

Rocky Shores of the Gulf of the Farallones National Marine Sanctuary

Table of Contents

Background	3
Glossary of Terms	7
Fact Sheet	9
Activities	11
Guidelines for a Successful Rocky Intertidal Field Trip	30
Script for Slide Show	33
Books and Resources	37
Selected Websites	38

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

The Coastal Ecosystem Curriculum will help your students achieve the following educational standards. These standards are from the Science Content Standards and the History/Social Science Standards for California Public Schools. Performance standards, indicated by bullets after each content standard, are specific for each activity. We suggest using the fact sheets with the slide shows to emphasize key points and to provide students with written material for future reference.

Slide Show and Fact Sheet

Biology/Life Sciences

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.
 - e. Know a vital part of an ecosystem is the stability of its producers and decomposers.

- Students will know there are many benthic producers in the rocky intertidal habitat and that animals depend on other parts of the ecosystem for food.

Earth Sciences

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.

Getting to know your species

Biology/Life Sciences

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

- Know biodiversity is the sum total of organisms and is affected by alterations of habitats.
- Students will know how to identify animals and algae commonly found in the rocky intertidal habitat.

Turban Snail and Mossy Chiton Investigation

Biology/Life Sciences

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

- Know biodiversity is the sum total of organisms and is affected by alterations of habitats.
- Students will be able to determine the difference between two classes of the Phylum Mollusca.
 - Know how to distinguish between the accommodation of an individual organism to its environment and the gradual adaptation of a lineage of organisms through genetic change.
 - Students will know how the marine snails and chitons have adapted to living in the rocky intertidal habitat.

Photo Quadrat Activity

Biology/Life Sciences

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

- Know biodiversity is the sum total of organisms and is affected by alterations of habitats.
- Students will know the biodiversity of the rocky intertidal habitat by determining the abundance of many species.

Seaweed Tasting

Biology/Life Sciences

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

- Know a vital part of an ecosystem is the stability of its producers and decomposers.
- Students will know which human food products contain primary producers from the marine environment.

Natural History of the Rocky Intertidal Habitat

The Pacific shores of North America are subject to extremely harsh conditions. Powerful waves formed from prevailing westerly winds and winter storms beat relentlessly against the coast. The tides temporarily cover the substrate with water and then expose the abundant life to terrestrial environmental factors. Despite all of these 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 nonliving 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 susceptible to desiccation (drying out), they can be exposed to heavy rainfall or direct sunlight, and are more visible to predators. 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 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

The rocky intertidal ecosystem is divided into a series of zones. Scientists define the zones 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. The following sections will give you an idea of the conditions in each zone and the organisms that are typically 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 rocky intertidal ecosystem is home to many different animals and algae. It 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.

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, black turban snails, and the rock louse live in the splash zone. The snails are able to attach to a rock 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 rock louse, an isopod, is a small crustacean that lives in the wrack line. They must keep their gills moist but will drown if submerged in water.

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 lose most of its photosynthetic pigment but still regain its photosynthetic abilities once a high tide reaches it.

The High Zone

Twice a day, for a total of only a few hours per day, the ocean water submerges 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 funebris*), 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, rockweed (*Fucus*), sea lettuce (*Ulva*), 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. 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 brown turban snail (*Tegula brunnea*), the black turban snail (*T. funebris*), 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. Iridescent seaweed (*Mazzaella*, *Gelidium*, and *Mastocarpus* species) attach their holdfasts, or rootlike 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 under 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 intertidal and subtidal regions of the ocean. 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, 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 animal 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 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, octopi, and nudibranchs can survive only within tidepools or subtidal regions. Sea anemones, sea stars, crabs, and many kinds of algae species may also reside here. Coralline algae species form thin layers on the surface of rocks. The algae may be pink with 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.

(Adapted from *PROJECT OCEAN: ROCKY SEASHORE HABITAT GUIDE*)

Introduction to Duxbury Reef

Duxbury Reef is located 16 miles north of San Francisco in Bolinas, California. It lies adjacent to Agate Beach at the end of Elm Street. Named after a ship called “Duxbury” which ran aground in 1850, it is considered an area of special biological significance. Duxbury Reef is composed of Monterey shale which contains cherts, porcelanites, organic shales, and thin hard sandstones. It is the largest exposed shale reef in California. The best time to visit Duxbury Reef is during a low tide when the rocks are exposed revealing a diverse habitat. As you walk down the path you first see bare rock where you will find living in large aggregations *Tegula funebris* commonly known as black turban snails. As you continue to head towards the ocean the rocks become covered in several different species of algae. Sea lettuce, coralline algae, rockweed, and turkish towel are just a few examples. If you are lucky and look very closely, you might see a nudibranch or sea slug searching for its next meal in one of the tidepools. Further out you’ll find sea grass, ochre sea stars, and giant green anemones. As you venture south you’ll even see some purple sea urchins. The Branson School has been monitoring the populations of algae and marine invertebrates since 1999. They have been collecting baseline data of species abundance.

Glossary of Terms

algae	(singular–alga); aquatic or marine organisms that resemble plants but have no seeds or roots, ranging from one-celled diatoms to multicellular seaweeds
byssal threads	hair-like filaments that mussels produce to bind themselves to rocks and other substrates
desiccation	the process of drying out, which is increased by the wind and the heat from the sun on exposed organisms in the rocky intertidal habitat
chiton	a mollusk with a long, flat foot, hardened shell, and symmetrical double gills; the shell is divided into eight adjoining segments; closely related to snails (Class:Polyplacophora)
ecosystem	an ecological relationship between an organism and its environment
encrusting algae	multicellular algae that covers the substrate instead of growing upright
exoskeleton	an external skeleton, like the “shell” of a crab
filter-feeder	an animal that feeds by passing surrounding water through a filtering device (like barnacle legs, clam gills, etc.) and filtering or straining out small particles of food
grazer	see herbivore
herbivore	an animal that only eats plants or algae
holdfast	the part of an alga that holds it to a firm surface (substrate) by root-like branches called haptera
intertidal	the area of the shore between the highest and lowest tidal levels
limpet	any member of marine gastropods with a simple, conical shell (Order Archeogastropoda)
mobile	moving; unattached to the ocean floor, opposite of sessile
nudibranch	sea slug; any member of marine gastropods without a shell (Order Nudibranchia)
organism	a living thing
photosynthesis	the process by which green plants and algae use energy from sunlight to produce sugar and oxygen from carbon dioxide and water
predator	an animal that kills and eats other animals

prey	an organism that is killed and eaten by other animals
regenerate	to grow back part of the body that has been removed or lost
rocky intertidal	stretches of the shoreline, between the highest and lowest tidal levels, that are rocky—not sandy
seaweed	any large photosynthetic protist, including kelp. They are not true plants but like plants they can make their own food.
sessile	stationary; attached to the sea floor or an object such as a rock, opposite of mobile
substrate	any surface on which an organism lives, ie rock, another animal, or plant
subtidal	below the intertidal, or below the level of the lowest tide
tube feet	an extension of the water vascular system of echinoderms (sea stars, sea urchins, etc.) which aids in locomotion, grasping, and feeding
wave action	the force of the waves crashing on the rocks and organisms
zonation	the distribution of the plants and animals into horizontal bands or zones. In the rocky intertidal, zonation is determined by the tidal height and wave action

Sanctuary Habitat: Rocky Shores

Along the coast of the Gulf of the Farallones National Marine Sanctuary lies a special habitat where the land meets the sea – the rocky intertidal. This rocky area between the low and high tides is biologically rich, supporting a diverse assemblage of plants and animals. Organisms living here face many challenges that are unique to living at the edge of the sea, where changing tides and pounding waves prevail. Inhabitants of the rocky intertidal have adapted to these conditions in many special ways.

DETERMINING FACTORS . . .



moon snail

WATER LOSS

As the tide goes out, water loss becomes a problem for residents of the intertidal zone. Mobile animals prevent drying out (desiccation) by hiding under wet algae and rocks or in crevices or tidepools. Less mobile organisms close up, like a mussel pulling together its valves or a limpet tightening down its shell onto the rock. Seaweed can lose up to 90% of its moisture and survive until the tide rises again.



photo by Joe Heath

Gulf of the Farallones National Marine Sanctuary offers many opportunities for tidepool discoveries.

