MARINE SCIENCE INSTITUTE
presents
DISCOVERY VOYAGE PROGRAM EDUCATORS' GUIDE

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INTRODUCTION

THE MARINE SCIENCE INSTITUTE

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, an outreach program called the Inland Voyage, 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 problem-solving field analysis, role-playing, debates, and games. 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.

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.

EDUCATORS' GUIDE
to the
DISCOVERY VOYAGE PROGRAM

This guide is meant to further understanding of Marine Science Institute's Discovery Voyage 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 San Francisco Bay ecology, including some specific organisms.

WELCOME TO THE DISCOVERY VOYAGE PROGRAM

Thank you for scheduling a Discovery Voyage. We will do all we can to make your trip exciting, memorable, and one of the best learning tools available to you.

The San Francisco Estuary is one of the world's great natural harbors, vital to the economy of California and the nation. It is a rich repository of marine life and the habitat for many species of birds and other wildlife. Abundant recreation and beauty are benefits for the five million people who live along the shores of this mountain-bordered inland sea. Begin your Voyage now by considering what is important for you to discover.

Your Discovery Voyage will be a full four-hour program investigating several characteristics and interrelationships in the fields of **ichthyology, plankton ecology, benthic ecology, and hydrology**. This is not just another "field trip" nor is it a cruise. Instead, the Discovery Voyage is an opportunity for you and your students to explore your questions and interests about this marine environment and incorporate new ideas into your curriculum. As you work with our staff you and your students will discover the value of the Estuary, perhaps the most complex system known to man.

PROGRAM OBJECTIVES

1. To provide an exciting educational experience that shows students how marine biologists study in the field; i.e. using oceanographic equipment such as an otter trawl and mud grab; identifying and analyzing live specimens.
2. To relate physical and behavioral adaptations of marine invertebrates to this unique environment called an estuary.
3. To emphasize how all the living organisms are interconnected in the marine food web, and also how they relate to the physical environment.
4. To gain an understanding, appreciation, and respect for marine ecosystems, and understand the special responsibilities of humans in the natural world.

PROGRAM LOGISTICS

GROUP SIZE, AND GRADE LEVEL

The program allows a group of up to 42 students, in the 4th grade to university level, to participate. We require at least 3 adults, so that each may chaperone one of three groups during the Voyage. In order to keep the activities truly "hands-on", we must limit the group size to 42 students. The group should be split into 3 cooperative learning groups prior to your arrival. Please have your students wear color-coded name tags for the program.

If your group is larger than 42 students you must make arrangements with the MSI staff prior to the Voyage.

ROLES OF ASSISTING ADULTS

For safety reasons and in order to keep costs at a minimum, we require the participation of all adults on the Voyage. We ask that you choose chaperones who will help motivate and excite the students. The role of the adults will be to assist in maintaining group continuity and to help keep

students on task. At each station, the group will break into four or five smaller groups to study the individual organisms. At least one adult will be assigned to each group to actively assist their students in observing, identifying, classifying and analyzing the organisms through the use of keys and charts. Our method of teaching is to ask thought-provoking questions that will lead the 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. Adults will also assist with overall group organization and safety. All adults will be briefed by our instructors at the beginning of the program.

CLOTHING AND GEAR

The weather on the Estuary can change very quickly from one minute to the next. Please warn students to wear clothes that are appropriate for a variety of weather conditions. Layered clothing that can be easily removed and put back on is the best to wear. Let students and adults know they should wear old clothing that they won't mind getting wet and muddy, because salt water and mud may ruin any good clothing. The deck of the ship will be wet, so appropriate rubber soled shoes or boots are recommended. **Sandals, open-toed shoes, or high-heels are not acceptable.** We are on deck for most of the Voyage, so sunscreen and sunglasses are recommended. Caps are not recommended, since the wind may blow them overboard. We are equipped with rain gear for everyone onboard, but students may be most comfortable in their own clothing and gear. For safety reasons, umbrellas are not allowed. Old towels can be brought to dry your hands, but please do not bring paper towels, since they create a lot of garbage.

ARRIVAL TIMES

Two, four-hour Voyages are scheduled on most days. They depart from the Institute at 8:00 a.m. and 1:00 p.m. We suggest you plan to be here 20-30 minutes prior to departure to allow time for using the shore restroom and, if on the afternoon Voyage, eating lunch on shore. There will not be time to eat during the program, unless medically necessary.

The ship has one head (toilet). Due to the nature of marine heads, sometimes it does not work. We have emergency plans as necessary for problems, but we urge you and your group to use the toilet on land before boarding. Please let your students know this beforehand, so if your group is running late, they know to get off the bus and head immediately to the restrooms.

ABOUT THE RESEARCH VESSEL

- The *R/V Robert G. Brownlee* is a 90-foot research vessel that is documented and inspected by the U.S. Coast Guard as an OCEANOGRAPHIC VESSEL.
- The Captain is licensed by the U.S. Coast Guard for 100-ton vessels.
- All instructors have been trained as deck hands; handling the lines is part of their duties.
- The Institute carries liability insurance in excess of School District requirements.
- A more than adequate supply of life jackets is kept on board, including plenty for both youths and adults. The introductory talk explains the procedures for when and how to put them on.
- Motion sickness medication is not recommended; the *Brownlee* is large enough so that it does not roll much during normal weather. If someone becomes queasy during the Voyage, a few soda crackers will usually suffice.

