, logical order: your question, how you attempted to answer it, what happened, and your conclusions. It is the most common way scientists communicate their findings to others.

Paper Contents

- Title
- Introduction
- Materials and Methods
- Results
- Discussion
- Acknowledgments
- Literature Cited

Title

The title of your paper should state the kind of work you are reporting. It should be simple and informative, and name the organism under study.

Introduction

What are you going to study?

Before you begin monitoring the sand crab population at your beach, research the topic thoroughly. Determine what is already known about sand crabs along the coast of California, and if what you want to know is new information. Library and internet research will help you understand the experiment, and the importance of the study. Research also allows you to make a prediction about what you are going to see.

In this section, provide relevant background information on the topic. At the end of the section, present the question you are trying to answer with your study, and why it is of interest to you. State your hypothesis, or what you think will happen.

Materials and Methods

How did you conduct the study?

Now that you have a hypothesis, you need to test whether it is true or false. Prepare a detailed procedure for your experiment, which includes a description of the equipment you used. Think of this section as the recipe for your experiment - it should be clear enough for someone else to follow your methods if they wanted to see how you got your results. Be sure to:

- think about each step in the experiment, and record exactly what you did.
- describe all of the sampling equipment.
- explain how you made your measurements.
- explain how your sampling represented a random survey of the beach.

Every experiment has controlled variables, things that you don't want to change throughout the study. This way, you can determine the effect of one variable. The sampling method must be the same for all monitoring events. All variables in your experiment will remain constant except for season --- you will sample in the Fall and in the Spring.

Results

What did you find out from the study?

Once every group has entered its data into the online database, you can begin to analyze the data collected by your class. You will find it difficult to see any pattern in the raw data (data sheets), so graph the data to reveal the trends. This will help you organize the data, and develop a picture of the sand crab population at your beach. At the sand crabs website, you can graph your data in three ways: crab distribution along the beach, crab size fequency, and crab sex frequency.

You may need to perform statistical tests, or calculations, on your raw data in order to get results that you can compare and interpret. For example, you could determine the average length of males and females for a group of transects. Record any calculations in a table.

Following data analysis, summarize your results in this section. Simply present what you found, not what you think. You will draw conclusions from your results in the Discussion section. Use graphs to illustrate your results, but describe the results using words as well. A reader should be able to understand your data by looking at the graphs alone, or by reading the text alone. Make sure you:

- include labeled graphs and statistical tables.
- refer to all graphs and tables in the written part of the section.
- clearly present information without interpretation.

Discussion

Did you get the results you expected?

Think about your results, and explain what they mean in this section. Your conclusions should describe how your results support or contradict your original hypothesis. If you determine you need more information to understand what is going on, suggest what you could do next to continue the study. If the study led you to ask more questions, present them at the end of this section.

Acknowledgments

You can thank any individuals who helped you with your study in this section. Provide their names, and how they helped you.

Literature Cited

In this section, list all books and articles you mentioned in your paper. Your teacher will provide you with a biliographic style to use. List your references in alphabetical order of the first author's last name. Here is a sample citation.

Smith, C.A. 1994. Effects of salinity on the growth of cordgrass. *Plant Journal* 53: 121 -- 129.

Creating a Scientific Poster

What is a Scientific Poster?

A poster is a visual presentation of information that combines text, color, and design to hold the audience's attention. A poster guides the reader from one idea to the next in a well organized and uncluttered manner.

Poster Contents

- Title
- Abstract
- Introduction
- Materials and Methods
- Results
- Discussion
- References
- Acknowledgments

Title

Your title indicates what the poster is about. It should be clear, eye-catching, and not too wordy. Place the title at the top of the poster, and use all capital letters. Include your name and school after the title.

Abstact

An abstract is a brief summary of the information presented in your poster. The abstract should include a statement of purpose for the study, a short description of the project, and an interpretation of your findings. The abstract should be 5 - 6 sentences in length.

Introduction

The introduction provides the background information for your study. Briefly describe the history of your topic, the purpose of your research, and end with a statement of your hypothesis.

Materials and Methods

This section describes how you conducted the study. Include the experimental design, techniques and instruments you used, as well as any photos or diagrams.

Results

The results section displays the data using graphs, tables, charts, or pictures. Make sure all figures are properly labeled and readable from a distance. You also need to state your findings clearly in writing.

