GULF OF THE FARALLONES NATIONAL MARINE SANCTUARY

# ROCKY INTERTIDAL MONITORING PROJECT

# TEACHER HANDBOOK

FARALLONES MARINE SANCTUARY ASSOCIATION FMSA

NATIONAL MARINE SANCTUARIES ™ GULF OF THE FARALLONES

# ACKNOWLEDGEMENTS

Many people contributed to the completion of the protocols and contents of this manual. For their efforts, the following deserve recognition and an abundance of thanks. This second edition is based on the hard work of those who put together the first edition.

This new edition brings the protocols developed by John Pearse, Ph.D, and Dawn Osborn at the University of California- Santa Cruz from Monterey Bay to the Gulf of the Farallones National Marine Sanctuary. They generously offered their guidance and hard work to us. Together with the west coast National Marine Sanctuaries,this new protocol will be used at many locations and thus will provide research scientists and resource managers information about the conditions at the rocky intertidal zones along the US Pacific Coast.

Special recognition goes to both Shannon Strong, an education intern who coordinated the project and to Kathy Soave of The Branson School in Ross, California. Maria Brown was instrumental in the project's development as executive director. This project would not have existed if not for her foresight and commitment to protect the Sanctuary through education and monitoring. Members of the staff of the Gulf of the Farallones National Marine Sanctuary shared their expertise in monitoring in the field.

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SECOND EDITION

# Table of Contents

# List of Figures

## Figures:



# List of Tables

## Tables:

# 1. Introduction

The Rocky Intertidal Monitoring Project is a long-term, baseline monitoring project implemented by high school students and teachers in coordination with the Gulf of the Farallones National Marine Sanctuary (NMS) and the Farallones Marine Sanctuary Association.

The protocols in this manual offer an in-depth approach to learning and understanding the ecology of one of the world's most diverse ecosystems, the rocky intertidal. Participants will learn about the variety of abiotic factors that are unique to this marine ecosystem. Through monitoring participants will gain a deeper understanding for rocky intertidal areas; they will be equipped to make a difference in protecting marine organisms and habitat. By comparing two different areas, students may be able to detect the impact of humans on the sensitive habitat of the rocky intertidal zone. This project incorporates ecology standards and investigation and experimentation standards from the Science Content Standards for California Public Schools.

Specifically, the Rocky Intertidal Monitoring Project endeavors to achieve the following goals:

1) to develop a baseline database of density and abundance of selected species;
2) to contribute to the conservation of the rocky intertidal habitat;
3) to educate students and the general public about intertidal species, habitat, and requirements for maintaining a healthy, diverse intertidal ecosystem; and
4) to increase stewardship in the Sanctuary.

A significant commitment by the teacher or adult leader is necessary in order to coordinate this project. A site must be chosen that is accessible to the students, and permanent transects must be established. We encourage sampling three times per year, plus at least a few learning sessions at the site. During sampling, quadrats will be placed along the transects, and invertebrates and algae will be counted. Back at school, students will analyze their data using computers. In addition, students are encouraged to share their results with the general public and other students through kiosks, presentations, student led tidepooling trips, poster contests, and through the Internet. Several years of data collection may allow Gulf of the Farallones NMS staff to make more informed management decisions for rocky intertidal areas.

This teacher handbook includes background information about the Gulf of the Farallones National Marine Sanctuary and the natural history of the rocky intertidal ecosystem. Protocols and examples of data sheets needed for this project are also included. You may need to alter the data sheets for your specific site.

Long-term Monitoring Program and Experiential Training for Students (LiMPETS) is a collaborative effort among the 5 west coast National Marine Sanctuaries: Olympic Coast in Washington, Cordell Bank, Gulf of the Farallones and Monterey Bay along the northern central California coast and Channel Islands in southern California. The protocols described here are consistent with the LiMPETS protocols. The website *limpets.noaa.gov* is the host of the database and a great resource on how to set up a sampling site, learn more about the rocky intertidal habitat and connect with the national marine sanctuaries.

If you have any questions regarding this handbook, please call the Farallones Marine Sanctuary Association at (415) 561-6625.

# 2. National Marine Sanctuaries

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

In 1972, in response to a growing awareness of the intrinsic environmental and cultural value of our coastal waters, Congress passed the Marine Protection, Research, and Sanctuaries Act. The Act authorizes the Secretary of Commerce to designate discrete areas as National Marine Sanctuaries to promote comprehensive management of their special conservation, recreation, ecological, historical, research, educational, or aesthetic resources. National Marine Sanctuaries may be designated in coastal and ocean waters, in submerged lands, and in the Great Lakes and their connecting waters. Since the Act was passed, thirteen National Marine Sanctuaries have been designated (Figure 1). National Marine Sanctuaries are administered by the National Marine Sanctuary Program 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.

## A. 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 continental 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.

## B. Farallones Marine Sanctuary Association

The Farallones Marine Sanctuary Association is a non-profit, membership organization incorporated on May 25, 1995. The Association 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 northern part of the Monterey Bay National Marine Sanctuary. The Association's mission is "dedicated to protecting Sanctuary wildlife and habitats through the development of a diverse community of informed and active ocean Sanctuary stewards." The goals include:

- to increase the awareness and appreciation of the Gulf of the Farallones National Marine Sanctuary;
- to educate the San Francisco Bay Area residents and visitors about the resources in the Gulf of the Farallones National Marine Sanctuary;
- to increase stewardship of the Gulf of the Farallones National Marine Sanctuary;
- to increase research and monitoring of resources within the Gulf of the Farallones National Marine Sanctuary;
- to maintain a cadre of trained individuals to respond to environmental emergencies in the Gulf of the Farallones National Marine Sanctuary.

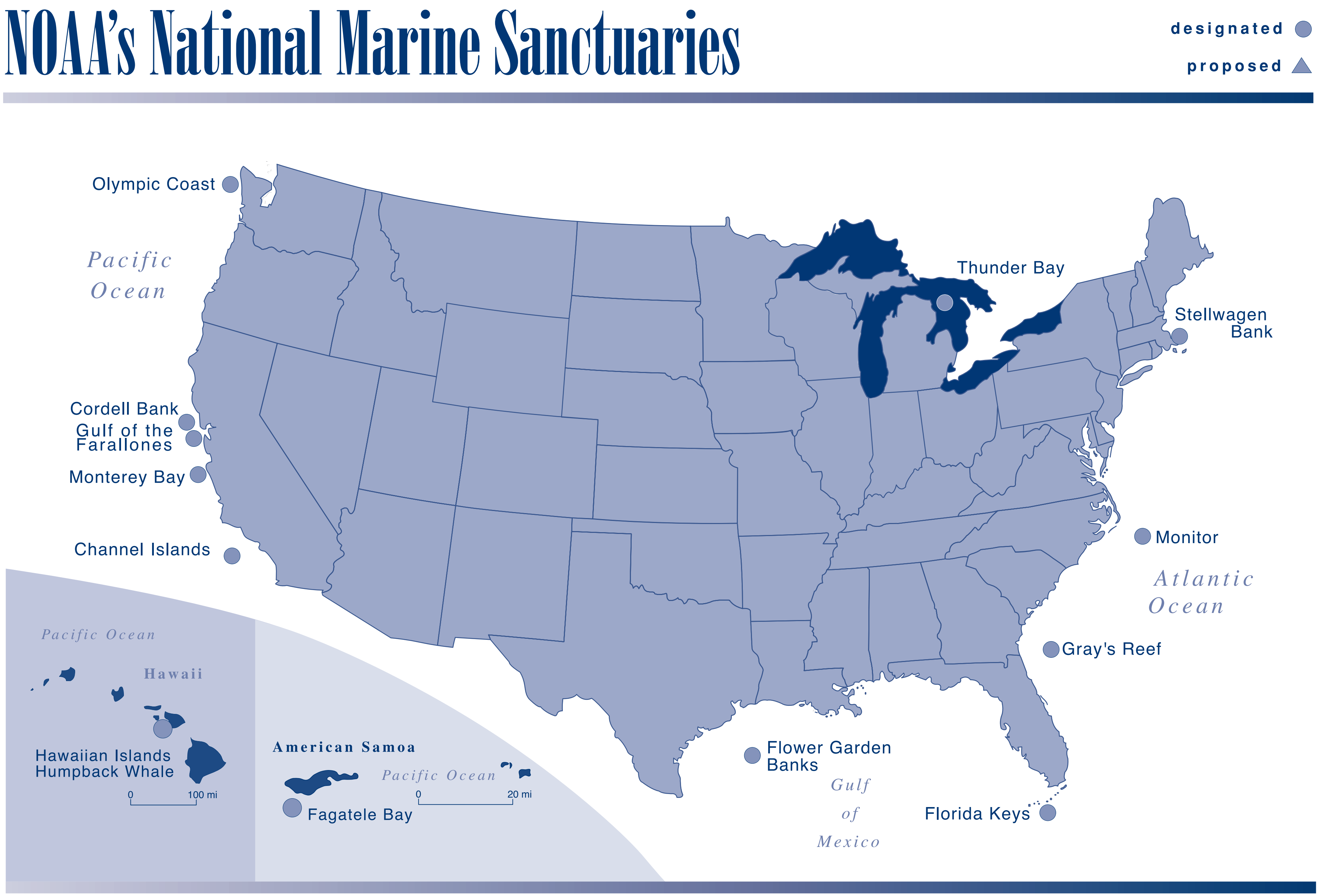



Figure 1. The National Marine Sanctuaries of the United States

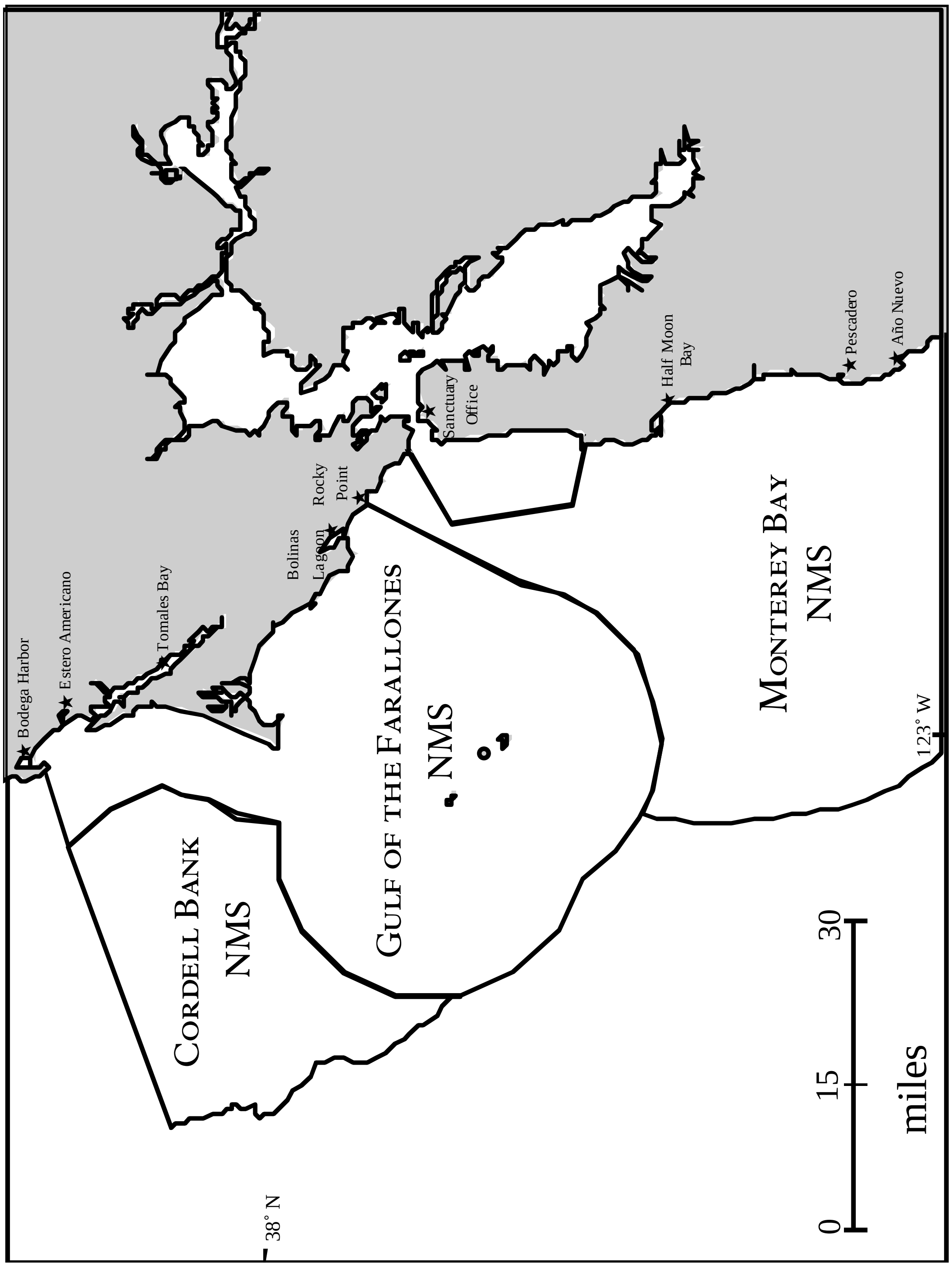



Figure 2. Boundaries of the three national marine sanctuaries near San Francisco, CA

# 3. Natural History of the Pacific Rocky Intertidal Habitat

The Pacific shores of North America are subject to extremely harsh conditions to the human eye. Powerful waves formed from prevailing westerlies and winter storms beat relentlessly against the coast. The tides temporarily cover the substrate with water and then expose the abundant life to the terrestrial environmental factors. With all of these potentially harsh conditions, life abounds in great diversity throughout the rocky intertidal of the Pacific. The water of the North Pacific inundates the coast with energy and food for the organisms that are able to withstand these conditions. Rocks provide shelter and substrate for thousands of invertebrates and algae. The following provides a brief summary of the rocky intertidal ecosystem.

