

**MARINE SCIENCE INSTITUTE**  
**INLAND VOYAGE INVERIBRSTE EDUCATORS' GUIDE**

**July 2008**

**INTRODUCTION**

Founded in 1970, the Marine Science Institute is a private, non-profit organization dedicated to providing interdisciplinary science education programs that cultivate a responsibility for the natural environment. Over the years, MSI has developed many different programs for students and adults of all ages, including a research trip called the Discovery Voyage program, seven outreach programs called the Inland Voyages, and various programs that occur on-site, such as the Shoreside and Ocean Lab programs. We are continuing to grow and develop by striving to make each program a science learning experience that will be enjoyed and remembered for many years.

Our goal is to actively involve students through hands-on science activities. Through these activities, students develop a deeper understanding and appreciation of our marine environment, simultaneously defining their own role within it. The California State Science Framework themes of energy, stability, evolution, patterns of change, scale and structure, and systems and interactions can be readily presented through this program. Given the flexibility of our programs, instructors can vary particular themes and apply them to different grade levels, thereby supporting this new approach to science education. If you have not already done so, please take a moment to fill out and return an assessment form for your class.

**MARINE SCIENCE INSTITUTE'S MISSION**

Our mission is to provide interdisciplinary science education that cultivates a responsibility for the natural environment.

The Institute achieves this goal through innovative marine science education programs that:

- Place students of all ages in contact with the natural environment;
- Emphasize the interdependence of all living things, their connection to the physical environment, and the special responsibilities of humans to the natural world;
- Facilitate active learning through the use of observation, critical thinking, and problem-solving skills in a cooperative setting; and
- Instill confidence, encourage involvement, and inspire accomplishment by providing positive role models.

**INLAND VOYAGE INVERTIBRATE PROGRAM LOGISTICS**

The Marine Science Institute offers many different types of Inland Voyage programs. The Inland Voyage Invertebrate program compares invertebrate communities living in the San Francisco Bay to those living along the Northern California coast. The program is “hands-on”

and discovery based, meaning that we allow students to handle live animals while asking them to infer relationships between each animals form and function. Two instructors will guide the group through a fun-packed, fifty-minute exploration of our bay's fish species.

#### LENGTH, GROUP SIZE, and FORMAT

The program allows one class of up to 30 students to participate at a time 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. One group will begin by studying the rocky shore invertebrates of our coast , while the other group will begin with invertebrates of San Francisco Bay. 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, When possible, the program will begin on the hour. 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 ASSISSTING ADULTS

In order to keep program costs at a minimum, we require the participation of at least one classroom teacher or adult. Each group of students will be working with one instructor and any available adults. At each station, the groups will break into even smaller groups to study individual organisms. Our method of teaching is to ask thought-provoking questions that will lead students to their own answers. We ask that adults do not provide answers to the students, but let them discover the answers on their own.

### **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.

#### Everything is related to everything else

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.

#### 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. You can probably think of many more examples of how organisms are dependent 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 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 remember the motto Reduce, Re-use, Recycle. The earth can recycle its components naturally but humans must make special efforts to preserve the natural resources.

## **INTERTIDAL HABITATS**

An invertebrate is an animal without an internal supporting structure, better known as a backbone. As a group, the invertebrates are highly successful in the natural world and well adapted to many habitats. 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. Intertidal invertebrates are simply invertebrates living between the range of the highest and lowest tides. In this program we will compare the invertebrates of the San Francisco Bay to those of the Rocky Shore of the Pacific Coast and see how different habitats favor different adaptations.

### **San Francisco Bay Habitat:**

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. Unlike the Invertebrates of our coast, most of the invertebrates living in the bay are non-native, having been introduced to the bay through human activities. Invertebrates living inside San Francisco bay have less need for rugged bodies of their coastal counterparts but they must deal with the added stress or changing salinities since they live in an estuary.