THERE IS NO SMOKING ABOARD THE SHIP!!

RESCHEDULING

Generally, the boat operates regardless of the weather. The main cabin can accommodate the group during rain, and rain gear is available for everyone. The Voyage will be rescheduled at no additional cost to the school if we have to cancel the program before the boat leaves the dock. Program cancellation will be at the Captain's discretion. If the Captain decides to return to the dock early due to unsafe weather conditions on the Bay, we will continue the program at the dock. The price of the program will be adjusted accordingly.

PROGRAM FORMAT

The Discovery Voyage program is set up with three main stations: Ichthyology, Plankton Ecology/Hydrology and Benthic Ecology. After an introduction, the group will divide in three groups (each with one instructor), and go to one of the stations. After rotating through the three 55-minute stations, a closing activity helps students apply all the new information they have learned. Throughout the program MSI instructors and adults will provide guidance and encouragement. Students can expect to handle and touch a variety of organisms as part of their observations.

7:45 or 12:45 Arrival: Group uses restrooms, and prepares to board the ship. Chaperones are briefed on their role in the program.

8:00 or 1:00 Students board vessel and assemble in main cabin.
Introduction: Students will be briefed on safety procedures and some facts about the San Francisco Bay Estuary. The theme for the day will be introduced (please read and return the student assessment form), and the students will be asked to think about why the Estuary is vitally important to the fish and wildlife in the area. Also discussed is our location, the program format, and how to gently and correctly handle the animals.

8:35 or 1:35 First station begins. For example – Ichthyology Station: Students deploy a 16-foot otter trawl (fish net) to catch fish. Concepts such as adaptations for habitat or food strategies are introduced, based on skill and grade level of the students. The group then breaks into smaller work groups with adults to lead.

*9:45 or 2:45 Second station begins. For example – Benthic Ecology: Students deploy a Peterson benthic grab to gather a bottom sediment sample. The sample is rinsed through screens to wash away sediment, leaving invertebrates to be collected and placed in buckets for closer study. Concepts about the invertebrates such as adaptations for predator/prey relationships, food strategies, or origin are introduced. The group breaks into smaller work groups with adults to lead.

10:40 or 3:40 Third station begins. For example – Plankton Ecology/Hydrology: Students collect a plankton sample and examine it under a video microscope, use a Secchi disk to measure the transparency of the water and, collect top and bottom water samples to analyze physical factors such as salinity, temperature and density.

11:40 or 4:40 Closing begins: This time will be spent connecting the three stations and defining the students' own role in the ecosystem. This can be done in a variety of ways, and depends on the your choice of theme. Students will brainstorm on ideas for how to keep the Estuary healthy, clean, and protected.

12:00 or 5:00 Ship arrives back at the dock.

*Snack time is available if you speak with the crew before the program begins. All of the students must have a snack with them. We encourage non-messy food that is easy to eat and is not crumbly (please **do not** bring chips, crackers, crunchy granola bars, etc.)

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 also think about recycling. 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

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

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

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

GEOLOGIC HISTORY

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

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

HUMAN HISTORY

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

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

designed to catch the heavier particles of gold. Eventually, sediments flowed southward causing massive population depletion of oyster beds.

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

INTRODUCED SPECIES

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

THE IMPORTANCE OF BIODIVERSITY

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

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

BIODIVERSITY IN THE BAY AREA

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

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

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

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

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

ESTUARY HABITATS

OPEN ESTUARY 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 currently supports two small commercial fisheries for herring and bay shrimp. The most important class of sport fishes are the *anadromous* fish, which live some or all of their adult lives in salt water, but move upstream into fresh water to spawn. These species include Chinook salmon, steelhead trout, striped bass, American shad, white and green sturgeon, and Pacific and river lamprey. These fish, and others such as leopard sharks, halibut, sculpins, and anchovies, are born in the marshlands and shallow areas bordering the Bay. The abundance of nutrients in the water can support a large number and variety of organisms.

Large predators of the open ocean do not frequently enter the Estuary. Protection from predators and an abundance of food make this a good place for the young of many species to live. A large portion of the marine animals that humans use for food spends 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 ducks. Even shallow open water is critical for invertebrates, ducks and various shorebirds.

OPEN ESTUARY PLANT AND ANIMAL SPECIES

Plankton
Spider crab *Pyromaia tuberculata*
Tube worm *Asychis sp.*
Mud mussel *Musculus senhousia*
Asian clam *Potamocorbula amurensis*
Leopard shark *Triakis semifasciata*
Bat ray *Mylobatis californica*
Starry flounder P*latichthys stellatus*

MUDFLAT ECOSYSTEM

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

MUDFLAT PLANT AND ANIMAL SPECIES

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

SALT MARSH ECOSYSTEM

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

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

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

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

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

SALT MARSH PLANT AND ANIMAL SPECIES

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

**endangered species*

UPLAND ECOSYSTEM

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

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

UPLAND ECOSYSTEM PLANT AND ANIMAL SPECIES

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

HUMAN IMPACT ON THE BAY

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

LOSS OF WETLANDS

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

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

DREDGING

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

DAMS & DIVERSIONS

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

POLLUTION

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

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

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

HEAVY METALS

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

Some heavy metals entering the Bay are:

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

PROTECTING THE ESTUARY

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

SCIENTIFIC METHOD_____

A Discovery Voyage on the *R/V Robert G. Brownlee* will be an opportunity for students to be marine scientists for a day. They need to bring a scientific attitude, and know they are the researchers on this Voyage, so the quality of science we conduct depends on their attentive and careful participation.