LIMITED SPACE

The rocky intertidal has a limited amount of surface area, especially in the lower zones, for the many organisms which dwell there. Organisms cope with limited space either by growing on each other, bulldozing others out of their territory, or growing quickly to out-compete their neighbors.

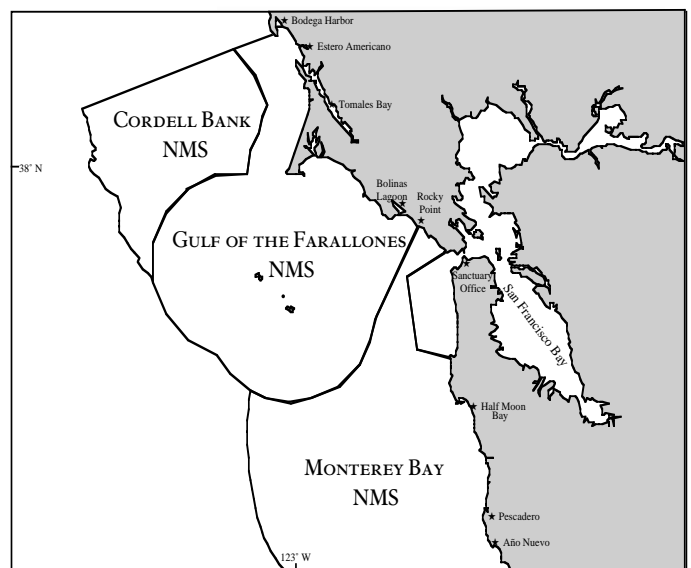


WAVE ACTION

Organisms must deal with the physical pounding of waves. Many rocky intertidal inhabitants anchor firmly and hold tight to the rocks as limpets do with their muscular foot, mussels with their byssal threads, and seaweed with their holdfasts. Body design, such as being flexible or very flat and close to the rocks, also minimizes the impact of waves. Some organisms, like tube-building worms, build their dwellings so that the seawater flows around them with the least resistance. Others avoid injury by staying close to protected surfaces, or hiding in cracks and under ledges.



sea palms



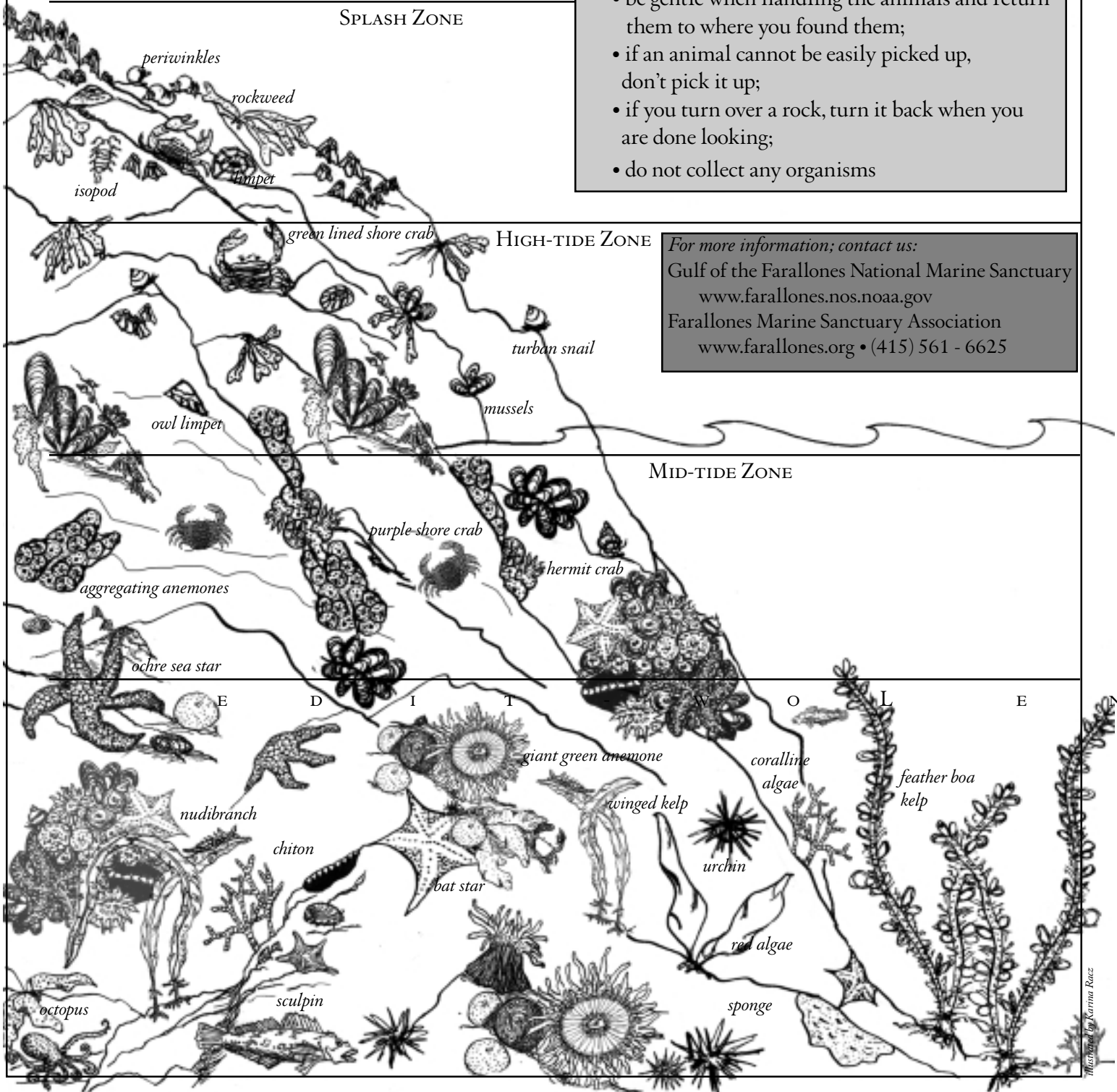
INTERTIDAL ZONATION ...

The rocky intertidal is divided into distinct horizontal bands resulting from the interaction between physical and biological factors. These zones are identified as the splash zone and the high, middle, and low tide zones. An organism's ability to tolerate physical and biological factors determines where they live. The upper zones are characterized by organisms that can tolerate extreme changes in desiccation, salinity, and temperature whereas the lower zones tend to be colonized by those that are better at dealing with biological pressures such as predation and competition for space.

TIDEPooling ETIQUETTE:

While exploring the rocky intertidal and getting acquainted with some of the inhabitants of the Sanctuary, please follow these guidelines:

- wet your hands before handling anything;
- be gentle when handling the animals and return them to where you found them;
- if an animal cannot be easily picked up, don't pick it up;
- if you turn over a rock, turn it back when you are done looking;
- do not collect any organisms



For more information; contact us:
 Gulf of the Farallones National Marine Sanctuary
www.farallones.nos.noaa.gov
 Farallones Marine Sanctuary Association
www.farallones.org • (415) 561 - 6625

Rocky Intertidal Activities

Getting to know your species

Objective

Students will learn the species of algae/plants and animals commonly found at Duxbury Reef in Bolinas, California.

Materials

Algae/plant and animal identification cards (available at www.farallones.org) and/or field guides
Duxbury Reef - Get to know your species worksheet

Background

The rocky intertidal habitat is home to a diverse population of marine organisms. There are many different species of algae and animals living on and in between the rocks. Students will learn to identify the alga and animal species by writing descriptions that will help them remember the different organisms.

Activity

1. Have your students review the algae/plant and animal identification cards.
2. Using the identification cards and/or field guides, have your students fill in descriptions of each algae and animal species listed on the worksheet.

Recommended field guides

Abbott, I.A. and G.J. Hollenberg. 1987. Marine Algae of California. Stanford, CA. Stanford University Press.

McConnaughey, B.H. and E. McConnaughey. 1992. Pacific Coast. New York. Alfred A. Knopf Publishers.

Meinkoth, N.A. 1994. National Audubon Society Field Guide to North American Seashore Creatures. New York. Alfred A. Knopf Publishers.

Credits

This activity was adapted from the LiMPETS Rocky Intertidal classroom kit.

