Inland Voyage

Marshes & Mudflats Habitat Program

A discovery-based program for K-12 grade

EDUCATOR'S GUIDE

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Marine Science Institute's Educational Philosophy

As you plan an Inland Voyage Habitat Program with the Marine Science Institute, please consider how this opportunity fits within your overall instructional objective. What learning outcomes do you desire from the experience? What do you need MSI to make happen during the program? How well is the class positioned to move your desired outcomes toward a reality?

One strength of the Marine Science Institute's programs is their flexible role within the learning cycle. Is your group just beginning to generate interest in marine science **(engage)**? Or, are they "hooked" and, instead, are ready to actively experience, to form predictions and make observations **(explore)**? Have your students been developing understandings for some time, and are now ready to speak the language of marine science **(explain)**? Or, does your group have a mature understanding of marine science, perhaps including aspects that are far afield from the habitats covered in the Inland Voyage Habitat Program, and now the students are ready to relate that knowledge to their own backyard **(apply)**? Regardless of where you place your group on the learning cycle, there is a rich experience and a measurable success awaiting your program!

But…what you do before, during and after the MSI Inland Voyage Habitat Program will determine to a very large extent how strong of a partner the Inland Voyage Habitat Program will be in helping you meet your learning objectives.

INTRODUCTION TO THE INLAND VOYAGE HABITAT PROGRAM

This program guide is intended to further your understanding of Marine Science Institute's Inland Voyage Habitat program curricula and program logistics. Through the use of this guide, teachers will know what to expect from our program and will gain a better understanding of the "Marshes and Mudflats" habitat. A "Creature Feature" section is included within the activity pages. This section is designed to help your students prepare and generate excitement for the marshes and mudflats habitat. The goal of the program is to instill in the students an appreciation for this diverse habitat and an understanding of how humans interact with the environment.

PROGRAM LOGISTICS

The Inland Voyage program is delivered to a school, library or camp by a vehicle called the Marine Science Mobile. The Marine Science Mobile is a paneled van that pulls a trailer-mounted, mobile aquarium behind it. Since this unit is both transport and life support for the marine organisms, the programs are presented outside and/or close to the Marine Science Mobile. We need an area accessible to the van that is large enough to set up a two-station program for up to 40 students. This area can be grassy or paved, and shade is always appreciated. If the area is separated from recess activities or any other traffic, the students will be more focused and attentive. Ultimately they will get more out of the experience if these factors are considered. Special arrangements due to weather conditions can be made if necessary.

There are seven different and exciting Inland Voyage programs that the Marine Science Institute offers to schools and groups. Five of these programs focus on marine habitats: Rocky Intertidal, Sandy Beach, Kelp Forest, Marshes and Mudflats, and Open Ocean. The two additional programs focus on groups of animals in or near the San Francisco Bay Estuary: Bay Fish and Bay and Ocean Invertebrates. Activities for all of these programs are designed to be grade appropriate for Kindergarten to High School grade levels. The programs are all "hands-on" and discovery based, meaning that we give students the animals and equipment necessary to discover sensory or factual information about the animals and their habitats. Two instructors will guide the group through a fun-packed, fifty-minute exploration of these fascinating worlds. One class can experience more than one habitat on a given day, but due to van space and set-up needs, we can only offer two different types of programs per each visit to the school.

Our marine science instructors are specially trained to teach all ages with interesting and innovative methods that encourage interaction and problem solving. Our basic curriculum for each program is described in detail here and should prove to be quite challenging. However, we encourage you to tailor your program by telling us about a particular *theme* that your class has been studying and what level your class is at-*engage, explore, explain, or apply*. **Please fill out the student assessment form and return via mail or fax.**

PROGRAM LENGTH, GROUP SIZE, AND GRADE

Each program allows up to 40 students to participate and is 50 minutes in total length. The two instructors will give a five-minute introduction and then the class will divide into two groups, with each group participating in two 20-minute stations. To expedite this transition, we ask that the class be divided in half prior to our arrival. The program will wrap up with a brief five-minute closing discussion. We also schedule a ten-minute window between programs. The ten-minute intermission is essential to the well-being of the animals and enables staff to set-up for the next program.

ROLE OF ASSISTING ADULTS

In order to keep program costs at a minimum, we require the participation of at least two adults. The adults are encouraged to participate in various facets of the program such as group management, animal handling, and small group activities.

MARSHES AND MUDFLATS HABITAT PROGRAM DESCRIPTION

During this 50-minute program, students will discover how fish and invertebrates are adapted to this intertidal environment. A short introduction to the habitat will be given to your group as a whole. Then the students will be divided into two equal groups, and they will rotate between two stations, guided by MSI's Marine Educators. The "stations" will focus on fish that thrive in the sloughs of the marshes, and invertebrates that inhabit the mudflats. Students will see and touch animals such as surfperches, flatfish, snails, worms, clams, crabs and more.

Basic Ecological Concepts

Ecology is the study of the relationships between organisms and their environments. An ecologist asks questions. Where does this organism live? 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 emerge. Understanding the following basic ecological concepts will help us appreciate the complexity of life residing in the various aquatic habitats covered in the Inland Voyage Habitat program.