Throughout the Voyage, students will be using the scientific method. The scientific method is a series of steps:

- OBSERVATION & INITIAL QUESTIONS: Make observations using all senses. What interesting questions can be asked? What doesn't seem to fit in the picture?
- HYPOTHESIS: A hypothesis is tentative explanation for a problem that can be tested with further investigation. A hypothesis can be made by doing research, asking other people for information, and reading other people's work about the subject.

- MATERIALS & METHODS: What methods should be used to answer a research question and obtain results? Think about the equipment needed to run the experiment.
- DATA & RESULTS: The next step is to run the experiment. It is important to understand that the hypothesis must be testable, meaning that information (or data) can be recorded from the experiment. The recorded data are considered the results of the experiment.
- CONCLUSION & DISCUSSION: Now is the time to answer the question "why?" Why did the experiment give these results? Do the results support the hypothesis? Why, or why not? In this section, discuss how the experiment could be improved. What were some scientific errors made during the experiment?

SCIENTIFIC CLASSIFICATION_____.

Scientific classification provides a universal naming system that can be recognized by everybody. To enable scientists to study the vast numbers and types of living things on this planet, they are divided - on the basis of similarities in structure and physiology - into smaller and smaller groupings.

Kingdom is the first division, and is separated into five distinct groups: Monera; Protista; Plantae; Fungi; and Animalia. A kingdom is then divided into phyla. Animals within a phylum can vary dramatically in size, appearance and habitat, but they all share a common basic structure and distinguishing characteristics. Class is the next division, and variations within a class belong in separate orders. Orders are broken down to families, and even more closely related animals are separated into a genus. The final division is from genus to species. The first name in the scientific name is the genus, the second is the species. For example, *Cancer productus*, is genus *Cancer*, and species *productus*.

The traditional definition of species is a breeding population that produce fertile offspring. This has been known to happen between families, thereby breaking down this definition. Usually, species are described on the basis of physical characteristics alone. For example, these two crabs are identified in the following way:

	Yellow shore crab	Spider crab
Kingdom:	Animalia	Animalia
Phylum:	Arthropoda	Arthropoda
Class:	Malacostraca	Malacostraca
Order:	Decapoda	Decapoda
Family:	Grapsidae	Majidae
Genus:	*Hemigrapsus*	*Pyromaia*
Species:	*oregonensis*	*tuberculata*

These two species are within the same order, but are in different families. The taxonomic order can be remembered with the simple mnemonic:

King Philip Came Qver For Ginger Snaps

Another way to classify animals is by where they live. While on the Brownlee, you will place the animals you catch into one of three communities. Animals that live at the bottom are called benthic organisms. Animals that drift with the currents are planktonic, while animals that are accomplished swimmers are nektonic. Following is information on these three communities, and water itself.

PLANKTON ECOLOGY_____

DEFINITIONS

In addition to benthic organisms, marine organisms can be classified as nektonic, swimming organisms whose movement is independent of water circulation, and planktonic, drifting or weakly swimming organisms that cannot move against water currents.

The plankton we will be studying are microscopic, and consist of either tiny plants (phytoplankton) or animals (zooplankton). Phytoplankton play the same role as plants on land. They are producers, meaning they can make their own energy, and produce oxygen and food for animals. Zooplankton are consumers; they eat phytoplankton and other zooplankton.

Zooplankton can be further divided into two groups: holoplankton - organisms that spend their entire life as plankton, and meroplankton - organisms that begin are plankton in their larval stages, but become benthic or nektonic as they grow and mature. An example of meroplankton is a barnacle larva. Planktonic for the first part of its life, it will mature into a benthic, sessile (sedentary) adult.

PLANKTONIC ADAPTATIONS

During the program we will investigate adaptations that allow organisms to lead a planktonic life. Phytoplankton, for example, need to be up at the top of the water in order to carry on photosynthesis. How can they control their buoyancy, and resist sinking to the bottom? Many of them have developed a way to produce and store oil, which is more buoyant than water, and this characteristic helps them to stay up top. Zooplankton, which feed on phytoplankton, must stay near the top of the water to be near their food source, so they have evolved hairy appendages (legs and flagellum) to slow their settling rate, and a light-sensitive eye spot.

Another adaptation among plankton is their reproductive capacity, which is very high. Diatoms can reproduce both sexually and asexually (cloning or budding), allowing one diatom to create as many as one million offspring in three weeks. Copepods are capable of producing offspring every four days, and these young mature and can reproduce after just one week! Their lifespan is approximately one year.

