MARINE SCIENCE INSTITUTE
INLAND VOYAGE FISH EDUCATORS' GUIDE

July 2008

INTRODUCTION

Founded in 1970, 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.

PROGRAM LOGISTICS

The Marine Science Institute offers many different types of Inland Voyage programs. The

Inland Voyage Fish program focuses on the fish species living in San Francisco Bay. The program is "hands-on" and discovery based, meaning that we give students the live animals and equipment necessary to discover sensory or factual information about the fish and their habitats. 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 cartilaginous fish (sharks and rays), the other group will begin with the bony fish. 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.

<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.

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 ca reful 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.

INTRODUCTION TO
THE SAN FRANCISCO ESTUARY ECOSYSTEM_____

The San Francisco Bay Estuary is California's largest and best-known *estuary*. A bay is a partially enclosed inlet of the ocean. An estuary, however, is a partially enclosed 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, streams and municipal water treatment plants. 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 of California. Seventy species of federally threatened or 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.

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 (has the same

temperature as its surroundings), and has fins, chances are the animal is a fish. The study of fish is called Ichthyology. Fish are nektonic animals, meaning they swim in the open water. This section focuses on the fish most likely to be seen in the Bay.

WHERE FISH ARE FOUND

The water column is divided into three zones; top, middle and bottom. Fish living in the top zone are usually long and torpedo-shaped. They eat plankton and exhibit counter-shading. Mid-water fish have football-shaped bodies and strong muscles to swim fast enough to catch smaller, slower fish. Bottom fish are usually flat, and are predators.

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.

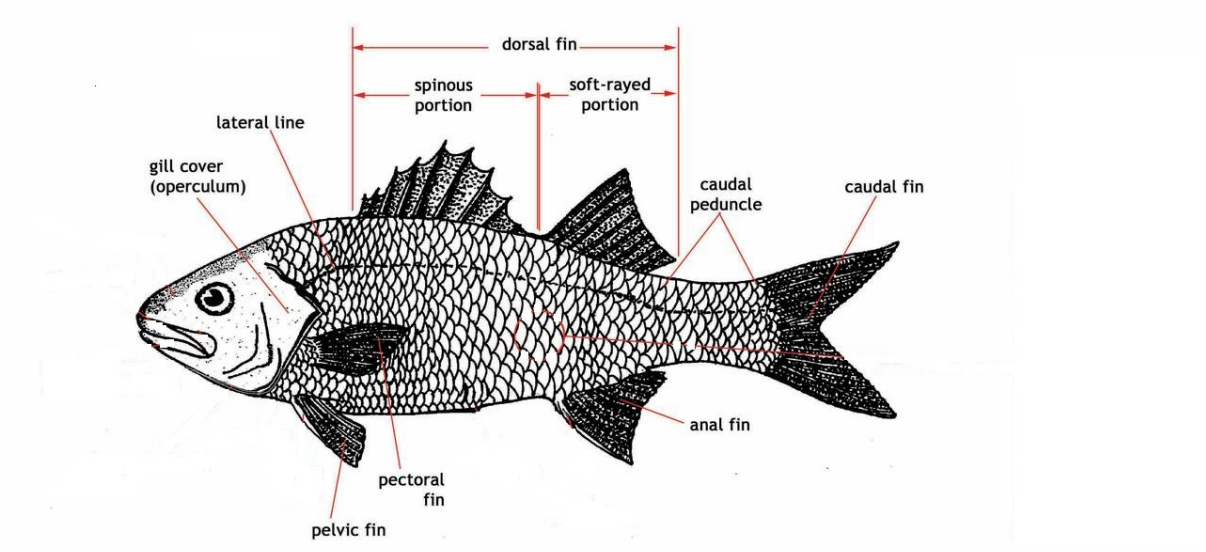
Shape

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!

MIDDLE DWELLERS:

SURFPERCH Shiner Surfperch, Barred Surfperch
Description: Perch are normal fish shape (laterally compressed) and dwell in the mid-water zone. The barred surfperch has 6-10 dark vertical stripes on each side; the shiner surfperch has 2-3 faint yellow vertical stripes on each side.
Food: Worms, plankton, and sand crabs.
Predators: Birds, fish, and marine mammals.
Fun Facts: Their front-positioned mouth and small teeth allows them to eat smaller fish and other invertebrates. The lateral line is visible as a dark, thin strip running the length of sides. Used as "ears," these lines sense vibrations in the water.

TOP DWELLERS:

SMELT Topsmelt, Northern Anchovies
Description: Smelt are long, silvery and torpedo shape, with small mouths located at the front of their body. Anchovies are also long and silver, but have long lower jaws.
Food: Plankton and small crustaceans.
Predators: Many different birds and fishes. Also fished commercially and as sport.
Fun Fact: Top-dwelling fish school or group together when threatened by predators. This behavior possibly confuses the predator into believing that the school is one big fish!