## Abiotic Factors

Many factors are important in determining the nature of the rocky intertidal communities. Abiotic factors are those caused by non-living things. They can include waves, tides, sun exposure, and changes in salinity. The intertidal is unique in that it is exposed to both terrestrial and marine conditions. The animals have to adapt to a variety of conditions. Wave action against the rocks threatens to crush the animals and plants that live within the intertidal. They can also tear organisms away from their homes and take them to the subtidal regions of the ocean. Tides rise and fall twice each day covering organisms with water and exposing them to the air. During low tide, they are more visible to predators, more susceptible to desiccation (drying out), and they can be exposed to heavy rainfall or direct sunlight. Rapid temperature changes can occur in these exposed zones of the intertidal. Salinity fluctuations can occur throughout the intertidal. Tidepools in higher zones can acquire freshwater from rainfall or streams or may heat up and increase in salinity as evaporation occurs rapidly on hot, sunny days. The substrate also determines the types of organisms that live in the intertidal. Some species depend on a softer substrate, such as mudstone found at Duxbury Reef in Marin County. These invertebrates can dig or eat into the rock for protection from wave action, predators, and desiccation. Other factors such as rock size, rock type, and the incline of the shore also determine the type of intertidal life that is present.

## Tides

The daily occurrence of tides is a major factor determining the diversity of organisms living within the rocky intertidal. The sea level rises and falls as a tide twice a day on the Pacific Coast of North America. The rise and fall of the ocean is a result of gravitational forces from the Moon and the Sun. The Moon has a greater effect on the tides because it is closer to the Earth. The Moon's gravity pulls on the Earth and creates a high tide on the side that faces the Moon. The opposite side also has a high tide because of the centrifugal force that keeps the Moon and Earth apart. The other two sides have low tide. As the Earth rotates each side will get a high and low tide. These tides are exaggerated during new and full moons, when the Moon is in alignment with the Sun and the Earth. At these phases of the moon, both the Sun and the Moon's gravitational pull work together to create both extreme high tides and extreme low tides, also known as spring tides. Neap tides result when the Moon and the Sun are at right angles to each other. At these times, the difference between high and low tide is smaller.

## Zonation

Zonation patterns are very common as environments change over abiotic gradients (e.g., mountain slopes, polar to the tropics, wetlands to deserts), yet in the intertidal zone, patterns can be seen and studied over very short distances. The rocky intertidal ecosystem is easily accessible and provides an excellent opportunity for people to explore the ecosystem and observe the organisms in their natural habitat. Before going to the intertidal it is helpful to know about the organisms that are there and where they can usually be found. This information can help you understand the ecology of the ecosystem.

Scientists have divided the rocky intertidal ecosystem into a series of zones. All zones are defined by the amount of exposure to air and by the amount of time the substrate is submerged under water. Intertidal zones are also identified by the types of organisms that are found there.

Zones range from the splash zone, closest to the terrestrial environment, to the low zone, closest to the ocean. Each zone is characterized by different abiotic factors and accommodates different communities of organisms. For example, organisms that need to be in water most of the time will not be found in the splash zone, as this area usually only receives splashes from waves at high tide. Each organism has adaptations to help them survive in the zone in which they live. If an animal is moved from the low zone to the high zone, it may not be able to survive in its new environment. The following will give you an idea of the conditions in each zone and the organisms that are typically found there.

## The Splash Zone

Few species have adaptations to survive within the area that gets only splashes from waves on most days and submerged by water for only a few hours per month. Periwinkle snails, barnacles, and rock lice live in the splash zone. The snails are able to attach to rocks using their muscular foot, and they seal themselves closed, keeping moisture inside. Barnacles cement themselves to a rock and are closed on top when it is low tide to avoid desiccation.

The major producers in the splash zone are the cyanobacteria that form the thin, black coating on many of the rocks. These are what the high zone periwinkles feed on. *Enteromorpha*, a type of green algae, is among the few species of algae that can survive in the splash zone. It can be bleached by the sun and loses most of its photosynthetic pigment but still regain its photosynthetic abilities once a high tide reaches it.

## The High Zone

Once or twice a day, for a total of only a few hours per day, the ocean waters submerge the high zone. A few invertebrates seal themselves up against their substrate in order to survive most of the day without seawater. The lined shore crab (*Pachygrapsus)*, survives in this zone by positioning its flat body in rock crevices, out of direct sunlight and hidden from larger predators.

Limpets, chitons, and the black turban snail (*Tegula funebralis*), all three mollusks, crawl on top of rocks primarily within this zone and use a sharp tongue called a radula to scrape off short growing algae. They form a watertight seal onto the rocks with their shell to protect themselves from desiccation. Both limpets and chitons can form depressions within certain types of rock, like mudstone, that serve as a home and provide the best possible seal. A chiton's shell consists of eight flexibly attached plates which tightly form to the contours of rock formations.

Although also present in the mid zone, rockweeds (*Pelvetiopsis* and *Fucus*), sea lettuce (*Ulva*), pin cushion algae (*Cladophora*), and nail brush algae (*Endocladia*), are examples of algae that are able to withstand long periods of time, about 72% of the day, without water in the high zone. Some species such as *Fucus gardneri* have moisture retention adaptations which enable it to survive for many hours exposed to sunlight and air. Others, such as *Ulva fenestrata*, withstand bleaching, losing its color due to sunlight, and is able to photosynthesize once it is wet again. Species such as *Endocladia* and *Mastocarpus* withstand drying simply by drying out (not bleaching) and probably benefit from this by staying free of epiphytes. These algae thrive and provide food and shelter for many invertebrates that inhabit this zone.

## The Mid Zone

The mid zone is marked by its very high density of living organisms. The black turban snail (*T. funebralis*), the aggregated anemone (*Anthopleura elegantissima*), and the proliferating anemone (*Epiactis prolifera*), are but a few of the invertebrates that reside here. The California mussel (*Mytilus californianus*) also occupies this zone. It uses its gills to extract oxygen and plankton (floating particles of food) from the water. When the tide ebbs, mussels can tightly close their two shells to avoid desiccation. They also form byssal threads that anchor themselves to other mussels and to the substrate, so they do not wash away with the crashing waves.

Sea stars of the genus *Pisaster* live in the mid zone. Sea stars have tube feet that work like suction cups that allow them to hold tightly onto rocks as waves, gulls, or people try to detach them. Occasionally, one or two of the “arms” are ripped off. However, these invertebrates are able to regenerate their “arms” and tiny tube feet that may be torn off.

In addition to the variety of invertebrates that remain in or visit the mid tide zone, many species of algae thrive in this region. Rainbow seaweed (*Mazzaella*), *Gelidium*, and *Mastocarpus* species attach their holdfasts, or root-like structures, to the substrate within this zone.

## The Low Zone

Species that survive within the low zone are less resilient to exposure to air and sunlight but more resilient to the submergence of water and waves. These places may be exposed to air only a few times a month. It is in this zone that most life exists within the intertidal ecosystems. The giant green anemone (*Anthopleura xanthogrammica*), and the sunflower star (*Pycnopodia helianthoides*) are two types of larger invertebrates that frequent the lower zone. The anemone is attached to the substrate and has stinging tentacles that catch and paralyze prey that drift by in the water. The sunflower star uses its tube feet to travel quickly along the substrate to fulfill its voracious appetite.

The purple sea urchin (*Strongylocentrotus purpuratus*) depends on its tube feet to survive in the low zone. Similar to sea stars, urchins depend on these tube feet for movement and attachment, but, in addition, sea urchins are able to use these suction cups for oxygen absorption, capturing floating bits of food, and using shells and kelp for shade during low tides. A sea urchin also has five sharp teeth on the underside of its body which enable the organism to graze efficiently on kelp and other algal species.

Of the algal species, sea palm (*Postelsia palmaeformis*) is a common organism in lower regions that receives an abundance of wave action. Surf grass (*Phyllospadix scouleri*) is a flowering plant that grows abundantly in both wave swept and protected rocky intertidal areas. Both species have flexible structures that withstand the forces of waves and are a habitat for small invertebrates.

## Tidepools

During low tide, tidepools often form throughout the different zones. This is because of the irregular rocky environment. A myriad of plants and animals live in these pools, because they provide the most protection from desiccation and predation. However, these inhabitants must be able to withstand temperature and salinity changes. At low tide, the tidepool is exposed to the sun, and the water will increase in temperature as well as start to evaporate, increasing its salinity.

Invertebrate and algae species inhabit these pools as well as several fish species. Sculpins, eels, and octopi can survive only within tidepools or subtidal regions. Sea anemones, sea stars, crabs, and many kinds of algae species may also reside here. Some coralline algae species form thin layers on the surface of rocks, and others are upright and articulated. The algae may be pink from the red pigments and white calcium carbonate which is the same material that composes the hard shell of many invertebrates. This acts as a defense for common grazers like sea urchins and snails.

## Human Impact: Why Monitor?

The rocky intertidal on the west coast of North America supports one of the richest and most diverse biotas in the world. This biota is subject to constant change, today largely from anthropogenic causes. At some sites, especially in southern California, harvesting and trampling have lead to dramatic decreases in the abundance and diversity of the biota. The very accessibility of the intertidal has lead to more and more people visiting it. And while reckless collecting might be decreasing now in response to better understanding, simply walking around on the rocks may be disturbing to some species, leading to unpredictable changes.

Moreover, by its very nature, the intertidal zone, both on rocky benches and sandy beaches, is exposed to many of the pollutants produced by human society. Contaminants released into the air fall on the surface of the sea and are carried into the intertidal, as are chemical contaminants such as oil spills. Waste materials dumped on the land are washed into the sea across the intertidal, some of it remaining there. The animals and plants of the intertidal may be affected more severely by human activities than those in most other parts of the sea. Fortunately, because of their accessibility, they also may be the easiest to monitor, and so can serve as our marine canaries.

In response to a rise in both air and sea temperatures, we can expect the distribution of species along our coast to change. Along the west coast of North America, many intertidal species are found from Alaska to Point Conception (northern species) or from northern California to Baja California (southern species), both co-occurring in central California. Global warming may result in a northward shift in the distributions of these species. Indeed, that was what was seen when species abundance was compared between the early 1930s and the mid 1990s at one site in Monterey Bay: several common southern California species that were rare or absent in the 1930s are now abundant in the Monterey Bay area.

Moreover, global warming will likely cause a rise in sea level. The tightly organized zonation patterns of the intertidal, with species sorted into bands according to tidal height, may be particularly sensitive to global warming. A rise in sea level not only could shift the different zones higher on the shore, but the zonation pattern itself could change as the shoreline configuration and associated wave forces change. In addition, long-term, interannual cycles of sea level could influence zonation patterns.

For all of these reasons, we believe in the importance of tracking organisms over time. Some species are particularly sensitive to disturbance, either negatively (e.g., rockweeds) or positively (e.g., sea lettuce and perhaps green pincushion algae) and by monitoring we may be able to detect human impact on this environment



(Adapted from ***PROJECT OCEAN: ROCKY SEASHORE HABITAT GUIDE*** and *LiMPETS.noaa.gov)*

# 4. Intertidal Monitoring

## A. Background

Intertidal regions provide habitat for over 2000 species of biologically significant algae and invertebrates but have been historically fairly neglected. However, the organisms found on or between the rocks of the coast provide the base of the food web upon which many larger consumers depend. Many researchers and local residents are now concerned about sensitive intertidal areas, because they have seen a decrease in both the species richness and diversity. Baseline studies throughout the sanctuary coastlines need to be completed so that changes in the numbers or diversity of species can be scientifically monitored and documented. With this type of study, better management decisions can be made about areas that are sensitive to human activities, such as tidepooling, illegal collection of organisms, and the displacement of animals.

Several scientists and students have conducted research along the Pacific coast to address human impact on the rocky intertidal zone. In a study conducted by Loana Addessi, the difference between densities of invertebrates and algae species from the spring of 1971 and the spring of 1991 was significant. The study showed that a greater concentration of human activities, such as tidepooling, collecting, and overturning rocks cause a decrease in algal cover and a decrease in most echinoderms. At the same time, there was an increase in two species of mollusks: *Stenoplax conspicua*, a chiton, and *Fissurella volcano,* the volcano limpet (Addessi 1994). Beauchamp and Gowing studied human trampling in Santa Cruz, California. They found a decrease in densities and species richness at a trampled site when compared with an untrampled site (Beauchamp and Gowing 1982).

Studies have been conducted within the Gulf of the Farallones National Marine Sanctuary's management area since 1995. The data have revealed little difference in densities or cover of organisms between the years at each study site. Long-term studies are necessary for determining the contribution of environmental, physical, and competitive factors to the differences of species diversity, abundance, and distribution between the years (Cosentino 1999). These studies have shown significant seasonal changes and have provided baseline data.

Beginning in the winter of 2000, The Branson School, led by Kathy Soave, conducted the first intertidal studies performed by high school students in conjunction with the Gulf of the Farallones NMS and Farallones Marine Sanctuary Association. They conducted three trial surveys, which were completed at Duxbury Reef below Agate Beach off Bolinas Bay in Marin County. They monitor two sites at this location, to examine the impact of human disturbance. In preparation for the intertidal monitoring, students meet after school to learn about the rocky intertidal ecology, including algae and invertebrate identification. They visit the site at Duxbury Reef many times to review the flora and fauna in the natural environment before the actual studies took place. The Branson School volunteers continue monitoring their site at Duxbury Reef every year by conducting surveys three times per year (fall, winter, and spring). The volunteers from The Branson School created an informational kiosk at Agate Beach. The kiosk displays information about the natural history of the area as well as proper etiquette while exploring rocky intertidal zones. The students also act as docents, guiding visitors during intertidal walks.

