LIVING ON THE EDGE

FIELD GUIDE TO THE ROCKY INTERTIDAL

SAN DIEGO MPA COLLABORATIVE

WILDCOAST

COSTASALVAJE

Table of Contents

ROCKY INTERTIDAL

IDENTIFICATION

ACTIVITIES

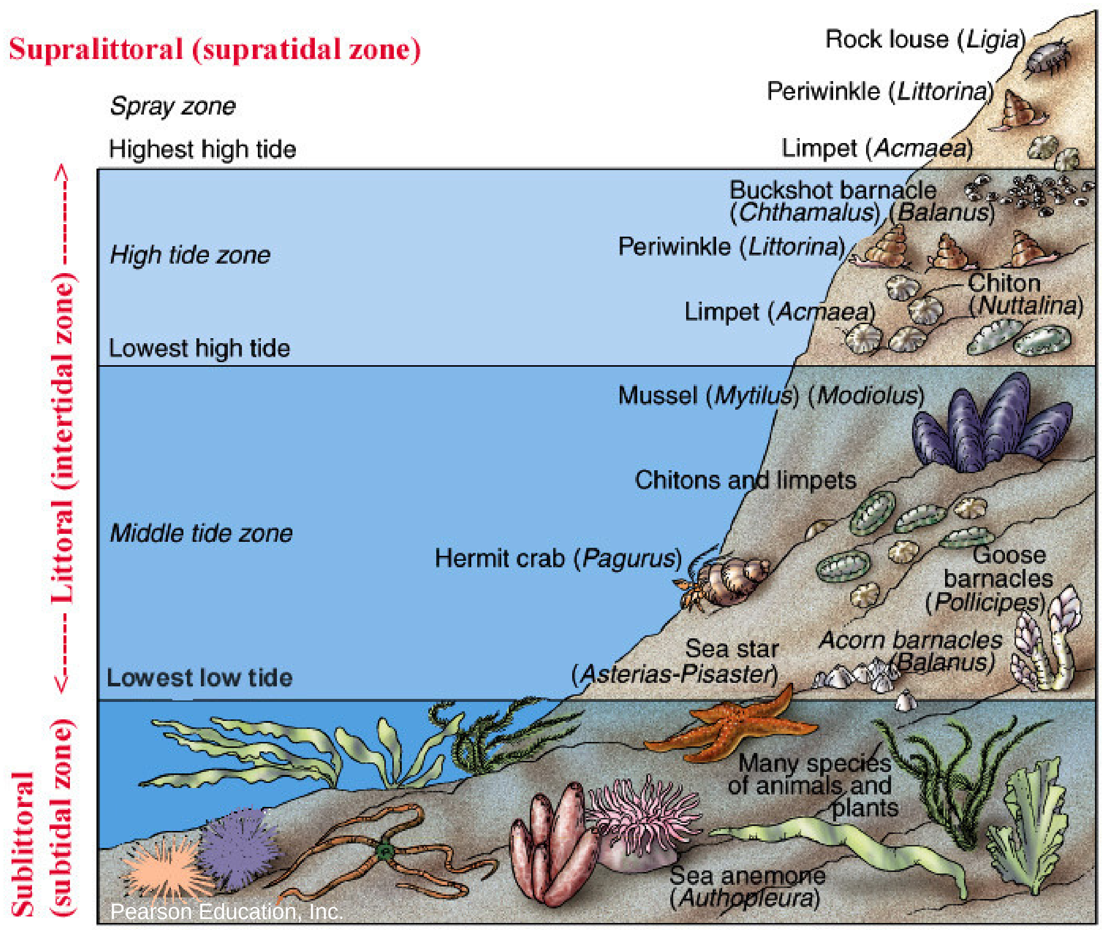
WILDCOAST COSTASALVAJE

SAN DIEGO MPA COLLABORATIVE

intro

The Intertidal Zone

The intertidal zone, the unique area between the high and low tide lines, is a harsh and unforgiving habitat. The highly conditioned species that live there are subject to the rigors of both the land and the sea, going from completely submerged to only occasionally wet within just a few feet of space. Organisms that inhabit the intertidal zone must endure extreme fluctuations in moisture level, temperature, salinity, and sunlight creating a robust assortment of biologically diverse organisms. These fascinating creatures boast an even more fascinating set of adaptations, creating an adventure for anyone who visits this space between the land and the sea.



Key Words

Intertidal Zone: The area between high and low tides.

High Tide: The tide when the water is at its highest level.

Low Tide: The tide when the water is at its lowest level.

Adaptation: A physical or behavioral change that helps an organism survive in its environment.

Photosynthesizer: An organism capable of using sunlight and carbon dioxide to make food (in the form of sugar). Most plants and algae are photosynthesizers.

Brown Algae: A group of organisms in the class Phaeophyceae, Kingdom Protista. Brown algaes are a large group of mostly marine multicellular algae, including many of the kelp (seaweed) species found in colder Northern Hemisphere waters. Many algaes, such as kelp, anchor themselves using a root-like structure called a holdfast, rather than the taproots present in plants.

Salinity: The concentration of dissolved salt in water.

Desiccation: A state of extreme dryness caused by prolonged periods of being out of the water.

Competition for space is a common challenge of living in the intertidal zone.

There are many **advantages** of living in the rocky intertidal including:

- Many organisms have adapted to the constant battering of waves by permanently affixing themselves to the rocks and other, mobile creatures get “stuck” in pools of water during the low tide. This, combined with the close proximity of organisms in the intertidal, creates an abundance of food.
- Photosynthesizers such as brown algae and plants are typically abundant in the intertidal and can help support an entire food chain.
- Wave action supplies a constant influx of oxygen and nutrients.
- Varied substrate provides good places to cling to and ample places to hide.

However, there are also many **challenges** of living in the rocky intertidal:

- Intertidal organisms must deal with both marine predators during high tide and terrestrial predators during low tide.
- Wave action can carry unprotected animals out to sea.
- The changing water level leads to variances in salinity (the saltiness of the water).
- The intertidal is marked by plentiful sunlight, which may lead to desiccation (drying out) and increased water temperatures.
- Space is often extremely limited, forcing organisms to compete for substrate.

In order to survive in this harsh environment intertidal organisms have evolved a wide array of specialized adaptations.

adaptations

Adaptations

To deal with the wide variety of challenges in the rocky intertidal, organisms developed an even wider array of adaptations:



THREAT: Constant pounding of waves
ADAPTATIONS: Some animals such as echinoderms (sea stars, urchins) cling fast to rocky substrates. Other organisms such as crabs find shelter inside of crevices or thick mats of kelp.

THREAT: Desiccation
ADAPTATIONS: Some bivalves, like clams, clamp down their shells to limit water loss. Some mollusks, such as marine snails, slow down evaporation rates with hard outer layers. Some crustaceans, like barnacles, cluster together to reduce individual exposure.

