Marsh and Mudflat: Background Information & Pre and Post Activities

BACKGROUND INFORMATION

BASIC ECOLOGICAL CONCEPTS

Ecology is the study of the relationships between organisms and their environments. An ecologist asks questions like: Where does this organism live and what characteristics make it particularly suited for that location? How does this organism get its food? What other organisms eat it? By asking questions such as these some basic principles have emerged. Understanding the following basic ecological concepts help us appreciate the complexity of life residing in and around the Bay.

<u>Everything is related to everything else</u>

Perhaps the easiest place to see interdependence in the environment is to look at food. All food on this planet is essentially made by plants through the process of *photosynthesis. Herbivores* are animals, which depend directly on plants for food. *Carnivores* eat herbivores. Take away all of the plants and there would be no animals. Can a plant, then, exist independently of all other organisms? No. Although it doesn't eat, a plant needs *nutrients* and is dependent on *decomposers* (bacteria and fungi) to break down dead organisms, thereby releasing these nutrients for use by the living plant.

<u>Everything depends on something else</u>

All organisms are also dependent on factors in the physical environment. They must have a source of water. Animals must have oxygen to breathe. Plants must have sunlight to perform photosynthesis. You can probably think of many more examples of how organisms are dependent on their environments.

<u>Everything must go somewhere</u>

No object ever disappears completely from the face of the earth. It may be broken down into atoms and be used to build something else, but those atoms are still there. In this way, nature deals with waste by recycling. Any plant or animal that does not become food for some animal becomes food for decomposers, which free the nutrients to be used again. Anything that cannot be decomposed must remain in the environment as it is. What are some examples of this kind of waste? The next time you throw something away, you might remember that there really is no "away" to throw it to.

Earth's resources are limited

How often do you run out of time to do what you want or need to do? Everyone knows that each day only has so much time in it, and that we have to be careful how we use it if we are going to accomplish everything we need to. The earth's available resources are like time in that we have to be careful how we use them, or they might run out. There is only so much gold, so much petroleum, so much fresh water, so much food, and so much space. All organisms are limited by the availability of resources, but humans have a special opportunity and a special responsibility. Although plants cannot make a decision to conserve clean water, humans can. To do this intelligently we must find out how much of each resource is available and then we must budget our use. We must also think about recycling. The earth can recycle its components naturally but humans must make special efforts to preserve the natural resources.

MUDFLAT ECOSYSTEM

At low tide, this muddy, intertidal ooze may appear to be lifeless, but by looking more closely one can notice important links in the food chain. Mud snails, clams, crabs, and worms, called benthic invertebrates, eat decomposing plants called *detritus*. To protect themselves from wave action, dehydration, and predators, the mud dwellers burrow themselves into the sediment. In winter, thousands of birds migrating from nesting areas in Canada and Alaska descend upon the Estuary to picnic on the invertebrates. Equipped with probing bills of all shapes and sizes, wading legs, and scratching claws, the birds search for the buried creatures. When the tide comes in, the invertebrates are prey to leopard sharks, starry flounders (which bite off the siphons of clams), and bat rays (which can suck invertebrates from their burrow). Many of the same invertebrates are also found deeper in the benthic zone, out of the reach of the tides.

MUDFLAT PLANT AND ANIMAL SPECIES

Anaerobic bacteria *Bacillus sp.*
Eel grass *Zostera latifolia*
Cord grass *Spartina foliosa*
Mud snail *Ilyanassa obsoleta*
Spaghetti worm *Thelepus crispus*
Yellow shore crab *Hemegrapsus oregonensis*
Isopod *Syniodotea laticauda*
Japanese littleneck clam *Venerupis phillippinarum*
Great egret *Casmerodius albus*
Black-crowned night heron *Nycticorax nycticorax*
Black-necked stilt *Himantopus mexicanus*
American avocet *Recurvirostra americana*

SALT MARSH ECOSYSTEM

Salt marshes serve as a transition zone between the open water of the Bay and mudflat or dry upland areas. It is the ecosystem that was once predominate in the Estuary. Today, less that 19% of the tidal salt marsh in both the Bay and Delta remain unspoiled.

The soil in these marshes is very salty. Most plants cannot grow in salty soils because the salt will literally suck fresh water out of them. Some plants, called *halophytes*, have adapted to the salt marsh. They excrete the salt through special cells (stomata) or repel salt from their root system.

There are three main plants in the salt marshes. *Cordgrass* is lowest in the water and serves as a boundary between the mud flats and the salt marsh. When it dies, the grass decomposes into minute parades called detritus. These particles are food for bacteria and small animals which in turn are eaten by larger animals. Cordgrass produces five to ten times as much nutrient materials and oxygen per acre as wheat.

The middle marsh, with high salinity and waterlogged soils, is dominated by *pickleweed*, whose succulent, jointed stems are often thickly interwoven with the orange parasitic *marsh dodder*. The pickleweed accommodates the salt by storing it in the "pickles" at the top of the plant, which eventually turn pink or red and flake off. *Salt grass* grows in the high marsh zone above the pickleweed, and excretes salt from its leaves through special glands.

Salt marshes host several rare mammals and birds. Two species of salt marsh harvest mouse inhabit marshes in the northern and southern reaches of the Estuary. Rare songbirds and sparrows are also in these areas. More well known are the two rare rails, the California black rail and the endangered California clapper rail. The clapper rail nests in the cordgrass area, and feeds at low tide on mussels, clams and shore crabs. A once abundant bird, the clapper rail now number around 1,000.

SALT MARSH PLANT AND ANIMAL SPECIES

Cordgrass *Spartina foliosa*
Pickleweed *Salicornia virginica*
Marsh dodder *Cuscuta salina*
Salt grass *Distichlis spicata*
Fennel *Foeniculum vulgare*
*Pygmy blue butterfly *Brephidiun exilis*
Brine fly *Ephydra cinerea*
*California clapper rail *Rallus longirostris obsoletus*
Great blue heron *Ardea herodias*
Snowy egret *Egretta thula*
Alameda song sparrow Melospiza melodia pusillula
Arrow goby *Clevelandia ios*
Jack rabbit *Lepus californicus*

*Salt marsh harvest mouse *Reithrodontomys raviventris*
*San Francisco garter snake *Thamnophis sirtalis tetrataenia*

**endangered species*

UPLAND ECOSYSTEM

The upland environments are large, dry areas surrounding the Bay. It is these areas that have been most altered by human actions. Uplands provide valuable buffer zones during high tides and winter storms. Many of the plants growing there are non-natives, such as eucalyptus and acacia. An unwelcome introduced species is the red fox, which preys on nesting birds such as the California clapper rail, and is increasing in number. A predator management plan is now in action to limit the red fox's impact on native animals.