Teachers can use the protocols, forms, bibliography, and suggested readings to assist them in helping the National Marine Sanctuary Program fulfill its mission of protecting marine wildlife through research and education. Long-term Monitoring Program and Experiential Training for Students (LiMPETS) is a collaborative effort among the 5 west coast National Marine Sanctuaries: Olympic Coast in Washington, Cordell Bank, Gulf of the Farallones and Monterey Bay along the northern central California coast and Channel Islands in southern California. Independent student monitoring efforts in several sanctuaries prompted the idea of creating an integrated coast-wide program, utilizing similar protocols and a centralized location for data. This handbook is a guide for teachers to set up new sites or continue to monitor the already established sites with their students. The centralized database is at limpets.noaa.gov.

## B. Teacher Guidelines

This project requires a substantial commitment from the teacher and the students. Three field days per year are suggested. We suggest going out in the fall to learn species and get familiar with the area, going out in the winter to continue that process and practice monitoring, and a third trip in the spring to monitor and enter the data into the database. Students and teachers must be able to properly identify invertebrates and algae. After data collection, time is required for data entry and analyzing the information. This project will include creating permanent transect lines in the rocky intertidal ecosystem. Students will monitor along these transects using quadrats. They will record data on invertebrates and algae.

This manual contains all of the information you will need to participate in the rocky intertidal monitoring project. The following chapters will describe how to mark a transect, how to use a quadrat, and the procedures for collecting and analyzing data. Examples of forms you will need are also included. You may need to alter these forms depending on your specific site. Below, you will find information to help make your project successful.

## California Science Standards

Through this project, successful students will have learned the following standards from the Science Content Standards for California Public Schools.

<u>Biology/Life Sciences</u>
6. Ecology. Stability in an ecosystem is a balance between competing effects. Students will:

a. Know biodiversity is the sum total of different kinds of organisms.

- Students will know the biodiversity of the rocky intertidal habitat. They will be able to compare the diversity in the high and low intertidal zones.

b. Know how to analyze changes in an ecosystem resulting from changes in ... human activity, ... or changes in population size.

- Students will know how to analyze the data from the monitoring project that addresses the question of human impact on a habitat. They will be able to describe the method of data collection and how it was designed to answer questions about human impact in the rocky intertidal habitat.

<u>Earth Sciences</u>
California Geology. 9. The geology of California underlies the state’s wealth of natural resources as well as its natural hazards.

- Students will understand the complexity of the rocky intertidal environment.

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 the abundance of algae and invertebrates They will be able to collect and record data without guidance from staff.
• Students will enter data into the computer and graph the trends in abundance.
• Students will display and analyze the results from different years or different sites.

b. Identify and communicate sources of unavoidable experimental error.

• Students will record sources of error while monitoring, such as movement of the quadrat square or transect tape during monitoring or mis-identification of algae.

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 rocky intertidal in relationship to seasonal oceanographic conditions.

# Preparation

Preparing yourself and your group for monitoring is essential for accurate results. The rocky intertidal ecosystem is a diverse and exciting area to study. However, the intertidal environment can also be complicated and difficult to understand without proper preparation. The more often that you and your students visit the monitoring site, the more confident you will become at identifying intertidal species. In addition, consulting experts in rocky intertidal ecology is extremely helpful. Field guides, slides, photographs, alga presses, and invertebrate artifacts are all great educational tools to learn the different species. References such as those found in the bibliography will help you become familiar with species and the ecology.

Make sure that your students understand the different environmental factors that occur within the rocky intertidal. Understanding the unique physical adaptations and behaviors of organisms to these environmental factors is also essential. Another ecological concept to master is the interactions between species. Learn how some species, including humans, help or harm other intertidal species. Finally, challenge the students to hypothesize where each species will live. If you are looking at human impact at the site, have the students hypothesize what differences they might see in areas with high human impact.

## Helpful Hints

1. Obtain literature that contains the natural history of the monitoring site. Use the Recommended Reading List or visit the Gulf of the Farallones NMS library.
2. Review with your students the results of intertidal studies, why studying the intertidal is important, and practice identifying species using slides.
3. Use a tide book or check on line when the lowest tides occur, and choose these days to take the students out to the site.
4. Discuss safety precautions.
5. Discuss proper etiquette while in the rocky intertidal.
6. Check out the field and/or classroom kit.
7. Bring field guides to help identify the species that you will be studying. ID cards are useful for the students.
8. Set up the site with permanent transects if needed before the first monitoring session.
9. Create student groups and assign to them their responsibilities before the survey day.
10. Collect data from all of the low zone quadrats during the lowest part of the tide cycle when you are there. Do not monitor in unsafe depths of the low zone. Use common sense. Depending on the tide, you may have to start in the high zone and work to the low zone, or vice versa.
11. Complete the scientific process by analyzing the data at limpets.noaa.gov.

## Safety Precautions

1. Always know the predicted times and heights for high and low tides.
2. Note where waves are breaking and washing.
3. Before venturing out on the rocks, determine a safe spot or escape route.
4. Have at least one other person with you at all times.
5. Do not turn your back to the waves.
6. Wear shoes with rubber soles for traction.
7. Walk slowly and carefully on the rocks.
8. Wear weather-appropriate clothing (e.g. rain gear, boots, hat).
9. Bring ample amounts of drinking water.
10. Bring a first-aid kit.
11. Bring an extra set of dry clothes.

## Tidepooling and Monitoring Etiquette

1. Avoid stepping on invertebrates and algae whenever possible.
2. Avoid wading in tidepools.
3. Wet hands with seawater before handling fish and invertebrates.
4. Return animals where you found them.
5. Replace rocks where you found them.
6. Do not take anything except pictures.
7. Do not leave any trash at the site.

### Post Monitoring Projects

There are many opportunities to extend this project beyond the monitoring. You may want to encourage students to work as a class, or individually, to share the results of this project with others. Students can create websites detailing their project and post their data on the Internet. Compare the results of your site to another site in the LiMPETS network and discuss with students in the other class via email. Students can participate in a Gulf of the Farallones NMS Research Symposium through a poster or a presentation. The project can be incorporated into a stewardship project. These are just a few ways students can educate others about their monitoring project.

## C. Training Materials

It is crucial that students know what species they are monitoring before they begin collecting data at the site. We have developed tools to help train students in the classroom. A trip to the field is priceless nevertheless.

## Checkout kits - Classroom and Field kits

Through LiMPETS, a classroom kit and a field kit were developed to help prepare you and your students for monitoring and to use during monitoring. The kits are available from the west coast National Marine Sanctuary offices. The contents of the kits are listed in Appendix 3

## D. Training Slide Show Script

This slide show is designed for training for Duxbury Reef. If monitoring at another site, we recommend changing the images of Duxbury Reef to your site.

1. Today is the first day of the rest of your life. No, really what I mean is that today you get to start an adventure that you will carry through the rest of your life. You get to participate in a very fun and exciting project that is outside at the ocean. You will be part of a program that we call LiMPETS. Students like you up and down the coast are helping the National Marine Sanctuaries protect the marine habitats with this project.

   Today you will learn how and why we monitor the rocky intertidal habitat.
   (Photo from J. Pearse)

2. The goals of the monitoring project are:
   • to directly involve you in the field, collecting long-term data
   • to inform you about the intertidal habitat and the species that live there
   • to collect and archive data that you and future students can analyze to detect changes in intertidal life over time.

   Today we are going to first learn the method of monitoring, then how to identify some of the species and the last part today will focus on why.
   (Photo from J. Pearse)

3. Have you heard of a National Marine Sanctuary? There are 13 areas that the US Congress has given special protection by designating them as national marine sanctuaries. The San Francisco Bay Area is a very special place, because we have 3 of the sanctuaries protecting the ocean near our coast.

4. Most northerly and offshore is Cordell Bank which is known for great fishing and bird watching. Gulf of the Farallones National Marine Sanctuary is where you are going to focus your efforts. To the south is the Monterey Bay National Marine Sanctuary that protects the marine habitats all the way down to Cambria.

5. Gulf of the Farallones National Marine Sanctuary protects the waters surrounding the Point Reyes and the Farallon Islands and the near shore waters of Bolinas Lagoon and Tomales Bay. Here is Duxbury Reef which is the area you are going to help monitor.
   (Photo by J. Saltzman)

6. This map is to give you a bit of an orientation to the site. The mesa cliffs at the bottom of the map is where the last photo was taken. The reef is very flat and there are two transects. Just beyond the reef flats is a channel and then the outer reef which receives most of the energy from the waves. There are 2 lines that we monitor which are about 100 meters apart which is about the length of a football field.

7. You will be using a few different pieces of equipment. The first is the transect tape. At Duxbury Reef there are two permanently marked transects as you saw in the last map. You will use a long tape measure to mark the transect.

The quadrat is a plastic square that is a half meter by a half meter which means it covers an area of a quarter of a square meter (0.25 $m^2$).

And for your monitoring pleasure, we have kneepads. You will need to get close to the ground to see what wonderful creatures are living there!
(Photo from J. Pearse)

8. There are two methods you will be using at the reef. The first is the vertical transect with permanent quadrats. The transect runs from the high zone through the mid zone to the low zone. Along the transect line, you will monitor a small area every 5 meters, starting at the permanent maker.

For each quadrat, you will count individuals of some species and count the number of squares for the other species. For the large conspicuous species, like the snails and sea stars, you will count the individuals. The quadrat is divided into 25 squares so that we can measure the relative abundance of the organisms. For all the algae and the small invertebrates like barnacles, you will count the number of squares that have any portion of an alga or animal in that square.
(Photo from J. Pearse)

9. The other method that we use is to count the number of large individuals in a permanent area. The giant green anemones are not very abundant. By examining an area of 100 square meters, we can get a better estimate of their abundance. Also you will count the number of ochre seastars (*Pisaster ochraceus).* When monitoring the survey area you will only look for 20 minutes with your partner. Only 20 minutes, no more and no less. This way the search will be comparable in the future.
(Photo from J. Pearse)

10. Before you go to the field, you will first need to know what algae and animals you are looking for and how to identify them. There are a few activities to help you learn. The first is part of this slide show where you will see the different species and will fill in you personal identification notes sheet. The second is a practice session with life size photos and quadrats. You will learn to identify species while practicing the data collection method.
(Photo from J. Pearse)

11. Another activity that will really help you learn is a practice session in the field. Even if you don’t go as a class, you may want to go to a rocky shore to start looking at the different organisms living there. Take your identification sheet with you and take more notes.
(Photo from J. Pearse)

12. Make sure you dress appropriately when you go to the shore. You will be very lucky if it is warm and sunny; most likely it will be cool, windy, and foggy. Make sure you wear warm clothes or else you will be very unhappy after an hour. Boots or sturdy shoes are important because it is wet and rocky and you don't want to slip and fall.
(Photo from J. Pearse)

13. How to Identify Algae. To begin, let me just say that identification of algae is not always easy. We have chosen species that other students have successfully learned and know that you too can learn also with a little bit of effort. There are 3 groups of algae – green, brown, and red algae. The brown and red aren't always those colors but it is a good way to start. The common names are often easier to pronounce but it is the species names that are important because a common name can be used for more than one species.

14. The green algae are actually pretty green. The first species is pretty easy: *Cladophora* (cladof-or-a) looks like golf course grass or moss. It is bright green and very short. Common names for this species vary - green pincushion alga or sea moss.

The other green algae are sea lettuce of the genus *Ulva* (ul-va). It looks leafy and green. This genus is often an indicator of high disturbance, such as trampling.

Surf grass is the only true plant that we find in the rocky intertidal. It is a flowering grass that has roots. It has very long blades and often is found in channels. *Phyllospadix* (phyl-lo-spade-ix) or surf grass is sensitive to pollution and has been used in many studies.
(Photos by K. Soave)

15. There are only two species of brown algae that we monitor. Both of them have the common name of rockweed and look pretty similar. *Fucus* (fu-cuss) is the larger rockweed, often called flattened rockweed. It is found in the mid zone. *Pelvetiopsis* (pel-ve-shee-op-sis) is the smaller, skinnier species, with a common name of slender or little rockweed.
(Photos by K. Soave)

16. Here is a photo with both *Fucus* and *Pelvetiopsis*. Which is which? The top is little rockweed and the larger one is *Fucus*.
(Photo by J. Saltzman)

17. These are some of the red algae. They do not look very red which is not very helpful. The upper right hand algae is a group of several species that we combine into a group called upright coralline algae. It is pink in color, with very flat branches and scales. This group is upright. There is another category without the upright scales that is very similar.

Turkish towel or *Mastocarpus* (mas-to-car-pus) is very brown despite being in the red algae group. It is about 1-4 inches in length, thick leaves and very bumpy. Think of the name as a bumpy towel.

The last algae on this slide is the opposite - a very smooth, iridescent algae. It is called rainbow or iridescent algae commonly and its scientific name is *Mazzaella* (maz-zee-el-la).
(Photos by K. Soave)

18. Because many algae species look so similar and are hard to tell apart, we have grouped two short, thin branching algae into one group called red algae turf or RAT for short. These two species look like little tufts sometimes. When in the field, you will be able to see the branches of this group to identify it. This is very abundant at Duxbury Reef.

Sea sacks or *Halosaccion glandiforme* (ha-lo-sack-ee-on glan-dee-for-may) are a fun algae. They are the balloon-like sacs. They grow to about an inch or two in height. They are rare at Duxbury Reef. (Photos by K. Soave)

19. Most algae have interesting life cycles or stages. During a dormant phase, some of them live as a crust on the rock. A crust is just a thin layer of cells that may not look like anything is alive, but it is. We distinguish two groups. The first is the pink coralline algae. Remember the upright coralline algae with the pink, flat, scaly branches. We distinguish that from the encrusting coralline algae. Both of these photos have pink coralline algae.

The second group is the tar spot algae which is the black crust on the rock. There are several species of algae that fit into this group. You would need a microscope to tell which species was which. We just group them together.
(Photos by K. Soave)

20. Now to the animals which are probably more familiar. There are many groups that we will be collecting data about. They are sea anemones, several mollusks, barnacles and sea stars.
(Photos by K. Soave)

21. There are three species of anemones that we find at Duxbury Reef. The most abundant one is the aggregating anemone, about an inch in diameter. The top picture shows them open, when under water. And the photo below shows them when exposed to the air. They are the green little blobs. This species will be pointed out to you on the reef so that you can see what they really look like when exposed to the air and not underwater. They often cover themselves with small rocks and sand to help keep the moisture in during the low tide period.