Discussion

The discussion explains what your results mean. Make conclusions about your research, and indicate whether or not your results supported your hypothesis.

References

If you cited the work of others in your introduction or discussion, list the sources in this section.

Acknowledgments

You can thank any individuals who assisted you in your research.

Poster Materials

- Poster board
- Heavy weight paper: white and contrasting color
- Rubber cement or glue

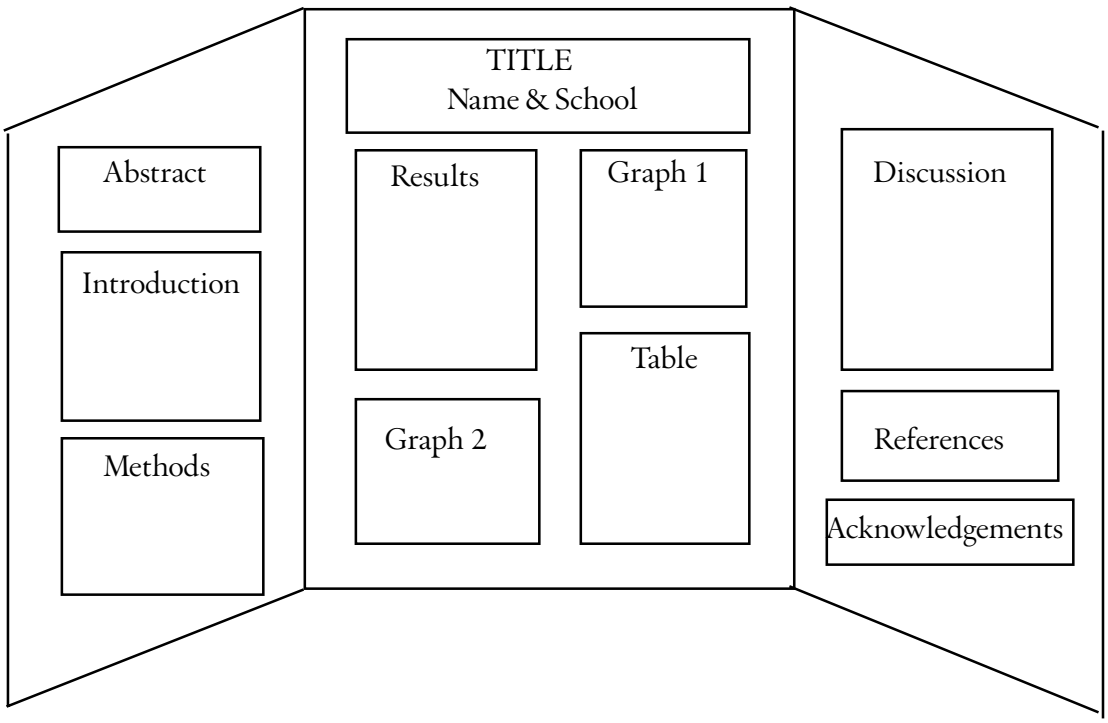
Print each poster section onto white paper and mount evenly onto colored paper. Glue the sections to the poster board (see below).

Tips for a Successful Poster

- Keep the style consistent.
- Balance large and small items.
- Choose one warm color to use thoughout your poster.
- Use black text.
- Avoid decorative, hard-to-read fonts.
- Use a larger font for the headings.
- Make sure the poster text can be read from a distance of 4 - 6 feet.
- Use photos of study site, specimens etc.
- Use active voice in your writing.

Poster Layout

Arrange the sections on the poster board before gluing them down. Make sure everything will fit without looking crowded. Ask someone to look over the poster for you before you assemble it .



Preparing and Presenting a Scientific Talk

What is a Scientific Talk?

A scientific talk is a professional version of show and tell. If done well, the speaker communicates new information and knowledge to an audience so that they can best understand and remember it. Presenting and attending oral presentations is an important part of science, as well as many other careers. A good talk:

- has an introduction, a body, and a conclusion.
- uses simple, direct language.
- summarizes the facts and data.

Preparing the Talk

Decide what you are going to say, practice saying it, and make notes to use during the talk. Your visual aids will guide you through your presentation, but you cannot simply read them to the audience.