### **Rocky Shore Habitat:**

The rocky shores of the Pacific coast have some of the world's richest intertidal life. These rocky shores are usually layered shale leading up to steep cliffs. The changing tide levels often form tidepools which are home to a huge diversity of marine invertebrates. These are regions of constant and radical change. During high tide the animals and plants are underwater, but during low tide they are exposed to pounding waves, drying wind, rain that dilutes salinity,

and air, which can be very hot or extremely cold. In addition to these stresses, intertidal animals are also exposed to predation from land animals such as sea gulls, sandpipers, and, unfortunately, humans. It's a tough life, and in order to survive, these intertidal dwellers have adapted to these kinds of adversity.

The intertidal zones extend from the highest wave-splashed rocks down to levels that are only uncovered by extreme low tides . There are five basic zones:

1. The splash zone is the uppermost zone that is closest to the cliff area, and is only covered during very high tides. It receives wind-blown spray which moistens animals such as blue-green algae, periwinkles, limpets and acorn barnacles. Barnacles are "clingers", and can close their shells and wait for the return of oxygenated, food-bearing water.
2. High tide is the next zone down, and may be exposed for 12 hours at a time. This area may have large rocks and boulders, which during winter storms can pound the animals at this level. Animals found here include the lined shore crab, California mussel, hermit crabs and turban snails.
3. The middle zone is less physically stressful, as exposure may last only six hours or less. It is the center of the intertidal region and has the most abundant number of inhabitants Giant, green sea anemones, sea stars, and purple sea urchins are a few of the species found here.
4. The low tide zone only exposed during times of the new or full moon (minus tides). It can be the largest zone, and has a complex diversity of animals competing for food and room to grow. Here, clinging animals are again apparent. Anemones resist drying at low tide by contracting their delicate feeding tentacles and looking like small stumps on the rock. Seastars can be found in clumps under rocks, using their tube feet to hold on. Mussels attach themselves to rocks by secreting tough byssal threads.
5. The subtidal zone is technically not an intertidal zone since it lies, by definition, below the reach of the lowest tides. Many of the animals in the low tide zone are also found in the sub tidal Zone.

**INVERTIBRATE CHARACTERISTICS.** The below invertebrates are some the most common animals used during this in-class presentation. Depending on time, class dynamics and the availability of specimens instructors may substitute similar species, or bring additional animals not on this list.

#### PHYLUM ARTHROPODA (joint-legged animals)

The largest single phylum, arthropods comprise eighty percent of all animal life, with at least 1,000,000 species! The group is ecologically diverse and inhabits every environmental niche with a high degree of success. This success is largely due to the adaptable nature of their basic body plan.

#### BLUE LEGGED HERMIT CRAB *Pagurus samuelis* (Rocky Shore Habitat)

Description: Hermit crabs are not true crabs! They have a long abdomen that isn't flexed under the thorax and is instead completely unprotected.

Food: They eat plankton and other small animals.  
Predators: Birds, fish, octopi and sea otters.  
Zone: They are found in the mid to high intertidal zone.  
Fun Facts: They seek protection in the shell of another animal. The blue legged hermit crab prefers to live in Turban Snail shells.

#### PURPLE SHORE CRAB *Hemegrapsus nudus* (Rocky Shore Habitat)

Description: These are wine-colored with purple spots on their claws.  
Food: They are scavengers and eats dead plants, detritus, or small animals.  
Predators: Fish, sharks and shorebirds.  
Zone: Hight zone.  
Fun Facts: They use camouflage and upturned claws for defense. They also hide under rocks. This crab's sex can be determined by gently picking one up, (be careful of its claws!), and examining its belly. If a "lighthouse" is found" on its underbelly, it is a male; if it has a rounded tail, it is a female.

#### LINED SHORE CRAB *Pachygrapsis crassipes* (Rocky Shore Habitat)

Description: They are purple with black and green lines. Joints have bright green connective tissue.

Food: They are scavengers, and eats detritus, small fish, or invertebrates.  
Predators: Their predators are fish and shorebirds  
Zone: High tide zone  
Fun Facts: They are often out of water, and scurry into crevices for protection.