THREAT: Predation from terrestrial species (birds and mammals)
ADAPTATIONS: In addition to fastening to substrate and closing their protective shells, organisms tend to gravitate towards the lower intertidal zones, towards deeper water and abundant hiding places, that is, for safety.

tidepools

Tidepools

The intertidal zone is the strip of land that exists between the high and low tide lines. During high tide this area may be completely submerged while low tide sees moisture only from the random wave.

Unique within this habitat is the "rocky intertidal," intertidal areas filled with rocks. When the tide goes out small pools of water are left behind in the rocks, creating a haven for those intertidal creatures looking for more moisture. These "tidepools" boast a distinctive assortment of creatures that lend themselves well to lessons focused on adaptations and biodiversity.

Tidepool Etiquette

- **Watch where you step,** that might not be a rock!
- **Leave things how you found them**. If you turn over a rock put it back exactly how you found it.
- **Take only pictures.** Leave all rocks, plants, animals, and other tidepool creatures exactly how you found them.
- **Leave animals be.** Tidepool organisms have a hard enough life as it is without being touched by a bunch of sticky fingers.
- **Be careful where you put your fingers.** Many animals like sea urchins and crabs have defenses against predators.
- **Never turn your back on the ocean**....it needs you too much! But seriously, watch out for waves and the incoming tide.

Tides

Key Words

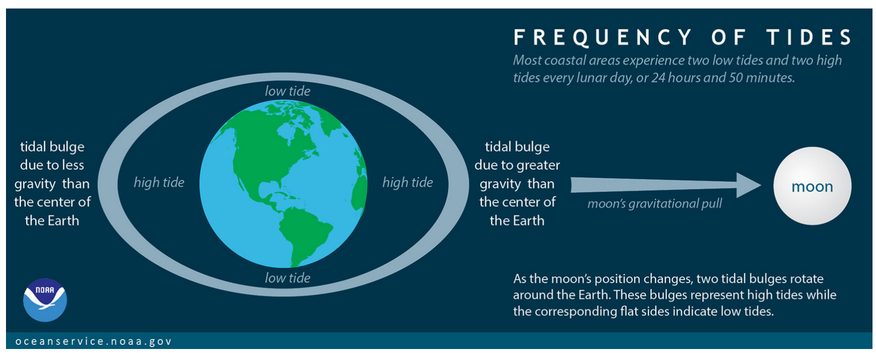
Tides: The periodic rising and falling of ocean water that results from the gravitational pulls of the sun and the moon.

Neap Tide: The weak tide created when the sun and moon are at a right angle with the Earth.

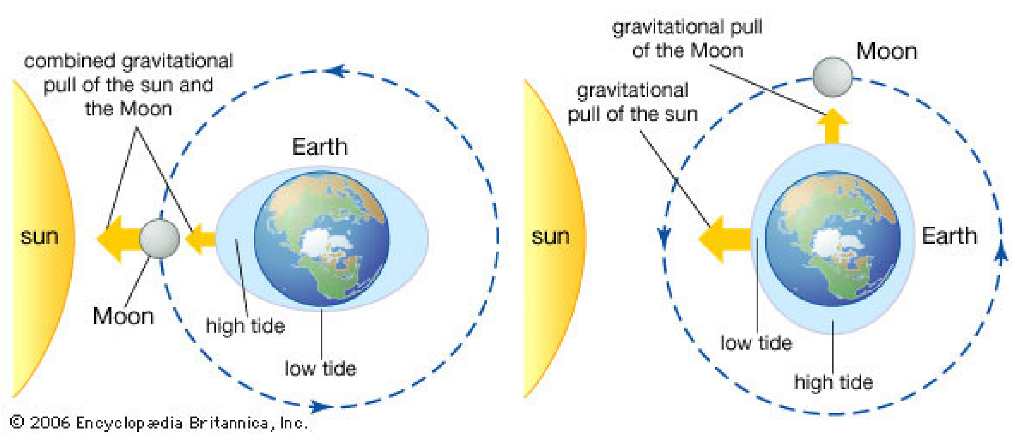
Spring Tide: The strong tide created when the sun and moon align with the Earth.

Tide Chart/Tide Table: A graph used to represent predicted high and low tides over a set period of time at a specific location.

Tides are are the periodic rising and falling of ocean water that occur at regular intervals because of the gravitational pulls of the sun and the moon. Tides seem to make the water creep up the beach with each incoming wave for part of the day until it reaches a so-called "high tide line" and then retreat back down the beach in the same manner. The height of tides is determined by the positions of the Earth, sun, and moon. The gravitational pulls of the sun and the moon pull the ocean water toward them, so the Earth will experience high tides on the sides of the Earth closest to the sun and the moon. Since the moon revolves around the Earth, the Earth revolves around the sun, and Earth rotates on its own axis the distances and relative position of each of these are constantly changing. Depending on the distances of the sun, Earth, and moon the tides may be higher or lower and the currents stronger or weaker.



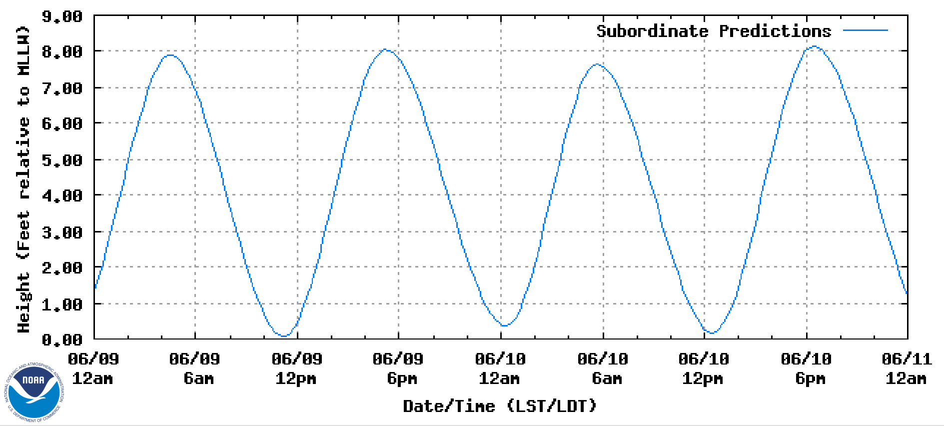
For example, when the sun and the moon are at a right angle with the earth, a phenomena known as a neap tide, their gravitational pulls partially cancel each other out creating weaker tides. When the sun and moon align with the Earth, called a spring tide, their gravitational pulls combine creating stronger tides. Since the sun is 360 times further from the Earth than the moon, the gravitational pull of the moon is twice as powerful as the pull of the sun. The Earth and the moon revolve around a common point every 27.3 days creating a tidal cycle that repeats approximately every 27.3 days.



tides

There are two high tides and two low tides each day which, because of the angle of the moon to the Earth, may not be of equal height. Tide heights may also differ from day to day due to the changing distance between the Earth and the moon. The timing and height of each high and low tide are predictable and any fluctuations may be measured by scientists and used to track hurricanes and winter storms.