Duxbury Reef - Get to know your species

Find the species of algae listed below using your photo identification sheet and write a description so you can remember them. *Some of the algae have been grouped together because it is very difficult to identify the individual species in the field.

ALGAE/PLANTS	DESCRIPTION
Sea Lettuce, <i>Ulva fenestrata</i>	
Upright Coralline algae, <i>Corallina sp.</i>	
Red Algal Turf, <i>Endocladia muricata</i> ♂ <i>Gelidium sp.*</i>	
Little Rockweed, <i>Pelvetiopsis limitata</i>	
Rockweed, <i>Fucus gardneri</i>	
Sea Moss, <i>Cladophora columbiana</i>	
Sea Sacs, <i>Halosaccion glandiforme</i>	
Turkish Towel, <i>Mastocarpus papillatus</i>	
Rainbow algae, <i>Mazzaella spp.</i>	
Tar Spot algae, <i>Mastocarpus spp.</i> ♂ <i>others*</i>	
Surf Grass, <i>Phyllospadix scouleri</i>	
Encrusting Coralline algae, <i>Lithophyllum sp. and others*</i>	

Duxbury Reef - Get to know your species

Find the species of animals listed below using your photo identification sheet and write a description so you can remember them.

ANIMALS	DESCRIPTION
Aggregating Anemone, <i>Anthopleura elegantissima</i>	
Giant Green Anemone, <i>Anthopleura xanthogrammica</i>	
Brooding Anemone, <i>Epiactis prolifera</i>	
Mossy Chiton, <i>Mopalia</i> sp.	
Limpets, <i>Lottia/Macclintockia</i> spp.	
Black Turban Snail, <i>Tegula funebris</i>	
Whelks, <i>Acanthinucella/Nucella</i> spp.	
Mussel, <i>Mytilus californianus</i>	
Barnacles, <i>Balanus/Chthamalus</i> spp.	
Bat Star, <i>Asterina miniata</i>	
Ochre Sea Star, <i>Pisaster ochraceus</i>	
Six Rayed Star, <i>Leptasterias hexactis</i>	

Turban Snail and Mossy Chiton Investigation

Objective

Students will learn the differences between two classes of Phylum Mollusca: Class Gastropoda and Class Polyplacophora.

Materials

Handout on the Black Turban Snail, *Tegula funebris*

Handout on the Mossy Chiton, *Mopalia muscosa*

Turban Snail and Mossy Chiton Activity Sheet

Turban Snail and Mossy Chiton Activity Answer Sheet

Background

The Phylum Mollusca is a very diverse group of animals. Molluscs include snails, clams, limpets, chitons, squid, and octopus. Molluscs have a large muscular foot, unsegmented soft body, an external or internal shell, and a mantle which secretes the shell. The Class Gastropoda (meaning “stomach foot”) includes marine, freshwater, and terrestrial snails. Gastropods have an asymmetrical shell for protection. They can retreat inside their shell and close their “trap door” or operculum. Most gastropods use a radula to scrape algae from rocks. The Class Polyplacophora (meaning “bearer of many plates”) includes chitons. Chitons are characterized by having a shell made up of 8 plates. They are nocturnal, feeding at night. They use their radula to scrape algae from rocks and shells of other animals.

Activity

1. Have your students read the background information from the handouts on Black Turban Snails and Mossy Chitons.
2. Using the handouts, have your students answer the questions from the activity sheet.
3. Review with your students the answers to the activity sheets.

Credits

This activity was adapted from the LiMPETS Rocky Intertidal classroom kit.

Black Turban Snail, *Tegula funebris*

Black turban snails are found from Vancouver Island to central Baja California. They are considered the most abundant and broadly distributed snail in the rocky intertidal zone. Their shell is dark purple to black on top and white underneath. Their foot is black on all sides and pale underneath.

Black turban snails are herbivores that graze on microscopic algae that grows on the surface of rocks and large attached algae. They use their radula to scrape algae off of rocks. They are important grazers in the rocky intertidal habitat. Their preferred diet is *Gigartina* and *Macrosystis*. Some predators include sea otters, rock crabs, and sea stars. Black turban snails are a favorite meal of the Ochre sea star. They are also easily collected by humans for bait and food.

They are found throughout the intertidal zone in large aggregations. Juvenile black turban snails are found in the upper intertidal zone where they live for about five to seven years. They then migrate to the lower intertidal zone. Turban snails can live for twenty to thirty years. When they die, their shell becomes home for hermit crabs. Their shells can also be broken down by wave action and become sand. Their blood contains hemocyanin which is a respiratory pigment which makes the blood blue. Their blood carries oxygen through their body. They use gills to remove oxygen from the water. If turban snails are exposed to air they are unable to breath.

Turban snails have separate sexes. The female will lay an egg ribbon on the rocks after being fertilized by a male. The young go through several planktonic stages before settling out in the rocky intertidal habitat. Turban snails have an operculum which they use as a “trap door”. They close their operculum to keep from drying out when the tide goes out and for protection from predators. They move very slowly using their muscular foot. But if they come into contact with a sea star, they can move quickly (for a snail). They can sense when a sea star is near because of the pheromones the sea star emits. Older black turban snail shells are often eroded or have holes from where predators have attempted to attack the turban snail.

References:

Morris, R.H., D.P. Abbott, and E.C. Haderlie. 1983. Intertidal Invertebrates of California. Stanford, CA. Stanford University Press.

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

Ricketts, E.F. and J. Calvin. 1978. Between Pacific Tides. Stanford, CA. Stanford University Press.

Mossy Chiton, *Mopalia muscosa*

Mossy chitons are found from Alaska down to Southern California. They are easily recognized by their “mossy” appearance. Their girdle is covered by stiff hair which resembles moss. The hair is made of the same material as human nails called keratin. On average, they are two inches but can grow up to four inches long. Their coloration is dull brown to dark olive. Most of the shell is visible. The shell is oval shaped and made up of eight separate plates. They are herbivores that use their radula to scrape algae off rocks. They feed mainly on *Gigartina papillata*, *Endocladia muricata*, and *Cladophora sp.* They are also important grazers in the rocky intertidal habitat. They live for about 10 years.

Mossy chitons have separate sexes. They have external fertilization, the gametes are released in the water where fertilization occurs. The young go through several planktonic stages before settling out in the rocky intertidal habitat. Mossy chitons have no eyes yet they have light sensitive organs on their shell so they can sense light and dark. Mossy chitons are nocturnal, which means they feed at night. They return to the same spot which is called their “home scar”. They use magnetic orientation to find their way back to their “home scar”. Mossy chitons travel up to two feet from their home. Mossy chitons can hold on with a muscular foot onto a hard surface to prevent being washed away by waves or eaten by predators. Having a shell that is divided into separate plates helps them conform to the shape of rocks which allows them to have a tight fit on a rock.

References:

- Morris, R.H., D.P. Abbott, and E.C. Haderlie. 1983. Intertidal Invertebrates of California. Stanford, CA. Stanford University Press.
- Neisen, T.M. 1994. Beachcomber's Guide to California Marine Life. Houston TX. Gulf Publishing Company.
- Ricketts, E.F. and J. Calvin. 1978. Between Pacific Tides. Stanford, CA. Stanford University Press.