Everything is connected to everything else!

Perhaps the easiest place to see interdependence in the environments is to look at food. All of the food on this planet is made available initially by plants through the process of photosynthesis. Herbivores are animals which depend directly on plants for food. Carnivores eat herbivores. Take away all the plants and there would be no more animals. Is it possible for a plant, then, to exist independently of all other organisms? No. Although it does not eat animals, 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.

Everything depends on something else!

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, so if there were no sun, there would be no life. You can probably think of many more examples of how organisms are interdependent on their environments.

Everything must go somewhere!

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 recycling. Any plant or animal that does not become food for some animal becomes food for decomposers when it dies. Decomposers free the nutrients so they may 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 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 do. 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 a plant 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 monitor 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.

MARSHES AND MUDFLATS

An ecosystem is a community of plants and animals and the environment in which they live. San Francisco Bay has distinct ecosystems, some of which are covered with water and some which are not. These ecosystems are divided into open water, salt marsh, mud flat, salt pond and upland areas. Many of the estuary's animals and plants con 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 ocean tidal fluctuations and currents, and as a result, the water of San Francisco Bay is termed brackish; its salinity ranges from approximately 15 to 30 parts per thousand (ppt) depending on rainfall and other factors. This salinity range for the Estuary compares with less than 1 ppt for fresh water (lakes and rivers) and 34 ppt for normal seawater.

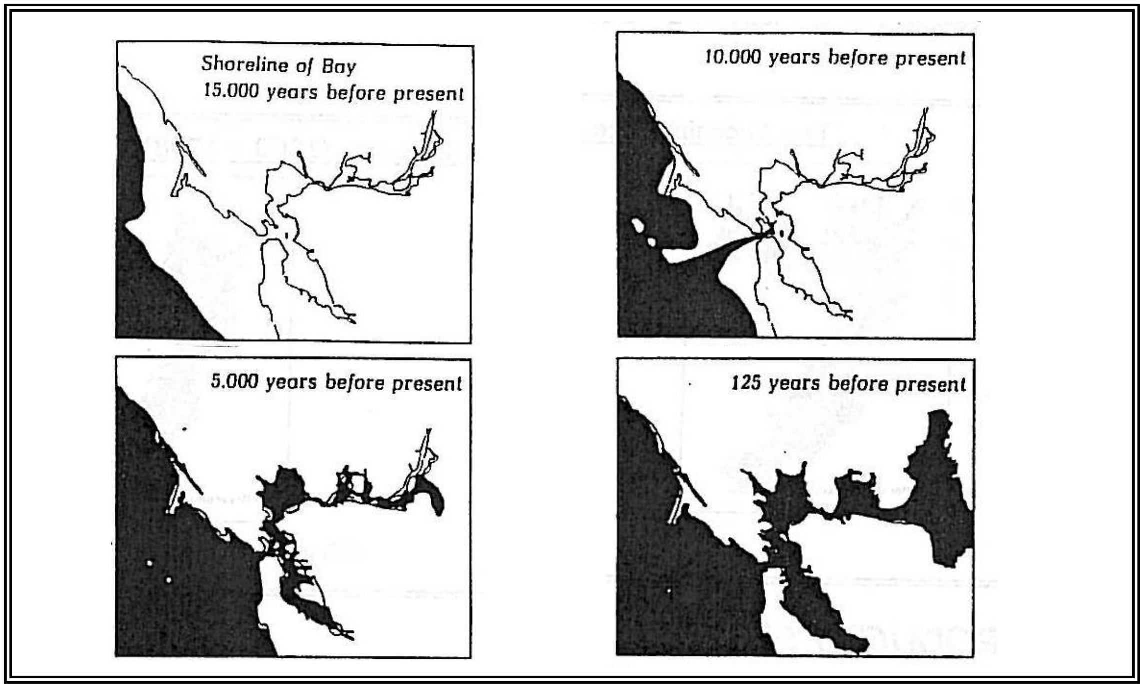
This rich complex ecological system supports the largest remaining marshes in the state, yet only about 20% of the bay's natural wetlands still exist. In comparison to the 190,000 acres of original tidal marsh, there are only about 40,000 acres of tidal marsh remaining around the Estuary today. Almost all of the destroyed marsh habitat was either filled or diked for human land use.

These remaining marshes are essential habitat for twenty species of endangered plants and animals use the habitat during at least a part of their lives. The San Francisco Garter Snake, the Salt Marsh Harvest Mouse, and the California Clapper Rail are examples of some of these endangered species. Migrating birds and waterfowl also utilize this ecosystem. Nearly half of the waterfowl and shorebirds migrating on the Pacific Flyway pass through the Estuary each year. The marshes and mudflats provide food and shelter for them on their journey.

GEOLOGIC HISTORY

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

As the glaciers slowly melted, the ocean waters rose. Ten thousand 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 thereafter, the water level rose rapidly, about one inch per year. At this rate, the shoreline advanced 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.