The giant green anemones are much larger than the aggregating anemones. They are often solitary while the aggregating ones are found in groups, actually in cloned groups. The giant greens live in the mid to low zone and are not that abundant where we will be monitoring.

The brooding anemone is a small brownish anemone that is rare. It gets its name from the way it reproduces. New anemones bud off from the adult and are seen on the base of the animal. (The identification card has a nice picture of this.)
(Photos by K. Soave)

22. Chitons are the first group of mollusks that we are going to discuss. Mollusks are often shelled animals with a large muscular foot. This phylum includes snails, mussels and clams. The Chitons are a more primitive group of mollusks with 8 separate plates, rather than 1 shell. They use the foot to hold on tightly to the rocks as the waves crash around. They can easily be overlooked, so this is another one that we will point out to you before monitoring begins. (The one on the left has what algae growing on its back? Encrusting coralline algae.)
(Photos by K. Soave and J. Saltzman)

23. Limpets are another interesting group of mollusks. They only have one shell that covers their muscular foot. The limpets that we monitor at Duxbury are small in size - a quarter to a half an inch in diameter. Some people think they look like little volcanoes. Another species that is found on the outer reefs in the high wave action area are owl limpets. They grow much larger, up to 2 inches in diameter. Keep your eyes open for them!
(Photos by K. Soave and A. Devitt)

24. There are two species of snails at Duxbury that we will monitor. The abundant turban snail lives in the high to mid zone. It has a very round shell and often brown to black on color. The turban snail is an herbivore and grazes on the algae. The welks are predatory and have an elongated shell. They are gray in color.

Hermit crabs live in snail shells. You will have to check each shell to see if it is a snail or a crab. Be sure to be gentle while picking up the snails and return them back where you found them, especially if they are under the algae.
(Photos by K. Soave and A. Devitt)

25. Barnacles are not in the mollusk group although you may have thought that at first. Yes, they do have a shell, but not the muscular foot. Barnacles are actually closely related to shrimp. A fun way to think about barnacles is that they are shrimp that have glued their heads to the rock, built a strong home around themselves, with doors that shut when the tide is out. They open the doors , called plates, under the water so they can kick their legs to filter food out of the water. The barnacles here are small - less than the width of your pinky finger (less than 1 cm in diameter). They are abundant in the high zone of the rocky intertidal habitat. You will not have to count all the barnacles in your quadrat, just how many squares are they present in.
(Photo by K. Soave)

26. Sea stars are the most well know and easily identified species in the rocky intertidal habitat. The most abundant species is the ochre (o-ker) sea star. It grows up to 10 inches in diameter and has a few color morphs – orange, brown and purple. Sea stars are predators and are very important in the dynamics of the rocky intertidal zone.

On the smaller side are six armed stars. They grow only to an inch in diameter.

Very rare at Duxbury, yet much more abundant at other rocky intertidal zones, are bat stars. They are very colorful and grow to about 5 inches in diameter. The name comes from the webbing between the arms of the bat star.
(Photos by K. Soave)

27. Now you should have a good idea of what lives in the rocky intertidal zone. The purpose of the monitoring is not only to introduce you to this wonderful world, but to monitor if the abundance and distribution of these species are changing over time.
(Photo from J. Pearse)

28. We are concerned because there are many changes in the natural world. The species that live at Duxbury Reef are able to survive the conditions of temperature and sea level now. We are in the middle of the ranges for northern and southern species. As we collect data over time, we may be able to detect changes in the ranges of intertidal species.

29. This graph supports the claim that the sea surface temperature has changed over the last 50 years. On the x-axis is the month and the y-axis is the average temperature. In blue, the temperature from the 1920s and in red are the monthly averages from the 1980s. Clearly the water was warmer more recently, by 1-2°C.

30. Another impact on the rocky intertidal species is people walking and investigating and having fun looking around the rocky intertidal zone. In the future, the Gulf of the Farallones National Marine Sanctuary will study the impact that people have on Duxbury Reef (Photo from J. Pearse)

31. In the Monterey Bay National Marine Sanctuary, there are several sites where students from other high schools are monitoring using the same methods as you. The sites are all quite different but by using the same methods and looking at the same species you will be able to compare your results with these other sites.
(Photo from J. Pearse)

32. A comparison of student collected data and professional collected data was made in Monterey Bay. On the same day, students and professional monitored the same quadrats.
(Photo from J. Pearse)

33. And not surprisingly the numbers were very close. We have confidence that you too can collect accurate and reliable data using these methods.

    This graph shows the abundance of ochre sea stars, with PISCO representing the professionals. On these three days, the students numbers were nearly the same as the professionals.

34. The last part of this project is data entry and analysis. This is a crucial part of the study. It is one thing to collect data over several years. It is much more valuable to analyze the trends in the data to be able to make predictions and understand how the natural system works and changes.

    You can learn more about the algae and animals at limpets.noaa.gov.
    (Photo from J.Pearse)

## A. Introduction

This chapter contains all of the necessary monitoring instructions for this project. You will find procedures for setting up transects and quadrats, and for collecting data on the abundance of invertebrates and algae. Please distribute copies of the necessary information to the appropriate students well before beginning the monitoring, so you can review it with students and answer any questions.

There are a few methods used to monitor the site. The vertical transect is a permanent survey area where the changes in high, mid and low communities becomes quite apparent to the students as they monitor. The quadrats are placed evenly along the transect at permanent locations. In each quadrat, large invertebrates are counted individually while smaller invertebrates and algae are measured by the number of squares that they are present in. The other monitoring area is the permanent area where large, more rare invertebrates are counted individually in the whole area.

The details on how to set up the areas at a new site are presented in the following sections. In offset boxes are directions specific to the Duxbury Reef site.

## B. Pre-Monitoring Instructions

## Purpose

Transects and quadrats are effective ways to evaluate the health of the rocky intertidal ecosystem. Establishing permanent transects gives students an exact location of where they will collect information about the dominant species of the site.

### Roles and Responsibilities

The teacher, or another individual who is very familiar with the site, is responsible for choosing a site, acquiring any necessary permits, establishing the permanent markers for the transects and plots. Transects should be marked on a day before monitoring begins.

### Procedure

#### Determining a Site

It is important to choose your site carefully. Safety should be your top priority. You should be able to get to your site easily and safely. While at the site, you should be able to safely monitor for a few hours. It is also important to have a site that has well defined zonation patterns. Make sure that there is a good representation of different species. Make sure that it is not mixed with a sandy beach area, as that environment changes seasonally.

**Notes for Duxbury Reef**

**Duxbury Reef** has been set up and monitored. In the following sections, side boxes like this will be used to discuss the specifics of Duxbury Reef.

If your class would like to investigate human impact, you should have two transect lines. Two areas, at least 100 m apart, will be monitored at the site. The two areas should have similar abiotic factors such as substrate, wave exposure, and fresh water sources. Try to limit the number of variables between the two areas. You will need to develop a way to measure human impact if you want to be able to say that the differences between the two sites are attributable to the human impact.

For already established sites along the west coast National Marine Sanctuaries, go to *limpets.noaa.gov.* The following locations are examples of possible new sites in the San Francisco Bay Area.

- Pinnacle Rock, Sonoma County (Gulf of the Farallones NMS)
- Point Bonita, Marin County (Monterey Bay NMS and Golden Gate National Recreation Area)
- Pigeon Point, San Mateo County (Monterey Bay NMS)

### Notes for Duxbury Reef

It takes about 50 minutes from San Francisco or from San Rafael to reach Duxbury Reef. There is a large parking lot and outhouses (always a consideration!). There are two permanent transects set up 100 m apart. The first is near the main entrance way to the reef and the second is north of the first. There is a fresh water runoff source and the first marker was placed deliberately not in the way of the flow. The reef is very flat and has a well defined zonation pattern between the low and mid zone. The change in species between the high and mid zone is not as clear. There are many channels that run through the reef that bring low zone species into the higher zones.

**Background Research**

Before determining the location of the permanent transect lines, familiarize yourself with the site. You and your students need to be able to identify confidently and accurately the various organisms on your species list. During low tides, spend ample time at the site to identify them. While in the intertidal, use field guides to help identify the different invertebrates and algae and other prominent species present. In the classroom, use color slides and photographs as well as alga presses to practice identification which are available for borrowing in the classroom kits ( Appendix 3).

The species list for Monterey Bay National Marine Sanctuary was developed with high school students in mind (Appendix 7). The species are pretty easily identified, although some of the algae may take more time to learn. Grazers and dominant predators are included. Monitoring species that are sensitive to pollution may provide evidence of human impact on those species.

Once you are able to determine the identity of the different organisms, you should approximate where the different intertidal zones start and end. For a more complete study of your site, it is beneficial to monitor all three zones: high, middle, and low. Some genera of plants and algae that are commonly used to indicate the three different zones are:

### Notes for Duxbury Reef

The species list for Duxbury Reef is a shorter list than the general list (Table 1). These species are easily identified and abundant on the reef. Identification cards for Duxbury Reef specifically are available for borrowing or for you to make your own set. Life-size photos of Duxbury Reef or a site in Monterey Bay are available in the classroom kits, to practice the counting method which are great for training !

| Low Zone | Middle Zone | High Zone |
|---|---|---|
| *Egregia* | *Mazzaella* | *Fucus* |
| *Alaria* | *Gastroclonium* | *Pelvetia* |
| *Prionitis* | *Gelidium* | *Pelvetiopsis* |
| *Phyllospadix* | *Mastocarpus* (& petrocelis stage) | *Endocladia* |
| *Chondracanthus* | | *Ulva* |
| Some *Mazzaella* | | *Enteromorpha* |

Familiarize yourself with abiotic factors as well. Look for sources and locations of freshwater. Discover the different types of substrate that are present at the beach. Determine how exposed or protected the site is at different points along the coastline. Also, be observant of human and pet visitors to the site. Approximate which areas are more or less frequented by these visitorson a map.

Find a map of your site or if necessary, draw one yourself. You will use this map to record the location of your permanent transects.

> **Notes for Duxbury Reef**
>
> A map of Duxbury Reef is in Figure 3. Farallones Marine Sanctuary Association has a permit for the markers at Duxbury Reef.

**Applying for a Research Permit**

Before marking your permanent transects for your monitoring site, find out if your site is regulated by a government agency such as the National Marine Sanctuary System or the California Department of Fish and Game. Contact the appropriate department for information regarding permit requirements. Duxbury Reef is in the Gulf of the Farallones National Marine Sanctuary and is protected as an Area of Special Biological Significance by the State of California.

The Guidelines for Submitting Applications for National Marine Sanctuary Research and Education Permits are available from each sanctuary. These guidelines describe the permitting process and outline the different sections of the permit that need to be completed for evaluation. The contents of the application include a cover letter, project summary, objectives, methods, personnel involved, environmental consequences, and the educational value of the project. The application must be submitted thirty (30) days before the requested effective date to allow time for evaluation and processing. Submit the application to the manager of the sanctuary in which the project is to be conducted. Once the application is accepted and you receive your permit, the applicant(s) must have the permit with them when collecting data at the study site.

**Determining the Location of the Transect** and **Marking the Transects**

Once you have studied your site and chosen appropriate places for transects, the transect length must be determined. The appropriate length will vary according to the location. The transect should not be so long

> **Notes for Duxbury Reef**
>
> The lengths of the transects are different according to the terrain. The site at Duxbury Reef was set up to examine the differences in two areas, potentially due to different human use patterns. The markers are in the high zone and the mid zone (Figure 4).

## Table 1. Species List for Duxbury Reef

| | | Vertical Transect/ Permanent Quatdrats | | Permanent Plot |
|---|---|---|---|---|
| | | count as individual | count presence in number of squares/25 | count as individual |
| **Green Algae and Flowering Plants** | | | | |
| *Cladophora coumbina* | sea moss | | * | |
| *Phyllospadix scouleri* | surf grass | | * | |
| *Ulva fenestrata* | sea lettuce | | * | |
| **Brown Algae** | | | | |
| *Fucus gardneri* | rockweed | | * | |
| *Pelvetiopsis limitata* | little rockweed | | * | |
| **Red Algae** | | | | |
| *Corallina* spp., *Calliarthron* spp., *Bossiella* spp. | Upright corraline algae | | * | |
| *Endocladia muricata* | Red Algal Turf | | * | |
| *Gelidium coulteri* | Red Algal Turf | | * | |
| *Halosaccion glandiforme* | sea sacks | | * | |
| *Mastocarpus papillatus* | turkish towel | | * | |
| *Mazzaella spp.* | rainbow seaweed | | * | |
| **Encrusting Algae** | | | | |
| Encrusting coralline algae | several species | | * | |
| *Mastocarpus* spp. and more | Tar-spot algae | | * | |
| **Sea Anemones** | | | | |
| *Anthopleura elegantissima* | aggregating anemone | | * | |
| *Anthopleura xanthogrammica* | giant green anemone | * | | * |
| *Epiactis prolifea* | brooding anemone | | * | |
| **Chitons** | | | | |
| *Mopalia* spp./*Nuttallina californica* /*Lepiochitona* spp. and others | | * | | |
| **Limpets** | | | | |
| *Lottia* spp./*Macclintockia* spp. | all including owls | | * | |
| **Snails** | | | | |
| *Acanthinucella* spp/*Nucella* spp. | welks | * | | |
| *Tegula* spp. | turban snails | * | | |
| **Mussels** | | | | |
| *Mytilus californianus* | mussel | | * | |
| **Barnacles** | | | | |
| *Balanus* and *Chthamalus* spp. | barnacles | | * | |
| **Sea Stars** | | | | |
| *Piaster ochraceus* | ochre sea star | * | | * |
| *Asterina miniata* | bat star | * | | |
| *Leptasterias hexactis* | six-armed star | * | | |

that the tide will cover the lower end on the monitoring days. Before marking the transects, make sure to look at the height of the low tide on the days that you will be monitoring. Choose a day for marking that has a similar tidal height, or make sure to put the low markers at a location that will be exposed when you come back to monitor.