Tides are reported in a tide chart or tide table which shows the predicted water level at a specific location over a certain period of time. Water levels are portrayed as a wave with time and date on the x-axis and water level on the y-axis. The crests of the wave represent the high tides, while the troughs represent the low tides. To determine what the water level will be at a given time find the date and time on the bottom of the chart, trace up to the tide line, and then look to the left side of the chart. Tide charts are specific to a certain time period, so new tide charts are issued regularly.



Tide charts for the United States may be found through NOAA:
https://tidesandcurrents.noaa.gov/tide_predictions.html

Tide charts in Mexico may be found through UNAM:
http://www.mareografico.unam.mx/portal/index.php?page=Estaciones

WILDCOAST COSTASALVAJE

Marine Protected Areas (MPAs)

MPAs

California's coastal and marine ecosystems are some of the most iconic and treasured resources in the state and contribute greatly to the history, identity, and economy of the area. Unfortunately these same ecosystems are also some of the most exploited and without proper care the long-term health of these resources is in jeopardy. Recognizing the need to safeguard California's coastal and marine ecosystems the state legislature passed the Marine Life Protection Act in 1999. This act aimed to protect California's precious marine resources by creating a statewide network of marine protected areas (MPAs). Designed to protect the diversity and abundance of marine life while still maintaining recreational access for people, MPAs now protect over sixteen percent, or 850 miles, of the California coast.

Just as state parks protect resources on land, MPAs protect resources in the ocean by managing human activities within biologically important areas. The Marine Life Protection Act recognizes that a combination of MPAs with varied amounts of allowed activities and protections (marine reserves, marine conservation areas, and marine parks) can help conserve biological diversity, provide a sanctuary for marine life, and enhance recreational and educational opportunities.

There are 11 MPAs in San Diego County that fall under three categories:

Key Words

Marine Protected Area (MPA): MPAs are areas in or near the ocean made to protect or conserve marine life and habitat, safeguard cultural sites, and provide enhanced recreational opportunities

Natural Resource: Materials or substances such as minerals, forests, water, or animals that are found in nature and are valuable to humans.

Take: To hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill.

State Marine Reserve (SMR)

Take, damage, injury, or possession of any marine resource (living, geological or cultural) is prohibited. Recreational activities are encouraged.

Matlahuayl
South La Jolla
Cabrillo

No-Take State Marine Conservation Area (SMCA)

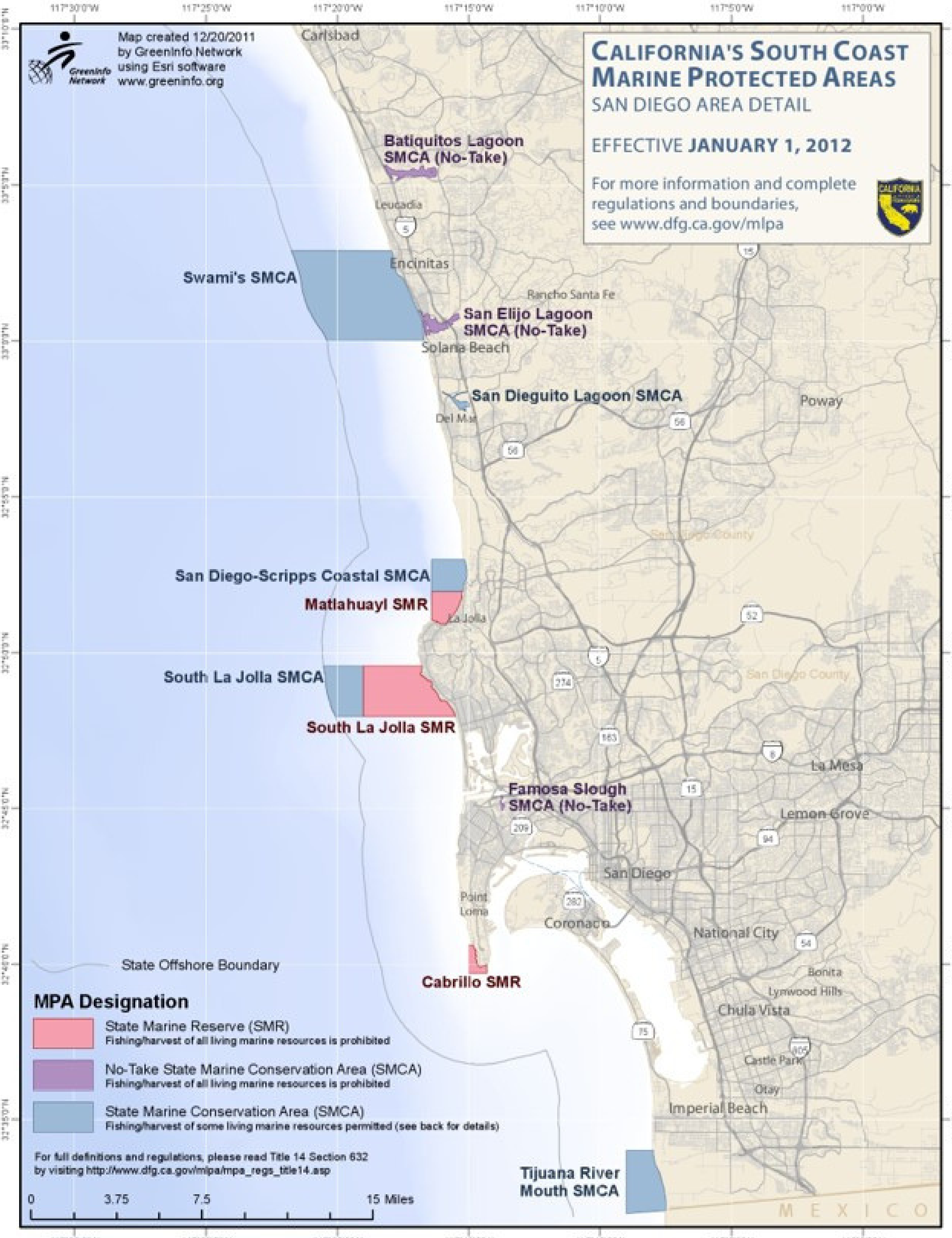
Take, damage injury, or possession of any natural resource (living, geological or cultural) is prohibited.

Batiquitos Lagoon
San Elijo Lagoon
Famosa Slough

State Marine Conservation Area (SMCA)

Take, including fishing/harvest of some marine resources is permitted. Some consumptive recreational and commercial activities are allowed at specific locations.