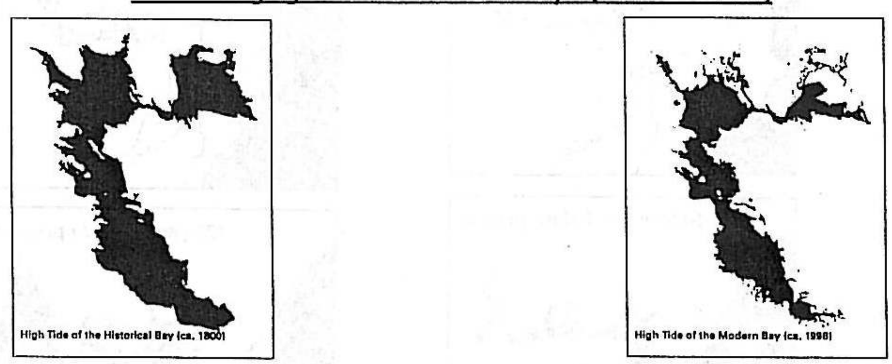
HUMAN HISTORY

Native Americans (*Ohlone*) occupied the shores as early as 3,500 years ago. The abundance of food and the mild climate supported over 10,000 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 passed 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 became severely polluted and over 60% of the Bay was filled or levied off from tidal action. In 100 years, the larger Bay territory decreased from about 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.

The Changing Size of the Estuary (1800 – 1998)



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INTRODUCED SPECIES

Scientists estimate that there are now about 150 non-native species living and reproducing in Bay waters. The first invasions occurred via the ballast water of ships in 1848, when gold seekers sailed into the area in masses. Ballast water is a term for water that is stored in the hold of the ships, and is used to stabilize large vessels. Once the vessels arrive in port, the ballast is flushed out, instantly transporting a myriad of foreign organisms into the Bay. Many foreign invertebrates have been particularly successful in adapting to the San Francisco Bay environment, and have taken over habitats that once belonged to native species. For example, the Asian Clam *Potamocorbula sp.* was brought over by ship ballast and was successful in taking over the bottom of the North Bay during the 1990's. This introduction resulted in the decrease of phytoplankton populations. The introduction of the red fox, *Vulpus fulva,* caused clapper rail, *Rallus longirostris,* populations to decrease so drastically that they are now on the endangered species list. (The fox preys on the eggs of the rail!). Exotic or Introduced species are now being more closely studied as an environmental phenomenon that could obliterate many native species in the Bay.

ESTUARINE ECOSYSTEMS

1. Open Water Ecosystem

The open waters of the estuary are a very special kind of environment. As the largest habitat in the Estuary, open water extends from the Delta to the Golden Gate and includes Suisun, San Pablo, and San Francisco Bays. The rivers and streams that empty into the Delta carry many nutrients from the land, as does the tidal cycle, which allows a vital exchange between the ocean and the Bay.

The Estuary supports some commercially important fish. Currently, there are two small commercial fisheries for herring and bay shrimp within the San Francisco Bay. Anadromous fish, which live some or all of their adult lives in salt water, but later move upstream into fresh water to spawn, are the most important class of sport fish in the Bay Area. These species include Chinook salmon, steelhead trout, striped bass, white and green sturgeon, and American shad.

Large predators of the open ocean do not enter the estuary frequently. Protection from predators and an abundance of food make this a good place for the young of many species to live. Many economically important fish spend part of their life cycle in an estuary. For this reason, estuaries are sometimes called the nurseries of the sea. The rich diversity of fish, in turn, provides feeding opportunities to harbor seals and diving birds. Even shallow open water is critical for invertebrates, ducks and various shorebirds.

2. Mudflat Ecosystem

At low tide, this muddy, intertidal ooze may appear to be lifeless, but by looking at it more closely you 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, these mud dwellers burrow into the sediment. In winter, thousands of birds migrate from nesting areas in Canada and Alaska and 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 flounder (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.

3. Salt Marsh Ecosystem

Salt marshes serve as a transition zone between the open water and mud flats of the Bay and the dry upland areas. It is the ecosystem that was once predominate in the Estuary. Today, less than 20% 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 (salt loving plants), have adapted to the salt marsh. They excrete the salt through special cells, called stomata, or they may even repel salt from their roots.

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 particles 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 material 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 orange parasitic, marsh dodder. The pickleweed accommodates the salt by storing it in the pickles at the top of the plant, which eventually turns pink or red and flakes off.