The upland ecosystem represents a diverse assortment of land from flood control projects, to salt pond levees, to areas for public recreational use. A network of hiking trails and shoreline parks are a valuable resource for many people to enjoy.

UPLAND ECOSYSTEM PLANT AND ANIMAL SPECIES

Mustard *Brassica sp.*
Poison hemlock *Coniun maculatun*
Coyote brush *Baccharis pilularis*
California laurel *Umbellularia californica*
Cabbage butterfly *Pieris rapae*
Northern harrier *Circus cyaneus*
Red-tailed hawk *Buteo jamaicensis*
Burrowing owl *Athene cunicularia*
Western fence lizard *Sceloporus occidentalis*
Barn swallow *Hirundo rustica*
California ground squirrel *Spermophilus beecheyi*

THE SAN FRANCISCO ESTUARY ECOSYSTEM

An *ecosystem* is "a community of plants and animals and the environment with which it is interrelated." The Bay has distinct ecosystems, some of which are covered with water and some of which are not. These areas are divided into open water, salt marsh, mud flat, salt pond and upland. Many of the Estuary's animals and plants can be found in more than one ecosystem or habitat.

The San Francisco Bay-Delta Estuary is California's largest and best-known *estuary*. A bay is a partially enclosed inlet of the ocean. An estuary is a partially enclosed coastal inlet where fresh water and salt water meet and mix. Fresh water enters San Francisco Bay primarily from the Sacramento and San Joaquin rivers and also from creeks and streams. Salt-water enters through the Golden Gate from the Pacific Ocean. These two kinds of water are mixed by winds and tidal currents, and as a result, the water of San Francisco Bay is termed *brackish*.

This rich and complex ecological system supports the largest sport fishing area and the largest remaining marshes in the state. Thirty species of endangered plants and animals use the Estuary during at least part of their lives. Two-thirds of the state's salmon and nearly half of the waterfowl and shorebirds migrating on the Pacific Flyway pass through the Estuary each year.

GEOLOGIC HISTORY

Twenty thousand years ago there was no Bay. At that time, much of the earth's water was frozen in glaciers that covered a large part of the northern continents. The Pacific shoreline lay out beyond the Farallon Islands, and the Bay itself was dry bedrock composed of sandstone, siltstone, chert, and greenstone known as the Franciscan Formation (Harold B. Goldman 1969).

As the glaciers slowly melted, the ocean waters rose, and by 10,000 years ago the ocean had spread inland through a gap in the outer Coast Range known today as the Golden Gate. For thousands of years the water rose rapidly, at a rate of about one inch a year, advancing the shoreline nearly 100 feet each year. Gradually the rate slowed until several thousand years ago when sediments accumulated in the shallows faster than the sea could cover them. This thick, young Bay mud supported the expansion of tidal mudflats and marshes along the Bay's shore, and offered habitat for a diverse population of organisms.

HUMAN HISTORY

Native Americans occupied the shores at least as early as 3,500 years ago. The abundance of food and the mild climate supported over 50,000 native people, but today the only physical remains of that society are 400 shell mounds, or middens, scattered around the Bay.

The Spanish established a mission and presidio at San Francisco in 1776, but there were few settlers in the region until 1848, when James Marshall found a golden nugget in the American River. The Gold Rush caused some of the earliest, major environmental destruction in California, and reduced the size of the Estuary considerably. Hydraulic mining, practiced by gold rushers between 1853 and 1884, added millions of cubic yards of sediment into Sierra foothill rivers, much of which was deposited in the Estuary. High-pressure water jets were used to quickly erode mountainsides. The resulting sludge and rock were sluiced through boxes designed to catch the heavier particles of gold. Eventually, sediments flowed southward causing massive population depletion of oyster beds.

Between 1860 and 1930, all but a small percentage of the Delta's 350,000 acres of freshwater marsh were diked and planted with crops to feed the state's growing population. The Bay's waters have been severely polluted and over 60% of the Bay has been filled with garbage or levied off from tidal action. In 100 years, the larger Bay territory has decreased from 720 to 480 square miles. In the process, many fishery resources have been lost and valuable wildlife habitat and recreation space have been lost or altered.

INTRODUCED SPECIES

Scientists estimate there are now about 212 non-native species now living and reproducing in Bay waters (Cohen and Carlton, 1995). The first invasions occurred in 1848, when gold seekers came to the area in wooden ships. Water stored in the hold of the ships, called ballast, is used to stabilize large vessels; once the vessel arrives in port, the ballast is flushed out, instantly transporting a myriad of foreign organisms into the Bay. Many invertebrates have been particularly successful in their adaptation to a new environment, and have taken over habitats that once belonged to native species. For example, the Asian clam *Potamocorbula* was brought over by ship ballast in 1986, and has taken over the bottom of the North Bay, resulting in depleted phytoplankton populations. The introduced red fox *Vulpus fulva* preys on the eggs of the endangered California clapper rail (*Rallus longirostris obsoletus*). Exotic or introduced species are now being more closely studied as an environmental phenomenon that could obliterate many native species in the Bay.

THE IMPORTANCE OF BIODIVERSITY

Biological diversity (or biodiversity) is the variety of all life forms on Earth - plants, animals and microorganisms. It refers to species (species diversity), variation within species (genetic diversity), and interdependence within species (ecosystem diversity). Today, 17,500 species become extinct every year. Obviously, this is having a negative effect on the biodiversity of Earth's ecological system. This accelerated rate of extinction should be of concern to us all for several reasons.

- The first and perhaps most important reason is *moral.* As the dominant species on the planet we have a responsibility to protect our only known living companions in the universe.
- Second, within the 5 to 30 million species that exist there is a vast unidentified wealth of *genetic and medicinal information*.
- The third reason is *aesthetic*. Although it is impossible to put a monetary value on the enjoyment we receive from seeing and learning about wild animals or hiking through forests and meadows, we nevertheless know that quality of life is enhanced by the amount of unpolluted areas which exist adjacent to human communities.
- The last, but not least reason is *interdependence*. An ecosystem is made up of both biotic (living: plants, animals, bacteria and fungi) and abiotic (non-living: soil, climate andgeological formations) components. These components are inextricably and intricately intertwined.

BIODIVERSITY IN THE BAY AREA

Sea otters used to be a common sight in the San Francisco Bay. Grizzly bears came down from the hills to hunt salmon and cougars singled out individual deer, elk and antelope from herds as big as 400! With the exception of deer and the few salmon that remain, all these animals have been extirpated (eradicated).

The two main causes of species extirpation in the Bay Area are *habitat loss* and *pollution*, although disease and human disturbance such as hunting, dredging and freshwater diversion are also part of the problem.