Turban Snail Investigation Activity Sheet

Black Turban Snail, *Tegula funebris*

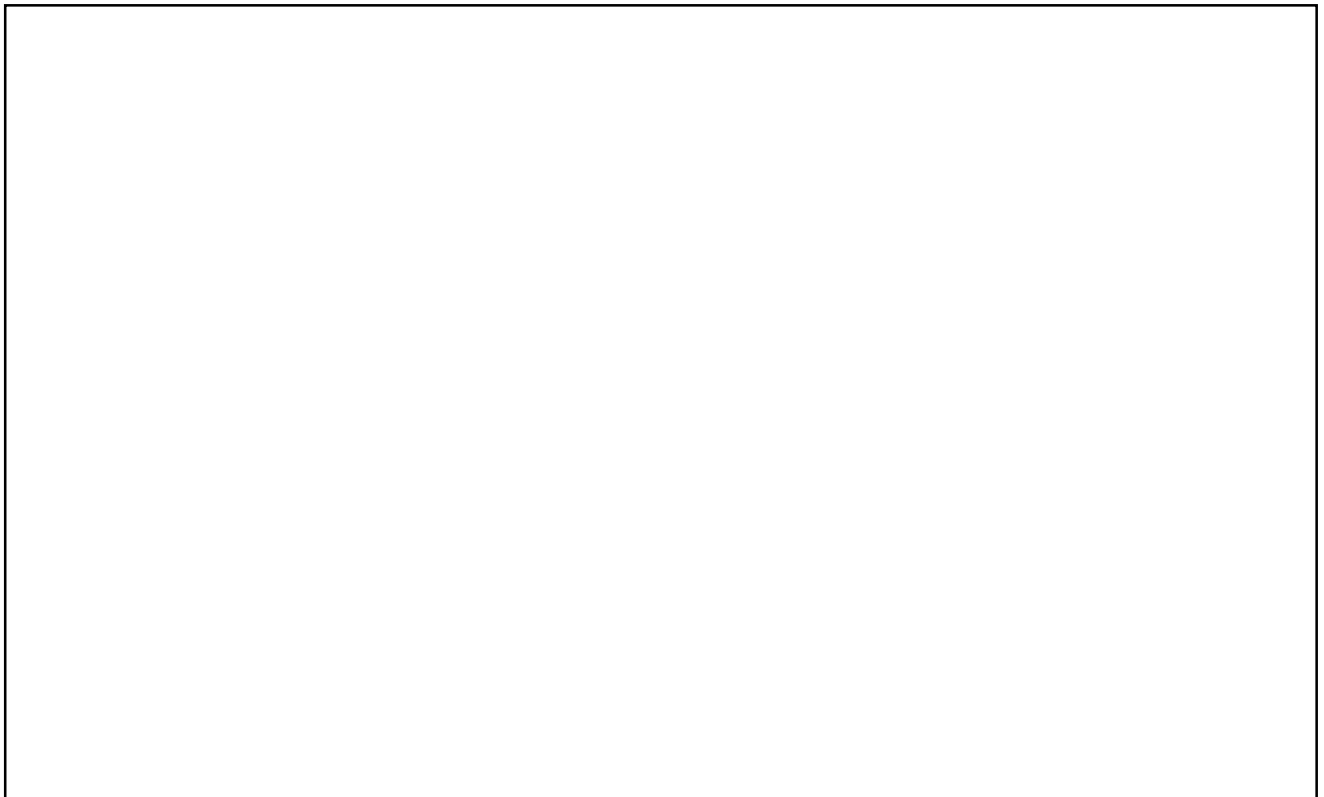
How and what do turban snails eat?

What color is their blood and why?

When a turban snail dies, what happens to its shell?

Why do you think we monitor turban snails?

Draw a black turban snail and describe how you would recognize it in the field.



Mossy Chiton Investigation Activity Sheet

Mossy Chiton, *Mopalia muscosa*

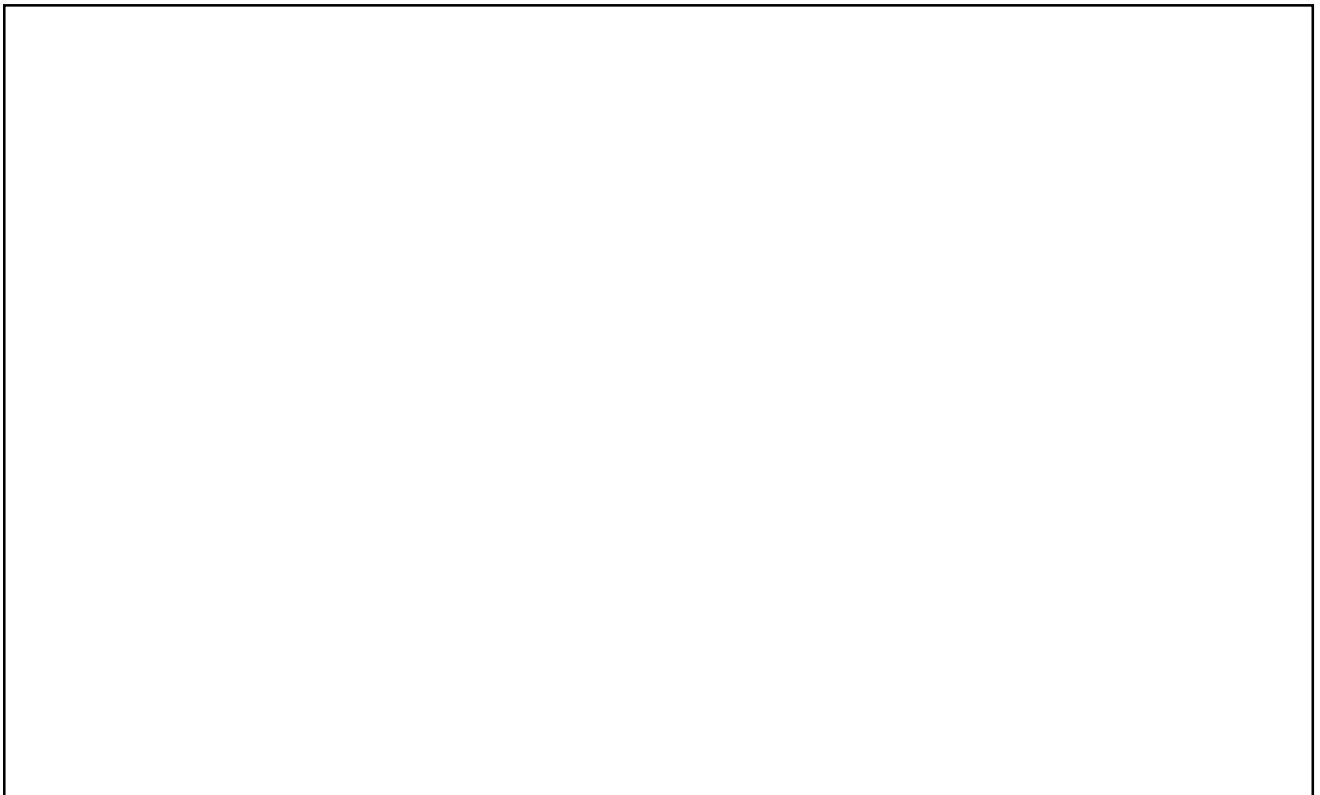
How do mossy chitons feed and what do they eat?

How many pieces make up the chitons shell?

How do mossy chitons find their way home?

Why do you think we monitor mossy chitons?

Draw a mossy chiton and describe how you would recognize it in the field.



Turban Snail and Mossy Chiton Investigation Answer Sheet

Black Turban Snail, *Tegula funebris*

How and what do turban snails eat?

Turban snails use a radula to scrape algae from hard rocks.

What color is their blood and why?

Their blood is blue from the respiratory pigment hemocyanin.

When a turban snail dies, what happens to its shell?

The shell is used by hermit crabs, others may be washed offshore, or they may be broken down by wave action and become sand.

Why do you think we monitor turban snails?

We monitor turban snails because they can be easily collected by humans. Turban snails are important grazers.

Draw a black turban snail and describe how you would recognize it in the field.

They have black whorls, the top of the shell is often eroded, and some may look purple in color. You have to pick them up to know if it is a snail or hermit crab.

Mossy Chiton, *Mopalia muscosa*

How do mossy chitons feed and what do they eat?

Mossy chitons use a radula to scrape algae from rocks.

How many pieces make up the chitons shell?

Chitons belong to the Class Polyplacophora which means many plates. Chitons shells consist of eight plates.

How do mossy chitons find their way home?

Mossy chitons make a home scar on the rock where they live. They use magnetic orientation to find their way back to their home.

Why do you think we monitor mossy chitons?

Just like the turban snails, mossy chitons are also important grazers in the rocky intertidal habitat.

Draw a mossy chiton and describe how you would recognize it in the field.

Mossy chiton shells are oval shaped and covered with stiff hairs which resemble moss.

Estimating abundance with life sized photos

Objective

Students will learn the sampling techniques used in LiMPETS (Longterm Monitoring Program and Experiential Training for Students, <http://LiMPETS.noaa.gov>) by practicing with life-sized photos. They will learn to identify organisms, to monitor abundance, and how to fill out data sheets.