SHARKS, RAYS AND SKATES

Sharks, rays and skates are all cartilaginous fish, and therefore belong to the class Chondrichthyes. While they do possess a backbone, are cold blooded and have gills, which qualify them as fish, their skeleton is made entirely of cartilage. This allows them superb flexibility- one of the reasons that sharks are such excellent hunters. Another major difference between Chondrichthyes and Osteichthyes (bony fish) is that they have five to seven gill openings on each side, as opposed to just one.

Sharks have been around for 400 million years. To put this in perspective, dinosaurs lived 65 million years ago. There are currently 390 recognized species of sharks and over 400 species of rays, although the exact number is unknown. Some species may be juveniles that look different than their adult counterparts. And, it is very likely that there are species that have never been seen. There is still much to learn about these animals that inhabit the earth's waters.

SHARK ADAPTATIONS

Form
Sharks have a streamlined torpedo-like shape.

Skin
The skin of the shark is composed of tiny tooth-like scales that do not grow with the body, but must be shed and replaced, unlike fish scales. These hard scales are called *dermal denticles* (skin teeth). These miniature teeth have nerves and blood vessels, just like ours. They increase the shark's hydrodynamic capabilities as well as protect against injury. They are so rough and abrasive that a shark attack victim may have areas of skin scraped off.

Teeth
Usually only the front 1 or 2 rows of teeth are functional. Tooth replacement occurs throughout their lifetime. They may shed as many as 30,000 teeth during their life. In some species when a shark loses a tooth, just the tooth is replaced. In other species, they may lose a whole row at a time. On average, sharks replace their teeth every 6-12 months.

Claspers
Males have these rod-like structures near their pelvic fins, which aid in the transfer of sperm to the females during mating.

Eyes
A shark's eyes are similar to a cat's in that they contain a tapetum lucidum. This structure acts like a mirror and gives them excellent night vision by increasing the shark's sensitivity to light.

Spiracles
Bottom-dwelling sharks, as well as rays and skates, possess spiracles. These are openings located behind the eyes that are connected to the gills. Water flows through the spiracles and over the gills when the animals are lying on the bottom.

Prey Detection

Sound- Sharks are attracted to low-frequency vibrations, even at a distance greater than 1 mile. Their lateral line detects sound and helps with balance.

Smell- Sharks can detect 1 part blood in 1 million parts of sea water.

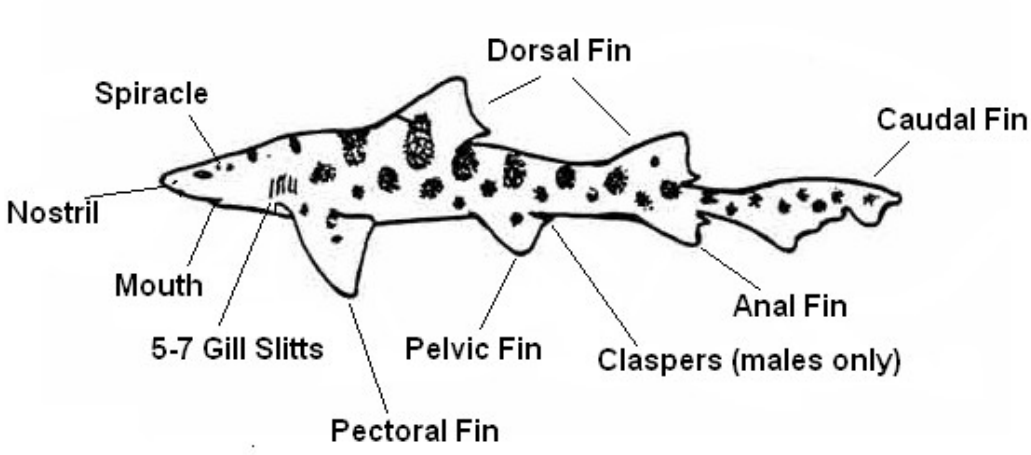
Vision- Sharks are sensitive to light, movements and contrast. They may be able to see color.

Ampullae of Lorenzini- These pores, located around the shark's mouth and nares, detect the presence of an electric field. Sharks can find prey without seeing or smelling it.

Birth
All sharks have internal fertilization, but there are three different types of gestation among species:

Oviparous- egg cases which are laid with developing embryos
Ovoviviparous- embryos develop internally with a yolk, but are unattached the mother (most common form of reproduction)

Viviparous- live birth (the most advanced form, but the least common)



SHARK ATTACKS
There are only about 100 people per year attacked by sharks, with up to 15% being fatal. Far more people die from bees, snakes, elephants, lightening and bathtub falls! For every one person killed by a shark, 6 million sharks are killed by people.

SHARK DEATHS
Each year 30-100 million sharks are caught for their meat, fins, hides, jaws and internal body parts. This is equivalent to 2.5-8 million every month, 80,000-280,000 every day, or 50-200 every minute! At least one shark is accidentally killed for every one caught deliberately. The population of some species has plummeted 80% in the past decade and some species will reach ecological extinction within the next ten years.