Layout the transect line and determine where the permanent quadrats will be located. They should not be over pools or crevices. The quadrat frame should not move when placed at the proper location. Determine the location of the permanent area for total counts of the large invertebrates. This should be in the mid to low range where the ochre stars and green anemones live. Again there should not be too many pools or crevices which will be hard to observe. At some sites there is only one permanent area. At Duxbury Reef, there are two permanent areas to compare differences between them.

At your site, draw the approximate locations of the transect line on your map of the area. Draw a picture noting unique features in the topography surrounding the beginning of each transect. Use a good map and a portable Global Positioning System (GPS)(if available) to determine the latitude and longitude. Use the Transect and Quadrat Locations Data Sheet to record the locations (Appendix 5). Fill out the table with the information on where you put the markers so that you or someone else can find them. Use a compass to find the direction to permanent landmarks.

Transects must be permanently marked. Transects should be marked in the high zone by clearing a 5 $cm^2$ area with the scrapers and wire brushes. With a rock hammer use a chisel or stake to create a 2-3 inch hole within the substrate. Place a 5-6 inch long piece of polyester rope into the hole. Mix the epoxy with a knife in the mixing container and pour the mixture into the hole. Make sure the rope is upright as the epoxy begins to harden. Repeat this process to place the markers in the low zone.

From the marker in the high zone, record on the Transect and Quadrat Locations Data Sheet the compass bearing towards a permanent landmark such as a tree or telephone pole. Record the bearing towards a permanent landmark on the beach. Record the landmark being used and take a picture if necessary. Have one person hold down the end of the transect tape at the area marked with the epoxy and rope in the high zone, meter 0, while the other person walks perpendicularly towards the waterline. Using a compass, note the direction you walk and record the bearing. As you walk towards the waterline, use a tape measure to approximate where the middle and low tide zones begin. Record these positions on the Transect and Quadrat Locations Data Sheet. If you are able, approximate and record the distance at which the subtidal begins. Again, note the meter on the attached form. If you are using a GPS, take a reading and record the information. Repeat this process for the other three transects.

## Notes for Duxbury Reef

The location information for Duxbury Reef is in Table 2. There are 4 permanent markers, 2 for each transect. Transect A is longer than Transect B because of the shape of the reef. The permanent quadrats are every 5 meters, except for one quadrat which is under a pool. On transect A, the quadrat at meter 20 is not monitored, instead a quadrat at meter 21 is done. The permanent areas are at the low end of the transects and are 10 m x 10 m squares. The transect tape and cones are used to mark the permanent area during surveys.

Photographs of the permanent markers with other key features are used to help locate the markers (Figure 5).

## CHECKLIST

**Equipment:**

- *Mixing Container for epoxy
- *Transect Markers (rope)
- *Wire Brushes
- *Epoxy
- *Rock Hammer
- *Paint Scraper
- *Chisel or stake
- *Rags
- *Mixing Knife for epoxy
- Tape Measure (100 m)
- Compass
- Pencils
- Clipboard
- GPS unit (optional)
- Camera and Film (optional)

* Denotes that these items are only needed for the initial marking of the transects.

**Forms:**

- Research Permit
- Transect and Quadrat Locations Data Sheet (Figure 5)
- Sample Transect and Quadrat Layout diagram (Figure 4)
- Site Map

## Making the Quadrats

You will need to make several 1/4 $m^2$ quadrats. Each will be divided into 25 squares, each 10 cm x 10 cm. This needs to be done prior to monitoring. The directions to make the quadrats are in Appendix 8 and on the website at http://limpets.noaa.gov/usefulInformation/quadrat.html.

**Notes for Duxbury Reef**

Quadrats are available in the checkout kit from the Sanctuary office.

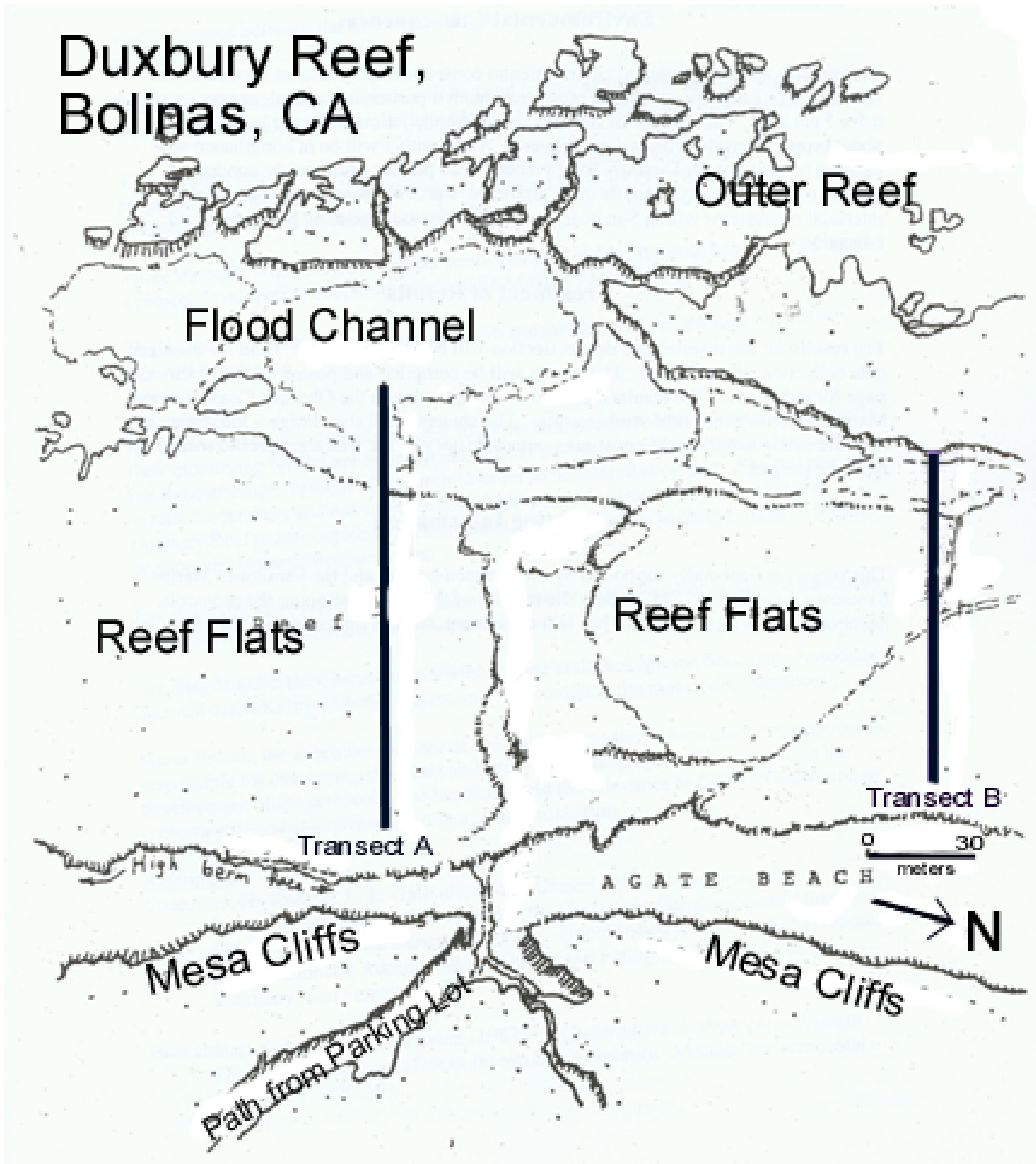



**Figure 3. Duxbury Reef Site Map**

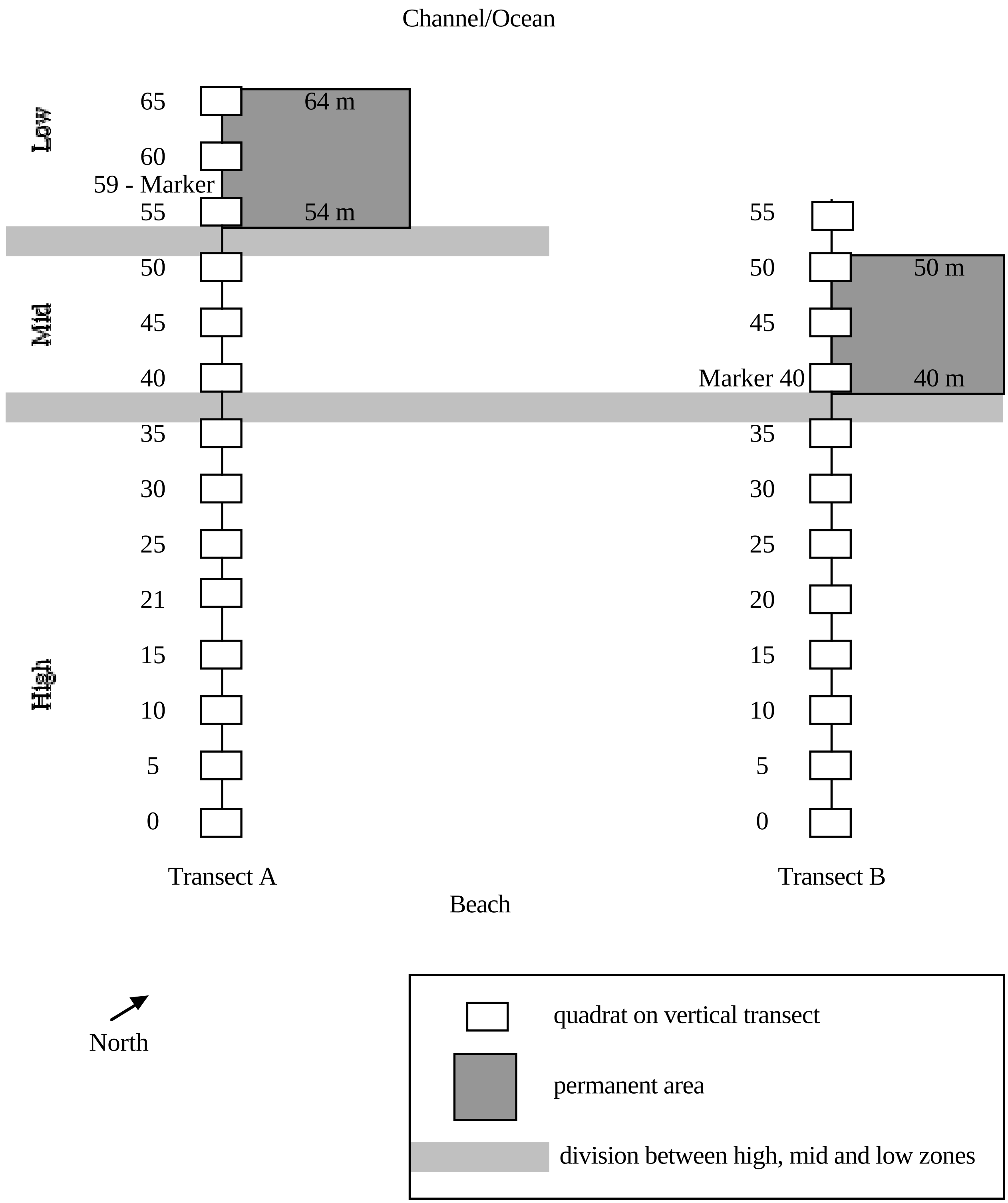


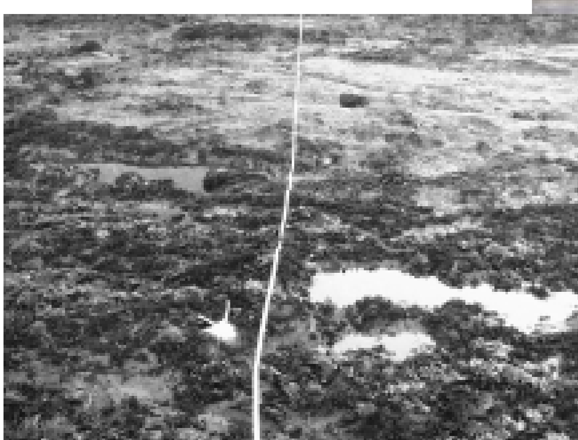

**Figure 4. Transect and Quadrat Layout At Duxbury Reef.** Two vertical transects, about100 meters apart, have permanent quadrats monitored every 5 meters, except at Transect A meter 21 rather than meter 20. The middle of the quadrat is placed on the middle of the tape measure at the appropriate meter marker. There are permanent areas associated with each vertical transect.