Swami's
San Dieguito Lagoon
San Diego-Scripps Coastal
South La Jolla
Tijuana River Mouth



CALIFORNIA'S SOUTH COAST MARINE PROTECTED AREAS
SAN DIEGO AREA DETAIL
EFFECTIVE JANUARY 1, 2012
For more information and complete regulations and boundaries, see www.dfg.ca.gov/mlpa
Map created 12/20/2011 by GreenInfo Network using Esri software www.greeninfo.org
Batiquitos Lagoon SMCA (No-Take)
Swami's SMCA
San Elijo Lagoon SMCA (No-Take)
San Dieguito Lagoon SMCA
San Diego-Scripps Coastal SMCA
Matlahuayl SMR
South La Jolla SMCA
South La Jolla SMR
Famosa Slough SMCA (No-Take)
Cabrillo SMR
Tijuana River Mouth SMCA
Carlsbad
Leucadia
Encinitas
Rancho Santa Fe
Solana Beach
Del Mar
Poway
La Jolla
La Mesa
Lemon Grove
San Diego
Point Loma
Coronado
National City
Bonita
Lynwood Hills
Chula Vista
Castle Park
Otay
Imperial Beach
San Diego County
MEXICO
State Offshore Boundary
MPA Designation
State Marine Reserve (SMR)
Fishing/harvest of all living marine resources is prohibited
No-Take State Marine Conservation Area (SMCA)
Fishing/harvest of all living marine resources is prohibited
State Marine Conservation Area (SMCA)
Fishing/harvest of some living marine resources permitted (see back for details)
For full definitions and regulations, please read Title 14 Section 632 by visiting http://www.dfg.ca.gov/mlpa/mpa_regs_title14.asp
0
3.75
7.5
15 Miles

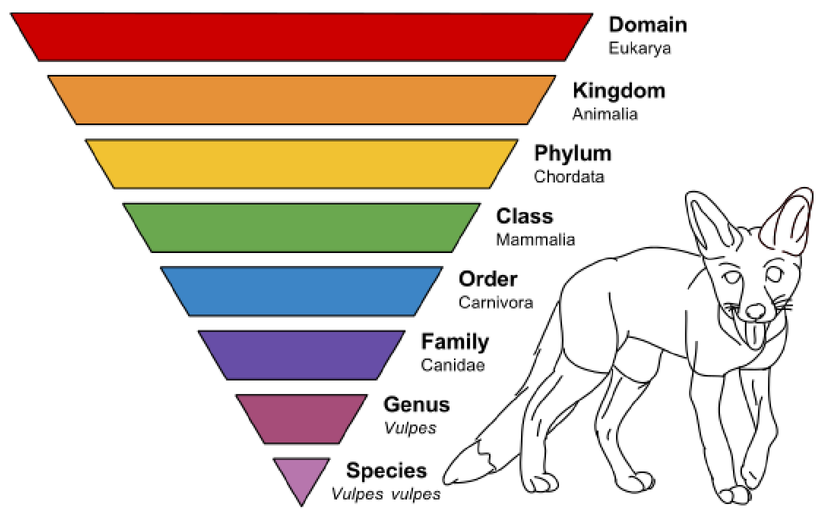
Taxonomy

Taxonomy is the branch of science concerned with the description, identification, nomenclature (naming), and classification of organisms. Scientists use morphological, behavioral, genetic, and biochemical observations to arrange species in a taxonomic hierarchy that groups like organisms together.

Scientists today use a system of classification based on the work of the Swedish botanist, physician, and zoologist Carl Linnaeus, also known as the "Father of Taxonomy," who lived from 1707-1778.

In modern science there are seven main taxonomic ranks: kingdom, phylum, class, order, family, genus, and species. Additionally, an eighth group called "Domain" is commonly included as the most general rank, above kingdom. A species is the most specific rank, while each rank above it characterizes more general categories of organisms and groups of organisms related to each other through inheritance of traits or features from common ancestors. As seen below, a red fox would could be classified as being in Domain Eukarya, the most general of all the ranks, all the way down to the species name *vulpes* which is only assigned to that specific organism.

Scientists typically refer to organisms using the modern naming system commonly referred to as *binomial nomenclature* in which organisms are given a name with two parts. The first part of the name identifies the genus to which the species belongs and the second identifies the species within the genus. This is called an organism's *scientific name.* In the example given below, scientists would refer to the red fox as *Vulpes vulpes*. Note the genus is capitalized while the species is not and both are italicized. The use of binomial nomenclature is preferred over the use of common names ("red fox" in the example below) because there is less room for confusion (for example the common name "panther" can be used to refer to any of a number of large cats) and the scientific name is the same in every language.



Annina Breen/Wiki

Red fox (*Vulpes vulpes*)

identification

WILDCOAST COSTASALVAJE

SAN DIEGO MPA COLLABORATIVE

Identification of Intertidal Organisms

Key Words

Taxonomy: The branch of science concerned with the description, identification, nomenclature (naming), and classification of organisms.

Binomial Nomenclature: A two-part name comprised of the organism's genus and species by which an organism is typically called. The genus is capitalized while species is not and both are italicized. Also called an organism's "scientific name." For example, the red fox is referred to as *Vulpes vulpes.*

Scientific Name: The two-part name assigned to an organism based on the system of binomial nomenclature.

Common Name: The name by which an organism is called in everyday language.

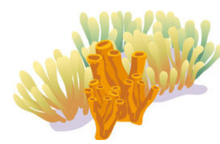
Most often we refer to organisms at a species level. However, when describing or identifying large numbers of organisms it is helpful to group them according to the most specific taxanomic rank of which that group shares. In the case of tidepool organisms, the amazing diversity of life that has found a way to survive in the harsh intertidal has made it necessary to group these organisms more broadly. When referring specifically to intertidal invertebrates (those organisms which do not have a backbone) we typically group them according to phylum.

There are five phyla of invertebrates commonly found in the intertidal:

PHYLUM: Porifera - "Pore Bearing"

Sponges

Simplest members of Kingdom Animalia
Multi-cellular but have no tissues or organs
Body supported by calcium carbonate or silicon-based "spicules"
Asymmetrical or radial symmetry
Sessile- do not move
Filter feeders



PHYLUM: Cnidaria - "Stinging Cells"

Jellyfish, anemones, corals

Have stinging cells called nematocysts to help catch food
Radial symmetry
Blind sac gut - same hole functions as mouth and anus
Two body plans: polyp and medusa

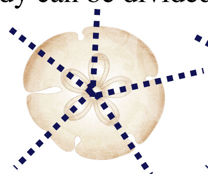
Polyp

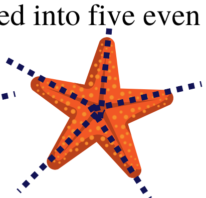
Medusa

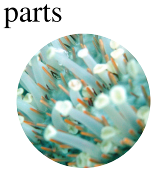
PHYLUM: Echinodermata - "Spiny Skin"

Sea stars, sand dollars, sea cucumbers, sea urchins

Penta-radial symmetry - body can be divided into five even parts
Tube feet for movement
Endoskeleton