Materials

5 Photo Quadrats (available at www.farallones.org)
5 Quadrats (see instructions for building a quadrat)
Photo Quadrat Data Sheet
Photo Quadrat Answer Sheet
Animal and algae ID cards (available at www.farallones.org)

Materials for building quadrats

2 (2 meter) PVC pipes
4 PVC elbows
PVC primer
PVC cement
rope/string

Activity

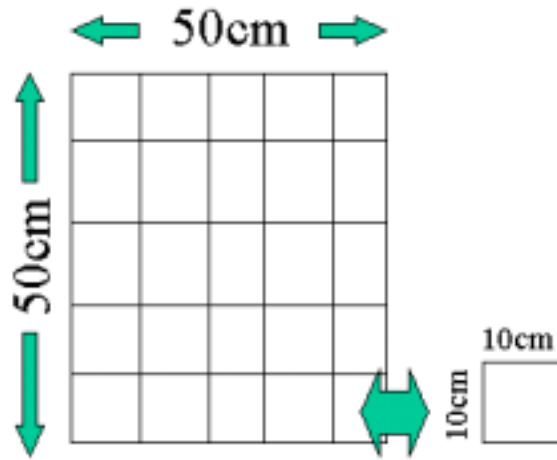
1. Students should work in groups and rotate through at least three photos. Place a quadrat and photo at each station. Each group should have one to two ID cards.
2. Students will place the photo quadrat on a desk or the floor and place the quadrat over the photo. For each photo, students will monitor the abundance of algae and animals in each quadrat. There are two methods as indicated on the datasheets. For individuals, a total count is recorded for the larger invertebrates. For “count and record”, the number of squares out of 25 with any portion of the algae or animal that is attached in square. This second method provides a relative abundance measurement.
3. Students should fill out the photo quadrat data sheet. Students look to see if each species listed on the data sheet is present in the quadrat.
4. Use the Photo Quadrat Answer Sheet to check students work. Discuss with entire class which if any category of organism were hard to identify.

Credits

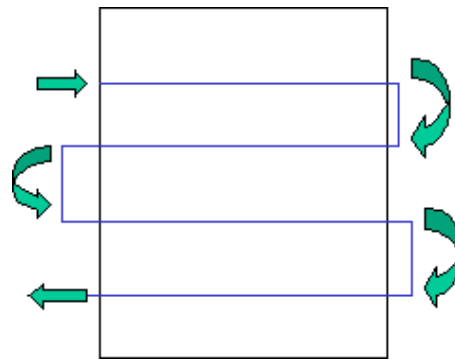
This activity was adapted from the LiMPETS Rocky Intertidal classroom kit.

Instructions for building a quadrat (go to <http://limpets.noaa.gov/usefulinformation/quadrat.html>)

1. Assemble 4 PVC pipes with 4 elbows to insure correct lengths. The pipes go inside the elbows. When all sides are aligned properly, mark the PVC pipes at the point where it meets the elbow. The insides of the quadrat should measure 50 cm on a side.



2. Drill holes 12.5 cm apart through the PVC pipes.
3. Primer the inside of the elbow and the outside of the PVC pipe where they will join (approximately an inch band on each). Make sure the elbow lines up with the line you marked on the PVC pipe.
4. Put a thin layer of the PVC cement on top of the primer, and then put the elbow and the length of PVC pipe together. Make sure the alignment is correct and then let dry (beware it dries quickly!)
5. Do one side at a time to insure it is aligned and lays flat before proceeding. Repeat previous steps until the frame is finished.
6. Cut 8 pieces of rope 60 cm in length. Put the ropes through the holes in the PVC pipes and tie a knot to secure in place.



7. The ropes will form 25 equal squares within the quadrat.

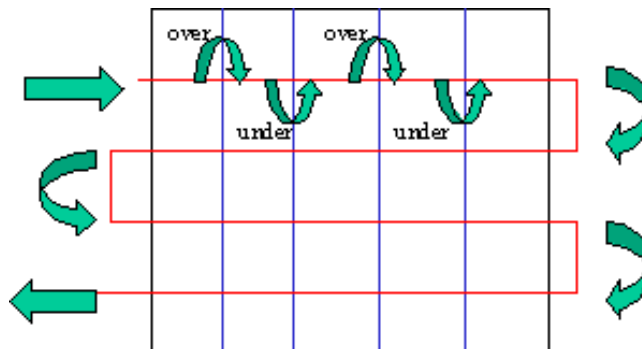


Photo Quadrat Data Sheet

Duxbury Data Sheet

Vertical Transect Across Intertidal

Date: _____ School/Leader: _____

Names _____

Place center of quadrat over the photo quadrat	Zone	Zone

Individuals - Count if any portion of the animal is in the 1/4 m² quadrat.

Giant green anemone - <i>Anthopleura xanthogrammica</i>		
Brooding anemone - <i>Epiactis prolifera</i>		
Chitons - <i>Mopalia</i> spp./ <i>Nuttallina californica</i> / <i>Lepitochitona</i> spp.		
Whelks - <i>Acanthinucella</i> spp./ <i>Nucella</i> spp.		
Turban snails - <i>Tegula brunnea/funebralis</i>		
Ochre star - <i>Pisaster ochraceus</i>		
Bat star - <i>Asterina miniata</i>		
Six-armed star - <i>Leptasterias hexactis</i>		

Count and record the # of squares out of 25 with any attached piece of:

Green pin-cushion alga - <i>Cladophora columbiana</i>		
Sea lettuces - <i>Enteromorpha</i> / <i>Ulva</i> spp.		
Surfgrasses (attached in square) - <i>Phyllospadix scouleri/torreyi</i>		
Flattened rockweeds - <i>Fucus gardneri/Hesperophycus californicus</i>		
Slender rockweeds - <i>Pelvetiopsis limitata/Silvetia compressa</i>		
Tar spot algae - <i>Mastocarpus</i> spp./ <i>Ralfsia</i> spp. and others		
Encrusting coralline algae (on rocks) - many species		
Upright coralline algae - <i>Bossiella/Calliarthron /Corallina</i> spp.		
Red Algal Turf - <i>Endocladia muricata and Gelidium coulteri</i>		
Turkish Towel - <i>Mastocarpus papillatus</i>		
Sea sacks - <i>Halosaccion glandiforme</i>		
Iridescent algae - <i>Mazzaella flaccida/splendens</i>		
Aggregating anemone (<5 cm) - <i>Anthopleura elegantissima</i>		
Limpets - <i>Lottia</i> spp./ <i>Macclintockia</i> spp.(0.5 - 2.5 cm)		
Sea mussel - <i>Mytilus californianus</i>		
Common acorn barnacles - <i>Balanus/Chthamalus</i> spp.		
Bare rock		
Loose sand		

Photo Quadrat Answer Sheet

Duxbury Data Sheet

Place center of quadrat over the photo quadrat

	Zone	Zone	Zone	Zone	Zone
	0 m	5 m	10 m	15 m	20 m
Individuals - Count if any portion of the animal is in the 1/4 m² quadrat.					
Giant green anemone - <i>Anthopleura xanthogrammica</i>	0	0	0	0	0
Brooding anemone - <i>Epiactis prolifera</i>	0	0	0	0	0
Chitons - <i>Mopalia</i> spp./ <i>Nuttallina californica</i> / <i>Lepitochitona</i> spp./others	0	0	0	0	0
Whelks - <i>Acanthinucella</i> spp./ <i>Nucella</i> spp.	0	0	0	6	0
Turban snails - <i>Tegula brunnea/funebralis</i>	0	42	51	3	2
Ochre star - <i>Pisaster ochraceus</i>	0	0	0	0	0
Bat star - <i>Asterina miniata</i>	0	0	0	0	0
Six-armed star - <i>Leptasterias hexactis</i>	0	0	0	0	0

Count and record the # of squares out of 25 with any attached piece of:

Green pin-cushion alga - <i>Cladophora columbiana</i>	0	2	0	0	0
Sea lettuces - <i>Enteromorpha/Ulva</i> spp.	4	0	0	0	0
Surfgrasses (attached in square) - <i>Phyllospadix scouleri/torreyi</i>	0	0	0	0	0
Flattened rockweeds - <i>Fucus gardneri/Hesperophycus californicus</i>	0	0	0	0	8
Slender rockweeds - <i>Pelvetiopsis limitata/Silvetia compressa</i>	0	0	0	0	0
Tar spot algae - <i>Mastocarpus</i> spp./ <i>Ralfsia</i> spp. and others	0	0	0	0	0
Encrusting coralline algae (on rocks) - many species	0	0	25	24	0
Upright coralline algae - <i>Bossiella</i> spp./ <i>Calliarthron</i> spp./ <i>Corallina</i> spp.	0	0	0	0	0
Red Algal Turf - <i>Endocladia muricata</i> and <i>Gelidium coulteri</i>	0	0	6	17	0
Turkish Towel - <i>Mastocarpus papillatus</i>	0	0	0	0	21
Sea sacks - <i>Halosaccion glandiforme</i>	0	0	0	0	0
Iridescent algae - <i>Mazzaella flaccida/splendens</i>	18	10	0	7	0
Aggregating anemone (<5 cm) - <i>Anthopleura elegantissima</i>	0	12	6	0	0
Limpets - <i>Lottia</i> spp./ <i>Macclintockia</i> spp. (0.5 - 2.5 cm)	5	2	0	0	0
Sea mussel - <i>Mytilus californianus</i>	1	0	0	0	0
Common acorn barnacles - <i>Balanus/Chthamalus</i> spp.	7	19	0	0	14
Bare rock	25	25	22	25	24
Loose sand	0	0	0	0	0

Rocky Intertidal Monitoring

Estimating Percent Cover Activity

Objective

Students will learn how to estimate percent cover of a sample area.

Materials

One set per group	0.25 m ² x 0.25 m ² quadrat 50 cm x 50 cm Red paper cut up into small pieces in a bag (25%) 70 cm x 1 m Blue paper cut up into small pieces in a bag (70%) 65 cm x 65 cm Green paper cut up into small pieces in a bag (42%) bungee cords
Display quadrat	0.25 m ² x 0.25 m ² quadrat 10 cm x 50 cm Red paper cut up into small pieces (5%) 1 m x 40 cm Blue paper cut up into small pieces (40%) 70 cm x 30 cm Green paper cut up into small pieces (21%) bungee cords

Background

The rocky intertidal zone is a space-limited habitat where algae and invertebrates compete for space. To understand how the community changes over time, researchers often measure or estimate the abundance of algae by looking at the percent coverage of a known area. There are several methods to determine the percent coverage. In this activity, students will estimate the coverage and distribution visually. In the photo quadrat activity, students use a relative abundance method by counting the number of squares out of twenty five in which the species is found. Another method is the point method. Each method has its pros and cons for reliability, accuracy, and precision.

Activity

1. Before the students arrive, cut up the paper into 0.5-2 inch sized, random shaped pieces and place each color into its own bag. Each color represents a different type of organism (critter). The percent cover for each color is calculated from a 0.25 m² x 0.25 m² quadrat.
2. Set up the display quadrat. Randomly distribute the 3 colors of paper in the quadrat with no overlapping.
3. Divide the students into groups. Explain that the colors represent organisms living on the rocks. Hand out one set of supplies to each group. Give each student his or her own data sheet.
4. Have students determine percent cover and record their estimates on their data sheet.
5. When all groups are done, discuss the questions to ponder.

Team Directions

1. Place bungee cords on quadrat, dividing it into quarters.

A	B
C	D

2. Empty the bag with Red critters out onto your work surface and arrange them according to the following instructions. Be sure to use all the pieces.
 - a. Space Reds randomly (drop a handful) in quarter A. It is OK if some are overlapping.
 - b. Arrange Reds evenly spaced in quarter B. No overlapping.
 - c. Arrange Reds clumped near the center in quarter C. No overlapping.
 - d. Arrange Reds clumped in one corner in quarter D. No overlapping.
3. Estimate the percent cover to the nearest 5% (i.e. 5%, 10%, 15%) for each quarter of your quadrat and record on the data sheet.
4. Add percent cover for quadrats A through D then divide by 4 to obtain the percent cover for the entire $0.25 \text{ m}^2 \times 0.25 \text{ m}^2$ quadrat.
5. Compare your percent cover estimate for Red critters to the actual value, which you can get from your teacher. How close were you? It is a very common for initial estimates to be higher than actual values. Don't despair! Practice makes perfect (or at least improves your skills).
6. Repeat for Blue and Green critters, comparing your estimates to the actual value as you go. Are you improving?
7. When you have finished, go to the display quadrat set up by your teacher containing all colored critters arranged together. As a team, estimate the percent cover in this quadrat for each color and record your data.
8. Return to your initial work area. Calculate the percent cover for each critter color from the display quadrat.

Questions to Ponder

1. Are some people better at estimating percent cover than others? What skills help?
2. Did your estimating skills improve with practice? How much practice do you think you would need to become reasonably accurate at this skill?
3. Why is it important to develop accurate percent cover estimating skills for monitoring projects?
4. Is it more difficult to estimate percent cover for each critter when they are isolated or when all species are found together?
5. Is it more difficult to estimate percent cover when the critters are randomly distributed or found in patches?

Credits

Written and designed by Kathy Soave and Maria Brown.

Estimating Percent Cover Data Sheet

Team Members _____

Team Directions

- Place bungee cords on quadrat, dividing it into quarters.

A	B
C	D

- Empty the bag with Red critters out onto your work surface and arrange them according to the following instructions. Be sure to use all the pieces.
 - Space Reds randomly (drop a handful) in quarter A. It is OK if some are overlapping.
 - Arrange Reds evenly spaced in quarter B. No overlapping.
 - Arrange Reds clumped near the center in quarter C. No overlapping.
 - Arrange Reds clumped in one corner in quarter D. No overlapping.
- Estimate the percent cover to the nearest 5% (i.e. 5%, 10%, 15%) for each quarter of your quadrat and record on the data sheet.
- Repeat for Blue and Green critters, comparing your estimates to the actual value as you go.

Critters	random	even	center clumped	corner clumped	Sum of 4 quarters		Total Percent Cover
Red						÷4	
Blue						÷4	
Green						÷4	

Display: Percent Cover for all Colors Combined

Critters	random	even	center clumped	corner clumped	Sum of 4 quarters		Total Percent Cover
Red						÷4	
Blue						÷4	
Green						÷4	
Total						÷4	

Seaweed Tasting

Objectives

Students will taste products made with seaweed and learn how cultures have different traditions in eating food from the ocean.

Materials

Food samples that often contain seaweed (check the ingredient labels)

examples: cheese (processed types only)
 chocolate milk
 cottage cheese
 frozen yogurt
 ice cream (not “natural” brands)
 kelp crackers
 nori
 peanut butter (not “natural” brands)
 pudding
 salad dressing
 sour cream
 whipped topping
 yogurt

Seaweed tasting data sheet

Background

Algae, commonly called seaweeds, are an important part of the rocky intertidal habitat. They provide shelter and food for animals. They grow in all zones along the shore. People in many cultures eat algae as vegetables or cook with alga products. Many common foods contain algae or alga products. Algae helps mix other ingredients together, making them smoother and creamier. Algae are rich in minerals and vitamins. The three most common forms of algae on food labels are sodium alginate, carrageenan, and agar. Kelp is grown in large quantities along the southern California coast for commercial harvesting. In Japan, demand for alga products is so great that mariculture algae farms produce over 10 billion sheets of nori (used in sushi) annually. Algae is useful in thickening cosmetics and drugs, preventing wines and beers from becoming cloudy, making jellies and gels, and making paint, soap, and rubber products.

Activities

1. Arrange food samples at numbered tasting stations
2. Explain to students how seaweeds are used as thickeners and to help mix solutions together (emulsifiers). In some of the food samples they will be able to see and taste the algae as a distinct substance and in others the algae will be completely mixed in.
3. Give directions for moving from station to station and filling out the data sheet.
4. After the students have completed their data sheets, total up the numbers of each sample on the board to see which foods were most and least liked.
5. Discuss the impact of harvesting algae.