Habitat is a broad term and can be broken down into various components, depending on the species. A species nesting site can be very different from where it forages or where it overwinters. For example, the California clapper rail is a non-migratory resident of the Bay Area. It is doubly threatened because its nesting habitat, the high tidal salt marshes, are being converted to salt ponds and urban developments, while its foraging habitat, eelgrass beds in low tidal areas, is being destroyed by increased motorboat use in the Bay.

Setting aside small wildlife preserves usually secures some habitat for some species, but it often results in two significant threats to populations: habitat fragmentation and genetic isolation. Populations limited to isolated habitats are vulnerable to extirpation by natural or human-caused catastrophes such as floods, developments or chemical spills. In addition, isolated populations have a severely limited genetic pool, which can lead to inbreeding and a general weakening of the population, bringing extinction that much closer.

Pollution is defined as a harmful degradable or non-degradable contaminant (usually waste, sediment or chemical in form) discharged into the environment. The primary sources of contaminants in the Estuary include urban runoff, river inflow from agricultural discharges, municipal waste treatment effluents, industrial effluents, and dredging and dredge material disposal.

HUMAN IMPACT ON THE BAY

Urban, industrial, and agricultural development of California has dramatically altered the San Francisco Estuary. The watershed of the San Francisco Estuary (the area of land that forms the drainage for many streams and rivers) covers 40 percent of California and extends north into Oregon. Nearly half of the Estuary's watershed has been turned into farms and range lands, and about a fifth is now irrigated. Changes in land use and population are the fundamental causes of many of the changes in the Estuary, including the diking and filling of its wetlands, the increase in pollution, and the increase in water diversion.

LOSS OF WETLANDS

Of the original 720 square miles of natural marshland that once covered two-thirds of the Estuary's surface, only about 75 square miles remain. The wetlands have been eliminated by filling and diking for urban development, agriculture, and salt evaporation ponds. Since these marshes are of great importance in the productivity of the Estuary, their loss has a definite and direct impact on fish and wildlife populations. At least seven species of insects, one reptile, three birds, and five mammals have completely disappeared from the Estuary, primarily as a result of habitat loss.

Many of the Estuary's rare or endangered species are found only in specific wetland habitats. Before the destruction of its marshes, the Delta was a major nesting area for waterfowl, and supported herds of tule elk and antelope, along with grizzly bear and mountain lion, all of which have now disappeared from this area. Today, over 100 species are now protected by a combination of state and federal laws, although destruction still occurs.

DREDGING

Over 7 million cubic yards of sediment are dredged from the shipping channels of the Bay each year. Most of this material is dumped at three sites in the Estuary: the Alcatraz Site; the San Pablo Site; and the Carquinez Strait Site. Local fisherman complain that this has ruined the fishing in recent years due to increased turbidity (opacity of water, an indicator of how much sediment, plankton or organic matter is suspended in the water). Benthic invertebrates may also be displaced by dredging, or buried by sediment disposal. Until 1975, dredged sediments were also used to fill in diked wetlands, including those underlying Foster City, the San Francisco and Oakland airports, and parts of Alameda.

DAMS & DIVERSIONS

About half of the average flow of fresh water coming into the Estuary is diverted to Bay Area cities, Delta farmers, and Southern California for farm irrigation. Dams and other disruptions of the natural flow of water have damaged *anadromous* (fish that spend their adult life in salt-water, yet migrate upstream to fresher water to spawn) fish populations. Pumps that draw water from the Sacramento River Delta, primarily for irrigation, suck up about half of the Chinook salmon that are born each year. The decline in the amount of fresh water input also affects the populations of plankton species and benthic organisms.

POLLUTION

Pollution is a harmful degradable or non-degradable substance (usually waste, sediment or chemical in form) discharged into the environment. Pollution has been a problem in the Bay since the early 1900s when raw sewage was dumped into the water and the first major oil refinery was built. The sources of pollution in the Bay include industry, farms, boats, and even our own houses, cars, gardens and pets. Although progress has been made over the past several decades, the region still does not meet the standards set by the Clean Water Act of 1972. Surface water pollution falls into two main categories, point source pollution and non-point source pollution.

Point Source Pollution - This type of pollution enters the water at a particular point, or site. An example is the 50 municipalities and 140 industries that dump untreated wastes into the Estuary each year, including 300 tons of trace metals. Areas of water with poor circulation, such as the far South Bay, are thought to be most vulnerable.

Non-point Source Pollution - Non-point source pollution does not enter the water from any one traceable source. After a rain, urban runoff carries pollutants such as oil, grease, lead and zinc from the streets, into rain gutters and into tributaries and stormchannels. These channels bypass any treatment and feed directly into the Estuary. Agricultural runoff, which contains pesticides, herbicides, nitrates and metals leached from the soil, is responsible for huge amounts of non- point source pollution entering the Estuary. Other contaminants are accidental spills, pollutants from landfills, smog which becomes acid rain, and fire.

HEAVY METALS

Of the many non-point source pollutants entering the estuary, heavy metals are a great concern because of their potentially toxic effects on animals, including humans. Very small amounts of some metals are essential to the proper functioning of body systems. However, excessive amounts of these metals have been shown to be highly carcinogenic and damage body systems necessary for life. Metals entering the estuary that are bioavailable can accumulate in animals, causing illness and even death.

Some heavy metals entering the Bay are:

- Cadmium: This may get into water from waste discharged by electroplating and battery plants. It is neither essential or beneficial for plants and animals, and considered a highly toxic metal.
- Copper: Essential to all organisms, mostly for respiration functions. A major source of copper is its common use as an algacide.
- Lead: Lead is not an essential element needed for human nutrition. The main source of lead is from automobile exhaust. Where bridges cross waterways, lead may be concentrated in sediment.
- Zinc: Zinc is essential for organisms in very small amounts. The main source of zinc is the residue left on roads due to the normal wear of rubber tires.

PROTECTING THE ESTUARY

The reduction of non-point source pollution is one area where people can make a dramatic impact on the overall health of the Estuary. All storm drains in the Bay Area lead directly to the Bay. Just one quart of oil dumped into a storm sewer can contaminate up to 250,000 gallons of Bay water. Recycling used motor oil rather than dumping it, taking a car to the car wash instead of washing it at home, and picking up litter are all examples of how an individual can make a difference. Other examples include substituting safe alternatives for toxic household products, recycling hazardous wastes, carpooling to reduce air pollution, and of course the 3 R's: Reuse, Reduce, and Recycle. Understanding that an individual has the power to have a positive impact, however small, and committing to making the appropriate changes in our everyday lives, is the first step in preserving the health of the Estuary.