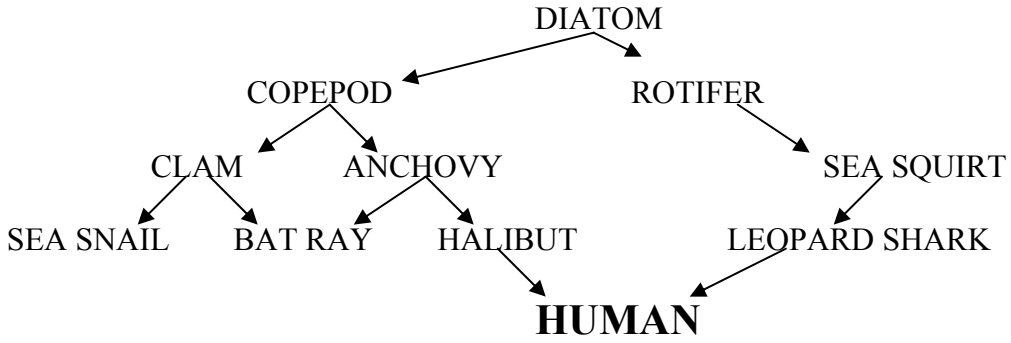
PLANKTON IN THE FOOD WEB

Producers are the foundation of almost all food webs. Phytoplankton (namely diatoms), are the bulk of the producers in the South Bay. These are eaten by small zooplankton, which in turn are eaten by bigger zooplankton (namely copepods). The environment is diverse enough that it is better described in terms of food webs rather than simple chains. Copepods, for example, eat detritus (dead animals and plant material) as well as phytoplankton. In turn, copepods can be eaten by top dwelling fish such as anchovies, or by benthic dwellers such as clams. There are

many interweaving paths through which energy - in the form of food - is transferred through the ecosystem.

Example of a Food Web

Arrows show which direction energy travels



PHOTIC ZONE

The amount of light penetration, or how deep light goes into the water is called the photic zone. This is important in studying plankton because the photic zone is the area where photosynthesis can occur, and therefore where plankton is found. We can measure this depth using a Secchi disk. This is a white disk that we lower into the water until it is barely visible. That is the point of maximum light penetration, and using the metric measurements on the line, we can estimate the photic zone of the water.

HYDROLOGY

"Hydro" is the Greek word for water, and "ology" means "the study of." So, hydrology is the study of water. The San Francisco Bay Estuary is a very complex body of water. In the northern part of the Bay, from Suisun Bay to the Golden Gate, fresh water from the Sacramento and San Joaquin rivers flows down toward the dense ocean water, making this mixture estuarine. Since the South Bay is geographically removed from fresh water inflow, and does not have as much circulation as the northern areas, the water is sometimes very close in salinity to ocean water.

SALINITY, TEMPERATURE & OXYGEN

Salinity is a measurement which tells us how much salt is in the water. We measure it in parts per thousand (ppt). The ocean averages about 35ppt. This means for every one thousand buckets of sea water, 35 of those buckets would be salt, and 965 would be water. The salinity of the water is a physical factor that determines which organisms can survive in this habitat. Some can only survive in ocean water and some only in fresh water, but estuarine species have become

much more salinity tolerant than ocean or fresh water species. This means that they can survive in high salinity during summer when there is no rainfall, and little fresh water entering the Bay, and also in lower salinity during winter and spring when rainfall brings fresh water from the mountains into the Bay.

Temperature is another physical factor that determines the species of organisms found in the Bay. In the summer, organisms in the South Bay must adapt to warmer temperatures. In the winter and spring, the temperature drops dramatically, and only the adaptable species will survive here. Others will have to migrate to warmer climates. The temperature in the Estuary varies a lot more than in the ocean. Primarily, this is because the ocean is much deeper with a larger volume of water which can absorb heat more easily than the shallow Estuary.

Dissolved oxygen is a third and very important factor since it supports fish and other marine life. Oxygen produced in the oceans and released from solution accounts for most of the oxygen in our atmosphere. There are two ways that oxygen can get into the water, photosynthesis by phytoplankton and by atmospheric exchange. Atmospheric exchange simply means that wind makes contact with waves, thereby mixing the water and air together to form oxygenated water. The units of oxygen are measured in %, or milligrams/liter. Temperature and oxygen are directly related. In the summer when temperatures are highest, oxygen levels are very low, because water is less able to hold oxygen in solution as it becomes warmer. For this reason many animals leave the South Bay at this time and travel north to colder and more oxygenated waters.

ICHTHYOLOGY

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.