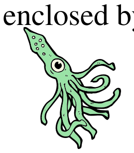


Tube Feet

PHYLUM: Mollusca - "Muscular Foot"

Sea snails, octopuses, squid, mussels, clams

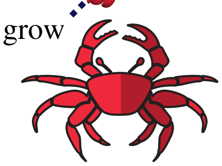
Bilateral symmetry
Sensory organs for sight, smell, taste
Muscular foot for movement which may be modified into tentacles
Body enclosed by a mantle that may secrete a shell



PHYLUM: Arthropoda- "Jointed Legs"

Lobster, crabs, insects

Bilateral symmetry
Exoskeleton
Body divided into sections
Molt (shed exoskelton) to grow
Includes crustaceans
Most successful phylum



Cabrillo National Monument
Intertidal Guide

Name ______________________

CNMC Cabrillo National Monument Conservancy

For more information:
www.nps.gov/cabr

The Rocky Intertidal

Welcome to one of the world's most unique ecosystems. This vast expanse where land meets sea supports a thriving body of marine organisms and plants all adapted to live under the harsh environmental pressures characteristic of this area. Dictated by the gravitational pull of the moon and sun, the tides predictably flow in and out daily creating a low, high, and middle tidal zone. Each of these zones maintains a unique community waiting for you to explore. Use this pocket guide to help you in your adventure and discover the amazing animals that call the intertidal home.

Guided adapted from: "Life Between the Tides"
by: Brandon & Rokop

Mussels *(Mytilus californianus)*

Mussel beds are firmly attached to the rocks by tough strands cemented in place. Shells are tear-shaped and dark blue-black in color. Mussels are commonly 3-5 in. long and open during high tide to filter feed on incoming plankton. Mussel beds are often interspersed with barnacles.

Gooseneck Barnacles *(Pollicipies polymerus)*

Gooseneck barnacles have a fleshy, muscular stalk reaching 4 to 6 in. in length with a calcareous tip. They can be found in clumps interspersed with mussel beds. Once they attach to the rocks as larvae, they do not move their entire lives. Barnacles filter feed when the tide is high using small feather like appendages called cirri to catch plankton.

Intertidal Safety Tips

- Remember you are entering a federally protected area, taking of any kind is against the law.
- Only explore in designated areas. Please stick to the path and heed trail warnings.
- Be respectful of the critters who live here, avoid disturbing their homes, and only touch with two fingers.
- Waves and algae can make the area extremely slippery. Wear sturdy shoes and step with caution.
- Be aware of the incoming tide. Do not turn your back to the waves and make sure that you can always reach dry land.

Sea Lettuce *(Ulva californica)*

Ulva forms dense green, turf-like stands atop rocks in the mid- and low-intertidal. Consists of smooth blades, roughly ¾ of an inch. *Ulva* leaves are edible and quite tasty, fresh or dried.

Dead Man's Fingers *(Codium fragile)*

Codium is a green algae that forms large drooping clumps with cylindrical branches that are spongy in texture. *Codium* is unique in that it only has one large cell wall, the outer skin.

Wire Weed *(Sargassum agardhianum)*

This brown algae forms thick stands in the mid- to low- intertidal. Averaging 1-3 ft. long, they have smally leafy blades and spherical floats.

Keyhole Limpet *(Megathura crenulata)*

Found on rock surfaces in the low- intertidal, these limpets have a small shell under their fleshy colored mantle ending in a large oval "keyhole". Their mantle can range in color from tan, brown, and black. The keyhole at the apex of their shell is used to both respire and excrete waste.

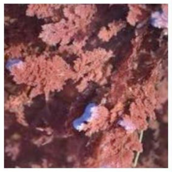
Black Turban Snail *(Tegula funebralis)*

Found in the high and mid- intertidal, *Tegula* often form clusters in crevices or on sides of rocks. They are 1 to 1.5 in. in height and deep purple-black in color. They feed on microscopic algae and seaweeds. Empty *Tegula* shells are also a favorite home for hermit crabs.

Seagrass *(Phyllospadix scouleri)*

Seagrasses are flowering plants that form large clumps in the lower intertidal. Algae that grow on the grasses are called epiphytes and the critters that graze epiphytes are called epifauna.

Coralline algae *(Corallina spp.)*



Corallines are small pink plants with stony segments that branch into a feather pattern. These are perhaps the most abundant of intertidal species in S. California.

Sea Bubble *(Colpomenia sinuosa)*

Colpomenia grows on rocks and other seaweeds in the mid intertidal. They are yellow-brown in color, hollow and bubble-like, and 1-3 in wide.

Owl Limpet *(Lottia gigantea)*

These are the largest of the Pacific Coast true limpets, growing up to 4 in. Most specimens are 2 in. with a lumpy, low profile shell mottled white, brown, and black. They graze on *Ulva* and return to the exact same spot after foraging. Owl limpet is considered a delicacy in Baja California.

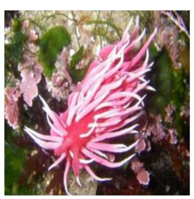
Kellet's Whelk *(Kelletia kelletii)*

The shell of the Kellet's Whelk is tan to white and can reach up to 6 in. in length. This species is sublittoral (meaning that it lives deeper than the intertidal zone) but can frequently be found in shallow water at low tide. The eggs of the Kellet's Whelk are cream in color and usually found lined up in a single file.

Hermissenda (*Hermissenda crassicornis*)

Hermissenda have an elongate body, up to 2 in. in length, and colored transparent blue, grey, or white. The projections on the top of their body (cerata) are usually orange-ish in color with white tips and contain small stinging cells called nematocysts that they obtain from their food, the sea anemone.

Hopkins Rose (*Hopkinsia rosacea*)



Rosy nudibranchs are unmistakable with their vibrant red and pink coloration. Their body is approximately 1 in. long and they can often be found in seagrass or on rocks in low pools. The branchial plumes from which they breath and rhinophores from which they smell are often covered by long distinctive projections called papillae.

Dorid Nudibranch (*Diaulula sandiegensis*)

Diaulula have distinct brown or black rings on the top of their elliptical shaped body. They get to be up to 3 in. long and 2 in. wide. The surface of their skin is velvety in texture due to the calcareous spicules embedded in their skin. These spicules are obtained from the sponges they eat and used to defend against predators.

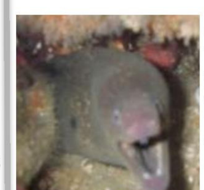
Sea Hare (*Aplysia californica*)

These soft-bodied sea slugs can have a reddish brown to greenish grey skin coloration. Sea hare's feed mostly on red seaweeds, giving them this coloration. They lay their eggs in long, yellow, spaghetti-like mats. Like octopus, the sea hare will produce a thick cloud of ink when disturbed to distract would be predators.