FISH ADAPTATIONS

An adaptation is a physical characteristic or behavior that an animal evolves to become better suited to their environment. Taking a look at the external form or structure of a fish can tell us a great deal about where it lives and how it makes its living. The shape of the fish's body, the size and shape of its fins, the size and placement of its mouth, and the coloration of the fish each has a story to tell.

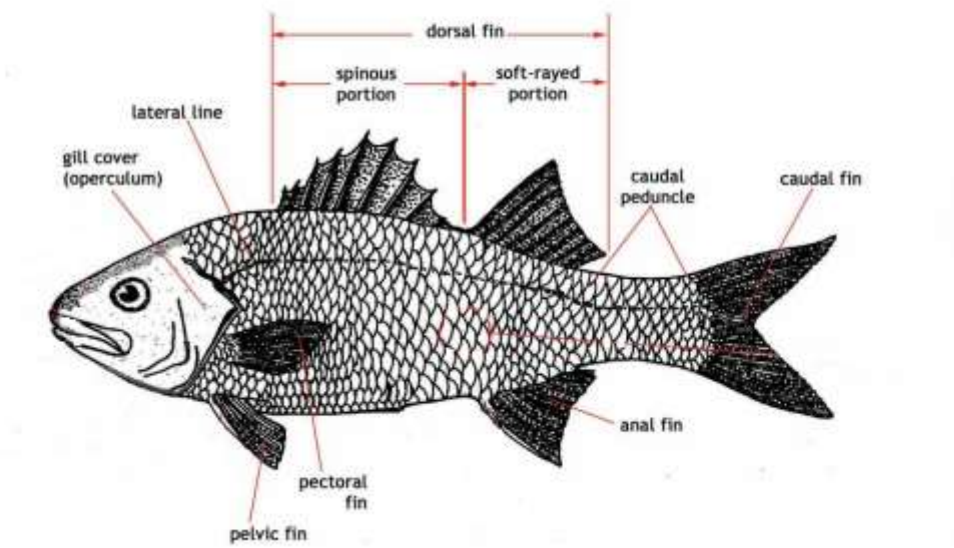
SHAPE

Fish that live on the bottom are often flat (or depressed), in order to conform to the surface on which they live. Mid-water fish are often laterally compressed for ease of movement through the grasses and crevices where they forage. Fish that live near the top of the water often have a long, slender, torpedo-shaped form in order to move quickly.

FOOD

Much can be learned about a fish's place in the food web by looking at its mouth. Fish like the California halibut, which are carnivorous and eat other fish, have big mouths and sharp teeth. Some fish, including anchovies, have sieve-like gill rakers (projections inside the gill openings that support the rakers) that filter plankton from the water. Bat rays, which feed on clams and other invertebrates, have a mouth positioned underneath their body, which is equipped with hard plates for crushing the shells of their prey.

EXTERNAL FISH ANATOMY



FINS

Fish have fins to help them move through the water. Each of the fins on their body has a different job. The tail fin, or caudal fin, gives the fish power and helps it move forward. The pectoral and pelvic fins help steer the fish, and in some fish help it move forwards and backwards. The anal and dorsal fins aid in stability, and in some cases they help propel the fish forward.

CAMOUFLAGE
Another external adaptation is the coloration fish have developed to avoid detection by their predators. The black bars of the leopard shark, for example, help disrupt the outline of its body. Many flatfish can change the color of their body to match that of the surface where they are living. Most fish display counter-shading, being dark on the top and light on the bottom. This helps them to blend in with the water and the bottom when seen from above and the sky when seen from below.

GILLS
Fish breathe by absorbing dissolved oxygen with their gills. Water taken in through the mouth moves over the gill filaments and passes out under the gill covers. Since less oxygen is present in water than in air, a fish's gills must be more efficient than lungs. Numerous filaments on the gill rakers (support for the filaments) are intended to increase the surface area of the gill, thus allowing greater intake of oxygen.

SENSORY ORGANS
Fish are able to perceive color. They do not have eyelids or tear producing glands. Nasal openings, or nares, can "smell" substances in the water. This is an especially important sense in salmon, which are thought to use nares to find their home spawning stream. Fish also have a sense of taste. Taste receptors are located in the mouth, head, and on other body surfaces. Feelers called barbels are located near the mouth. Fish can both hear and make sounds. The ear is entirely internal, and serves as a balance organ as well as an organ for hearing. Fish also sense their environment through the lateral lines which run the length of both sides of their body. The lateral line detects pressure changes in the water and enables the fish to register movement and distance.

Following is some information on specific Bay fish to help your students prepare for their program.

BOTTOM DWELLERS:

FLATFISH California Halibut, Diamond Turbot, Starry Flounder

Camouflage: Flatfish have an amazing ability to change color depending on the type of ground cover in the area. Thus, if a brown-colored flatfish living on a muddy bottom suddenly found itself in an area covered with white and brown rocks, its color would quickly change to a mottled white/brown appearance to blend in with its new surroundings!

Food: Eat mainly worms, tiny crabs, clams, or small fish.

Predators: Sharks, marine mammals, and humans.

Fun Fact: Flatfish actually begin life with one eye in the traditional position on each side of the head. Immediately after birth, however, one eye begins migrating across the head to lie next to the other eye on the opposite side. Because the fish lays flat on one side, having two eyes on one side is a distinct advantage in sighting both predators and prey!

BENTHIC ECOLOGY

A benthic invertebrate is an animal without a backbone that lives down in the bottom sediments. As a group, the invertebrates are highly successful in the natural world and well adapted. They are found everywhere: on land and in the soil, in freshwater, in saltwater, and in the bodies of other animals. In fact, invertebrates make up 97% of all the animals on the earth. This section will be devoted to the intriguing group of invertebrates that make the Estuary their home.

Many people don't realize how many communities of invertebrates live in and on the muddy, bottom sediments of the S.F. Bay Estuary. This area is called the benthos, and is a habitat for many varieties of plant and animal life. Crabs, snails and sea squirts live on top of the Bay's mud, while clams, mussels and tube worms feel more at home in the mud. Each has its own set of adaptations to feed, move and hide from predators.

Following is information on some Bay invertebrates that may be included in your Discovery Voyage program.

BAY INVERTEBRATE CHARACTERISTICS

PHYLUM PORIFERA (pore-bearing animals)

Red Beard Sponge *Microciona prolifera*

Description: Very bush-like in appearance, often mistaken for a plant, with numerous finger-like projections.

Food: Eats bacteria and dead plant and animal material (detritus) by absorbing these particles from the water as it flows through their bodies.

Predators: Sea slugs (nudibranchs).

Origin: Atlantic Ocean.