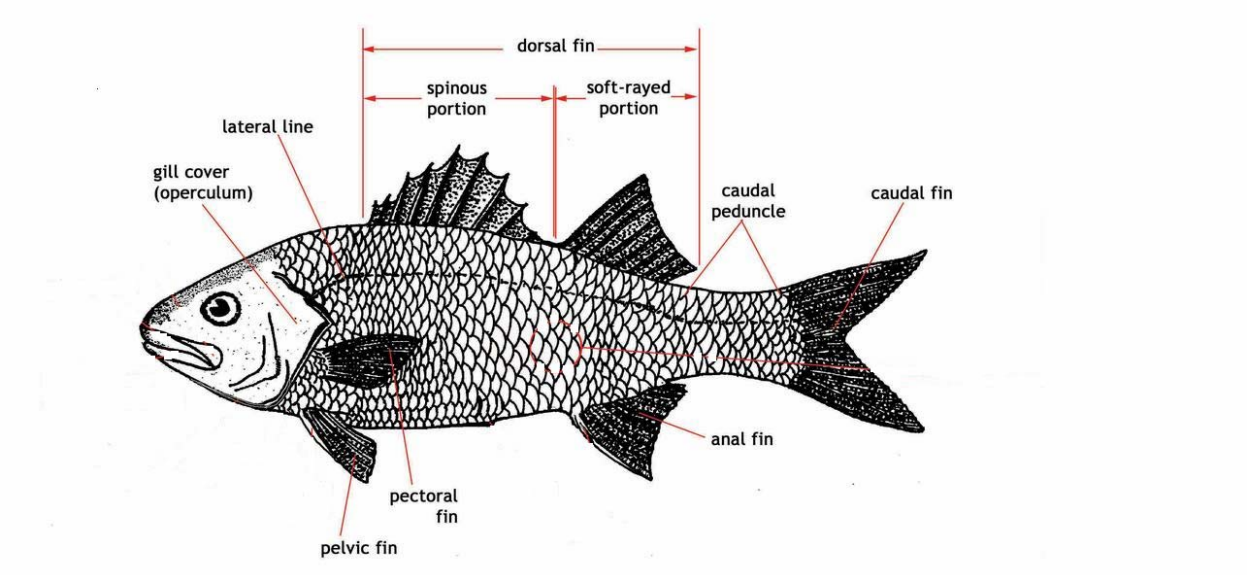
SHAPE

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!

SHARKS Leopard Shark, Brown Smoothhound

Descriptions: Leopard sharks are grey with heavy black bars and spots. Brown smoothhounds are a solid, coppery-brown color.

Food: Eat mainly small fish, shrimp, crabs, and clams.

Predators: Humans are the main predators of adult sharks.

Fun Facts: Sharks have no bones; their skeletons are made up of cartilage, like our noses. They can hear prey up to 1 mile away! Although they have generally poor eyesight, they have a great sense of contrast. Their eyes have a special layer that intensifies light so they can see their prey in near darkness.

Sharks have ancestors older than the dinosaurs by 200 million years! Although they have bad reputation, only 7 out of 365 species of sharks are truly dangerous to humans. Most are small, timid creatures more likely to flee from a swimmer than attack.

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!

BENTHIC ECOLOGY_____

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

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

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

BAY INVERTEBRATE CHARACTERISTICS

PHYLUM PORIFERA (pore-bearing animals)

Red Beard Sponge *Microciona prolifera*

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

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

Predators: Sea slugs (nudibranchs).

Origin: Atlantic Ocean.

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

PHYLUM MOLLUSCA (soft-bodied animals)

Asian Clam *Potamocorbula amurensis*

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

Food: Filter feed on plankton.

Predators: Diving birds, crabs, and bottom feeding fish.

Origin: China and Japan.

Fun Fact: This clam was introduced by the ballast of ships in 1986, and has since spread throughout the Estuary.

Green Mud Mussel *Musculista senhousia*

Description: Smooth, small (2 cm) dark shells with wavy brown and green bands.

Food: Filter feed on plankton and detritus.

Predators: Shorebirds and bottom feeding fishes.

Origin: Introduced from Japan with the Pacific oyster.

Fun Facts: Mussels are like tiny sewing machines! To keep from getting tossed about in the waves and/or tides, mussels form sticky threads, called byssal threads, and anchor themselves to the mud at the bottom of the Bay. These threads then harden and keep the animals from being swept away!

PHYLUM ANNELIDA (segmented worms)

Tube Worm *Asychis sp.*

Description: The brown, tubular structure made of mud is actually the home of the tube worm, while the long, red, slender creature inside is the worm itself.

Food: Because it eats much of the dead plant and animal material decomposing on the bottom, the tube worm can be thought of as one of the trash collectors of the Estuary! They are also great recyclers.

Predators: Bottom feeding fish and crabs.

Origin: Introduced to the Estuary with the Eastern oyster.

Fun Fact: The tube is constructed of both mud and mucus. To construct a tube, the worm eats mud and digests the living and dead microscopic plant and animal particles found inside. When finished, it secretes the mud back out again, mixed with sticky mucus, which flows down the sides of its body like a coat of paint on a house. Gradually, the tube is formed and the worm lives protected inside.

PHYLUM ARTHROPODA (jointed limbs)

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

PHYLUM CNIDARIA (stinging nettle)

Orange Anemone *Diadumene cincta*
Description: Small, approximately 1 cm, flower-like body. usually pale pink or orange in color. Often found attached to the inside of empty shells, or on sponges.
Food: Zooplankton. Their flower-like appearance is due to several delicate tentacles flowing in and out of the solid tube-like column of its body. These tentacles are equipped with stinging cells which immobilize prey, then carry it down its tubular column and into its mouth.
Predators: Snails, seastars, sea slugs (nudibranchs).
Origin: Atlantic Ocean.
Fun Fact: If a sea anemone is left undisturbed for a few minutes, you can usually see its flowery tentacles appear.