Two-spot Octopus (*Octopus bimaculoides*)

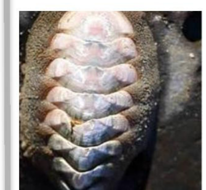
Found in holes or crevices, octopus are secretive creatures. They have a sack-like body roughly 2-8 in. in size with 8 sucker bearing arms about three times the length of their body. They are rapidly able to change their skin color and texture to match their surroundings using small pigment cells called chromatophores.

Moray Eel (*Gymnothorax mordax*)



Moray eels are often light to dark brown or greenish in color and can be found in holes or crevices. They can reach as long as 5 ft. and up to 14 lbs. They often eat small fish, octopus, and crustaceans, These eels have two sets of jaws and extremely sharp teeth. Be careful when sticking your hands in holes where a moray might mistake your finger for a delicious fish.

Conspicuous Chiton (*Stenoplax conspicua*)



These are the largest of the Southern California chitons attaining a length of nearly 4 in. They have an elongated body covered on top by scales or plaques. These chitons are nocturnal and avoid sunlight by hiding under rocks in smooth sandy areas.

Sand-castle Worms (*Phragmatopoma californica*)

A cream colored worm with lavender tentacles and black bristles. This worm is a tube builder and is almost always found in a colony that forms a honeycomb design. Though the worm itself is only 2 in. long, they cement together tiny grains of sand and shells to create reefs as big as 6 ft.

Banded Brittle Star (*Ophionereis annulata*)

Brittle stars belong to a different group than the sea stars. Their primary difference is that they have brittle segmented arms that allow them more mobility that their sea star cousins. Brittle stars are often found under boulders or in kelp holdfasts as they do not like being in the sunlight.

Anemone (*Anthopleura xanthogrammica*)

The solitary sea anemone is the largest of the S. California anemones. They can reach a diameter of up to 10 in., but are often 3 to 5 in. and are light green in color. Their coloration comes from the symbiotic algae that live in them. Anemone catch their prey using stinging cells called nematocysts.

Knobby Sea Star (*Pisaster giganteus*)

Knobby sea stars can be found in the lower intertidal stuck firmly to rocks with their suction cup tube feet. They are distinguished by the bright blue circles around their knobby spines. Sea stars feed on urchins by covering them with their long arms, pushing their stomachs out of their bodies, and digesting the animal externally.

Bat Star (*Patiria miniata*)

Bat stars come in a multitude of colors of red, orange, brown, and many more. Unlike other sea stars they have web like structures between their five arms. Bat stars in the tidepools are mostly small, ranging from 1 to 3 in. in diameter and found on the underside of rocks or in sandy areas.

Spiny Lobster (*Panulirus interruptus*)

Though larger lobsters are found mostly offshore, juvenile lobsters can sometimes be found in the seagrass beds of the intertidal. Lobsters are nocturnal and feed on urchins or other animal remains. Due to their commercial importance, they are illegal to take under a certain size and without a permit.

Sea Urchin (*Strongylocentrotus purpuratus*)

Purple sea urchins range between 2 and 4 in. in diameter. Along with their spines, they have small tube feet that help them move around or stick to rocks. They are voracious predators and feed frequently on Giant Kelp. When the urchin's predators are removed from an ecosystem, they can run rampant and form urchin barrens.

Shore Crab (*Pachygrapsus crassipes*)

Shore crabs are commonly found in crevices in the mid- to high intertidal. The have a small, square-shaped body roughly 2 in. wide and are green or red in coloration. They will move quickly sideways to avoid predators but will "battle" when threatened. They consumer plant material and other forms of detritus.

Globose Kelp Crab (*Taliepus nuttallii*)

Globose Kelp Crabs are deep purple to reddish brown in color and can reach nearly 1 ft. in size. Though they can be found swept into the intertidal, these crabs normally live in the kelp forest adjacent to the tidepools. You will often find them crawling around and eating the Giant Kelp, *Macrocystis pyrifera*.

Tidepool in a Pan

Lesson adapted from Buggy and Buddy
All photos from:
https://buggyandbuddy.com/tide-pool-science-experiment-kids/

Materials
Dish pan or paint tray
Lots of rocks and stones in various sizes
Mini toy sea creatures
Water

Directions
1. Fill your dish pan with rocks and stones. Make sure to arrange them so there are varying levels of rocks in your pan, resembling the levels of a tidepool.

2. Place your mini animals in the tide pool model.

3. Before adding water, discuss which animals will be underwater first as water is added.

4. Begin to add water one pitcher or cup at a time. (Pay attention to which animals are covered with water first.)

5. Continue adding water until you reach high tide. Notice how all the animals are underwater during high tide.

6. Before dropping your water level to low tide, discuss which animals will be exposed to the air first. Begin removing water one pitcher at a time until you've reached low tide. Notice how at low tide most animals are exposed to air. (This is a great time to talk about any body parts or movements sea creatures have to help them with low tide!)

Gravity and Tides

Lesson by: NatureBridge

Overview & Objectives

This kinesthetic learning activity will help students learn about the Earth's tides by acting them out. Students will learn about the gravitational forces of the sun and moon, lunar phases, and vocabulary describing the tides.

• Students will understand how the gravitational pull of the moon and the sun, along with differential gravitational forces, affect the ocean's movements.

• Students will learn the phases of the moon and vocabulary describing tides.

Materials

• Rubber bands (one for each student)

Preparation

• Gather materials

Activity

• To begin the conversation about the causes of tidal movement, ask these questions. The answers are in parentheses.

What makes waves on the ocean? (Wind)
What are tides? (The tide is the cyclic rising and falling of Earth's ocean surface.)
What makes tides go up and down? (The moon and sun)
Does the moon have gravity? (Yes)
Does the sun have gravity? (Yes)
What effect does the moon's gravity have on the ocean? (It causes a tidal bulge on the side of the Earth closest to the moon)

• Place a rubber band on a table in a circular shape. It represents the oceans. Now place one finger in the middle of the rubber band. The finger represents the Earth and ocean's center of gravity. Call the finger "e". Now place a finger from your other hand along the inside edge of the rubber band. This finger represents the force the moon exerts on the Earth's oceans. Call this finger "m." Following a straight line, slowly pull m away from e. At this point, the rubber band stretches.

This is a simplistic model of the effect of differential gravitational forces on the oceans. The moon exerts a much stronger pull on the water molecules closest to it. The molecules on the other side of the Earth receive a much weaker pull. In very simple terms, the difference in the moon's pull on the two sides of the Earth creates a stretched effect on the oceans. These pulling forces are called differential gravitational forces.

Gravity and Tides Cont.

• Now have all students except one form a tight circle, sitting or standing, with their elbows interlocked and facing inward. This circle is a very simplistic model of the Earth if it were covered with water at a consistent depth.
• The lone student represents the moon and walks slowly around the outside of the circle. As the moon passes by, the students in the circle who are nearest the moon lean toward it. The students the opposite side of the circle also bulge out, representing differential gravitational forces.
• After the moon passes by, the students return to an upright position.
• If necessary, the teacher can stand in the middle of the circle and point to where students should lean outward.
• Have the moon stop at several points in the circle and let the class see where high and low tides are in relation to the moon's orbit. High tides are the areas where the students are leaning out away from the center of the circle. Low tides are at the sides of the circle, halfway between the high tides.
• Students take turns being the moon until everyone is leaning outward at the correct times.