Fun Fact: A sponge may also be thought of as a mini "hotel" or "apartment complex," as it provides an excellent habitat for other living creatures. One sponge may contain hundreds of tiny organisms. Sea anemones may be present, along with spider crabs, which are able to camouflage within the sponge.

PHYLUM MOLLUSCA (soft-bodied animals)

Asian Clam *Potamocorbula amurensis*

Description: Shells are white, tan or yellow. One shell is larger than the other producing a distinct "overbite".

Food: Filter feed on plankton.
Predators: Diving birds, crabs, and bottom feeding fish.
Origin: China and Japan.
Fun Fact: This clam was introduced by the ballast of ships in 1986, and has since spread throughout the Estuary.

Green Mud Mussel *Musculista senhousia*
Description: Smooth, small (2 cm) dark shells with wavy brown and green bands.
Food: Filter feed on plankton and detritus.
Predators: Shorebirds and bottom feeding fishes.
Origin: Introduced from Japan with the Pacific oyster.
Fun Facts: Mussels are like tiny sewing machines! To keep from getting tossed about in the waves and/or tides, mussels form sticky threads, called byssal threads, and anchor themselves to the mud at the bottom of the Bay. These threads then harden and keep the animals from being swept away!

PHYLUM ANNELIDA (segmented worms)

Tube Worm *Asychis sp.*
Description: The brown, tubular structure made of mud is actually the home of the tube worm, while the long, red, slender creature inside is the worm itself.
Food: Because it eats much of the dead plant and animal material decomposing on the bottom, the tube worm can be thought of as one of the trash collectors of the Estuary! They are also great recyclers.
Predators: Bottom feeding fish and crabs.
Origin: Introduced to the Estuary with the Eastern oyster.
Fun Fact: The tube is constructed of both mud and mucus. To construct a tube, the worm eats mud and digests the living and dead microscopic plant and animal particles found inside. When finished, it secretes the mud back out again, mixed with sticky mucus, which flows down the sides of its body like a coat of paint on a house. Gradually, the tube is formed and the worm lives protected inside.

PHYLUM ARTHROPODA (jointed limbs)

Spider Crab *Pyromaia tubercula*
Description: Pear-shaped crab with long, spindle-like legs.
Food: Uses front claws to eat algae and detritus.
Predators: Bottom fish, sharks and shorebirds.
Origin: Native to the Pacific Coast.
Fun Facts: This crab gets both its nicknames for good reason. The first is obvious because it clearly looks like a spider! The second name comes through observing the fuzzy appearance of its shell and legs. The crab takes pieces of its surroundings

and attaches it to its carapace and legs. This ensures camouflage and a meal when desired.

PHYLUM CNIDARIA (stinging nettle)

Orange Anemone *Diadumene cincta*

Description: Small, approximately 1 cm, flower-like body. usually pale pink or orange in color. Often found attached to the inside of empty shells, or on sponges.

Food: Zooplankton. Their flower-like appearance is due to several delicate tentacles flowing in and out of the solid tube-like column of its body. These tentacles are equipped with stinging cells which immobilize prey, then carry it down its tubular column and into its mouth.

Predators: Snails, seastars, sea slugs (nudibranchs).

Origin: Atlantic Ocean.

Fun Fact: If a sea anemone is left undisturbed for a few minutes, you can usually see its flowery tentacles appear.

PHYLUM CHORDATA

Solitary Tunicate or Sea Squirt *Mogula Manhattensis*

Description: Globular or "bag-shaped" body, usually translucent and yellowish in color

Food: Filter feed on plankton using two straw-like siphons to pull water in and out of its body.

Predators: Mainly sharks.

Origin: Atlantic Ocean.

Fun Fact: A tunicate's body is inflated with water. When a tunicate is gently squeezed, it will squirt out water like a fountain from one of its siphons; hence, its nickname!

GLOSSARY

ADAPTATION	Modification of an organism in order to survive within its habitat.
ALGAE	Primitive aquatic plants that lack true stems, roots and leaves. They are in their own kingdom.
BENTHOS	The substrate at the bottom of a body of water; the adjectival form of benthos is benthic.
BIODEGRADABLE	Something capable of being broken down to simple compounds, especially into harmless products, by the action of microorganisms.
BIODIVERSITY	The richness, abundance and variety of life across all trophic levels of which all ecological systems, including the planet earth, are comprised.

BIVALVE	A Mollusk having two shell hinged together. e.g. clam, oyster and mussel.
BRACKISH	Water that has more salt than fresh water but not as much as seawater.
BYSSAL THREAD	Tough threads of protein secreted by a gland in the foot of the mussel and used to attach it to rocks, piers etc.
CAMOUFLAGE	Method of hiding in which organisms blend in with their surroundings.
CARAPACE	In crustaceans, a hard portion of the exoskeleton that covers the fused head and thorax.
CARNIVORE	An animal that consumes other living animals.
COMMUNITY	A group of plants or animals living in the same area and depending on one another for survival.
CONSUMER	An organism that gets its nutrients by eating other organisms.
CRUSTACEAN	An animal with a hard outside shell, antennae, mandibles and compound eyes. e.g. crabs, shrimps and barnacles.
DECOMPOSER	An organism that breaks down organic material and releases simple substances usable by other living things. Examples of decomposers are bacteria and fungi.
DECOMPOSITION	The breakdown of substances into inorganic forms.
DEPOSIT FEEDER	An animal that feeds by ingesting substrate and filtering out the small organic particles on the substrate.
DETRITIVORE	An animal that eats detritus.
DETRITUS	Dead plant and animal material.
DICHOTOMOUS KEY	A tool used to identify organisms based on their physical features.
DISSOLVED OXYGEN	Oxygen that has dissolved in water and can be used for respiration.
ECOLOGY	The study of relationships between organisms and their environment.
EDGE COMMUNITY	A productive area where land and sea interface. This community, because of its proximity to land, receives huge inputs of sediment, nutrients and freshwater, which in turn supports a diversity of plants and animals.
ENDANGERED	An organism that is threatened with extinction.
ENVIRONMENT	The sum of all physical and biological factors that affect an organism.
ESTUARY	A semi-enclosed body of water where salt water and fresh water meet and mix.
EXOSKELETON	A hard encasement deposited on the surface of an animal, such as the outer covering of arthropods that provides protection from abrasion, predation, desiccation, etc.
FILTER FEEDER	An animal which extracts food particles by straining the water. Examples of filter feeders are clams, oysters, sponges and some fish.