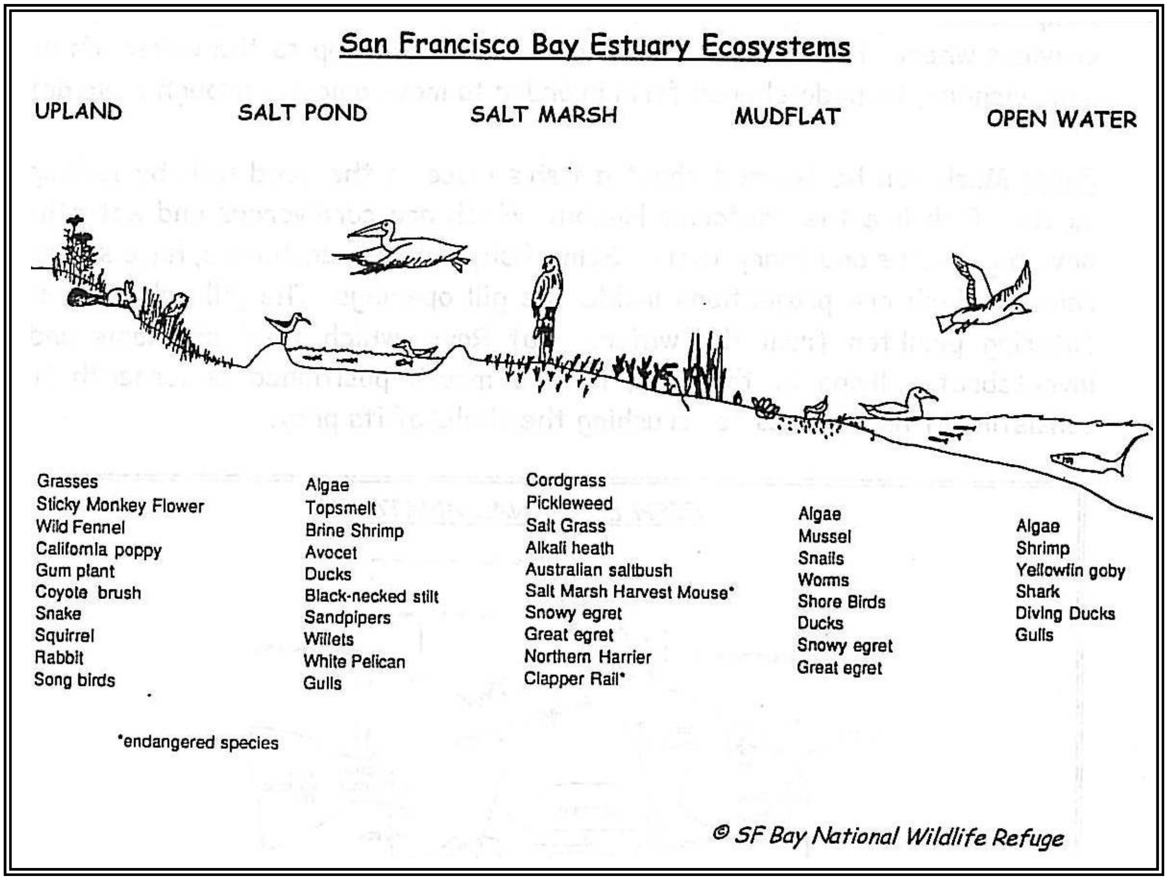
Salt grass grows in the high marsh zone above the pickleweed and excretes salt from its leaves through special glands. Other plants characteristic of the high marsh zone are Australian saltbush and alkali heath.

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 California Clapper Rail. The clapper rail nests in the cordgrass and feeds at low tide on mussels, clams and shore crabs. Once an abundant bird, the Clapper Rail now numbers less than 700 individuals.

4. 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 in this area is the aforementioned red fox. 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 biking and hiking trails, and shoreline parks are a valuable resource for many people to enjoy.



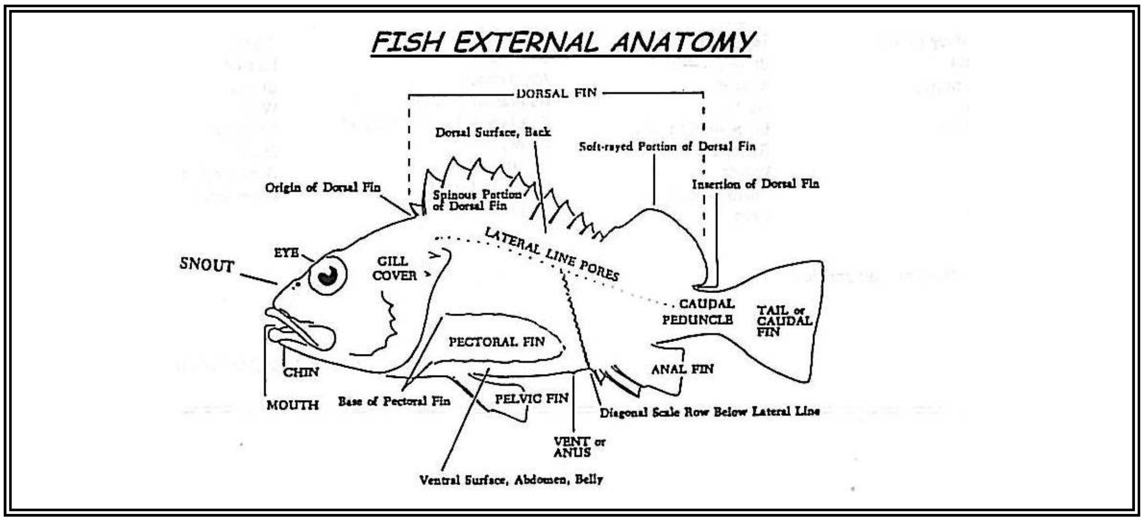
BAY FISH

Perhaps the most familiar of all the organisms that live in the bay are the fish. If an animal lives in the water, has a backbone, breathes with gills, is cold-blooded, which means it has the same internal temperature as its surroundings, and has fins, then chances are the animal is a fish. The study of fish is called Ichthyology. Fish are nekton, meaning they swim in the open water. This section focuses on the fish most likely to be seen in the Bay.