# Table 2. Transect and Quadrat Locations at Duxbury Reef

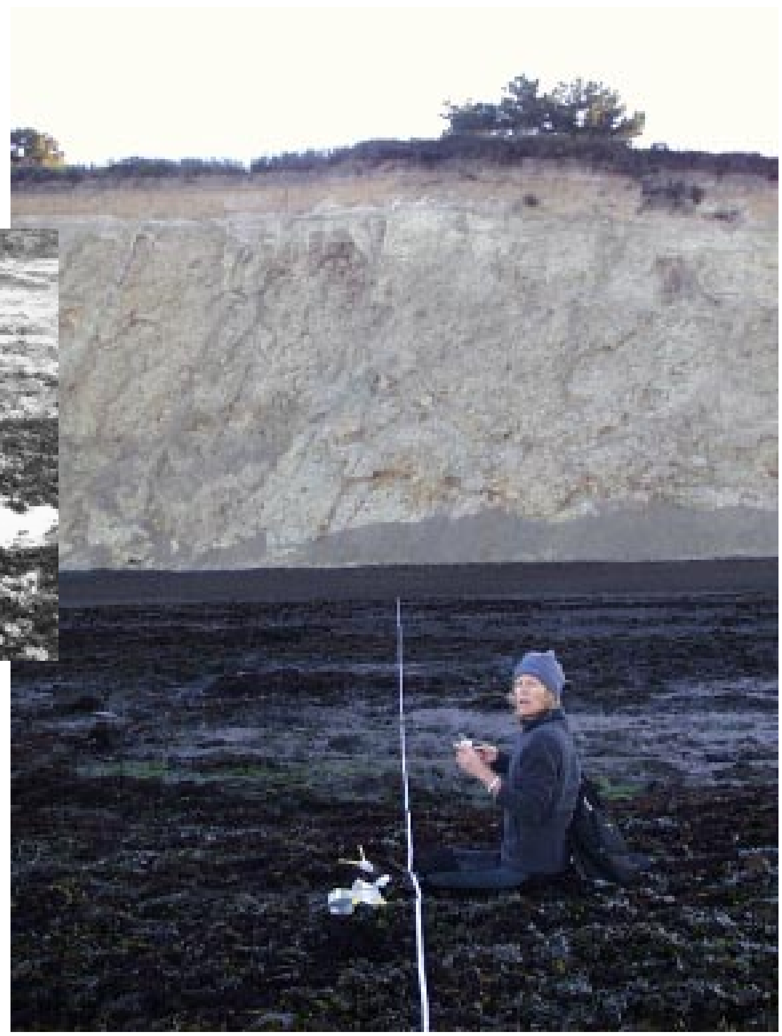
### Permanent Transects

| Transect | A | B |
|---|---|---|
| Starting Location | 0 marker | 0 marker |
| Direction to low marker(degrees) | 320° | 200° |
| Length between markers (m) | 59 m | 40 m |
| Distance to mid zone (m) | 37 m | |
| Distance to low zone (m) | 52 m | |
| GPS Location | | |
| High Marker Latitude (N) | 37° 53.835' N | 37° 53.881' N |
| High Marker Longitude (W) | 122° 42.644' | 122° 42.689' |
| Low Marker Latitude (N) | 37° 53.818' N | 37° 53.861' N |
| Low Marker Longitude (W) | 122° 42.677' | 122° 42.712' |
| High marker (0 m) | Marker is to the south from the trail, about 15 m. Look up to the cliff and the marker is to the left of the rusty spot on the cliff. It is where the algae starts. A half foot tall pointed rock is just to the south of it. | Marker with a yellow plastic rope is in the rocky flats. Walk down from the sandy beach, past the bare rock to where the rockweed begins. It is below the large tree on the bluff above. |
| Low marker | The low marker is south of a huge square pool. There is a small ridge and the marker is below and farther past the ridge. | The rocks are high at about 40 m where the transect runs between two pools. The pool to the south is a long rectangle running parallel to the shore. The pool to the north is about 1 meter away and horizontally lower/much deeper. |
| Permanent area - TOP (m) | 54 m | 40 m |
| Permanent area - BOTTOM (m) | 64 m | 50 m |
| Location of Permanent Quadrats | Every 5 meters, 0 to 65 m (except 21 m instead of 20 m), 14 permanent quadrats | Every 5 meters, 0 to 55 m, 12 permanent quadrats |

Looking down the B transect. Notice the marker sticking up in the lower left corner. Use the ridge break patterns to find to help locate the marker.



View looking at pool on low B marker



View from low marker on B transect.

**Figure 5. Photographs of Permanent Markers at Transect B.**

## C. Survey Day

### Assigning Students to their Survey Group

Before monitoring, students should be assigned to the following groups and given the appropriate data sheets.

1. Field log – 1 group of 2 people
2. Total counts in permanent area – 2 groups of 2 people
3. Vertical transect with permanent quadrats – groups of at least 2 people

**Notes for Duxbury Reef**

Usually, we have about 22 students for each monitoring session. This means that we have 4 students on the permanent areas and 8 students on each transect lines. Each group of 3 students can monitor 14 quadrats in 2 hours.

**The following tasks should be accomplished on the survey day:**

1. Complete the field log.
2. If the transect markers are covered with anything, use the wire brushes to clean them.
3. For the total counts in permanent area datasheet, check to make sure the time is recorded.
4. On the vertical transect with permanent quadrats datasheets, check to make sure A or B is circled and the location of each quadrat is recorded.

## D. Field Log Instructions

### Purpose

The general conditions of the area will be recorded on the Field Log (Appendix 4). This form should be the first one completed upon arriving at the site. It is important to make objective, accurate, and quantifiable observations using the detailed instructions on the next page. If intertidal monitoring is performed weekly, some variables, such as percent cloud cover, wind speed, and air temperature may be helpful in looking at a possible correlation with data trends. For studies that are conducted only several times throughout the year, these variables cannot be considered significant. Some information from the field log may explain observer bias. For example, cold, cloudy, and rainy conditions may yield less accurate results due to observer impatience and/or discomfort. Finally, recording field log information is a good method of practicing observation and recording skills that are instrumental in obtaining accurate results.

### Checklist

Field Log
Beaufort Wind Scale (Appendix 6
Pencil
Thermometer
Clipboard
Tide chart

**Notes for Duxbury Reef**

We try to keep all the equipment for the field log in one plastic box.

## Roles and Responsibilities

One person should record the required information on the field log.  The other people in the group should help the recorder determine the correct information for each topic.

## Procedures

Complete the form using the following instructions.

**1. Names, School Name and Location.**
Record the names of the people that are completing the Field Log . Be sure to include school name and location because the data may be combined with other schools and locations.

**2. Date**:
Record the date, including month, day, and year, that you are conducting the study.

**3. Time**:
Use the starting time when the group arrives on the beach.  Use military form – 24-hour clock.

**4. Low Tide Level and Time**:
Use a tide log to determine the time and water height at low tide.  If possible, use a tide log that provides tide levels throughout the day, and record the level that correlates with the time the study is being carried out.

**5. Beaufort Wind Scale**:
Use the scale provided to determine, in an objective and quantifiable manner, the approximate wind speed.

**6. Air Temperature**:
While holding the weather thermometer at eye level, read the meniscus and determine where the bottom of the meniscus appears.  Record this temperature in °C.

**7. Percent Cloud Cover**:
Assessing this information is more accurate when dividing the sky into quarters and approximating the percent cover for each quarter.  (Do not include the sky that falls under a thumb's height above the horizon).  Add the four percentages together.  Divide by four to get the average percent cloud cover.  Then, circle the range of percentages that includes your calculated number.

**8. Location/Sources of Fresh Water**:
List the sources of fresh water and draw on the site map the location of streams or other sources of fresh water influx.

**9. Observations/Unusual Events**:
Record other weather conditions not listed in the above spaces.  For example: rain, strong gusts of wind, rained the entire previous week, etc.  Also, record events that do not usually occur at the site. For example: beached animals, drift algae, sediment in tidepools, loss of daylight, etc.

## E. Vertical Transect with Permanent Quadrats
## Purpose

A major concern over the next several decades will be the effect of rising sea levels, as a consequence of global warming on the biota of the rocky intertidal. Presumably, species will shift up in their distribution as sea level rises. Will that really happen? We can collect data to provide the answer.

## Checklist

- Vertical Transect Across Intertidal Datasheets
- Algae and Invertebrate Field Guides
- Transect/Meter Tape
- Transect and Quadrat Locations Sheet
- 1/4 $m^2$ Quadrats
- Pencils
- Clipboards

**Notes for Duxbury Reef**

For 3 groups of 3 students each on each transect line (18 students total), we have 3 sets of datasheets (Figure 6) with clipboard, a quadrat and field guides. Each transect line needs one transect/meter tape so we need at least two 50 m tapes for the vertical transect method.

## Roles and Responsibilities

In each group, designate one person as the recorder and one or more people as the counter(s). The recorder is responsible for accurately recording the values in the appropriate columns on the provided data sheets for the correct quadrat. The counter(s), with the help of field guides, are responsible for identifying and assessing the abundance or percent cover for each species found in the quadrat. The counter(s) are also responsible for communicating the data clearly to the recorder.

## Procedure

Each group will survey quadrats at a permanent locations. The instructor will provide the location of each quadrat. Depending on the tidal cycle, be sure to survey the low tide region during the lowest part of the tide cycle when you are there.

**Notes for Duxbury Reef**

Quadrats are evenly spaced every 5 meters along the transect. Begin at 0, then 5, 10, 15, etc along the transect tape. The one exception is at 20 m where the quadrat sampled is at 21 m instead on Transect A.

Find the location for the quadrat along the meter tape. Place the center of quadrat over this point on transect tape at the location (0, 5, 10, etc.). Remember to record, at the top of the data sheets, the meter and transect designation (A or B) that the quadrat is at located before collecting data. Each quadrat will require two different methods:

1. Individuals - This method is for the larger invertebrates. Count and record the number of individuals (if any portion of the animal) is in the 1/4 $m^2$ quadrat. To count the turban snails, gently lift them, check to make sure there isn't a crab in the shell, and place them in the center of the quadrat. They will redistribute themselves and you will be sure to get an accurate count of snails (and not hermit crabs).

2. Relative abundance - Count and record the number of squares out of 25 with any attached piece of algae or individual invertebrate. This is not a true abundance yet this method gives a relative way to measure the percent cover for algae and small invertebrates which are often very abundant.

## F. Permanent Area with Total Counts

### Purpose

Because sea stars are important predators in the rocky intertidal but are not extremely abundant, it is not likely that the 1/4 $m^2$ quadrats will contain individuals of any species. However, any presence of these important predators at the site should be recorded. Their presence is one way to indicate the health of the rocky intertidal ecosystem. Therefore, surveying a large area for sea stars is necessary.

In this procedure, all the individuals of selected large, conspicuous, presumably important species are counted in one or more large defined areas. Teams of 2-3 people systematically go through each defined area and count every individual they see. Of course, the teams will always miss some individuals, so their counts are just estimates of the true abundance. The species that are counted can include sea stars, abalones, owl limpets, solitary sea anemones, and feather-boa kelp, as determined in the initial surveys (go to *limpets.noaa.gov* for more information about other species and variation in methods).

### Checklist

- 4 small traffic cones for each area
- watch or stop watch
- Total Counts - Permanent Area Datasheet
- Tape Measure
- Clipboard
- Pencils

**Notes for Duxbury Reef**

Only giant green anemones (*Anthopleura xanthogrammica*) and ochre stars (*Piaster ochraceus*) are counted in the large permanent areas. Also, there are two permanent areas, each assoicated with a transect. A tape measure is needed to set up the cones to mark the area off of the transect area.

### Roles and Responsibilities

Designate one person as the recorder, one person as the timer and everyone in the group is a counter. The recorder is responsible for documenting the findings on the Total Counts - Permanent Area Datasheet (Figure 8) and assisting the searcher in finding the designated large organisms. The timer is responsible for watching the time and limiting the search to 20 minutes.

**Duxbury Data Sheet**
**Vertical Transect Across Intertidal**

Date: School/Leader:

Names

| | A or B (Circle one) | |
|---|---|---|
| Transect Mark - Place center of quadrat over this point on transect tape | meters | meters |
| | | |
| **Individuals - Count if any portion of the animal is in the 1/4 $m^2$ quadrat.** | | |
| Giant green anemone - *Anthopleura xanthogrammica* | | |
| Brooding anemone - *Epiactis prolifera* | | |
| Chitons - *Mopalia* spp./*Nuttallina californica/Lepitochitona* spp./others | | |
| Whelks - *Acanthinucella* spp./*Nucella* spp. | | |
| Turban snails -*Tegula brunnea/funebralis* | | |
| Ochre star - *Pisaster ochraceus* | | |
| Bat star - *Asterina miniata* | | |
| Six-armed star - *Leptasterias hexactis* | | |
| | | |
| **Count and record the # of squares out of 25 with any attached piece of:** | | |
| Green pin-cushion alga - *Cladophora columbiana* | | |
| Sea lettuces - *Enteromorpha/Ulva* spp. | | |
| Surfgrasses (attached in square) - *Phyllospadix scouleri/torreyi* | | |
| Flattened rockweeds - *Fucus gardneri/Hesperophycus californicus* | | |
| Slender rockweeds - *Pelvetiopsis limitata/Silvetia compressa* | | |
| Tar spot algae - *Mastocarpus* spp./*Ralfsia* spp. and others | | |
| Encrusting coralline algae (on rocks) - many species | | |
| Upright coralline algae - *Bossiella* spp./*Calliarthron* spp./*Corallina* spp. | | |
| Red Algal Turf - *Endocladia muricata and Gelidium coulteri* | | |
| Turkish Towel - *Mastocarpus papillatus* | | |
| Sea sacks - *Halosaccion glandiforme* | | |
| Iridescent algae - *Mazzaella flaccida/splendens* | | |
| | | |
| Aggregating anemone (<5 cm) - *Anthopleura elegantissima* | | |
| Limpets - *Lottia* spp./*Macclintockia* spp.(0.5 - 2.5 cm) | | |
| Sea mussel - *Mytilus californianus* | | |
| Common acorn barnacles - *Balanus/Chthamalus* spp. | | |
| Bare rock | | |
| Loose sand | | |

**Figure 6. Vertical Transect - Permanent Quadrat Datasheet**

## Procedure

Place the cones at the corners of the permanent area, using the tape measure and the vertical transect line to know where the area is.

To do the counts of large organisms, systematically search the delineated area, searching successive swaths about the width of outstretched arms. The search should be for exactly 20 minutes. Make sure to look in crevices. Record the number of each species and color variant of ochre sea stars.