FOOD CHAIN	A sequence of living organisms in an ecosystem in which members of one level feed on those in the level below and in turn are eaten by those in the level above them.
FOOD WEB	An assemblage of organisms in an ecosystem, including plants, herbivores and carnivores, which shows the relationship of "who eats whom."
FOOT	The wide, flat or wedge-shaped muscle of mollusks used for crawling, adhering and/or digging.
GEOLOGY	The study of the composition and structure of the earth.
GILL	An organ used for underwater breathing or respiration by fishes and some invertebrates.
HABITAT	The particular area in which an organism normally lives.
HERBIVORE	An animal that eats plants.
ICHTHYOLOGY	The study of fish.
INVERTEBRATE	An animal without a backbone.
MANTLE	An outer sheet of fleshy tissue (in mollusks) secreting the shell and forming the chamber to enclose the internal organs.
MOLLUSK	The second largest Phylum of animals. Mollusks have soft bodies, a foot, visceral mass, and a mantle. Most also have a shell made of calcium carbonate. Snails, clams, slugs, squid and octopus are examples of mollusks.
MUDFLAT	The salty soil area of land between the lowest low and highest low tide that is flooded with sea water daily and upon which very few plants grow.
NEAP TIDES	Low amplitude tides that occur during quarter moons, when the moon's pull is at a right angle in relation to the pull of the sun.
NEMATOCYST	In cnidarians, stinging capsules used in defense and gathering food.
NUTRIENTS	The raw materials necessary for continuing life processes.
OMNIVORE	An organism that eats both plant and animal material.
OVOVIVIPAROUS	Reproductive strategy where mother bear young that develop internally but are unattached to a placenta inside the mother (born live from an egg).
PHOTOSYNTHESIS	The process used by plants to make food; in this process light energy is used to combine carbon dioxide and water to make carbohydrates (sugar and starch); oxygen gas is given off as a by-product.
PHYTOPLANKTON	Algae, usually microscopic, which freely drift in the sunlit portions of the water column.
PLANKTON	Drifting aquatic plants and animals; the adjectival form of plankton is planktonic, and a planktonic organism is called a plankter.
POLLUTION	Harmful impact on the environment resulting from human activities.
PREDATOR	An animal that captures other animals for food.
PREY	An animal caught for food.

PRODUCER	An organism that makes its own food; an example of a producer is a green plant.
RESPIRATION	Process used by animals and plants to release energy from food; this process requires oxygen and releases carbon dioxide and water.
SALINITY	The amount of salt in the water. Measured in parts per thousand.
SALT MARSH	Salt-water wetland between terrestrial and marine ecosystems; salt marshes can also be seasonal or tidal wetlands.
SCAVENGER	An organism that is an opportunistic feeder; scavengers usually include dead and decaying animal flesh in their diets.
SIPHONS	The feeding tubes used by some bivalves (clams and oysters) to filter plankton.
SPECIES	A population of plants or animals that are able to produce viable of with each other and not with other species.
SPRING TIDES	Occurs every two weeks near the times of either the full or new moon. These are high amplitude tides that occur when the sun, moon, and the earth are lined up.
SYMMETRY	Correspondence in size, form, and arrangement of parts.
TENTACLE	A slender, flexible appendage.
TIDES	The daily rise and fall of the sea level along a shore, occurs twice a day on our local shores.
UPLAND	Ground that is elevated above the lowlands, marshlands, or rivers.
VERTEBRATE	An animal with a backbone. The back bone can be made of bone or of cartilage like in some fish (sharks and rays).
VIVIPAROUS	Reproductive strategy where mothers bear young that are nourished through a placental attachment (live birth).
WATER-VASCULAR	A system of canals, bulbs and appendages filled with sea water. This system is involved in locomotion in echinoderms.
WETLANDS	Areas that periodically have waterlogged soils, support plants adapted to wet soil, and are covered or occasionally submerged by water.
ZOOPLANKTON	Animal plankton.

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PRE-VISIT ACTIVITIES

You may want to ask your librarian to set aside ecology or marine science books for your class, or ask students to bring books and magazines from home to share.

POST-VISIT ACTIVITIES

WEB OF LIFE

Have the students stand in a circle. Ask the students about the habitat they just saw (this will work for any habitat). Ask them where in that habitat all energy begins, (sun).

- Hand the student who answered correctly a ball of yarn.
- Ask what uses the sun's energy to create food (plants). Have them name a plant they saw.
- Have the student with the ball of yarn (still hanging on to the end of the string) toss the ball itself over to the "plant" student.
- Ask, "Who uses plants for energy?" And continue this discussion using herbivores, carnivores, decomposers, and of course, humans,
- With each completed step, students continue to toss the yarn to each other around the circle, creating a complex and interrelated food web.
- Now pick a random student. Because of hunters, or pollution, or loss of habitat (several reasons apply), the component he or she represents has died and must sit down. As he does so, he inadvertently creates a tug on the yarn, thus affecting other aspects of the web of life. Every student, then, who feels a tug on the yarn they are holding is affected in some way by the death of that one individual, and must sit down and tug on their own yarn.

Eventually, all students will be seated and you can discuss the results

<u>ACTIVITY: Marshes and Mudflats Creature Feature</u>

Objective:

The objective of this activity is to familiarize and excite students about the creatures that live in the San Francisco Bay Estuary marshes and mudflats.

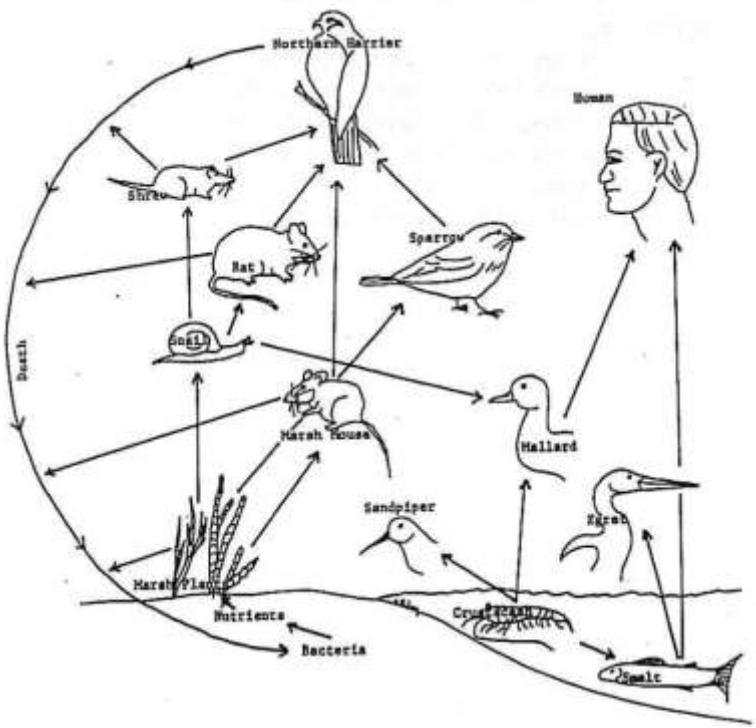
Procedure:

There are many possibilities for classroom activities using the “Creature Feature” information cards.