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 tells a story.

Shape: Fish that live on the bottom are often flat or vertically depressed, in order to conform to the surface on which they live. Mid-water fish are often laterally compressed, which means that the fish is squished on the sides. This laterally compressed body shape allows for ease of movement through the grasses and crevices where they forage. Fish that live near the top to the water often have a long, slender, torpedo-shaped form in order to move quickly through wave action.

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, which are projections inside the gill openings. The gill rakers function in filtering plankton from the water. Bat Rays, which feed on clams and other invertebrates living in the mud, have a mouth positioned underneath its body consisting of hard plates for crushing the shells of its prey.



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 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 help keep the fish upright. In some cases they help make the fish move forward.

Camouflage: Another external physical adaptation is the coloration they have developed to avoid detection by their predators. The black bars of a 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. Fish that have counter-shading possess a dark color on their back and a light color on the bottom. This helps them to blend in with the darkness of the water and the bottom when seen from above and the lightness of 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 air, a fish's gills must be more efficient than lungs. Numerous filaments on the gill rakers, which support the filaments, are intended to increase the surface area of the gill, thus allowing a 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 or 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 line, which runs the length of the both sides of their body. The lateral line detects pressure changes in the water and enables the fish to register movement and distance.

BAY INVERTEBRATES

An invertebrate is an animal without a backbone. 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 earth.

Many people don't realize how many invertebrates live in and also on the muddy bottom sediments of the San Francisco Bay Estuary. This area is called the benthos, which means bottom, and is a habitat for many varieties of plants and animals. 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.

For specific information on invertebrate adaptations and feeding strategies, please refer to the "Creature Feature" Activity on pages 15-17 and the Invertebrate Buffet Activity on pages 20-22.

PLANT AND ANIMAL SPECIES LIST OF SAN FRANCISCO BAY ECOSYSTEMS

- ***Endangered species are indicated with a preceding bullet***

OPEN WATER ESTUARY

PLANTS:

Diatoms (varieties)
Red Algae
Seaweed -*Enteramorpha sp.*

ANIMALS:

Invertebrates

Copepod - *Harppacticoid sp.*
Spider Crab - *Pyromaia tubercula*
Tube Worm - Asychis sp.
Green Mud Mussel - *Musculus senhouusia*
Asian Clam - *Potamocorbula amurensis*

Vertebrates

Leopard shark - *Triakis semifasciata*
Bat Ray - *Mylobatis californica*
Starry flounder - *Platichthys stellus*
Winter run Chinook Salmon - Salmenoid

MUDFLAT ECOSYSTEM

PLANTS:

Anaerobic Bacteria - *Bacillus sp.*
Eel grass - *Zostera latifolia*
Cord grass - *Spartina foliosa*

ANIMALS:

Invertebrates

Mud snail - *Hyanassa obsolete*
Spaghetti worm - *Thelepus crispus*
Yellow Shore Crab - *Hemigraspus oregonensis*
Isopod - *Syniodotea laticauda*
Japanese littleneck clam - *Venerupid japonica*
Shrimp
Worms
Oyster drill snail

Vertebrates:

Great Egret - Casmerodius Albus
Black Crowned night Heron - Nycticoraz nycticoraz
Black-necked stilt - Himantopus mexicanus
American Avocet - Recurvirostra Americana
Shiner Surfperch
Starry Flounder
Other fish

SALT MARSH ECOSYSTEM

PLANTS:

Cordgrass - *Spartina foliosa*
Pickleweed - *Salicornia virginica* and *Salicornica europea*

Marsh Dodder - *Cuscuta salina*
Salt Grass - *Distichilis spicata*
Fennel - *Foeniculum vulgare*

ANIMALS:

Invertebrates:

Pygmy Blue Butterfly - *Brephidium oxilis*
Salt Marsh Mosquito - *Aedes Squamiger* and *Aedes dorsalis*
Barnacle - *Balanus sp.*
Brine Fly - *Ephydra sp.*

Vertebrates:

- California Clapper Rail - *Rallus longisrostris*

Great Blue Heron - *Ardea herodias*
Snowy egret - *Leucophoyx thula*

- Alameda Song Sparow -

Mud Goby - *Clevelandia iox*
Jack Rabbit - *Lepus californicus*
Red Bellied Harvest Mouse - *Reithrodontomys raiventris*

- Salt Marsh Harvest Mouse - *Reithrondontomys megalotis*

San Francisco Garter Snake - *Thamnophis elegans*

UPLAND ECOSYSTEM

PLANTS:

Mustard - *Brassica campestris, Brassica nigra*
Hemlock - *Conium maculatum*
Coyote Bush - *Baccharis pilularis*
California Laurel - *Umbellularia californica*

ANIMALS:

Invertebrates:

Crane Fly - *Tpulatrivittata*
Mosquito - *Aedes squaiger*
Cabbage butterfly - *Pieris rapae*

Vertebrates:

Northern Harrier - *Circus cyaneus*
Red-tailed Hawk - *Buteo jamaicensis*
Burrowing Owl - *Speotyto cunicularia*
Western fence lizard - *Scelporus occidentalis*
Barn swallow - *Hirundo rustica*
Ground squirrel - *Citellus beecheyi*

CLASSROOM ACTIVITIES FOR MARSHES AND MUDFLATS STUDIES

ACTIVITY #1: Marshes & Mudflats Creature Feature

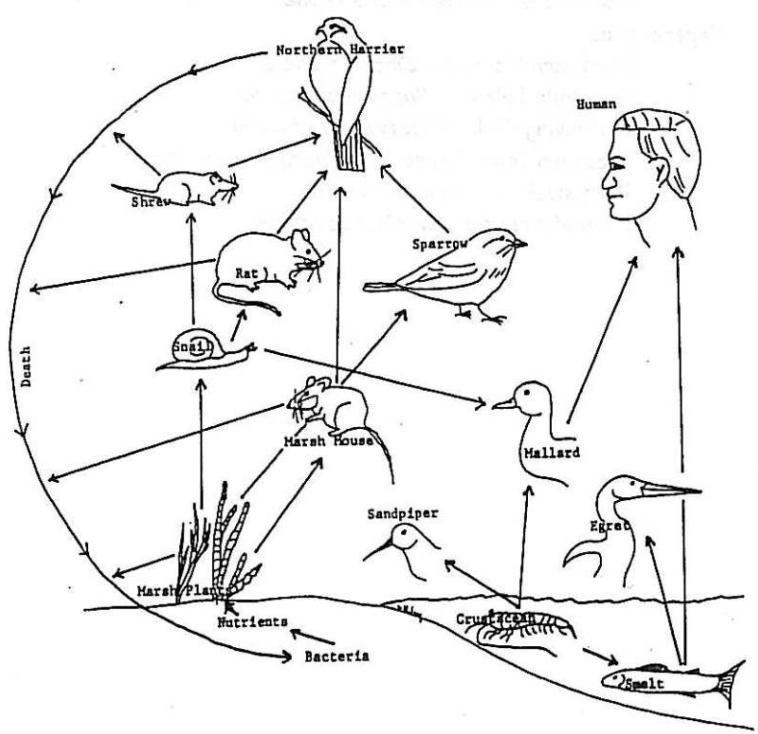
Objective:
The objective of this activity is to familiarize and excite students about the creatures that live in the San Francisco Bay Estuary marshes and mudflats.

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.



M A R S H E S & M U D F L A T S C R E A T U R E F E A T U R E

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, however one eye begins migrating across the head to lie next to the other eye on the opposite side.

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 and have optimal maneuverability. They can hear prey up to one mile away. Although they have generally poor eyesight, they have a great sense of light contrast.

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 invertebrates.

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.

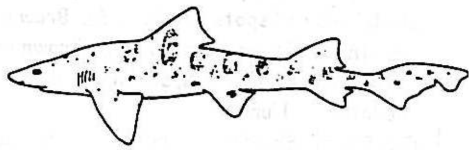
Red Beard Sponge
Description: Very bush-like in appearance, often mistaken for a plant, with numerous finger-like projections. The sponge is orange or red in color.
Food: Eats bacteria and dead plant and animal material (detritus) by absorbing these particles from the water.
Predator: Sea slugs (a.k.a. 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 hundreds of tiny organisms.

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.



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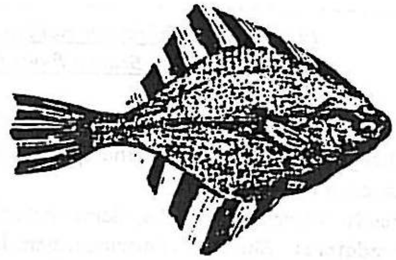
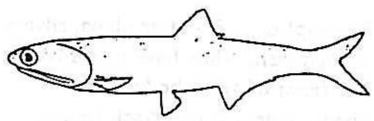
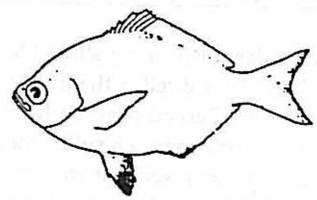


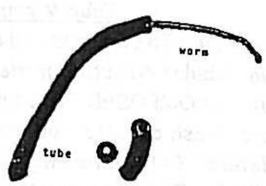
BOTTOM DWELLING FISH



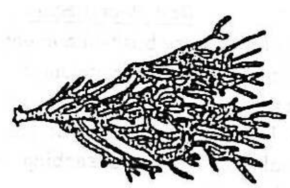
TOP DWELLING FISH



MIDDLE DWELLING FISH

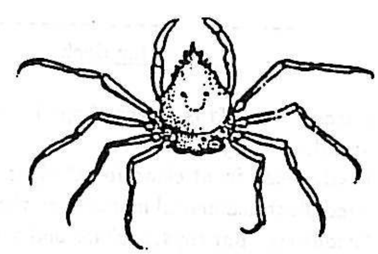


Tube Worm
Asychis sp.