Credits

(Adapted from *PROJECT OCEAN: ROCKY SEASHORE HABITAT GUIDE*)

Seaweed Tasting Data Sheet

Sample	Product	Like	Okay	Don't Like
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Comments and Observations

Observations and Predictions of Tides

For another Rocky Intertidal Activity, look in the Sandy Beaches of the Gulf of the Farallones Unit at the Observations and Predictions of Tides activity on page 14. The objective of this activity is to have students investigate the change in water level due to the tides. They will investigate tidal predictions, tidal observations, and see for themselves the impact of the tides on the shoreline.

References

Our Restless Tides...<http://co-ops.nos.noaa.gov/restles1.html>

Tides Online...<http://tidesonline.nos.noaa.gov>

Tides and Tide Prediction...<http://scilib.ucsd.edu/sio/tide>

Why Tides? ...<http://www.sfgate.com/getoutside/1996/jun/tides.html>

Guidelines for a Successful Rocky Intertidal Field Trip

Recommended Tidepooling Sites within the Gulf of the Farallones and Northern Monterey Bay National Marine Sanctuaries:

- Shell Beach, Sonoma Co. (707)785-2377
- Sculpture Beach, Point Reyes, Marin Co. (415)464-5100
- Duxbury Reef, Agate Beach, Marin Co. (415)499-6387 or 6405
- Steep Ravine, Mt. Tamalpais State Park, Marin Co. (415)388-2070
- Slide Ranch, GGNRA, Marin Co. (415)331-6155
- Point Bonita, Marin Co. (415)331-9622
- Fitzgerald Marine Reserve, Moss Beach, San Mateo Co. (650)728-3584
- Pillar Point, San Mateo County (415)728-3377
- Pigeon Point, San Mateo County (650)879-2120
- Bean Hollow, San Mateo County (650)879-2170

For more information or directions on how to get there, call the numbers listed above, check out the website www.farallones.org, or call the Sanctuary Visitor Center at (415) 561-6625.

Protect Seashore Algae and Animals:

While at the seashore, investigate the algae, the animals, and their habitats. Investigate and enjoy them. Do not destroy them.

Tidepool Etiquette

- Leave the specimens in their natural habitat
Do all of your investigation at the seashore. Do not remove animals. If you touch an animal, wet your hands first. Do not take any organisms (dead or alive) away for collections.
- Turn the rocks back over
When turning over a rock, do so gently. Try not to crush the animals living on, beside, or under the rock. Put the rock back the way it was.
- Re-cover the animals with algae
When investigating animals living on or under algae, return the animals and cover them again with moist protective algae; otherwise, the sun may dry them out or predators may find them.
- Avoid walking on animals
When walking on rocky shores, try to walk on bare rocks or on the patches of sand and mud between rocks. Try not to crush barnacles and other organisms living on the surface. Watch out for closed-up anemones that look like rocks.

Planning Hints for Teachers

1. Materials you might want to take along with the first-aid kit: hand lenses, spotting scopes, field glasses, invertebrate and bird field guides, clear plastic containers to look at organisms through the water, snacks, drinking water, and sunscreen.

2. You might want to visit the site beforehand so that you are certain it is appropriate for all students. This will help you gear your activities and discussion to its unique qualities.
3. Schedule a familiarization time when you first arrive at the rocky intertidal. Discussion can include these points: What is the surf condition? What is the weather and sky condition? What do you notice about the rocks? (Stress that they are very slippery!) What is the time of low and high tide? How far does the tide appear to come up on the beach?

Safety Tips

1. Take only a manageable size group to the rocky intertidal. Have an adequate number of adults along to help supervise. One adult for no more than five students is a good idea for elementary students at the rocky intertidal and for secondary students a ratio of one adult to eight students is good.
2. Assign students to a buddy system, no matter how old they are. This provides the students with a working partner and eliminates the possibility of losing one student and not noticing until faced with a distressed parent. A buddy system should be in place **before leaving the school**.
3. Be sure students are dressed properly in layers; long pants, tennis shoes, and a warm jacket are musts for the seashore. It is usually cooler at the beach than elsewhere. Students should also bring a change of clothes and shoes.
4. Have a first-aid kit with you.
5. Check the tides before going to the intertidal zone. It is best to get there at least one hour before the time of low tides and then follow the tide out. Check to see what time the tide will start to rise. Remember that the height of the tide may vary from that listed in the tide table dependent on your exact location and storm surge. Check the correction factors in the tide table. Tide tables are available at sporting goods stores, the chamber of commerce, tourist information offices, in local newspapers, and online at the National Oceanic and Atmospheric Administration's (NOAA) website at <http://www.co-ops.nos.noaa.gov/>.
6. Caution students not to let the tide come in behind them, and to watch for that extra large "sneaker wave." Practice the phrase "**Never turn your back on the ocean**" with your students. Buddies should remind one another of this whenever necessary.
7. Do not climb shoreline rock faces; the tide will rise and might trap you. In addition, shoreline cliffs are frequently made of soft sandstone or clay, and might crumble beneath your weight. Not only is this dangerous to you, but it also adds to erosion.
8. No students in the water! Climbing on rocks, playing near the water, wading and wave chasing where currents exist are all potentially dangerous activities.

Discoveries and Observations

- Observe zonation patterns
- Feel sea anemones sting (stickiness) from nematocysts (stinging cells) in tentacles
- Gently test the strength of mussels, barnacles, limpets, and snails stuck to rocks
- Notice the clumping behavior (animals growing/living in groups) Why?
- Compare differences (biological & physical) between high & low tide pools
- Observe:
 - Byssal threads of mussels
 - Crabs and fish under rocks and in crevices
 - Sea urchins in holes
 - Snail trapdoors (operculum)
 - Drift algae and holdfasts on beach (beach wrack)
 - Tube feet of sea stars and urchins
 - Sand and rocks stuck to and covering sea anemones
 - Camouflage (coloring)
 - Sea stars everting (sticking out) stomach to feed
 - Sea stars righting response (if turned over, how do they turn back?)
 - Snail and fish eggs
 - Hermit crabs fighting over shells
 - Animals living/hiding under algae Why?
 - Animals living in kelp holdfasts

Ask your class these questions:

1. What would happen if everyone took something away with them after visiting the tide pools?
2. What would happen if an animal wasn't placed back exactly where it had been found? (Think about zonation patterns and adaptations.)
3. Why is the Gulf of the Farallones National Marine Sanctuary important?
 - To protect the marine environment for the benefit of current and future generations.
 - To conduct research on marine organisms and processes so that we can increase our depth of understanding.
 - To raise awareness of the importance of a healthy and protected marine environment and to inspire greater stewardship by Bay Area residents.

Life Between the Tides: The Rocky Intertidal Slide Show

#	Topic (photographer)	Script
1	title	This slide show was made possible by the Gulf of the Farallones National Marine Sanctuary and the Farallones Marine Sanctuary Association.
2	map of Sanctuary	Our local rocky intertidal habitat is part of the Gulf of the Farallones National Marine Sanctuary. The sanctuary is an area of ocean, estuaries, and shoreline that is special, unique, and important to many living organism.
3	coastline	The intertidal is the narrow ribbon of coastal habitat where the waves meet the shore. Along some of the coastline, the waves have pounded the shore for thousands of years, breaking up the rocks and leaving the particles on the sandy beaches. In other places, the rugged rocks and jagged cliffs persist as the ocean crashes on top of them. This is called the rocky intertidal zone.
4	intertidal	This rocky area at the edge of the sea is a complex and unique ecosystem that supports a rich and diverse group of organisms. An ecosystem is the relationship between an organism and its habitat. The rocky intertidal habitat is part of a unique ecosystem whose organisms have adapted to the stressful life of surviving on the border of the ocean.
5	deep tide pool with sea star (J. Foote)	Because of the rise and fall of the tides, these organisms live in the ocean and on land. The tides happen when the water level of the ocean slowly changes, due to the moon's gravitational pull on the water in our oceans.
6	high tide	High tide is when the water comes in and covers the organisms in the tide pools.
7	low tide	Low tide occurs when the water goes out, exposing the rocky surface of the earth and all the organisms on it to the sun and air. Every 24 hours, there are two high tides and two low tides. That is a lot of change for a little animal like a barnacle. Imagine your home flooding and then drying up two times every day!
8	intertidal in sunlight (D. Hatch)	When the water level recedes, the animals and algae are exposed to the wind and sun. This causes one of the biggest problems for our intertidal friends: <i>desiccation</i> . Desiccation means that the organisms dry out and lose water.
9	operculum (J. Heath)	Since these are marine organisms that depend on water for food and support, desiccation can weaken them with each low tide. They have to adapt to being exposed when the tide goes out, and they do this by preventing water loss in several different ways. Some organisms close up as tight as they can to keep water from escaping, like this Black Turban snail closing its “trap door” or operculum.