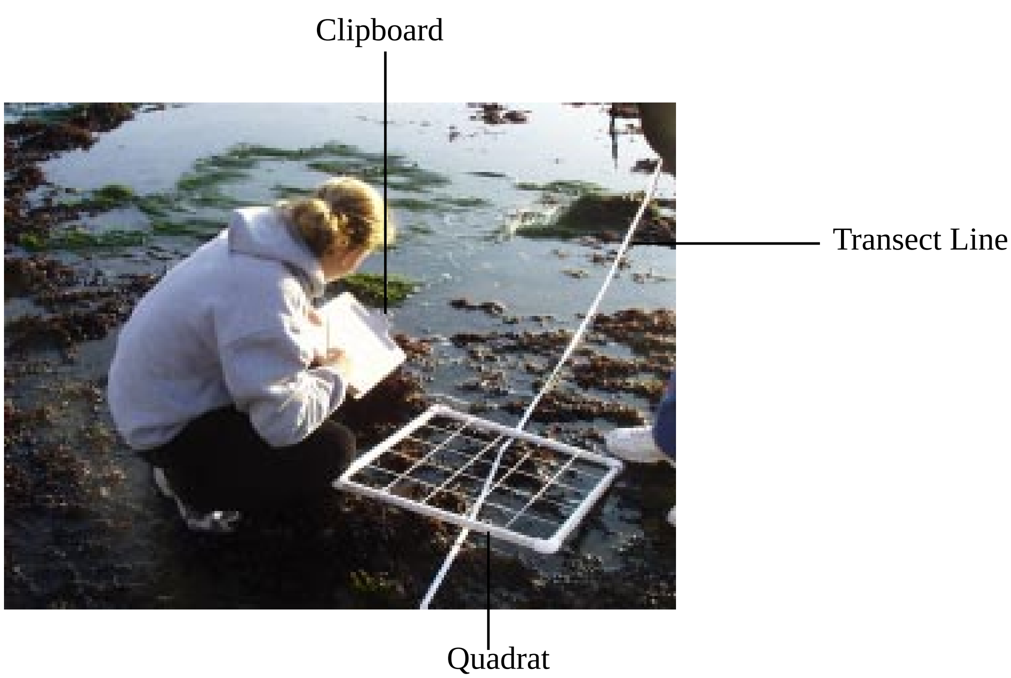



**Figure 7. Example of quadrat layout.** The center of the quadrat is placed on the number of the transect tape at the approporiate permanent location.

**Duxbury Datasheet**
**Total Counts - Permanent Area**

Date: School/Leader:

Names

From meter mark on transect tape,
A - 54 m - 64 m, 10 m to the north/point side
B - 40 m - 50 m, 10 m to the north/point side
Count for 20 minutes exactly, no more, no less.

**A or B (Circle one)**

Total # Individuals - count even if only a portion of the animal is in the area.

| | Total Number of Organisms |
|---|---|
| Giant green anemone - *Anthopleura xanthogrammica* | |
| Ochre star - *Pisaster ochraceus* (purple/brown) | |
| Ochre star - *Pisaster ochraceus* (orange) | |

Time: ______________________

**Figure 8. Total Counts - Permanent Area Data Sheet**

# 6. DATA ENTRY

## Purpose

After collecting the raw data, it must be analyzed to allow a comparison between the quadrats and intertidal zones. Entering the numbers into a computer database program will facilitate calculations. A database for the west coast National Marine Sanctuaries is currently under development. This will be available at *limpets.noaa.gov*. You will need a password to enter the data.

## Checklist

- Data Sheets
- Pencils
- password
- internet access

## Roles and Responsibilities

With your partner(s), designate one person to enter the data into the computer and the others to refer to the correct data sheet and communicate the values to the person at the computer.

*Note: Although the computer may make calculations automatically, it is important to know the formulas and to make your own calculations to double-check that the computer is correct.

## Procedure

### General Data Entry Tips

- As one person reads the data from the data sheet, the other enters it into the database on the computer.
- You can turn on the number lock and use the set of number keys on the right of your keyboard for quicker data entry.
- Both people check for the accuracy of the entries as the data is entered.
- The reader checks over the data again after it has all been entered and printed.
- Follow the directions on the website.
- If you enter something incorrectly or are unsure of what to do, contact the database manager.

# 7. Data Analysis and Final Assessment Options

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 intertidal life 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 different graphing options. Students can compare their results to those of other schools monitoring other rocky intertidal areas along California. The data will be part of a comprehensive dataset for areas in and near the five National Marine Sanctuaries along the west coast.

## 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 monitoring for turban snails or any other invertebrate, you could not be 100% certain of conditions unless you were to census every animal. 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.

This section on statistical analysis will be developed in the future.

# 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 rocky intertidal 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 hermit crabs live?
- How can you tell the difference between little rockweed and *Fucus sp.*?
- How do you monitor the abundance of algae vs. snails or limpets?
- Why might it be important to monitor the rocky intertidal habitat?

***Sampling***

- Record the weather conditions.
- Describe the rocky intertidal habitat.
- What other animals were found other than the ones in the monitoring list?
- Why do we sample along transects? Why permanent quadrats?
- What trends did you observe, if any?

## 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: monitoring quadrats along a transect or counting animals in a large area. 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.

## 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 so they will have a clear understanding of the habitat 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 , research the topic thoroughly. Determine what is already known zonation in the rocky intertidal habitat 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 consistent survey of the habitat.

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 zonational pattern.

You may need to perform statistical tests, or calculations, on your raw data in order to get results that you can compare and interpret.

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

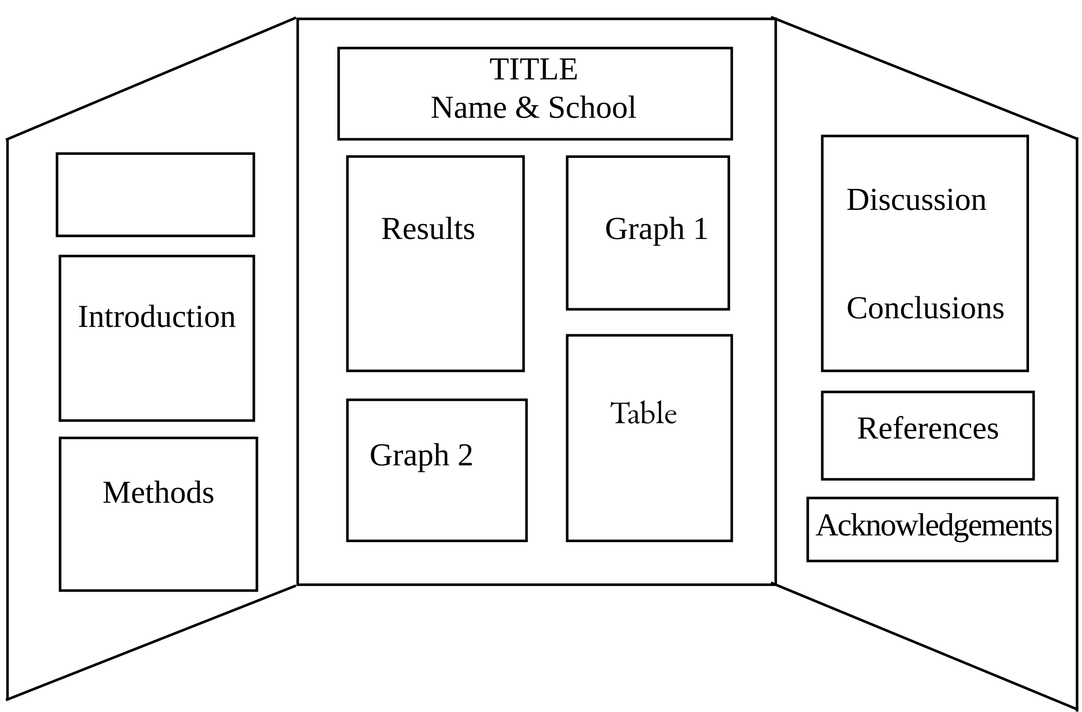
Print each poster section onto white paper and mount evenly onto colored paper.  Glue the sections to the poster board (see below).

## 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 you 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.

# 8. Bibliography

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Beauchamp, K.A. and M.M. Gowing. 1982. “A Quantitative Assessment of Human Trampling Effects On A Rocky Intertidal Community.” *Marine Environmental Research* 7:279-293.

Breen, R. 1997. *Monitoring Guidelines and Sampling Procedures at Fitzgerald Marine Reserve*.

California Marine Waters Areas of Special Biological Significance Reconnaissance Survey Report: Duxbury Reef Reserve and Extension. 1979. California State Water Resources Control Board Division of Planning and Research Surveillance and Monitoring Section.

Chan, G. L. 1974. The Effects of the San Francisco Oil Spill on Marine Life—Part II. Unpublished Report, College of Marin, Kentfield, California.

Cosentino, N. 1998. *Monitoring the Rocky Intertidal Communities at Point Bonita, Marin County, California*. Funded by U.S. Dept. of Interior, National Park Service, Golden Gate National Recreation Area.

Cosentino, N., J. Roletto, E. Gartside, and T. Chess. 1999. Monitoring the Rocky Intertidal Communities within the Gulf of Farallones and Monterey Bay National Marine Sanctuaries 1998. Unpublished Report, National Oceanic and Atmospheric Administration, Gulf of the Farallones National Marine Sanctuary, San Francisco, CA.

*Fifth Biennial Workshop on Research in the Gulf of the Farallones*. 2000. Gulf of the Farallones National Marine Sanctuary.

Maloney, E. S. 1985. *Chapman Piloting: Seamanship and Small Boat Handling*. New York: Hearst Marine Books.

*PROJECT OCEAN: Rocky Seashore Habitat Guide*. San Francisco Bay Chapter, Oceanic Society. Available from the Gulf of the Farallones National Marine Sanctuary.

Ricketts, E.F., J. Calvin, and J.W. Hedgpeth. 1985. *Between Pacific Tides*. Stanford, CA: Stanford University Press.

*A Tour of the Sanctuaries*. 1996. Santa Barbara Natural History Museum and National Oceanic and Atmospheric Administration.

# 9. Further Readings


**Recommended for teachers:**

Abbott, I.A., and G.J. Hollenberg. 1976. *Marine Algae of California*. Stanford: Stanford University Press.

Brusca, G.J. and R.C. Brusca. 1978. *A Naturalist's Seashore Guide-Common Marine Life of the Northern California Coast and Adjacent Shores*. Eureka, CA: Mad River Press, Inc.

Dawson, E.Y. and M.S. Foster. 1982. *Seashore Plants of California*. Berkeley: University of California Press.

Evens, J.G. 1993. *The Natural History of the Point Reyes Peninsula*. Point Reyes National Seashore Association.

Fitch, J. and R.J. Larenberg. 1975. *Tidepool and Nearshore Fishes of California*. Berkeley: University of California Press.

*Fitzgerald Marine Reserve Master Plan*. 1999. Brady/LSA.

Horn, M., K. Martin, and M. Chotkowski. 1998. *Intertidal Fishes: Life in Two Worlds*. Berkeley: Academic Press.

Kozloff, E.N. 1993. *Seashore Life of the Northern Pacific Coast*. Seattle and London: University of Washington Press.

McConnaughey, H. B. and E. McConnaughey. 1988. *Pacific Coast*. New York: Alfred A. Knopf.

Morris, R.H., D.P. Abbott, and E.C. Haderlie. 1980. *Intertidal Invertebrates of California*. Stanford: Stanford University Press.

Wertheim, A. 1984. *The Intertidal Wilderness*. San Francisco: Sierra Club Books.

**Recommended for students:**

Carefoot, T. 1983. *Pacific Seashores*. Seattle: University of Washington Press.

Coulombe, D.A. 1984. *The Seaside Naturalist*. New York: Prentice Hall Press.

Niesen, T.M. 1994. *Beachcomber's Guide to California Marine Life*. Houston, TX: Gulf Publishing Company.

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Russo, R. and P. Olhausen. 1981. *Pacific Intertidal Life*. New York: Nature Study Guild.

# APPENDIX 1

## MASTER LIST OF MATERIALS

**Monitoring Equipment:**

- 4-6 1/4 $m^2$ quadrats
- 2 transect tapes or measured line of at least 100 m, measured in meters
- 4 traffic cones (4 as minimum, 8 if two groups counting)
- knee pads (nice but not necessary)
- pencils
- 8+ clipboards
- compass
- invertebrate and algae field guides
- waterproof camera
- first aid kit
- GPS (or other location device) (optional)
- buckets for carrying equipment
- tidebook

**Permanent Transect Equipment: (needed only for initial transect marking with the exception of the wire brushes which are needed for cleaning off markers occasionally)**

- 4 Transect Markers (rope)
- Mixing Container
- Mixing Knife
- Epoxy
- Paint Scraper
- Wire Brushes
- Rags
- Rock Hammer

**Forms:**

*Field Log
*Vertical Transect Across Intertidal Datasheet (many copies)
*Total Counts - Permanent Area Datasheet(many copies)
Research Permit
Transect and Quadrat Locations Datasheet
Site Map
Beaufort Wind Scale

***Denotes that these forms should be printed on waterproof paper**

# Appendix 2

## Annotated List of Materials

| Item | Supplier | Price | Phone |
|---|---|---|---|
| PVC Piping | Any hardware store | Variable | |
| Compasses | Lombardi Sports Inc. | $25.95 | (415) 771-3600 |
| Epoxy | West Marine Products | $23.38 | (415) 332-0202 |
| "Rite in the Rain" Paper | J.L. Darling Corporation | $21.25/pack | (253) 922-5000 |
| Plastic Algae/Plant Field Guide | Oregon Dept. of Fish and Wildlife | $2-4 each | (541) 867-4741 |
| Plastic Marine Invertebrate Guide | The Mountaineers Books (Seattle, WA) | $2.75-4 each | (206) 223-6303 |

# APPENDIX 3
# CONTENTS OF THE CLASSROOM AND FIELD KITS

Contact the closest National Marine Sanctuary Office to schedule the use of a kit. We recommend purchasing your own equipment if possible. All the field equipment costs about $200 or less.