Red Beard Sponge
Microciona prolifera

Green Mud Mussel
Musculus senhousia



Spider Crab
Pyromaia tubercula

<u>ACTIVITY #2: Make a Marsh</u>

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?

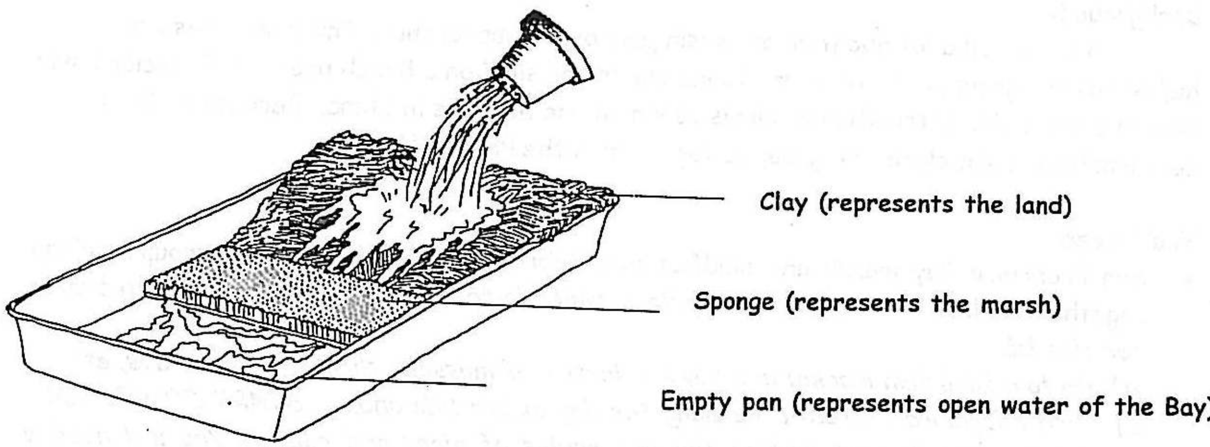
5. Filtering demonstration: Give each group of students a cup filled with some soil AND a cup filled with Tang (or other powdered drink mix). Ask the students to pour half of their soil onto the land-portion of their model. Then, ask them to pour half of their Tang onto the land-portion of the model. 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:

<u>Questions and ideas to reiterate after activity</u>
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?



ACTIVITY #3: Invertebrate Buffet

Objective:

Students will learn through observation how invertebrates move, eat, and defend themselves from predators.

Background:

We can tell a lot about an organism just by its appearance. Invertebrates are a highly diverse group, yet, the clams found under the sand on a beach near San Francisco may have the same characteristics as clams found on the beaches in China. Because of their commonalties, both clams are grouped together in the Phylum Mollusca.

You'll need:

- San Francisco Bay marsh and mudflat invertebrates. Enough for each group working together in class. *There are two options available to collect a variety of invertebrates for this lab.*
  - A) *Go to a local fish market and buy a selection of mussels, shrimp, clams, crabs, etc.*
  - B) *Visit a local waterfront area along the Bay at low tide and……. START COLLECTING! Good places to look include the undersides of piers and rocks. You will need a California Department of Fish and Game Collection Permit. Permits cost about $42 and last for two years.*
- Paper plates, paper towels, and small scissors (if you are working with dead animals)
- Petri dishes and extra Bay water if working with live animals
- Student Handout: Invertebrate Buffet Chart
- Teacher Handout: Invertebrate Buffet Answer Chart
- Field Guide (optional) or "Creature Feature" page from previous activity.

Procedure:

1. Initiate a discussion on invertebrates and adaptations necessary to survive on a sandy beach. What are some animals that you would expect to find on or under the sand at the beach? What adaptations do some of these animals have to protect themselves from the abrasive sand, from predators, from the drying sun, etc.?
2. Initiate a discussion on feeding strategies for invertebrates. Students must understand the difference between predators, scavengers, filter feeders, suspension feeders, and deposit feeders before the activity begins.
3. Introduce or reintroduce the necessary vocabulary words needed for the activity i.e. invertebrate, benthos, detritus, filter feeder, prey, scavenger, camouflage, and phylum.
4. Hand out a selection of the invertebrates, and other materials, including the Student Handout (one per student).
5. Students will examine the animals using all of their science skills (observing, communicating, comparing, categorizing and relating) while working with the animals and complete the Invertebrate Buffet chart. It may not be possible to figure out all of the answers with complete certainty, but tell the students to make their best hypotheses based on what they already know and what they observe.