#### YELLOW SHORE CRAB *Hemigrapsus oregonensis* (Bay Habitat)

Description: These crabs are yellow to gray, with yellow to white pincers.  
Food: They feed on plankton and green algae. Also scavenges on detritus  
Predators: Their predators are rays, sharks, and shorebirds  
Zone: High tide zone.  
Fun Facts: These crabs can burrow quickly into mud or sand to avoid capture. Their bodies are more delicate than their coastal cousins the Purple and Lined Shore Crabs.

#### SPIDER CRAB OR DECORATOR CRAB *Pyromaia tubercula* (Bay Habitat)

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 estuaries and bays  
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.

#### ACORN BARNACLE *Balanus glandula* (Found in both Bay and Rocky Shore Habitat)

Description: Barnacles are white and volcano shaped. They glue themselves to rocks, ships, whales and pilings, and wait for food to wash by.

Food: They eat plankton.

Predators: Their enemies include worms, snails, sea stars, fish, shorebirds. They live in colonies in the high to mid zones.

Fun Facts: They reach out with their feathery legs to strain out food(plankton) and absorb oxygen. Although the species is widespread in both the Rocky Shore and Bay Habitats the bodies of specimen living in these two habitats can be highly variable. Specimens living on the coast tend to be flatter to avoid being washed off rocky by wave action while bay specimens both grow taller and have more delicate shells.

## PHYLUM MOLLUSCA (soft bodied animals)

Mollusks are the second largest group of invertebrates, with over 100,000 living species. This diverse phylum is an ecologically important group, and has played a role in the geological structure of our Earth. Fossilized deposits of their shells form limestone beds throughout the world.

They have a soft body divided into a head, a foot, and a visceral hump which contains the internal organs. The body is usually protected by a hard shell which is secreted by the mantle, although there are numerous groups where the shell is vestigial or lacking. Many are equipped with hard mouthparts, including a toothed radula (scraping tongue), and a pair of biting jaws. More than 80% of all living molluscan species are gastropods (snails).

### CALIFORNIA MUSSEL *Mytilus californianus* (Rocky Shore Habitat)

Description: These bivalves are black, and attaches to rocks, pilings or anything else by secreting a liquid that quickly hardens in sea water to form strong threads called byssus.

Food: To eat, they open their shell and, with tiny hairs called cilia, makes a water current which brings oxygen to the gills, and microscopic plankton to their mouths.

Predators: Sea stars and humans. Sometimes humans get sick from microorganisms that the mussel has ingested.

Fun Facts: They live upside down in its shell with the head nearest the point of attachment. they attach by sticky byssal threads secreted by glands at the base of the foot.

### GREEN MUD MUSSEL *Musculista senhousia* (Bay Habitat)

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 current, 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!

### ASIAN CLAM *Potamocorbula amurensis* (Bay Habitat)

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.

#### TURBAN SNAIL *Tegula funebris* (*Rocky Shore Habitat*)

**Description:** Shell can be brown or black, with a spiral, coiling shell.

**Food:** They scrape algae off rocks with a scraping tongue (radula), or eat seaweed.

**Predators:** Shorebirds, fish, crabs, other snails, and people.

**Zone:** Throughout the intertidal zone.

**Fun Fact:** They have a trap-door contraption called an operculum to close and protect them from predators and water loss. They can live up to 25 years.

#### PHYLUM CNIDARIA (flower-like animals)

This phylum includes sea anemones, jellyfish, corals, sea pens and hydroids. They are all built around a circular body plan (radially symmetrical), with a crown of tentacles with stinging cells. Their mouth is in the center. Most attach to rocks, pilings and even kelp. Cnidarians have two basic body plans, a mobile medusa (like a jellyfish), and a sessile polyp (like a sea anemone). One or both of these forms may be present in the life cycle of one species.