You may wish to conduct an “Each One – Teach One” with your students. Make enough copies of the creature information cards so that there is one featured animal per student when pages are cut apart. Let students choose a creature card randomly. Give students time to read the card or further research their chosen organism. Props and pictures are fun additions to this activity. Then, let the each one – teach one begin. Set up teaching “stations” around the room. Devise an organized way to have the students teach and learn from each other as they move between teaching stations.

Alternate activities could include:

1. The creation of a marshes and mudflats food web using the creature information cards and poster boards.
2. Human Impact Activity: Have students pick a creature information card and research the impacts that humans have on that specific organism.



MARSHES & MUDFLATS CREATURE FEATURE

FLATFISH: California Halibut, Diamond Turbot, Starry Flounder

Camouflage: Flatfish have an amazing ability to change color depending on the type of ground cover in the area.

Food: Worms, tiny crabs, clams or small fish.

Predators: Sharks and marine mammals.

Fun Fact: Flatfish usually begin life with one eye on each side of the body. Immediately after birth.

SHARKS: Leopards and Brown Smoothhounds

Description: Leopard sharks are gray with heavy black bars and spots on the body. Brown smoothhounds are solid, coppery-brown in color.

Food: Mainly small fish, shrimp, crabs and clams.

Predators: Humans

Fun Facts: Sharks have no bones; they are made of cartilage, which is the same material found in our noses. This gives them the ability to swim swiftly

SURFPERCH: Shiner and Barred Surfperch

Description: Perch are shaped like a deflated football. They dwell in the middle layers of the open water. Barred Surfperch have 6 -10 vertical stripes on each side. Shiner Surfperch have 2 - 3 yellow vertical stripes on each side.

Food: Mainly invertebrates like worms, clams, and snails. They may also eat algae or small fish.

Predators: Birds, fish and marine mammals.

Fun Facts: A front-positioned mouth and small teeth allow perch to eat small fish and other

SMELT: Topsmelt or Jacksmelt

Description: Smelt are long, silvery and torpedo shaped fish. They have a small mouth located at the front of their body.

Food: Plankton and small fishes.

Predators: Many different birds, fishes and marine mammals. Smelt are fished commercially and for sport.

Fun Facts: Smelt are schooling fish, which group together when threatened by predators. This behavior possibly confuses the predator into believing that the school is one big fish.

Red Beard Sponge

Description: Very bush-like in appearance, often mistaken for a plant, with numerous finger-like projections. The sponge is orange or red in color.

Food: Eats bacteria and dead plant and animal material (detritus) by absorbing these particles from the water.

Predator: Sea slugs (a.k.a. nudibranchs)

Fun Fact: A sponge may also be thought of as a mini hotel or apartment complex, as it is a colonial organism. Similarly, it provides an excellent habitat for other living creatures. One sponge may contain

Tube Worm

Description: The worm is red and lives in a brown, tubular structure made of the mud itself. **Food:** DECOMPOSER. The tube worm is thought of as a "trash collector" of the Estuary. **Predators:** Bottom feeding fish and crabs.

Fun Facts: The worm constructs it's tube of both mud and mucous. To construct a tube, the worm eats mud, & digests the microscopic food particles found inside. When finished, it secretes the mud, mixed with sticky mucus, which flows down the sides of its body like a coat of paint on a house.

Spider Crab

Description: It is a pear-shaped crab with long, spindle-like legs.

Food: Uses front claws to eat algae and other dead plant and animal material on the bottom.

Predators: Bat rays, sculpins and other bottom fish.

Fun Facts: This crab earns its common name because it looks like a spider. The crab actually decorates its body with camouflaging materials from the area in which it resides.

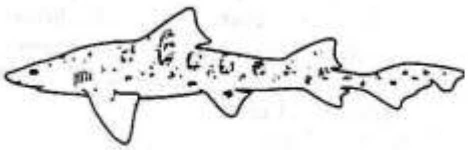
Green Mud Mussel

Description: A smooth, small shell that is a dark, color with wavy brown and green bands.

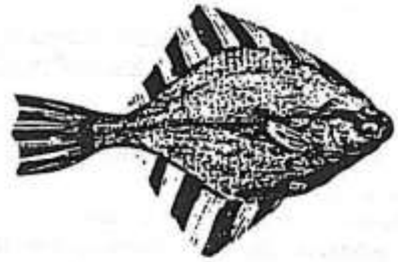
Food: Filter feeding on plankton.

Predators: Birds, crabs and bottom feeding fish.

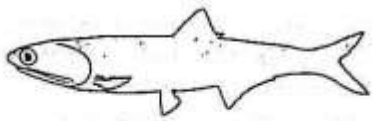
Fun Facts: Mussels are like tiny sewing machines. To keep from getting tossed about in the waves and or tides, mussels form sticky threads from a gland near their foot, which are called byssal threads. The threads are used to tie themselves to the mud at the bottom of the bay. These threads then harden and keep the animals from being swept away.



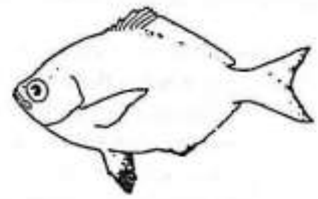
SHARKS



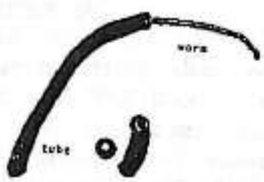
BOTTOM DWELLING FISH



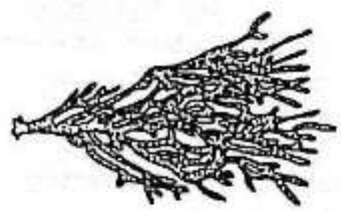
TOP DWELLING FISH



MIDDLE DWELLING FISH

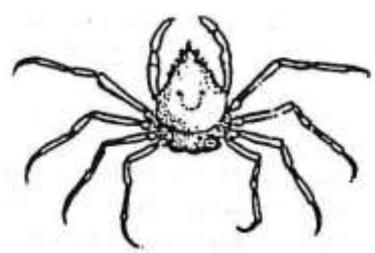


Tube Worm
Asychis sp.



Red Beard Sponge
Microciona prolifera

Green Mud Mussel
Musculus senhousia



Spider Crab
Pyromaia tubercula

ACTIVITY: Make a Marsh

Objective:

Students will explore how wetlands filter water that runs off the land. Students will learn how wetlands absorb water and the role this plays in replenishing ground water and flood control.