Extensions
In addition to the moon, have another student play the sun. Students act out the combined gravitational pull of the moon and the sun. Remember the sun's gravitational pull is not as strong as the moon's.
• For this scenario only demonstrate the areas where the sun is in alignment with the moon (spring tide) and where the sun, Earth, and moon form a 90 degree angle (neap tide).
• When the sun, Earth, and moon are in alignment, the tides are more extreme.
• When the sun, Earth, and moon form a 90 degree angle, the gravitational pull of the sun and moon mostly cancel each other out. The difference between high and low neap tides is relatively small.
• Give students a copy of a current tide chart. Ask them how many times a day the high and low tides occur. Compare what happens on the tide chart when the moon is full, new, and in the first or third quarter. See the References section for information on locating a tide chart.

Adapted by John Carlstroem and Linn Jensen from the Adopt-A-Beach School Education Program, Tidal Waves. 1983

References
1001 Questions Answered About the Seashore by Jacquelyn Berrill and N.J. Berrill. Oceanography: An Invitation to Marine Science by Tom Garrison

Tide charts for the California Coast can be obtained from many coastal sporting goods stores. Saltwatertides.com and Tidesonline.com also provide free online tide charts.

Slow Motion Ocean (Making Waves)

Lesson by: California State Parks

Activity Summary
Students create waves by blowing through straws on a pan of water. They then use a model to observe the way that approaching shallow water causes waves to break.

Introduction
Most ocean waves are caused by wind blowing across the surface of the ocean. The stronger the wind and the longer the time it blows across the water, the larger the waves.

As a wave approaches a beach, it encounters shallow water. The lower part of the wave, being in contact with the land under the sea, is more influenced by friction with the bottom and slows down more than the top. Thus, the top of the wave "outruns" the bottom, which is what causes waves to "break."

If a wave encounters a reef or shallow bottom far from the shore, much of the energy is dissipated by the offshore breakers. When the water remains deep until close to shore, the waves tend to hit the shore with much more force.

Students should be reminded that a wave isn't a mass of water moving from one place to another. If it were, the place from which the waves came would soon run out of water. Rather, a wave is energy moving through the water, which displaces the water slightly.

Grouping
3-5 students per group

Time
Approximately 30 minutes, if the wave bottles are already made; more if the students are making the bottles

Anticipated Outcomes
Students will understand that wind is the cause of most waves.
Students will understand why waves "break."

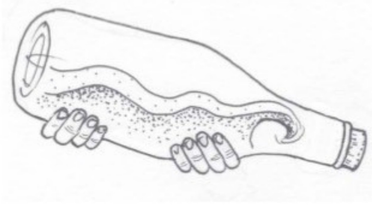
Materials
For each group: 1 shallow pan (pie tin, baking pan, paint tray, or? ... maybe with sand in it?)
1 or 2 straws
1 clear large ketchup or other bottle with a long tapered neck and cap (see diagram)
Corn syrup and vegetable oil (the amount will depend on the bottle size)
Blue food coloring
Recommended: plastic tape for taping the cap on the bottle
Alternative to straws: battery operated or electric fan

Slow Motion Ocean (Making Waves) Cont.

Teacher Preparation: Try this activity yourself before doing it with students!
Obtain materials above
Depending on students, either have them prepare the wave bottles, or try to arrange for a parent volunteer to do so. To make the wave bottle:
Obtain one bottle per group. The bottle should have a long tapered neck.
Fill the bottle about a quarter full with corn syrup.
Mix in a few drops of blue food coloring.
Slowly pour in some vegetable oil until the thick part of the bottle is about half full.
Cap the bottle tightly, and seal the cap with plastic tape.

Procedure
Making Waves:
1. Ask students what they think causes waves.
2. Ask students what they predict will happen if wind blows across the surface of water.
3. Either demonstrate or have students experiment with forming waves by either blowing across the surface of water in a pan or using a fan to blow wind across the surface.
4. If using an electric fan, caution students about the danger of water and electricity.
5. Have students experiment (or demonstrate) with the fan on fast and slow speeds.
6. If using straws, have students blow on the water without straws, then with straws to concentrate the force. Have them blow hard and soft, and at different angles.

Breakers:
1. Have the students slowly tip the wave bottles, observing what happens as the mixture approaches the narrow end, which simulates a coast getting shallower.
2. Call on students to describe their observations.



Discussion
1. See above.
2. Discuss the difference between wind-driven waves and tsunamis.
3. Discuss the effect of waves breaking on tide pool organisms, and on wave spray on zone

Assessment
• Can students explain what causes waves and what causes waves to break?

References
Littlefield: Awesome Ocean Science!, p. 26 Project WET Curriculum Activity Guide, p. 450-451

Drying Out in the Water?

Lesson by: California State Parks

Activity Summary
Students place pieces of carrot in the air, tap water, sea water, saturated salt solution, and salt. They then observe the carrot pieces the next day and observe changes in size and turgidity (rigidity).

Introduction
Few fresh water organisms can live in ocean water, and few marine organisms can survive in fresh water. One reason for this is osmosis, or movement of water across a semi-permeable membrane such as a cell membrane, from an area of high concentration (of water) to the other side of the membrane where there is a lower concentration of water. Most fresh water organisms will lose water from their cells if placed in sea water. If they lose too much water, they die.

Tide pool organisms, especially those in small pools in the upper zones, must be able to either leave the tide pool or deal with very salty water on a warm summer day when water evaporates from the pool, or with water that is less salty than ocean water on a rainy day. Some deal with this varying salinity by clamping down on rocks or closing shells. Others have tough skins that aren't very permeable to water. Others have a high tolerance for a range of salinities.

Grouping
Groups of 2-4 students

Time
Day 1: 10-30 minutes
Day 2: 15-30 minutes + discussion

Anticipated Outcomes
Students will understand that water can move in and out of cells and organisms.
Students will understand that losing too much water is harmful to an organism.
Students will understand that tide pool organisms must have adaptations for dealing with a variety of salinities.

Materials
- Paper and pencils
- Rock salt and table salt
- Carrots ("baby carrots?")
- Knife (teacher or parent volunteer uses)
- 5 similar containers for each group: plastic cups, baby food jars, beakers, or?
- 6" of masking tape or some other way to label containers
- Optional: ruler with millimeters

Drying Out in the Water Cont.

Teacher Preparation (Try this experiment yourself before doing it with students!)