#### GIANT GREEN ANEMONE *Anthopleura xanthogrammica* (*Rocky Shore Habitat*)

**Description:** Their column is olive green to brown, and tentacles are emerald green.

**Food:** In their tentacles they catch fish, shrimp, and plankton.

**Predators:** Their enemies include nudibranchs (sea-slugs), snails, fish and sea stars.

**Zone:** Mid-intertidal

**Fun Facts:** They can move by gliding along on its disc, or may even release this disc and walk on its tentacles. They can plump themselves full of sea water to keep itself moist during low tide. Needle-like stinging cells on the tentacles inject paralyzing compounds into their prey.

#### ORANGE ANEMONE *Diadumene cincta* (*Bay Habitat*)

**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 ECHINODERMATA (Spiny-skinned animals)

These animals have characteristic spines, hard calcareous projections of their skeleton. Like us, echinoderms possess an internal skeleton that is made of interlocking calcite plates, They usually have five- rayed symmetry, and move with their tube feet -- long flexible appendages

tipped with a suction cup. These are hooked up to a water-vascular system, consisting of fluid filled hydraulic canals, Tube feet also function in clinging, motion, respiration, sensing and food gathering. Echinoderms are found exclusively in salt water and most can not survive the fluctuating salinities of the San Francisco Bay.

**OCHRE STAR : *Pisaster ochraceus***

Description: They have rows of white-tipped spines, and are usually orange or purple.

Food: To eat they squeeze a mussel shell until it opens just a little, then insert their own stomach into the mussel shell to digest the contents outside of its own body.

Predators: Humans and shorebirds.

Zone: Mid to low tide zones.

Fun Facts: They can regenerate their legs. Their arm tips have light sensors.

**BAT STAR: *Patiria miniata***

Description: These are webbed between the arms and are often brightly orange, or purple.

Food: They eat other seastars, sea squirts and algae.

Predators: Humans and shorebirds.

Zone: Low tide zone.

Fun Facts: Worms can live in their arm grooves.

**LEATHER STAR: *Dermasterias imbricata***

Description: They feel soft and slippery, and are lead-gray with patches

Food: They eat urchins, sponges, anemones, and other sea stars.

Predators: Humans and shorebirds.

Zones: Low tide zone.

Fun Fact: Sometimes they have a garlic or sulfur odor.

**PURPLE SEA URCHIN: *Strongylocentrotus purpuratus***

Description: Round calcium carbonate shells with short, purple spines, these urchins can burrow into rocks.

Food: They graze and feed on algae. They have tube feet which catch and pass food to their mouths, which are located underneath their bodies.

Predators: Their predators are sea stars, fish, people. Pollution is also a threat.

Zone: Low tide.

Fun Fact: These are one of the sea otters favorite food.

**PHYLUM CHORDATA** Members of the phylum Chordata have spinal columns. All vertebrates, including humans are members of the phylum Chordata. In this presentation will only look at one chordate, the Sea Squirt. These animals are of the Sub-Phylum Urochordata. In early development they have a spinal chords like a vertebrate but as they grow they develop into a self bodied animal without a spinal chord or backbone. Vertebrate or Invertebrate? You can be the judge.

**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

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**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

**BRACKISH:** Water that has more salt than fresh water but not as much as seawater.

**BIODEGRADABLE:** Something capable of being broken down to simple compounds, especially into harmless products, by the action of microorganisms.

**CAMOUFLAGE:** Method of hiding in which organisms blend in with their surroundings.

**CARNIVORE:** An animal that consumes other living animals.

**CONSUMER:** An organism that gets its nutrients by eating other organisms.

**DISSOLVED OXYGEN:** Oxygen that has dissolved in water and can be used for respiration.

**ECOLOGY:** The study of relationships between organisms and their environment

**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.

**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."

**GEOLOGY:** The study of the composition and structure of the earth.

**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.

**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.

**NUTRIENTS:** The raw materials necessary for continuing life processes.

**OMNIVORE:** An organism that eats both plant and animal material

**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 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.

**VERTEBRATE:** An animal with a backbone. The back bone can be made of bone or of cartilage like in some fish (sharks and rays).

**WETLANDS:** Areas that periodically have waterlogged soils, support plants adapted to wet soil, and are covered or occasionally submerged by water.