PHYLUM CHORDATA

Solitary Tunicate or Sea Squirt *Mogula Manhattensis*
Description: Globular or "bag-shaped" body, usually translucent and yellowish in color
Food: Filter feed on plankton using two straw-like siphons to pull water in and out of its body.
Predators: Mainly sharks.
Origin: Atlantic Ocean.
Fun Fact: A tunicate's body is inflated with water. When a tunicate is gently squeezed, it will squirt out water like a fountain from one of its siphons; hence, its nickname!

ACTIVITIES FOR YOUR CLASS

PRE-VISIT ACTIVITIES_____

Here are some activities to prepare your students for their Discovery Voyage program. In addition you may want to ask your librarian to set aside ecology or marine science books for your class, or ask students to bring books and magazines from home to share.

SCIENCE

ANIMAL ADAPTATIONS

Have your class research and discuss how estuarine animals protect themselves from their predators or what adaptations they have to become better predators. Have the class team up in small groups and be responsible for researching one phylum. Within each group, each student can choose one animal from this phylum. They can begin with the background information in this preparation guide, and then use books, tapes or any other resource to put together a report

SCIENTIFIC CLASSIFICATION

Demonstrate the meaning of scientific classification by having students categorize inanimate objects according to their own framework. You could use fruit, or something ordinary such as different kinds of nails (wood, standard, aluminum, galvanized, ringed, headless), to each small group. Have them categorize and then share their results with each other to start a general discussion on classification. Do we need it? Is any one type of classification better than another? Is there a benefit to sticking to one standardized system of classification?

DICHOTOMOUS KEYS

To demonstrate how a dichotomous key works, play a "20 Questions" style game. Pick one student without disclosing his/her identity, then have the rest of the class discover who you've picked by asking yes-or-no questions. During this process, you can construct a key based on their questions. Tell them to go from the most general to the most specific. For example:

1a. Is the student male……...Go to question 2
1b. Is the student female……Go to question 7
2a. Does the student have blond hair…….Go to question 3
2b. Does the student have dark hair……..Go to question 9
3a. Does the student have blue eyes……..Go to question 4
3b. Does the student have brown eyes……...Go to question 11

NO GARBAGE LUNCH (Part 1)

Within a day or two of your class trip, hold a surprise "lunch raid" by making a collection of all the garbage (man-made materials only!) to be potentially thrown out after lunch is over.

- Sort the garbage into piles such as plastics, paper, aluminum, etc., and count the number of items in each pile. Make a colorful bar graph depicting your findings.
- Discuss the results and the importance of recycling.
- Discuss where the solid garbage goes. Much of it goes into landfills which are actually "bay fills." How long can this go on?

- Challenge your class to make “No Garbage” lunches. This means bringing a lunch box or a bag that can be used again. Reuse containers for sandwiches and snacks.
- Talk about the drawbacks of snack food that come in cute little packages but create lots of garbage. What could we do instead? (Buy bulk size).
- Encourage the three "R’s": Reuse, Reduce (garbage) and Recycle.

ORGANISM REACTIONS

A. Varying salinity

Have students make wet mounts of a thin section of red onion bulb. Mount in 1% NaCl (salt) solution and observe effects. Flush with fresh water and observe effects. Have students explain the reactions.

B. Varying temperature

Put equal numbers of fruit flies in jars and keep them at different temperatures for a few minutes. Observe relative activity rates. If a pond or other body of water is nearby, measure air and water temperatures at different times of the day to see which environment has more stable temperatures.

SOCIAL SCIENCE

GEOGRAPHY

Make a map of the Bay Area, or a 3-D model of the Bay Area. Emphasize the mountains, and the Hayward and San Andreas Faults. Clay, or a mixture of baker's dough works well.

PYRAMID OF LIFE (From Joseph Cornell's *Sharing Nature with Children*)

Give each student a slip of paper and have them secretly write on it the name of a plant or animal that lives in your area. Collect all slips of paper and begin to construct a "human pyramid" (performed in a flat position, rather than one child on top of another, if safety is a concern or the group is large).

Begin by asking, "From what source does the earth get its energy?"(Sun) "What form of life is the first to make use of that energy?" (Plants) Next, divide students into groups (from their secret slips) depending on whether they are plants, plant-eaters (herbivores), meat-eaters (carnivores), or omnivores (let the omnivores choose which group they'd like to be in). Try to construct a food pyramid beginning with all the plants on the bottom. Who is next? And next? Is it too top heavy to work? What will happen to all the animals on top with nothing to support them underneath? What needs to be done to correct it? Conclude by pretending to yank out a plant; what happens to the pyramid?

MAP GAME

The class is divided into two teams. One member of each team puts their back to a map of the Bay Area. The teacher calls out a city or landmark that is found on the map, and then says "Go". The students turn around to find the city or landmark, trying to do so before the other one does. The first correct answer gets a point for their team, and the team that gets the most points wins. Emphasize the geography of the Bay Area, "Find and name the mountains forming the east side of the Bay." "Find and name a river that empties into the South Bay." Be careful with these; there are a few rivers. "Find the bridge that connects Oakland and San Francisco and name it."