● For each group, cut 5 carrot slices of approximately equal diameter and thickness. "Baby carrots" are good for this because their sides are less tapered than fresh carrots, and they have had the outer layers removed. Alternatively, use large carrots and cut cubes of equal size. This may be preferable if you choose to have the students measure the sides of the carrots and calculate volume.

● Either obtain some sea water or prepare an artificial sea water sample by dissolving about 28 grams (1 ounce) of table or rock salt in a liter (quart) of water.

● Make a saturated salt solution by adding salt to a liter of warm water until no more will dissolve, then add more. Let this stand overnight, and add more if all of the salt has dissolved. Keep doing this until no more will dissolve. Regular table salt will produce "cloudy" water; rock salt is recommended.

● Either put together sets of materials for the students or set up stations where they will pick up their materials. Each group will need the following:

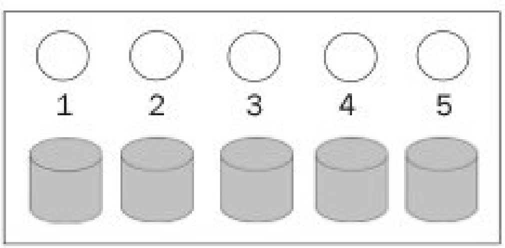
- 5 containers such as plastic cups, baby food jars, Petri dishes, or beakers
- Tap water, sea water, saturated salt solution, dry table salt
- Pencil (not pen, as pen will run if it gets wet while pencil won't)
- White paper
- 6 inches of masking tape or some other way to label the containers Consider starting this experiment late one day and finishing it the next morning.

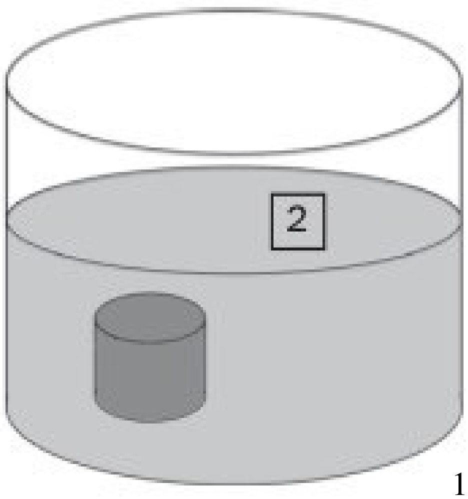
Procedure

1. Ask the students to tell what they think would happen to a fresh water animal if it were put into the ocean.
2. Ask the students what they think would happen to an ocean animal if it were placed in a fresh water lake.
3. Ask the students to predict, in writing, what they think would happen to a piece of carrot if it were put overnight in ocean water, very salty water, dry salt, tap water, and the air.
4. Explain the following procedure to the students, using materials to demonstrate:

a. Use masking tape to number the 5 containers. Place the following into the containers:

#1: nothing (air)
#2: tap water (approx 1" deep)
#3: 1"of sea water
#4: 1" of saturated salt solution
#5: nothing yet…will add dry salt after the carrot piece is in the container





Drying Out in the Water Cont.

b. Place 5 carrot disks on a piece of paper and draw around each of them with a pencil. Be sure to keep track of which piece goes with each circle by numbering the circles to correspond with the 5 numbered containers.
c. Place the carrot disks into the containers, being sure that the numbers correspond. For #5, place the carrot disk in and cover it with table salt. Set the experiment aside where it won't be disturbed.
d. The next day, have students observe the containers/carrots, then have them remove the carrot disks and record their observations about both their size and turgidity (stiffness).
• Students should notice that the carrot disk in the saturated solution is floating, while the others are on the bottom. This is because the saturated salt solution is denser than the carrot disk.
• They might measure the diameters, or simply place the disk on the corresponding circle drawn the day before.
• For older students, consider having them calculate the volume before and after.
5. After the students have recorded their observations, discuss the observations and the implications for organisms. (Do this before cleaning up, so you can show examples.)

Typical results might be: (water moves from a high density [%] of water to where there is a lower % of water)
● Carrot in air - will lose about 1/3 of its diameter and become soft (air has little water in it)
● Carrot in tap water - will stay the same, and may become more turgid/firm (higher % water outside carrot)
● Carrot in sea water - will lose about 1/10 of diameter and become softer (lower % water outside carrot)
● Carrot in saturated salt solution - will lose a little more, become softer, and float (still lower % water outside, and carrot cellulose tissue is less dense than water)
● Carrot in dry salt - will lose about 1/3 of its diameter and become soft (water diffuses out into salt)

Discussion
1. Why did some of the disks shrink? (Water left the cells because there was more water (a higher percentage) in them at the start than in the surrounding water (or air or salt), so more molecules were moving outward from the cells than inward. This is called osmosis.
2. Why didn't the tap water disk shrink? (water entered cells as fast as it left)
3. Why did some carrots get soft? (water left the cells)
4. What would happen to a fresh water animal placed into the ocean? Why can't people on a life raft in the ocean just drink the ocean water?
5. What would happen to an ocean animal placed in fresh water?
6. How might tide pool organisms deal with a salty pool on a sunny day? With a tide pool that was becoming more diluted (less salty) during a rain storm?

Wrestling for Resources

Lesson by: Greater Farallones Association

Objective

Students will be introduced the concept of sustainable development with a simple classroom activity that illustrates how "cooperative behavior" between people competing for a limited resource can benefit all involved.

Materials and Supplies

M&M candies or other small prizes, enough to award 15 to each student

Background

Pairs of students will thumb wrestle to represent competing for a limited resource. For each time one person traps the other person's thumb, the "thumb trapper" earns one point. The goal for each pair is to score the most number of points. Be aware that calling the pair of students either partners or opponents when introducing the activity may influence the outcome. Some students will fight to get the most points and neither in the pair will get many. Other students will figure out if they work together, they both can easily earn lots of points. By working together, student pairs are cooperating and both benefit. This cooperative behavior is important in sustainable development.

Activity

1. Tell your students that they are going to thumb wrestle for M&M's.
2. Pair the students up and tell them they have 30 seconds to play and to count the number of thumb trappings by each student. For each thumb trapping, each individual earns one M&M.
3. Say go and 30 seconds later say stop.
4. Pass out one M&M for each point.
5. Discuss the strategies that each pair developed. Some pairs will get 5-7 and other will figure out that they can get 20 or more. How much time does it take to earn one point?
6. Have students think about how people in the fishing industry compete for a single resource such as a local population of fish and how they can work together. The students with larger hands might be compared with factory ships that can sweep the ocean with nets miles long, leaving less for the small fishing boats. Students who work together and trade off winning are like those who share the common resources. If resources are shared through policies like quotas, everyone can benefit with more employment, controls on catch sizes, and higher market price. Even the fish can benefit.

Extension

Have your students find newspaper articles on declining fisheries and the solutions proposed. Review the results of quota that have been imposed elsewhere (See California Sea Grant's Cooperative Extension Newsletter from November-December 1994 on the British Columbia halibut fishery quotas).