- **Outline the talk.** Follow the steps of the scientific method.

  1. Begin by introducing the topic to the audience. Describe why the topic is of interest and what was known about it prior to your study. Share your own observations that led to your question. Clearly state your purpose for conducting the study. (3 - 4 minutes)
  2. Describe the materials and methods you used to collect your data. Indicate where and when you did your research, and for how long. (2 - 3 minutes)
  3. Summarize your data, pointing out any trends or unexpected results. Explain what your results mean. (5 - 6 minutes)
  4. Express your conclusions about your research. Review what you set out to learn, and discuss what your found out. If you had inconclusive results, indicate what you would do differently in the future. (3 - 4 minutes)

- **Prepare the visual materials** (**handouts, overhead transparencies, or computer presentation**).

  handouts - pass out before your talk, allow the group a minute or two to look them over.
  transparencies - your teacher can help you photocopy these to use with an overhead projector.
  computer presentation - if available, use a program such as Powerpoint to combine words and pictures into a series of slides.

- **Draft words to go with the visual aids.** You are choosing words to be spoken, not read. Make sure what you plan to say sounds logical and natural.

- **Rehearse the talk.** Practice, practice, practice, then practice again. Do not simply memorize the words to say. Practice speaking aloud to make sure your thoughts flow easily. Practice your talk in front of a friend or family member, someone who can help you identify any awkward or unclear points in your presentation. Rehearse with your visual aids, so you aren't fumbling with them for the first time in front of an audience. This will help you time your talk, and smoothly move from one image to the next.

Tips for Visual Aids

- Select images that relate to and clarify the material covered in your talk.

• Printed information shoud be brief - use the fewest number of words possible.
• Make sure your visual aids are easy to understand, and visible to the entire audience.
• Use contrasting colors (black and white, blue and yellow) to distinguish your images.
• Do not include too many visual aids in your talk - the audience will spend more time and energy reading than listening to you.
• Do not read your visual aids to the audience! They are meant to support what you are saying, not be the only things you say.

Presenting the Talk

Like it or not, you are presenting yourself as well as your information. Your voice and body language can say more than your words.

• **Speak clearly - no mumbling.** Speaking too softly or too loudly will distract and frustrate your audience. Speaking too quickly makes your talk difficult to understand, and indicates nervousness. Slow down, and say your words thoughtfully.

• **Vary the tone of your voice.** Use a conversational tone when addressing a group. The sound of your voice should capture the group's attention, and reflect that you are interested in what you are saying.

• **Project your voice.** Make sure everyone in the room can hear you. Take care not to talk when your back is turned to the audience.

• **Maintain eye contact.** Try to look at the audience as you speak, especially when you are emphasizing an important point.

• **Be aware of your posture.** Stand up straight, but not rigidly. You don't want to look unconcerned, or uncomfortable. Although it is difficult when standing in front of people, try to appear relaxed and confident.

Acanthocephalan Parasites

A parasite is an organism that grows, feeds, and is sheltered on or in a different organism while potentially harming the host. The organism that the parasite lives with is called a host. The Acanthocephala phylum of spiny-headed worms require two hosts: they live in crustaceans and insects as juveniles, and in the digestive tracts of vertebrates as adults. In the Gulf of the Farallones National Marine Sanctuary, *Profilicollis* species have caused die-offs of Surf Scoters (diving ducks) and could affect the few sea otters living here.

Surf Scoter (*Melanitta perspicillata*)

Life Cycle of Acanthocephala

Some coastal birds are a definitive host for Acanthocephala, meaning that the parasite can reproduce. Birds carry adult parasites in their small intestine where female worms produce eggs, which are passed in the bird's feces. The eggs are eaten by intermediate hosts and the parasite changes into an infective stage called a cystacanth. The definitive host is infected when it ingests an infected intermediate host. The cystacanth excysts in the small intestine and matures into an adult worm. *Profililcollis* species use Pacific mole crabs (*Emerita analoga*) and spiny mole crabs (*Blepharipoda occidentalis*) as intermediate hosts, and Surf Scoters (*Melanitta perspicillata*) as definitive hosts. The parasites affect sea otters (*Enhydra lutris*) as well, but they are a dead-end host because the parasites are not able to reproduce.