Background Information:

Wetlands are important in many ways. First, wetlands help prevent flooding by functioning as an absorbent area between dry land and a body of water. Second, wetlands filter and purify run-off water before it flows into the body of water. During heavy rainfall, wetlands act like a sponge, absorbing water that, without the wetland, would flow quickly and directly into the body of water, creating a potential flood. Similarly, without a wetland to filter particles out of the water during heavy rains, the water draining directly into the bay would be full of silt and pollutants. Polluted water can harm the organisms that live in it. Water with too much silt can cause many problems. Fish gills may become clogged making it difficult to breathe. Oysters, clams, and mussels can become clogged with sediment and die. Phytoplankton may not receive enough sunlight to survive due to the muddy water. In addition, fish and other organisms may not be able to see their food sources in the dirty water, birds and other animals that depend upon fish may not get enough to eat, and migrating fish may be confused by the silty water and fail to reach their spawning grounds.

You'll Need:

- A rectangular container (roasting pan, cake pan, or paint pan)
- Sponges
- Small cups (some with small holes poked into the bottom)
- A bag of potting soil
- Powdered drink mix (Tang works best)
- Clay (a big box from an art supplier or craft store)
- Optional: Monopoly, Lego, or other small toy buildings

Procedure:

Begin by reviewing what the group has learned about wetlands. What role do they play in the San Francisco Bay Estuary? Explain that the students will be constructing a model that will demonstrate some of the important functions of the marshes. Divide students into small groups of about four individuals. Note that this activity can be demonstrated to a large group. Go over the process of building the model. With younger students (K-5) you may wish to set up before hand. If the student construction method is chosen, then allow time to construct and test their models.

Marsh construction guidelines:

1. Spread a layer of clay in one half of the pan to represent the land. Leave the other half of the pan empty to represent the Estuary.
2. Shape the clay so that it gradually slopes down to the water. Smooth the clay along the sides of the pan to seal the edges. Optional: Add buildings and houses to the clay. You can also form meandering streams in the clay that lead into the body of water.

3. Fit the sponge snugly across the pan along the shallow edge of the clay. It is important that the sponge fits snugly inside the pan. It may be necessary to cut some of the sponges to create a solid sponge wall. See diagram for details. The sponge represents a wetland or marsh area located between the dry land and open water.

4. Flooding demonstration: Give each group of students a cup (the cup should have holes poked into the bottom of it to simulate a rain storm). Students should hold their empty cups over the clay land-portion of their model. Fill each group's cups with water to simulate a rain- storm. Observe the path and final destination of the rainwater.
   Ask: What happened when it "rained" on the land-portion of the model?
   Did any of the rainwater reach the estuary (the empty portion of the pan)?
   Why didn't most of the rainwater make it into the estuary?

   Now…. Instruct the students to remove the marsh (sponge) from their models. Simulate another rainstorm over the land by filling the cups with water and observe. The water should have "run-off" the land into the estuary.

   Ask: What happened this time when it "rained" over the land-portion of the model?
   How do wetlands help prevent flooding?

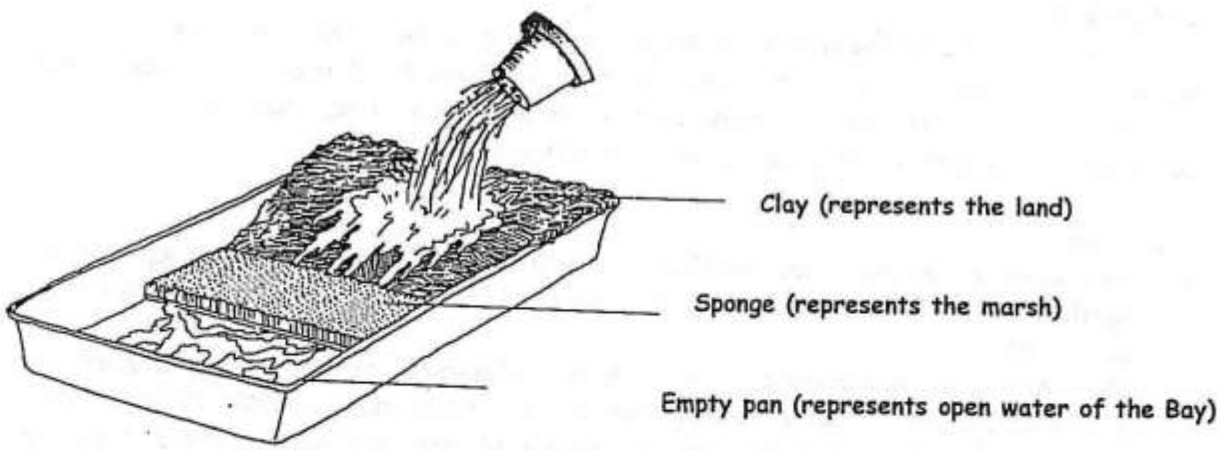
5. Filtering demonstration: Give each group of students a cup filled with some soil AND a cup filled with Tang (or other powdered drink mix). Ask the students to pour half of their soil onto the land-portion of their model. Then, ask them to pour half of their Tang onto the land-portion of the model. Explain that most land is not hard clay but a mixture of loose and harder sediments. Because so many humans live on the land surrounding the Bay, there are also pollutants on the land (hence the Tang).

   Simulate a rainstorm over the land as described above in the flooding demonstration: the first rainstorm should occur with the marshes intact, then with the marshes removed. Students should add additional soil and Tang between rainstorms.
   Ask: What happened to the soil when it "rained" over the land portion of the model?
   What happened to the Tang?
   What happened to the soil and Tang when the marshes were removed?

Conclusion:

Questions and ideas to reiterate after activity

What happened each time when it “rained” on the models?
Do the wetlands affect the speed of water runoff?
How do wetlands help prevent flooding?
What happens to the soil when it rains?
How does a wetland help purify water?
How might muddy water affect fish?
How might animals and plants be affected by the muddy water after heavy rains?
What specific kinds of pollutants might, in reality, wash into the Bay during rainstorms?
How does the presence of marshes limit the amount of suspended pollutants in the Bay water?
How might all this affect you?
How can we prevent these undesirable effects?



WRITING THANK YOU LETTERS

Write letters to the instructors and/or your class sponsor to tell them about the trip. When we receive letters and pictures back from the kids our instructors remember what a thrill it is to be teachers. The sponsors also enjoy getting direct feedback from the class and teacher to reinforce that they are making a difference for kids learning science. Please include the day, date and time of your trip so we can try to remember your group a little better.