**<u>LiMPETS Rocky Intertidal Classroom Kit Checklist</u>**

- o 1 LiMPETS CD - with activities and a slide show
- o 5 quadrats (1/4 $m^2$)
- o 5 photo quadrats
- o 3 Laminated Black Turban Snail Handouts
- o 3 Laminated Owl Limpet Handouts
- o 10 Photo Species ID Cards
- o Folder:
  - Activity 1 - Get to know the species
  - Activity 1 - Get to know the species answer key
  - Activity 2 - Personal field guide
  - Activity 3 - Photo quadrat data sheet
  - Activity 3 - Photo quadrat answer key

**<u>LiMPETS Rocky Intertidal Field Kit Checklist</u>**

- o 10 quadrats (1/4 $m^2$)
- o 5 50 m tape measures (open reel fiberglass tapes)
- o 10 clipboards with rubber bands
- o 10 flexible rulers
- o 10 laminated Species ID Cards
- o 5 Field Guides: <u>Pacific Intertidal Life.</u> Ron Russo and Pam Olhausen. 1981. Nature Study Guild.
- o 5 knee pads

*Suggested Equipment not included:*

*Pencils*
*10 plastic coated paper clips for measuring owl limpets in cracks*
*First Aid Kit*

(The rulers and paper clips are used when monitoring for owl limpets. There are no owl limpets at Duxbury Reef in the area we monitor and therefore they are not included in the suggested equipment list for Duxbury Reef.)

# Appendix 4
# Field Log

**Names**______________________________________________________________

School Name ___________________________________________________________

Location ______________________________________________________________

**Date**______________ **Start Time**__________

**Low Tide Level (ft)**______ **@ Time**_________

**Beaufort Wind Scale (1-12)** ______ **Air Temperature (∞C):** ______

**Percent Cloud Cover** 0 1-25% 26-50% 51-80% 81-100%

**Location/Sources of Fresh Water:**

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**Observations/Unusual Events:**

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

# Appendix 5
## Blank Transect and Quadrat Location Datasheet

### Transect and Quadrat Locations

Site: ______________________ Date: ______________________

**Permanent Transects**

| Transect | **A** | **B** |
|---|---|---|
| Starting Location | | |
| Direction to low marker(degrees) | | |
| Length between markers (m) | | |
| Distance to mid zone (m) | | |
| Distance to low zone (m) | | |
| GPS Location | | |
| High Marker Latitude (N) | | |
| High Marker Longitude (W) | | |
| Low Marker Latitude (N) | | |
| Low Marker Longitude (W) | | |
| High marker (0 m) | | |
| Low marker | | |
| Permanent area - TOP (m) | | |
| Permanent area - BOTTOM (m) | | |
| Location of Permanent Quadrats | | |

# APPENDIX 6: 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 7
# SPECIES PF ALGAE, PLANTS, AND ANIMALS MONITORED IN MONTEREY BAY NATIONAL MARINE SANCTUARY

This list was made by John Pearse and Dawn Osborn of the University of California at Santa Cruz. They created this list by working with high school students to see which species the students could identify and which species were present. At the LiMPETS website, you can learn more about the specific sites (e.g. 33rd or Rockview) referred to in this list in parentheses.

Monitoring method:
[1]counted as individuals.
[2]counted as number out of 25 10 x 10cm squares occupied within a 1/4 $m^2$ quadrat.

**GREEN ALGAE/FLOWERING PLANTS**
[2]*Cladophora columbiana* - green pin-cushion alga (not at 33rd) **High zone indicator**
[2]*Codium fragile* - dead man's fingers (not at 33rd) **Easy to ID, potentially invasive**
[2]*Enteromorpha* spp./*Ulva* spp. - sea lettuces **Early colonizers, indicative of high disturbance areas**
[2]*Phyllospadix scouleri/torreyi* - surfgrasses **Competitive dominant in low zone, sensitive to pollution**

**BROWN ALGAE**
[1]*Egregia menziesii* - feather-boa kelp **Low zone indicator**
[2]*Fucus gardneri/Hersperophycus californicus* - flattened rockweeds (not at 33rd) **High zone indicator**
[2]*Pelvetiopsis limitata/Silvetia compressa* - slender rockweeds (not at 33rd) **Sensitive to trampling, high zone indicator**

**RED ALGAE**
[2]*Bossiella* spp./*Calliarthron* spp./*Corallina* spp. - upright coralline algae **Resistant to trampling and pollution, especially *Corallina* spp.**
[2]*Cryptopleura* spp. - frilly red alga (only at 33rd) **Low zone indicator**
[2]*Endocladia muricata* - scouring-pad alga (not at 33rd) **Sensitive to trampling, high and upper mid zone indicator**
[2]*Gracilariopsis lemaneiformis* - vermicelli alga (only at Rockview and 33rd) **Low zone indicator, usually on sand-covered rocks**
[2]*Halosaccion glandiforme* - sea sacks or sea nipples **Distinctive open-coast species, fun to count**
[2]*Mazzaella flaccida/splendens* - iridescent algae **Mid zone indicator, competitive dominate, potentially harvested for carrageen**
[2]*Plocamium* spp. - Christmas card alga (33rd only) **Low zone indicator of delicate beauty**

<u>ENCRUSTING ALGAE</u>
[2]Encrusting coralline algae - *Lithophyllum* spp./*Lithothamnion* spp. and others on rocks **Resistant to trampling and pollution, dominant species on primary substrate**
[2]Tar-spot algae - *Mastocarpus* spp. (encrusting form)/*Petrospongium rugosum*/*Ralfsia* spp. and others **Resistant to trampling and pollution, dominant species on primary substrate**

**SPONGES**
[2]*Hymeniacidon* sp. - yellow introduced finger sponge (only at 33rd) **Introduced species in bays and protected areas**

**SEA ANEMONES**

[2]*Anthopleura elegantissima* - aggregating anemone **Major space competitor and predator**
[1]*Anthopleura sola* - sunburst anemone **Southern species near northern limit, major space competitor and predator**
[1]*Anthopleura xanthogrammica* - giant green anemone (not at 33rd) **Northern species, major space competitor and predator, associated with mussels**

**WORMS**

[2]*Phragmatopoma californica* - honeycomb tube worm **Major space competitor, mid zone indicator**

**CHITONS**

[1]*Mopalia* spp./*Nuttallina californica*/*Lepitochitona* spp. and others - chitons (not at 33rd) **Major grazers**

**LIMPETS**

[1]*Lottia gigantea* (>2.5 cm) - owl limpet (not at 33rd) **Major grazer, harvested by people**
[2]*Lottia* spp. (0.5-2.5 cm, on rocks) - limpets **Major grazers, shore bird prey**

**SNAILS**

[1]*Acanthinucella* spp./*Nucella* spp. - whelks (not at 33rd) **Major predators**
[1]*Tegula brunnea/funebralis* - turban snails **Major grazers, harvested by people**

**ABALONES**

[1]*Haliotis cracherodii* - black abalone (Davenport Landing, Point Pinos and Carmel Point only) **A protected species harvested by people, preyed upon by sea otters, and subject to the withering-foot disease that has devastated populations in southern California**

**MUSSELS**

[2]*Mytilus californianus* - California sea mussel (not at 33rd) **Competitive dominant, major space occupier in mid zone**

**BARNACLES**

[2]*Balanus glandula* and *Chthamalus dalli/fissus* - common acorn barnacles (not at 33rd) **High and mid zone space competitors, major prey**
[2]*Pollicipes polymerus* - leaf barnacle (not at 33rd) **Mid zone indicator**
[2]*Tetraclita rubescens* - pink acorn barnacle (not at 33rd) **Southern species near northern limit**

**CRABS**

[1]*Pagurus* spp. - hermit crabs **Important detritavores, fun to count**

**SHRIMPS**

[1]*Heptacarpus* spp. - broken back shrimps (only at 33rd) **Living in the low zone in tide pools, sensitive to pollution, fun to count**

**SEA STARS**

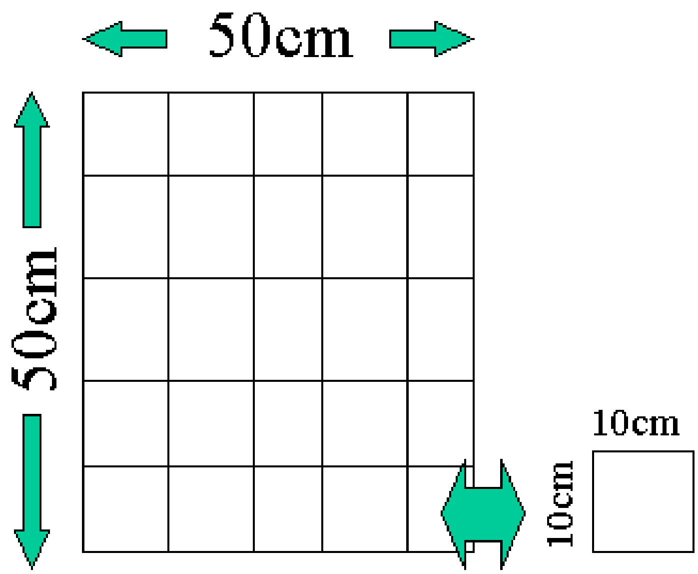
[1]*Pisaster ochraceus* - ochre sea star (not at 33rd) **Important predators, vulnerable to parasitic castration**
[1]*Asterina miniata* - bat star (Point Pinos only) **Conspicuous, fun to find**

**SEA URCHINS**

[1]*Strongylocentrotus purpuratus* - purple sea urchin (juveniles are green) **Major herbivore, easy to identify**

# APPENDIX 8
# HOW TO MAKE A QUADRAT

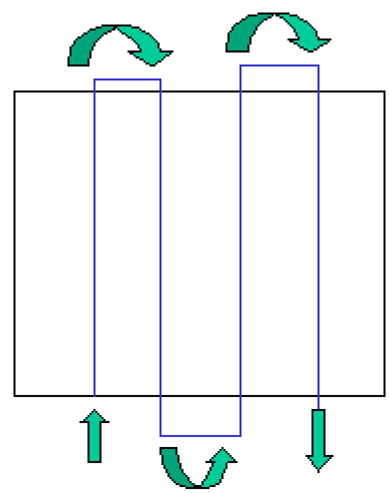
Overall shape and size of 1⁄4 meter squared quadrat and the 10cm x 10cm individual squares.




To make a 1⁄4 meter squared quadrat you will need the following supplies:

* 3/4" Sch (schedule) 40 PVC (you will need at least 2.2m for each quadrat)
* 3/4" 90 degree angle PVC elbows (4/quadrat)
* PVC primer (We use Low VOC, IPS Weld On, P-70 purple primer, stock # 10277) use in well ventilated area, preferably outside!
* PVC glue (We use; Low VOC, IPS Weld On Series 2000 plastic pipe cement, PVC 2700 clear regular bodied) use in well ventilated area, preferably outside!
* Nylon string (approximately 5m per quadrat, enough to tie knots and fix frays)
* Saw to cut PVC (We use a hack saw)
* Drill with an 1/8" drill bit to make 16 holes (4 holes per side, once strung you will have 25 squares)
* Matches, lighter, glue gun or candle to melt ends of string (this insures that knots will stay taught)
* Meter tape
* Vice (to hold PVC and/or quadrat in place while you saw and /or drill)
* Hammer and nail (once you have measured where the holes will be drilled, tap the nail to make a small indentation on the PVC, this will make the drilling easier, the drill will be less likely to slip)
* Tape (wrap tape around the end of the nylon string prior to stringing, this will make stringing much less frustrating, the sting should feed through the holes nicely)
* Pencil (to mark PVC for gluing and drilling)
* Latex gloves (the primer stains)
* Old newspaper (the primer stains)

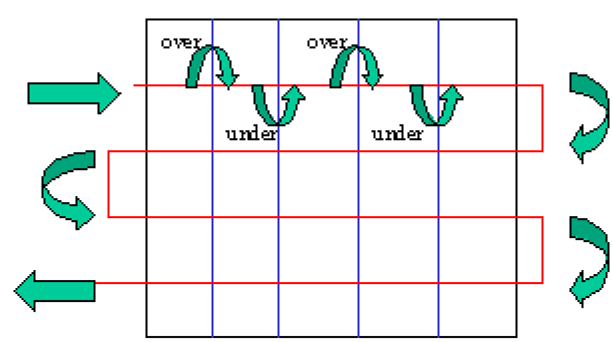
1. Cut the PVC (use extreme caution when using a saw) into the correct lengths about 0.48m each, it may vary slightly some elbows may be more snug than others.
2. Prior to gluing (make sure you are in a well ventilated area, preferably outside!) assemble the PVC lengths with the elbows to insure correct length, when all sides are aligned properly mark the PVC at the point where it meets the elbow (when you glue make sure the elbow lines up with the line again). The insides of the quadrat should measure 50 cm on a side.
3. Next lay out the newspaper, put on the latex gloves and then primer the inside of the elbow and the outside of the PVC pipe where they will join (approximately a 1⁄4" band on each).
4. Next put a thin layer of the PVC cement on top of the primer, then put the elbow and the length of PVC together. Make sure the alignment is correct and then let dry (beware, it dries quickly!).
5. Do one side at a time insuring it is aligned and will lay flat before proceeding, then repeat previous steps until the frame is finished.
6. Using a meter tape measure the PVC and mark with a pencil (near the center of the inner side) the spot where the holes will be drilled (the holes should be 10cm apart, thus you will have 4 holes per side).
7. Repeat until you have marked all four sides.
8. Once marked, put the frame in a vice (so that it will be steady) now take a nail and place it on the mark and tap it until there is an indentation in the PVC (this will make a nice groove and will keep the drill from slipping).
9. Repeat until all of the spots are marked.
10. Now using a drill, drill holes straight through the two walls of the PVC.
11. Once all of the holes are drilled, cut a 2.5m piece of nylon string and place an inch or two wide band of tape on the end (this will make threading the string much easier).
12. Weave the string through so that you have a nice taught grid!
    See directions below
13. Okay last step, to insure that the string stays taught and the ends do not fray you can either glue the knot with a glue gun or you can melt the ends of the string by burning the string with a match, lighter, candle or rope burner (just be careful not to burn through the string or burn yourself).



**How to Weave the String**

A. Start stringing the first 2.5m length of string here. Tie knot, pull tight through first hole, then continue to string following the arrows.

B. Pull string taught, tie knot, then glue or burn knots at both ends.




C. Start Stringing the second 2.5m length of string here. Tie knot, then continue to string alternately going over and under the first length of string, following the arrows.

D. Pull string taught, tie knot, then glue or burn knots.