For more information contact:
Farallones Marine Sanctuary Association
(415) 561-6625 www.farallones.org

Acanthocephalan parasite inside a Pacific mole crab

Effects on Organisms

Pacific mole crabs are the primary intermediate host for Acanthocephalans. In *Emerita analoga* the parasites are located in the posterior hemocoel near the midgut. They look like white footballs, and can be seen by the naked eye. The parasites are not lethal to mole crabs, although they could affect their behavior, perhaps making them easier prey. In both the definitive and dead-end hosts, Acanthocephalans induce peritonitis, which is inflammation around the abdominal cavity. Peritonitis occurs when larval Acanthocephalan parasites that reside in the intestine migrate through the intestinal wall, allowing bacteria to infect the abdominal cavity.

In 1995, the California Department of Fish and Game estimated that 1000-4000 Surf Scoters died due to an unusually high load of Acanthocephalan parasites. Mortality is hindering the growth of the threatened California sea otter population. Forty to fifty percent of sea otter deaths are caused by infectious disease, of which the most prevalent is Acanthocephalan peritonitis. High school students are investigating parasite load as part of sand crab monitoring in the Gulf of the Farallones National Marine Sanctuary.

Sea otter (*Enhydra lutris*)

Acanthocephalan Parasites: Investigation in Pacific Mole Crabs

Objective

Students will investigate the presence of parasites in Pacific mole crabs. Students will learn about the life cycle of a parasite and how it influences organisms in a food web. They will examine the anatomy of sand crabs while using dissection techniques and scientific equipment.

Materials and Supplies for each group

Parasite fact sheet
Student worksheet
Microscope or magnifying glass
2 Petri dishes - 1 for crab, 1 for parasites
Large waste bowl or 100 ml beaker
Squirt water bottle filled with fresh water
Small scissors
2 Tweezers/forceps
Caliper
Gloves

Background

Acanthocephalans (spiny head worms) are parasites that use Pacific mole crabs as their primary intermediate host. In the crabs, the parasites reside in the posterior hemocoel near the midgut. Surf Scoters (diving ducks) are the definitive host (parasite can reproduce) for acanthocephalans, but the parasite affects sea otters as well. Acanthocephalans have caused Surf Scoter die-offs and disease in sea otters by causing peritonitis (inflammation of the abdominal cavity).

Teacher Notes

1. Each class should collect and look for parasites in 30 crabs (> 10 mm). Each group of 2-3 students should dissect 2 crabs.
2. Kill the crabs by placing them in a covered container in a freezer for more than 4 hours. Make sure to note the date and beach where the crabs were collected.
3. This lab will take one class period allowing for introduction, set-up, dissection, entering data, and follow-up questions. Dissecting one crab takes about 10 minutes.
4. You can see the parasites with the naked eye, but using a microscope or magnifying glass will make the identification of the parasites easier.
5. Have the students contain all the crab parts in their large waste bowl, then dispose of all the dead material in a trash can.

Acanthocephalan Parasites: Investigation in Pacific Mole Crabs
Student Worksheet

<u>Materials and Supplies for each group</u>
Microscope or magnifying glass
2 Petri dishes - 1 for crab, 1 for parasites
Large waste bowl or 100 ml beaker
Squirt water bottle filled with fresh water
Small scissors
2 Tweezers/forceps
Caliper
Gloves

<u>Vocabulary Words</u>
parasite
intermediate host
definitive host
hemocoel
peritonitis
excyst

<u>Procedure</u>
1. Measure the carapace length and determine the gender of the crab. Record this information on the data table.
2. With the scissors, cut off the posterior end of the crab, from the notch back (a little bit more than the telson).
3. Cut the crab's carapace up the middle and pry the 2 sides open with your fingers or tweezers.
4. Put the crab in a petri dish and place the petri dish under the microscope. You are now looking at the midgut.
5. You are looking for small white "footballs" that are right under the carapace. You might have to dig around in the gut a little with the tweezers, but if there are parasites they are pretty evident. Flushing the inside of the crab with water using the squirt bottle can help find parasites. Make sure you keep pulling out the insides of the crab to thoroughly check the whole gut area for parasites.
6. Remove the parasite(s) and place them in a petri dish filled with fresh water. The parasite will excyst after a few minutes. Look at the head end - it should have spines.
7. Record the number of parasites on the data table. It is just as important to record zeros as crabs with parasites!