A single factory in Costa Rica reportedly turns 235,000 sharks into cartilage pills every month (which have no known beneficial affect to humans.) Sharks are caught mercilessly for their fins. In 1999, Hong Kong imported 6, 297 tons of shark fins, which were taken from over 28 million sharks. Shark fin soup sells for as much as $150 a bowl in many Asian restaurants. Every year at least 50,000 blue sharks are caught, their fins are cut off, and the shark is thrown back into the ocean alive to die. Why? Fishermen are allowed a certain weight on their boats. They can sell shark fins for $100/lb, but only get $.50/lb for the meat. It is more beneficial for them to fill their boats with pricey fins.

HUMAN USES OF SHARKS
Sharks are found in every marine environment and have tremendous value for humans:
- Cartilage is used as artificial skin for burn victims.
- Corneas are used experimentally in human transplant.
- Their blood contains anti-clotting agents.
- Liver oil aids in white blood cell production and is a source of vitamin A.
- They are known to have very low disease and extremely low cancer rates.
- Squalamine, which is found in a shark's stomach, liver and gall bladder, can inhibit the growth of human brain tumors.

RAYS AND SKATES

Rays are differentiated from sharks by their body shape. Their heads and bodies are flattened, and their gill slits are found on their undersides. Their pectoral fins are attached to their heads and extend forward, creating a disk-like shaped body. The spiracles of rays are generally much larger than those of a shark, and they are used to pull in water over their gills for respiration (unlike sharks which use their mouths). Some have denticles and some don't. Guitarfish and skates are both considered rays.

What is a Skate?

A skate is a ray. Skates are in the family Rajidae, which is the largest family of cartilaginous fishes. They normally have denticles and spines on their bodies and tails, or just their tails. They generally have two dorsal fins and a small caudal fin. All skates lay egg cases.

SAN FRANCISCO BAY SHARKS, RAYS, AND SKATES

Leopard Shark (*Triakis semifasciata)*

Description: A gray shark with heavy black bars and spots on their backs and sides. They reach 7' in length, although sharks larger than 6' are unusual.

Food: Eat a variety of animals- crabs, clams (they bite off the siphons), shrimp, innkeeper worms, fish eggs and fish. Their favorite fish are midshipman, sanddabs, shiners, bat rays and smoothhounds.

Range: Oregon to Baja, but are particularly abundant in Northern CA bays. Highly mobile, though they remain in the Bay throughout the year, with some movement out during the fall and winter.

Behavior: Found in schools.

Fun Facts: Are ovoviviparous and produce 4-33 young. Gestation is 10-12 months, and the pups are 8-9" at birth. Remains of leopard sharks have been found in Native American middens.

Brown Smoothhound *(Mustelus henlei)*

Description: A sleek bronze shark that reaches about 3' in length.

Food: Crabs, shrimp, anchovies, mudsuckers, and flatfish.

Range: Oregon to the Gulf of CA, plus Ecuador and Peru. They may move out of the SF Bay in the winter when the salinity drops.

Behavior: Usually found in same-sex schools.

Fun Facts: Females live to age 13, and males to age 7. Smoothhounds are preyed upon by sevengill sharks and leopard sharks.

Bat Ray *(Myliobatis californica)*

Description: Dark gray on top, and white below. Their heads are thick, with a very round snout. A spine is found at the base of their long, thin tail. They reach 6' in across.

Food: Clams, crabs, shrimp, innkeeper worms, herring, mudsuckers and shiner surfperch. They flap their fins to remove mud and sand, exposing prey.

Range: Oregon to the Gulf of California.

Behavior: Found singly or in large groups, sometimes numbering in the thousands

Fun Facts: Females live to at least 24 years. Males may not live to more than 6 years.

Big Skate *(Raja binoculata)*
Description: Kite-shaped, with a long, pointed snout. They are gray to brown, and have two large eyespots, one on the top of each "wing."
Food: Fish and crustaceans.
Range: The Bering Sea to Baja.
Behavior: Usually found in areas of soft substrate.
Fun Facts: Elephant seals dine on their eggs. Largest big skate on record was 8' long.

Shovelnose Guitarfish *(Rhinobatos Productus)*
Description: These tan fish have a pointed snout, a spadeshaped, flattened head, and a long tail. They reach 5.5' in length.
Food: Shiner surfperch, mudsuckers, staghorn sculpin and flatfish.
Range: San Francisco to the Gulf of California. They inhabit waters down to 300' (but are mostly found in 40' or less) and are occasionally found in estuaries.
Behavior: Often found in large groups, especially during the spring.
Fun Facts: Females may produce as many as 28 young, which are 6" when born. Their remains are abundant in Native American middens.

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

BRACKISH

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.

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

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.

NEKTON Swimming animals of open water, the adjectival form of nekton is nektonic.

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.