ART

FISH PRINTING

Fish printing, or gyotaku (gyo=fish, taku=rubbing), was invented by the Japanese in the 1800's and has since evolved into an art form. Prints can be made on paper, cloth, or t-shirts.

- Obtain whole fish, octopus, or squid from market. It should be thawed out.
- Wipe the outside of the fish to remove moistness and mucous. Be careful not to damage the scales.
- Lay fish on a newspaper covered table.
- Using a wide stiff brush, paint the side of the fish with fabric paint or water-based printers' ink of any color. Don't use too much paint as it will smear.
- Paint the fins and the tail last.
- Slowly lower the paper or cloth onto the painted fish and gently pat the material all over the fish. Make sure you get the tail and fins. Lift the print straight up from the fish.
- Place print in a safe place to dry and admire!

CAMOUFLAGE CRITTERS

Discuss the concept of camouflage, its usefulness to an animal, and perhaps how it evolved through natural selection. Have students draw an animal camouflaged for a particular environment (forest, meadow, stream bottom, etc.) Or, choose environments on the school grounds and create a critter (from paper, clay, pipe-cleaners, even raw vegetables!) that is camouflaged in those surroundings.

MATH

MEASURING

Using the metric system, we measure plankton in micrometers. Have the students make measuring sticks and send them out on a measuring hike. Tell them to find things of certain lengths. Let them figure out how many microns are in the items they measure.

GRAPHING

Make a tide table. Have the students check the newspaper each day for the tides. Then record each day on a graph. Watch how the tides go up and down each day and get higher and lower as the month progresses.

POST-VISIT ACTIVITIES

SCIENCE

AQUARIUMS

Set up an aquarium in your classroom. All you need is a small aquarium, an undergravel filter system, an air pump connected to a bubbler, and fish or invertebrates. Most aquarium stores can direct you, or ask us at MSI. Students can watch the fish as they move their gill openings. How many times do they "breathe" per minute? Have your class figure out what the animals need to survive: food, water changes, oxygen, etc.

TIDES

Make a tide table. Have the students check the newspaper each day for the tides. Record each day on a graph. Watch how the tides go up and down each day and get bigger and smaller as the month progresses. Ask the students to check the moon each night and correlate the phases of the moon.

NO GARBAGE LUNCH (Part 2)

After our program, once again hold a lunch raid and compare how much garbage they have this time as opposed to the last time (there should be much less). Let the colorful bar graphs of the two days emphasize the dramatic difference the students themselves are making to the health of the planet!

WEB OF LIFE

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

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

BEACH WALK

If time and funds permit, organize a visit to a rocky beach location at low tide (ask about MSI's TIDEPOOL EXPEDITION program). This is a great way to incorporate a different ecosystem, into a marine biology unit. A visit to the tide pools drives home the idea that intertidal animals have a different set of adaptations and problems to deal with. They also provide an opportunity for students to apply what they learned on the Discovery Voyage to a different marine ecosystem. Three good local tidepool areas to visit are Fitzgerald Marine Reserve, Pillar Point, and Pescadero Beach.

Equipment needed

- Rubber boots or hip waders
- Identification books or keys
- Magnifying glasses

Important rules to follow

- Study and observe the animals and plants where you find them. Do not pick up and move organisms to a different location.
- When searching for animals, replace any over-turned rocks as you found them. Turn them over gently, and replace them carefully so as not to leave the underside exposed to the sun or elements.
- Avoid disturbing unusual ecological areas that may be more sensitive to disturbances, or any other types of animals that you might see such as marine mammals and birds.
- Please teach and practice conservation!

ART

TURN YOUR CLASSROOM INTO A BAY

Put blue paper around the classroom and have the students draw in various plants and fish, or have them cut out pictures of marine creatures to put on the blue paper. Let them put some benthic invertebrates on the bottom and plankton on the top!

MOBILES

Let the kids make mobiles of the fish they saw. Take a hanger, some string, some cut-out drawings or pictures of fish and have fun! Attach the fish to the string. Then attach the string at varying lengths to the hanger. Be creative, use pictures of plankton and benthic critters. Possibly take two copies of the fish, glue the edges together, and stuff with some already used paper (recycle it!) and have a 3-D mobile. Older groups can make mobiles in the form of a food chain.

ENGLISH

WRITING

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

ORAL PRESENTATION

Have the class team up in small groups and have each group do a short oral presentation on one of the animals they learned about in the program. If they have done the pre-visit activity of researching an animal, they can use that information, plus add what they have just learned. In the presentation they could include what phylum it belongs to and why, where it lives in the Bay, what it eats, what might eat it, and any special offensive or defensive adaptations it may have.