Data Table

Date	Beach	Size (mm)	Gender (F, FE, M)	Number of Parasites

Questions

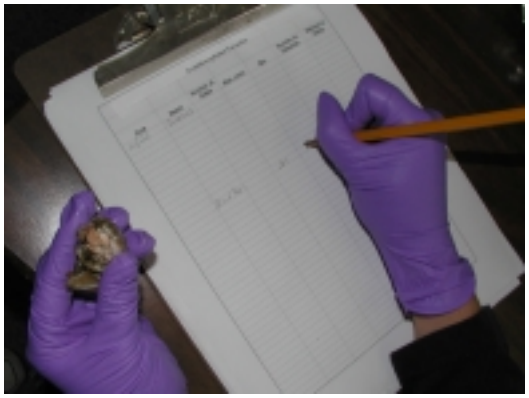
1. What did you observe while dissecting and looking for parasites?

2. After comparing your data with your classmates, what trends do you notice?

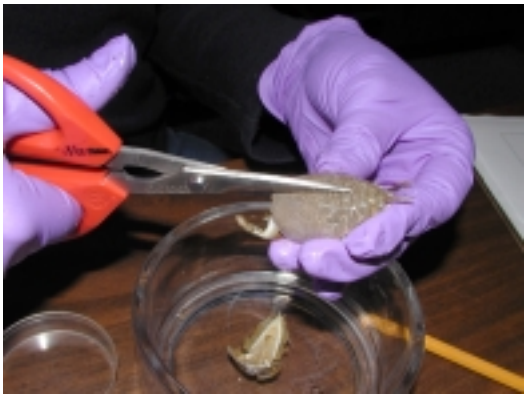
3. How do acanthocephalan parasites affect other organisms?

4. How could you determine what is a harmful level of parasites?

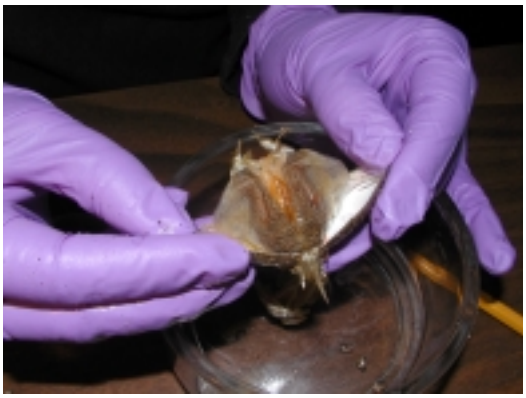
Dissection Steps



1. Record the size and gender for each crab on the data table.

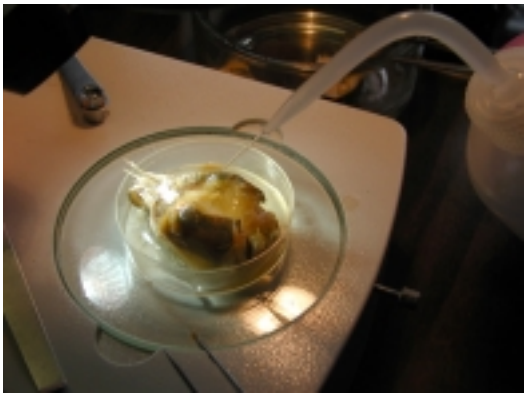


2. After cutting off the telson, cut the carapace up the middle.



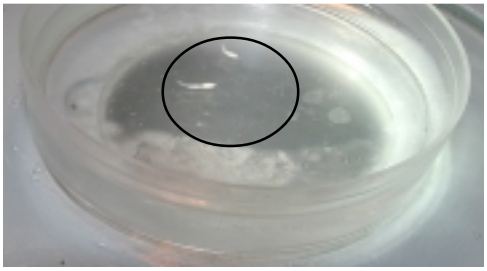
3. Pull apart the sides of the carapace to expose the midgut.

4. Look initially to see if you can see small white parasites inside.



5. Flushing the inside of the crab with water and digging around with your forceps will help you locate all the parasites.

6. The parasites look like small white footballs. Record how many parasites you found for each crab on the data table.



7. When the parasites are in fresh water, they excyst afer a few minutes.

All photos by Larry Lynch

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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

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