- 10 limpets
(J. Heath) Limpets pull their conical shells tight against the rock.
- 11 barnacles
(J. Heath) Barnacles seal off their openings with sheets of hard armor made of calcium carbonate.
- 12 wet algae Animals that can move around more easily, like sea snails, nudibranchs, and crabs will hide under wet algae, in crevices, and other damp places.
- 13 sea urchins But many organisms can't close up tight or hide. These sea urchins simply have to live in wetter areas, like crevices or low in the intertidal so they stay under water as long as possible and avoid desiccation.
- 14 closed anemone This anemone has tried to close up as tight as it can but its soft body can't keep water in as effectively as a mussel shell can. Therefore, anemones have to live in the lower intertidal as well. In addition to living in wet areas, urchins and anemones also use pieces of sea shells like sunscreen. They pull up broken shell fragments and algae onto their spines and skin to cover their bodies and keep from getting sunburned.
- 15 feather boa kelp
(D. Hatch) Many algae, like this feather boa kelp, have a mucus coating that keeps water from evaporating away.
- 16 sea lettuce Others, like this sea lettuce, can dry out almost completely when they are exposed at low tide and then spring back when the tide comes back in.
- 17 waves on rocks In addition to this change from high tide to low tide, organisms also have to deal with the pounding of the waves as they crash against the rocks. This force from the waves is called *wave action*.
- 18 rockweed Many rocky intertidal organisms hold on tight to the rocks to avoid being washed away every time a wave comes crashing down. These rockweeds are using their holdfasts to anchor themselves down to the rock.
- 19 mussel Mussels use their strong byssal threads in the same way.
- 20 barnacles and
mussels
(J. Heath) Barnacles make a cement that binds them to the rocks, so waves don't even bother them.
- 21 sea palms Body design also minimizes the impact of the waves. These sea palms are flexible and strong under the pounding surf and can bend with the flow of the water. They are so well adapted to the crashing waves that they are mainly found in areas of high wave action.
- 22 encrusting algae Organisms that lie flat against the rock avoid wave action like this encrusting algae.

- 23 bat stars Sea stars and crabs also have flattened body shapes so that the waves wash over them. Their flat shape helps them hide from wave action in thin crevices.
- 24 sea stars and anemones In addition to environmental stresses like wave action and desiccation, rocky intertidal organisms also have to deal with biological stresses from the other organisms that are struggling to survive in this narrow habitat, such as competition for space and food.
- 25 covered substrate *Substrate* is the material that the organisms live on top of. Competition for a rock to live on is a major challenge in the lives of intertidal organisms.
- 26 hermit crab
(G. Zumwalt) Organisms cope with limited substrate in several ways. Some grow on top of each other, such as the limpet and pink crustose coralline algae on this hermit crab's shell.
- 27 barnacles Some settle in open spots quickly, like barnacles.
- 28 limpet Some limpets bulldoze other animals off the rocks to make room for themselves.
- 29 anemone colonies
(S. Walters) Some anemone colonies physically compete with each other for territories by striking each other with elongated tentacles. Notice the dividing line between the two anemone colonies at the top of this picture.
- 30 algae
(D. Howard) Many algae simply grow very quickly to beat out their neighbors for sunlight.
- 31 barnacle Securing a spot to live is just the beginning! Predators have to hunt for their prey and the prey have to escape getting eaten. This is a closely matched battle as there is a prey defense for almost every weapon that predators have. This barnacle has multi-layered shell to protect its body from the drill-like tongue of dogwinkles.
- 32 mussel
(J. Heath) This mussel avoids being eaten by pulling its shells together tightly. Only the strongest sea stars can force it open.
- 33 regenerating sea star
(J. Heath) Even though sea stars are a top predator, gulls can attack and eat them. Sea stars deal with this by growing back body parts that gulls have bitten off. This is called *regeneration*.
- 34 anemone
(W.E. Townsend) Anemones use their stinging tentacles for defense and offense. They can paralyze their prey with their tentacles but they also will use them to sting a sea star that tries to feed on them.
- 35 coralline algae
(J. Heath) Even algae can develop a defense against herbivores that graze on them. This coralline algae is hard, fortified by calcium, making it difficult to graze on. Many algae produce toxins that taste bad to the herbivores, driving them away.

- 36 tidepool
(J. Heath) The rocky intertidal habitat is part of a unique ecosystem whose organisms are very special, and they don't live in this combination anywhere else. The Gulf of the Farallones National Marine Sanctuary works to protect the rocky intertidal habitat and also conducts research and monitoring programs to discover trends.
- 37 rocky intertidal The Gulf of the Farallones National Marine Sanctuary is important because it protects the marine environment for the benefit of current and future generations, it conducts research on marine organisms and processes so that we can increase our depth of understanding, and it raises awareness of the importance of a healthy and protected marine environment and to inspire greater stewardship by Bay Area residents.

Books and Resources

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- Behrens, D.W. 1991. Pacific Coast Nudibranchs. Monterey, CA. Sea Challenger.
- 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, CA. University of California Press.
- Fitch, J. and R. J. Larenberg. 1975. Tidepool and Nearshore Fishes of California. Berkeley, CA. University of California Press.
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- Lawlor, E.P. 1992. Discover Nature at the Seashore. Harrisburg, PA. Stackpole Books.
- McConnaughey, B.H. and E. McConnaughey. 1992. Pacific Coast. New York. Alfred A. Knopf Publishers.
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- Neisen, T.M. 1994. Beachcomber's Guide to California Marine Life. Houston TX. Gulf Publishing Company.
- Ricketts, E.F. and J. Calvin. 1978. Between Pacific Tides. Stanford, CA. Stanford University Press.
- Smith, R.I. and J.T. Carlton, ed. 1975. Light's Manual: Intertidal Invertebrates of the Central California Coast, third edition. Berkeley, CA. University of California Press.

Posters

Welcome to Our Home, A 2'x3' full color poster showing common animals and plants found in Oregon's rocky intertidal areas. from Oregon Fish and Wildlife. Ordering information at <http://www.dfw.state.or.us/springfield/publications.htm>

Selected Web Sites

Teacher Resources

Marine and Environmental Education and Research. This site contains resources and information regarding marine life and environment. <http://www.meer.org>

The Bridge – Ocean Sciences Education Teacher Resource Center. This site provides online resources. <http://www.vims.edu/bridge/>

The Oceanic and Atmospheric Sciences Internet Locator from the NOAA Central Library. <http://www.lib.noaa.gov/docs/windandsea.html>

The Santa Cruz Museum of Natural History loans a tidepool kit to teachers. <http://www.santacruz museums.org/education/kits.html>

Longterm Monitoring Program and Experiential Training for Students...<http://LiMPETS.noaa.gov>

General Information

California's Rocky Intertidal Zones...<http://ceres.ca.gov/ceres/calweb/coastal/rocky.html>

Coyote Point Museum. <http://www.coyoteptmuseum.org>

Exploring Monterey County...http://www.mtycounty.com/mbs_pgs/RockySh.html

Life on the Rocky Shore...<http://library.thinkquest.org/J001418/index.html>

Monterey Bay National Marine Sanctuary Site Characterization...
<http://www.bonita.mbnms.nos.noaa.gov/sitechar/rocky.html>

NOAA Ocean Explorers...<http://oceanexplorer.noaa.gov>

Tidepool Treasures...<http://tlc.ousd.k12.ca.us/~acody/tidepool.html>

Rocky Intertidal Creatures

Web page from Intertidal Biology Course at UC Santa Cruz. This site has photographs of intertidal animals. <http://www.biology.ucsc.edu/classes/bio1611>

Monterey Bay Aquarium. click on “feature creature” to get to the living species list. <http://www.mbayaq.org>