GLOSSARY

ADAPTATION	Modification of an organism in order to survive within its habitat.
ALGAE	Primitive aquatic plants that lack true stems, roots and leaves. They are in their own kingdom
BENTHOS	The substrate at the bottom of a body of water; the adjectival form of benthos is benthic.
BIODEGRADABLE	Something capable of being broken down to simple compounds, especially into harmless products, by the action of microorganisms.
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.
CLAY	Small particles of sediment which cannot be individually felt or seen; particle diameters are smaller than 1/256 (.0039)mm.
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.
DETRITIVORE	An animal that eats detritus.
DIATOM	A type of microscopic, one-celled photosynthetic organism. All diatoms are surrounded by a silica shell and most are a golden brown in color.
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.
SAND	Sediment particle which can be distinguished with the naked eye; particle diameters range from 1/16 (.0625) mm.
SCAVENGER	An organism that is an opportunistic feeder; scavengers usually include dead and decaying animal flesh in their diets.
UPLAND	Ground that is elevated above the lowlands, marshlands, or rivers.
VERTEBRATE	An animal with a backbone. The back bone can be made of bone or of cartilage like in some fish (sharks and rays).
WETLANDS	Areas that periodically have waterlogged soils, support plants adapted to wet soil, and are covered or occasionally submerged by water.

SAN FRANCISCO ESTUARY RESOURCES_____

AUDUBON SOCIETY OF SANTA CLARA CO.
22221 McClellan Rd. Cupertino.CA 95014 (408) 252-3747 -helps preserve South San Francisco Bay.

BAY AREA ENVIRONMENTAL EDUCATIONAL RESOURCE GUIDE
An online guide for environmental resources.

THE BAY INSTITUTE
500 Palm Drive #200, Novato, CA 94949 (415) 506-0155, www.bayinfo@bay.org – researches and helps protect the estuary.

CALIFORNIA STATE COASTAL COMMISSION
45 Fremont Street, Suite 2000 S.F., CA 94105-2219 (415) 904-5214 regulates coastal development, aids required local planning efforts.

COYOTE POINT MUSEUM.
1651 Coyote Point Drive, San Mateo, 94401 (650) 342-7755 -exhibits of baylands and wildlife.

COYOTE HILLS REGIONAL PARK
8000 Patterson Pass Road, Fremont, CA, (510) 795-9385, www.ebpark.org/parks/coyote.htm - For thousands of years, the Ohlone Indians occupied this area of salt and fresh water marshes along the bay. The shell mounds within the park's boundaries are evidence of their thriving activity. Also widely known for its rich diversity of birds and rarely seen species. Visitors have a rare 360-degree view of the Bay Area from the top of Red Hill some 300 feet above sea level.

DON EDWARDS SAN FRANCISCO BAY NATIONAL WILDLIFE REFUGE
U.S. Fish and Wildlife Service, Box 524, Newark, CA 94560 (510) 792-0222 – Protects open space for wildlife, maintains educational interpretive center.

ENVIRONMENTAL VOLUNTEERS
3921 East Bayshore Rd.., Palo Alto, CA 94303 (650) 961-0548 - natural science education programs and field trips for children grades K-8.

GOLDEN GATE NATIONAL RECREATION AREA
Fort Baker, Marina, Fort Mason, Aquatic Park, San Francisco, (415) 561-4700 - bird watching, fishing, hiking, picnicking.

HEADLANDS INSTITUTE
Golden Gate national Recreation Area Building 1003, Sausalito, CA, (415) 332-5771. Residential Field Science Program offers 1-5 day programs to groups of K-12 students throughout the schoolyear.

MOUNTAIN VIEW SHORELINE PARK
Stierlin Rd., Mountain View, CA (650) 903 -6392 - Bird watching, hiking & picnicking.

PALO ALTO JUNIOR MUSEUM

1451 Middlefield Rd., Palo Alto, CA 94301 (650) 329-2111 - natural science education services for Palo Alto area.

SAN FRANCISCO BAY MODEL REGIONAL VISITOR CENTER

2100 Bridgeway Blvd., Sausalito CA 94965 (415) 332-3871, www.baymodel.org - educational, self-guiding scale hydraulic model of the Bay.

SAVE THE BAY

1600 Broadway, Suite 300, Oakland, CA, (510) 452-9261, www.savesbay.org.

YOUTH SCIENCE INSTITUTE

16260 Alum Rock Avenue, San Jose, CA 94127 (408) 258-4322 - Science education programs for children of all ages.

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Directions to Marine Science Institute

Redwood City, California
(650) 364-2760 Fax (650) 364-0416
Boat (650) 269-1179 (use only if late for a morning or Saturday voyage)
www.sfbaymsi.org

From 280

1. Take the Woodside Road exit towards Redwood City (east).
2. Continue on Woodside Road until it becomes Seaport (go under Hwy 101).
3. Follow Seaport, turn left onto Chesapeake Drive (second light).
4. Turn left on Saginaw.
5. Turn right on Cardinal Way (watch for Seaport Plaza).
6. At the end of the road veer right, pass the Stanford Boathouse, and continue on to the Institute.

From 101

1. Take the Seaport Blvd exit at Redwood City.
2. Follow Seaport, turn left at Chesapeake Drive (second light).
3. Turn left on Saginaw.
4. Turn right on Cardinal Way (watch for Seaport Plaza).
5. At the end of the road veer right, pass the Stanford Boathouse, and continue on to the Institute.