INVERTEBRATE BUFFET

Data Sheet

NAME: ______________________________

DATE: ______________________________

SPECIES OR TYPE	*SKETCH*	*HOW DOES IT MOVE ?*	*WHAT & HOW DOES IT EAT?*	*WHO IS ITS PREDATOR?*	*HOW DOES IT PROTECT ITSELF ?*

Possible words to use:

Filter feeder
Suspension feeder
Burrows or digs
Scavenger
Predator
Camouflage

INVERTEBRATE BUFFET

Teacher Answer Sheet

SPECIES OR TYPE	SKETCH	HOW DOES IT MOVE ?	WHAT & HOW DOES IT EAT?	WHO IS ITS PREDATOR?	HOW DOES IT PROTECT ITSELF ?
Mussel		Anchors with byssal threads. Has a foot.	Plankton- Filter Feeder	Humans, bottom fish, birds, snails (predatory)	Hard shell, Ability to anchor itself with threads
Snail		Muscular foot	Some eat shelled animals by drilling a hole	Birds, bottom feeding fish	Hard shell, Trap door over shell opening
Worm		Burrow, wriggle	Detritus, algae, other worms	Bottom fish, crabs, and birds	Protective tube, jaws
Shrimp		Flips tail to move backwards	Mysids, clams, & algae	Many fish, humans, & birds	Camoflauge
Crab		Walks sideways	Dead matter (detritus) - Scavenger	Humans, Birds, & Bottom fish	Exoskeleton, & pincers
Clam		Burrows with foot	Plankton - filter feeder	Shorebirds, bottom fish, and humans	Shell

Possible words to use:

Filter feeder
Suspension feeder
Burrows or digs

Scavenger
Predator
Camouflage

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.
Appendage: An arm or other limb or projection that branches from an animal's body. e.g. crabs' legs, shrimp antennae.
Benthos: The bottom dwelling community; 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.
Bivalve: A Mollusk having two shell hinged together. e.g. clam, oyster and mussel.
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 imitate the appearance of their surroundings.
Carapace: In crustaceans, a hard portion of the exoskeleton that covers the fused head and thorax.
Carnivore: An animal that eats other animals. "A meat eater".
Cartilaginous: Fish are divided into two main categories, those with bony skeletons and those with skeletons made of cartilage. the former are called teleosts or bony fish, the latter elasmobranchs or cartilaginous fishes.
Community: A group of plants or animals living in the same area and depending on one another for survival.
Consumer: An organism that consumes meat by preying on animals or consumes plant matter.
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.
Detritus: Dead plant and animal material, and the bacteria decomposing them.
Dorsoventrally compressed: flattened from top to bottom.
Ecology: The study of relationships between organisms and their environment.
Environment: The sum of all physical and biological factors that affect an organism.
Estuary: Semi-enclosed coastal body of water where fresh and salt water mix.
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, showing the relationship of "who eats whom."
Foot: The wide, flat or wedge shaped muscle used for crawling, adhering and/or digging is mollusks.
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 which feeds on plant material.
Ichthyology: The study of fish
Intertidal: The area between the high tide mark and low tide mark on the seashore.
Invertebrate: An animal without a backbone.
Laterally Compressed: Flattened from side to side.
Nutrients: The raw materials necessary for continuing life processes. Food for the plants:

Phosphates and Nitrates.
Mantle: An outer sheet of fleshy tissue secreting the shell and forming a chamber to enclose the internal organs in mollusks.
Mudflat: The salty soil area of land between the lowest low and the highest low tide that is flooded with sea water daily and upon which very few plants grow.
Necton: Swimming animals of open water; the adjectival form of necton is nectonic.
Nematocyst: In cnidarians, stinging capsules used in defense and gathering food.
Niche: The way of life of an organism, including the habitat, food, nest sites, and other things it need to survive
Omnivore: An organism that eats both plant and animal material
Parts Per Thousand: A unit of measure of the concentration of dissolved substances; equivalent to grams per liter. A smaller unit, parts per million, is equivalent to milligrams per liter.
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.
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 food (does not have to eat); an example of a producer is a green plant.
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 will eat just about anything; scavengers usually include dead and decaying animal flesh in their diets
Sedimentation: The process of material settling to the bottom of the Bay. The greatest single impact of sedimentation in the Bay occurred between 1853-1884 when the Gold Rush miners used high-pressure hoses to mine the soils of the Sierra in search of gold.
Sessile: Not moving from place to place.
Shrimp: A long-tailed crustacean having a fused head and thorax and a s
segmented abdomen.
Species: A group of organisms whose members share a common gene pool and who interbreed to produce fertile offspring.
Siphon: A tube-like structure in certain marine animals, such as clams and octopi, allowing the passage of water.
Tentacle: A slender, flexible appendage.
Tide: The daily rise and fall of sea level along a shore, occurs twice a day in local waters.
Turbidity: The clouding of naturally clear liquid due to suspension of fine solids.
Upland: Ground that is elevated above the lowlands, marshlands or rivers.
Wetlands: Areas that periodically have waterlogged soils, support plants adapted to wet soil, and are covered occasionally submerged by water.

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